



REPUBLIC OF KENYA

LEARNING GUIDE

FOR

ELECTRICAL ENGINEERING (POWER OPTION)

LEVEL 6



TVET CDACC
P.O. BOX 15745-00100
NAIROBI

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FOREWORD

The provision of quality education and training is fundamental to the Government's overall strategy for social economic development. Quality education and training will contribute to achievement of Kenya's development blue print and sustainable development goals. This can only be addressed if the current skill gap in the world of work is critically taken into consideration.

Reforms in the education sector are necessary for the achievement of Kenya Vision 2030 and meeting the provisions of the Constitution of Kenya 2010. The education sector has to be aligned to the Constitution and this has triggered the formulation of the Policy Framework for Reforming Education and Training (Sessional Paper No. 4 of 2016). A key provision of this policy is the radical change in the design and delivery of the TVET training which is the key to unlocking the country's potential in industrialization. This policy document requires that training in TVET be Competency Based, Curriculum development be industry led, certification be based on demonstration and mastery of competence and mode of delivery allows for multiple entry and exit in TVET programs.

These reforms demand that industry takes a leading role in TVET curriculum development to ensure the curriculum addresses and responds to its competence needs. The learning guide in Electrical engineering (power option) enhances a harmonized delivery the competency-based curriculum for Electrical engineering (power option) level 6.

It is my conviction that this learning guide will play a critical role towards supporting the development of competent human resource for the Electrical engineering (power option) sector's growth and sustainable development.

**PRINCIPAL SECRETARY, VOCATIONAL AND TECHNICAL TRAINING
MINISTRY OF EDUCATION**

PREFACE

Kenya Vision 2030 is anticipated to transform the country into a newly industrializing, “middle-income country providing a high-quality life to all its citizens by the year 2030”. The Sustainable Development Goals (SDGs) further affirm that the manufacturing sector is an important driver to economic development. The SDG nine that focuses on Building resilient infrastructures, promoting sustainable industrialization and innovation can only be attained if the curriculum focuses on skill acquisition and mastery. Kenya intends to create a globally competitive and adaptive human resource base to meet the requirements of a rapidly industrializing economy through life-long education and training. TVET has a responsibility of facilitating the process of inculcating knowledge, skills and attitudes necessary for catapulting the nation to a globally competitive country, hence the paradigm shift to embrace Competency Based Education and Training (CBET). The Technical and Vocational Education and Training Act No. 29 of 2013 and the Sessional Paper No. 4 of 2016 on Reforming Education and Training in Kenya, emphasized the need to reform curriculum development, assessment and certification to respond to the unique needs of the industry. This called for shift to CBET to address the mismatch between skills acquired through training and skills needed by industry as well as increase the global competitiveness of Kenyan labor force.

The TVET Curriculum Development, Assessment and Certification Council (TVET CDACC), in conjunction industry/sector developed the Occupational Standards which was the basis of developing competency-based curriculum and assessment of an individual for competence certification for an Electrical engineering (power option) level 6. The learning guide is geared towards promoting efficiency in delivery of curriculum. The learning guide is designed and organized with clear and interactive learning activities for each learning outcome of a unit of competency. The guide further provides information sheet, self-assessment, tools, equipment's, supplies, and materials and references.

I am grateful to the Council Members, Council Secretariat, Electrical engineering (power option) experts and all those who participated in the development of this learning guide.

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ACKNOWLEDGEMENT

This learning guide has been designed to support and enhance uniformity, standardization and coherence in implementing TVET Competency Based Education and training in Kenya. In developing the learning guide, significant involvement and support was received from various organizations.

I recognize with appreciation the critical role of the participants drawn from technical training institutes, universities and private sector in ensuring that this learning guide is in-line with the competencies required by the industry as stipulated in the occupational standards and curriculum. I also thank all stakeholders in the Electrical engineering (power option) sector for their valuable input and all those who participated in the process of developing this learning guide.

I am convinced that this learning guide will go a long way in ensuring that workers in Electrical engineering (power option) sector acquire competencies that will enable them to perform their work more efficiently and make them enjoy competitive advantage in the world of work

DR. LAWRENCE GUANTAI M'ITONGA, PhD
COUNCIL SECRETARY/CEO
TVET CDACC

ACRONYMNS AND ABBREVIATIONS

CAD	Computer Aided Design
CCTV	Closed Circuit Tele Vision
CDACC	Curriculum Development, Assessment and Certification Council
EHS	Environment Health and Safety
IEE	Institute of Electrical Engineers
HVAC	Heating Ventilation and Air Conditioning
IBMS	Integrated Building Management System
K.C.S. E	Kenya Certificate of Secondary Education
KNQA	Kenya National Qualification Authority
KNQF	Kenya National Qualification Framework
KEBS	Kenya Bureau of Standards
KPLC	Kenya Power and Lighting Company
NCA	National Construction Authority
NEMA	National Environment Management Authority
OSHA	Occupational Safety and Health Act
PPE	Personal Protective Equipment
PV	Photo Voltaic
TVET	Technical and Vocational Education and Training
WIBA	Work Injury Benefits Act

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CHAPTER 1: INTRODUCTION

1.1. Background Information

This learning guide has been developed in line with the functions of TVET CDACC as stipulated in Article 45 (1a) of the Technical and Vocational Education and Training (TVET) Act No. 29 of 2013, the Sessional Paper No. 2 of 2015 that embraces Competency Based Education and Training (CBET) system. It is therefore, the sole intent of this document to provide guidelines for a Competency-Based Electrical Engineering (power option) curriculum for level 6

This learning guide consists of interactive learning activities, content, self assessment and relevant and related references that enhances implementing of Electrical engineering (power option) level 6 qualification. It enables the trainee to acquire the competencies that enable him/her to undertake the various processes in welding and fabrication. The Guide further provides illustration, web links, case studies, examples and resources on how to implement all the learning outcomes/elements described in the Curriculum and occupational standards with a particular focus to a trainee.

1.2. The Purpose of Developing the Trainee Guide

Electrical Engineering (Power option) Level 6 curriculum development process was initiated using the DACUM methodology where jobs/occupations were identified. Further, job analysis charts and occupational standards were generated in collaboration with the industry players under the guidance of TVET CDACC (Curriculum Development Assessment and Certification council). The result of the process was an Electrical engineering (Power option) level 6 curriculum. The curriculum was further broken down to end up with units of learning. To effectively implement Electrical engineering (power option) curriculum, learning guides are required to provide training content and guide the learner and trainers on the learning process aimed at imparting the relevant knowledge, requisite skills and the right attitude to the industry. Learning guides are part of the training materials

1.3. Layout of the Trainee Guide

The learning guide is organized as per chapters. Chapter one presents the background information, and purpose of developing the trainee guide. Each of the units of learning/unit of competency is presented as a chapter on its own. Each chapter presents the introduction of the unit of learning/unit of competency, performance standard and list of the learning outcome/elements in the occupational standards.

Learning Activities

For each learning outcome, the learning activities are presented covering the performance criteria statements and trainees demonstration of knowledge in relation to the range in the occupational standard and content in the curriculum.

Information Sheet

The information sheet is section under each learning outcome that provides the subject matter in relation to definition of key terms, method, processes/procedures/guidelines, content, illustrations (photographs, pictures, video, charts, plans, digital content, and simulation) and case studies.

Self-Assessment

Self-assessment based on the performance criteria, required knowledge, skills and the range as stated in the occupational standards. The section further provides questions and assignments in which trainees demonstrate that they have acquired the required competences and an opportunity to reflect on what they have acquired. It is expected that the trainer keeps a record of their plans, their progress and the problems they encountered which will go in trainee's portfolio. A portfolio assessment consists of a selection of evidence that meets the pre-defined requirements of complexity, authenticity and reliability. The portfolio starts at the beginning of the training and will be the evidence for the development and acquisition of the competence (summative and formative) by the student. It is important to note that Portfolio assessment is highly emphasized in the learning guide

Finally the guide presents tools, equipment's, supplies and materials for each learning outcome as guided by the performance criteria in occupational standards and content in curriculum. References, relevant links and addendums are provided for further reading. The units of competency comprising this qualification include the following common and core unit of learning:

This course is designed to equip electrical technicians with the competencies required to perform electrical installation, power line construction, electronics, electrical machine installation, machine automation, security system installation, solar installation, Electrical equipment and system maintenance, project management and power generation.

Common Units of Learning

Table 1: Common Units of Learning

Unit Code	Unit Title	Duration in Hours	Credit Factors
ENG/CU/PO/CC/01/6	Engineering Mathematics	110	11
ENG/CU/PO/CC/02/6	Electrical principles	240	24
ENG/CU/PO/CC/03/6	Workshop Technology	60	6
ENG/CU/PO/CC/04/6	Technical Drawing	130	13
Total		540	54

Core Units of Learning

Table 2: Core Units of Learning

Unit Code	Unit Title	Duration in Hours	Credit Factors
ENG/CU/PO/CR/01/6	Electrical Installation	120	12
ENG/CU/PO/CR/02/6	Electrical transmission power line	190	19
ENG/CU/PO/CR/03/6	Electrical Machine Installation	130	13
ENG/CU/PO/CR/04/6	Electronics	120	12
ENG/CU/PO/CR/05/6	Automation of Electrical machine	130	13
ENG/CU/PO/CR/06/6	Security System installation	110	11
ENG/CU/PO/CR/07/6	Solar System Installation	70	7
ENG/CU/PO/CR/08/6	Electrical Equipment and System maintenance	130	13
ENG/CU/PO/CR/09/6	Electrical project management	120	12
ENG/CU/PO/CR/10/6	Power Generation	110	11
	Industrial Attachment	480	48
Total		1,710	171
Grand Total		2,610	261

The core units of learning are independent of each other and may be taken independently.

The total duration of the course is 2,610 hours (87 weeks at 30 hours per week) inclusive of industrial attachment.

Entry Requirements

An individual entering this course should have any of the following minimum requirements:

a) Kenya Certificate of Secondary Education (K.C.S.E.) with a minimum mean grade of C- (C minus)

Or

b) Level 5 certificate in a related course with one year of continuous work experience

Or

c) Equivalent qualifications as determined by Kenya National Qualifications Authority (KNQA)

Industrial attachment

An individual enrolled in this course will be required to undergo an industrial attachment in an Electrical firm for a period of at least 480 hours. Attachment will be undertaken upon completion of the course or the unit of learning.

Assessment

The course will be assessed at two levels: internally and externally. Internal assessment is continuous and is conducted by the trainer who is monitored by an internal accredited verifier while external assessment is the responsibility of TVET/CDACC.

Certification

A candidate will be issued with a Record of Achievement on demonstration of competence in a unit of competency. To attain the qualification Electrical Technician Level 6, the candidate must demonstrate competence in all the units of competency as given in qualification pack. These certificates will be issued by TVET CDACC in conjunction with training provider.

CHAPTER 2: ENGINEERING MATHEMATICS /APPLY ENGINEERING MATHEMATICS

2.1. Introduction of the Unit of Learning / Unit of Competency

This unit describes the competencies required by a technician in order to apply algebra, apply trigonometry and hyperbolic functions, apply complex numbers, apply coordinate geometry, carry out binomial expansion, apply calculus, solve ordinary differential equations, solve Laplace transforms ,apply power series, apply statistics, apply numerical methods, apply vector theory apply matrix, apply Fourier series and numerical methods.

2.2. Performance Standard

The trainee will apply algebra, trigonometry and hyperbolic functions, complex numbers, coordinate geometry, carryout binomial expansion, calculus ordinary differential equations, Laplace transforms, power series, statistics Fourier series, vector theory, matrix and numerical methods in solving engineering problems.

2.3. Learning Outcomes

2.3.1. List of Learning Outcomes

- a) Apply Algebra
- b) Apply Trigonometry and hyperbolic functions
- c) Apply complex numbers
- d) Apply coordinate geometry
- e) Carry out Binomial Expansion
- f) Apply Calculus
- g) Solve ordinary differential equations
- h) Apply Laplace transforms
- i) Apply power series
- j) Apply statistics
- k) Apply Fourier series
- l) Apply vector theory
- m) Apply matrix
- n) Numerical methods

2.3.2. Learning Outcome No. 1. Apply Algebra

2.3.2.1 Learning Activities.

Learning Outcome No. 1. Apply Algebra	
Learning Activities	Special Instructions
• Perform calculations involving indices as per the concept • Perform calculations involving logarithms as per the concept • Solving simultaneous as per the rules • Solving quadratic equations as per the concept	

2.3.2.2. Information Sheet No.2/ LO1.

Algebra is used throughout engineering, but it is most commonly used in mechanical, electrical, and civil branches due to the variety of obstacles they face. Engineers need to find dimensions, slopes, and ways to efficiently create any structure or object.

Definitions

Algebra is the study of mathematical symbols and the rules for manipulating these symbols; it is a unifying thread of almost all of mathematics. It includes everything from elementary equation solving to the study of abstractions such as groups, rings, and fields.

Content

Indices

An index number is a number which is raised to a power. The power, also known as the index, tells you how many times you have to multiply the number by itself. For example, 2^5 means that you have to multiply 2 by itself five times $= 2 \times 2 \times 2 \times 2 \times 2 = 32$

Laws of indices

- (i) $x^0 = 1$
- (ii) $x^{-n} = \frac{1}{x^n}$
- (iii) $x^n \cdot x^m = x^{n+m}$
- (iv) $x^n \div x^m = x^{n-m}$
- (v) $(x^n)^m = x^{m \cdot n}$
- (vi) $x^{\frac{n}{m}} = \sqrt[m]{x^n}$

Application of rules of indices in solving problems.

- $y^a \times y^b = y^{a+b}$

Examples

$$2^4 \times 2^8 = 2^{12}$$

$$5^4 \times 5^{-2} = 5^2$$

- $y^a \div y^b = y^{a-b}$

Examples

$$2^{-3} = 1/2^3 = 1/8$$

$$3^{-1}=1/3$$

- $ym/n = (n\sqrt[n]{y})m$

Examples

$$16^{1/2} = \sqrt{16} = 4$$

$$8^{2/3} = (\sqrt[3]{8})^2 = 4$$

- $(y^n)^m = y^{nm}$

Example

$$2^5 + 8^4$$

$$= 2^5 + (2^3)^4$$

$$= 2^5 + 2^{12}$$

$$y^0 = 1$$

Example

$$5^0 = 1$$

Logarithms

If a is a positive real number other than 1, then the logarithm of x with base a is defined by:

$$y = \log_a x \quad \text{or} \quad x = a^y$$

Laws of logarithms

(i) $\log_a(xy) = \log_a x + \log_a y$

(ii) $\log_a\left(\frac{x}{y}\right) = \log_a x - \log_a y$

(iii) $\log_a(x^n) = n\log_a x$ for every real number

Simultaneous equations with three unknown

Simultaneous equations are equations which have to be solved together to find the unique values of the unknown quantities which are time for each of the equations. Two methods of solving simultaneous equations analytically are:

- (i) By substitution
- (ii) By elimination

Examples

Solve the following simultaneous equation by substitution methods

$$3x - 2y + z = 1 \dots \dots (i)$$

$$x - 3y + 2z = 13 \dots \dots (ii)$$

$$4x - 2y + 3z = 17 \dots \dots (iii)$$

From equation (ii) $x = 13 + 3y - 2z$

Substituting these expression $(13 + 3y - 2z)$ for x gives

$$3(13 + 3y - 2z) + 2y + z = 1$$

$$39 + 9y - 6z + 2y + z = 1$$

$$11y - 5z = -38 \dots \dots (iv)$$

$$4(13 + 3y - 2z) + 3z - 2y = 17$$

$$52 + 12y - 8z + 3z - 2y = 17$$

$$10y - 5z = -35 \dots \dots (v)$$

Solve equation (iv) and (v) in the usual way,

From equations (iv) $5z = 11y + 38$; $z = \frac{11y+38}{5}$

Substituting this in equation (v) gives

$$10y - 5\left(\frac{11y + 38}{5}\right) = -35$$

$$10y - 11y - 38 = -35$$

$$-y = -35 + 38 = 3$$

$$y = -3$$

$$z = \frac{11y + 38}{5} = \frac{-33 + 38}{5} = \frac{5}{5} = 1$$

$$\text{But } x = 13 + 3y - 2z$$

$$x = 13 + 3(-3) - 2(1)$$

$$= 13 - 9 - 2$$

$$= 2$$

Therefore, $x = 2$, $y = -3$ and $z = 1$ is the required solution

For more worked examples on substitution and elimination method refer to Engineering Mathematics by A.K Stroud.

Quadratic Equations

Quadratic equation is one in which the highest power of the unknown quantity is 2. For example $2x^2 - 3x - 5 = 0$ is a quadratic equation? The general form of a quadratic equation is $ax^2 + bx + c = 0$, where a, b and c are constants and $a \neq 0$ of solving quadratic equations.

- By factorization (where possible)
- By completing the square
- By using quadratic formula
- Graphically

Example

Solve the quadratic equation $x^2 - 4x + 4 = 0$ by factorization method

Solution

$$\begin{aligned}x^2 - 4x + 4 &= 0 \\x^2 - 2x - 2x + 4 &= 0 \\x(x - 2) - 2(x - 2) &= 0 \\(x - 2)(x - 2) &= 0\end{aligned}$$

i.e $x - 2 = 0$ or $x - 2 = 0$

$x = 2$ or $x = 2$

i.e. the solution is $x = 2$ (twice)

For more worked examples on how to solve quadratic equations using, factorization, completing the square, quadratic formula refer to basic engineering mathematics by J.O Bird, Engineering mathematical by K.A STROUD etc

2.3.2.3. Self-Assessment

This section must be related with the Performance Criteria, Required Knowledge and Skills and the Range as stated in the Occupational Standards.

Q1. (a) Solve the following by factorization

(i) $x^2 + 8x + 7 = 0$

(ii) $x^2 - 2x + 1 = 0$

(b) Solve by completing the square the following quadratic equations

(i) $2x^2 + 3x - 6$

(ii) $3x^2 - x - 6 = 0$

Q.2 Simplify as far as possible

(i) $\log(x^2 + 4x - 3) - \log(x + 1)$

(ii) $2\log(x - 1) - \log(x^2 - 1)$

Q.3 Solve the following simultaneous equations by the method of substitution

$$\begin{aligned}x + 3y - z &= 2 \\2x - 2y + 2z &= 2 \\4x - 3y + 5z &= 5\end{aligned}$$

Q.4 Simplify the following

$$F = (2^{\frac{1}{2}}x^{\frac{1}{4}})^4 \div \sqrt{\frac{1}{9}x^2y^6} \times (4\sqrt{x^2y^4})^{-1/2}$$

Describe quadratic equations.

Differentiate between the two methods of solving simultaneous equations

- (i) By substitution
- (ii) By elimination

Indices is the study of mathematical symbols and the rules for manipulating these symbols. True or false?

Quadratic equation is one in which the highest power of the unknown quantity is 2. True or false

2.3.2.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Calculator
- Writing materials

2.3.2.5. References

- Basic Engineering Mathematics by J.O Bird
- Engineering Mathematics by K.A STROUD
- Technical mathematics book 2 by J.O bird

2.3.3. Learning Outcome No. 2. Apply trigonometry and hyperbolic functions

2.3.3.1. Learning Activities

Learning Outcome No. 2. Apply Trigonometry And Hyperbolic Functions	
Learning Activities	Special Instructions
• Perform calculations using trigonometric rules • Perform calculations using hyperbolic functions	

2.3.3.2. Information Sheet No 2/LO2.

Trigonometry is the branch of mathematics which deals with the measurement of sides and angles of triangles and their relationship with each other. Two common units used for measuring angles are degrees and radians.

Trigonometric ratios

The three trigonometric ratios derived from a right - angled triangle are the same, cosine and tangent refer to basic engineering mathematics by J.O Bird to read more about trigonometry ratios.

Solution of right-angled triangles

To solve a triangle means to find the unknown sides and angles, this is achieved by using the theorem of Pythagoras and or using trigonometric ratios.

Example

In a triangle PQR shown below find the length of PQ and PR

$$\tan 38^\circ = \frac{PQ}{QR} = \frac{PQ}{7.5}$$

Hence

$$\begin{aligned} PQ &= 7.5 \times \tan 38^\circ \\ &= 7.5 \times 0.7813 \\ &= 5.86 \text{ cm} \end{aligned}$$

$$\cos 38^\circ = \frac{QR}{PR} = \frac{7.5}{PR}$$

$$PR = \frac{7.5}{\cos 38^\circ} = \frac{7.5}{0.7880} = 9.518 \text{ cm}$$

For more worked examples refer to basic engineering mathematics by J.) Bird. Also use it to learn about angles of elevation and depression.

Compound angle formulae

$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$$

$$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$$

$$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B}$$

Refer to technician mathematics book 3 by J.O Bird and learn more about compound angle formulae

Conversion of a $a \cos wt + b \sin wt$ into the general form $R \sin(wt + 2)$

Let $a \cos wt + b \sin wt = R \sin(wt + \alpha)$

Expanding the right hand side using the compound angle formulae gives

$$\begin{aligned} a \cos wt + b \sin wt &= R(\sin wt \cos \alpha + \cos wt \sin \alpha) \\ &= R \cos \alpha \sin wt + R \sin \alpha \cos wt \end{aligned}$$

Equating the coefficients of $\cos wt$ on both sides gives.

$$a = R \sin \alpha \text{ i.e. } \sin \alpha = \frac{a}{R}$$

Equating the coefficients of $\sin wt$ on both sides gives

$$b = R \cos \alpha \text{ i.e. } \cos \alpha = \frac{b}{R}$$

If the values of a and b are known, the values of R and α can be calculated.

From Pythagoras theorem.

Diagram

$$R = \sqrt{a^2 + b^2}$$

And from trigonometric ratios,

$$\alpha = \tan^{-1}\left(\frac{a}{b}\right)$$

Example

Express $3 \sin \theta + 4 \cos \theta$ in the general form $R \sin(\theta + \alpha)$

Let $3 \sin \theta + 4 \cos \theta = R \sin(\theta + \alpha)$

Expanding the right hand side using the compound angle formulae gives

$$3 \sin \theta + 4 \cos \theta = R [\sin \theta \cos \alpha + \cos \theta \sin \alpha]$$

$$= R \cos \alpha \sin \theta + R \sin \alpha \cos \theta$$

Equating the coefficient of:

$$\cos \theta; = R \sin \alpha \text{ i.e. } \sin \alpha = \frac{4}{R}$$

$$\sin \theta : 3 = R \cos \alpha \text{ i.e. } \cos \alpha = \frac{3}{R}$$

Thus the values of R and α can be evaluated.

Diagram

$$R = \sqrt{4^2 + 3^2} = 5$$

$$\alpha = \tan^{-1} \frac{4}{3} = 53.13^\circ \text{ or } 233.13^\circ$$

Since both $\sin \alpha$ and $\cos \alpha$ are positive, α lies in the first quadrant where all are positive, Hence 233.13° is neglected.

Hence

$$3 \sin \theta + 4 \cos \theta = 5 \sin (\theta + 53.13^\circ)$$

Example

Solve the equation $3 \sin \theta + 4 \cos \theta = 2$ for values of θ between 0° and 360° inclusive

Soln:

From the example above

$$3 \sin \theta + 4 \cos \theta = 5 \sin (\theta + 53.13^\circ)$$

Thus

$$5 \sin(\alpha + 53.13^\circ) = 2$$

$$\sin(\theta + 53.13^\circ) = \frac{2}{5}$$

$$\theta + 53.13^\circ = \sin^{-1} 2/5$$

$$\theta + 53.13^\circ = 23.58^\circ \text{ or } 156.42^\circ$$

$$\theta = 23.58^\circ - 53.13^\circ = -29.55^\circ$$

$$= 330.45^\circ$$

$$\text{OR } \theta = 156.42^\circ - 53.13^\circ$$

$$= 103.29^\circ$$

Therefore the roots of the above equation are 103.29° or 330.45°

For more worked examples refer to Technician mathematics book 3 by J.) Bird.

Double /multiple angles

For double and multiple angles refer to Technician mathematics by J.O Bird

Factor Formulae

For worked examples refer to Technic mathematics book 3 by J. O Bird, Pure mathematics by backhouse and Engineering mathematics by KA Stroud.

Half –angle formulae

Refer to pure mathematics by backhouse and Engineering mathematics by K.A STROUD

Hyperbolic functions

Definition of hyperbolic functions, *Sinhx cosh x and tanh x*

- Evaluation of hyperbolic functions
- Hyperbolic identities
- Osborne's Rule
- Solve hyperbolic equations of the form $a \cosh x + b \sinh x = C$

For all the above refer, to Engineering mathematics by K.A STROUD

2.3.3.3. Self-Assessment

Q1. A surveyor measures the angle of elevation of the top of a perpendicular building as 19° . He moves 120m nearer the building and measures the angle of elevation as 47° . Calculate the height of the building to the nearest meter.

Q2. Solve the equation $5 \cos \theta + 4 \sin \theta = 3$ for values of θ between 0° and 360°

Inclusive.

Q3. Prove these identities

$$(i) \cosh 2x = \cosh^2 x + \sinh^2 x$$

$$(ii) \sinh(x + y) \sinh x \cosh y + \cosh y \sinh x$$

Q.4 Solve the equation

$$3 \sinh x + 4 \cosh x = 5$$

Define trigonometry

5. Describe trigonometric ratios
6. Differentiate various hyperbolic functions
7. Perform calculations on various hyperbolic functions
8. Trigonometry is the branch of mathematics which deals with the measurement of sides and angles of triangles and their relationship with each other. True or false?
9. Hyperbolic function is in the form $\sin X$, $\tan X$. True or False?

2.3.3.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

Writing materials

Geometrical set

Calculator

2.3.3.5. References

- Basic engineering mathematics by J.O Bird
- Technical mathematics book 3 by J.O Bird
- Pure mathematics book 1 by Backhouse
- Engineering mathematics by K a Stroud

2.3.4. Learning Outcome No.3 Apply Complex Number

2.3.4.1. Learning Activities

Learning Outcome No. 3. Apply Complex Number	
Learning Activities	Special Instructions
- Preparing complex numbers using ARgand diagrams - Performing operations involving complex number - Performing calculations involving complex number using De Moirés theorem	

2.3.4.2. Information Sheet chapter 2/LO3

Apply Complex Number

A number of the form $a + ib$ is called complex number where a and b are real numbers and $i = \sqrt{-1}$ we call ' a ' the real part and ' b ' the imaginary part of the complex $a + ib$ if $a = 0$ then ib is said to be purely imaginary, if $b = 0$ the number is real.

Pair of complex number $a + ib$ are said to be conjugate of each other.

Addition and subtraction of complex numbers

Addition and subtraction of complex numbers is achieved by adding or subtracting the real parts and the imaginary parts.

Example 1

$$\begin{aligned}
 &(4 + j5) + (3 - j2) \\
 &(4 + j5) + (3 - j2) = 4 + j5 + 3 - j2 \\
 &= (4 + 3) + j(5 - 2) \\
 &= 7 + j3
 \end{aligned}$$

Example 2

$$\begin{aligned}
 (4 + j7) - (2 - js) &= 4 + j7 - 2 + js = (4 - 2) + j(7 + 5) \\
 &= 2 + j12
 \end{aligned}$$

Multiplication of complex numbers

Example 1

$$\begin{aligned}
 &(3 + j4)(2 + j5) \\
 &6 + j8 + j15 + j^2 20 \\
 &6 + j23 - 20 \text{ (since } j^2 = -1) \\
 &= -14 + j23
 \end{aligned}$$

Examples 2

$$\begin{aligned}
 &(5 + j8)(5 - j8) \\
 &(5 + j8)(5 - j8) = 25 + j40 - j40 - j^2 64 \\
 &= 25 + 64 \\
 &= 89
 \end{aligned}$$

A pair of complex numbers are called conjugate complex numbers and the product of two conjugate. Complex numbers is always entirely real. $\cos\theta + jsin\theta$

Argand diagram

Although we cannot evaluate a complex number as a real number, we can represent diagrammatically in an argand diagram. Refer to Engineering Mathematics by K.A Stroud to learn more on how to represent complex numbers on an argand diagram. Use the same back learn three forms of expressing a complex number.

Demoivre's Theorem

Demoivre's theorem states that $[r(\cos\theta + j\sin\theta)]^n = r^n(\cos n\theta + jsinn\theta)$

It is used in finding powers and roots of complex numbers in polar

Example

Find the three cube roots of $z = 5(\cos 225^\circ + j\sin 225^\circ)$

$$Z_1 = Z^{\frac{1}{3}} \left(\cos \frac{225^\circ}{3} + j\sin \frac{225^\circ}{3} \right)$$

$$1.71 (\cos 75^\circ + j\sin 75^\circ)$$

$$z_1 = 1.71 (\cos 75^\circ + j\sin 75^\circ)$$

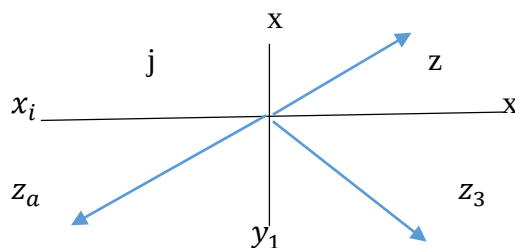
Cube roots are the same size (modules) i.e 1.71 and separated at intervals of $\frac{360^\circ}{3}$, i.e 120°

$$z_1 = 1.71 / 75^\circ$$

$$Z_2 = 1.71 \cos(195^\circ + j\sin 195^\circ)$$

$$z_s = 1.71 (315^\circ + j\sin 315^\circ)$$

Sketched Argand diagram.



Refer to engineering mathematics by K.A Stroud and learn more on how to find the expansion of

$\cos^n \theta$ and $\cos^n \theta$

LOCI problems

We sometimes required to find the locus of a point which moves in the Argand diagram according to some stated condition.

Examples

If $Z = x + jy$, find the equation of the locus $\left[\frac{z+1}{z-1}\right] = 2$

$$\sin\theta Z = x + jy.$$

$$Z + 1 = X + jy + 1 = (x + 1) + jy = r_1 \text{ angle } \theta_1 = z_1$$

$$z - 1 = x + jy - 1 = (x - 1) + jy = r_2 \text{ angle } \theta_2 = z_2$$

$$\therefore \frac{z+1}{z-1} = \frac{r_1 \theta_1}{r_2 \theta_2} = \frac{r_1}{r_2} \theta_1 - \theta_2$$

$$\therefore \left(\frac{z+1}{z-1}\right) = \frac{r_1}{r_2} = \left(\frac{z_1}{z_2}\right) = \frac{[(x+1)^2 + y^2]}{[(x-1)^2 + y^2]}$$

$$\frac{[(x+1)^2 + y^2]}{(x-1)^2 + y^2}$$

$$\therefore \frac{(x+1)^2 + y^2}{(x-1)^2 + y^2} + 4$$

$$\therefore (x+1)^2 + y^2 = 4((x-1)^2 + y^2)$$

$$x^2 + 2x + 1 + y^2 = 4(x^2 - 2x + 1 + y^2)$$

$$= 4x^2 - 8x + 4 + 4y^2$$

$$\therefore 3x^2 - 10x + 3 + 3y^2 = 0$$

2.3.4.3. Self-Assessment

1. Find the fifth roots of $-3 + j3$ in polar form and in exponential form
2. Determine the three cube roots of $\frac{2-j}{2+j}$ giving the results in a modulus/ argument form.

Express the principal root in the form $a + jb$

3. If $z = x + jy$, where x and y are real, show that the locus $\left(\frac{z-2}{z+2}\right) = 2$ is a circle and determine its center and radius.
4. Describe De Moirés theorem
5. Perform calculations involving complex number using De Moirés theorem
6. Explain Argand diagram
7. A number of the form $a + ib$ is called complex number where a and b are real numbers and $i = \sqrt{-1}$ TRUE OR FALSE?
8. Demoivre's theorem states that $[r(\cos\theta + jsin\theta)]^n = r^n(\cos n\theta + jsinn\theta)$ TRUE OR FALSE?

2.3.4.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Calculator
- Writing materials
- Geometrical set.

2.3.4.5. References

1. Technician Mathematics Book (4 and 5) by J.O Bird
2. Engineering Mathematics by K.A Stround
3. Mathematics for Engineers by Dass

2.3.5. Learning Outcome No. 4. Apply Co-ordinate Geometry

2.3.5.1. Learning Activities

Learning Outcome No. 4. Apply Co-Ordinate Geometry	
Learning Activities	Special Instructions
• Calculating polar equations using coordinate geometry • Drawing graphs of given polar equations using the Cartesian plane • Determining normal and tangents using coordinate geometry	

2.3.5.2 Information Sheet No. 2/L04

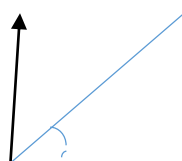
Introduction

The position of a point in a plane can be represented in two forms

- Cartesian co-ordinate (x, y)
- Polar co-ordinate (r, θ)

The position of a point in the corresponding axis can therefore generate Cartesian and polar equations which can easily change into required form to fit the required result.

Example



Convert $r^2 = \sin\theta$ into Cartesian form.

$$\cos\theta = \frac{x}{r}$$

$$\sin\theta = \frac{y}{r}$$

Form Pythagoras theorem $r^2 = x^2 + y^2$

$$r^2 = \sin\theta$$

$$(x^2 + y^2) = \frac{y}{r}$$

$$(x^2 + y^2)r = y$$

$$(x^2 + y^2)(x^2 + y^2)^{\frac{1}{2}} = y$$

$$(x^2 + y^2)^{\frac{3}{2}} = y$$

Example 2

Find the Cartesian equation of

$$(i) \quad r = a(1 + 2\cos\theta) \quad (ii) \quad r\cos(\theta - \alpha) = p$$

[The $\cos\theta$ suggest the relation $X = \cos\theta$, so multiplying through by r]

$$\therefore r^2 = a(r + 2r\cos\theta)$$

$$\therefore x^2 + y^2 = a\left(\sqrt{x^2 + y^2} + 2x\right)$$

$$\therefore x^2 + y^2 + 2x = a\sqrt{(x^2 + y^2)}$$

Therefore the Cartesian equation of $r = a(1 + 2\cos\theta)$ is $(x^2 + y^2 - 2ax)^2 = a^2(x^2 + y^2)$

$$(ii) \quad r\cos(\theta - \alpha) = p$$

$\cos(\theta - \alpha)$ May be expanded

$$\therefore r\cos\theta\cos\alpha + r\sin\theta\sin\alpha = p$$

$$(iii) \quad \text{Therefore the Cartesian equation of } r\cos(\theta - \alpha) = p \text{ is } x\cos\alpha + y\sin\alpha = p$$

Example 3

Find the polar equation of the circle whose Cartesian equation is $x^2 + y^2 = 4x$

$$x^2 + y^2 = 4x$$

Put $x = r\cos\theta, y = r\sin\theta$, then

$$r^2\cos^2\theta + r^2\sin^2\theta = 4r\cos\theta$$

$$\therefore r^2 = 4r\cos\theta$$

Therefore the polar equation of the circle is $r^2 = 4r\cos\theta$.

For more information on the conversion of Cartesian equation to polar equation and vice versa refer to pure mathematics by J.K Backhouse

2.3.5.3. Self-Assessment

1) Obtain the polar equation of the following loci

$$(i) \quad x^2 + y^2 = a^2$$

$$(ii) \quad x^2 - y^2 = a^2$$

$$(iii) \quad y = 0$$

$$(iv) \quad y^2 = 4a(a - x)$$

$$(v) \quad x^2 + y^2 - 2y = 0$$

$$(vi) \quad xy = c^2$$

2) Obtain the Cartesian equation of the following loci

$$(i) \quad r = 2$$

$$(ii) \quad a(1 + \cos\theta)$$

$$(iii) \quad r = a\cos\theta$$

$$(iv) \quad r = a\tan\theta$$

$$(v) \quad r = 2a(1 + \sin 2\theta)$$

$$(vi) \quad 2r^2\sin 2\theta = c^2$$

$$(vii) \quad \frac{l}{r} = 1 + 8\cos\theta$$

$$(viii) \quad r = 4a\cot\theta\operatorname{cosec}\theta$$

3) Differentiate between Cartesian co-ordinate and Polar co-ordinate

4) Perform calculations on polar equations

5) The position of a point in a plane can be represented in two forms: Cartesian co-ordinate (x, y) or Polar co-ordinate (r, θ) TRUE OR FALSE?

6) The equation $r^2 = x^2 + y^2$ illustrates Pythagoras theorem. TRUE OR FALSE?

2.3.6 Learning Outcome No.5 Carry out Binomial Expansion

2.3.6.1 Learning Activities

Learning Outcome No. 5. Carry Out Binomial Expansion	
Learning Activities	Special Instructions
- Determining roots of numbers using binomial theorem - Determining errors and small changes using binomial theorem - To cover the Performance Criteria statements - Trainees to demonstrate knowledge in relation to; The <i>Range</i> in the Occupational Standards and <i>Content</i> in the curriculum	

Carry out Binomial expansion

Binomial is a formula for raising a binomial expansion to any power without lengthy multiplication. It states that the general expansion of $(a + b)^n$ is given as

$$(a + b)^n = a^n b^0 + n a^{n-1} b^1 + \frac{n(n-1)a^{n-2}b^2}{2!} + \frac{n(n-1)(n-2)a^{n-3}b^3}{3!} + \dots$$

Where n can be a fraction, a decimal fraction, positive or negative integer.

Example 1

Use binomial theorem to expand $(2 + x)^3$

Solution

$$(a + b)^n = a^n b^0 + n a^{n-1} b^1 + \frac{n(n-1)a^{n-2}b^2}{2!} + \frac{n(n-1)(n-2)a^{n-3}b^3}{3!} + \dots$$

$$A = 2, b = x \text{ and } n = 3$$

$$(2 + x)^3 = 2^3 x^0 + 3 \cdot 2^2 x^1 + \frac{3(3-1)2^1 x^2}{2!} + \frac{3(3-1)(3-2)2^0 x^3}{3!} + \dots$$

$$= 18 + 12x + 6x^2 + x^3$$

For more examples on positive power refer to Technician Mathematic Book by J.O Bird.

Binomial theorem for any index

It has been shown that

$$(1 + x)^n = 1 + nx + \frac{n(n-1)}{2!} x^2 + \dots$$

The series may be continued indefinitely for any value of n provide $-1 < x < 1$

Example

Use the binomial theorem to expand $\frac{1}{1-x}$ in ascending power of x as far as the term in x^3 .

Solution

Since $\frac{1}{1-x}$ may be written $(a - x + x)^{-1}$, the binomial theorem may be used. Thus

$$(1 - x)^{-1} = 1 + -1(-x) + \frac{-1(-2)}{2!} x^2 + \frac{-1(-2)(-3)}{3!} + \dots$$

$$\frac{1}{1-x} = 1 + x + x^2 + x^3 + \dots$$

Provided $-1 < x < 1$

Practical application of binomial theorem

Example1

The radius of a cylinder is reduced by 4% and its height increased by 2%. Determine the appropriate percentage change in its volume neglecting products of small quantities.

Solution

Volume $V = \pi r^2 h$

Let original values be, *radius* = r

Height = h

New values

radius = $(1 - 0.04)r$

Height = $(1 + 0.02)h$

New volume

$$= \pi(1 - 0.04)^2 r^2 (1 + 0.02)h$$

Using binomial theorem, $(1 - 0.04)^2 = 1 - 2(0.04) + (0.04)^2 = 1 - 0.08$

$$= \pi r^2 h(1 - 0.08)(1.02) = \pi r^2 h(0.94)$$

Percentage change $= \frac{(0.94-1)100\%}{1} = -6\%$

The new volume decreased by 6%

2.3.6.3. Assessment

1. Expand as far as the third term and state the limits at which the expansions are valid.

(i) $\frac{1}{(1+2x)^3}$

(ii) $\sqrt{4+x}$

2. Show that if higher power of x are neglected

$$\sqrt{\frac{1+x}{1-x}} = 1 + x + \frac{x^2}{2}$$

3. The second moment of area of a rectangular section through its centroid is given by $\frac{bl^3}{12}$. Determine the appropriate change in the second moment of area if b is increased by 3.5% and l is reduced by 2.5%
4. Explain binomial theorem
5. Describe binomial expansion
6. Identify roots of numbers using binomial theorem
7. Binomial theorem can be used to identify small changes and errors TRUE OR FALSE?
8. Binomial is a formula for raising a binomial expansion to any power without lengthy multiplication. TRUE OR FALSE?

2.3.6.5. References

1. John Bird- Higher Engineering Mathematics sixth edition
2. Pure Mathematics: JK BackHouse

2.3.7. Learning Outcome No. 6. Apply Calculus

2.3.7.1. Learning Activities

Learning Outcome No. 6. Apply Calculus	
Learning Activities	Special Instructions
• Determining Derivatives from first principles • Determining derivatives of inverse trigonometric functions • Determining the rate of change and small changes using differentiation • Determining integrals of algebraic functions • Determining integrals of trigonometric functions • Determining integrals of logarithmic functions • Determining integrals of hyperbaric and inverse hyperbaric functions.	

2.3.7.2 Information Sheet No. 2/ LO6

Calculus is a branch of mathematics involving calculations dealing with continuously varying functions. The subject falls into two parts namely differential calculus (differentiation) and integral calculus (integration)

Differentiation

The central problem of the differential calculus is the investigation of the rate of change of a function with respect to changes in the variables on which it depends.

Differentiation from first principles.

To differentiate from first principles means to find $f'(x)$ using the expression.

$$f'(r) = \lim_{\delta x \rightarrow 0} \left\{ \frac{f(x + \delta x) - f(x)}{\delta x} \right\}$$

$$\delta x \rightarrow 0 \left\{ + \frac{(x + \delta x) - f(x)}{\delta x} \right\}$$

$$f(x) = x^2$$

$$f(x + \delta x) = (x + \delta x)^2 = x^2 + 2x\delta x + \delta x^2$$

$$f(x + \delta x) - f(x) = x^2 + 2x\delta x + \delta x^2 - x^2$$

$$= 2x\delta x + \delta x^2$$

$$\frac{f(x + \delta x) - f(x)}{\delta x} = \frac{2x\delta x + \delta x^2}{\delta x}$$

$$= 2x + \delta x$$

$$\text{As } \delta x \rightarrow 0, \frac{f(x + \delta x) - f(x)}{\delta x} \rightarrow 2x + 0$$

$$\therefore f'(x) = \lim_{\delta x \rightarrow 0} \left\{ \frac{f(x + \delta x) - f(x)}{\delta x} \right\} = 2x$$

At $x = 3$, the gradient of the curve i.e $f'(x) = 2(3) = 6$
Hence if $f(x) = x^2$, $f'(x) = 2x$. The gradient at $x = 3$ is 6

Methods of differentiation

There are several methods used to differentiate different functions which include:

- (i) Product Rule
- (ii) Quotient Rule
- (iii) Chain Rule
- (iv) Implicit Rule

Example:

Determine $\frac{dy}{dx}$ given that $y = x^2 \sin x$

Solution

From product rule: $uv(x) = u \frac{dv}{dx} + v \frac{du}{dx}$
 $u = x^2$ and $v = \sin x$
 $\frac{du}{dx} = 2x$ $\frac{dv}{dx} = \cos x$

$$\begin{aligned} \therefore \frac{dy}{dx} &= x^2(\cos x) + \sin(2x) \\ &= x^2 \cos x + 2x \sin x \\ y &= \frac{x^2 + 1}{x - 3} \end{aligned}$$

Soln. Using Quotient rule:

$$\frac{u(x)}{v(x)} = \frac{v \frac{du}{dx} - u \frac{dv}{dx}}{v^2}$$

$$\begin{aligned} u &= x^2 + 1 & v &= x - 3 \\ \frac{du}{dx} &= 2x & \frac{dv}{dx} &= 1 \\ \therefore \frac{dy}{dx} &= \frac{(x-3)(2x) - (x^2+1)(1)}{(x-3)^2} \\ &= \frac{2x^2 - 6x - x^2 - 1}{(x-3)^2} \\ &= \frac{x^2 - 6x - 1}{(x-3)^2} \\ &= \frac{x^2 - 6x - 1}{x^2 - 6x + 9} \end{aligned}$$

For more examples on the cases of application of the other, highlighted rates refer to Engineering Mathematics by K Stroud.

Application of differentiation

Differentiation can be used to determine velocity and acceleration of a moving body. It can also be applied to determine maximum and minimum values.

Example: A rectangular area is formed using a piece of wire 30cm long. Find the length and breadth of the rectangle if it is to enclose the maximum possible area.

Solution.

Let the dimension of a rectangle be x and y

Perimeter of rectangle = $2x + 2y = 36$

i.e $x + y = 18$(i)

Since it's the maximum area that is required a formula for the area A must be obtained in terms of one variable only.

Area = $A = xy$

From equation (i) $y = 18 - x$

Hence $A = x(18 - x) = 18x - x^2$

Now that an expression for the area has been obtained in terms of one variable it can be differentiated with respect to that variable

$\frac{dA}{dx} = 18 - 2x$ for maximum or minimum value i.e $x = 9$

$$\frac{d^2A}{dx^2} = -2, \text{ which is negative giving a maximum value}$$

$$y = 18 - x = 18 - 9 = 9$$

Hence the length and breadth of the rectangle of maximum area both 9 cm i.e a square gives the maximum possible area for a given perimeter length. When perimeter is 36cm maximum area, possible is 81cm^2 .

Integration

Process of integration reverses the process of differentiation. In differentiation if $f(x) = x^2$ then $f'(x) = 2x$.

Since integration reverse the process of moving from $f(x)$ to $f'(x)$, it follows that the integral of $2x$ is x^2 i.e it's the process of moving from $f'(x)$ to $f(x)$. Similarly if

$y = x^2$ then $\frac{dy}{dx} = 3x^2$. Reversing this process shows that the integral of $3x^2$ and x^3 .

Integration is also the process of summation or adding parts together and on elongate 's' shown a $\int$ is used to replace the words 'integrated of'. Thus $\int 2x = x^2$ and $\int 3x^2 = x^3$

Refers to engineering mathematics by K.A. Stroud and learn those on definite and indefinite integrals.

Methods of integration and application of integration

The methods available are:

- By using an algebraic substitution
- Using trigonometric identities and substitutions

- c. Using partial fraction
- d. Using the $t = \tan \frac{\theta}{2}$ substitution
- e. Using integration by parts

Refer to Engineering mathematics by K.A Stroud and learn more about methods of integration,

Also use the above stated book to learn more on application on integration to find areas, volumes of revolutions etc

2.3.7.3. Self-Assessment

1. Find the co-ordinator, of the points on the curve

$$y = \frac{1/3(5 - 6x)}{3x^2 + 2}$$

Where the gradient is zero.

2. If $y = \frac{4}{3x^3} - \frac{2}{x^2} + \frac{1}{3x} - \sqrt{x}$. Find $\frac{d^2y}{dx^2}$ and $\frac{d^3y}{dx^3}$

3. Find $\int \cos 6x \sin 2x \, dx$

4. Evaluator $\int_3^4 \frac{x^3 - x^2 - 5x}{x^2 - 2x + 2} \, dx$

5. Explain calculus
6. Perform calculations on inverse trigonometric functions
7. Differentiate algebraic functions, trigonometric functions and logarithmic functions
8. Perform calculations on integrals of hyperbolic and inverse hyperbolic functions.
9. Cross product is a method of differentiation. TRUE OR FALSE?
10. Use of partial fraction is a method of differentiation. TRUE OR FALSE

2.3.7.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Writing materials
- Calculator

2.3.7.5. References

1. Technician Mathematics Book (4 and 5) by J.O Bird
2. Engineering Mathematics by K.A Stroud
3. Mathematics for Engineers by Dass

2.3.8. Learning Outcome No. 7. Solve Ordinary Differential Equations

2.3.8.1. Learning Activities

Learning Outcome No. 7. Solve Ordinary Differential Equations	
Learning Activities	Special Instructions
• Solve first order and second order differential equations using the method of undetermined coefficients. • Apply boundary conditions to find the particular solution	• Find general solution • Find particular solution

2.3.8.2. Information Sheet No. 2/ LO7

An equation involves differential co-efficient is called a differential equation examples.

$$(i) \quad \frac{dy}{dx} = \frac{1+x^2}{1-y^2}$$

$$(ii) \quad \frac{d^2y}{dx^2} + 2\frac{dy}{dx} - 8y = 0$$

The order of a differential equation is the order of the highest differential is coefficient present in the equation.

Differential equations represent dynamic relationship i.e quantities that change, and are thus

An equation which involve differential co-efficient is called a differential equation.

Example:

$$(i) \quad \frac{dy}{dx} = \frac{1+x^2}{1-y^2}$$

$$(ii) \quad \frac{d^2y}{dx^2} + 2\frac{dy}{dx} - 8y = 0$$

The order of a differential equation is the order of the highest differential coefficient present in the equation.

A differential equation represent dynamic relationships, ie quantities that change, and are thus frequently occurring in scientific and engineering problems.

Formation of a differential equation

Differential equations may be formed in practice from a consideration of the physical problem to which they refer. Mathematically, they can occur when arbitrary constants are eliminated from a given function.

Example

Consider $y = A\sin x + B\cos x$, where A and B are two arbitrary constants. If we differentiate, we get

$$\frac{dy}{dx} = A\cos x - B\sin x \text{ and } \frac{d^2y}{dx^2} = -A\sin x - B\cos x = -(A\sin x + B\cos x)$$

i.e. $\frac{d^2y}{dx^2} = -y$

$\therefore \frac{d^2y}{dx^2} + y = 0$

This is a differential equation of the second order.

For the formation of first order differential equations, refer to Technician Mathematics 4 and 5 by J.O Bird.

Types of first order differential equations:

1. By separating the variables
2. Homogeneous first order differential equations
3. Linear differential equations
4. Exact differential equations

Refer to Engineering Mathematics by K.A Stroud, Technician 4 and 5 by J.O Bird for worked out examples and further exercises.

Application of first order differential equations.

Differential equations of the first order have many applications in engineering and science.

Example:

The rate at which a body cools is given by the equations $\frac{d\theta}{dt} = -k\theta$ where θ the temperature of the body above the surroundings is and k is a constant. Solve the equation for θ given that $t = 0$,

$$\theta = \theta_0$$

Solution

$$\frac{d\theta}{dt} = -k\theta$$

Rearr

angin

g

gives

dt

$$= \frac{-1}{k\theta}$$

Integrating both sides gives $\int dt = \frac{-1}{k} \int \frac{d\theta}{\theta}$

i.e. $t = \frac{-1}{k} \ln \theta + c \dots \dots \dots (i)$

Substituting the boundary conditions $t = 0$, $\theta = \theta_0$ to find c gives

$$0 = \frac{-1}{k} \ln \theta_0 + c$$

i.e
$$c = \frac{1}{k} \ln \theta_0$$

Substituting $c = \frac{-1}{k} \ln \theta_0$ in equation (i) gives

$$t = \frac{-1}{k} \ln \theta + \frac{1}{k} \ln \theta_0$$

$$t = \frac{1}{k} (\ln \theta_0 + \ln \theta) = \frac{1}{k} \ln \left(\frac{\theta_0}{\theta} \right)$$

$$kt = \ln \left(\frac{\theta_0}{\theta} \right)$$

$$e^{kt} = \frac{\theta_0}{\theta}$$

$$e^{-kt} = \frac{\theta}{\theta_0}$$

Hence
$$\theta = \theta_0 e^{-kt}$$

Further problems on application of differential equations may be found in Engineering Mathematics by K.A Stroud, Technician 4 and 5 by J.O Bird.

Formation of the second order differential equation

For, formation of second order differential equations refer to *Engineering Mathematics by K.A Stroud, Technician 4 and 5 by J.O Bird.*

Application of second order differential equations

Many applications in engineering give rise to the second order differential equations of the form

$$a \frac{d^2 y}{dx^2} + b \frac{dy}{dx} + cy = f(x)$$

Where a, b, c are constants coefficient and $f(x)$ is a given function of x .

Example include:

- (1) Bending of beams
- (2) Vertical oscillations and displacements
- (3) Damped forced vibrations

For more worked examples refer to Engineering Mathematics by K.A Stroud, Technician 4 and 5 by J.O Bird.

2.3.8.3 Self-Assessment

Q1. Solve the following equations:

- (i) $x(y - 3) \frac{dy}{dx} = 4y$
- (ii) $(xy + y^2) + (x^2 - xy) \frac{dy}{dx} = 0$
- (iii) $\frac{dy}{dx} + y \tan x = \sin x$

Q2. The charge, q , on a capacitor in an LCR circuit satisfies the second order differential equation

$$L \frac{d^2 q}{dt^2} + b \frac{dq}{dt} + \frac{1}{c} q = E$$

Show that if $2L = cR^2$ the general solution of this equation is

$$q = e^{\frac{-t}{cR}} \left(A \cos \frac{1}{cR} t + B \sin \frac{1}{cR} t \right) + cE$$

If $i = \frac{dq}{dt} = 0$ and $q = 0$ when $t = 0$. Show that the current in the circuit is

$$i = \frac{2E}{R} e^{\frac{-t}{cR}} \sin \frac{1}{cR} t$$

3. Explain differential equations
4. Describe method of undetermined coefficients
5. Perform calculations on first order and second order differential equations using the method of undetermined coefficients
6. An equation which involve differential co-efficient is called a differential equation. TRUE OR FALSE?
7. Linear differential equations is not a first order differential equation. TRUE OR FALSE?

2.3.8.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Calculator
- Writing materials

2.3.8.5. References

1. Technician Mathematics Book (4 and 5) by J.O Bird
2. Engineering Mathematics by K.A Stround
3. Mathematics for Engineers by Dass

2.3.9 Learning Outcome No. 8. Apply Laplace transforms

2.3.9.1 Learning Activities

Learning outcome No. 8. Apply Laplace transforms	
Learning Activities	Special Instructions
• Derive Laplace transform from first principle. • Solve Laplace transforms using initial and final value theorem. • Determine inverse using Laplace transform using partial fractions, • Solve differential equations by using Laplace transform • To cover the Performance Criteria statements • Trainees to demonstrate knowledge in relation to; The <i>Range</i> in the Occupational Standards and <i>Content</i> in the curriculum	• Rule of partial fractions

2.3.9.2. Information Sheet No 2/LO8

Definition

The Laplace transform of a function $F(t)$ is denoted by $\mathcal{L}[F(t)]$ and is defined as the integral of $F(t)e^{-st}$ between the limits $t = 0$ and $t = \infty$.

i.e $\mathcal{L}[F(t)] = \int_0^{\infty} F(t)e^{-st} dt$

in determining the transform of any function, you will appreciate that the limits are substituted for t , so that the result will be a function of s .

$$\therefore \mathcal{L}[F(t)] = \int_0^{\infty} F(t)e^{-st} dt = f(s)$$

Deriving the Laplace transform from the first principles

To find the Laplace transform from first principles.

Example

To find the Laplace transform of $F(t) = a$ (constant)

$$\mathcal{L}(a) = \int_0^{\infty} a e^{-st} dt = \left[a \frac{e^{-st}}{-s} \right]_0^{\infty} = -\frac{a}{s} [e^{-st}]_0^{\infty}$$

$$= \frac{-a}{s} [0 - 1] = \frac{a}{s}$$

$$\therefore \mathcal{L}(a) = \frac{a}{s}$$

Example

To find the Laplace transform of $F(t) = e^{at}$

Solution

$$\begin{aligned}\mathcal{L}(e^{at}) &= \int_0^{\infty} e^{at} e^{-st} dt \\&= \int_0^{\infty} e^{-(s-a)t} dt \\&= \left[\frac{e^{-(s-a)t}}{-(s-a)} \right]_0^{\infty} \\&= \frac{-1}{s-a} (0 - 1) \\&= \frac{1}{s-a} \\ \therefore \mathcal{L}(e^{at}) &= \frac{1}{s-a}\end{aligned}$$

For more worked examples on how to derive the Laplace transform from first principles refer to Advanced Engineering Mathematics by K.A Stround.

Inverse Transforms

Here we have the reverse process, ie given a Laplace transform, we have to find the function of t to which it belongs.

For example, we know that $\frac{a}{s^2+a^2}$ is the Laplace transform of $\sin at$ so we can write

$$\mathcal{L}^{-1}\left(\frac{a}{s^2+a^2}\right) = \sin at$$

The symbol $\mathcal{L}^{-1}$ indicating the inverse transform and not the reciprocal.

For worked examples on how to find inverse of the Laplace transform refer to Further Engineering Mathematics by K.A Stround.

Solution of differential equation by Laplace transforms.

To solve a differential equation by Laplace transform we go through four distinct stages.

- (1) Re-write the equation in terms of Laplace transform
- (2) Insert the given initial conditions
- (3) Rearrange the equation algebraically to given the transform of the solution.

For worked examples and exercises refer to Further Engineering Mathematics by K.A Stround.

2.3.9.3. Self-assessment

Q1. Derive the Laplace transform of each of the following expressions

- (i) $f(t) = \sin 2t$
- (ii) $f(t) = \cos at$
- (iii) $f(t) = e^{at}$

Q2. Find the inverse Laplace transform of each of the following expressions

- (i) $\frac{4}{s^2+4s+5}$
- (ii) $\frac{s+5}{s^2+10s+29}$
- (iii) $\frac{2s-3}{s^2+6s+10}$

Q3. Solve the following differential equations using Laplace transforms

- (i) $x'' + x' + 2x = 4\cos 2t$
- (ii) $x'' - 4x = 4t$

4. Describe Laplace transform from first principle

5. Explain inverse transform

6. Differentiate initial and final value theorem.

7. Perform calculations using Laplace transform

8. The Laplace transform of a function $F(t)$ is denoted by $\mathcal{L}[F(t)]$ and is defined as the integral of $F(t)e^{-st}$ between the limits $t = 0$ and $t = \infty$. TRUE OR FALSE

9. Insert the given initial conditions is not one of the stages of solving a differential equation by Laplace transform. TRUE OR FALSE

2.3.9.4 Tools, equipment's

- Calculator
- Laplace transform Tables
- Writing material

2.3.9.5 References

1. Further Engineering Mathematics by K.A Stround
2. Mathematics for Engineers by Dass

2.3.10. Learning Outcome No. 9. Apply Power Series

2.3.10.1 Learning Activities

Learning Outcome No. 9. Apply Power Series	
Learning Activities	Special Instructions
- Obtaining power series using Taylor's the Obtaining power series using Taylor's theorem - Obtaining power series using Maclaurins Theorem.	

2.3.10.2 Information Sheet No. 2/ LO9

The power series of claurins theorem different functions can be carried out using two theorems.

- (i) Taylor's Theorem
- (ii) Maclarins theorem

Taylor's series states that;

$$f(x + h) = f(x) + hf'(x) + \frac{h^2}{2!}f''(x) + \frac{h^3}{3!}f'''(x) + \dots$$

Examples

Express $\sin(x + h)$ as a series of powers of h and hence evaluates $\sin 44^\circ$ correct to four decimal places.

Soln

$$f(x + h) = f(x) + hf'(x) + \frac{h^2}{2!}f''(x) + \frac{h^3}{3!}f'''(x) + \dots$$

$$f(x) = \sin x$$

$$f'(x) = \cos x$$

$$f''(x) = -\sin x$$

$$f'''(x) = -\cos x$$

$$f^{iv}(x) = \sin x$$

$$\therefore \sin(x + h) = \sin x + h\cos x - \frac{h^2}{2} \sin x - \frac{h^3}{6} \cos x \dots$$

$$\sin 44^\circ = \sin(45^\circ - 1^\circ)$$

$$= \sin(\pi/4) - 0.01745$$

$$= \sin \pi/4 - 0.01745 \cos \frac{\pi}{4} - \frac{0.01745^2}{2} \sin \pi/4 + \frac{0.01745^3}{6} \cos \pi/4$$

$$\text{But } \sin 45 = \cos 45 = 0.707$$

$$= 0.707 (1 - 0.01745 - 0.0001523 + 0.0000009)$$

$$= 0.707(0.982395)$$

$$= 0.69466$$

0.6947(4dp)

For the use Maclaurins theorem refer to Engineering Mathematics by Strond.

2.3.10.3. Self-Assessment

1. Use Manchurians theorem to expand $\ln(3x + 1)$. Hence use the expansion to evaluate $\int_0^1 \frac{\ln(3x+1)}{x^2} dx$ to four decimal places
2. Use Taylors series to expand $\cos\left(\frac{\pi}{3} + h\right)$ in terms of h as far as h^3 . Hence evaluate $\cos 68^\circ$ correct to four decimal places
3. Describe power series of claurins theorem
4. Differentiate between Taylor's Theorem and Maclarins theorem
5. Perform calculations on power series using Taylor's theorem
6. Perform calculations on power series using Maclaurins Theorem
7. Taylor's Theorem can be used to obtain power series. TRUE OR FALSE?
8. Taylor's series states that;
9. $f(x + h) = f(x) + hf'(x) + \frac{h^2}{2!}f''(x) + \frac{h^3}{3!}f'''(x) + \dots$ TRUE OF FALSE?

2.3.10.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Advanced Calculator

2.3.10.5. References

1. Strond, 6th Edition Advanced Engineering mathematics

2.3.11. Learning Outcome No. 10. Apply statistics

2.3.11.1. Learning Activities

Learning Activities No. 10. Apply Statistics	
Learning Activities	Special Instructions
• Perform identification collection and organization of data • Perform interpretations analysis and presentation of data in appropriate format • Evaluate mean median mode and standard deviation obtained from the given data • Performing calculations based on laws of probability • Performing calculations involving probability distributions and mathematical expectation sampling.	

2.3.11.2. Information Sheet No. 2/ LO10

Statistics is discipline which deals with collection, organization, presentation and analysis of data.

Data consist of set of record observations that carry information on a particular setting with the availability of data.

A statistical exercise normally consist of four stages.

1. Collection of data
2. Organization and presentation of data in convenient form
3. Analysis of data to make their meaning clear
4. Interpretation of 1b results and the conclusion

In statistic we consider quantities that are varied. This quantities are referred as variables.

Variables are denoted by letters

Examples

- Heights
- Ages
- Weighs
- Times

Types of data;

1. Quantitative data
2. Qualitative data

Presentation of data

The aim of presenting data is to communicate information.

The type of presentation chosen depend on the requirement and the interest of people receiving that particular information.

Frequently the first stage in presenting is preparing a table.

Tabulation of data

Frequency distribution

Given a set of draw data we usually arrange into frequency distribution where we collect like quantities and display them by writing down their frequencies.

For those on data presentation refer to engineering mathematics by K.A stroud.

Measures of central tendencies

This is single value which used to represent entire set of data. It is typical value to which most observation fall closest than any other value.

There are mainly measures of central tendencies.

- i. Arithmetic mean
- ii. Median
- iii. Mode

Refer to Engineering mathematics for Engineers by H.K Dass

Measurers of Dispersion

They include;

1. Range
2. Standard deviation
3. Quartiles

Normal Distribution

This is a continuous distribution. It is derived as the limiting for of the Binomial distribution for large values of n and p and q are not very small.

The normal distribution is given by the equation

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2\sigma^2}(x-\mu)^2}$$

Where μ is the mean and σ is the standard deviation, $\pi = 3.14159$ and $e = 2.71828$

$$P(x_1 < x < x_2) = \int_{x_1}^{x_2} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2\sigma^2}(x-\mu)^2} dx \dots \dots \dots (1)$$

On substitution $z = \frac{x-\mu}{\sigma}$ in (1) we get $f(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2\sigma^2}z^2} \dots \dots \dots (2)$

Here $mean = 0$, $standard deviation = 1$

Equation (2) is known as standard form of normal distribution.

Normal curve

Shown graphically: the probabilities of heads in 1 losses are

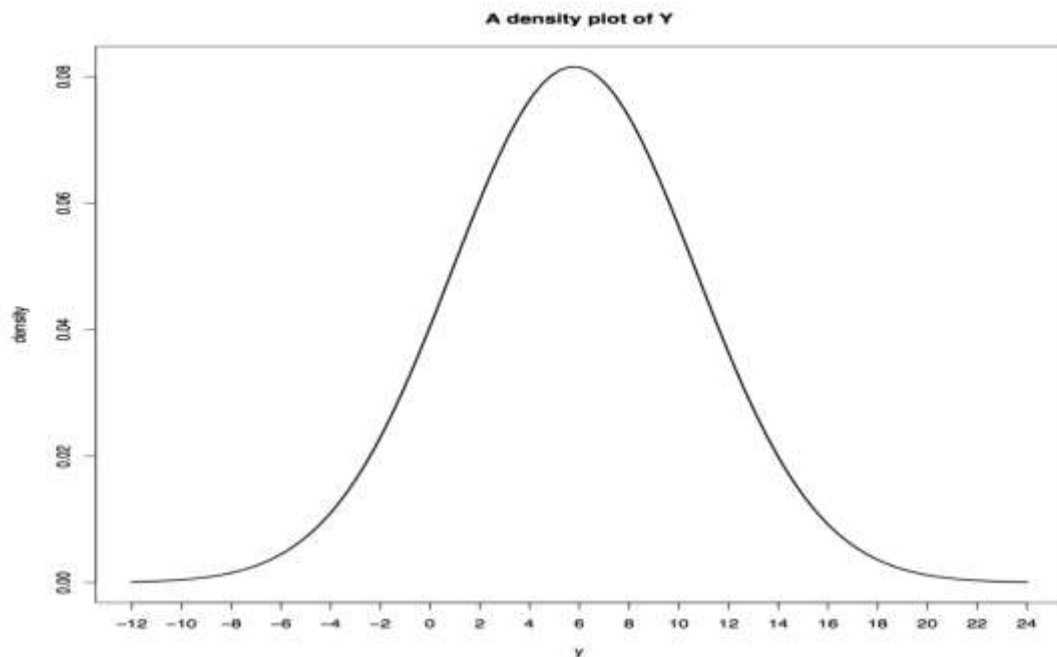


Figure 1: A density plot of Y

Area under the normal curve

By taking $z = \frac{x-\mu}{\sigma}$, the standard normal curve is formed.

The total area under this curve is 1. The area under the curve is divided into two equal parts by $z = 0$. Left hand side area and right hand side area to $z = 0$ is 0.5. The area between the ordinate $z = 0$ and any other ordinate can be calculated.

Example 1

On the final examination in mathematics the mean was 72 and the standard deviation was 15. Determine the standard scores of students receiving grades

- a) 60 b) 93 c) 72

Solution

$$\text{a) } z = \frac{x-\mu}{\sigma} = \frac{60-72}{15} = -0.8$$

$$\text{b) } z = \frac{93-72}{15} = 1.4$$

$$\text{c) } z = \frac{72-72}{15} = 0$$

For more refer to Mathematics for Engineers by H.K Dass .

Read on Poisson and standard deviation of Binomial distribution.

2.3.11.3 Self-Assessment

1. A machine produced components whose masses are normally distributed with mean μ and standard deviation σ if 89.8 % of the components have a mass of at least 88g and 3% have a mass less than 84.5g. Find the mean and the standard deviation of the distribution (6mks).

2. The diameters of bolts produced by a certain machine are distributed by a probability density function

$$f(x) = \begin{cases} kx(3-x), & 0 \leq x \leq 3 \\ 0 & \text{Otherwise} \end{cases}$$

Find the;

- a. Constant k .
- b. Probability that the diameter of a bolt-selected at a random will fall in the interval

$$1 < x < 2.5$$

- c. Mean and the variance of the distribution (14mks)

3. Tumaini Ltd, is supplied with petrol once a week. The weekly demand, x hundreds of liters, has the probability density function

$$f(x) = \begin{cases} k(1-x), & 0 \leq x \leq 1 \\ 0 & \text{Otherwise} \end{cases}$$

Where c is a constant

Determine the

- (i) Value of c
 - (ii) Mean of x
 - (iii) Minimum capacity of the petrol tank if the probability that it will be exhausted in a given week is not to exceed 0.02.
4. Metal bars produced in a factory have masses that are normally distributed with mean μ and standard deviation σ . Given that 9.4% have a mass less than 45kg and 7% have a mass above 75kg.
 - (i) Evaluate the values of μ and σ and
 - (ii) Find the probability that a mass of a metal bar selected at random will be less than 40kg.
 5. Define statistics
 6. Differentiate between mean, mode and median
 7. Perform data collection and organization techniques
 8. Perform interpretations analysis and presentation of data in appropriate format
 9. Evaluate mean median mode and standard deviation obtained from the given data
 10. Describe laws of probability and perform appropriate calculations based on the laws
 11. In statistic we consider quantities that are varied. TRUE OR FALSE?
 12. Measures of central tendencies is a single value which used to represent entire set of data. TRUE OR FALSE?

2.3.12. Learning Outcome No. 11. Solve Ordinary differential equations

2.3.12.1 Learning Activities

Learning Outcome No. 11. Apply Fourier series	
Learning Activities	Special Instructions
- Obtain Fourier coefficients using Fourier series - Obtain Fourier series for a periodic function of period 2π - Obtain Fourier series for a periodic function of period T - Obtain Fourier series for odd and even functions using Fourier series techniques - Obtain half-range Sine and Cosine series	Harmonic analysis

2.3.12.2. Information sheet No 2/L011

Problem involving various forms of oscillations are common in field of modern technology and Fourier series enable us to represent a periodic function as an infinite trigonometrical series in sine and cosine series.

Periodic functions

A function $f(x)$ is said to be periodic if its function values repeat at regular intervals of the independent variable. The regular interval between repetitions is the period of the oscillations.

For more examples refer to Further Engineering Mathematics by K.A Stroud on page 826.

Fourier series periodic functions of period 2π

We define Fourier series in the form

$$f(x) = \frac{1}{2}a_0 + a_1\cos x + a_2\cos 2x + a_3\cos 3x \pm \dots +$$

$$+ b_1\sin x + b_2\sin 2x + b_3\sin 3x \pm \dots$$

This is written in the form

$$f(x) = \frac{1}{2}a_0 + \sum_{n=1}^{\infty} (a_n\cos nx + b_n\sin nx)$$

Where n is a positive integer.

Fourier coefficients, a_0 , a_n , and b_n are given by

$$a_0 = \frac{1}{\pi} \int_{-\pi}^{\pi} f(x) dx$$

$$a_n = \frac{1}{\pi} \int_{-\pi}^{\pi} f(x) \cos nx dx$$

$$b_n = \frac{1}{\pi} \int_{-\pi}^{\pi} f(x) \sin nx dx$$

For worked examples on how to determine the Fourier series to represent a periodic function of period 2π refer to *Further Engineering Mathematics* by K.A Stroud on page 842 to 876.

Functions with periods other than 2π

If $y = f(x)$ is defined in the range $\frac{-T}{2}$ to $\frac{T}{2}$ i.e has a period T , we can convert this to an interval of 2π by changing the units of the independent variable.

In many practical cases involving physical oscillations, the independent variable is time (t) and the periodic interval is normally denoted by T

i.e $f(t) = f(t + T)$

The Fourier series to represent the function can be expressed as

$$f(t) = \frac{1}{2}a_0 + \sum_{n=1}^{\infty} (a_n \cos n\omega t + b_n \sin n\omega t)$$

With the new variable, the Fourier coefficients becomes

$$f(t) = \frac{1}{2}a_0 + \sum_{n=1}^{\infty} (a_n \cos n\omega t + b_n \sin n\omega t)$$

$$a_0 = \frac{2}{T} \int_0^T f(t) dt$$

$$a_n = \frac{2}{T} \int_0^T f(t) \cos n\omega t dt$$

$$b_n = \frac{2}{T} \int_0^T f(t) \sin n\omega t dt$$

For worked examples on how to determine Fourier series for a periodic function of period T , refer to *Further Engineering Mathematics* by K.A Stroud on page 879 to 886.

Odd and even functions

For information about odd and even functions refer to *Further Engineering Mathematics* by K.A Stroud on page 858. Also find worked out examples on odd and even functions.

Half-range series

Sometimes a function of period 2π is defined over the range 0 to π , instead of the normal $-\pi$ to π or 0 to 2π . In this case we make an assumption on how a function behaves between $x = -\pi$ to $x = 0$, and the resulting Fourier series will therefore apply only to $f(x)$ between $x = 0$ and $x = \pi$ for which it is defined. For this reason, such series are called half range series. For more information, worked example and exercises refer to *Further Engineering Mathematics* by K.A Stroud on page 868.

2.3.12.3. Self-Assessment

1. Describe Ordinary differential equations
2. Explain Fourier series

3. Perform calculations on Fourier series for a periodic function of period 2π and T
4. Perform calculations on Fourier series for odd and even functions using Fourier series techniques
5. A function $f(x)$ is said to be periodic if its function values repeat at regular intervals of the independent variable. TRUE OR FALSE?
6. If $y = f(x)$ is defined in the range $\frac{-T}{2}$ to $\frac{T}{2}$ i.e has a period T . TRUE OR FALSE?
7. Determine half-range Sine and Cosine series
8. Determine the Fourier series for the function defined by

$$f(x) = \begin{cases} 1 - x & -\pi \leq x < 0 \\ 1 + x & 0 < x \leq \pi \\ f(x + 2\pi) \end{cases}$$

Find the half-range Cosine series for the function defined by

$$f(t) = \begin{cases} 4 - t & 0 < t < 4 \\ f(t + 8) \end{cases}$$

2.3.12.4. Tool, equipment

- Calculator

2.3.12.5 References

1. Further Engineering Mathematics by K.A Stroud
2. Mathematics for Engineers by Dass

2.3.13. Learning Outcome No. 12. Apply Vector theory

2.3.13.1. Learning Activities

Learning Activities No. 12. Apply Vector theory	
Learning Activities	Special Instructions
• Calculate vector algebra dot and cross products using vector theory • Determine the gradient, divergence and curl. • Perform vector calculation using Greens theorem • Perform vector calculations using Stroke's theorem • Determine conservative vector fields, line and surface integrals using Gauss's theorem	

2.3.13.2. Information sheet No. 2/LO12

Physical quantities can be divided into two main groups, scalar quantities and vector quantities.

A Scalar quantity is one that is defined completely by a single number with appropriate units e.g Lengths, area, volume, mass, time etc.

A Vector quantity is defined completely when we know not only its magnitude but also the direction in which it operates, e.g. force, velocity, acceleration etc.

Refer to *Engineering mathematics by K. A Stroud* to learn more on components of 0 Vector in terms of unit Vectors on page 368.

Dot and cross product of vectors. The Scalar product of two vectors is denoted by $\vec{a} \cdot \vec{b}$ (sometimes called the 'dot product').

The dot product of two vectors is defined as $\vec{a} \cdot \vec{b} = |\vec{a}| |\vec{b}| \cos \theta$ where θ is the angle between $\vec{a}$ and $\vec{b}$.

Refer to *Technician mathematics 3 by J.O. Bird* on page 297.

Examples

Solution

$$\vec{a} = 2\vec{i} + 3\vec{j} + 5\vec{k} \text{ And } \vec{b} = 4\vec{i} + \vec{j} + 6\vec{k}, \vec{a} \cdot \vec{b}$$

$$\vec{a} \cdot \vec{b} = 2.4 + 3.1 + 5.6$$

$$= 8 + 3 + 30$$

$$= 41$$

A typical application of scalar products is that of determining the work done by a force when moving a body. The amount of work done is the product of the applied force and the distance moved in the direction of the applied force.

Example

Find the work done by a force F newtons acting at point A on a body, when A is displaced to point B, the coordinates of A and B being (3, 1, -2) and (4, -1, 0) metres respectively and when

$$F = -i - 2j - k \text{ Newton's.}$$

Solution

If a vector displacement from A to B is d , then the work done is $F \cdot d$ Newton Meters or joules. The position vector OA is $3i + j - 2k$ and OB is $4i - j$

$$\begin{aligned} AB &= d = OB - OA \\ &= (4i - j) - (3i + j - 2k) \\ &= i - 2j + 2k. \end{aligned}$$

$$\begin{aligned} \text{Work done} &= F \cdot d = (-1)(1) + (-2)(-2) + (-1)(2) \\ &= -1 + 4 - 2 \\ &= 1 \text{ Nm or joule} \end{aligned}$$

For more worked examples refer to Technician mathematics 3 by J. O. Bird.

Cross Product

The vector or Cross product of two vectors $\vec{a}$ and $\vec{b}$ is C where the magnitude of C is $|\vec{a}||\vec{b}|\sin\theta$ where θ the angle between is $\vec{a}$ and $\vec{b}$.

For more information refer to Technician mathematics 3 by J.O Bird and Engineering mathematics by K. A Stroud.

Examples

$$\vec{p} = 2i + 4j + 3k \text{ and } \vec{q} = i + 5j - 2k \text{ find } \vec{p} \times \vec{q} = \begin{vmatrix} i & j & k \\ 2 & 4 & 3 \\ 1 & 5 & -2 \end{vmatrix}$$

$$\begin{aligned} &= i \begin{vmatrix} 4 & 3 \\ 5 & -2 \end{vmatrix} - j \begin{vmatrix} 2 & 3 \\ 1 & -2 \end{vmatrix} + k \begin{vmatrix} 2 & 4 \\ 1 & 5 \end{vmatrix} \\ &= -23i + 7j + 6k \end{aligned}$$

Typical applications of vector products are to moments and to angular velocity.

Refer to Technician mathematics. 3 by J.O Bird on page 308.

Vector field Theory

Refer to further Engineering mathematics by K.A Stroud to learn and also go through the worked examples and exercises on:

- (i) Gradient
- (ii) Divergence
- (iii) Curl

Greens theorem

Learn how to perform vector calculations using Green's theorem by referring to further Engineer mathematics by KA. Stroud

Stoke's Theorem

Refer to further Engineer Mathematics by K.A Stroud to learn how to perform vector calculations using Stroke's theorem.

Gauss's Theorem

Refer to the some book to learn how to determine line and surface integrals using Gauss's theorem.

2.3.13.3 Self-Assessment

- 1) Differentiate between algebra dot and cross products in vector calculations
- 2) A Scalar quantity is one that is defined completely by a single number with appropriate units e.g Lengths, area, volume, mass, time. TRUE OR FALSE?
- 3) The vector or Cross product of two vectors $\vec{a}$ and $\vec{b}$ is C where the magnitude of C is $|\vec{a}||\vec{b}|\sin\theta$ where θ the angle between is $\vec{a}$ and $\vec{b}$. TRUE OR FALSE?
- 4) Describe Greens theorem, Stroke's theorem and Gauss's theorem and their applications
- 5) Explain gradient, divergence and curl.
- 6) If $\vec{a} = 2\vec{i} - 3\vec{j} + 4\vec{k}$ and $\vec{b} = \vec{i} + 2\vec{j} + 5\vec{k}$ determine
 - (1) $\vec{a} \cdot \vec{b}$
 - (2) $\vec{a} \times \vec{b}$

Find the work done by a force F Newtons acting at a point A on a body, when A is displaced to point B ,the coordinates of A and B being (5, 2, -4) and (3,-1,1) meters respectively , and when $F = -2\vec{i} - 3\vec{j} - 2\vec{k}$ Newton's.

2.3.13.4. Tools, Equipment

- Calculator

2.3.13.5 References

1. Further engineering mathematics by KA Stroud.
2. Mathematics for Engineers by Dass.
3. Technician mathematics book 3 by J.O. Bird.

2.3.14. Learning Outcome No.13 Apply Matrix

2.3.14.1 Learning Activities

Learning Activities No. 13. Apply Matrix	
Learning Activities	Special Instructions
Apply matrix in calculating operation on matrices in addition and subtraction, multiplication	

2.3.14.2. Information sheet No. 2/ LO13

Introduction

A matrix is a set of real or complex numbers (or elements) arranged in rows and columns to form a rectangular array.

A matrix having M rows and N columns is called a $M \times N$ (i.e M by N) matrix and is referred to as having order $M \times N$.

A matrix is indicated by writing the array with large square brackets e.g

$\begin{bmatrix} 5 & 7 & 2 \\ 6 & 3 & 8 \end{bmatrix}$ is a 2×3 matrix i.e 2 by 3 matrix where 5,7,2,6,3 and 8 are the elements of the matrix.

Operation on matrices

1. Addition and subtraction

Matrices can be added or subtracted if they are of the same order.

Example

$$\begin{aligned} \text{Given matrix } A &= \begin{bmatrix} -1 & 2 & 5 \\ 3 & 0 & 4 \\ 1 & -3 & 2 \end{bmatrix} \text{ and } B = \begin{bmatrix} 3 & 2 & -1 \\ -2 & 1 & 6 \\ 1 & -4 & 5 \end{bmatrix} \\ A + B &= \begin{bmatrix} -1 & 2 & 5 \\ 3 & 0 & 4 \\ 1 & -3 & 2 \end{bmatrix} + \begin{bmatrix} 3 & 2 & -1 \\ -2 & 1 & 6 \\ 1 & -4 & 5 \end{bmatrix} = \begin{bmatrix} (-1+3) & (2+2) & (5-1) \\ (3-2) & (0+1) & (4+6) \\ (1+1) & (-3-4) & (2+5) \end{bmatrix} \\ &= \begin{bmatrix} 2 & 4 & 4 \\ 1 & 1 & 10 \\ 2 & -7 & 7 \end{bmatrix} \end{aligned}$$

2. Multiplication of Matrices

Example

$$\begin{aligned} \text{Given matrix } A &= \begin{bmatrix} -1 & 2 & 5 \\ 3 & 0 & 4 \\ 1 & -3 & 2 \end{bmatrix} \text{ and } B = \begin{bmatrix} 3 & 2 & -1 \\ -2 & 1 & 6 \\ 1 & -4 & 5 \end{bmatrix} \\ A \times B &= \begin{bmatrix} -1 & 2 & 5 \\ 3 & 0 & 4 \\ 1 & -3 & 2 \end{bmatrix} \begin{bmatrix} 3 & 2 & -1 \\ -2 & 1 & 6 \\ 1 & -4 & 5 \end{bmatrix} \\ &= \begin{bmatrix} 1 \times 3 + 2 \times -2 + 5 \times 1 & -1 \times 2 + 2 \times 1 + 5 \times -4 & -1 \times -1 + 2 \times 6 + 5 \times 5 \\ 3 \times 3 + 0 \times -2 + 4 \times 1 & 3 \times 2 + 0 \times 1 + 4 \times -4 & 3 \times -1 + 0 \times 6 + 4 \times 5 \\ 1 \times 3 + -3 \times -2 + 2 \times 1 & 1 \times 2 + -3 \times 1 + 2 \times -4 & 1 \times -1 + 6 \times -3 + 2 \times 5 \end{bmatrix} \\ &= \begin{bmatrix} -3 - 4 + 5 & -2 + 2 - 20 & 1 + 12 + 25 \\ 9 + 0 + 4 & 6 + 0 - 16 & -3 + 0 + 20 \\ 3 + 6 + 2 & 1 - 3 - 8 & -1 - 1 + 10 \end{bmatrix} \end{aligned}$$

$$= \begin{bmatrix} 2 & -20 & 36 \\ 13 & * & 10 & 17 \\ 11 & -10 & -9 \end{bmatrix}$$

Note that in matrices $AB \neq BA$

For more examples on matrices operations refer to Pure Mathematics I.

Determinant of a 3×3 matrix

Refer to engineering mathematics by K.A Stroud and learn more on how to find the determinant of a 3×3 (“3 by 3”) matrix.

Inverse of a 3×3 matrix

Example

To find the inverse of $A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 1 & 5 \\ 6 & 0 & 2 \end{bmatrix}$

Evaluate the determinant of A i.e $|A|$

a) For $A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 1 & 5 \\ 6 & 0 & 2 \end{bmatrix}$, $|A| = 1(2 - 0) - 2(8 - 30) + 3(0 - 6) = 28$

b) Now from the matrix of the cofactors

$$C = \begin{bmatrix} 2 & 22 & -6 \\ -4 & -16 & 12 \\ 7 & 7 & -7 \end{bmatrix}$$

c) Next we have to write down the transpose of “ C ” to find the adjoint of “ A ”

$$\text{Adj } A = C^T = \begin{bmatrix} 2 & -4 & 7 \\ 22 & -16 & 7 \\ -6 & 12 & -7 \end{bmatrix}$$

d) Finally we divide the elements of $\text{adj } A$ by the value of $|A|$ i.e 28 to get A^{-1} the inverse of A .

$$A^{-1} = \begin{bmatrix} \frac{2}{28} & \frac{-4}{28} & \frac{7}{28} \\ \frac{22}{28} & \frac{-16}{28} & \frac{7}{28} \\ \frac{-6}{28} & \frac{12}{28} & \frac{-7}{28} \end{bmatrix} = \frac{1}{28} \begin{bmatrix} 2 & -4 & 7 \\ 22 & -16 & 7 \\ -6 & 12 & -7 \end{bmatrix}$$

Solution of linear equation in three unknowns

Solve the set of equations

$$x_1 + 2x_2 + x_3 = 4$$

$$3x_1 - 4x_2 - 2x_3 = 2$$

$$5x_1 + 3x_2 + 5x_3 = -1$$

First write the set of equations in matrix form

$$\begin{bmatrix} 1 & 2 & 1 \\ 3 & -4 & -2 \\ 5 & 3 & 5 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 4 \\ 2 \\ -1 \end{bmatrix}$$

Next step is to find the inverse of A where A is the square matrix on the left hand side.

$$|A| = \begin{vmatrix} 1 & 2 & 1 \\ 3 & -4 & -2 \\ 5 & 3 & 5 \end{vmatrix} = -14 - 50 + 29 = 29 - 64 = -35$$

Therefore $|A| = -35$

$$\text{Matrix of co-factors } C = \begin{bmatrix} -14 & -25 & 29 \\ -7 & 0 & 7 \\ 0 & 5 & -10 \end{bmatrix}$$

$$\text{The matrix of the } Adj A = C^T = \begin{bmatrix} -14 & -7 & 0 \\ -25 & 0 & 5 \\ 29 & 7 & -10 \end{bmatrix}$$

$$\text{Now } |A| = -35, \text{ therefore } A^{-1} = \frac{adj A}{|A|} = \frac{1}{-35} \begin{bmatrix} -14 & -7 & 0 \\ -25 & 0 & 5 \\ 29 & 7 & -10 \end{bmatrix}$$

$$\therefore x = A^{-1} \cdot b = \frac{1}{-35} \begin{bmatrix} -14 & -7 & 0 \\ -25 & 0 & 5 \\ 29 & 7 & -10 \end{bmatrix} \begin{bmatrix} 4 \\ 2 \\ -1 \end{bmatrix}$$

$$\text{Finally } x = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 2 \\ 3 \\ -4 \end{bmatrix}$$

$$\therefore x_1 = 2, x_2 = 3, x_3 = -4$$

Eigen values and Eigen vectors

In many applications of matrices to technological problems involving coupled oscillations and vibrations equations are of the form

$$A \cdot x = \lambda x$$

Where A is a square matrix and λ is a number. The values of λ are called the eigenvalues. Characteristic values or latent roots of the matrix A and the corresponding solution of the given equation $A \cdot x = \lambda x$ are called the eigenvectors or characteristic vector of A .

For more information refer to Engineering Mathematics by K.A Stroud.

2.3.14.3. Self- Assessment

1. Define a matrix
2. A matrix having M rows and N columns is called a $M \times N$ (i.e M by N) matrix and is referred to as having order $M \times N$. TRUE OR FALSE?
3. $A \cdot x = \lambda x$ are called the eigenvectors or characteristic vector of A . TRUE OR FALSE?
4. Differentiate between Eigen values and Eigen vectors
5. Perform calculations using matrix
6. Determine a Determinant of a 3×3 matrix
7. Determine an Inverse of a 3×3 matrix
8. Solve the following set of linear equations by matrix method

$$x_1 + 3x_2 + 2x_3 = 3$$

$$2x_1 - x_2 - 3x_3 = -8$$

$$5x_1 + 2x_2 + x_3 = 9$$

9. Find the inverse of the matrix $A = \begin{bmatrix} 2 & 1 & 4 \\ 3 & 5 & 1 \\ 2 & 0 & 6 \end{bmatrix}$

10. If $A.x = \lambda x$, $A = \begin{bmatrix} 2 & 2 & -2 \\ 1 & 3 & 1 \\ 1 & 2 & 2 \end{bmatrix}$. Determine the eigenvalues of the matrix A and an eigenvector corresponding to each eigenvalue.

2.3.15. Learning Outcome No.14. Apply Numerical Methods

2.3.15.1. Learning Activities

Learning Activities No.14 Apply Numerical Methods	
Learning Activities	Special Instructions
• Apply numerical methods in solving engineering problems	

2.3.15.2. Information Sheet No. 2/ LO14

The limitation of analytical methods, have led engineers and scientist to evolve graphical and numerical methods. The graphical methods though simple give results to a low degree of accuracy. Numerical methods can, however, be derived which are more accurate.

Numerical methods are often of a repetitive nature. These consist of repeated execution of the same process where at each step the results of the proceeding step is used. This is known as iteration process and is repeated till the result is obtained to a derived degree of accuracy.

The numerical methods for the solution of algebra and transcendental equations include

- 1) Method of false solution/ regular false method
- 2) Newton-Raphson method.

Example

Find by Newton Raphson method the real roots of $xe^x - 2 = 0$ correct to 3 decimal places.

Solution

Let $f(x) = xe^x - 2$ and $f(1) = e - 2 = 0.7183$

So a root lies between 0 and 1. Its near to 1 let's take $x_0 = 1$

Also $f'(x) = xe^x + e^x$ and $f'(1) = e + e = 5.4366$

Therefore by Newton-Raphson rule, the first approximation x_1 is given by

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)} = 1 - \frac{0.7183}{5.4366} = 0.8679$$

Therefore $f(x_1) = 0.0672$, $f'(x_1) = 4.4491$

Thus the first approximation x_2 is given by

$$x_2 = x_1 - \frac{f(x_1)}{f'(x_1)} = 0.8679 - \frac{0.0672}{4.4491} = 0.8528$$

Hence the required root is 0.853 correct to 3 dp

Finite differences and interpolation

Suppose we are given the following values for $y = f(x)$ for a set of values of x :

$$x: x_0 \quad x_1 \quad x_2 \quad \dots \quad x_n$$

$$y: y_0 \quad y_1 \quad y_2 \quad \dots \quad y_n$$

Then the process of finding any value of y corresponding to any value of $x = x_i$ between x_0 and x_n is called interpolation.

The interpolation is the technique of estimation the value of a function for any value of the intermediate value of the independent variable while the process of computing the value of the function outside the given range is called extrapolation.

Example

The table gives the distance in nautical miles of the visible horizon for the given height in feet above the earth's space.

Height (x)	100	150	200	250	300	350	400
Distance (y)	10.63	13.03	15.04	16.81	18.42	19.90	21.27

Find values of y when $x = 2.8$ feet and 410 feet

The difference table is as given below

x	y	Δ	Δ^2	Δ^3	Δ^4
100	10.63				
		2.40			
150	13.03		-0.39		
		2.01		0.15	
200	15.04		-0.24		-0.07
		1.77		0.08	
250	16.81		-0.16		-0.05
		1.61		0.03	
300	18.42		-0.13		-0.01
		1.48		0.02	
350	19.90		-0.11		
		1.37			
400	21.27				

- i) If we take $x_0 = 200$, then $y_0 = 15.04$, $\Delta_{y_0} = 1.77$ $\Delta^2_{y_0} = -0.16$ $\Delta^3_{y_0} = 0.03$ etc

$$\text{Since } x = 218 \text{ and } h = 50 \therefore p = \frac{x-x_0}{h} = \frac{18}{50} = 0.36$$

Using Newton Raphson forward interpolation formula, we get

$$\begin{aligned}
 y_{218} &= y_0 + p\Delta_{y_0} + \frac{p(p-1)\Delta^2_{y_0}}{1.2} + \frac{p(p-1)(p-2)}{1.2.3} \Delta^3_{y_0} + \dots \\
 f(218) &= 15.04 + 0.36(1.77) + \frac{0.36(-0.64)}{2}(-0.16) \\
 &\quad + \frac{0.36(0.64)(-1.64)(0.03)}{6}(0.03) + \dots \\
 &= 15.04 + 0.637 + 0.018 + 0.001 + \dots = 15.696 \text{ nautical miles}
 \end{aligned}$$

ii) Since $x = 410$ is near the end of the table, we use Newton backward interpolation formula.

$$\text{Therefore taking } x_n = 400, p = \frac{x - x_n}{h} = \frac{10}{50} = 0.2$$

Using the backward differences

$$y_n = 21.27, \nabla y_n = 1.37, \nabla^2 y_n = 0.11, \nabla^3 y_n = 0.02$$

Newton backward difference gives

$$y_{410} = y_{405} + p\Delta y_{400} + \frac{p(p+1)\nabla^2 y_{400}}{1.2} + \frac{p(p+1)(p+2)}{1.2.3} \nabla^3 y_{400} + \dots$$

$$21.27 + 0.2(1.37) + \frac{0.2(1.2)}{2}(-0.11) + \dots = 21.53 \text{ nautical miles}$$

Refer to *Higher Engineering Mathematics* by Dr B.S and learn forward and backward interpolation formulae

2.3.15.3 Self-Assessment

1. Describe numerical methods
2. The graphical methods though simple give results to a low degree of accuracy. Numerical methods can, however, be derived which are more accurate. TRUE OR FALSE
3. The process of computing the value of the function outside the given range is called interpolation. TRUE OR FALSE
4. Differentiate between Method of false solution/ regular false method and Newton-Raphson method.
5. State the applications of numerical methods
6. Using Newton-Raphson forward formula find the values of $f(1.6)$, if

X	1	1.4	1.8	2.2
$f(x)$	3.49	4.82	5.96	6.5

7. State Newton interpolation formula and use it to calculate the value of $\exp(1.85)$ given the following table

X	1.7	1.8	1.9	2.0	2.1	2.2	2.3
$f(x)$	5.474	6.000	6.686	7.389	8.166	9.025	9.914

CHAPTER 3: WORKSHOP TECHNOLOGY /PERFORM WORKSHOP PROCESSES

3.1. Introduction of the Unit of Learning / Unit of Competency

Workshop Technology processes is the use of electrical skills gained from various electrical workshop practices to install and troubleshoot electrical instrument and devices in electrical wiring, or distribution and power generation. These skills are applied in various industries e.g. in telecommunication, electrical manufacturing. This unit covers electrical safety, use and storage of workshop tools/instruments /equipment/materials, installation of electrical instruments and devices, and troubleshooting and repair/replacement of electrical tools and equipment. Upon completion of this unit of competency, a trainee should be able to perform installation, troubleshooting and maintenance of electrical instruments and devices while observing the appropriate safety measures. This unit prepares trainees to pursue electronics as a gainful career in the field of electrical engineering.

3.2. Performance Standard

Calibrate, operate safely and maintain the workshop tool and equipment as per standard operating procedures, manufacturer's recommendations, perform first aid procedures as per standard operating procedures, dispose waste materials as per the EHS requirements, identify and diagnose faulty tools as per diagnostic procedures and the standard operating procedures, repair/replace faulty tools/equipment as per the workplace procedures, and test& troubleshoot repaired or replaced tool/equipment as per the standard operating procedures. Observe safety as per IEE Standards

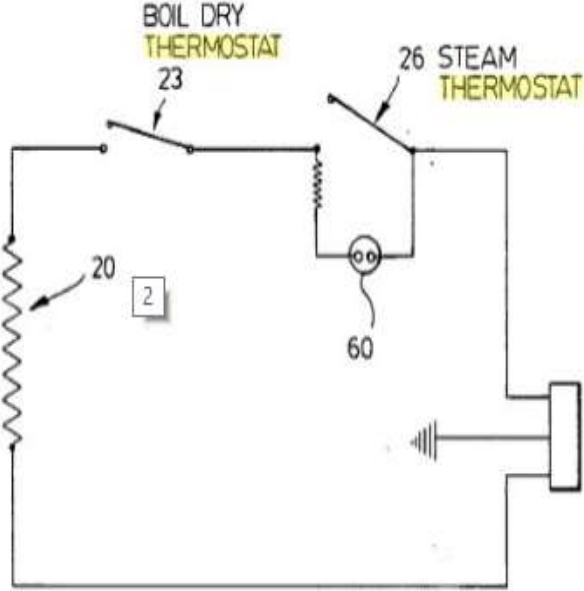
3.3. Learning outcomes

3.3.1. List of Learning Outcomes

- a) Apply workshop safety
- b) Use of workshop tools, Instruments and equipment.
- c) Prepare workshop tools and instruments for an electrical installation practical
- d) Prepare the workshop for an Electrical practical
- e) Store Electrical tools and materials after practical.
- f) Troubleshoot and repair workshop tools and equipment

3.3.2. Learning Outcomes No. 1 Apply workshop safety

3.3.2.1 Learning activities

Learning Outcome No. 1. Apply workshop safety	
Learning Activities	Special Instructions
 Activity: Obtain and an electrical kettle to be connected to a power supply • Wear PPEs • Obtain the necessary tools for inspecting/testing the functionality of the kettle. • Check safety of power supply socket/system as per the standard operating procedures. • Perform safety inspection of the electrical kettle as per standard operating procedures	• Observe manufacturer's manual instructions for the specific electrical kettle • Observe IEE regulations • Observe organizational procedures manual • Provide the trainee with varied opportunities to learn safety precautions taken in handling different electrical appliances, equipment, and machines.

3.3.2.1. Information Sheet No. 3/ LO1

Introduction

This learning outcome entails the trainee observing electrical safety and procedures, safety regulations in obtaining electrical equipment, earthing concepts in electrical safety, electrical machine, handling electric power systems, and demonstrating knowledge of workshop rules, electrical hazards and treatment/first aid procedures in accordance with the need of an activity. Also, it covers, various technical facilities in the electrical workshop including mechanical and electrical equipment.

Definition of key terms

Classes of fires: These are the types of fires based on the burning material e.g. wood, charged electrical device, etc.

Electrical equipment: These are the essential requirements for electrical workshop practices to take place. They include; set of screw drivers, pliers, phase testers, multimeter, etc.

Recommended sources for further information; *Electrical Safety Handbook 3E* by Cadick. J. et al.

Set up procedure for an electrical equipment;

1. Wear PPE
2. Obtain the electrical equipment, set of screw drivers, pliers, phase testers, multimeter
3. Check the condition of the equipment components, thermostat, heating element, switch, and the indicator light
4. Connect power cable to the equipment and to the power supply socket.
5. Ensure the electrical equipment is set up properly, and the power cable is in good condition.

Recommended sources for further information; *Electrical Safety Handbook 3E* by Cadick. J. et al. 2016 IEEE IAS Electrical Safety Workshop (ESW)

Watch an 8.42 min video on electrical safety and electrical safe work from the web link: <https://slideplayer.com/slide/8724303/>

Content

Safety: types of electrical hazards and safety precautions, use of PPE, working environment, classifications of fires, first aid for electrical operator, overview of OSHA regulations and workplace procedures. Electrical, tools & equipment: types of screw drivers, pliers, and electrical measuring instruments and measure various electrical parameters like current, voltage, power

Personal protective equipment in electrical workshop practices:

- Safety cloth
- Gloves
- Shoes



Figure 2: Personal protective equipment

Source: *Electrical Protection Handbook* (©1990)Bussman, Cooper Industries, Inc



Figure 3: damaged insulation

Source: *Electrical Protection Handbook* (©1990)Bussman, Cooper Industries, Inc.

Conclusion

This outcome covered electrical safety, symbols in electrical circuit diagrams, electrical tools & equipment.

Trainees' assignment;

- Observe safe working of electrical circuit protective devices.
- Perform safety procedures for conducting, insulating materials, capacitors, inductors, and resistors.
- Perform fire safety inspection of the working area.
- Perform safety procedures of first aid in case of electrical hazards.
- Perform testing of electrical appliance for safety

Trainer

Check that the trainee working behaviour exhibit evidence of application of safety practices and electrical housekeeping procedures and policies. Ensure assignments are completed on time. Observe trainees' working behaviour on an on-going basis.

Recommended sources for further information; *Electrical Safety Handbook 3E* by Cadick. J. et al.

3.3.2.3 Self-Assessment

1.



This sign means Highly Flammable.

- A. True
- B. False

2.



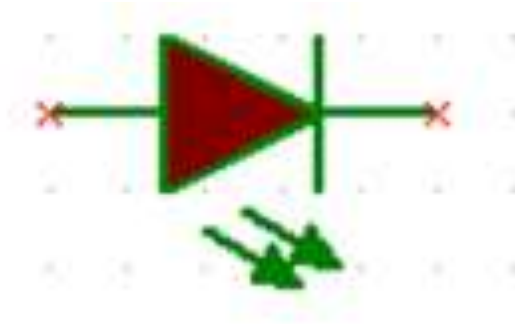
- a. 25000 ohms +- 10%
 - b. 27000 ohms +- 10%
 - c. 250000ohms +- 5%
 - d. 27000 ohms +- 5%
3. To clean the tip of of the soldering iron, use
- a. A PCB eraser
 - b. A cloth
 - c. A dry sponge
 - d. A wet sponge
4. The first stage in PCB fabrication is
- a. Preparing the artwork
 - b. Exposure
 - c. Developing and rinsing
 - d. Tinning
5. Identify the component



- a. Edge rounder
- b. PCB mega station
- c. PCB cutter

d. UV exposue unit

6. Identify the component



- a. Diode
- b. LED
- c. LDR
- d. CAPACITOR

7. An oscilloscope is a device that is used to generate different waveforms.

- a. True
- b. False

8. The edge rounder is an equipment used to drill holes on the PCB.

- a. True
- b. False

9. Developing and rinsing is the last stage in PCB fabrication.

- a. True
- b. False

10. Solder wire is an alloy made up of tin and lead.

- a. True
- b. False

11. It is not possible to measure voltage values across resistances in a circuit using a function generator.

- a. True
- b. False

Practical question

1. Adhere to proper use of PPE as per standard operating procedure
2. Follow workshop rules as per standard operating procedure
3. Follow proper use of safety equipment as per the manufacturers recommendations
4. Adhere to first aid procedures

3.3.2.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

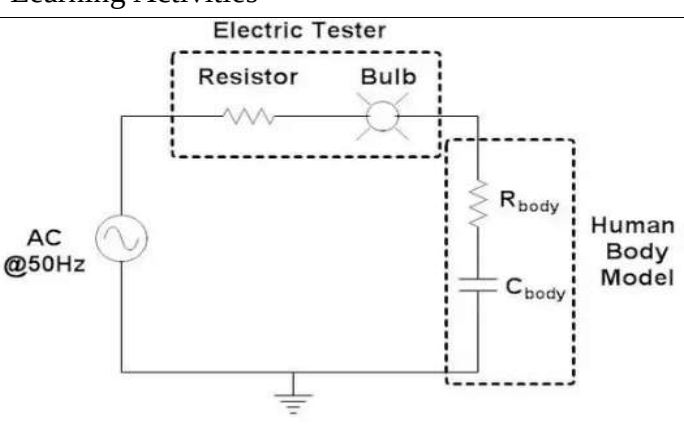
- Set of screw drivers
- Pliers
- Phase testers
- Multimeter
- Electrical measuring instruments
- Lab coat
- Gloves

3.3.2.5. References

1. Cadick, J. (2012). Electrical safety handbook. McGraw-Hill Professional.
2. Brian Scaddan, Electric Wiring: Domestic
3. Peter J. Seebacher, Home Infrastructure (Project 3) (PDF)

3.3.3. Learning Outcomes No. 2 Use of Workshop Tools, Instruments and Equipment

3.3.3.1 Learning activities

Learning Outcome No. 2. Use of workshop tools, Instruments and equipment.	
Learning Activities	Special Instructions
 Activity 1: Use circuit testers or electrical tester - Obtain a specific circuit tester e.g. a phase, continuity tester, etc. - Check safety/ inspect the specific tester as per the standard operating procedures. - Use the tester as per the manufacturer's instructions Activity 2: Use cordless drills - Obtain a specific circuit drill. - Check safety/ inspect the specific drill as per the standard operating procedures. - Use the drill as per the manufacturer's instructions Activity 3: Use voltmeters or multimeters - Obtain a specific voltmeters/ multimeters. - Check safety/ inspect the specific drill as per the standard operating procedures. - Calibrate the specific instrument as per the standard operating procedures. - Use the instrument as per the manufacturer's instructions	- Observe manufacturer's manual instructions for the specific electrical kettle - Observe IEE regulations - Observe organizational procedures manual - Provide the trainee with varied opportunities to learn use of various electrical testers.

3.3.3.2. Information Sheet No. 3/ L02

Introduction

This learning outcome involves the safety, classification, use, care, and maintenance of various workshop tools, instruments, and equipment. It also, involves demonstration of knowledge of workshop rules, electrical hazards and first aid procedures in accordance with the need of an activity. It also covers, wiring regulations, types of cables and electric accessories including switches, plugs, circuit breakers, fuses etc., symbols for electrical wiring schematics e.g. switches, lamps, sockets etc., drawing and practice in simple house wiring and testing methods, wiring schemes of two-way and three-way circuits and ringing circuits, voltage and current measurements. Electric soldering and soldering tools; soldering methods and skills, drilling and soldering components.

Definition of key terms

Ampere: The SI unit of electrical current.

Electrical equipment: These are the essential requirements for electrical workshop practices to take place. They include; set of screw drivers, pliers, phase testers, multimeter, etc.

Apparent Power: Apparent power is the product of the rms voltage and the rms current. Measured in volt-amperes.

Recommended sources for further information;

- Electrical Safety Handbook 3E by Cadick. J. et al.
- Watch a 1.04min on use of an electrical tester - circuit tester from the link:
<https://youtu.be/Moad9c1wTwk?t=41>
- Watch a 5.24min on use of an electrical circuit testers from the link:
<https://youtu.be/togB4pyjdUA?t=98>

Electrical principles

An electric circuit is formed when a conductive path is established to allow free electrons to move continuously. This free movement of electrons through an electric conduct is called current. Voltage motivates electrons to flow in a circuit. Voltage is the measure of how much of potential energy exists to move electrons from one specific point in a circuit to another specific point the circuit. While the electrons move in a circuit, they experience some friction or opposition motion. This is called resistance. It is the force resisting the flow of electrons across two points in a circuit. Resistance and voltage determines the amount of current in a circuit,

Recommended sources for further information;

Electrical Safety Handbook 3E by Cadick. J. et al. 2016 IEEE IAS Electrical Safety Workshop (ESW)

Watch a 22.10 min video on electrical principles from the web link:

<https://youtu.be/49Zlel5XaDU?t=474>

Watch a 13.44 min video on electrical principles from the web link:

<https://youtu.be/ytATo6tS9yE?t=192>

Content

Safety: safety and care precautions in using various electrical tools. Electrical tools, equipment and instruments: use of screw drivers, pliers, electrical testers, and electrical measuring instruments and measure various electrical parameters like current, voltage, power.



Figure 4: Electric drill

Source: Electrical Safety Handbook 3E by Cadick. J. et al.

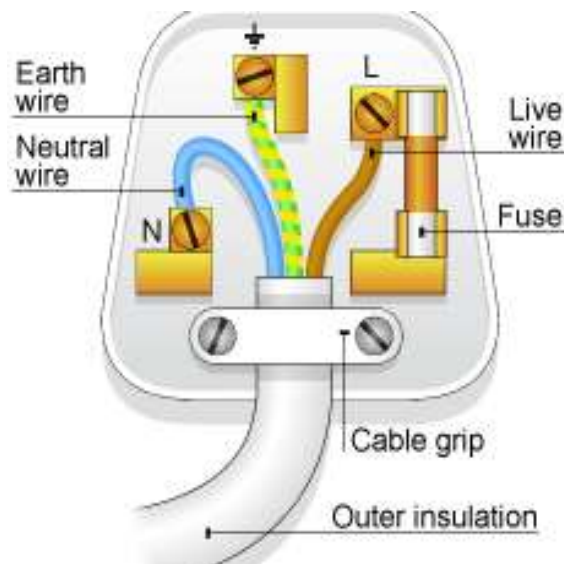


Figure 5 : cable head

Source: Electrical Safety Handbook 3E by Cadick. J. et al.



Figure 6: receptacle

Source: Electrical Safety Handbook 3E by Cadick. J. et al.

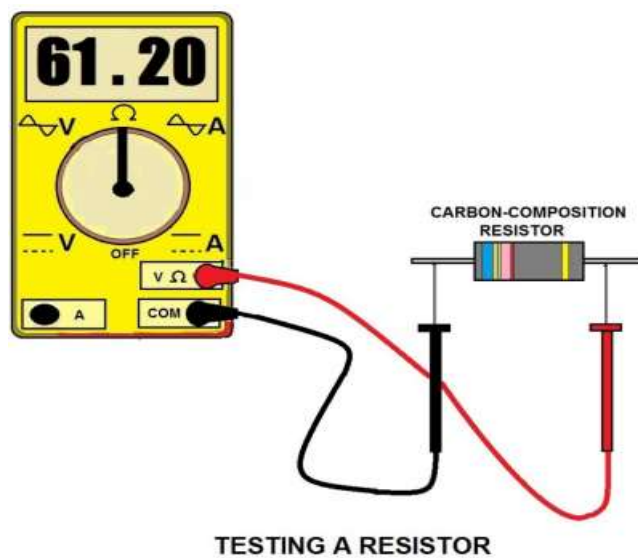


Figure 7: testing a resistor

Source: Electrical Safety Handbook 3E by Cadick. J. et al.

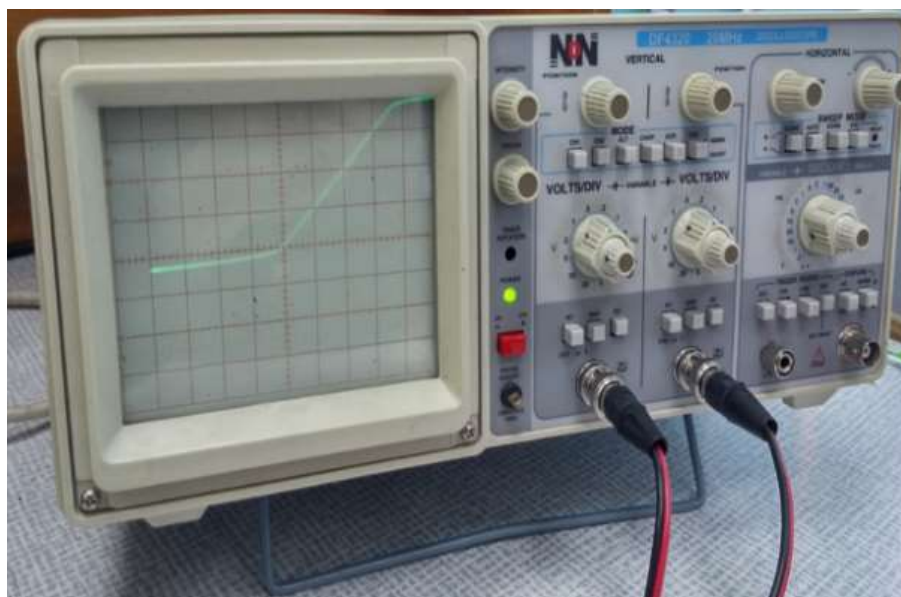


Figure 8: Continuity tester Multimeter, Oscilloscope

Source: Electrical Safety Handbook 3E by Cadick. J. et al.

Conclusion

This outcome covered electrical safety, classification, use, care, and maintenance of various workshop tools, instruments, and equipment.

Trainees' assignment;

- i. Set and use oscilloscope

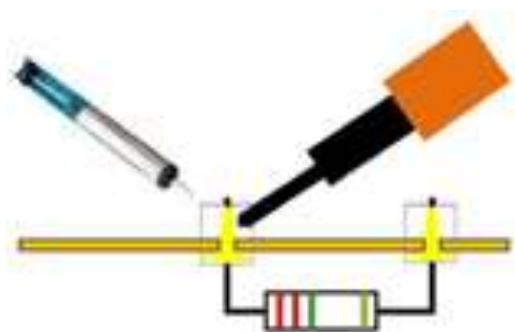
Trainer

Check that the trainee working behaviour exhibit evidence of application of safety practices and electrical housekeeping procedures and policies. Ensure assignments are completed on time. Observe trainees' working behaviour on an on-going basis.

Recommended sources for further information; *Electrical Safety Handbook 3E* by Cadick. J. et al.

3.3.3.3. Self-Assessment

1. The process shown below is called



- a. Soldering
- b. Desoldering
- c. Tinning
- d. Drilling

2. Name the following

			
1	2	3	4

3. Ampere is the SI unit of electrical voltage. TRUE OR FALSE?
4. Real power is the product of the rms voltage and the rms current. Measured in volt-amperes. TRUE OR FALSE?

Practical question;

1. Identify Workshop tools, Instruments and equipment
2. Use Tools, Instruments and equipment as per the manufactures manuals
3. Perform Calibration of workshop instruments as per the standard operating procedure
4. Follow Proper handling of workshop tools, Instruments and equipment
5. Adhere to Care and Maintenance of workshop tools, Instruments and equipment

3.3.3.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

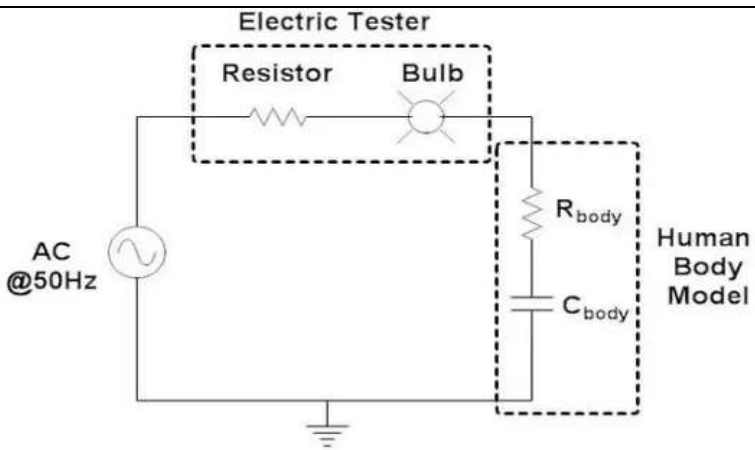
- Hacksaws
- Pliers
- Phase testers
- Multimeter
- Set of screw drivers
- Side cutters, etc.
- Lab coat
- Hammers

3.3.3.5. References

1. Cadick, J. (2012). Electrical safety handbook. McGraw-Hill Professional.
2. Brian Scaddan, Electric Wiring: Domestic
3. Peter J. Seebacher, Home Infrastructure (Project 3) (PDF)

3.3.4. Learning Outcomes No. 3. Prepare workshop tools, Instruments and equipment

3.3.4.1. Learning activities

Learning Outcome No. 3. Prepare Workshop Tools For An Electrical Installation.	
Learning Activities	Special Instructions
 Activity 1: Use circuit testers or electrical tester - Obtain a specific circuit tester e.g. a phase, continuity tester, etc. - Check safety/ inspect the specific tester as per the standard operating procedures. - Use the tester as per the manufacturer's instructions Activity 2: Use cordless drills - Obtain a specific circuit drill. - Check safety/ inspect the specific drill as per the standard operating procedures. - Use the drill as per the manufacturer's instructions Activity 3: Use voltmeters or multimeters - Obtain a specific voltmeters/ multimeters. - Check safety/ inspect the specific drill as per the standard operating procedures. - Calibrate the specific instrument as per the standard operating procedures. - Use the instrument as per the manufacturer's instructions	Observe manufacturer's manual instructions for the specific electrical kettle Observe IEE regulations Observe organizational procedures manual Provide the trainee with varied opportunities to learn use of various electrical testers.

3.3.3.1. Information Sheet No. 3/ L03

Introduction

This learning outcome involves the selection, classification, use, care, and maintenance of various workshop tools, instruments, and equipment. It also, involves application of procedures in accordance with the need of an activity for an electrical installation. It also covers, wiring regulations, types of cables and electric accessories including switches, plugs, circuit breakers, fuses etc., symbols for electrical wiring schematics e.g. switches, lamps, sockets etc., drawing and practice in simple house wiring and testing methods, wiring schemes of two-way and three-way circuits and ringing circuits, voltage and current measurements. Electric soldering and soldering tools; soldering methods and skills, drilling and soldering components.

Definition of key terms

Cable – A cable is made up of one or more conductors and their insulated surrounding

Hammers – Voltage is the difference in electrical potential between two different points, it can be thought of as electrical pressure, and it is denoted by the letter V or U.

Circuit breaker – A type of protective device for circuits, it will protect a circuit from overload and fault currents.

Main switch – Although not a protective device, in a typical household, the mains switch is located in the consumer unit. Its purpose is to disconnect the supply of electricity to the installation.

How to proceed with an Electrical Installation;

Prepare a detailed electrical wiring diagram to start with.

Then calculates the Electrical Loads, Currents, Cable sizes and the Protective devices for the Electrical Installation.

Based on this information, worked out the quantities of material and components needed for the job.

There are specifications for carrying out Electrical Installation Work so that the completed installation will abide to rules and regulations of the Electrical Industry. The Electrical Conductors [cables or wires] needed to be selected according to the current rating [Capacity] and Voltage Drop when the rated current flows in the conductors. This selection of the conductor is called Conductor Sizing. The conductors can be of Copper or Aluminium. Copper is the material used mostly for indoor installations and Aluminium for mostly Power Transmission. The outer Insulation of the conductors are selected according to the Temperature, the conductors are used for when carrying current. The over current protection for conductors are very important and there are Fuses and Circuit Breakers incorporated to safeguard current carrying conductors. Ground Fault Circuit Interrupters or Earth Leakage Circuit Breakers or Residual Current Circuit Breakers will safeguard people from getting Electric Shock from Live or Hot Circuit conductors or equipment.

Power point

Power points (receptacles, plugs, wall sockets) need to be installed throughout the house in locations where power will be required. In many areas the installation must be done in compliance with standards and by a licensed or qualified electrician. Power points are typically located where there will be an appliance installed such as telephone, computers, television, home theater, security system, CCTV system.

Light fittings and switches

The number of light fitting does depend on the type of light fitting and the lighting requirements in each room. A lighting designer can provide specific recommendations for lighting in a home. Layout of lighting in the home must consider control of lighting since this affects the wiring. For example, multiway switching is useful for corridors and stairwells so that a light can be turned on and off from two locations. Outdoor yard lighting, and lighting for outbuildings such as garages may use switches inside the home.

Electrical this is cabling installed from the electrical switchboard to the light fitting or any other device that is to be controlled by the automation system. For example, if you have four down lights in a room and you wish to control each light individually, then each light will be wired back using electrical cabling back to the electrical switchboard. This means you will have four electrical cables installed from the electrical switchboard to the location where the light fittings will be installed. Each cable will be a three core active, neutral and earth cable. If in that room you also have a free standing lamp plugged into a power point and you also want to control this from your automation system, you will need to have that power point individually wired back to the electrical switchboard. So if you want to individually control every light fitting and every power point or power outlets then each one of these devices must be individually wired back to the electrical switchboard. As you can see this start to become quite a lot of electrical cabling so planning is essential.



Figure 9: industrial main switch

Source: Electrical Safety Handbook 3E by Cadick. J. et al.

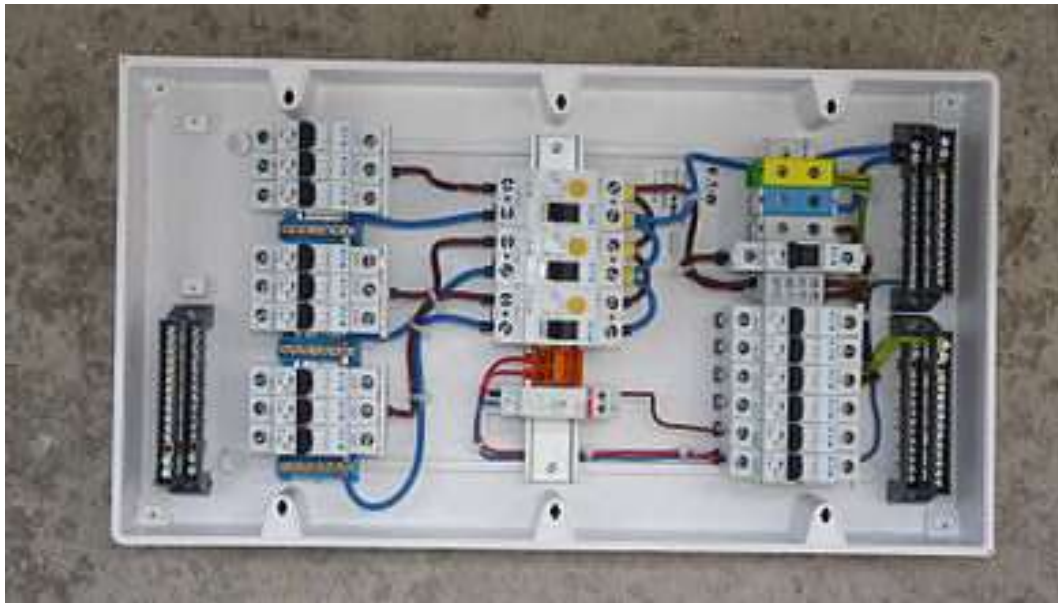


Figure 10: Single-phase ~230 V/40 A/9 kW fuse box for apartment rewiring

Source: Electrical Safety Handbook 3E by Cadick. J. et al.

Source; Brian Scaddan, Electric Wiring: Domestic; Peter J. Seebacher, Home Infrastructure (Project 3) (PDF)

Recommended sources for further information;

Brian Scaddan, Electric Wiring: Domestic

Peter J. Seebacher, Home Infrastructure (Project 3) (PDF)

Electrical Safety Procedures

1. Avoid loose wires, cables, and connections.
2. Assume any exposed wire/metal is live with electricity unless otherwise verified.
3. Familiarize oneself with all ON/OFF buttons on equipment, circuit breakers, and disconnect switches of a bench.
4. Only make changes to the experimental setup when the circuit power is turned off and all power sources read zero voltage and zero current, as applicable.
5. Use wires of suitable length for their appropriate applications. Long wires or connections can cause clutter on a bench, and very short wires or connections can be too tight and may be easily disconnected.
6. Separate higher power equipment and connections from lower power equipment, such as microcontrollers, to avoid both interference and electrical interconnections between sensitive electronic devices and higher power devices.
7. Make sure that all DC power supplies, AC sources, and other power sources start from a zero voltage and zero current output or as directed in an experiment. Starting from a non-zero voltage is possible in certain applications where a voltage source should have a specific initial condition.

8. Turn off all equipment before leaving the lab once an experiment concludes.
9. Do not allow a single user to perform an experiment alone. Make sure at least two users perform an experiment when operating more than 50 V DC and three-phase AC.

Energy management

Energy management is a new and upcoming topic in particular at the home. Older systems tended to be cable however all new systems use one of a variety of wireless solutions. This enables them to be effectively retrofitted into existing homes with the minimum of disruption.

If a cabled system is selected cabling needs to be deployed to the major appliances in the home. The cabling is installed as part of the data cabling as per detailed in this article in the section titled "Data Network Cabling". In addition to a cable being installed to every major appliance you also need to install a data cable near the electricity meter.

The major appliances being considered at this stage are:

- Electric hot water system
- Air Conditioning
- Pool pump
- Fridge / freezer
- Electric vehicle charger
- Battery energy storage systems (BESS)

Conclusion

Should a wireless system be selected the need for such disruption is removed. Smart plugs or switches can be used to connected the major appliances to the electricity supply and the home energy management system will wirelessly control them

Content

Safety: Safe working habits and precautions in setting up electrical work stations.

Electric Supply: Power sources, Electric wirings, signs, symbols and data.

3.3.3.2 Self-Assessment

1. The meter shown in the picture
 - A. Multimeter
 - B. Voltmeter
 - C. Power meter

D. None of the above



2. The shown above figure is called
- A. Consumer unit
 - B. MCB
 - C. RCD
 - D. LCD



Practical question

1. Prepare List of required tools and instruments
2. Perform issuing of required tools and instruments
3. Perform confirmation of the issued tools and instruments
4. Check functioning of the issued tools and instruments in line with the standard operating procedure
5. Perform Sharpening of the cutting tools

3.3.3.3 Tools, Equipment, Supplies and Materials for the specific learning outcome;

- Hacksaws
- Pliers
- Phase testers
- Multimeter
- Set of screw drivers
- Side cutters, etc.
- Lab coat
- Hammers
- Oscilloscope
- Soldering tools, etc.

3.3.3.4 References

1. Cadick, J. (2012). Electrical safety handbook. McGraw-Hill Professional.
2. Electrical Safety Handbook 3E by Cadick. J. et al.
3. 2016 IEEE IAS Electrical Safety Workshop (ESW)
4. Brian Scaddan, Electric Wiring: Domestic
5. Peter J. Seebacher, Home Infrastructure (Project 3) (PDF)

3.3.5. Learning Outcomes No. 4. Prepare workshop for an electrical practical

3.3.5.1. Learning Activities

Learning Outcome No. 4. Prepare workshop for an Electrical practical.	
Learning Activities	Special Instructions
Activity: Disassembling & re-assembling an electrical equipment • Study the original connection of movable switch board • Remove the connection • Take out the equipment • Reinstall and reconnect the wire • Do the safety test	Observe manufacturer's manual instructions for the specific electrical kettle Observe IEE regulations Observe organizational procedures manual Provide the trainee with varied opportunities to learn preparation procedures required for electrical practices.

3.3.5.2 Information Sheet No. 3/L04

Introduction

This learning outcome involves the setting up of workstations, making provisions for power supply and availing tools, equipment and materials for a specific practice. It also, involves demonstration of knowledge of workshop rules and safe working procedures in accordance with the need of the practical and the standard operating procedures.

Definition of key terms

Configuration -Arrangement of nodes, elements, etc. to create an electronic circuit with a particular function.

Terminal -It is a point at which a conductor from an electrical component, device or network comes to an end and provides a point of connection to external circuits.

Recommended sources for further information; *Electrical Safety Handbook 3E* by Cadick. J. et al.

Watch a 1.39min on electrical wiring from the link:

<https://youtu.be/9uMIQycxygQ?t=59>

Electrical Safety Procedures

1. Avoid loose wires, cables, and connections.
2. Assume any exposed wire/metal is live with electricity unless otherwise verified.
3. Familiarize oneself with all ON/OFF buttons on equipment, circuit breakers, and disconnect switches of a bench.
4. Only make changes to the experimental setup when the circuit power is turned off and all power sources read zero voltage and zero current, as applicable.
5. Use wires of suitable length for their appropriate applications. Long wires or connections can cause clutter on a bench, and very short wires or connections can be too tight and may be easily disconnected.
6. Separate higher power equipment and connections from lower power equipment, such as microcontrollers, to avoid both interference and electrical interconnections between sensitive electronic devices and higher power devices.
7. Make sure that all DC power supplies, AC sources, and other power sources start from a zero voltage and zero current output or as directed in an experiment. Starting from a non-zero voltage is possible in certain applications where a voltage source should have a specific initial condition.
8. Turn off all equipment before leaving the lab once an experiment concludes.
9. Do not allow a single user to perform an experiment alone. Make sure at least two users perform an experiment when operating more than 50 V DC and three-phase AC.

Content

Safety: Safe working habits and precautions in setting up electrical work stations.

Electric Supply: Power sources, Electric wirings, signs, symbols and data.

Illustrations

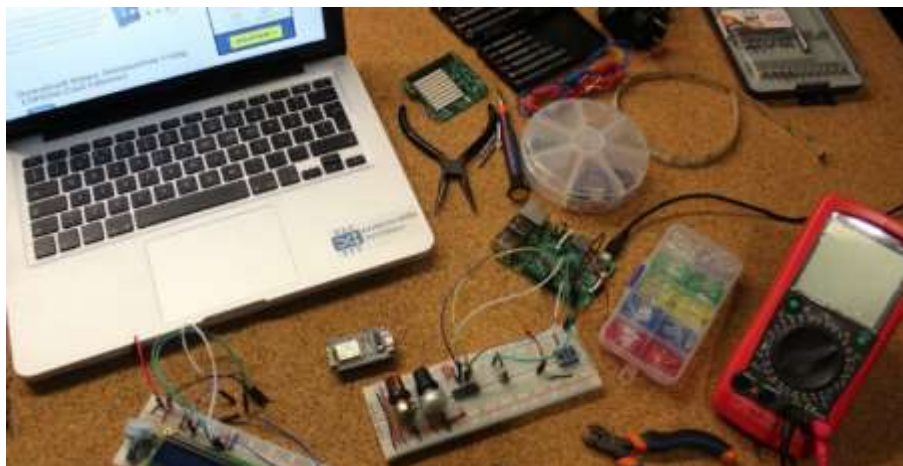


Figure 11: Electric supply

Source: Brian Scaddan, Electric Wiring: Domestic

Cadick, J. (2012).



Figure 12: electric tools and equipment

Source: Brian Scaddan, Electric Wiring: Domestic

Conclusion

This outcome covered electrical safety, inspection, set up and powering of workstations.

Trainees' assignment;

Set up workstation for operating cathode ray oscilloscope and function generator for measurement of ac signal parameters.

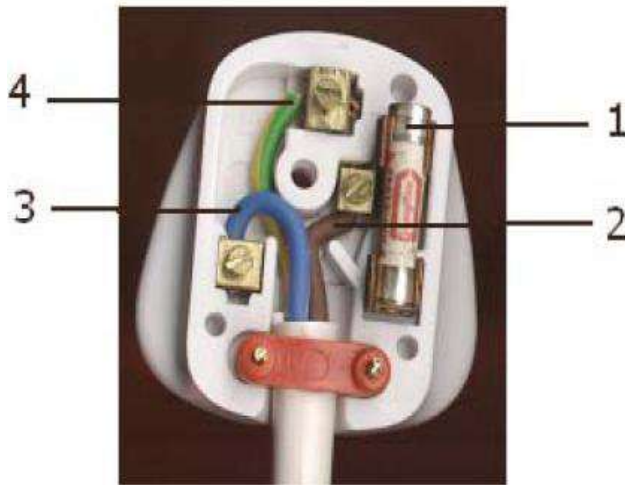
Trainer

Check that the trainee working behaviour exhibit evidence of application of safety practices and electrical housekeeping procedures and policies. Ensure assignments are completed on time. Observe trainees' working behaviour on an on-going basis.

Recommended sources for further information; Electrical Safety Handbook 3E by Cadick, J. et al.

3.3.5.3. Self-Assessment

1. Arrangement of nodes, elements, etc. to create an electronic circuit with a particular function is called Configuration. TRUE OR FALSE?



2. The pin number 2 is connected to
 - a. Earth
 - b. Live
 - c. Neutral
 - d. Fuse
3. The pin number 4 of the plug is connected to
 - a. Earth
 - b. Live
 - c. Neutral
 - d. Fuse
4. Termination is a point at which a conductor from an electrical component, device or network comes to an end and provides a point of connection to external circuits. TRUE OR FALSE?
5. Schematic is Symbolic and simplified diagram of an electric or electronic circuit. TRUE OR FALSE

Practical question

1. Arrange Practical working section as per the number of practical to be carried out.
2. Confirm Power supply availability in every practical section as per the practical to be carried out
3. Supply Tools and materials required as per the practical to be carried out.

3.3.5.4.Tools, Equipment, Supplies and Materials for the specific learning outcome

- Hacksaws
- Pliers
- Phase testers

- Multimeter
- Set of screw drivers
- Side cutters, etc.
- Lab coat
- Hammers
- Oscilloscope

3.3.5.5. References

1. Cadick, J. (2012). Electrical safety handbook. McGraw-Hill Professional.
2. Electrical Safety Handbook 3E by Cadick, J. et al. 2016 IEEE IAS Electrical Safety Workshop (ESW)
3. Brian Scaddan, Electric Wiring: Domestic
4. Peter J. Seebacher, Home Infrastructure (Project 3) (PDF)
5. Watch a 22.10 min video on electrical principles from the web link:
<https://youtu.be/49Zlel5XaDU?t=474>
6. Watch a 13.44 min video on electrical principles from the web link:
<https://youtu.be/ytATo6tS9yE?t=192>

3.3.6. Learning Outcomes No. 5 Store Electrical tools and materials after practical

3.3.6.1 Learning Activities

Learning Outcome No. 5. Store Electrical tools and materials after practical	
Learning Activities	Special Instructions
 Activity: Return tools and materials for storage • Checklists of tools and materials • Sorting of tools and materials • Functional tools in store • Non-functional tools in the store	•

3.3.6.2. Information Sheet No. 3/ L06

Introduction

This learning outcome involves the classification of tools and materials, storage of workshop tools & equipment, disposal of waste and demonstration of knowledge of workshop rules and safe working procedures in accordance with the need of the practical and the standard operating procedures.

Definition of key terms

5S: Sort, Systematize, Sweep, Sanitize, and Self-Discipline

Lubricant: A substance introduced to reduce friction between moving surfaces.

Pneumatic tool: Instrument activated by air pressure.

Recommended sources for further information;

Electrical Safety Handbook 3E by Cadick. J. et al.

Watch a 1.39min on electrical wiring from the link:

<https://youtu.be/9uMIQycxygQ?t=59>

Procedure for taking the inventory of inventory of tools and equipment

- i. Secure inventory forms of tools and equipment.
- ii. Study the parts of the inventory form.
- iii. Check whether the list of tools and equipment in the form tallies with the existing tools and equipment found in the workshop including their specifications and condition.
- iv. List down any losses and damages you find while conducting the inventory
- v. Fill out the remarks column of the inventory forms for any losses/ damages.
- vi. Recommend for replacement of lost tools and equipment and repair/ replacement of damaged tools and equipment.

Recommended sources for further information;

Electrical Safety Handbook 3E by Cadick. J. et al. 2016 IEEE IAS Electrical Safety Workshop (ESW)

Watch a 22.10 min video on electrical principles from the web link:

<https://youtu.be/49Zlel5XaDU?t=474>

Watch a 13.44 min video on electrical principles from the web link:

<https://youtu.be/ytATo6tS9yE?t=192>

Content

Safety: Safe handling of electrical tools and equipment. Tools and Equipment: checklists of tools and materials, sorting of tools and materials, Conditions of PPE, functional tools in store, and non-functional tools in the store.

Illustrations

Table 3 Sample of inventory form of tools and equipment

Item No.	Quantity	Unit	Description	Condition	Remarks
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					

Prepared by: _____ Date: _____ Name and
Signature

Conclusion

This outcome covered electrical safety, inspection, set up and powering of workstations.

Trainees' assignment;

Arrange and store tools and equipment accordingly in a specific tool cabinet and a tool rack assigned to you.

Trainer

Check that the trainee working for evidence of application of safety practices, classified tools and equipment according to their types, arranged the tools by their types in the shelves and placed equipment in designated location as per the standard operating procedures. Ensure assignments are completed on time. Observe trainees' working behaviour on an on-going basis.

Recommended sources for further information;

Electrical Safety Handbook 3E by Cadick. J. et al. Cardenas, Elpidio.1989,

Fundamental and Elements of Electricity. Philippines: national Bookstore.

Max B. Fajardo Jr. & Leo R. Fajardo. 2nd edition, Electrical Layout and Estimate

3.3.6.3. Self-Assessment

1. Is a device for making, breaking, or changing connections in an electric circuit under the conditions of load for which it is rated? It is not designed for interruption of a circuit under short-circuit conditions?
 - a. Generator
 - b. Switch
 - c. Fuse
 - d. Transformer
2. A large single panel, frame, or assembly of panels on which are mounted, on the face or back or both, switches, over current and other protective devices, buses. This panel is generally accessible from the rear as well as from the front and are not intended to be installed in cabinets?
 - a. Panelboard
 - b. Switchboards
 - c. Panelbox
 - d. Substations
3. A single panel or a group of panel units designed for assembly in the form of a single panel, including buses and with or without switches and/or automatic over current protective devices for the control of light, heat or power circuits, designed to be placed in a cabinet or cutout box placed in or against a wall or partition and accessible only from the front.
 - a. Panelboard
 - b. Switchboards
 - c. Outletbox

- d. Substations
- 4. An electrical shock is received when passes through the body.
 - a. Magnetic field
 - b. Water
 - c. Electric current
- 5. It is safe to use electrical appliances in a wet area.
 - a. True
 - b. False
- 6. The component inside a 3-pin plug is called a fuse.
 - a. True
 - b. False
- 7. Lubricant is a substance introduced to reduce friction between moving surfaces. TRUE OR FALSE?
- 8. Pneumatic tool is an instrument activated by air pressure. TRUE OR FALSE?
- 9. Explain inventory tools.

Practical question

1. Check Tools against the issuing list after practicals
2. Store out Tools as per their standard operating procedure
3. Clean Tools as per the workshop standard operating procedure
4. Dispose Waste materials as per the EHS
5. Store Tools in their respective sections as per the workshop procedures

3.3.6.3. Tools, Equipment, Supplies and Materials for the specific learning outcome

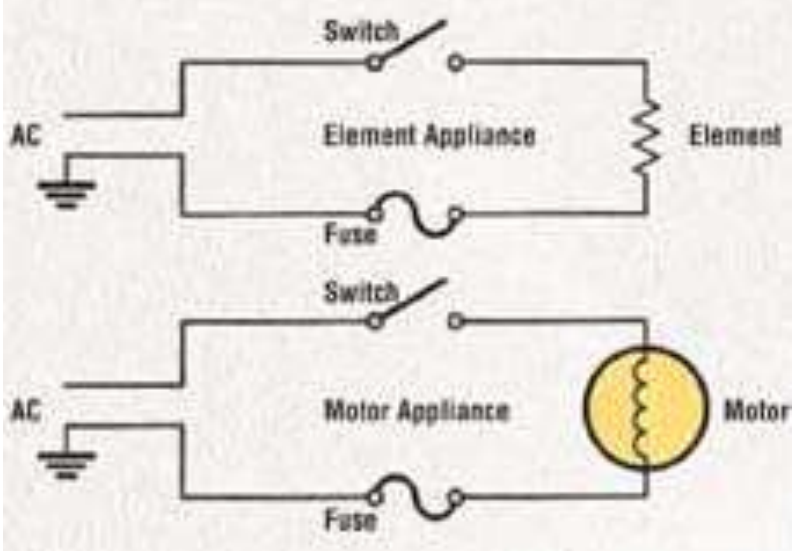
- Hacksaws
- Pliers
- Phase testers
- Multimeter
- Set of screw drivers
- Side cutters, etc.
- Lab coat
- Hammers
- Oscilloscope
- Soldering tools, etc.

3.3.6.4.References

1. Cadick, J. (2012). Electrical safety handbook. McGraw-Hill Professional.
2. Electrical Safety Handbook 3E by Cadick. J. et al. 2016 IEEE IAS Electrical Safety Workshop (ESW)
3. Brian Scaddan, Electric Wiring: Domestic
4. Peter J. Seebacher, Home Infrastructure (Project 3) (PDF)

3.3.7. Learning Outcome No. 6. Troubleshoot and repair/replace workshop tools and equipment

3.3.7.1. Learning Activities

Learning Outcome No. 6. Troubleshoot and repair/replace workshop tools and equipment	
Learning Activities	Special Instructions
 Activity: Carry out troubleshooting on electric kettle not heating • Check the power socket if cable is properly plugged • Ensure sure the power switch is pushed ON • Check if the lead connector is properly pushed in • Check the power fuse and replace if possible • Check if there is power inside the kettle • Check the power switch or fuse which needs to be replaced. • Check the heating element and replace if possible.	Manufacturer's manual instructions should be followed

3.3.7.2.Information Sheet No3/L07

Introduction

This learning outcome covers common fault in electrical equipment, troubleshooting, safety in troubleshooting, rules and procedures on troubleshooting equipment, repair/replacement of the equipment, and safe testing of the equipment.

Definition of key terms

Troubleshooting: Troubleshooting is process of analysing the operation of a faulty circuit to determine what is wrong with the circuit, and identifying the defective component(s) and carrying out appropriate repair.

Recommended sources for further information;

Electrical Safety Handbook 3E by Cadick. J. et al.

Watch a 6.44min on Electric Kettle Repair from the link:

<https://youtu.be/NyJXPTCEcu4?t=5>

Procedure for investigating an electrical problem

- Gather the information
- Understand the malfunction
- Identify which parameters need to be evaluated
- Identify the source of the problem
- Correct/repair the component
- Verify the repair
- Perform root cause analysis

Recommended sources for further information;

Electrical Safety Handbook 3E by Cadick. J. et al.

2016 IEEE IAS Electrical Safety Workshop (ESW)

Watch a 22.10 min video on electrical principles from the web link:

<https://youtu.be/49Zlel5XaDU?t=474>

Watch a 13.44 min video on electrical principles from the web link:

<https://youtu.be/ytATo6tS9yE?t=192>

Content:

Safety in troubleshooting, common electrical faults, testing procedures, methods to troubleshoot electrical equipment, and procedure for repair/replacement of electrical tools and equipment.



Figure 13: Faulty socket

Source: Cadick, J. (2012).



Figure 14: Faulty risks in electric

Source: Cadick, J. (2012).

Conclusion

This outcome covered electrical safety, inspection, set up and powering of workstations.

Trainees' assignment;

Carry out troubleshooting residential house wiring using fuse, switch, indicator, and lamp and energy meter.

Trainer

Check that the trainee working for evidence of application of safety practices, and adherence to manual instructions of the specific equipment as per the standard operating procedures. Ensure assignments are completed on time. Observe trainees' working behaviour on an on-going basis.

Recommended sources for further information;

Electrical Safety Handbook 3E by Cadick. J. et al.

Cardenas, Elpidio.1989, *Fundamental and Elements of Electricity*. Philippines: national Bookstore.

3.3.7.3.Self-Assessment

1. Explain the terms
 - A. Service entrance
 - B. Service head
 - C. Service point
 - D. Service mast
2. A factory assemble cable of one or more conductors each individually insulated and enclosed in a metallic sheath of interlocking tape of smooth or corrugated tube. This type of cable is especially used for service feeders, branch circuit and for indoor, outdoor work. What is this cable?
 - A. Metal Clad Cable (MC)
 - B. Armor Cable (AC)
 - C. Mineral Insulated Cable (MI)
 - D. Underground Feeder (UF)
3. Fabricated assembly of insulated conductors enclosed in flexible metal sheath. It is used both on exposed and concealed work. Identify what type of cable.
 - A. Metal Clad Cable (MC)
 - B. Armor Cable (AC)
 - C. Mineral Insulated Cable (MI)
 - D. Non Metallic Sheathed Cable (NM)
4. Is a moisture resistant cable used for underground connections including direct burial in the ground as feeder or branch circuit?
 - A. Metal Clad Cable (MC)
 - B. Armor Cable (AC)
 - C. Mineral Insulated Cable (MI)
 - D. Underground Feeder (UF)
5. Moisture and Heat Resistant Thermoplastic used for dry and wet locations?
 - A. T
 - B. XHHW
 - C. THHN
 - D. THW
6. Minimum vertical clearance of an overhead service drop measured from the ground, at the electrical service entrance or above areas or sidewalks accessible only to pedestrian lanes, measure from final grade line or other accessible surface only for service drop cabled together with a grounded bare messenger wire and limited to 300 volts to ground?
 - A. 3.5 mts
 - B. 3.00 mts
 - C. 5.00 mts
 - D. 5.50mts
7. A Machine which converts Electric Power into Mechanic all Power?
 - A. Motor

- B. Generator
 - C. Alternator
 - D. Rectifier
8. The Flow of Electricity in a circuit; rate of which electricity flows thru a conductor?
- A. Voltage
 - B. Current
 - C. Energy
 - D. Power

Practical question

1. Identify Faulty tools as per their expected functioning
2. Diagnose Faulty component as per the fault diagnosis procedures
3. Repair/Replace faulty components as per the expected functioning
4. Test Repaired/Replaced tool as per the expected functioning

3.3.7.4.Tools, Equipment, Supplies and Materials for the specific learning outcome

- Hacksaws
- Pliers
- Phase testers
- Multimeter
- Set of screw drivers
- Side cutters, etc.
- Lab coat
- Hammers
- Oscilloscope
- Soldering tools, etc.

3.3.7.5.References

1. Cadick, J. (2012). Electrical safety handbook. McGraw-Hill Professional.
2. Cardenas, Elpidio.1989, Fundamental and Elements of Electricity. Philippines: national Bookstore.
3. Max B. Fajardo Jr. & Leo R. Fajardo. 2nd edition, Electrical Layout and Estimate

CHAPTER 4. ELECTRICAL PRINCIPLES/ APPLY ELECTRICAL PRINCIPLES

4.1. Introduction of the Unit of Learning/Unit of Competency

Electrical Principles presents the basic theories and concepts taught at entry level in Tertiary Institutions. This series of content provides examples to trainers to enable them to develop a strong foundational knowledge of electrical and electronics engineering. The unit comprises of basic theory and practical lessons. Electrical principles link to other core units by providing knowledge in mathematics, physical sciences, mechanical sciences, workshop technology, and electrical machines.

This unit is designed to equip the trainee with the knowledge skills and attitude necessary to understand a wide range of Electrical Principles in their work. This includes basic electrical quantities, direct current (DC) circuits, alternating current (AC) circuits in electrical installation, use of earthing in electrical installation, apply lighting protection measures, apply electromagnetic field theory, apply electrodynamics, apply energy and momentum in electromagnetic field, apply electrical circuit analysis, use two port network, demonstration of refrigeration and air conditioning.

It is recommended that a trainee should have the following learning resources to help him/her in this unit: scientific calculators, relevant reference materials, stationeries, relevant practical materials, and computers with internet connections. Trainees are expected to adhere to the strict rules and regulations once inside the electrical workshops to avoid accidents. The trainee should also read and understand OSHA and WIBA rules and regulations.

In this unit the trainee will be engaged in learning activities such as oral questioning, class discussions, practical activities, supervised exercises, assignments, and written tests.

4.2. Performance Standard

Use electronic calculators when performing calculations in the unit, maintain the area of your working clean to avoid accidents in the workshop, identify

4.3. Learning Outcomes

4.3.1. List of Learning Outcomes

- a) Use the concept of basic electrical quantities
- b) Use the concepts of DC to AC circuits in electrical installation
- c) Use basic electrical machines
- d) Use power factor in electrical installation
- e) Use earthing in electrical installation
- f) Apply lightning protection measures
- g) Apply electromagnetic field theory
- h) Apply electrodynamics
- i) Apply energy and momentum in electromagnetic field

- j) Apply transients in electrical circuit analysis
- k) Use two port network
- l) Demonstrate understanding of refrigeration and air conditioning

4.3.2. Learning Outcome No 1: Use of Basic Electrical Machines

4.3.2.1. Learning Activities

Learning Outcome #No.1 Use of Basic Electrical Machines	
Learning Activities	Special Instructions
• State the Ohms Law • Compute electrical parameters such as power, current , voltage and resistance when given any two parameters • Set up an experiment to test the Ohms law	

4.3.2.2. Information Sheet No4/01

Introduction

An electrical machine is generally a device that converts mechanical energy into electrical energy and vice versa with the exception of an electrical transformer, which does the conversion of AC power from one voltage level to another. Other electrical machines are electrical generator and electrical motor.

Electric Generator: It is an electrical machine that converts mechanical energy into electrical energy. It operates on the principle of electromagnetic induction. It follows faraday's laws of electromagnetic induction, which states that whenever a conductor moves in a varying magnetic field, an electromotive force, emf, is induced within the conductor. It is also known as the generator action.

Electric Motor: It is an electrical machine that converts electrical energy into mechanical energy. The operating principle states that a current-carrying conductor experiences a torque (mechanical force) whenever it is put in a magnetic field. It is also known as the motoring action.

Transformers: It is a special type of machine because it does not convert any energy form one form to another. Instead, it transfers electrical power between circuits with different electrical voltage levels. Transformers increase (step-up) or decreases (step-down) voltages as it corresponds with the decrease or increase in current. In an ideal situation, the input and output power and frequency are the same.

Meaning of SI Unit: SI Units means the standard international unit which represents a complete metric system of units of measurements.

SI Units of various Types of electrical parameters

Table 4: SI Units of electrical parameters

Unit Name	Unit Symbol	Quantity
Ampere (amp)	A	Electric current (I)
Volt	V	Voltage (V, E) Electromotive force (E) Potential difference ($\Delta\phi$)
Ohm	Ω	Resistance (R)
Watt	W	Electric power (P)
Decibel-milliwatt	dBm	Electric power (P)
Decibel-Watt	dBW	Electric power (P)
Volt-Ampere-Reactive	var	Reactive power (Q)
Volt-Ampere	VA	Apparent power (S)
Farad	F	Capacitance (C)
Henry	H	Inductance (L)
siemens / mho	S	Conductance (G) Admittance (Y)
Coulomb	C	Electric charge (Q)
Ampere-hour	Ah	Electric charge (Q)
Joule	J	Energy (E)
Kilowatt-hour	kWh	Energy (E)
Electron-volt	eV	Energy (E)
Ohm-meter	$\Omega \cdot m$	Resistivity (ρ)
siemens per meter	S/m	Conductivity (σ)
Volts per meter	V/m	Electric field (E)
Newtons per coulomb	N/C	Electric field (E)
Volt-meter	V·m	Electric flux (Φ_e)
Tesla	T	Magnetic field (B)
Gauss	G	Magnetic field (B)
Weber	Wb	Magnetic flux (Φ_m)
Hertz	Hz	Frequency (f)
Seconds	s	Time (t)
Meter / metre	m	Length (l)
Square-meter	m ²	Area (A)
Decibel	dB	
Parts per million	ppm	

Source: <https://www.rapidtables.com/electric>

Ohm's Law

Ohm's law states that "voltage or potential difference between two points is directly proportional to the current or electricity passing through the resistance, and inversely proportional to the resistance of the circuit."

The formula for Ohm's law is $V=I/R$.

Applications of Ohm's Law

Used in determination of voltage, current or impedance or resistance of a linear electric circuit

Calculations involving various Electrical parameters. (Power, Current, Voltage, Resistance)

Power can be calculated using formulas illustrated below:

$$P = I \times V = R \times I^2 = V^2 / R$$

Where P is power in Watts, V (voltage), I (current in amperes) (DC) and R is the resistance.

Note: in case of AC (alternating current), it is important to find power factor.

$PF = \cos \phi$ Where ϕ is the power factor angle, the angle between the voltage and the amperage

From the above combined with ohms law,

Power (P)

$$P = V \times I = R \times I^2 = V^2 / R$$

Current (I)

$$I = V / R = P / V = \sqrt{(P / R)}$$

Voltage (V)

$$V = I \times R = P / I = \sqrt{(P \times R)}$$

Resistance (R)

$$R = V / I = P / I^2 = V^2 / P$$

Instruments used in measuring various types of electrical parameters

1. Analogue meter

Can be used to measure either one circuit value for instance voltage, resistance and current or measure of these at ago. They have a needle that swings indicating the value to be measured as illustrated below.



Figure 15 analogue meter

Source: https://en.wikipedia.org/wiki/Ohm#/media/File:Electronic_multi_meter.jpg

2. Digital meter

Such meters are accurate as they indicate real digital value unlike the analog meters subject to parallax errors while reading the measurement.



Figure 16: digital meter

Source: https://en.wikipedia.org/wiki/Ohm#/media/File:Electronic_multi_meter.jpg

An Experiment to conduct Ohms Law

Circuit diagram for ohms law

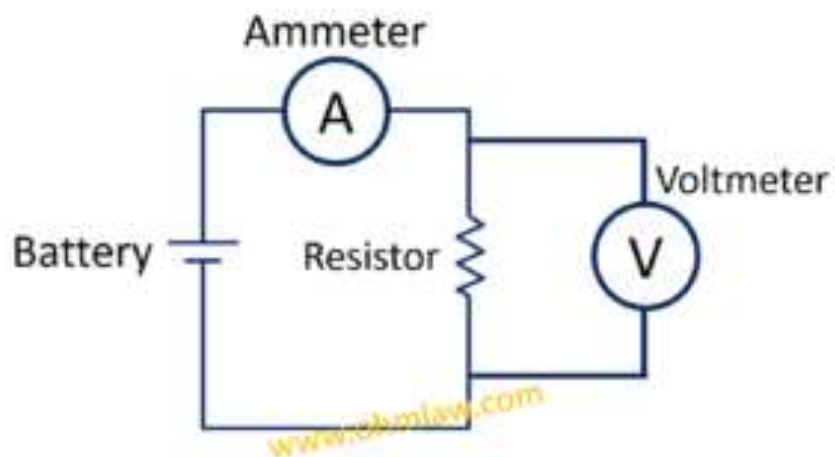


Figure 17: circuit diagram for ohms law

Source: www.ohmlaw.com

Experiment procedure

1. Connect the resistor on the breadboard.
2. Connect the source to the breadboard.
3. Connect the ammeter in series.
4. Connect the voltmeter in parallel.
5. Increase the voltage step-by-step from 0 to 10 V and note the voltage/current.

Ohm's Law Experiment

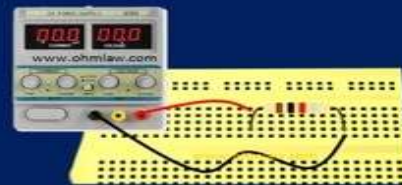
Step 1: Connect resistor on breadboard

Find the values of resistor using a color coding chart and connect it on the breadboard.



Step 2: Connect the source

Use the variable dc power supply to power the circuit. A variable dc power supply provides variable voltages.



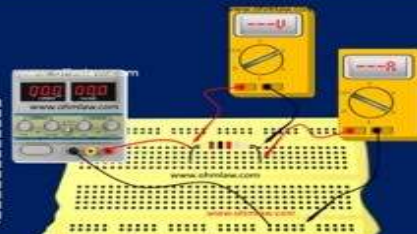
Step 3: Connect ammeter in series



Current always remains same in series so we need to connect the ammeter in series to the circuit.

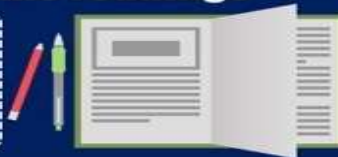
Step 4: Connect Voltmeter in parallel

Voltage always remains same in parallel, so we connect a voltmeter in parallel to the resistor.



Step 5: Note the readings

Using variable dc power supply vary the voltage from 1 -10 V and note the readings.



www.ohmlaw.com

Figure 18: visual representation of steps

Source: (<http://ohmlaw.com/ohms-law-experiment/>)

4.3.2.3. Self-Assessment

- a) Describe an electric generator and electric motor
- b) Perform calculations on Voltage, current and voltage
- c) State the Ohms Law
- d) A generator is an electrical machine that converts electrical energy into mechanical energy. TRUE OR FALSE?
- e) A transformer is a special type of machine because it does not convert any energy form one form to another. TRUE OR FALSE?
- f) Conduct ohms experiment with ease
- g) What types of losses occur in the magnetic frame of the transformer when the transformer is energized?
- h) What information can be obtained from open circuit test of a transformer?
- i) Why HV side is always kept open side in open circuit test?
- j) What is the power factor of a transformer under no-load test situation?
- k) How does no load current compare to full load current?

4.3.2.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Computers with internet connection

4.3.2.4 References

1. Juha Pyrhonen, Tapani Jokinen, Valeria Hrabovcova, Design of Rotating Electrical Machines, New York, NY: John Wiley & Sons, 2013.
2. <http://ohmlaw.com/ohms-law-experiment/>

4.3.3. Learning Outcome No. 2. Use the concept of DC and AC circuits in electrical installation

4.3.3.1. Learning Activities

Learning Outcome No. 2 Use the concept of DC and AC circuits in electrical installation	
Learning Activities	Special Instructions
- Conduct an experiment to measure Kirchhoff's voltage/current law - Carry out calculation involving parallel and series circuits	

4.3.3.2 Information Sheet No. 4/ LO2

Introduction

Electrical circuits are used to connect loads to the power supply. Common loads are motors, resistors, lamps and heaters. A switch is used to close or open the path of electrical energy flow. Various loads are called circuit elements and can be in series or parallel. They are connected to the power supply using soldered wires called leads. A lead that connects several circuit elements is called a common lead.

Calculations Involving Parallel and Series Circuits

Resistors in Series and in Parallel

The two resistors R_1 and R_2 in Figure 7.3.1 are connected in series to a voltage source ΔV . By current conservation, the same current I is flowing through each resistor.

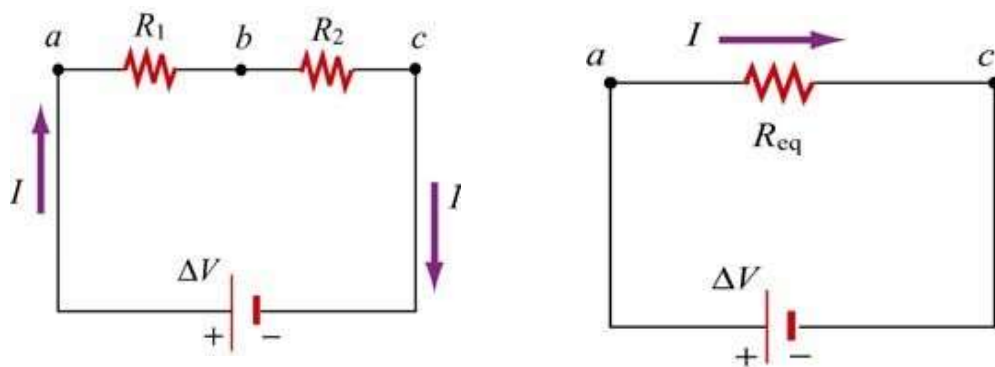


Figure 19: resistors in series

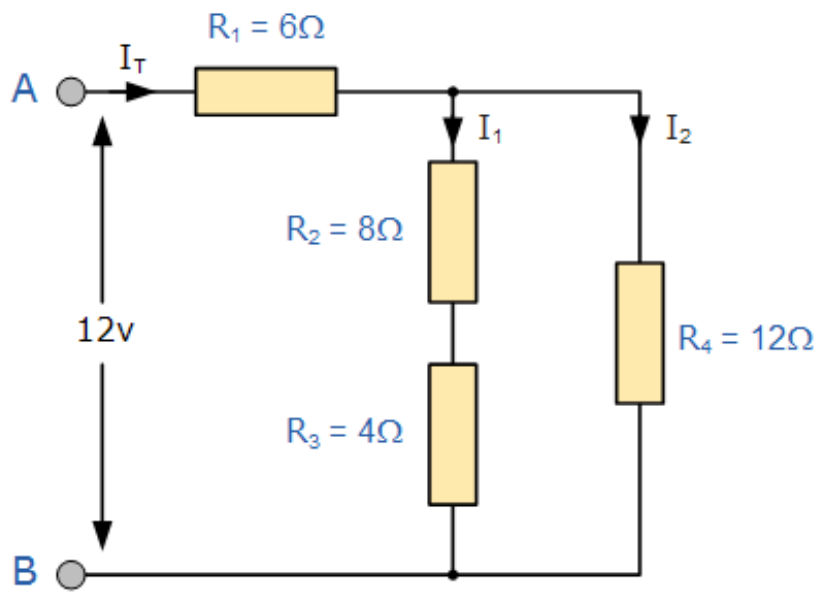


Figure 20: series calculation

Considering the above circuit, calculations of resistors in parallel and series can be calculated as follows

Series calculation

Resistors R_1 and R_2 are in series. The total resistance can be calculated as

$$R_2 + R_3 = 8\Omega + 4\Omega = 12\Omega$$

Replacing R_1 and R_2 result in the diagram below

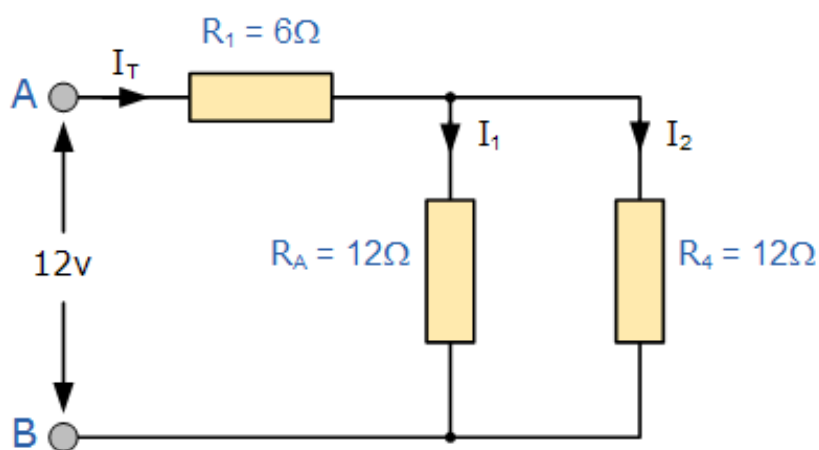


Figure 21: total resistance in circuit

Parallel calculation

From the above diagram RA is in parallel with R4

Using the resistor parallel equation, the total resistance can be calculated as :

$$R_{(\text{combination})} = \frac{1}{R_A} + \frac{1}{R_4} = \frac{1}{12} + \frac{1}{12} = \frac{1}{R_{(\text{com})}} = 6\Omega$$

The final resistive circuit can be illustrated as in the figure below.

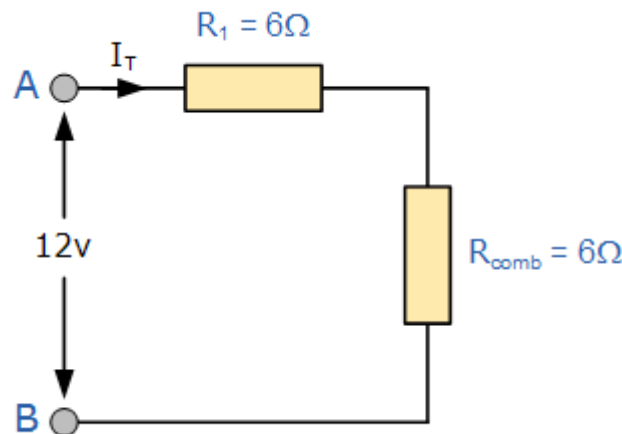


Figure 22: parallel calculation

Source :(https://www.electronics-tutorials.ws/resistor/res_5.html)

AC and DC network theorems

Electromotive Force

Electrical energy supply is necessary to maintain a constant current in a closed electrical circuit. The energy source is commonly referred to as electromotive force, emf. Popular emf sources are solar cells, batteries, and thermocouples. They are also considered as “charge pumps” since they push charges from areas of low potential to high one.

Kirchhoff’s Circuit Rules

There are two fundamental rules used in analyzing electrical circuits, called Kirchhoff’s Laws. They are two laws:

1. Kirchhoff’s First Law: It states that at any junction of a circuit, the sum of currents coming into the junction is equal to the sum of currents leaving it. In other words, the sum of currents at a node is zero. It is also known as the Junction Rule or Kirchhoff’s Current Law.

As an example, consider the figure below:

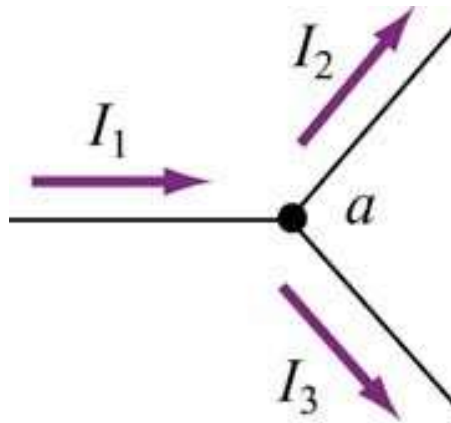


Figure 23: Kirchhoff's first law

$$I_1 = I_2 + I_3 \text{ or } I_1 + I_2 + I_3 = 0$$

2. Kirchhoff's Second Law: It states that the sum of voltage sources, emf, supplying a circuit loop is equal to the total energy absorbed by the elements in the circuit, potential differences, pd. In other words, the total amount of electrical energy put into a circuit is equal to the total amount of electrical energy taken out by the circuit elements. It is also known as Kirchhoff's Voltage Law.

As an example, consider the diagram below that shows a voltage source, emf and different loads with potential difference, Pd1, Pd2, Pd3 and Pd4.

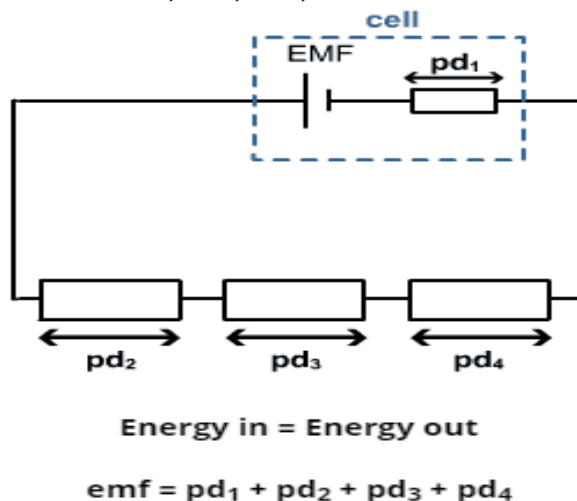


Figure 24: Kirchhoff's second law

Basic solar photovoltaic systems;

Materials that convert sunlight to electrical energy are known as photovoltaic. In attempt to boosting the output of the photovoltaic cells, they are interconnected to form large chains called panels/modules.

PV systems is made up of PV modules and arrays. Besides, the system is made up of mounting structures with pointing panels facing the sun and components that convert the produced direct current alternating current.

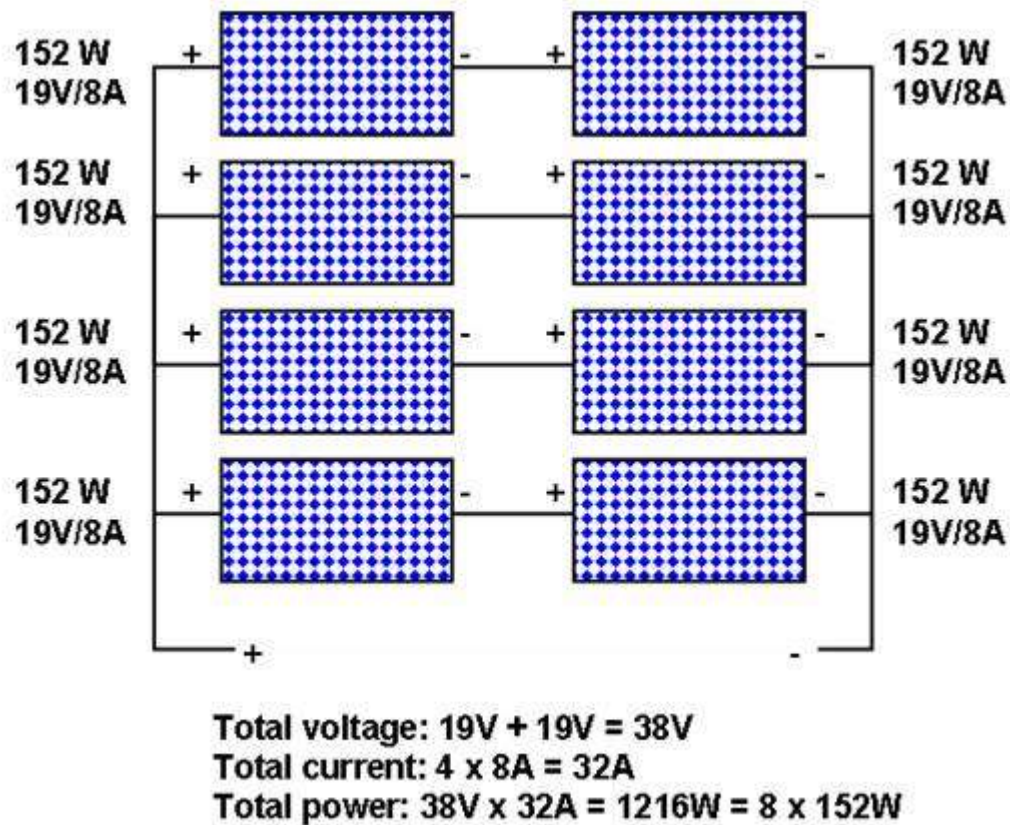


Figure 25: example of a PV solar panel

Experiment 2: Study Kirchhoff's Current Law (KCL) and Kirchhoff's Voltage Law (KVL)

Apparatus:

3 AC Ammeters (0-10 amp)

3 AC Voltmeters (0-300 V)

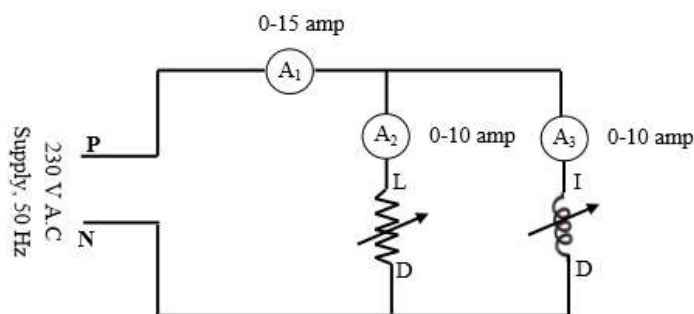
Rheostat

Inductive Load

Connecting wires

Procedure:

KCL:



Note down the initial readings of all ammeters A_1 , A_2 , and A_3 and all voltmeters V_1 , V_2 and V_3 .

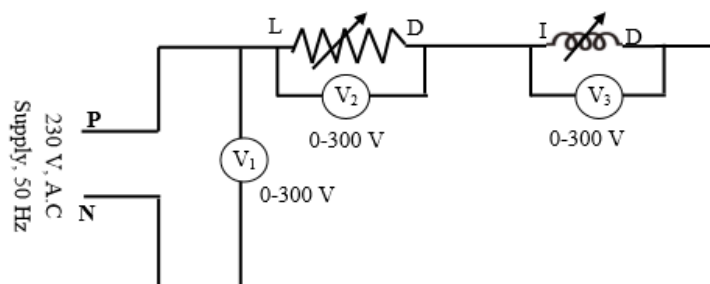
Connect the circuit as shown in the diagram.

Vary both the resistive and inductive load and record the readings of the ammeters and voltmeters

Repeat procedure (3) with different values

Calculate percentage error.

KVL:



Connect the apparatus as shown in the circuit diagram

Vary both the rheostat and inductive load to obtain and note down the readings V_1 , V_2 , and V_3 .

Repeat procedure (3) with different values

Calculate percentage error.

Precautions

Make the

connections

properly

Accurately note

down the

voltmeter and

ammeter

readings

Ensure the

connections are

tight.

Figure 26: example 2

Observation Table:

Table 5: Observation table

KVL

Sl.No.	V_1 in (Volts)	V_2 in (Volts)	V_3 in (Volts)	$V_1' = \sqrt{V_2^2 + V_3^2}$	% Error
1					
2					
3					

KCL

Sl.No.	A_1 in (Volts)	A_2 in (Volts)	A_3 in (Volts)	$A_1' = \sqrt{A_2^2 + A_3^2}$	% Error
1					
2					
3					

4.3.3.3. Self-Assessment

1. State Kirchhoff's voltage law
2. State Kirchhoff's current law
3. Kirchhoff's voltage Law states that at any junction of a circuit, the sum of currents coming into the junction is equal to the sum of currents leaving it. TRUE OR FALSE?
4. Materials that convert sunlight to electrical energy are known as photovoltaic. TRUE OR FALSE?
5. Perform an experiment to demonstrate Kirchhoff's law
6. Differentiate between calculations Involving Parallel and Series Circuits
7. What are the applications of the Kirchhoff's laws?

4.3.3.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.3.5. References

James W. Nilsson, Susan Riedel, Electric Circuits, New Jersey: Prentice Hall Press, 2010.

4.3.4. Learning Outcome No. 3. Use of basic electrical machines

4.3.4.1. Learning Activities

Learning Outcome No.3. Use of basic electrical machines	
Learning Activities	Special Instructions
- Identify AC and DC machines - Demonstrate the understanding of application of AC and Dc machines - Demonstrate motor starting methods	

4.3.4.2. Information Sheet No. 4/ Lo3

Introduction

Electrical Machines

Any devices that does the conversion of electrical energy to mechanical energy and vice versa is called an electrical machine. Transformer form part of electrical machines although they only convert voltage level from one level to another.

Types of Electrical machine

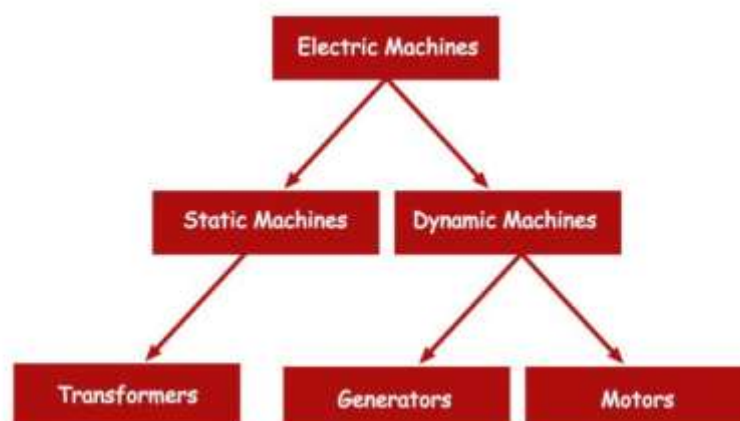


Figure 27: type of electrical machine

DC machines

Is a high versatile device that is likely to meet load demands requiring high acceleration and deceleration torques as well as high starting torque. The field winding for DC machines is located on the stator and windings of the armature is on the roto as shown below.

AC Single and three phase motors.

A motor is an electrical machine that converts electrical energy to mechanical energy.

Generators

Is an electrical machines that operates on the principal of electromagnetic induction hence converting mechanical energy to electrical energy? It is made up of a stator and

a rotor. At the rotor, mechanical energy is provided through prime mover also called the turbine.

Transformers

Electrical machine that either steps up or down voltage suitable for consumption.

Working Principle of a Transformer

The basic principle of a transformer's operation is the phenomenon of mutual induction. The figure above shows the simplest form of a transformer. Basically a transformer It consists of two inductive coils; primary and secondary winding. Though the windings are electrically separated, they are magnetically linked.

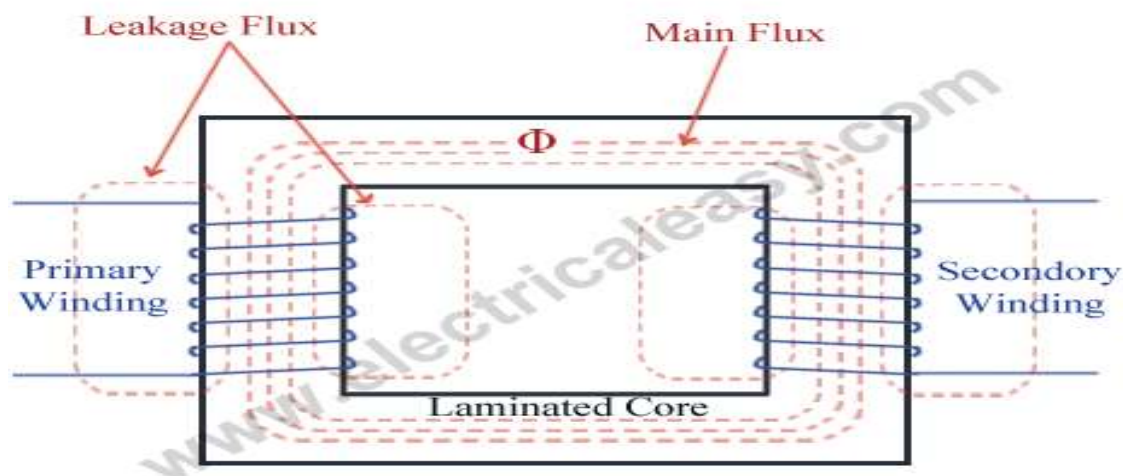


Figure 28: transformer

Source: www.electricalcaeasy.com

When the primary side is connected to an AC voltage supply, an alternating magnetic flux is produced around the primary winding. The laminated core provides magnetic path for the transfer of the flux on the primary side to the secondary winding. The flux that is successfully linked to the secondary side is called useful flux or main flux. The unlinked flux is known as leakage flux.

Since the induced flux is alternating, it forms a varying magnetic field, which meets the requirement of Faraday's law of electromagnetic induction. As a result, an emf is induced on the secondary winding called the mutually induced emf.

Types of Transformers

Transformers are broadly classified in terms of construction, purpose, type of power supply, use, and type of cooling.

Construction

Transformers fall into two categories based on their construction:

- (i) Core type transformer
- (ii) Shell type transformer

Core Type Transformer

The windings are wound in a cylindrical form then mounted on the core limbs. The windings are layered and the layers are insulated from each other using materials such as mica, paper and cloth. Low voltage windings are easier to insulate. Therefore, they are placed closest to the core.

Shell Type Transformer

The coils are wound in a rectangular or distributed form. They are also mounted in layers stacked with insulation between them.

- Purpose
 1. Step up transformer: Increases the supply voltage with a corresponding decrease in current on the secondary side.
 2. Step down transformer: Decreases supply voltage with a corresponding increase in current at the secondary side.
- Type of supply
 1. Single phase transformer
 2. Three phase transformer
- The use
 1. Power transformer: Used in a power transmission network
 2. Distribution transformer: Used in distribution network
 3. Instrument transformer: Used in relay and protection purpose in different instruments in industries
 - a) Current transformer (CT)
 - b) Potential transformer (PT)
- Type of cooling
 - a) Oil-filled self-cooled
 - b) Oil-filled water cooled
 - c) Air blast (air cooled)

Calculations involving single and three phase AC and DC transformers

Power Formulas in DC Circuits

- $P = V \times I$
- $P = I^2 \times R$
- $P = V^2 / R$

Where:

P = Power in Watts

V = Voltage in Volts

I = Current in Amperes

R = Resistance in Ohms (Ω)

Power Formulas in Single Phase AC Circuits

- $P = V \times I \times \cos \Phi$
- $P = I^2 \times R \times \cos \Phi$
- $P = V^2 / R (\cos \Phi)$

Figure 29: single phase transformer calculations

Where:

P = Power in Watts

V = Voltage in Volts

I = Current in Amperes

$R = \text{Resistance in Ohms } (\Omega)$

$\cos \phi = \text{Power Factor}$

Power Formulas in Three Phase AC Circuits

- $P = \sqrt{3} \times V_L \times I_L \times \cos \phi$
- $P = 3 \times V_{Ph} \times I_{Ph} \times \cos \phi$
- $P = 3 \times I^2 \times R \times \cos \phi$
- $P = 3 (V^2 / R) \times \cos \phi$

Where:

$P = \text{Power in Watts}$

$V = \text{Voltage in Volts}$

$I = \text{Current in Amperes}$

$R = \text{Resistance in Ohms } (\Omega)$

$\cos \phi = \text{Power Factor}$

Three-phase Voltage and Current

Connection	Phase Voltage	Line Voltage	Phase Current	Line Current
Star	$V_P = V_L \div \sqrt{3}$	$V_L = \sqrt{3} \times V_P$	$I_P = I_L$	$I_L = I_P$
Delta	$V_P = V_L$	$V_L = V_P$	$I_P = I_L \div \sqrt{3}$	$I_L = \sqrt{3} \times I_P$

Figure 30: three-phase voltage and current

Source: V. Vodovozov,(2012)

Three-phase Transformer Line Voltage and Current

Primary-Secondary Configuration	Line Voltage Primary or Secondary	Line Current Primary or Secondary
Delta - Delta	$V_L \Rightarrow nV_L$	$I_L \Rightarrow \frac{I_L}{n}$
Delta - Star	$V_L \Rightarrow \sqrt{3}.nV_L$	$I_L \Rightarrow \frac{I_L}{\sqrt{3}.n}$
Star - Delta	$V_L \Rightarrow \frac{nV_L}{\sqrt{3}}$	$I_L \Rightarrow \sqrt{3}.\frac{I_L}{n}$
Star - Star	$V_L \Rightarrow nV_L$	$I_L \Rightarrow \frac{I_L}{n}$

Figure 31: three-phase line voltage and current

Source: (<https://www.electronics-tutorials.ws/transformer/three-phase-transformer.html>)

DC Machines

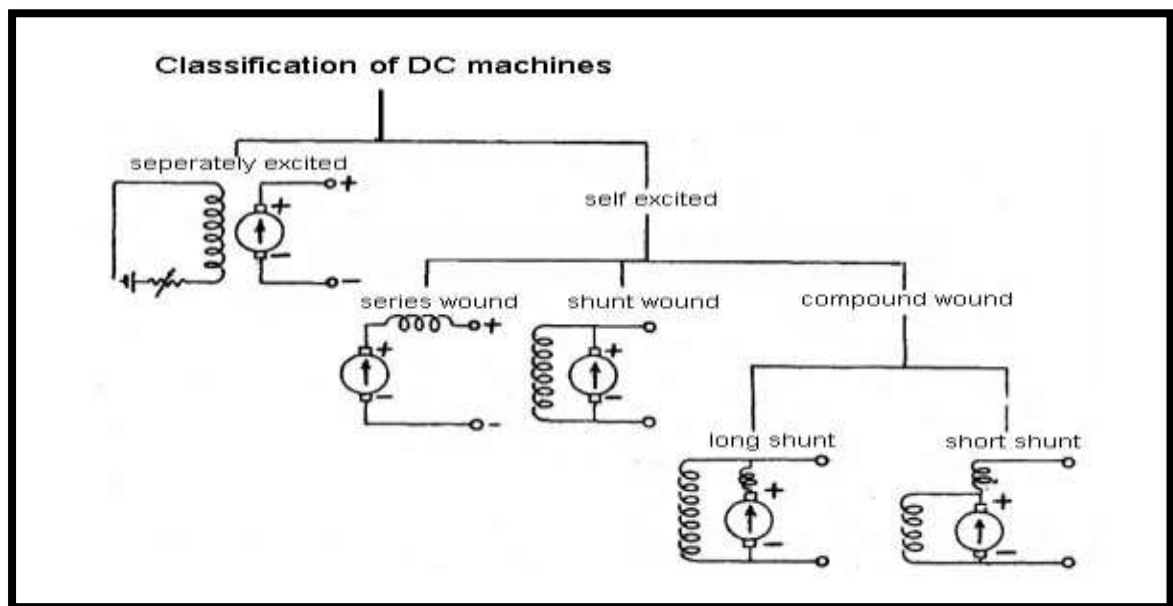


Figure 32: classification of DC machines

Source: (<https://www.electronics-tutorials.ws/transformer/three-phase-transformer.html>)

A DC machine can act as either a motor or a generator, which makes this classification suitable for both DC motors and DC generators. These machines are grouped into two broad categories based on the method of field excitation:

- i) Separately excited DC Machines: The field and armature windings are powered by different power sources..
- ii) Self-excited DC machines: The field and armature windings are interconnected in either series or parallel. They are further classified into:
 - Series Dc Machines: The field and the armature windings are connected in series. As a result, the field windings carry the entire load current.
 - Shunt Wound Dc machines: The field and armature windings are connected in parallel. As a result, the full voltage is applied on the field windings.
 - Compound Dc machines: There are two sets of field windings, one connected in series and another in parallel with the armature windings.

Motor Starting methods

- Direct-on-line starting

Refers to the connection of the motors directly to the supply at a specific voltage. It is suitably used stable supplies and shaft systems and pumps that are mechanically fit.

It simple and most commonly used. Temperature rise during starting is the lowest among other starting methods.

- Star-delta starting

It is mostly used induction motors to reduce the starting current. The current supplied to the windings of the stator is Y connected, later it is reconnected to the windings in delta connection when it gains speed.

- Auto-transformer starting

Applies auto transformer coupled in series connection with the motor when it starts.

- Soft starting

The device ensures soft starting of the motor. These are usually based on semi-conductors that aid in reducing the initial voltage of the motor resulting in a lower torque of the motor.

- Frequency converter starting

They can either be used to either continuously feed the motor or for start-up only. It makes it possible for use of low current for startup since motors have the ability to produce rated torque at rated current from zero till maximum speed.

Source: (<https://automationforum.co/starting-methods-of-motor/>)

Advantages and disadvantages of motor starting methods

Special machines

Are machines with specific design to perform particular applications not possible to be performed by other conventional machines. To design a special machine, the electrical control design integrates with the hydraulic, mechanical and pneumatic system.

Examples include;

- Assembly Machines
- Process Machines
 - Semi – Automatic
 - Fully Automatic
- Stand Alone Systems
- Integrated Systems
- Lifts, Pick and place, Transfer tables, Gantries

Application of AC and DC machines

- AC Motor Application
- Fan
- Pumping Motor
- Coolers
- DC Motor Application
- Printer
- Toy
- Electric Train

Table 6: experiment 1

EXPERIMENT 1	Special Instructions
Objective: Perform open circuit test on a single phase transformer to Calculate: The circuit parameters in reference to the primary side of the transformer Transformer's open circuit loss/iron loss/core loss Apparatus Required: One A.C Wattmeter - (0- 250 W) One A.C Voltmeter - (0-250 V) One A.C ammeter - (0-2.5 A) Variac: 230 V, 10 A, 50 Hz, 1-Phase Single Phase Transformer (50 Hz) Connecting wires	Precautions ➤ All connections should be tight and clean ➤ Special care necessary when selecting meter ranges for open circuit tests ➤ Strict adherence to workshop rules and regulations

Voltmeter (V)	Ammeter (A)	Wattmeter (W)

Procedure:

Make the connections as per the circuit diagram.

Ensure that the secondary side of transformer is open

Ensure the variac is at zero position before switching on the power supply.

Switch on A.C power supply.

Apply full voltage supply (230V) to the primary side of the transformer by varying the position of the variac.

Note down the ammeter, voltmeter and wattmeter readings

Reset the Variance to zero position before switching off the power Supply.

4.3.4.3. Self-Assessment

- 1) Describe an electrical machine
- 2) Differentiate operation of various types of electrical machines
- 3) Explain the difference between DC and AC machines
- 4) Perform various motor starting methods
- 5) Describe special machines and their applications
- 6) Transformer form part of electrical machines although they only convert voltage level from one level to another. TRUE OR FALSE?
- 7) A generator is an electrical machine that converts electrical energy to mechanical energy. TRUE OR FALSE?
- 8) At the rotor, mechanical energy is provided through prime mover also called the turbine. TRUE OR FALSE?

4.3.4.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Electrical workshop
- Relevant practical materials

4.3.4.5 References

V. Vodovozov, Electric Drive Systems and Operation, London: Ventus Publishers, 2012.

Circuitglobe.com

4.3.5 Learning Outcome No. 4: Demonstrate Understanding of Three Phase Power Supply

4.3.5.1 Learning Activities

Learning Outcome No.4. Demonstrate Understanding Of Three Phase Power Supply	
Learning Activities	Special Instructions
- Measure reactive power in a three-phase circuit using this method - Conduct an experiment to measure the readings of two wattmeter's in this experiment, if the load is purely resistive	

4.3.5.2 Information Sheet No. 4/ L03

Three Phase System

Definition: The system which has three phases, i.e., the current will pass through the three wires, and there will be one neutral wire for passing the fault current to the earth is known as the three phase system.

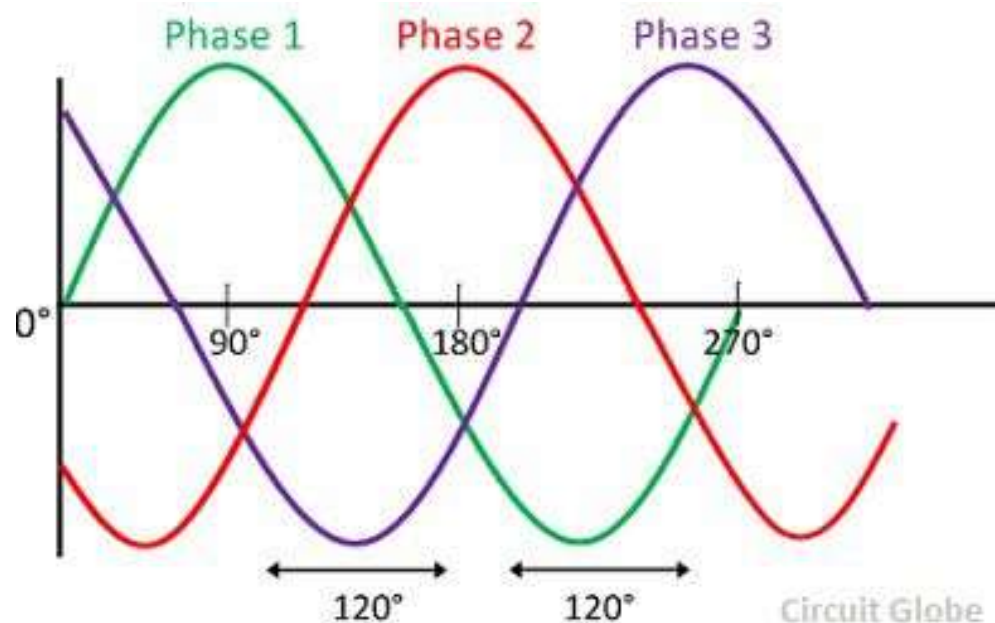


Figure 33: three phase system

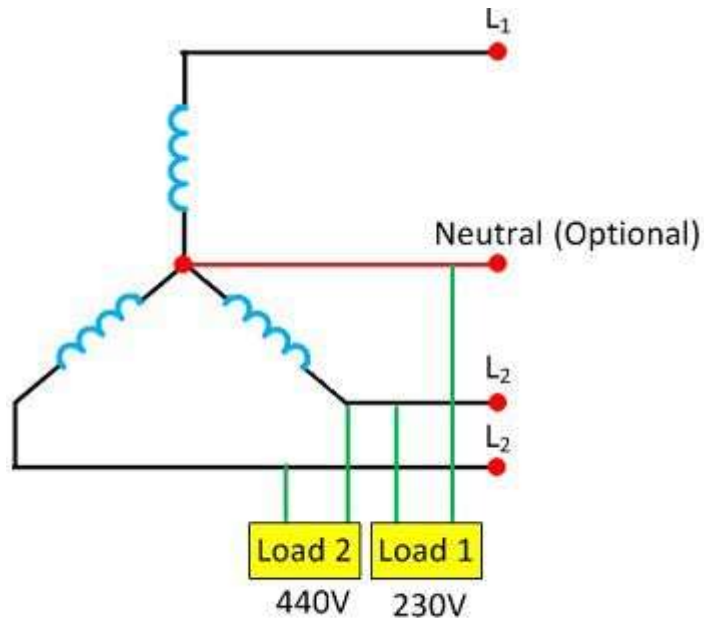
Source: Source: (<https://www.electronics-tutorials.ws/transformer/three-phase-transformer.html>)

The 120° phase difference of the three phases is must for the proper working of the system. Otherwise, the system becomes damaged.

Types of Connections in Three-Phase System

Star Connection

The star connection requires four wires in which there are three phase conductors and one neutral conductor as shown below



3 - phase Star Connected System

Circuit Globe

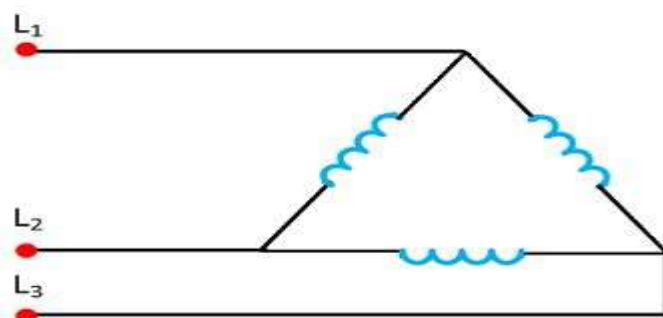
Figure 34: 3-phase star connected system

Source: circuit globe

The voltage between the single phase and the neutral is 230V, and the voltage between the two phases is equal to the 440V.

Delta Connection

The delta connection has three wires, and there is a no neutral point. The line voltage of the delta connection is equal to the phase voltage.



3 - Phase Delta Connection

Circuit Globe

Figure 35: 3-phase delta connection

Source: circuit globe

Connection of Loads in Three Phase System

The loads in the three-phase system may also connect in the star or delta. The three phase loads connected in the delta and star is shown in the figure below.

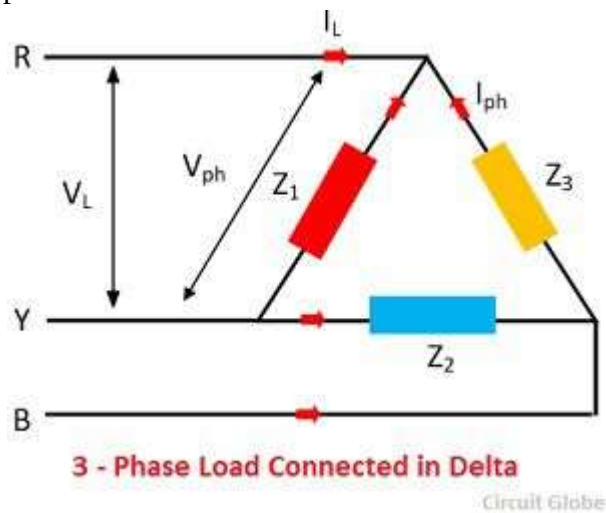


Figure 36: 3-phase load connected in delta

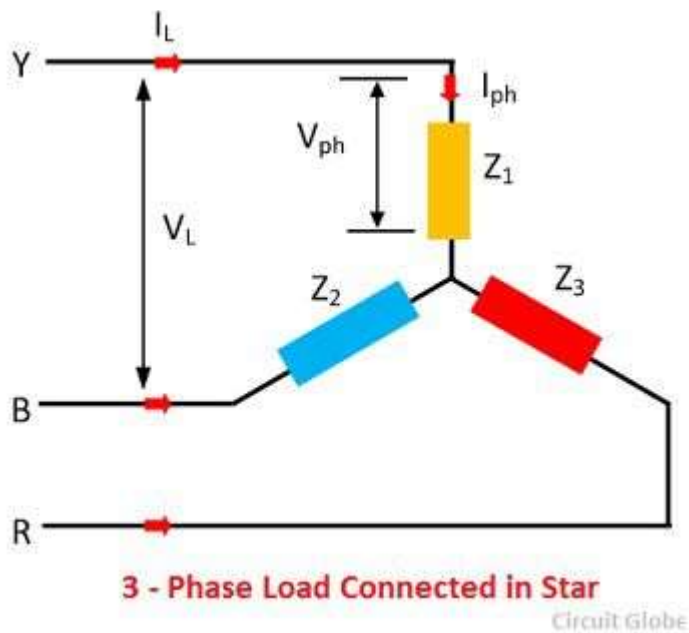


Figure 37: 3-phase load connected in star

Source: circuit globe

The three phase load may be balanced or unbalanced. Under balance condition, all the phases and the line voltages are equal in magnitude.

Review of Three-Phase Voltage System Properties

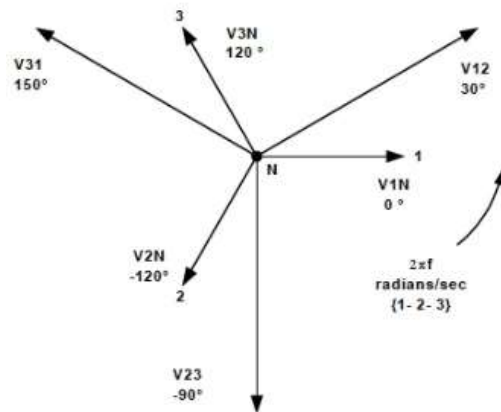


Figure 2
Three-Phase 4-Wire Wye System Voltage Phasors
Sequence {1-2-3}

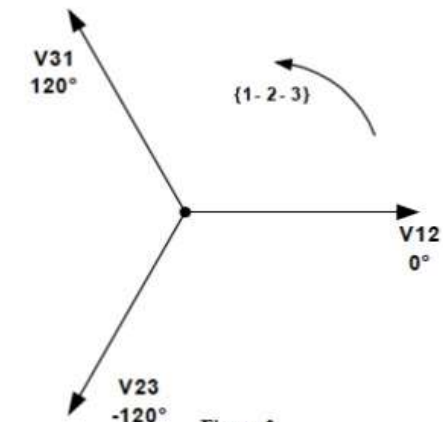


Figure 3
Three-Phase 3-Wire Delta System Voltage Phasors
Sequence {1-2-3}

Measurements of three phase power supply

1. Three watt meters method
2. Two watt meters method
3. Single wattmeter method.

The most common method is the three wattmeters method and it is used in measuring power in 3 phase, 4 wire system. The figure below describes connection for a star connected loads used in measuring power.

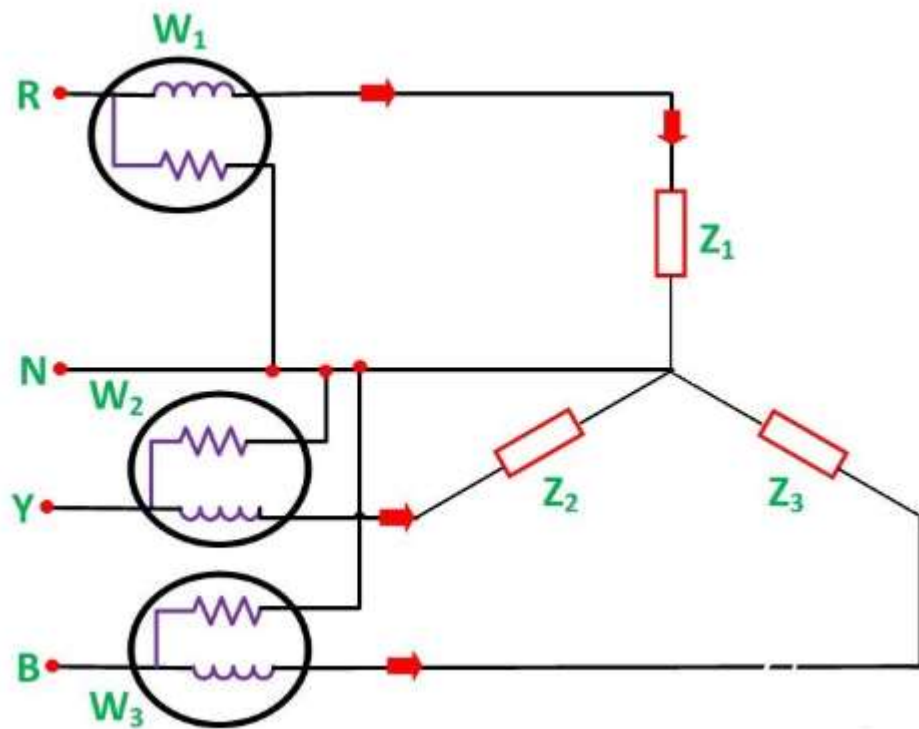


Figure 38: connection for a star connected loads used in measuring power

Source; circuit globe

$$\text{Total power } P = W_1 + W_2 + W_3$$

Where,

$$W_1 = V_1 I_1$$

$$W_2 = V_2 I_2$$

$$W_3 = V_3 I_3$$

Experiment 3: Measure power factor

Tabulation:

Table 7: measure power factor

Sl. No.	Condition	I_R	I_Y	I_B	V_R	V_Y	V_B	M.F.	W_1	W_2
1	Balanced Load									
2	Unbalanced Load									

To measure: Three phase power and power factor in a balanced three-phase circuit by using two single-phase wattmeter. Calculate the three phase power for unbalanced load condition. Apparatus: 2 AC Wattmeters (0- 600 V, 750 W) 2 AC Voltmeters - 1 nos. (0-600 V) 3 AC Ammeters (0-5 A) Load Box Procedure: Connect the apparatus as shown on the circuit diagram Switch on AC power supply. Note down the ammeter, Voltmeter and ammeter readings for balanced load conditions Repeat procedure (3) but with unbalanced load condition Switch off the AC power supply Calculation: Calculate P_M, P_c and % Error. See Appendix 3 for the circuit diagram	Precautions: Ensure the connections are tight and clean Ensure the ammeter readings does not exceed the ammeter's current ratings Reverse the connection of the measuring device in case of a negative deflection

Figure 39: circuit diagram

Source: circuit globe

4.3.5.3 Self-Assessment

Questions:

1. State reactive power
2. The delta connection requires four wires in which there are three phase conductors and one neutral conductor TRUE OR FALSE?
3. The loads in the three-phase system may also connect in the star or delta. TRUE OR FALSE?
4. Perform experiment on three phase power supply
5. Demonstrate three phase voltage system properties
6. Is it possible to measure reactive power in a three phase circuit using this method?
7. What would be the readings of two wattmeters in this experiment, if the load is purely resistive?
8. What would be the readings of two wattmeters in this experiment, if the load is purely inductive?
9. If one of the wattmeter reads zero, what is the power factor of the load?

4.3.5.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.5.5 References

1. V. Vodovozov, Electric Drive Systems and Operation, London: Ventus Publishers, 2012.
2. Circuitglobe.com

4.3.6 Learning Outcome No. 5. Use of Power Factor in Electrical Installation

4.3.6.1 Learning Activities

Learning Outcome No. 5. Use of Power Factor in Electrical Installation	
Learning Activities	Special Instructions
Demonstrate understanding of power factor Demonstrate understanding of power triangle Demonstrate understanding of power factor correction methods	

4.3.6.2. Information Sheet No. 4/L05

Power factor, active & reactive power basic concept

Power factor- In ac circuit there is often a phase difference between the current and voltage. Power factor or PF is the cosine of this angle phase difference, $\cos \phi$.

Power factor types-

- Leading power factor- Current leads voltage occurs in a capacitive load circuit,
- Lagging power factor- Current lags behind voltage. Occurs in inductive load circuit

Value of Power factor- As power factor is a cosine function its possible value ranges from -1 to +1

Active and reactive component of power factor

$VI \cos \phi$ is called active or watt full component, whereas $VI \sin \phi$ called reactive or watt less component.

AC Circuit Power Triangle

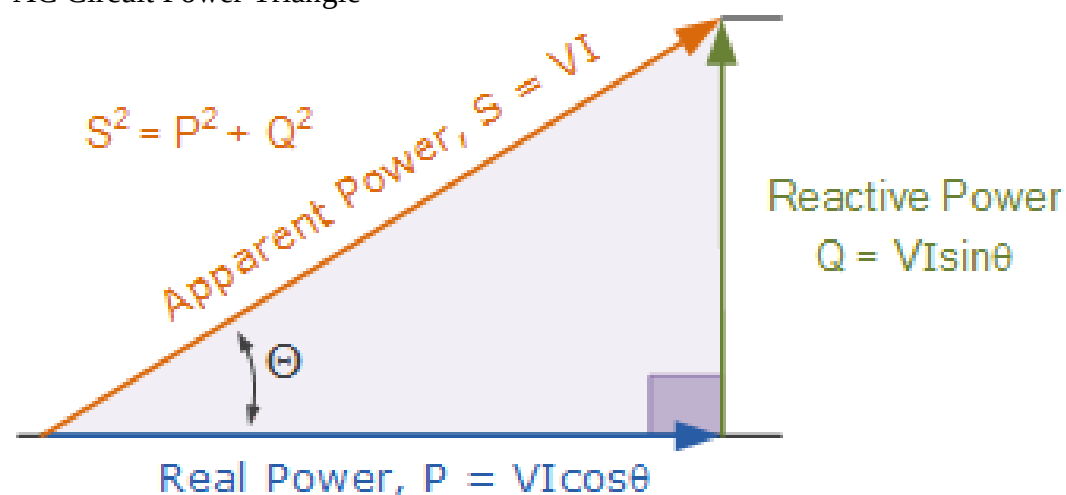


Figure 40: AC Circuit power triangle

Source: circuit globe

Where:

- P is the Real power that performs work measured in watts, W
- Q is the Reactive power measured in volt-amperes reactive, VAr
- S is the Apparent power measured in volt-amperes, VA
- θ is the phase angle in degrees. The larger the phase angle, the greater the reactive power
- $\cos(\theta) = P \div S = W/VA = \text{power factor, p.f.}$
- $\sin(\theta) = Q \div S = VAr/VA$
- $\tan(\theta) = Q \div P = VAr/W$

The power factor is calculated as the ratio of the real power to the apparent power because this ratio equals $\cos(\theta)$.

EXPERIMENT 4: To measure power factor in a single phase AC circuit by using three ammeters.

Table 8 to measure power factor in a single phase AC

Apparatus: 1 AC Wattmeter. (0- 250 V, 0- amp) 1 AC Ammeter (0-10 A) 2 AC Ammeter (0-5 A) 1 AC Voltmeter (0-300 V) Variance: 1-Phase, 230 V, 10 A, 50 Hz Resistor: 450 ohm R-L Load Box Connecting wires Procedure Connect the circuit as shown in the circuit diagram Ensure the variance is at zero position before starting the experiment Switch on AC supply. Set the supply voltage by varying the position of the Variance Vary the RL load to obtain different readings of ammeters, and wattmeter. Repeat step 5 and note down the readings. Reset the Variance to zero position before switching off the power supply Calculation: Calculate the value of P, $\cos \theta$.	Precautions: All connection should be neat and tight The current should not exceed ammeter rating

See Appendix 4 for circuit diagram and tabulation table	

Appendix 4

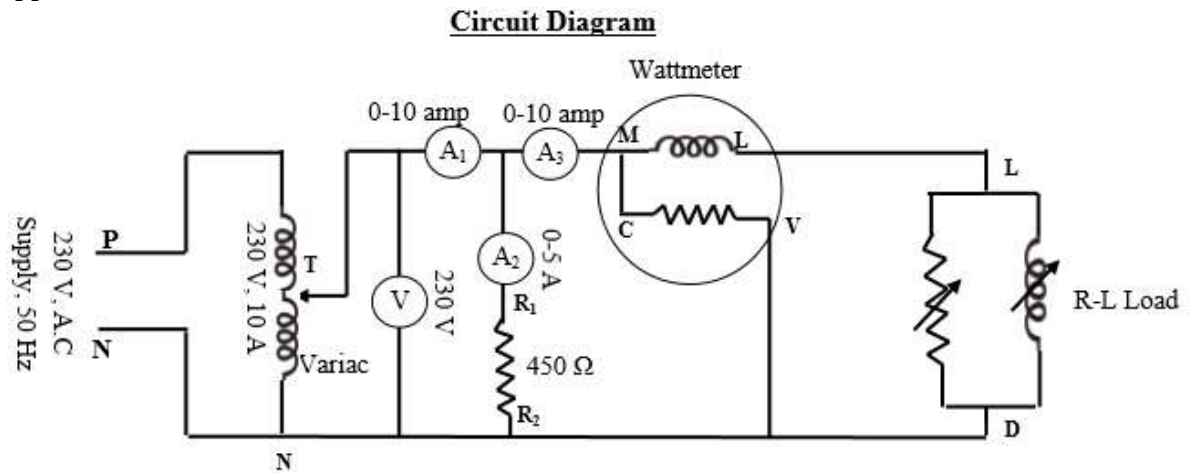
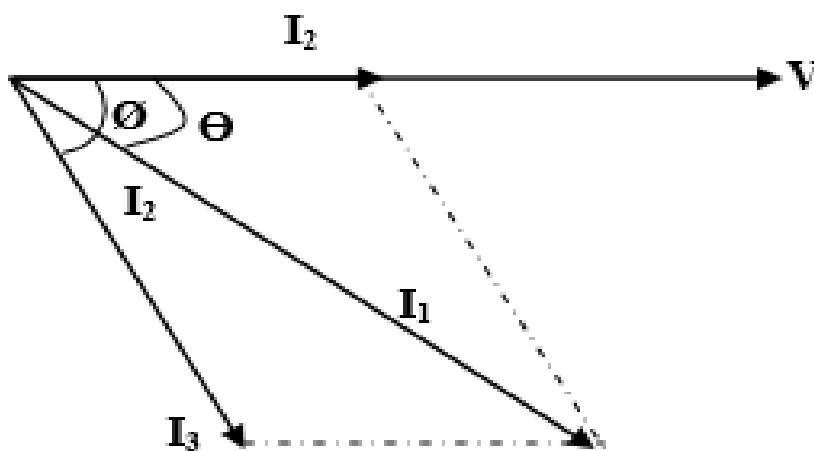


Figure 41: circuit diagram

Phasor Diagram



Phasor diagram of the above circuit.

Figure 42: phasor diagram

Source; circuit globe

4.3.5.3 Self-Assessment

1. In an a.c. circuit which power is more apparent or real and why?
2. What is the basic difference between an inductive load and purely inductive load?
3. The practical loads are purely inductive or inductive?
4. Perform calculations on power factor correction methods?
5. Explain power factor
6. Differentiate active & reactive power
7. Demonstrate understanding of power triangle
8. Describe power factor correction methods
9. Lagging power factor- Current leads voltage occurs in a capacitive load circuit. TRUE OR FALSE?
10. Leading power factor- Current lags behind voltage. Occurs in inductive load circuit. TRUE OR FALSE?

4.3.5.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.5.5 References

1. S. P. Chandra, Principles of electric machines and power electronics. John Wiley & Sons, 2007.

4.3.7. Learning Outcome No. 6. Use of Earthing In Electrical Installation

4.3.7.1 Learning Activities

Learning Outcome No. 6. Use of Earthing In Electrical Installation	
Learning Activities	Special Instructions
Connect earthing cable	

4.3.6.2 Information Sheet No5/L05

Introduction

Earthing is the process of connecting electric currents to the earth, purposely for safety. Electrical wiring is directed to the earth so that in case of exposure of the live wire or any other insulation mishaps, there is no immediate danger to the surrounding and the circuit. Live electric currents can cause extensive damages as it spreads faster and has devastating effects. The idea behind this action is neutralizing the electric currents in case they stray due to human neglect or equipment malfunctioning.

Earthing is done through embedding a metallic rod or plate into the ground. The process by which the metallic rod – earth electrode – is placed into the ground is technically called Earth Resistance, and is measured in Ohms.

Importance of Earth in Electrical Networking

1. The exercise helps in saving human beings from electrocution in case there is a fuse blow. Earthing neutralizes the electric currents by creating alternative current paths.
2. Helps to neutralize the effects of lightning or short circuits
3. If there is any faulty equipment or machinery connected to the network, earthing prevents it from being destroyed by the live currents.
4. Prevents friction from occurring in case of static electricity
5. Earthing stabilizes electric currents in electronics. Different equipment needs a certain voltage to function optimally, hence earthing regulates the amount of current passing through to avoid damage.

Functions of Electric Earthing Systems

1. To prevent the destruction of lives and properties in case of exposure to a live current
2. Keep the voltage of any electrical gadget in check
3. Create a harmless alternative path in case there is a faulty electric current

Types of Earthing

Earthing is divided into two:

1. System/Neutral, and
2. Equipment

System or neutral earthing is achieved by stabilizing the voltage to match that produced by the ground. It is designed to shield electrical equipment from being short-circuited. It is done by connecting part of the current of the plant to the ground. The ground provides a low-voltage path that prevents any live current from causing harm. As for the neutral earthing, the current is connected to the ground which acts as the central electric panel. As the neutral conductor, the ground should have an identical voltage to stabilise the current flow.

Equipment earthing maintains the current flow against harming people or things that are non-conductors. Its main target is people who are closer to live currents. This is done by connecting frames of these equipment to the earth.

The two types of earthing are enjoined so that the harmless (fault) current passing through its systems reduces the probability of someone or something being destroyed. It also maintains the potential gradient of current at the processing substation. If the systems have to work differently, the cons will be a higher current on short-circuiting, a reduced intensity of current flows and expenses in terms of materials used to relay earthing into the ground. If the two systems are integrated, the cost of implementation and efficiency gained will be worthwhile.

Experiment 5: Measurement of Earth Resistance by use of Earth Tester by Three Point method or Fall Potential Test

The fall potential is the most popular method of measuring the earth resistance of a grounding system.

Take measurement in different directions as shown in below fig.

Procedure

1. Connect C1 and P1 terminals on the test set to the earth electrode.
2. Drive a probe into the earth 100 to 200 feet from the center of the electrode and connect to terminal C2. This probe should be driven to a depth of 6 – 12 inches.
3. Drive another probe into the earth midway between the electrodes and probe C2 and connect to terminal P2. This probe should be driven to a depth 6 – 12 inches.
4. Record the resistance measurement.
5. Move the potential probe 10 feet farther away from the electrode and make a second measurement.
6. Move the potential probe 10 feet closer to the electrode and make a third measurement.

7. If the three measurements agree with each other within a few percent of their average, then the average of the three measurements may be used as the electrode resistance.
8. If the three measurements disagree by more than a few percent from their average, then additional measurement procedures are required.

4.3.6.3. Self-Assessment

1. State earthing
2. Describe the importance of earthing
3. Differentiate various types of earthing
4. What is a Building Protection and Grounding System?
5. What existing objects are included in a Building Protection and Grounding System Design?
6. How does a Building Protection and Grounding System work?
7. Electrical wiring is directed to the earth so that in case of exposure of the live wire or any other insulation mishaps, there is no immediate danger to the surrounding and the circuit. TRUE OR FALSE?
8. If there is any faulty equipment or machinery connected to the network, earthing prevents it from being destroyed by the live currents. TRUE OR FALSE?
9. The process by which the metallic rod – earth electrode – is placed into the ground is technically called Earth Resistance, and is measured in Ohms. TRUE OR FALSE?

4.3.6.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.6.5 References

1. T. Linsley, Basic Electrical Installation Works, Routledge, 2018.

4.3.8 Learning Outcome No. 7. Apply Lightning Protection Measures

4.3.8.1 Learning Activities

Learning Outcome No. 7. Apply Lightning Protection Measures	
Learning Activities	Special Instructions
ACTIVITY • Set up earthing equipment and materials • Carry out the earthing procedure PROCEDURE • Provide down conductor tapes in locations as indicated on the drawings. • Down conductors shall be either: Installed surface on the structure concealed behind the cladding OR Reinforcing bars within the concrete structure. 1. Down conductor tapes shall terminate on to dedicated reinforcing bars which shall be utilized as the final connection to earth via the pile foundations. The Contractor shall include for supervising and testing the installation of the reinforcing bars including all joints prior to the concrete being poured. 2. Down conductors to be connected at roof level to a common loop tape. Provide horizontally mounted conductor tapes at levels indicated on the drawings. These shall provide a common connection for all down conductors, structure, cladding, steelwork and exposed metalwork	

4.3.7.2. Information Sheet No 4/LO7

Lightning physics, effects, and risk assessment

Definition of Key Words

Lightning Flash/Discharge – it is the discharge of electrical currents in the atmosphere occasioned by two charged clouds. The cumulonimbus clouds often form these oppositely charged regions, and the flash comes about by when it touches the earth surface.

Lightning Flash Density – this is the frequency by which a specific type of lightning flashes in an area over a given period of time. It is measured yearly, documenting the number of times the flash discharge in a particular area.

Lightning Protection System – these are components designed from conductors that are installed to reduce the damaging effect of lightning.

Lightning Strike – this is the action or effect caused as a result of the lightning flash on or at a given point.

Lightning Strike attachment Point – this is the contact point where the lightning strike touches. It may be on the ground on a structure.

Lightning stroke – this is a single current impulse at the contact point from the lightning strike.

Thunderday – this is a presumptive date or day in a calendar year when thunder is recorded in a given location.

Zone of Protection – an area protected from the lightening by the lightning protection system.

Types of lightning strikes

- Direct strike: This type occurs when lightning strikes an individual
- Side flash: It occurs in case lightning strikes a tall object and part of strikes extends to individuals close to it.
- Ground current: Is in form of dissipated strikes that results from objects being transferred to the ground. The dissipated energy can possibly electrocute individuals that are near the point of focus.
- Conduction: Occurs in case an individual is in contact with a metal material that has been struck by lightning.

Components of lightening protection systems;

Copper air terminals are usually made up of either copper or aluminum. The air terminals are connected through cable with minimal two ground rods buried 10 feet below the grade.

- copper cable
- copper clad ground rods
- surge suppressors

Application of lightning systems

- Lightning protection system (LPS)
- Lightning arrester

Maintenance of lightening system

4.3.7.3. Self-Assessment

1. Define lightning
2. Describe the procedure for testing lightning system
3. Describe the various methods used in earthing in domestic installation
4. What are the applications of lightning systems?
5. Differentiate the various components of lightening protection systems
6. Lightning Flash Density is the frequency by which a specific type of lightning flashes in an area over a given period of time. TRUE OR FALSE

7. Zone of Protection is an area protected from the lightening by the lightning protection system. TRUE OR FALSE?

4.3.7.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.7.5. References

1. T. Linsley, Basic Electrical Installation Works, Routledge, 2018.

4.3.9. Learning Outcome No. 8. Apply Electromagnetic Field Theory

4.3.9.1 Learning Activities

Learning Outcome No. 7. Apply Electromagnetic Field Theory	
Learning Activities	Special Instructions
Conduct the hertz experiment	

4.3.8.2 Information Sheet No4/LO8

Electromagnetic Field Theory

An electromagnetic field is a typical field produced when charged particles (electrons) are charged. Any particles charged electrically are surrounded by electric field. The charged particles produce magnetic field. In case of change in velocity of charged particle, and electromagnetic field is produced.

Sources of Electromagnetic Fields

Solar radiation/ natural radiation: Are radiations that originates from the sun

Artificial radiation: Originates from a remote sensing system

Terrestrial radiation: Are radiations emitted by the Earth's surface

Detectors of Electromagnetic radiation

1. X-ray machines,
2. radios
3. cell phones

Application of Electromagnetic waves

1. Communication
2. Heating water
3. Cooking
4. Detecting of flogged bank notes

Electromagnetics Laws

- Faraday's Law

It states that when the magnetic flux linking a circuit changes, an electromotive force is induced in the circuit proportional to the rate of change of the flux linkage.

- Lenz's law

It states that the direction of an induced current is always such as to oppose the change in the circuit or the magnetic field that produces it.

- Fleming's Laws

Fleming's Left Hand Rule

It states “Hold out your left hand with the forefinger, second finger and thumb at the right angle to one another. If the forefinger represents the direction of the field and the second finger represents that of the current, then thumb gives the direction of the force.”

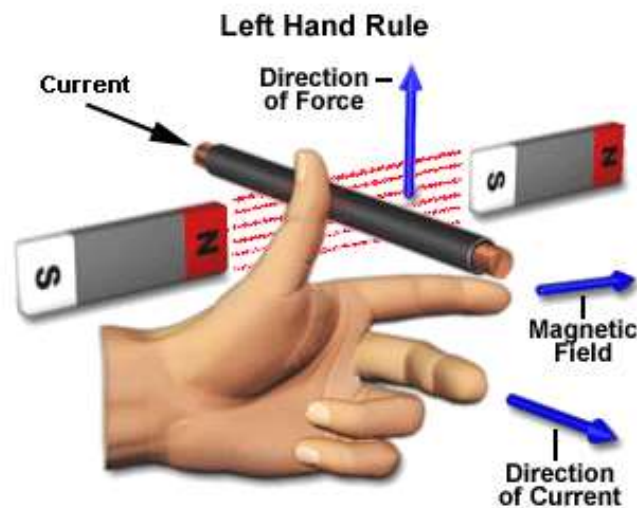


Figure 43: Fleming's left hand rule

Source: circuit globe

Fleming's Right Hand Rule

This rule states “Hold out the right hand with the first finger, second finger and thumb at the right angle to each other. If forefinger represents the direction of the line of force, the thumb points in the direction of motion or applied force, then second finger points in the direction of the induced current”.

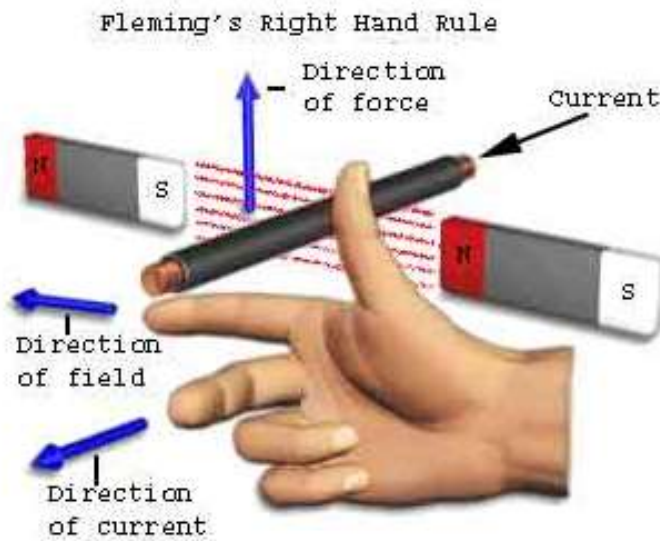


Figure 44: Fleming's right hand rule

Source: circuit globe

Properties and Effects of Electromagnetic waves

1. Energy and Momentum

Electromagnetic waves have energy and momentum that are both associated with their wavelength and frequency.

2. Energy

The energy (E) of a photon can be related to its frequency (f) by Planck's constant (h):

$$E = hf = hc/\lambda$$

The ratio of speed of light (c) to wavelength (λ) can be substituted in place of f to give the same equation to energy in different terms. Note that energy cannot take any value: it can only exist in increments of frequency times Planck's constant (or Planck's constant times c divided by wavelength). Energy of a wave is therefore "quantized."

3. Momentum

Momentum is classically defined as the product of mass and velocity and thus would intuitively seem irrelevant to a discussion of electromagnetic radiation, which is both massless and composed of waves.

However, Einstein proved that light can act as particles in some circumstances, and that a wave-particle duality exists. And, given that he related energy and mass ($E=mc^2$), it becomes more conceivable that a wave (which has an energy value) not only has an equation to mass but a momentum as well.

And indeed, Einstein proved that the momentum (p) of a photon is the ratio of its energy to the speed of light.

Wave Characteristics and Shielding

An electromagnetic wave shield reduces the energy of electromagnetic waves by means of the reflection, absorption, and multiple reflection of the waves. By attenuating the electromagnetic waves, the shield avoids disruptions to precision equipment.

Skin Effect

It states that the tendency of a high-frequency alternating current to flow through only the outer layer of a conductor

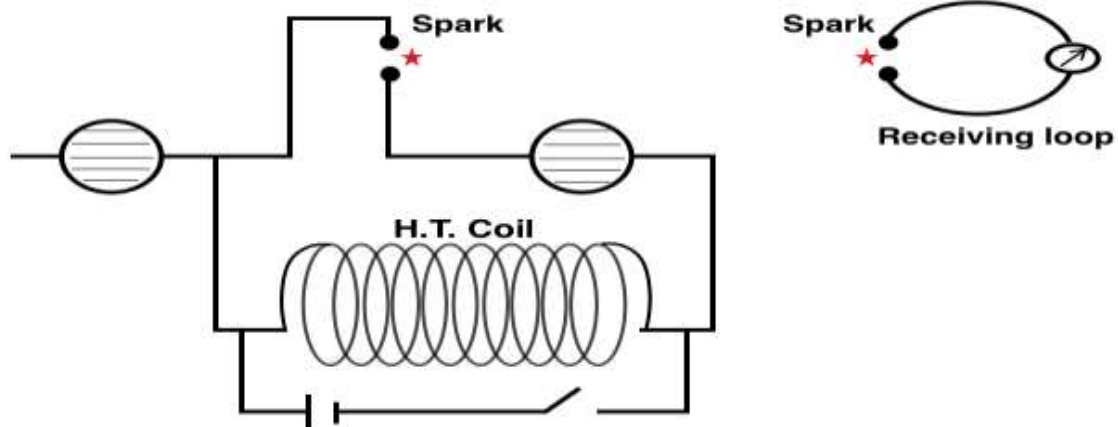
The hertz experiment

Description:

Hertz experiment was the first to prove the existence of electromagnetic waves. He also concluded that electromagnetic waves do not require a medium to travel.

Apparatus

1. High tension coil.
2. Polished brass knobs.
3. Receiving loop.



Working

Hertz used the high-tension coil to generate large amount of potential difference across the circuit. When the high potential difference was gained and propagated to the brass knobs, there appeared a spark between the knobs. Spark indicates that there was electron jump between the knobs.

As soon as the spark was observed between the knobs in the circuit, a spark was also seen between the knobs of the receiving loop.

4.3.8.3. Self-Assessment

- a) Explain shielding
- b) Explain sources of terrestrial radiation
- c) Describe detectors of electromagnetic radiation
- d) Differentiate various electromagnetic laws
- e) Describes Flemings Left and Right-hand Rules
- f) What is the importance of Flemings Rules?
- g) Define Skin effect.
- h) The charged particles produce magnetic field. TRUE OR FALSE?
- i) Electromagnetic waves have energy and momentum that are both associated with their wavelength and frequency. TRUE OR FALSE?

4.3.8.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.8.5. References

1. J. C. T. Adolf, Engineering Electromagnetic Fields and Waves, New York: John Wiley and Sons, Inc., 1975.

4.3.10 Learning Outcome No. 9. Apply Electrodynamics

4.3.10.1 Learning Activities

Learning Outcome No. 9. Apply Electrodynamics	
Learning Activities	Special Instructions
Determine factors that affect electrodynamics	

4.3.9.2. Information Sheet No. 4/ LO9

Meaning of Electrostatics Is the study of stationary electric charges.

A rod of plastic rubbed with fur or a rod of glass rubbed with silk will attract small pieces of paper and is said to be electrically charged.

Meaning of terms in magnetostatics

- Magnetic field or Magnetic Induction (B)

The field where the magnet attracts or repels magnetic materials

$$F = q \times v \times B$$

Where;

F= Force,

V = Speed of Particles,

B = magnitude of the field.

- Magnetic Field Strength (H)

The amount of magnetizing force (how much force it has to magnetize, magnetic materials)

The SI unit of Magnetic Field Strength is Ampere/meter (A/m)

$$H = NI/1c$$

Where 1c = magnetic path in meter.

- Magnetic Flux (Φ)

Magnetic Flux which is denoted by Φ or Φ_m or Φ_B . Or it is the amount of magnetic field or magnetic lines of force passing through a surface like conducting area, space, air, etc. The SI Unit of magnetic flux is Wb (Weber).

$$\Phi = BAc$$

Where

Ac=area in m²

- Magnetization (M)

It is the density of permanent magnet or electromagnet dipole moments in magnetic materials. The SI Unit of Magnetization is Ampere/meter (A/m) and it is also a vector quantity. The SI formula for Magnetization is

$$M = m/V$$

Where,

m = Total magnetic moment

And V= volume in m³

Introduction

The earliest recorded study on the concept of electromagnetic induction gives credit to Henry (American) and Faraday (English). The two did independent research on this subject in the 19th century. Faraday, received the full credit because his publication earlier than Henry.

What is electromagnetism Induction?

It is the phenomenon whereby a fluctuating magnetic flux through a coil of wire generates an *emf* (electromotive force) in the wire. It is the basic principle behind the generation of electricity to date.

Emf generated depends on:

- The strength of the magnetic flux, $\Delta\Phi_B$
- The number of loops in the coil of wire, N
- The rate at which the flux fluctuates, Δt

$$\varepsilon = -N \frac{\Delta\Phi_B}{\Delta t}$$

Experiment 8: *To investigate electromagnetic induction and determine the factors that affect it*

Mass (g)	Period (s)	Frequency (Hz)	Peak Voltage (V)
50			
150			
250			
350			
450			

Apparatus:

bar magnet;
coil of magnet wire (20 or 22 awg);
three rectangular ceramic magnets;
a spring system;
slot weight system;
two large binder clips;
Pasco Science Workshop software and interface
Voltage leads
Motion sensor

Procedure:

Part I - Lenz's Law and the Induced Current

Boot up the computer (if necessary) and logon. Open Science Workshop.

Take a good look at your experimental setup. You will need to return it to this arrangement later in the experiment (step 8). But for now, unhook your spring from the lab stand and lay the entire assembly (spring, binder clips, magnets and slot weight hanger) on your lab table out of the way.

Goto file/open and then choose to look on the t: drive.
Open the setup file frdy1-1
which you will find in the 151 Lab folder on the t:drive.

Now grab the bar magnet so that the red end (north pole) points downward, as though it were an arrow head on an arrow. Start the data collection by double clicking REC. Now center the magnet above the loops and thrust the magnet downward toward the loops from above. (The north end of the magnet should be approaching the plane of the loops first.) Watch the computer monitor as you do this. You should see a voltage peak displayed on your screen. Now pull the magnet upward and watch the display again. Repeat this down and up motion of the magnet several times, being careful to note the polarity of the voltage peak when you move the magnet down

and up. Stop the data collection by double clicking on STOP. Now record what you have observed in the provided data chart at the end of this handout Redo step 4 above, focusing on the silver end (south pole) of the magnet. Record your Observations. Analyze your table and conclude on the direction the induced current will flow in the loops when compared to the direction that the magnetic flux was changing. Begin the data collection by and move the magnet up and down as in steps 4 and 5. Have an alternating exercise whereby you move the magnets faster then slowly as you make observations. Conclude the data collection. Skream through the data. Do you note anything about the magnitude of the induced voltage in comparison with the speed with which you moved the magnet? Tabulate your result and then make a bold conclusion. Do you agree with the findings of Henry and Faraday?	

ANALYSIS:

1. Close Science Workshop and open up Vernier's Graphical Analysis software. If you are doing this somewhere other than Penn State's physics lab, you may use a spreadsheet software or some other graphing software.
2. Enter your data from steps 8 - 22 into the graphing software. Put the frequency value in the X data column and the peak voltage in the Y data column.
3. Do a linear curve fit and print out your graph.
4. Assuming the number of loops in your coil of wire was about 80, and using your graph you just printed out as needed, calculate the magnetic flux change that was occurring as you oscillated the magnets back and forth in steps eight through twenty two. Show your calculation and explain your reasoning step by step.

4.3.9.3. Self-Assessment

- a) Explain Electrostatics
- b) Perform calculations in magnetostatics
- c) Explain electromagnetic Induction
- d) What are the various applications of Electrostatics?
- e) Perform calculations involving electromagnetic Induction
- f) Magnetic field or Magnetic Induction (B) is the field where the magnet attracts or repels magnetic materials. TRUE OR FALSE?

g) The SI Unit of Magnetization is Ampere/meter (A/m) and it is also a vector quantity. TRUE OR FALSE?

4.3.9.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.9.5. References

1. J. C. T. Adolf, Engineering Electromagnetic Fields and Waves, New York: John Wiley and Sons, Inc., 1975.

4.3.11 Learning Outcome No. 10. Apply energy and momentum in electromagnetic field

4.3.10.1. Learning Activities

Learning Outcome No. 10. Apply energy and momentum in electromagnetic field	
Learning Activities	Special Instructions
Apply energy and momentum in electromagnetic field	

4.3.10.2. Information Sheet No. 4/ LO10

Energy conservation theorem:

- Poyntings' Theorem

The Poynting Theorem is in the nature of a statement of the conservation of energy for a configuration consisting of electric and magnetic fields acting on charges. Consider a volume V with a surface S . Then “the time rate of change of electromagnetic energy within V plus the net energy flowing out of V through S per unit time is equal to the negative of the total work done on the charges within V .”

Momentum Energy Flow

Describing Fluid Flow

There are various mathematical models that describe the movement of fluids and various engineering correlations that can be used for special cases. However, the most complete and accurate description comes from *partial differential equations* (PDEs). For instance, a flow field is characterized by balance in mass, momentum, and total energy described by the continuity equation, the Navier-Stokes equations,

The solution to the mathematical model equations gives the velocity field, pressure, p ; and temperature, T ; of the fluid in the modeled domain. In principle, this set of equations is able to describe flows from the creeping flow in a microfluidic device to the turbulent flow in a heat exchanger and even the supersonic flow around a jet fighter. However, solving Equation for a case such as the jet plane shown below is not feasible and while it is possible to solve the whole of Equation for a microfluidic device, it is a lot of work down the drain. Much of computational fluid dynamics (CFD) is therefore devoted to selecting suitable approximations to Equation so that accurate results are obtained with a reasonable computational cost.

Electromagnetic Energy flow

Electromagnetic radiation, in classical physics, the flow of energy at the universal speed of light through free space or through a material medium in the form of the electric and magnetic fields that make up electromagnetic waves such as radio waves, visible light, and gamma rays. In such a wave, time-varying electric and magnetic fields are mutually linked with each other at right angles and perpendicular to the direction of motion.

An electromagnetic wave is characterized by its intensity and the frequency ν of the time variation of the electric and magnetic fields. In terms of the modern quantum theory, electromagnetic radiation is the flow of photons (also called light quanta) through space. Photons are packets of energy $h\nu$ that always move with the universal speed of light.

Electron deflection tube: using an electric field Demonstration The deflection tube allows you to show the parabolic path of an electron beam passing through a uniform electric field. The graduated scale allows you to take measurements if you wish. This is the main advantage of the deflection tube over the fine beam tube. Most of the qualitative ideas of this experiment can be shown using the experiment <u>Deflecting an electron beam</u>. Apparatus and materials Power supply, EHT, 1 (or 2 if a second one is available) Power supply, 6.3 V, AC, for the heater filament (this is often included on the HT supply) Magnadur magnets, 2 (optional) Electron deflection tube and stand Health & Safety and Technical notes The tubes are fragile (and expensive!) and should be handled carefully. They will implode if broken. Use the stands specifically designed for holding them. <u>Read our standard health & safety guidance</u> Set the tube up according to the manufacturer's instructions. Ensure that you can identify the following: The 6.3 V supply to the cathode heater, if you connect the wrong voltage to the heater you can easily damage the tube beyond repair. The EHT supply for the anode. Set this to zero. The cathode is often one of the heater terminals. The terminals for the deflecting plates. Procedure a Set up the deflection tube in its special stand. b Connect the 6.3 V supply to the filament. Make sure you connect the 6.3 V supply to the filament. (See technical note 2 above.)	

c Start with the deflection plates connected together and also connected to the anode on the tube. d Connect the negative terminal of the EHT supply to the filament and the positive terminal to the anode. e Set the EHT to zero volts, and switch on the 6.3 V supply to the heater filament. f With no output from the EHT supply, the light from the filament produces a line on the inclined fluorescent screen where the light strikes it. g Increase the potential difference (p.d.) to about 3 kV: a fluorescent line appears. This is the path of the electron beam. Point out that the electron beam travels in a straight horizontal line. h Then, while one plate is left connected to the anode, connect the other plate to the negative terminal of the EHT supply. This produces a vertical electric field between the plates, deflecting the beam into a parabolic path. i If you have not shown an electron beam being deflected by magnets, you could do it here. (See <u>Deflecting an electron beam.</u>)	

1 This experiment is best demonstrated to the students in groups of four to five in a darkened room if full value is to be obtained.

2 Always reduce the anode to zero volts when not actually observing the beam, because the tube has a finite life time

3 The beam is deflected, which shows there is a force on it. The force is consistent with the beam being made of negatively charged particles.

4 The beam is deflected by a finite amount. So it must be made of something with mass. This seems obvious now, but, it is an important piece of deduction. We can deduce that the beam is made of particles with some mass and a negative charge.

5 The beam stays intact as it is deflected. At first glance, this suggests that all the particles are the same. However, the mathematics shows that the shape of the curve is independent of the charge and mass of the particles. This is because, if the charge

increases, the acceleration will increase in both the electron gun and between the deflection plates.

Likewise, any changes in mass will produce the same proportional change in acceleration in both the electron gun and the deflecting field (see Guidance note Deflection in electric fields).

6 The beam travels at a uniform horizontal velocity and so the horizontal displacement varies linearly with time. It also experiences a constant vertical force, so it has a constant vertical acceleration, a . The vertical displacement, s_v , varies as the square of time, t . ($s_v = 0.5at^2$). Hence the path of the beam is a parabola (see Guidance note Deflection in electric fields).

7 The fluorescent screen has a graticule on it, and the shape of the parabolic path for different accelerating voltages can be recorded.

8 This is analogous to a ballistic experiment in a uniform gravitational field. Whenever you throw something on the surface of the Earth, it traces out a parabola because the vertical *acceleration* is constant and the horizontal *velocity* is constant.

4.3.10.3 Self-Assessment

- a) Explain Energy conservation theorem
- b) Describe Poyntings' Theorem
- c) Perform calculations on fluid flow calculations
- d) Describe electromagnetic radiation
- e) The most complete and accurate description comes from *partial differential equations* (PDEs). TRUE OR FALSE?
- f) An electromagnetic wave is characterized by its intensity and the frequency ν of the time variation of the electric and magnetic fields. TRUE OR FALSE?
- g) Photons are packets of energy $h\nu$ that always move with the universal speed of light. TRUE OR FALSE?

4.3.10.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.10.5 References

1. J. C. T. Adolf, Engineering Electromagnetic Fields and Waves, New York: John Wiley and Sons, Inc., 1975.

4.3.12. Learning Outcome No. 11. Apply Transients in Electrical Circuit Analysis

4.3.12.1. Learning Activities

Learning Outcome #No. 11. Apply Transients In Electrical Circuit Analysis	
Learning Activities	Special Instructions
Apply Transients in Electrical Circuit Analysis	

4.3.12.2. Information Sheet No. 4/ LO11

Meaning of Growth and decay in R-L & R-C circuits

(A) Growth of current

- Suppose in the beginning we close the switch in the up position as shown in below in the figure

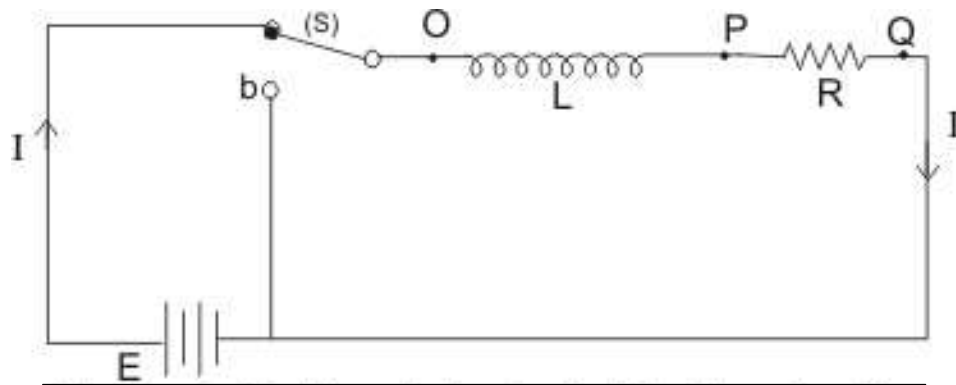


Figure 45: Growth and decay in R-L and R -C circuits

Switch is now closed and battery E , inductance L and resistance R are now connected in series

- Because of self-induced emf current will not immediately reach its steady value but grows at a rate depending on inductance and resistance of the circuit
- Let at any instant I be the current in the circuit increasing from 0 to a maximum value at a rate of increase dI/dt
- Now the potential difference across the inductor is

$$V_{op} = L \frac{dI}{dt}$$

and across resistor is

$$V_{pq} = IR$$

Since

$$V = V_{op} + V_{pq}$$

so we have,

$$V = L \frac{dI}{dt} + IR \quad \text{---(6)}$$

Thus rate of increase of current would be,

$$\frac{dI}{dt} = \frac{V - IR}{L} \quad \text{---(7)}$$

- In the beginning at $t=0$ when circuit is first closed current begins to grow at a rate,

$$\left(\frac{dI}{dt}\right)_{t=0} = \frac{V}{L}$$

from the above relation we conclude that greater would be the inductance of the inductor, more slowly the current starts to increase.

- When the current reaches its steady state value I , the rate of increase of current becomes zero then from equation (7) we have,

$$0 = (V - IR)/L$$

or,

$$I = V/R$$

From this we conclude that final steady state current in the circuit does not depend on self-inductance rather it is same as it would be if only resistance is connected to the source

- Now we will obtain the relation of current as a function of time Again consider equation (6) and rearrange it so that

$$\frac{dI}{\left(\frac{V}{R}\right) - I} = \frac{R}{L} dt$$

let $V/R = I_{\max}$, the maximum current in the circuit .so we have

$$\frac{dI}{I_{\max} - I} = \frac{R}{L} dt \quad \text{---(8)}$$

- Integrating equation (8) on both sides we have

$$-\ln(I_{\max} - I) = \frac{R}{L} t + C \quad \text{---(9)}$$

where C is a constant and is evaluated by the value for current at $t=0$ which is $i=0$

so,

$$C = -\ln(V/R) = -\ln I_{\max}$$

putting this value of C in equation (9) we get,

$$\ln\left(\frac{I_{\max} - I}{I_{\max}}\right) = -\frac{R}{L} t$$

Or,

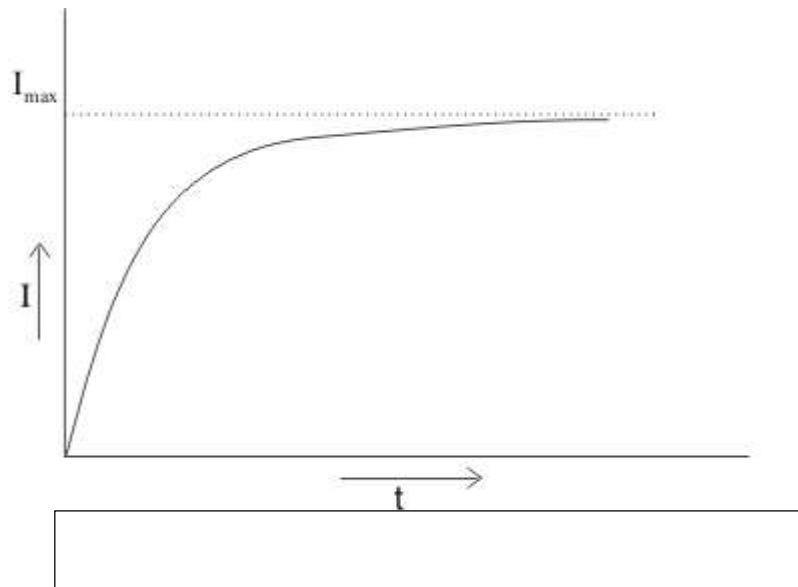
$$\frac{I_{\max} - I}{I_{\max}} = e^{-\frac{R}{L} t}$$

Or,

$$I = I_{\max} (1 - e^{-\frac{R}{L} t}) \quad \text{---(10)}$$

This equation shows the exponential increase of current in the circuit with the passage of time

Figure below shows the plot of current versus time



- If we put $t = \tau_L = L/R$ in equation 10 then,

$$I = I_{\max} \left(1 - \frac{1}{e}\right) = .63 I_{\max}$$

Hence, the time in which the current in the circuit increases from zero to 63% of the maximum value of $I_{\max}$ is called the constant or the decay constant of the circuit.

- For LR circuit, decay constant is,
 $\tau_L = L/R$ ---(11)
- Again from equation (8),

$$\frac{dI}{dt} = \frac{R}{L} (I_{\max} - I_0) = \frac{I_{\max} - I_0}{\tau_L}$$

Or,

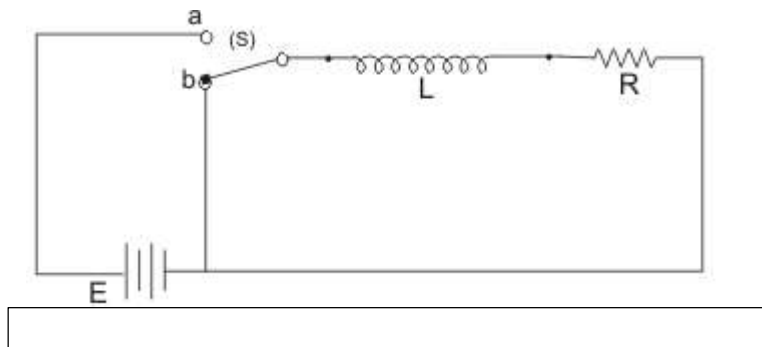
$$\frac{dI}{dt} \propto \frac{1}{\tau_L}$$

This suggests that rate of change current per sec depends on time constant.

- Higher is the value of decay constant, lower will be the rate of change of current and vice versa.

(B) Decay of current

- When the switch S is thrown down to b as shown below in the figure ,the L-R circuit is again closed and battery is cut off



- In this condition the current in the circuit begins to decay
- Again from equation (8) since $V=0$ this time, so the equation for decay is

$$L \frac{dI}{dt} + RI = 0$$

Or,

$$\frac{dI}{I} = -\frac{R}{L} dt$$

Integrating on both sides

$$\int \frac{dI}{I} = -\frac{R}{L} \int dt$$

Or,

$$\ln I = -\frac{R}{L} t + C_1 \quad \text{---(12)}$$

In this case initially at time $t=0$ current $I=I_{\max}$ so

$$C_1 = \ln I_0$$

Putting this value of C_1 in equation (12)

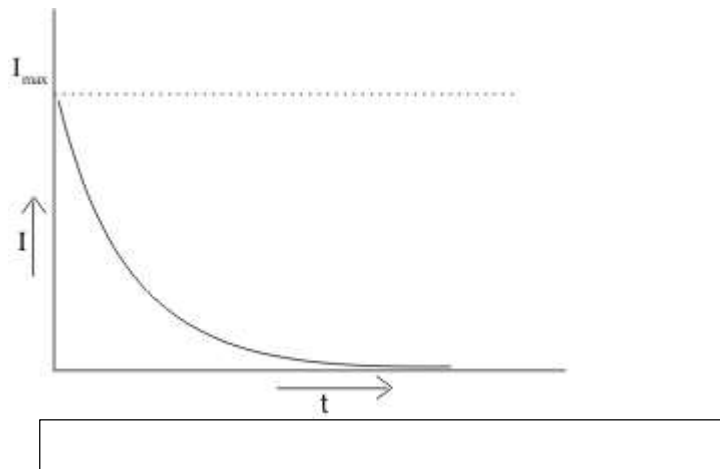
$$\ln I = -\frac{R}{L} t + \ln I_{\max}$$

Or,

$$I = I_{\max} e^{-\frac{R}{L} t} \quad \text{---(13)}$$

Hence current decreases exponentially with time in the circuit in accordance with the above equation after the battery are cutoff from the circuit.

Figure below shows the graph between current and time



- If in equation (13)
 $t = \tau_L = L/R$
then
 $I = I_{\max} e^{-1} = .37 I_{\max}$
hence the time in which the current decrease from the maximum value to 37% of the maximum value $I_{\max}$ is called the time constant of the circuit
- From equation (13) it is clear that when R is large ,current in the L-R circuit will decrease rapidly and there is a chance of production of spark
- To avoid this situation L is kept large enough to make L/R large so that current can decrease slowly
- For large time constant the decay is slow and for small time constant the decay is fast

Application of Growth and decay in R-L & R-C Circuits

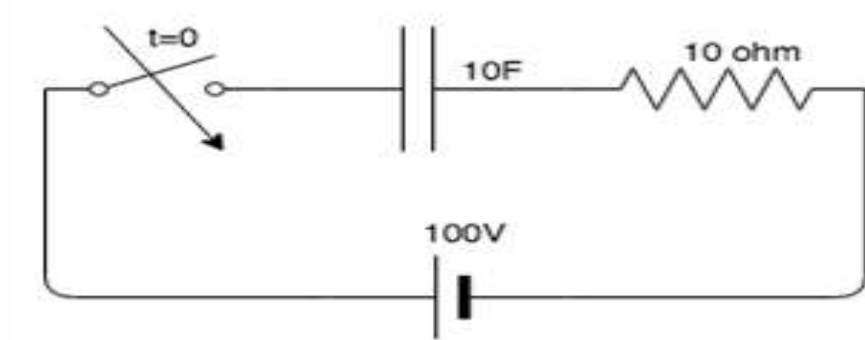
- Series Inductor Resistor
- Oscillator
- Capacitors

4.3.12.3. Self-Assessment

- Differentiate R-L & R-C circuits
- Perform calculations on R-L & R-C circuits
- Describe growth of current in R-L & R-C circuits
- the time in which the current in the circuit increases from zero to 63% of the maximum value of $I_{\max}$ is called the constant or the decay constant of the circuit. TRUE OR FALSE?
- Higher is the value of decay constant, lower will be the rate of change of current and vice versa. TRUE OR FALSE?
- Describe decay current in R-L & R-C circuits

g) What are the applications of Growth and decay in R-L & R-C Circuits?

If the switch is closed at $t=0$, what is the current in the circuit?



4.3.12.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.12.5. References

1. James W. Nilsson, Susan Riedel, Electric Circuits, New Jersey: Prentice Hall Press, 2010.

4.3.13. Learning Outcome No. 12. Use two port networks

4.3.13.1 Learning Activities

Learning Outcome No. 12. Use two port networks	
Learning Activities	Special Instructions
Apply Transients in Electrical Circuit Analysis	

4.3.13.2. Information Sheet No. 4/ LO12

Meaning of passive networks

A passive network is a type of computer network in which each node works on a predefined function or process.

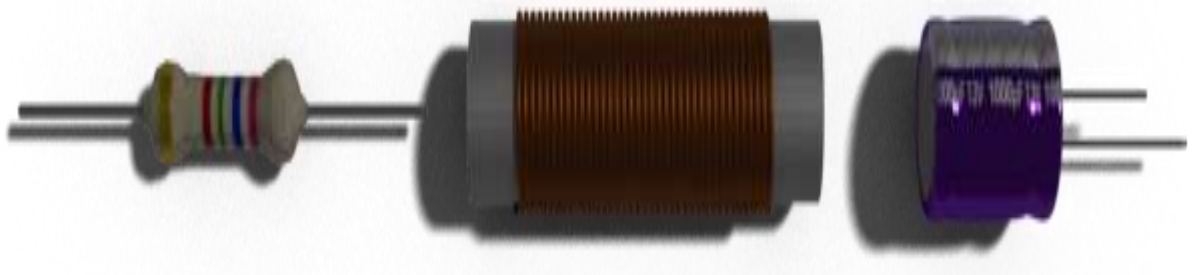
Passive networks don't execute any specialized code or instruction at any node and don't change their behavior dynamically.

Typically, this behavior is related to each network router node

- Types of Passive network

Resistors

A resistor is taken as a passive element since it cannot deliver any energy to a circuit.



Inductors

An inductor is also considered as passive element of circuit, because it can store energy in it as a magnetic field, and can deliver that energy to the circuit, but not in continuous basis.

Capacitors

A capacitor is considered as a passive element because it can store energy in it as electric field.

Transformers

A transformer is also a passive electronic component. Although this can seem surprising since transformers are often used to raise voltage levels – remember that power is kept constant.

Characteristic impedance in T & pie networks

Transforming from Pi to T and vice versa

Any pi network can be transformed to an equivalent T network. This is also known as the Wye-Delta transformation, which is the terminology used in power distribution and electrical engineering. The pi is equivalent to the Delta and the T is equivalent to the Wye (or Star) form.

The impedances of the pi network (Z_a , Z_b , and Z_c) can be found from the impedances of the T network with the following equations:

$$Z_a = ((Z_1 * Z_2) + (Z_1 * Z_3) + (Z_2 * Z_3)) / Z_2$$

$$Z_b = ((Z_1 * Z_2) + (Z_1 * Z_3) + (Z_2 * Z_3)) / Z_1$$

$$Z_c = ((Z_1 * Z_2) + (Z_1 * Z_3) + (Z_2 * Z_3)) / Z_3$$

Note the common numerator in all these expressions which can prove useful in reducing the amount of computation necessary.

The impedances of the T network (Z_1 , Z_2 , Z_3) can be found from the impedances of the equivalent pi network with the following equations:

$$Z_1 = (Z_a * Z_c) / (Z_a + Z_b + Z_c)$$

$$Z_2 = (Z_b * Z_c) / (Z_a + Z_b + Z_c)$$

$$Z_3 = (Z_a * Z_b) / (Z_a + Z_b + Z_c)$$

Note the common denominator in these expressions.

In the case where all the impedances are reactive (i.e. they are all in the form jX), it is handy to note that the -1 factors from squaring $j*j$ on the top cancels the -1 from bringing the j in the denominator up top.

Synthesis of pi and T networks to transform resistances and create phase shifts

Assuming that the desired port impedances are purely resistive (i.e. real), you can design a T or pi network with purely reactive components both to produce a desired phase shift (beta) and transform the impedances with the following equations. Note that beta can be any value, except for zero or pi.

$$Z_1 = -j * (R_1 * \cos(\beta) - \sqrt{R_1 * R_2}) / \sin(\beta)$$

$$Z_2 = -j * (R_2 * \cos(\beta) - \sqrt{R_1 * R_2}) / \sin(\beta)$$

$$Z_3 = -j * \sqrt{R_1 * R_2} / \sin(\beta)$$

$$Z_a = j * R_1 * R_2 * \sin(\beta) / (R_2 * \cos(\beta) - \sqrt{R_1 * R_2})$$

$$Z_b = j * R_1 * R_2 * \sin(\beta) / (R_1 * \cos(\beta) - \sqrt{R_1 * R_2})$$

$$Z_c = j * \sqrt{R_1 * R_2} * \sin(\beta)$$

Beta is the phase lag passing through the network from either port 1 to port 2 or vice versa. Note that if beta is 0 or pi, these expressions break down, except if $R_1=R_2$. If you need to transform resistive impedances and you don't want any phase shift, you have to use a transformer.

In many practical applications, the load or generator impedances may be reactive (i.e. Z (port 1) and Z (port 2) are some general $R+jX$). This can be accommodated by absorbing the external reactive impedance into the network, reducing or increasing the series or shunt impedance as required. For instance, if a T network is required to connect between two impedances: $50+j0$ and $100-j20$ with 45 degrees of phase shift:

First, calculate the Z 's assuming resistive impedances: $R_1=50$, $R_2= 100$

$$Z1 = -j * (50 * .707 - \sqrt{50*100})/.707 = +j 50 \text{ ohms}$$

$$Z2 = -j * (100 * .707 - \sqrt{50*100})/.707 = 0 \text{ ohms}$$

$$Z3 = -j * \sqrt{50 * 100} / .707 = -j 100 \text{ ohms}$$

(the example is somewhat contrived, and it winds up creating an L network for the resistive case).

Now, a reactive component is added to Z2 to exactly cancel the external reactive component. This changes Z2 from 0 ohms to +j20 ohms. The final network is then:

$$Z1 = +j50, Z2 = +j20, Z3 = -j100 \text{ ohms}$$

If you are working with a pi network, you would want to transform the external impedances into their corresponding shunt forms first, so that the reactive component is a shunt value, which would be absorbed (or combined) with the corresponding shunt component of the pi network.

Cascade ABCD two-port networks

Telephone subscriber lines have become a topic of intense interest for organizations attempting to transmit Internet signals on telephone lines. Basic loop standards exist, and tables of twisted-pair primary constants extending to 20 MHz are in the literature. Asymmetric digital-subscriber lines (ADSLs) are now available for high-speed Internet service. The telephone industry has always used two-port networks in the form of ABCD matrices to cascade sections of telephone cable. These configurations allow you to join the sections by matrix multiplication. However, because the elements in the matrices are complex numbers and several sections make up a chain, you need to organize the process of matrix multiplication. A short computer program performs this task (Listing 1). You enter the number of matrices in the chain and then enter the real and imaginary parts for each A, B, C, and D element. The product then appears on the screen.

A represents the open-circuit transfer function, B represents the short-circuit transfer impedance, C represents the open-circuit transfer admittance, and D represents the short-circuit current ratio. You can find the ABCD matrix for a ladder network composed of RLC elements by slicing the network into series and shunt matrices. You then multiply the product of the first two by the third, and the progression continues with additional subscripts identifying the components. In the final product, the elements A, B, C, and D—with all their component symbols—may become quite cumbersome. To avoid these complicated expressions in the matrix for the ladder network, don't use them. Rather, enter the numerical values for the series and shunt components along with the necessary 0,0s and 1,0s. You can use this concept for any network comprising passive components that you can separate into isolated two-port sections. You can also use the method to predict the degradation a bridged tap produces in a telephone cable.

The progression of entering values for cascaded networks is normally from left to right, or from source to load with the current pointing toward the load. If you reverse the progression, the direction of the current is usually reversed, and the location of elements

A and D is reversed to conform to the reciprocity theorem. The matrices for a single series component and a single shunt component are as follows:

You can use these simple matrices to represent RLC components, transformers, and bridged taps in telephone cables. However, for a telephone cable, you must consider the reflected wave. Thus, you must express the A, B, C, D elements by the following hyperbolic functions:

Where the propagation constant, γ , d is the electrical length of the cable, and Z_0 is the characteristic impedance. In the United States, the nominal value for Z_0 is 100 Ω , which is also the specified value for the source and load impedance. Because γ is a complex number, A, B, C, and D are also complex numbers, or the polar equivalent thereof. These numbers are not difficult to calculate; however, the parameters depend on the application (References 1 and 2). The following example shows how to enter the data and read the results:

Within the solid bars, N1 through N4 show the entered data for the components. The bottom line shows the matrix product as it appears on the screen. For this network, the matrix elements are $A=43+j0$, $B=0-j25$, $C=0+j12$, and $D=7+j0$. The open-circuit voltage ratio is $V_1/V_2=A=43$. The open-circuit transfer admittance $I_1/V_2=C=0+j12$. The input impedance is $Z_N=A/C=0-j(43/12)$. Listing 1 uses easy-to-read and-compile QuickBasic. (DI #2455)

4.3.13.3. Self-Assessment

- Describe passive networks
- Explain the operation of various types of passive network
- Explain characteristic impedance in T & pie networks
- Passive networks don't execute any specialized code or instruction at any node and don't change their behavior dynamically. TRUE OR FALSE?
- Asymmetric digital-subscriber lines (ADSLs) are now available for high-speed Internet service. TRUE OR FALSE?
- Describe Cascade ABCD two-port networks
- Perform calculations on passive networks
- What are the applications of passive networks?

4.3.13.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop

4.3.13.5. References

- James W. Nilsson, Susan Riedel, Electric Circuits, New Jersey: Prentice Hall Press, 2010.

4.3.14. Learning Outcome No. 13. Demonstrate understanding of refrigeration and air conditioning

4.3.14.1. Learning Activities

Learning Outcome No. 13. Demonstrate understanding of refrigeration	
Learning Activities	Special Instructions
• Demonstrate understanding the operation principle of a refrigerator and an air conditioner • Demonstrate understanding of the differences between refrigerator and an air conditioner	

4.3.14.2 Information Sheet No. 4/L013

Meaning of Refrigeration and Air Conditioning

Key differences in the design and operation.

Supply

A major difference between refrigeration and air conditioning is the point of supply for the gases. Refrigeration systems have gas installed in a series of tubes. Air conditioning systems use built-in chemicals, but also air from the room or rooms being heated.

Circulation

Air conditioners have circulation systems designed to project cool air away from the units while refrigeration units have circulation systems designed to retain coolant in a confined space. Air conditioners, while also employing tubes in the coolant system, have fans for the dispersal of air. Unlike refrigeration systems, which keep gases contained to a pre-determined space, air conditioning systems disperse cool air throughout areas of unknown volume.

Vaporization

Both air conditioning and refrigeration units depend on converting liquid to gas in the cooling process, but the manner in which they achieve this is different for each system. Air conditioners use something called an evaporator to convert a liquid to a gas. Vaporization is the process of converting a liquid to a gas and can be accomplished one of two ways: boiling or evaporation. Thus air conditioning units vaporize liquid through evaporation while refrigeration systems do so through boiling

Operation of Refrigeration and Air conditioning

Refrigeration system

The refrigeration system must have 4 parts. A condenser, an evaporator, compressor and an expansion device. Starting with the compressor, refrigerant gas is compressed to a higher pressure. After passing through the compressor, it passes to the condenser. The high pressure gas transfers its heat to the surrounding air and condenses. It then passes through the expansion device, which is a restriction separating the high side from the low side. After passing through the expansion device, the pressure is reduced because the compressor is removing gas from the end of the evaporator. This lowers the boiling temperature of the refrigerant. The lower temperature absorbs heat from the air passing over the evaporator and boils the liquid to a gas. The gas then passes into the compressor and the cycle repeats.

Air conditioners

Air conditioners use refrigeration to chill indoor air, taking advantage of a remarkable physical law: When a liquid converts to a gas (in a process called phase conversion), it absorbs heat. Air conditioners exploit this feature of phase conversion by forcing special chemical compounds to evaporate and condense over and over again in a closed system of coils.

The compounds involved are refrigerants that have properties enabling them to change at relatively low temperatures. Air conditioners also contain fans that move warm interior air over these cold, refrigerant-filled coils. In fact, central air conditioners have a whole system of ducts designed to funnel air to and from these serpentine, air-chilling coils.

When hot air flows over the cold, low-pressure evaporator coils, the refrigerant inside absorbs heat as it changes from a liquid to a gaseous state. To keep cooling efficiently, the air conditioner has to convert the refrigerant gas back to a liquid again. To do that, a compressor puts the gas under high pressure, a process that creates unwanted heat. All the extra heat created by compressing the gas is then evacuated to the outdoors with the help of a second set of coils called condenser coils, and a second fan. As the gas cools, it changes back to a liquid, and the process starts all over again. Think of it as an endless, elegant cycle: liquid refrigerant, phase conversion to a gas/ heat absorption, compression and phase transition back to a liquid again.

Plant layout of Refrigeration and Air conditioning system
Air conditioner layout

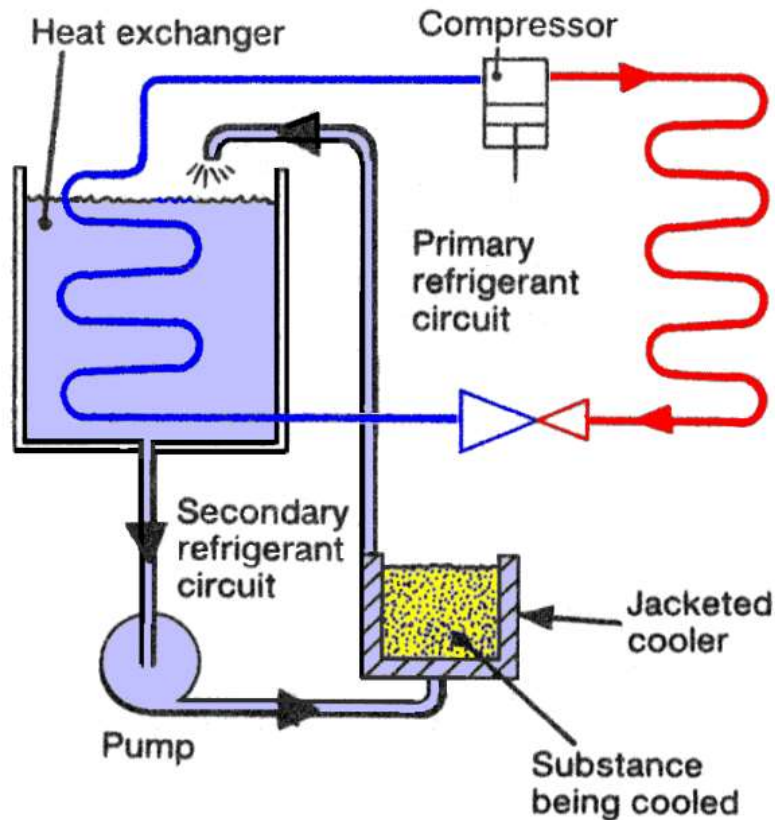


Figure 46: Refrigeration and air conditioning

4.3.15.3 References;

Air Conditioning - Basic Refrigeration Cycle. (n.d.). Retrieved from https://www.swtc.edu/Ag_Power/air_conditioning/lecture/basic_cycle.htm
How Air Conditioners Work. (2011, June 28). Retrieved from <https://home.howstuffworks.com/ac1.htm>

4.3.14.3. Self-Assessment

- Define the terms refrigeration systems, air conditioning and vaporization
- Illustrate various refrigeration plant layouts
- Describe Refrigeration and Air Conditioning
- Differentiate between Refrigeration and Air Conditioning
- Explain operational Principle between a Refrigerator and Air Conditioner
- What is the importance of Refrigeration and Air Conditioning?
- Describe Plant layout of Refrigeration and Air conditioning system

- h) A major difference between refrigeration and air conditioning is the point of supply for the gases. Refrigeration systems have gas installed in a series of tubes. TRUE OR FALSE?
- i) The compounds involved are refrigerants that have properties enabling them to change at relatively low temperatures. TRUE OR FALSE?
- j) Define the terms refrigeration systems, air conditioning and vaporization
- k) Describe Refrigeration and Air Conditioning
- l) Differentiate between Refrigeration and Air Conditioning
- m) Explain operational Principle between a Refrigerator and Air Conditioner
- n) What is the importance of Refrigeration and Air Conditioning?
- o) Describe Plant layout of Refrigeration and Air conditioning system
- p) To keep cooling efficiently, the air conditioner has to convert the refrigerant gas back to.....
 - a) Solid
 - b) Semi solid
 - c) Liquid
 - d) Gas
- q) When hot air flows over the cold, low-pressure....., the refrigerant inside absorbs heat as it changes from a liquid to a gaseous state.
 - a) Condenser coil
 - b) evaporator coils
 - c) heating coils
- r) is the process of converting a liquid to a gas and can be accomplished one of two ways: boiling or evaporation
 - a) Circulation
 - b) Vaporization
 - c) Cooling
- s) A major difference between refrigeration and air conditioning is the point of supply for the gases. Refrigeration systems have gas installed in a series of tubes.
 - a) True
 - b) False
- t) The compounds involved are refrigerants that have properties enabling them to change at relatively low temperatures.
 - a) True
 - b) False

Practical exercise

- a) Demonstrate understanding the operation principle of a refrigerator and an air conditioner
- b) Demonstrate understanding of the differences between refrigerator and an air conditioner
- c) Draw and illustrate various refrigeration plant layouts

4.3.14.2.Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.14.5. References

1. James W. Nilsson, Susan Riedel, Electric Circuits, New Jersey: Prentice Hall Press, 2010.

CHAPTER 5 TECHNICAL DRAWING / PREPARE AND INTERPRET TECHNICAL DRAWING

5.1 Introduction of the Unit of Learning / Unit of Competency

Technical Drawing is the skill of creating a range of plans/ drawings that visually communicate an idea that needs to be constructed or how it functions. Competencies in Technical Drawing are applied in a wide range of areas that include electronics, architecture, manufacturing, engineering, and computer drafting and modelling. This unit covers technical drawing principles, interpretation of technical drawings, drawing equipment and materials, plain geometry, solid geometry, pictorial and orthographic drawings, computer-aided design and drafting, and safe drawing procedures. The essential resources in this course include but not limited to drawing room, computer lab, drawing equipment and materials, computers, CAD package, and a projector. Upon the completion of this course, a trainee should be able to produce a wide range of technical drawings/ designs while following good technical drawing practices. Technical drawing prepares the trainee as a drafting/design technician in the fields of electrical, mechanical and architectural engineering.

5.2 Performance Standard

Drawing equipment and materials are gathered and utilized according to task requirements, waste materials are disposed in accordance with workplace procedures and environmental legislations, drawing lines are used as per standard drawing conventions, different plain geometrical forms are produced according to standard drawing conventions, different solid geometries are produced as per standard drawing conventions, varied pictorial and orthographic drawings are produced according to the standard drawing conventions, and appropriate CAD packages are applied as standard operating procedures.

5.3 Learning Outcomes

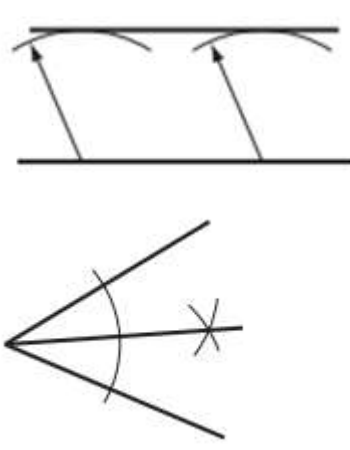
5.3.1. List of Learning Outcomes

- a) Use and maintain drawing equipment and materials
- b) Produce plain geometry drawings
- c) Produce solid geometry drawings
- d) Produce pictorial and orthographic drawings of components
- e) Apply CAD packages

5.3.2 Learning Outcome No.1: Use and maintain drawing equipment and materials

5.3.2.1 Learning Activities

Select equipment and materials in construction of parallel lines, bisecting angles and lettering.

Learning Activity	Special Instructions
Select equipment and materials required draw the illustrated tasks.  Parallel lines ,Bisecting angles  Lettering Learning Activity Select equipment and materials required draw the various tasks.	Provide the trainee with a variety of exercise to build confidence in selecting appropriate drawing equipment and tools.

5.3.2.2 Information Sheet No 2/LO1: Use and maintain drawing equipment and materials

Introduction

This area of competence covers use and care of technical drawing equipment and materials, overview of ISO technical drawing standards, drawing office procedures, environmental legislations and work place procedures regarding disposal of waste, and the use of personal protective equipment.

Definition of key terms

Drawing.

This is the use of lines, shapes, and sizes to construct objects or structures either in 2-dimesnional or 3-dimensional view.

Technical drawing

Technical drawing a precise detailed representation of an idea using symbols, lines, and signs in creating objects in the manufacturing of engineering articles.

Drafting

This is the act of producing a picture/sketch either in 2-dimesnional or 3-dimensional view and providing dimensions and notes. It is usually a quick sketch/ presentation with details and not to scale.

Designing

This is the act of producing drawings to clearly define the requirements for concepts or products in order to be in line with the expected outcome.

Principles of Engineering Drawing

Engineering drawings should be language-independent in order for drafting/ design technician anywhere in the world can specify a product that can be made and assembled in different countries. Thus, technical drawing serves a language of its own in transmitting information from drafter/designer to the manufacturer and the assembler. Technical Drawing is defined by rules that are embodied in the publications of standards organizations e.g. the British Standards Institution (BSI), the American National Standards Institute (ANSI) and in the International Standards Organization (ISO), which the global body giving guidelines superseding individual countries standards.

Recommended resource for further information

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Watch a 4.11min video on technical drawing tools on the link:

<https://youtu.be/k3IhsuJnfh8?t=189>

Content

Identification and care of drawing equipment, identification and care of drawing materials, drawing standards and drawing office procedures, workplace procedures, use and maintenance of drawing equipment and materials, and use of Personal Protective Equipment (PPEs).

Conclusion

This outcome covered drawing instruments and materials, ISO drawing rules, drawing office procedures, and use of PPEs in drawing practices.

Trainees' assignment;

- Select different types of drawing sheets as determined by desired quality of a specific job.
- Select drawing pencils required for different drawing features i.e. used in object drawing, outlines, hidden details, and construction lines.

Trainer

- Check that the completed assignments show evidence of understanding of drawing office procedures and housekeeping procedures. Ensure assignments are completed on time. Observe trainee's work behavior from time to time.

5.3.2.3 Self-Assessment

1. The accuracy of the drawing depends on the quality of the instruments used.
 - a) True
 - b) False
2. Which of the following instrument is made of thin strips of wood arranged in a line to form a rectangle and on which, the drawing is made?
 - a) Mini – drafter
 - b) Drawing Board
 - c) Protractor
 - d) Scale
3. Which of the following tools is used to draw horizontal lines?
 - a) Mini – drafter
 - b) Protractor
 - c) T – square
 - d) French curve
4. Which of the following instrument can be used to draw accurate perpendicular lines, parallel lines and angular lines?
 - a) Mini – drafter
 - b) T – square
 - c) Protractor
 - d) Set square
5. According to the Indian Standard Institute (ISI), which among the following designation has the size 1000 x 700 (in mm)?

- a) B0
 - b) B1
 - c) B2
 - d) B3
6. Which is the most common tool used for drawing circles?
- a) French curve
 - b) Mini – drafter
 - c) Divider
 - d) Compass
7. For drawing circles with a large radius, which of the following tool is used?
- a) Bow compass
 - b) Lengthening bar compass
 - c) Divider
 - d) Protractors
8. The preferred size of the drawing sheets is recommended by the _____
- a) B.I.S.
 - b) ASME
 - c) ASTM
 - d) NIST
9. The untrimmed size for _____ sheet is 240 mm x 330 mm.
- a) A1
 - b) A3
 - c) A4
 - d) A5
10. SP: 46 (2003) recommends the borders of _____ mm width for the sheet sizes A0 and A1, and _____ mm for the sizes A2, A3, A4 and A5.
- a) 10, 20
 - b) 15, 20
 - c) 20, 10
 - d) 15, 10
11. The false statement regarding orientation mark.
- a) The orientation mark coincides with one of the centering marks
 - b) Represents the direction to which sheet is placed
 - c) Orientation mark can be used for the orientation of drawing sheet on the drawing board
 - d) Facilitate positioning of the drawing for reproduction purpose

12. The size of the title block is _____ mm x _____ mm.
a) 25 x 10
b) 100 x 25
c) 65 x 185
d) 185 x 65
13. The number of folding methods for folding of various sizes of drawing sheets is _____
a) 1
b) 2
c) 3
d) 4
14. Which of the following is reducing scale?
a) 10:1
b) 10:2
c) 0.5:1
d) 2:1
15. 8. 1:10000 is enlarging scale.
a) True
b) False
16. _____ is not an essential thing for free-hand sketching.
a) A soft-grade pencil
b) French curves
c) A soft rubber-eraser
d) A paper in form of a sketch-book or a pad
17. Which statement is false?
a) Drawing for instruction manual: This is assembly drawing without dimensions. This is also used for explaining the working principle of each part
b) Exploded assembly drawing: This type of assembly drawing is used for explaining the working principle of any machine
c) Drawing for catalogue: Special assembly drawings are prepared for catalogues, with overall and principal dimensions
d) Patent drawing: It is generally assembly drawing either in pictorial form or principal view of orthographic projection of a machine
18. Select and apply different drawing paper holders

5.3.2.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Drawing room
- Computer lab
- Drawing equipment and materials
- CAD packages
- Projector
- Computer

5.3.2.5 References

Heather, S and Shrock, C.R (2019) Begging AUTOCAD Exercise Workbook. Industrial Press, Inc USA

Davies, B. L., Robotham, A. J., & Yarwood, A. (1991). Computer-aided drawing and design. London: Chapman & Hall.

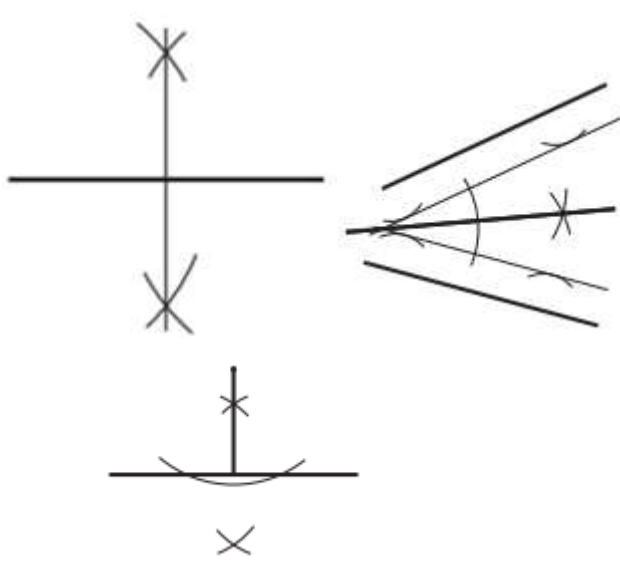
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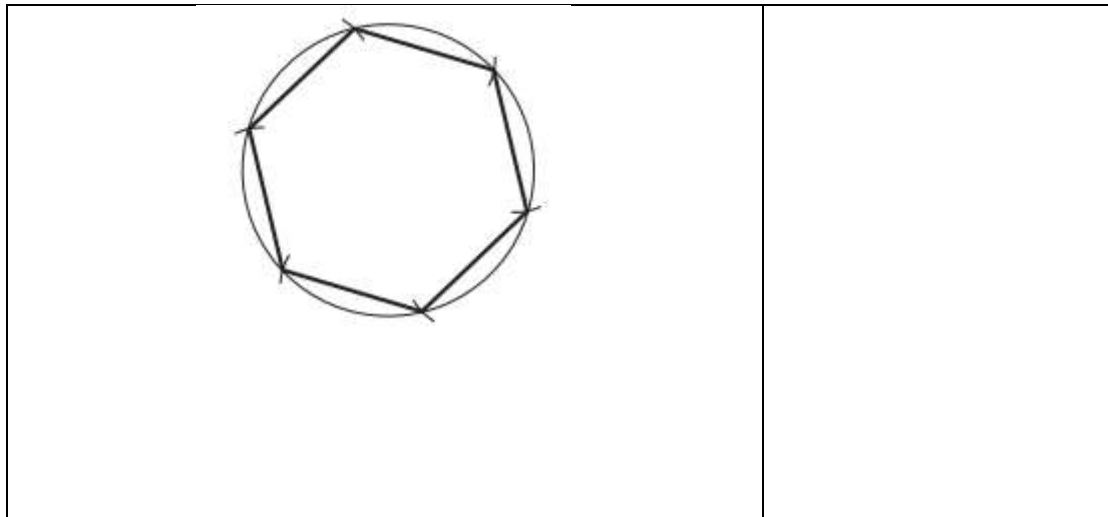
Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Morling, K 92012) Geomtric and Engineering Drawing. Routledge, amazon

5.3.3 Learning Outcome No. 2: Produce plain geometry drawings

5.3.3.1 Learning Activities

Learning Outcome #2: Produce plain geometry drawings	
Learning Activities	Special Instructions
Activity 1: Produce different types of two-dimensional figures i.e. lines, different angles, bisecting angles, and geometric forms - Select appropriate equipment and materials for the specific work - Draw varied lines, different angles, bisect angles, and varied 2-D geometrical forms Activity 2: Measure different angles, lines, and geometric forms - Select appropriate equipment and materials for the specific work Carry out measuring of varied lines, different angles, bisect angles, and varied 2-D geometrical forms Produce different types of two-dimensional figures i.e. lines, different angles, bisecting angles, and geometric forms Measure different angles, lines, and geometric forms. 	Provide feedback and focused instruction to aid trainees to refine their, develop their competencies producing a variety of plain geometries.



5.3.3.2 Information Sheet No.2/LO2: Produce plain geometry drawings

Introduction

This outcome covers a variety of plain geometry drawings that include lines, triangles, quadrilaterals, polygons, dimensioning and drawing rules.

Definition of key terms

Drawing instruments

These are the tools/equipment that are essential in producing drawings

Drawing materials

These are consumables that are utilized in technical drawing.

Plane geometry

This type of geometry involves production of drawings in two dimensions.

Solid geometry

Solid geometry involves production of drawings in three dimensions.

Plane geometry principle

A line projects as a true length when a view is taken looking perpendicular to the line.

A line parallel to the vertical plane will appear as a true length in elevation. A line parallel to the horizontal plane will appear as a true length in plan. Parallel lines appear parallel in every orthographic view. If a line is parallel to any line on a plane, it is parallel to the plane. A line projects as a point when we look along its true length. A plane projects as an edge when any line on the plane projects as a point. The true shape of a plane is seen on a projection plane which is parallel to the plane. Two planes intersect in a line.

Content

Plane geometry: Types of lines, construction of different geometric forms, construction of different angles, measurement of angles, bisection of different angles and lines, polygons, circles, triangles, and drawing symbols and abbreviations.

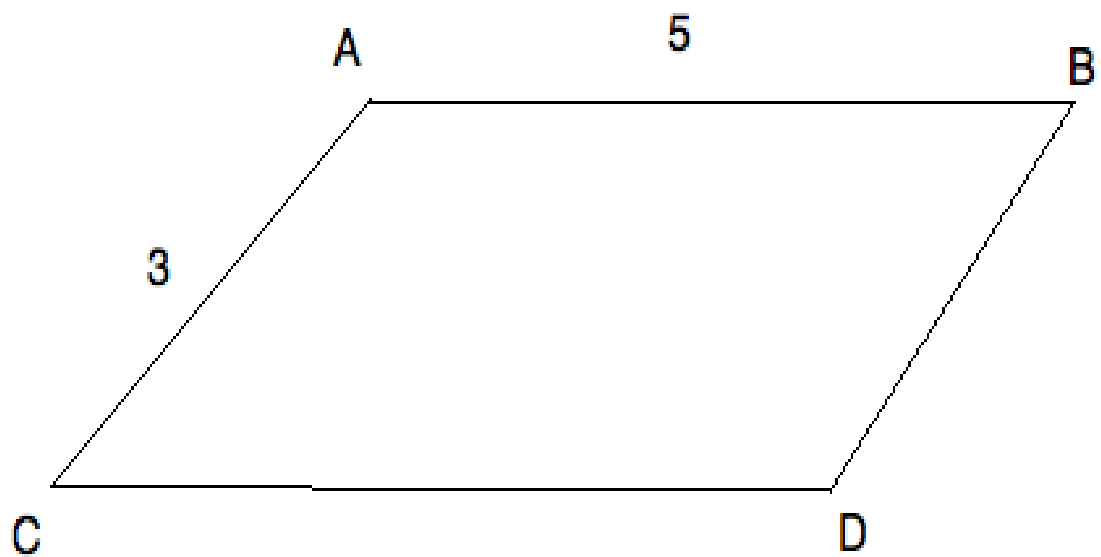


Figure 47: Plane Geometry

Plain geometry can take various shape such as in figure 1 and figure 2

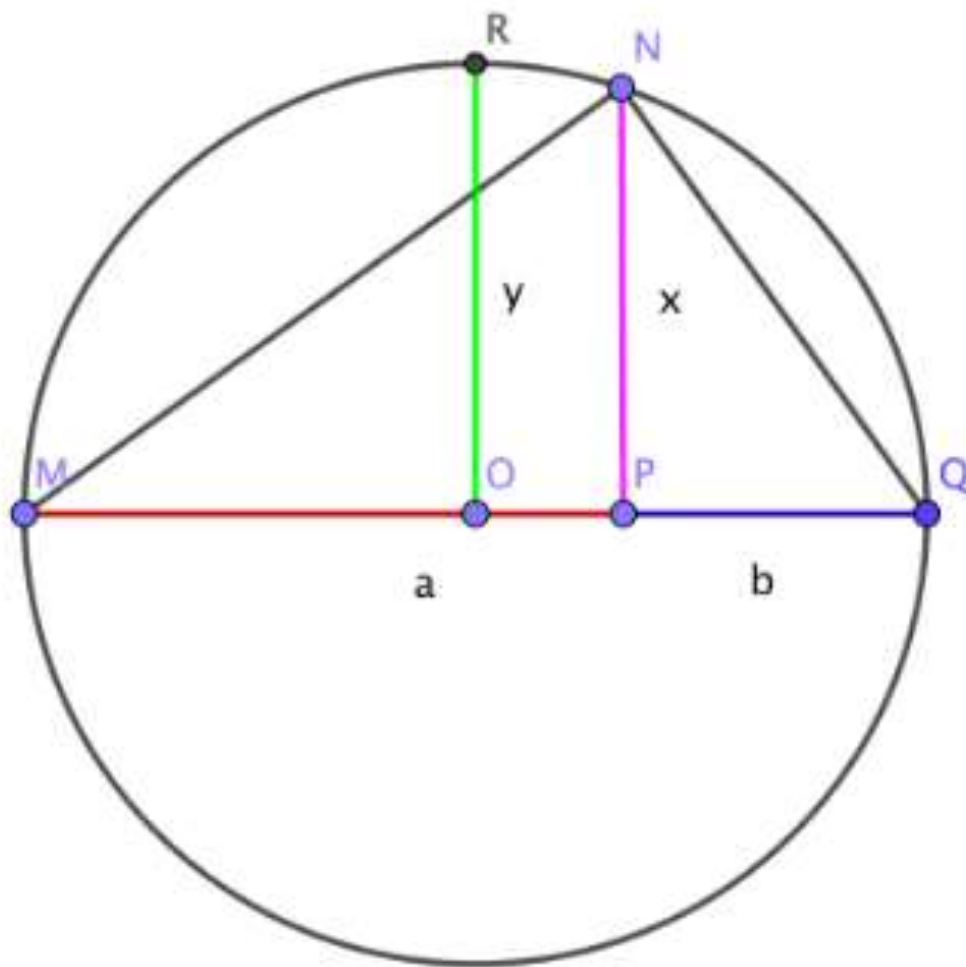


Figure 48: Plane Geometry circle

Conclusion

This outcome covered plane geometries drawings i.e. types of lines, polygons, triangles, quadrilaterals, dimensioning and drawing rules.

.

Trainees' assignment;

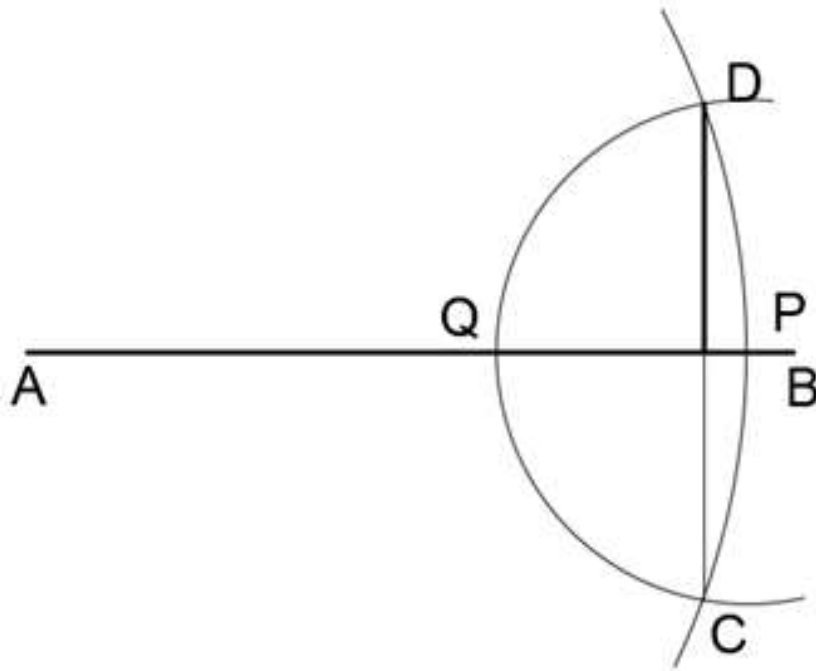
- Construct an equilateral triangle, given one of the sides, $AB = 100$.
- Construct a square given the diagonal
- Construct a triangle given the base, the altitude and the vertical angle (base 100mm and vertical angle 65°)
- Construct a triangle given the perimeter and the ratio of the sides
- Construct a triangle similar to another triangle but with a different perimeter

Trainer

- Check that the completed assignments show evidence of understating a variety of plane geometries, drawing rules and housekeeping procedures. Ensure assignments are completed on time. Observe trainees' work from time to time.

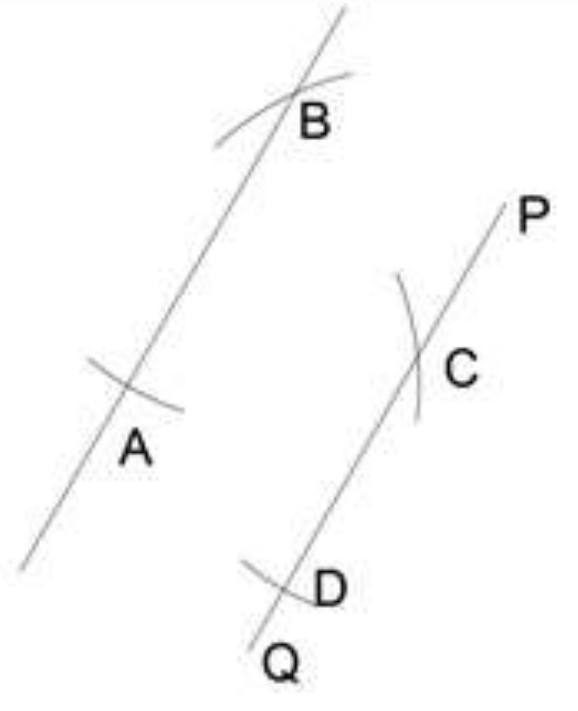
5.3.3.3 Self-Assessment

1. While drawing a perpendicular to a line from a point within the line but nearer to the end of the line, all the arcs drawn in the process are of _____
 - a) Different radii
 - b) Different radii but one
 - c) Same radii but one
 - d) Same radii
2. In the given figure which of the following construction line is drawn first?



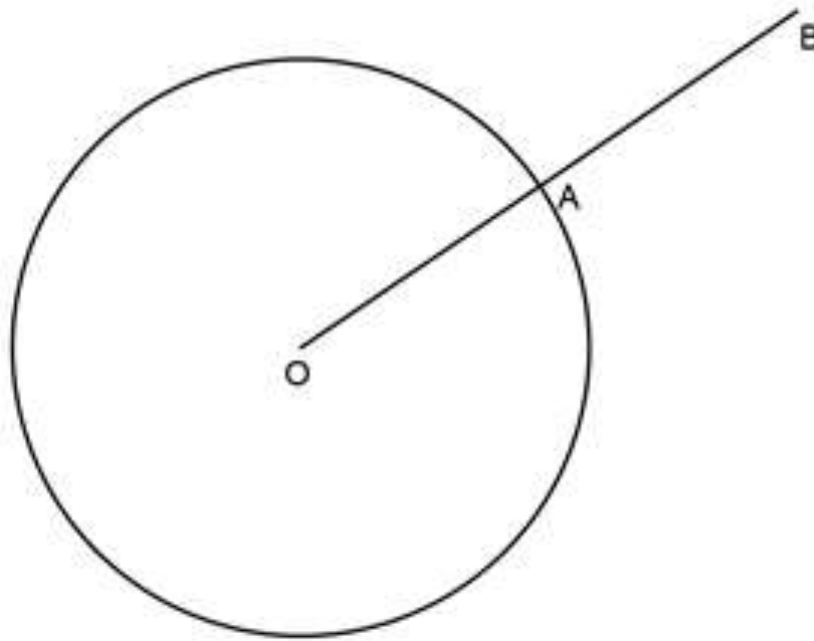
- a) Line AP
 - b) Arc DPC
 - c) Arc DQC
 - d) Line DC
3. For drawing parallel lines to a given line through a given point we make use of _____
 - a) Arcs
 - b) Triangles
 - c) Lines
 - d) Quadrilaterals

4. Which of the following arcs is made first to draw a parallel line to the given line PQ?

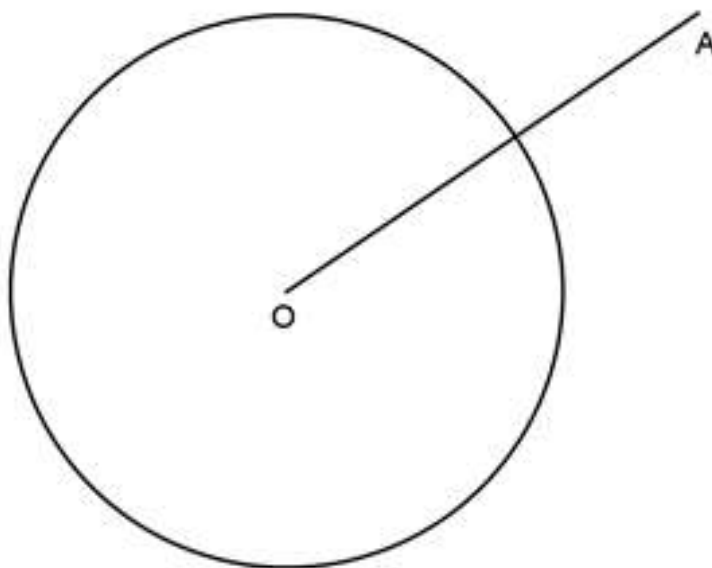


- a) A
 - b) B
 - c) C
 - d) D
5. A tangent to a circle is a line which touches the circle at one and only one point.
- a) True
 - b) False
6. The line perpendicular to a tangent and is passing through the point of contact is called as _____
- a) Perpendicular bisector
 - b) Angle bisector
 - c) Normal
 - d) Tangent

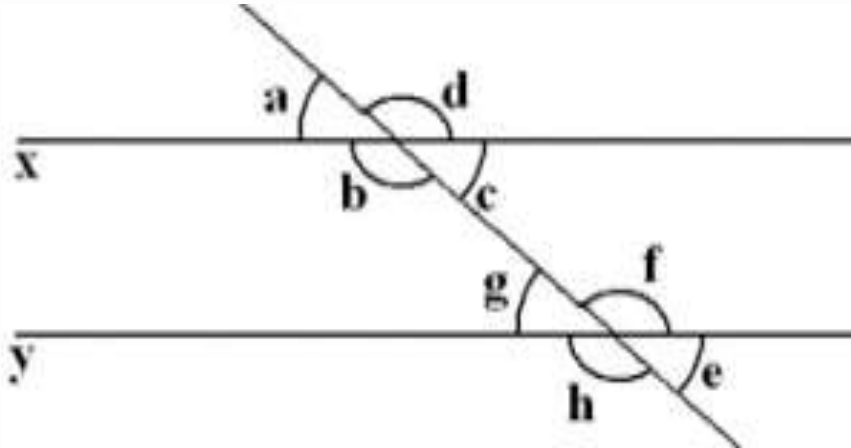
7. In the following figure, the tangent at point A can be drawn by _____



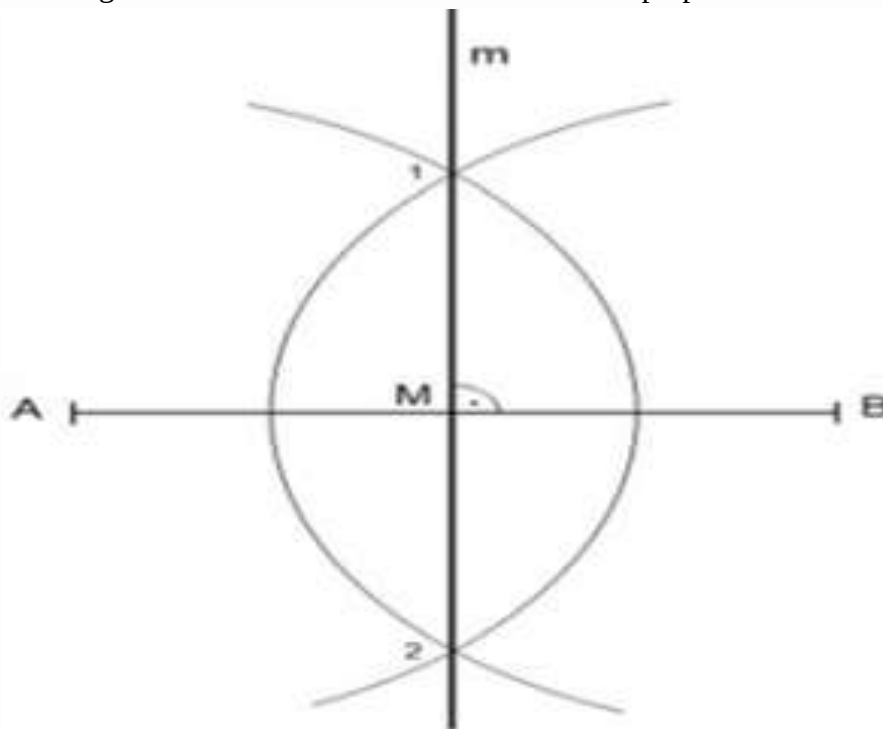
- a) Angle bisector
 - b) Perpendicular bisector
 - c) Rectangle
 - d) Arc
8. How many tangents can be drawn from a point outside a given circle?
- a) 4
 - b) 3
 - c) 2
 - d) 1
9. In the following figure, how will make a tangent from the point outside the circle?



- a) By drawing a semicircle with diameter as OA
 - b) By drawing a perpendicular bisector
 - c) By drawing an angle bisector
 - d) By drawing circle with the same radius from A
10. Which geometric principle is used to justify the construction below?



- 11.
- a) A line perpendicular to one of two parallel lines is perpendicular to the other
 - b) Two lines are perpendicular if they intersect to form congruent adjacent angles
 - c) When two lines are intersected by a transversal and alternate interior angles are congruent, the lines are parallel
 - d) When two lines are intersected by a transversal and the corresponding angles are congruent, the lines are parallel
12. The diagram below shows the construction of the perpendicular bisector of AB.

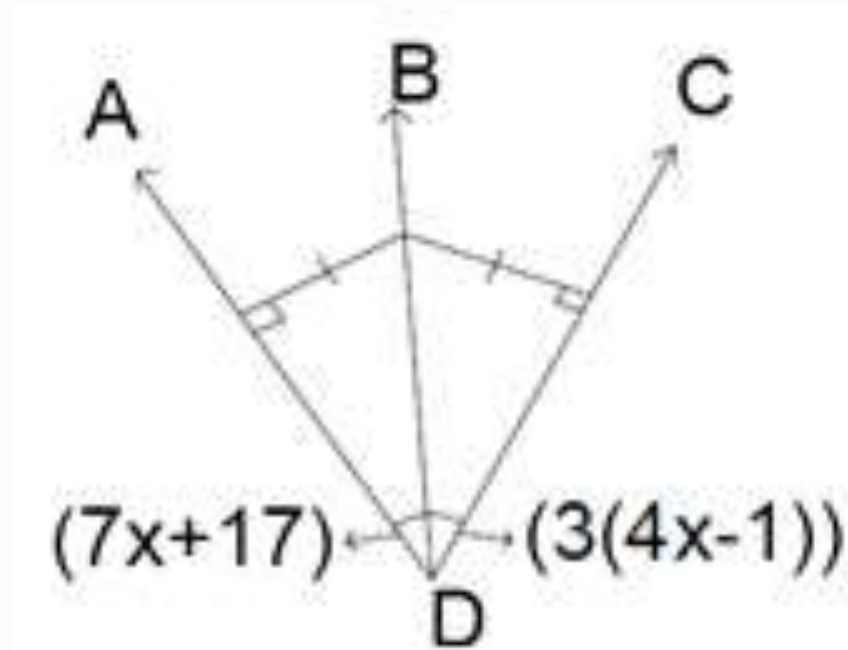


Which statement is not true?

- a) $AM=MB$

- b) $MB = \frac{1}{2}AB$
- c) $AM = 2AB$
- d) $AM + MB = AB$

13. Find angle BDC shown in the figure below.



- a) 30
 - b) 65
 - c) 60
 - d) 45
15. Construct an isosceles triangle given the perimeter and the altitude (perimeter 150mm and altitude 70mm).
16. Construct a rhombus given the diagonal and the length of the sides
17. Construct a trapezium given the lengths of the parallel sides, the perpendicular distance between them and one angle
18. Construct a regular octagon given the diameter, i.e. within a given square

5.3.3.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Drawing room
- Computer lab
- Drawing equipment and materials
- CAD packages
- Projector
- Computer

5.3.3.5 References

Heather, S and Shrock, C.R (2019) Begging AUTOCAD Exercise Workbook. Industrial Press, Inc USA

Davies, B. L., Robotham, A. J., & Yarwood, A. (1991). Computer-aided drawing and design. London: Chapman & Hall.

Hubka, V. (2015). Principles of engineering design. Elsevier.

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Morling, K (2012) Geometric and Engineering Drawing. Routledge, amazon

5.3.4 Learning Outcome No. 3: Produce solid geometry drawings

5.3.4.1 Learning Activities

Learning Outcome #4: Produce solid geometry drawings	
Learning Activities	Special Instruction
• Construct two dissimilar square prisms meeting at right angles. • Construct two dissimilar hexagonal prisms meeting at an angle. • Construct two dissimilar hexagonal prisms meeting at an angle. • Construct two dissimilar hexagonal prisms meeting at an angle.	

5.3.4.2 Information Sheet #3: Produce solid geometry drawings

Introduction

In this outcome, these areas are covered interpretation of sketches and drawings of patterns, surface development of interpenetrating solids and truncated solids, and interpenetration of solids.

Content

Solid geometry: interpretation of sketches and drawings, surface development of prisms, cylinders, truncated prisms, cones, and pyramids. Development of surfaces of interpenetration cylinders and truncated solids, and interpenetration of cylinder to cylinder and cylinder to prism or prism to prism of equal and unequal diameters

First angle projection

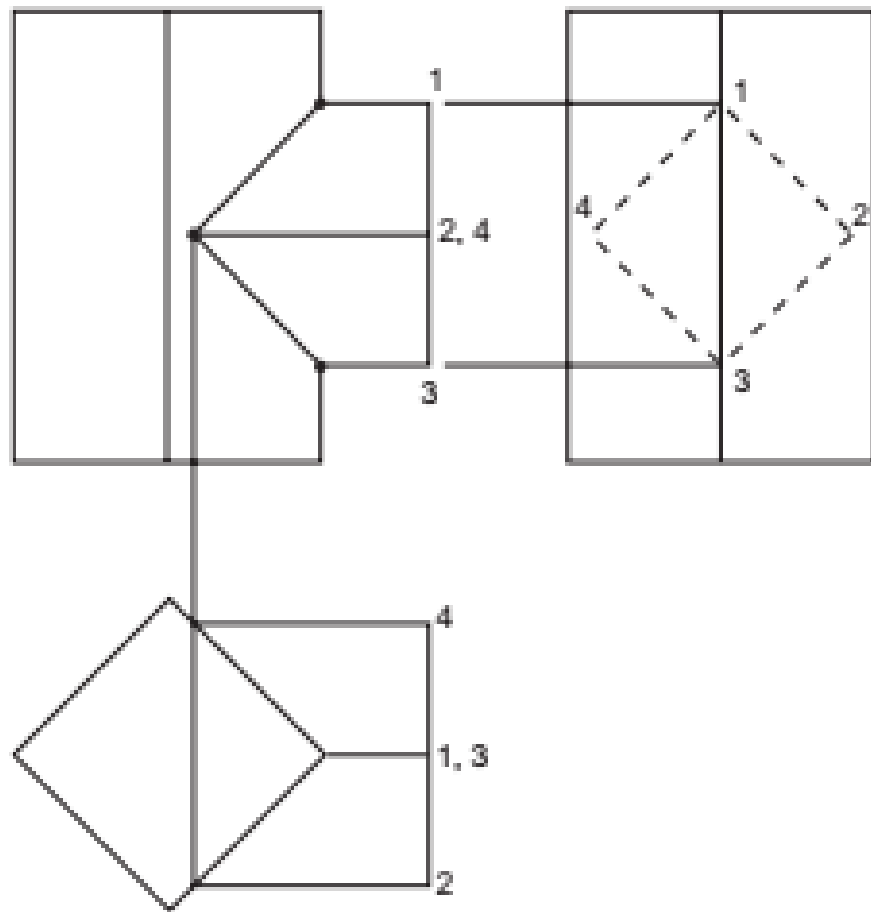


Figure 49: First angle Projection Source: Morling, (2012)

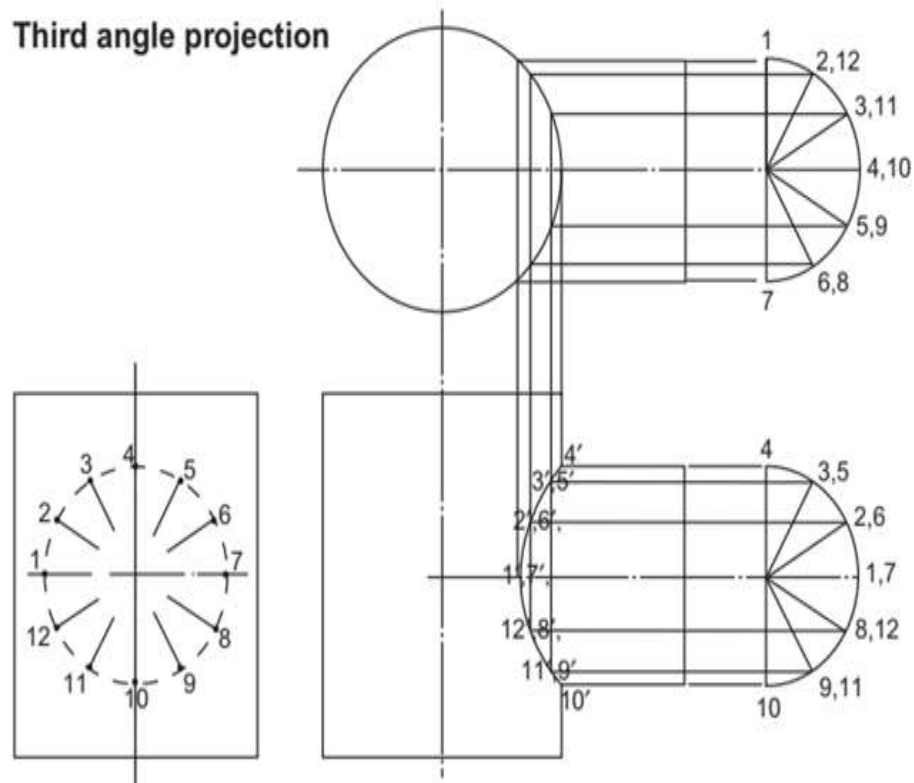


Figure 50: Third and first angle Projection

Watch the video; [htt9UMxr7BT8CEps://www.youtube.com/watch?v=](https://www.youtube.com/watch?v=htt9UMxr7BT8CEps)

Conclusion

This outcome covered interpretation of sketches and drawings, surface development of solids, and interpenetration of surfaces.

Trainees' assignment;

- Construct an equilateral triangle, given one of the sides, $AB = 100$.
- Construct Two dissimilar square prisms meeting at an angle
- Construct a hexagonal prism meeting a square prism at right angles
- Construct a square prism meeting a square pyramid at right angles
- Construct a cylinder meeting a square pyramid at an angle

Trainer

- Check that the completed assignments show evidence of understating a variety of solid geometries, drawing rules and housekeeping procedures. Ensure assignments are completed on time. Observe trainees' work from time to time.

Recommended sources for further information;

Geometric and Engineering drawing Third Edition K Morling.

5.3.4.3 Self-assessment

1. A cylinder is placed on H.P on its base and section plane is parallel to V.P cutting the solid the section gives _____
a) parabola
b) circle
c) rectangle
d) ellipse
2. A cylinder is placed on H.P on its base and section plane is parallel to H.P cutting the solid the section gives _____
a) parabola
b) circle
c) rectangle
d) ellipse
3. A cylinder is placed on H.P on its base and section plane is inclined to V.P and perpendicular to H.P cutting the solid the section gives _____
a) parabola
b) circle
c) rectangle
d) ellipse
4. If a plane is inclined with both the reference plane then the plane come under _____
a) auxiliary plane
b) oblique plane
c) perpendicular plane
d) cross planes
5. If a plane is inclined to both the reference planes then the traces would meet at _____ line except the plane perpendicular to picture plane.
a) XY reference
b) Vertical reference
c) Above the XY reference plane

d) Below the XY reference plane

6. When a surface of the plane is inclined to the H.P and an edge is parallel to the H.P and inclined to V.P. The projections are drawn in 2 stages.
a) True
b) False
7. Draw a radial element (0, 1) in one of the orthographic views. Find the points on the line of interpenetration (ie, p & q) and project them to the other views.
8. Repeat with more radial elements until you have enough points to draw the lines of interpenetration

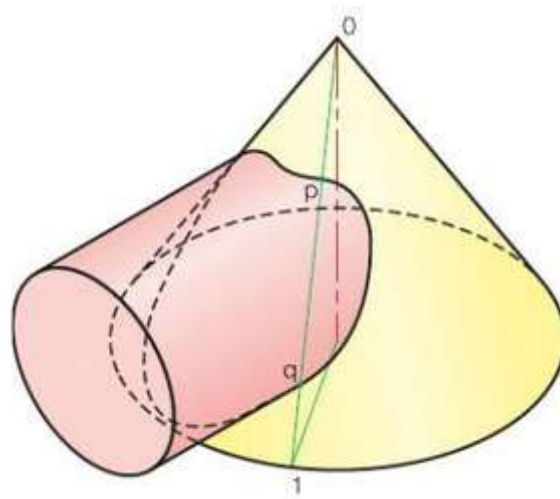


Figure 51: Cylinder intersecting a cone

9. Given pyramid is cut by plane, $\perp$ to the frontal plane and inclined at 70° to the top plane. The cutting plane cuts the axis of the pyramid at 15mm from the apex. Draw the projections of the remaining part of the pyramid and the true shape of the cut section

5.3.4.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

• Drawing room	• CAD packages
• Computer lab	• Projector
• Drawing equipment and materials	• Computer

5.3.4.5 References

Heather, S and Shrock, C.R (2019) Begging AUTOCAD Exercise Workbook. Industrial Press, Inc USA

Davies, B. L., Robotham, A. J., & Yarwood, A. (1991). Computer-aided drawing and design. London: Chapman & Hall.

Hubka, V. (2015). Principles of engineering design. Elsevier.

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Morling, K 92012) Geomtric and Engineering Drawing. Routledge, amazon

5.3.5. Learning Outcome No 4: Produce pictorial and orthographic drawings of components

5.3.5.1. Learning Activities

- Produce orthographic views in first angle and third angle elevations.
- Isometric Projection (Isometric Drawing).
- Produce Circles and Curves Drawn in Isometric Projection.
- Produce components in oblique projection.

Learning Outcome #4: Produce pictorial and orthographic drawings of components	
Learning Activities	Special Instructions
• Produce orthographic views in first angle and third angle elevations	
• Produce isometric projection (isometric) drawing of the above components.	
• Produce Circles and Curves Drawn in Isometric Projection	
• Produce the above component in oblique projection.	

5.3.5.2 Information Sheet #4: Produce pictorial and orthographic drawings of components

Introduction

This outcome covers meaning of pictorial and orthographic drawings and sectioning, symbols and abbreviations, drawing of isometric, oblique, axonometric, auxiliary and perspective views, drawing of first and third angle projections, sectioning of components, and free hand sketching of tools, equipment, components, geometric forms and diagrams.

Definition of key terms

- Orthographic projection
- Oblique projection

Recommended resources

Engineering Drawing with CAD Applications by O.OSTROWSKY

Geometric and Engineering drawing Third Edition K Morling

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Solid geometry principles

All views presented in a solid geometry are assumed to be from the same object, and only the particular object but from different points of view and that all views are at the same scale. All the visible edge are depicted by a line and assumptions are made that those edge progress away from the viewer to form faces that are flat and at right angles. The true angle between a line and a plane is seen in a view showing the line as a true length and the plane as an edge. All horizontal sections of an upright or inverted right cone are circles. A sphere appears as a circle in every view. A sphere and cone in contact will have a common tangent plane. When two spheres touch one another: the point of contact lies on the line joining the two centres, the distance between their centres is equal to the sum of the radii, and the point of contact can be located in any view, by dividing the line in the ratio of the radii. The vertical trace of a plane is the line in which the plane meets the vertical plane. The horizontal trace of a plane is the line in which the plane meets the horizontal plane.

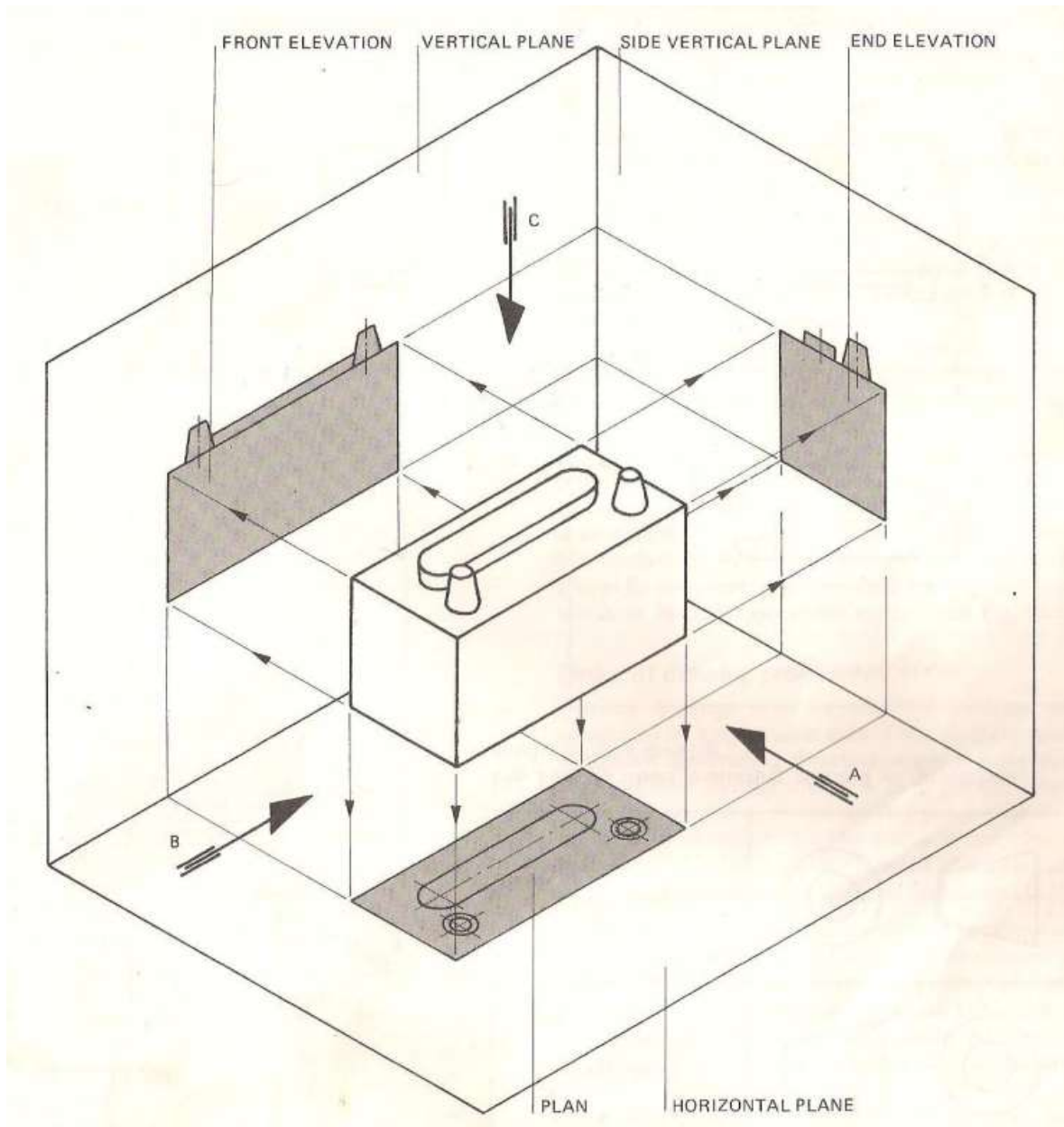


Figure 52: Isometric drawing

Content

Solid geometry: orthographic drawings, oblique projections, pictorial projections, axonometric, auxiliary and perspective views, drawing of first and third angle projections, sectioning of components, and free hand sketching of tools, equipment, components, geometric forms and diagrams.

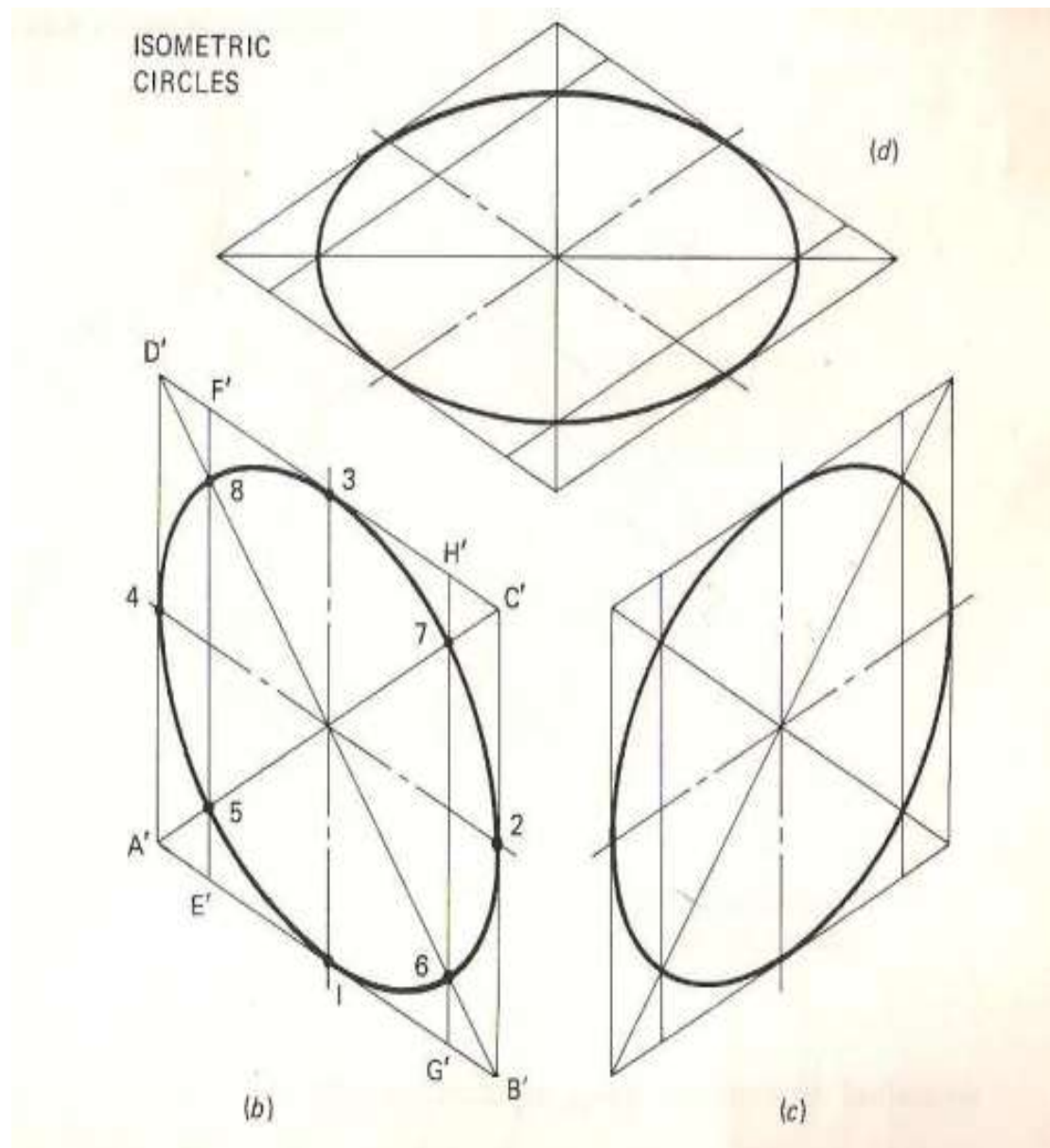


Figure 53: Isometric circles

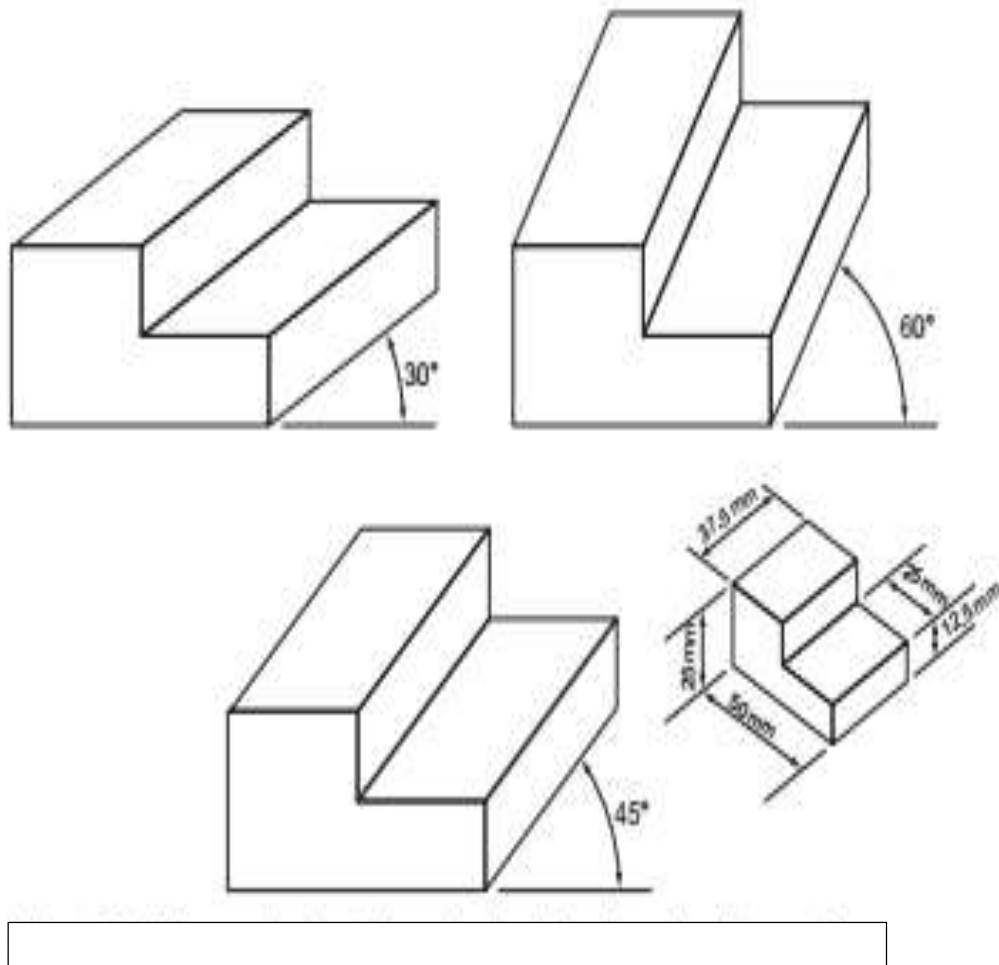


Figure 54: Oblique Projection

Illustrations on dimensioning

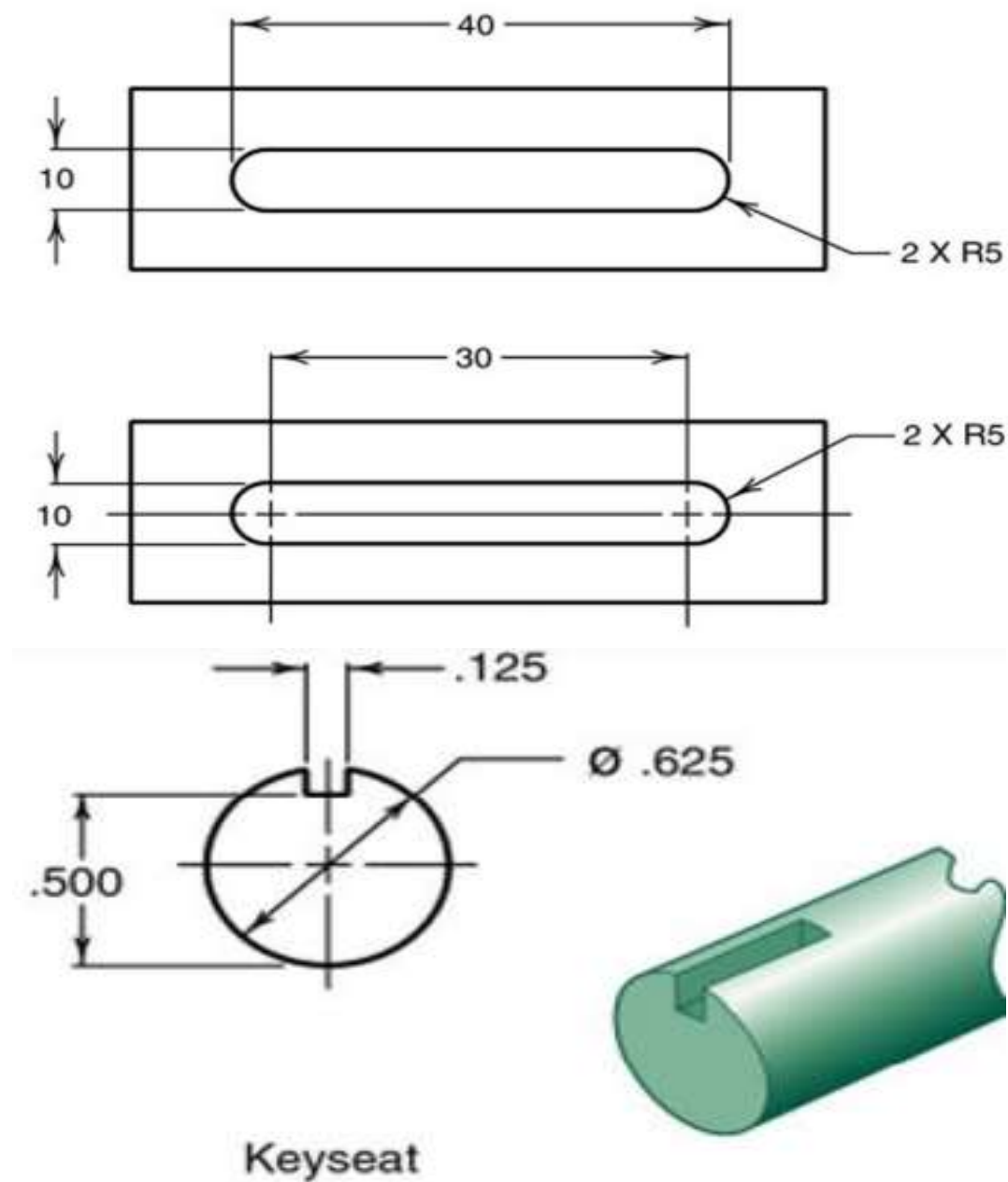


Figure 55: Technical drawing key seat Slots Keyway

Conclusion

This outcome covered orthographic views, pictorial drawing, oblique drawings, sectioning, axonometric, auxiliary first, and third angle projections, and free hand sketching.

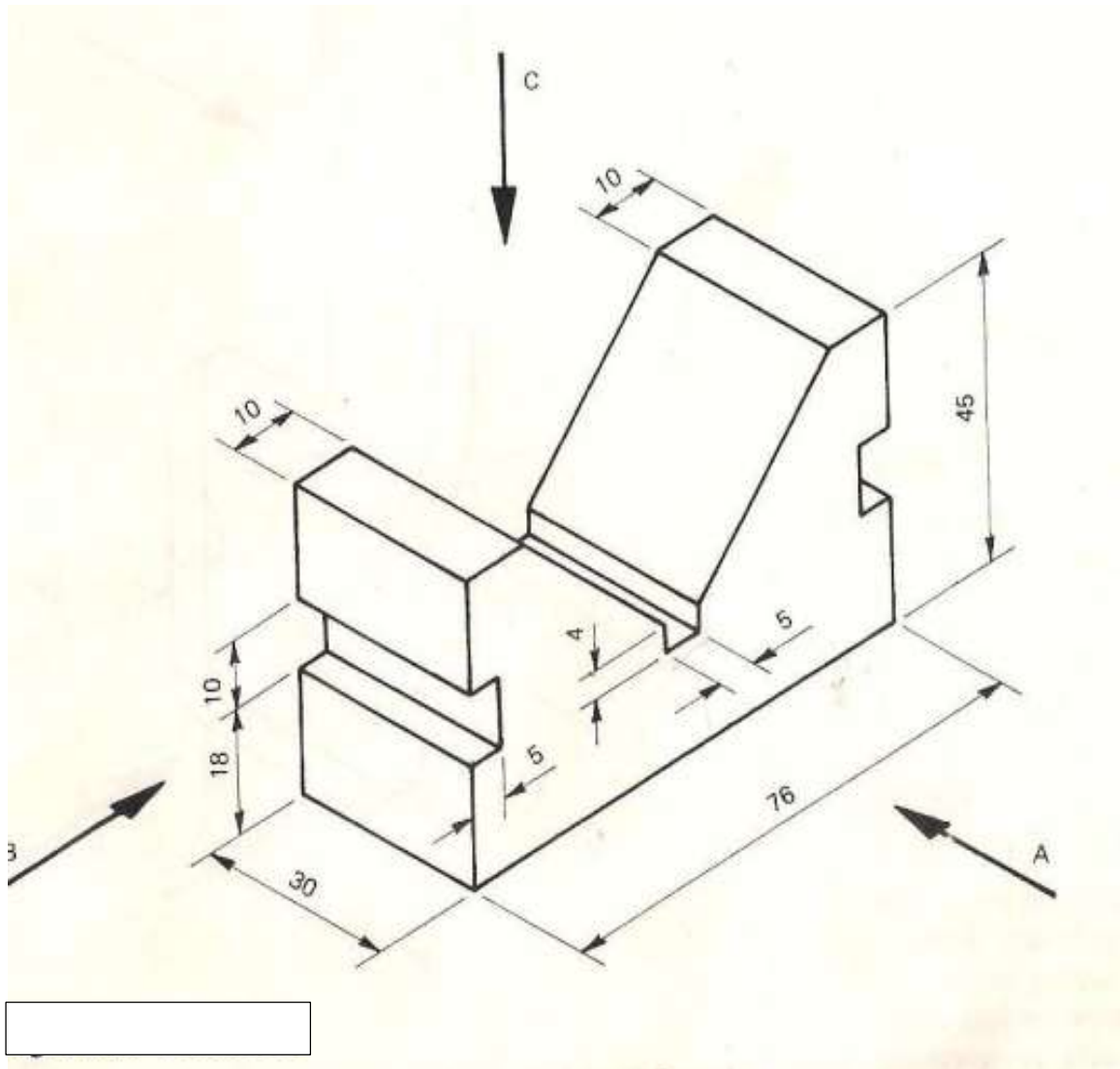


Figure 56: Vee Block, (source, Morling, 2012)

Trainees' assignment;

Draw the following views of the stub below in first angle projection.

- a) Front elevation looking from the direction arrow A
- b) End elevation looking from the direction arrow B
- c) A plan

Show all the hidden detail and fully dimension the finished drawing

The casting is symmetrical about the vertical centre line and both lugs are identical

Construct Two dissimilar square prisms meeting at an angle

Draw twice full size of the front elevation looking in the direction of arrow A. from this front elevation, project an end elevation and plan looking in the direction of the arrows B and C respectively. Insert five main dimensions and add the title block and the scale.

Trainer

- Check that the completed assignments show evidence of understating a variety of solid geometries, drawing rules and housekeeping procedures. Ensure assignments are completed on time. Observe trainees' work from time to time.

Recommended sources for further information;

Geometric and Engineering drawing Third Edition K Morling.

Engineering Drawing with CAD Applications by O.OSTROWSKY

2.3.5.3 Self-Assessment

1. Orthographic projection is drawn using two methods which is _____
 - a) Second angle and third angle method
 - b) First angle and third angle method
 - c) First angle and fourth angle method
 - d) Second angle and fourth angle method

2. The method in which the object is placed in the first quadrant is known as _____ method.
 - a) third angle
 - b) second angle
 - c) first angle
 - d) fourth angle

3. In first angle method the top view is drawn _____ of the front view.
 - a) above
 - b) right Side

- c) left side
- d) bottom

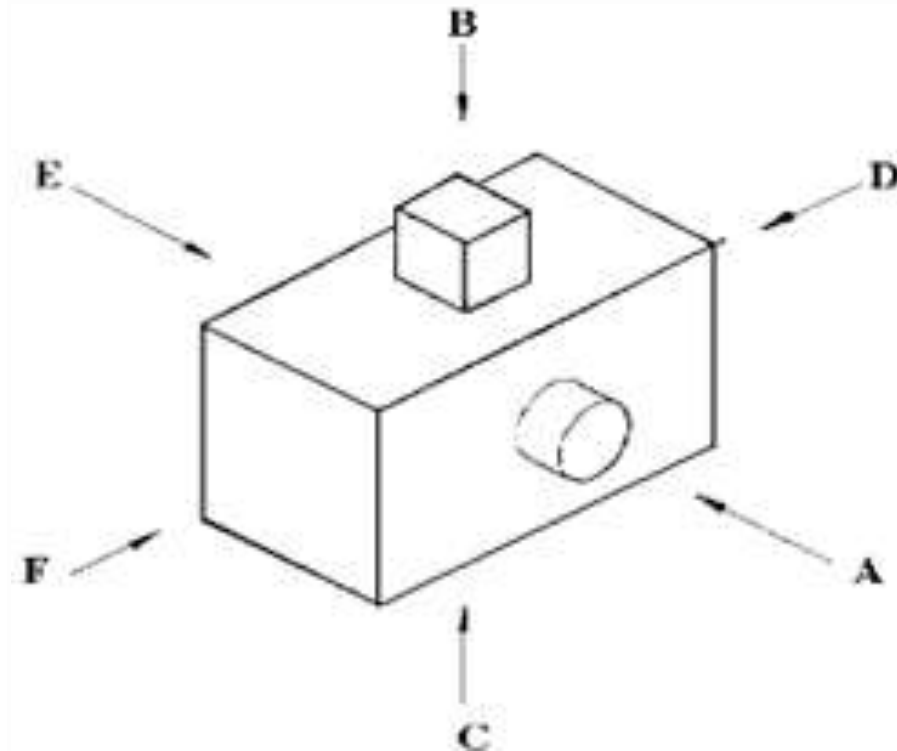
4. The method in which the object is placed in the third quadrant is known as _____ method.

- a) third angle
- b) second angle
- c) first angle
- d) fourth angle

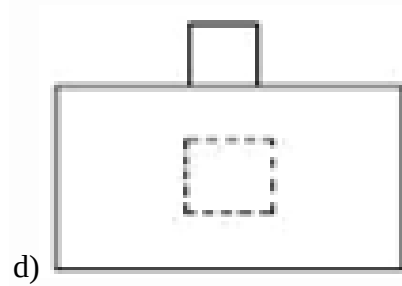
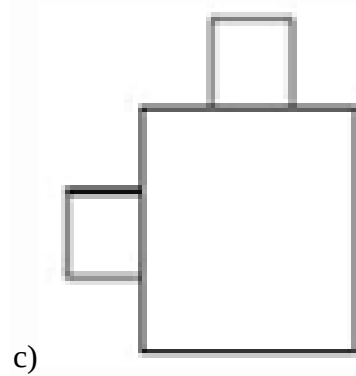
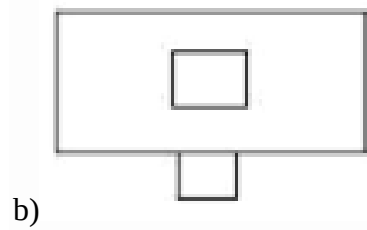
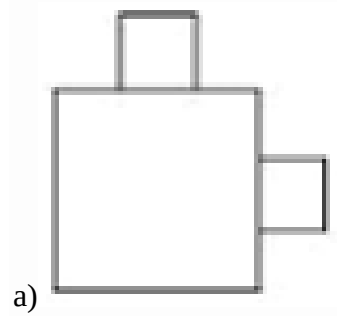
5. In third angle method the top view is drawn _____ of the front view.

- a) above
- b) right Side
- c) left side
- d) bottom

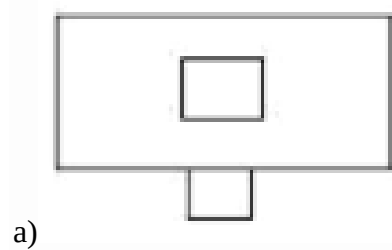
6. Question 6 to 11 is for the diagram drawn below:-

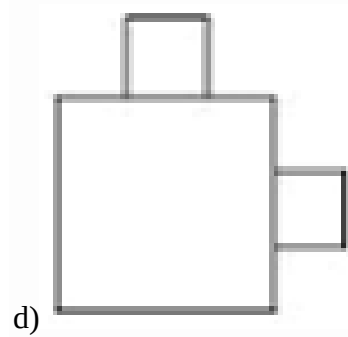
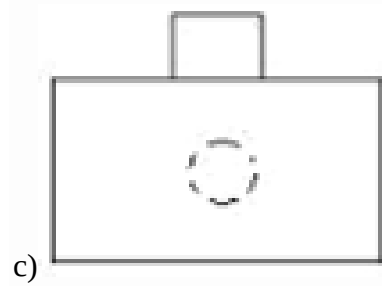
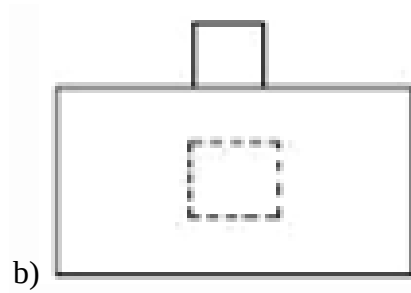


7. Taking 'A' as the FRONT VIEW. Which view will letter 'D' represent?

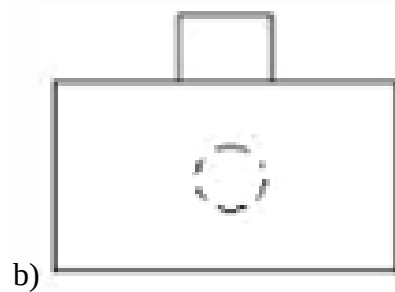
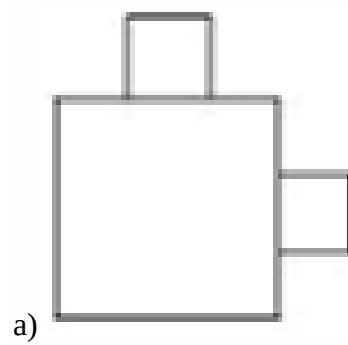


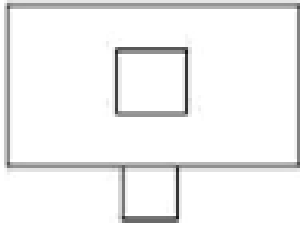
8. Which view will letter 'C' represent?



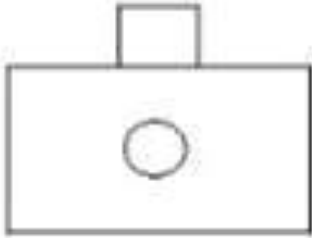


9. Which view will letter 'E' represent?



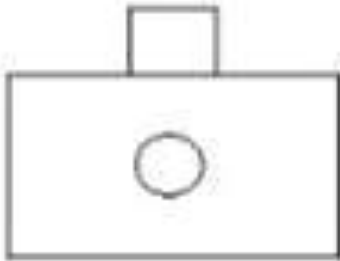


c)

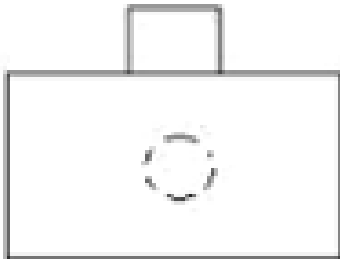


d)

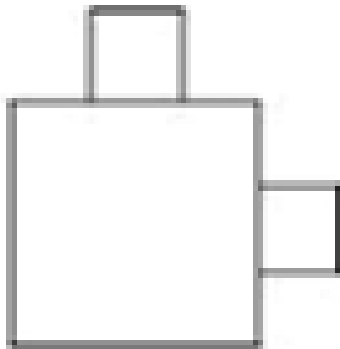
10. Which view will letter 'B' represent?



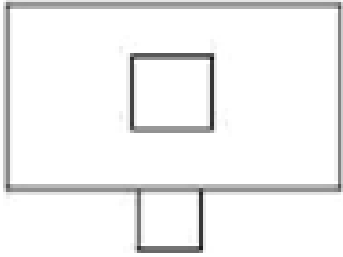
a)



b)

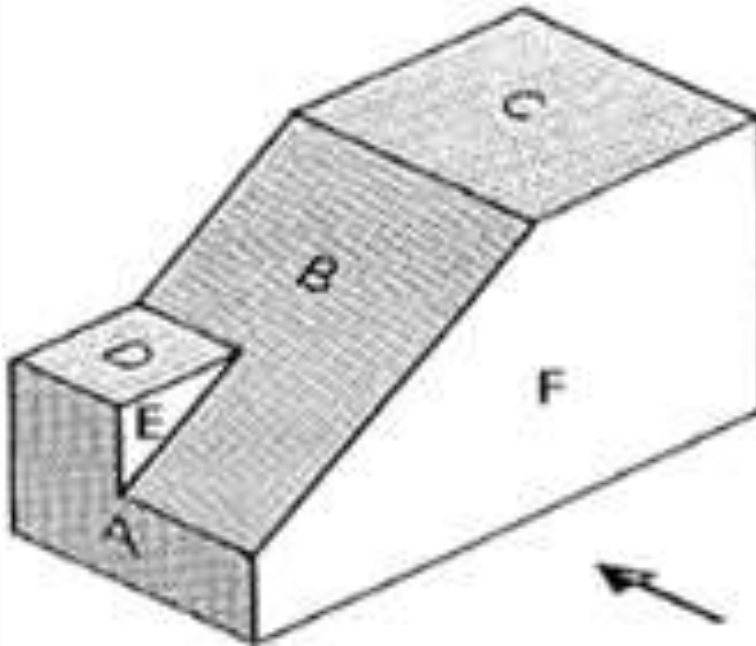


c)

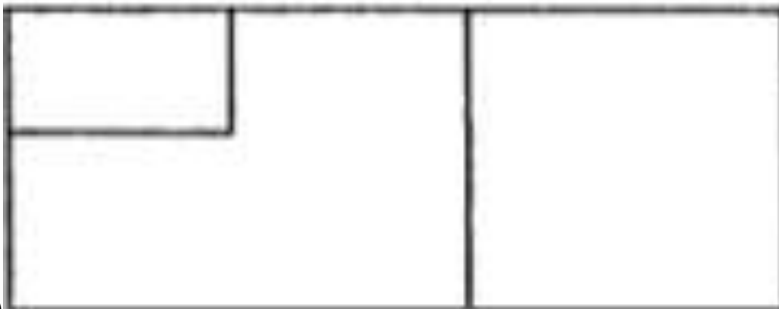


d)

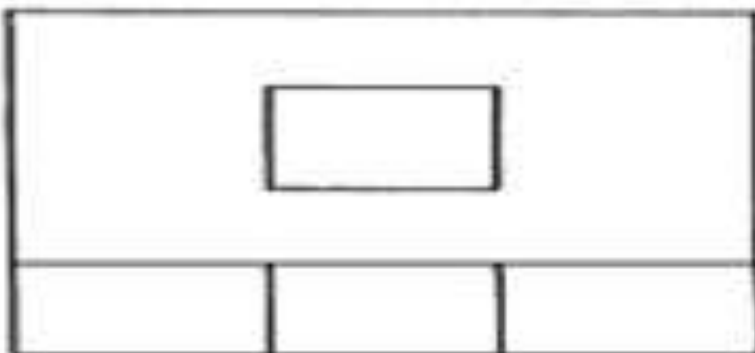
11. Questions 12 and 13 are for the diagram drawn below:-



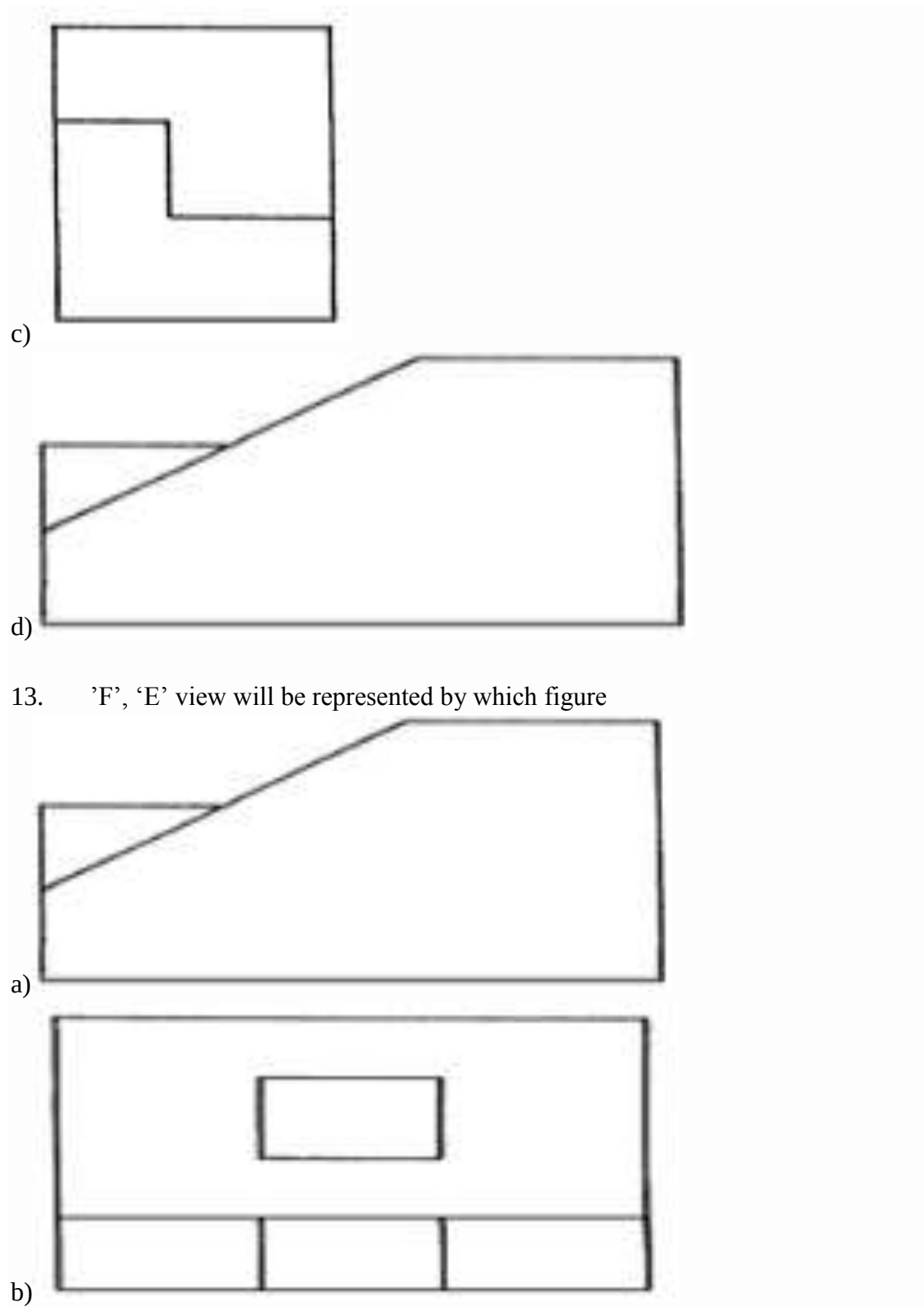
12. 'A', 'B' view will be represented by which figure?

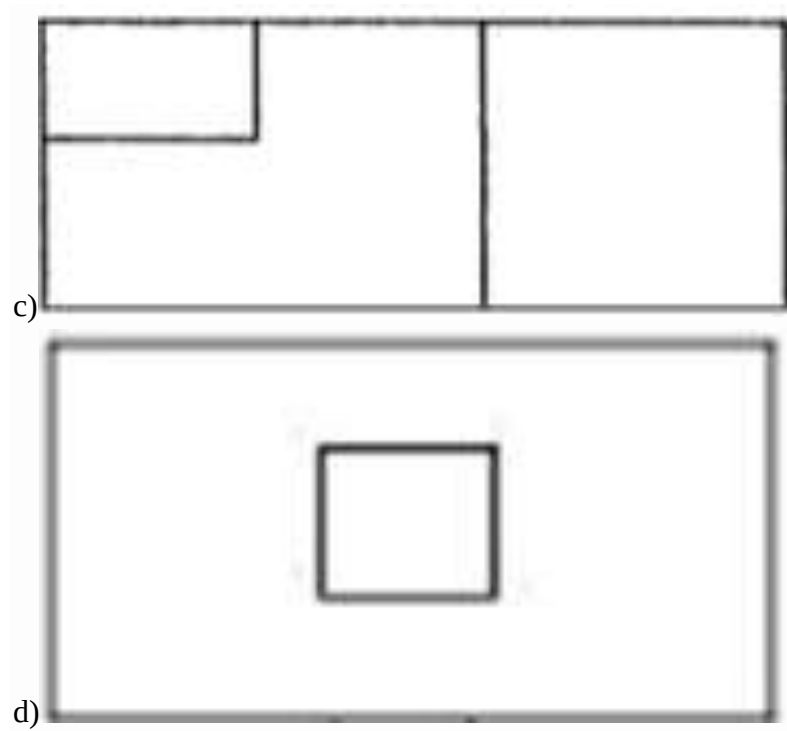


a)



b)





14. Any object can be viewed from_____ mutually perpendicular views.
- a) Two
 - b) Four
 - c) Three
 - d) Six

2.3.2.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Drawing room
- Computer lab
- Drawing equipment and materials
- CAD packages
- Projector
- Computer

2.3.4.5 References

Heather, S and Shrock, C.R (2019) Begging AUTOCAD Exercise Workbook. Industrial Press, Inc USA

Davies, B. L., Robotham, A. J., & Yarwood, A. (1991). Computer-aided drawing and design. London: Chapman & Hall.

Hubka, V. (2015). Principles of engineering design. Elsevier.

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Morling, K 92012) Geomtric and Engineering Drawing. Routledge, amazon

5.3.6. Learning Outcome No. 5: Apply CAD packages in drawing

5.3.6.1 Learning Activities

Learning Outcome #5: Apply CAD packages in drawing	
Learning Activities	Special Instructions
• Draw a drawing the views of the various figures using CAD application and save on the desktop. • Draw a variety of figures using CAD applications • Draw 2 dimensional objects of the given views. • Draw 2 dimensional objects of the given views.	Make sure your computers have CAD packages. understand

5.3.6.2 Information Sheet #5: Apply CAD packages in drawing

Introduction

This outcome covers use of CAD applications to draw pictorial and orthographic drawings and sectioning, symbols and abbreviations, drawing of isometric, oblique, axonometric, auxiliary and perspective views, drawing of first and third angle projections, sectioning of components.

Definition of key terms

- 2D and 3D drafting technique
- Computer aided design

Content

Solid geometry: application of CAD technology in orthographic drawings, oblique projections, pictorial projections, axonometric, auxiliary and perspective views, drawing of first and third angle projections, and sectioning of components.

Illustrations on dimensioning

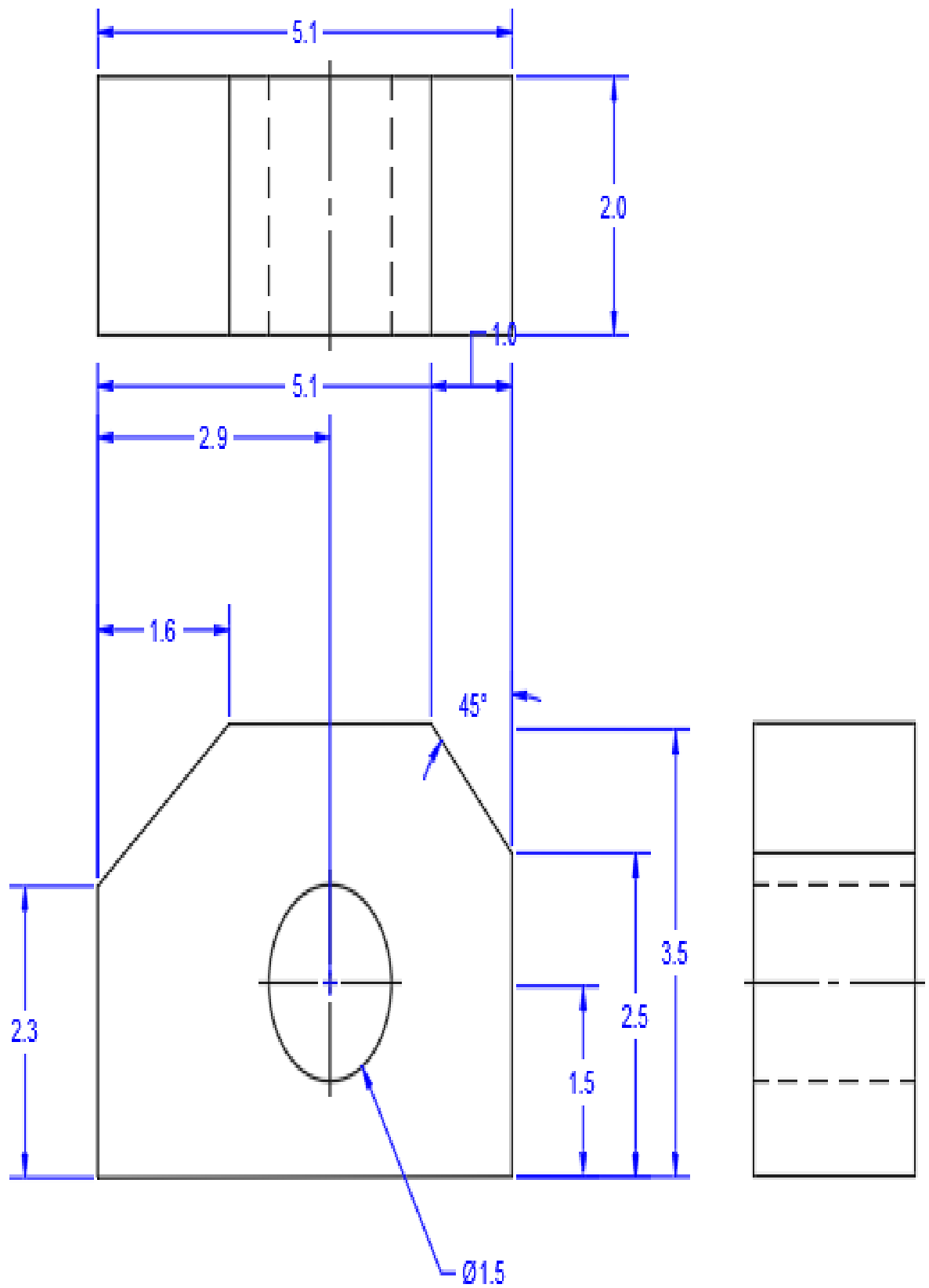


Figure 57: Dimensioning

Conclusion

This outcome covered application of CAD in orthographic views, pictorial drawing, oblique drawings, sectioning, and axonometric, auxiliary first, and third angle projections.

Trainees' assignment;

- i. Use CAD application to draw the following views of the figure below in first angle projection.
 - a) Front elevation looking from the direction arrow A
 - b) End elevation looking from the direction arrow B
 - c) A plan

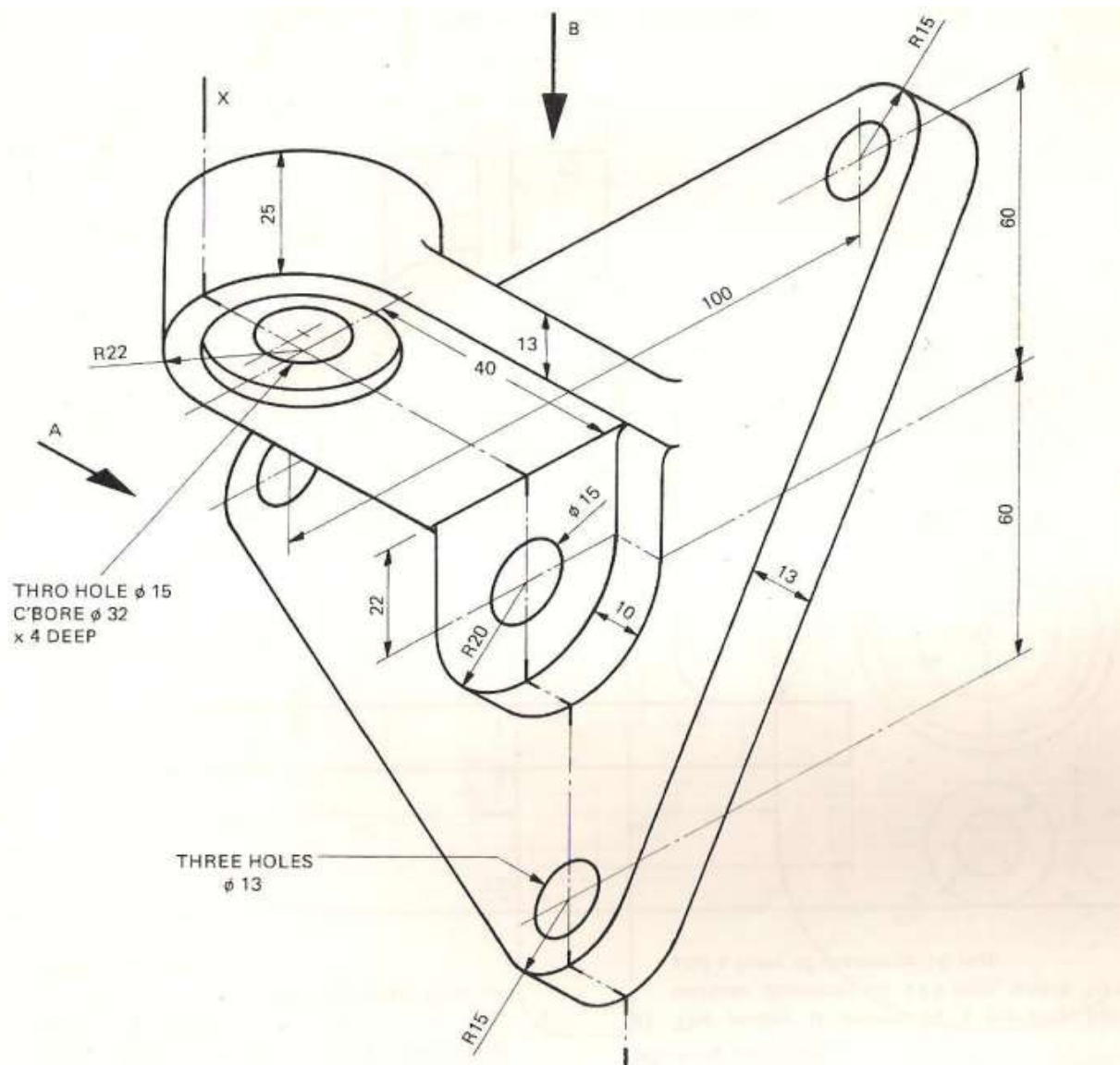


Figure 58: Auto Cad Diagram

Trainer

Check that the completed assignments show evidence of understating a variety of solid geometries, use of CAD technology, safe use of computers and housekeeping procedures. Ensure assignments are completed on time. Observe trainees' work from time to time.

5.3.6.3. Self-Assessment

1. The computer-aided design (CAD) hardware doesn't include.
 - a) Graphic display terminals
 - b) Computer
 - c) Computer programmes
 - d) Keyboard
2. How many types of CAD are there?
 - a) 6
 - b) 4
 - c) 2
 - d) 5
3. Modern CAD systems are based on:
 - a) ICG
 - b) GCI
 - c) GIF
 - d) IFG
4. The computer communicates with the user via:
 - a) CPU
 - b) CRT
 - c) Graphics
 - d) Display button
5. The process of designing consists of _____ identifiable steps.
 - a) 8
 - b) 5
 - c) 4
 - d) 6
6. Implementing CAD improves communications.
 - a) True
 - b) False

7. The functionality areas of CAD application can be grouped into _____ categories.
- 2
 - 3
 - 4
 - 5
8. The colour on CRT screen is obtained by the combination of:
- Red, yellow, blue
 - Red, green, blue
 - Green, black, yellow
 - Red, black, yellow
9. The input devices in CAD can be divided into:
- 2
 - 5
 - 3
 - 4
10. An orthographic projection map is a map projection of _____
- Sphere
 - Earth
 - Cartography
 - Top view

5.3.6.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Drawing room
- Computer lab
- Drawing equipment and materials
- CAD packages
- Projector
- Computer

5.3.6.5. References

Davies, B. L., Robotham, A. J., & Yarwood, A. (1991). Computer-aided drawing and design. London: Chapman & Hall.

Hubka, V. (2015). Principles of engineering design. Elsevier.

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Morling, K 92012) Geomtric and Engineering Drawing. Routledge, amazon

CHAPTER 6: ELECTRICAL INSTALLATION / PERFORM ELECTRICAL INSTALLATION

6.1. Introduction of the Unit of Learning / Unit of Competency

This unit specifies the competencies required for performing electrical installation. Competencies required includes; applying EHS Standards, conducting site survey, designing installation, performing system sizing, preparation of working drawings, planning for logistics, preparation of list of tools equipment and materials, preparation of installation work plan, establishment of installation team, preparation of work site, marking, piping and fixing accessories, performing installation, terminating installation, testing and inspecting installation and finally preparation of tenders and service contracts.

The resources required to implement this unit of competence include but not limited to, Assorted personal protective equipment, measuring tools and equipment, communication equipment, measuring tools, cutting tools, drawing tools, Drilling tools, fastening tools, stationery, assorted cables, Assorted protective devices, pipes and trunkings, cable lugs, joints Accessories, Occupational safety act documents, NEMA regulations, National construction authority regulations, IEEE regulations and county by laws. The trainee should also have the competencies in regard to work place health and safety, by observing the regulations as stipulated in the IEEE regulations regarding safety and the OSHA act.

6.2. Performance Standard

Applying Environmental Health and safety standards in the Design of specific Electrical Installations as stipulated in the OSHA act, and prepare working drawings, perform system sizing, prepare installation work plan and list of tools and equipment in line with the national and international standards and carry out the actual installation as per the IEEE regulations and in line with the established procedures and standards. The electrical installation is then inspected and tested as per the IEEE regulations and finally the preparation of tender documents and service contract is done in line with the laws of contracts and tendering.

6.3. Learning Outcome

6.3.1 List of Learning Outcomes

- a) Apply EHS Standards
- b) Conduct site survey
- c) Design Electrical installation
- d) Perform system sizing
- e) Prepare working drawings
- f) Plan for logistics
- g) Prepare list of tools, equipment and materials
- h) Prepare installation work plan
- i) Establish installation team
- j) Prepare work site

- k) Perform marking, pipe and fixing of accessories
- l) Perform Electrical Installation
- m) Terminate Electrical Installation
- n) Test and Inspect Electrical Installation
- o) Prepare Tenders and Service contract

6.3.2. Learning Outcome No. 1. Apply EHS Standards

6.3.2.1 Learning Activities

Learning Outcome No. 1. Apply EHS Standards	
Learning Activities	Special Instructions
1. Practice correct handling, usage and maintenance of different types of Personal Protective Equipment • Helmets • Shields • Goggles • Gloves • Safety boots • Aprons • Overcoats 2. Carry out a mock firefighting exercise using the correct workshop procedures and standards. 3. Practice first aid procedures as per the OSHA standards • Rescuing Electric shock victim • Applying methods of resuscitation ➤ Mouth to Mouth Resuscitation ➤ Cardiopulmonary resuscitation (CPR)	

6.3.2.2 Information Sheet No. 6/ LO1

Introduction

This element of training is concerned with safety regulations at the work place as per the environmental health and safety standards as stipulated in various health and safety occupational acts

The OSHA act.

At the workplace, (OSHA) Occupational Health and Safety Act, ensures proper safety, health, and welfare of all the employees and persons lawfully in attendance.

It is a requirement for an occupier to ensure proper health of the employees. It is important to create awareness of the associated risks and dangers hazardous to human life. Besides, the occupier needs to ensure proper lighting, ventilation, sanitary convenience and cleanliness in controlling noise and air pollution at the work place. A health committee responsible for this should be established according to the prescription regulations under the law.

Nevertheless, it is important to ensure preventive and protective measures against the associated risks annually. It will ensure that the machinery, tool and equipment and chemicals used are safe and in compliance with the safety and health act. A fine of

either 500,000- or six-months imprisonment is charged on any occupier who fails to comply with this act.

Free Protection

According to Occupational Safety and Health Act of 2017, an employer should provide a free protection including protective equipment, clothing (gloves, goggles and head covering). Besides, proper PPE helps in reducing associated illness and accident risk hence creating a safe environment suitable for working.

Training

According to Occupational Safety and Health Act of 2007, an employer should provide proper training, instruction and supervision of its employees. The training should be done during the recruitment, during either transfer of change of job and on introducing new equipment or technology to the firm. Besides, the training can be carried out during either working hours or adapted according to the change of associated risks.

Labor Inspection System

Occupational Safety and Health Act of 2007 provide for labor inspection act.

According to national legislation, it is important to enter, inspect and closely examine working premises to ensure they are in good condition for example in case of a medical practitioner inspector, he needs to carry out medical examinations.

Failure of an occupier to facilitating the inspector and obstructing the persecutions of his or her duties, he or she is charged a fine of either 100000 shillings or six months imprisonment.

Work Injury Benefits Act (WIBA)

Is an act of parliament in Kenya with a provision of compensating employees in case of injuries and diseases contracted at work.

Obligations of Employer

It is important for every employer obtaining and maintaining insurance policy with approved insurer by the cabinet secretary in regard to the employer's liability under the act to its employees.

Employer to keep Records

An employer should keep records of the employee's earnings ready in case called upon by the inspection director.

Right to Compensation

Deliberate and willful misconduct by the employees is not entitled to compensation by the employer.

Accidents outside Kenya

In case of accident outside the country, the employee is entitled for compensation so long as is not deliberate. However, this is not guaranteed in case outside deployment is continuous for a period of 12 months or longer.

Reporting of accidents and occupational diseases

Either a written or verbal notice should be provided by the employer to the employee on occurrence of any disease or accident.

Notice of injury or accident by employer to Director

An employer should provide a notice to the director in case of occurrence of the disease or accident by the employer in seven days on receiving the notice.

Order of reporting accidents and occupational diseases

1. Notice of Accident by Employee to Employer
2. Notice of injury or accident by employer to Director
3. Employee to submit to medical examination
4. Claim for Compensation

Environmental Management and Coordination Act 1999

Is an act of parliament that establishes appropriate legal and institutional framework for managing the environment as well as other matters that are related to it. It is important for the following reasons:

- It emphasizes that every citizen is entitled to untidy and healthy environment and provides basic regulations entitled to protecting the environment in Kenya.
- It ensures authorities' control and proper harvesting of forests to protect the water catchment areas and reduce soil erosion.

An electrical technician should familiarize with the act to ensure all the works are completed according to the law.

IEE regulations

The installation of electrical works should be according to the laid down regulations, policies and procedures. The regulations ensure safety to the building and safe guard against any injury to animals and human beings. The various regulations are contained in the IEE regulations.

The IEE Wiring Regulations (BS 7671) provides the national standards useful for the domestic and industrial wiring. Although applied in Kenya, the IEE regulations originated from Britain.

The IEE Regulations describes the methods and standards to be followed for the safe selection and erection of wiring installations. The regulations emphasize on earthing, bonding, protection, and circuit designs of electrical wirings. The regulations outline the fundamental requirements, procedures and safety in earthing systems of the electrical works.

The following is a summary on the main areas of an electrical installation covered in the IEE regulations on testing, inspection and certification of an electrical installation.

1. Testing Continuity of Protective Conductors
2. Testing Continuity of Ring Final Circuit Conductors
3. Testing Insulation Resistance
4. Special Tests
 - Protection by Barriers or Enclosures
 - Protection by Non-conducting Location
5. Testing Polarity

6. Testing Earth Electrode Resistance
7. Testing Earth Fault Loop Impedance
8. Prospective Fault Current
9. Check of Phase Sequence
10. Functional Testing
11. Voltage Drop
12. Periodic Inspection
13. Certification
14. Electrical Installation Certificate
15. Periodic Inspection Report
16. Minor Electrical Installation Works Certificate
17. Schedule of Test Results (as per BS 7671)
18. Schedule of Inspections (as per BS 7671)

Common Causes and source of Electrical Accidents

1. Inappropriate equipment or installation
2. Unsuitable environment
3. Work practices that are unsafe.

Personal Protective Equipment (PPE)

PPE is an appropriate safe clothing, google or helmet designed in protecting workers against either infection or injury.

Basic types of Personal protective equipment

1. Head Protection
2. Face and Eye Protection
3. Foot Protection
4. Hands Protection
5. Body Protection
6. Hearing Protection
7. Fall Protection
8. Respiratory Protection

Electrical Safety Gear

It is important for electricians to put on electrical safety gear to protect against electrical hazards including arc flash and an electric shock.

Also, electricians must be trained by their employers to:

1. Properly use electrical safety gear, also known as personal protective equipment (PPE).
2. Know when to use electrical safety gear
3. Know what type of electrical safety gear is necessary for the assigned job
4. Be aware that electrical safety gear has limitations on protecting electrical workers from serious injury
5. Know how to wear and take off the electrical safety gear, and,
6. Know how to properly maintain PPE.

Importance of Personal protective equipment

It helps protect technicians from injuries.

When selecting and using Personal protective equipment:

1. Choose a suitable equipment to the user, considering the size, fit and weight of the PPE.
2. In case more than one item of Personal protective equipment is worn at the same time, make sure they can be used together,
3. Instruct and train users prior.

Maintenance of Personal protective equipment

For effective and proper use of PPE, the following should be observed.

- use the right replacement parts matching the original
- keep available replacement Personal protective equipment
- Responsible person for maintenance
- Have a supply of a suitable disposable suits important for dirty jobs where laundry costs are high.

Monitor and review Personal protective equipment as follows:

- Check regularly that Personal protective equipment is used and find out why it is not
- Safety signs can remind when PPE should be worn
- Note equipment changes, materials and methods and update suitably.
- Firefighting, classes of fire and firefighting equipment

Classes of fire

- Class A - Involves solid materials.
- Class B - Involving flammable liquids.
- Class C - Involves gases.
- Class D - Involves metals.
- Class E - Involves live electrical apparatus. (Technically 'Class E' doesn't exist however this is used for convenience here)
- Class F - Involving cooking oils

Types of fire extinguishers

- Water extinguishers

Is the most effective class A fire extinguisher fueled by solid materials. In this category, there are other types including water jet and water with additives.

- Foam extinguishers

Applied on class A and B fires. Suitably used both in putting off liquid fires and solids. However, they are not suitable for use in a free-flowing liquid fires and labelled cream.

- Powder extinguishers

Is a multipurpose extinguisher used in class A, B and C fires and labelled blue in color.

- Carbon dioxide extinguishers (CO2)

Suitably used in regions with several electrical equipment including server rooms and offices since they are appropriate on fires that involve electrical apparatus. They do not leave any residue as opposed to the foam extinguisher.

- Wet chemical extinguishers

Are appropriately used on class F that involves cooking oils and fats. They are quite effective when applied appropriately.

Fire blankets

The table below summarizes the classes of fire and their extinguishers.

Type of extinguisher	Color	Fire classification	
Water	Red	Class A	Water extinguishers are applied on Class A fires. They're not suitable for fires fueled by flammable liquids or where electricity is involved.
Foam	Cream	Class A and B	Foam is a versatile fire extinguisher. Applied for Class A and B fires.
CO2	Black	Class B and E	Are applied for fires involving electrical apparatus. They have no post fire security hence the possibility of fire reigniting
Dry Powder	Blue	Class A, B and C	Are applied on Class A, B and C fires. It is not recommended for use inside because it can obscure vision and damage goods and machinery.
Wet Chemical	Yellow	Class F	Are for fires that involve cooking fats and oils. They are most suitable for use in restaurants and kitchens.

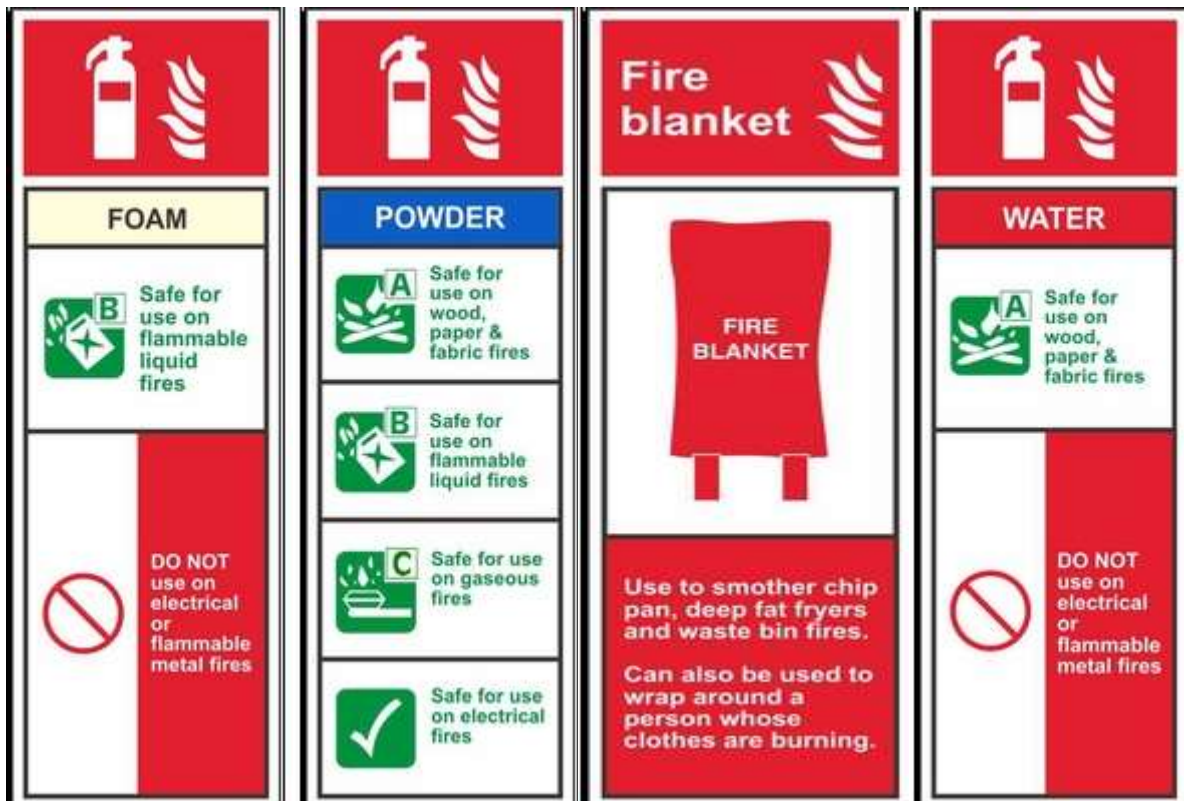


Figure 59: type of fire and the fire extinguisher

Source: <http://www.strikefirstusa.com/2016/05/five-classes-of-fires-fire-extinguishers-stop-them/>



Figure 60: Signs for different types of fire extinguishers.

Source: <http://www.strikefirstusa.com/2016/05/five-classes-of-fires-fire-extinguishers-stop-them/>

First aid procedures

Electric Shock

In case of the following signs and symptoms, immediately call for a medical emergency:

- Cardiac arrest
- Heart rhythm problems
- Respiratory failure
- Muscle pain and contractions
- Seizures
- Numbness and tingling
- Unconsciousness

While waiting for medical help, follow these steps:

1. Look first. Don't touch. The person may still be in contact with the electrical source. Touching the person may pass the current through you.
2. Turn off the source of electricity if possible. If not, move the source away from you and the affected person, using a non-conducting object made of cardboard, plastic or wood.
3. Check for signs of circulation (breathing, coughing or movement). If absent, begin cardiopulmonary resuscitation (CPR) immediately.
4. Prevent shock. Lay the person down and, if possible, position the head slightly lower than the trunk, with the legs elevated.

As a first aid procedure, electric shock victims who have stopped breathing can be helped by applying two resuscitation methods.

1. Cardiopulmonary resuscitation (CPR)
2. Mouth to mouth

Cardiopulmonary resuscitation (CPR)

Cardiopulmonary resuscitation is a lifesaving technique applied in emergencies such as heart attack from an electric shock.

Administration of Cardiopulmonary resuscitation

Before you begin administering Cardiopulmonary resuscitation, ensure the following:

- Is the environment safe for the person?
- Is the person conscious or unconscious?
- If the person appears unconscious, tap or shake his or her shoulder and ask loudly, "Are you OK?"
- If the person doesn't respond and two people are available, call the local emergency number medical assistance.

Proceed to administer Cardiopulmonary resuscitation as follows:

Compressions: Restore blood circulation

1. Put the person on his or her back on a firm surface.
2. Kneel next to the person's neck and shoulders.
3. Place the heel of one hand over the centre of the person's chest, between the nipples. Place your other hand on top of the first hand. Keep your elbows straight and position your shoulders directly above your hands.

4. Use your upper body weight (not just your arms) as you push straight down on (compress) the chest at least 2 inches (approximately 5 centimetres) but not greater than 2.4 inches (approximately 6 centimetres). Push hard at a rate of 100 to 120 compressions a minute.
5. If you haven't been trained in CPR, continue chest compressions until there are signs of movement or until emergency medical personnel take over. If you have been trained in CPR, go on to opening the airway and rescue breathing.

Mouth-to-Mouth Resuscitation

The following procedure should be followed when applying the mouth to mouth resuscitation

Make sure the person is lying on a hard, flat surface. Look into the mouth and throat to ensure that the airway is clear. If an object is present, try to sweep it out with your fingers (wear disposable surgical gloves if they are available). If vomiting occurs, turn the person on his or her side and sweep out the mouth with two fingers. Do not place your finger in the mouth if the person is rigid or is having a seizure.

Tilt the head back slightly to open the airway. Put upward pressure on the jaw to pull it forward.

Pinch the nostrils closed with thumb and index finger. Place your mouth tightly over the person's mouth. Use a mouthpiece if one is available. Blow two quick breaths and watch for the person's chest to rise.

Release the nostrils. Look for the person's chest to fall as he or she exhales. Listen for the sounds of breathing. Feel for the person's breath on your cheek. If the person does not start breathing on his or her own, repeat the procedure

6.3.2.3. Self-Assessment

1. Describe OSHA
2. Explain OSHA act
3. Describe Work Injury Benefits Act (WIBA)
4. What is the importance of OSHA act?
5. Explain resuscitation
6. Explain the classes of fire
7. Describe environmental management and coordination act 1999
8. Wet chemical extinguishers are appropriately used on that involves cooking oils and fats
 - a) class A
 - b) class B
 - c) class D
 - d) class F
9. Which of the following is not a resuscitation method?
 - a) Cardiopulmonary resuscitation (CPR)
 - b) Mouth to mouth
 - c) WIBA
10. Which of the following is false

- a) Class A - Involves solid materials.
 - b) Class B - Involving flammable liquids.
 - c) Class C - Involves solids.
 - d) Class D - Involves metals
11. A fine of either 500,000- or six-months imprisonment is charged on any occupier who fails to comply with OSHA act.
- a) True
 - b) False
12. Deliberate and willful misconduct by the employees is not entitled to compensation by the employer.
- a) True
 - b) False

Practical exercise

- a) The trainees in groups of 5, to perform Cardiopulmonary resuscitation (CPR) Mock exercise.
- b) Practice correct handling, usage and maintenance of different types of Personal Protective Equipment for example Helmets, Shields, Goggles and Overcoats
- c) Carry out a mock firefighting exercise using the correct workshop procedures and standards.
- d) Practice first aid procedures as per the OSHA standards

6.3.2.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- 1. Helmets
- 2. Shields
- 3. Goggles
- 4. Gloves
- 5. Safety boots
- 6. Aprons
- 7. Overcoats
- 8. Fire extinguishers
- 9. First aid Kits
- 10. Match box
- 11. Dry wood and papers

6.3.2.5. References

- 1. Brian S., IEng, MIET, (2008), Wiring Regulations: Inspection, Testing and Certification 17th Edition IEE, Elsevier Ltd, Corporate Drive, Suite 400, Burlington, MA 01803, USA.
- 2. Francis G. T., (1972), Electrical installation technology, Longman, London.
- 3. Christopher K, (2013), Practical Guide to Inspection, Testing and Certification of Electrical Installations, Routledge, New York
- 4. Brian, S, (1990), Modern Electrical Installation for Craft Students,

6.3.3. Learning Outcome No. 2. Conduct site survey

6.3.3.1. Learning Activities

Learning Outcome No. 2. Conduct site survey	
Learning Activities	Special Instructions
1. Carry out a site survey to identify the type of installation to be done as per the Kenya power procedures. • Domestic installation • Industrial Installation • Commercial installations • Street lighting • Integrated building management system (IBMS) 2. Carry out the measurements as per the expected installation • Length of the conduit and cables. • Conduit and cable sizes • Total area of the building • Existing temperatures • Humidity 3. Generate the survey report and share it with relevant parties. • Kenya power • County government • client	

6.3.3.2. Information Sheet No. 6/ LO2

- Definitions of key terms
- methods, processes/ procedures/ guidelines
- content
- illustrations (photographs, pictures, videos, charts, plans, digital content, simulations)
- case studies

This element is designed to equip the trainee on competencies required to do a quality survey of the site for electrical installation work. The type of installation is decided on the basis of the nature of the building, and the amount of electrical consumption.

The site is normally surveyed for suitability for the type of installation to be done as per the contract.

Types of installation.

- Domestic installation

Involve majorly either single phase or three phase installation. The power supply for single phase is 240 V while power supply for the three phase is 415 v. Residential electrical wiring is sheath insulated to prevent users form electrical shock. Appliances that use three phase include refrigerators and washing machines.

- Commercial installation

Is majorly a three-phase design (415V). The set up enables the individual work load while allowing a greater output while working concurrently. In this type of wiring, there is greater insulation called the TTHT (thermoplastic high resistant nylon coated). It helps in protecting electrical wiring against corrosive liquids and gases.

- Industrial installation

Is the installation intended for use in manufacturing or processing of products including systematic labor or habitual employment and includes special installations in which the wiring systems are specially designed to handle the extreme environments in terms of corrosion, high temperatures, acids and humidity.

The type of wiring will also be chosen depending on whether the kind of building is permanent or semi-permanent buildings. This will enable the technician decide on whether to carry out temporary or permanent installation.

Conditions of the site are evaluated according to the established procedures. These procedures are drawn from the OSHA act, IEE regulations and the Kenya power standards and procedures.

Factors that should be considered when surveying a site for an electrical installation include but not limited to availability of water and Electricity, availability of communication facilities, installation conditions like temperature, humidity and moisture. All these conditions must be recorded and assessed because they directly affect electricity in terms of safety.

The installation route is identified as per the Kenya power and Energy and Petroleum regulatory authority and standards.

Measurements are then taken on site to determine the amount of cables, conduits and other related electrical accessories that will be needed depending on the design as per the expected installation.

Survey report is then generated and shared with the relevant parties according to the established procedures for Kenya power and county governments.

6.3.2.3 Self-Assessment

1. Describe industrial installation.
2. Describe commercial installation.
3. Describe domestic installations.
4. Differentiate various types of installation
5. Determine factors that should be considered when surveying a site for an electrical installation

6. helps in protecting electrical wiring against corrosive liquids and gases
 - a) Circuit breaker
 - b) Fuse
 - c) TTHT (thermoplastic high resistant nylon coated)
7. The power supply for single phase is V while power supply for the three phase is..... v.
 - a) 240,240
 - b) 240,415
 - c) 415,240
8. Residential electrical wiring is sheath insulated to prevent users form electrical shock.
 - a) True
 - b) False
9. The installation route is identified as per the Kenya power and Energy and Petroleum regulatory authority and standards.
 - a) True
 - b) False

Practical exercise

1. Identifying installation tools and material and carry out Domestic installation
2. Carry out the measurements as per the expected installation

6.3.2.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Cutting tools
- Measuring tools
- Measuring equipment
- Hammers
- Chisels
- Allen keys
- Draw wires

6.3.2.5. References

1. Brian S., IEng, MIET, (2008), Wiring Regulations: Inspection, Testing and Certification 17th Edition IEE, Elsevier Ltd, Corporate Drive, Suite 400, Burlington, MA 01803, USA.
2. Francis G. T., (1972), Electrical installation technology, Longman, London.
3. Christopher K, (2013), Practical Guide to Inspection, Testing and Certification of Electrical Installations, Routledge, New York
4. Brian, S, (1990), Modern Electrical Installation for Craft Students,

6.3.4. Learning Outcome No. 3. Design Electrical Installation

6.3.4.1. Learning Activities

Learning Outcome #No 3	
Learning Activities	Special Instructions
1. Design an electrical installation as per the specific wiring system • Wiring systems ➤ For lighting and power ➤ For switchgear ➤ For alarm systems • Type and size of building • IEE regulations. 2. Visit Kenya power regional office to obtain blue prints on standard procedures in electrical designs. • IEE regulations • Kenya power by laws	• Contact authorities responsible for local building inspection during the design process. It helps in determining in case the local standards have been adopted and determining edition of the NEC enforced.

6.3.4.2 Information Sheet No. 6/ LO3

This element equips the trainee on knowledge and skills on the types of electrical installation designs that will suit the client.

Definition of terms

Circuit breaker: An automatic device that stops current flow in an electric circuit

Circuit: A closed path for the flow of electrons from either a current or voltage source

Current: electric charge flow through a conductor.

Fuse: A device consisting of a strip of wire that melts and breaks a circuit in case current exceeds limit.

Wiring systems.

The following are some of the wiring systems that can be adopted.

Cleat wiring system

Is made up of the normal VIR or PVC wires that are insulated, braided and compounded on the ceilings by use of porcelain cleats, wood or plastic.

Advantages of Cleat Wiring

- Inspection is easy and simple.
- It is cost effective
- Faults on cables can easily be seen and repaired.

Disadvantages of Cleat Wiring:

- It is not durable, reliable and sustainable.
- It is only applicable on 250/440V at low temperatures
- Associated with other risks including electric shock and fire

Conduit Wiring

Involves use of conduit in protecting and enrooting electrical wiring in construction. It may be made from fiber, plastic, metal or fie clay. There are two types of conduit wiring including Surface Conduit Wiring and Concealed Conduit wiring

Factors to consider in designing electrical installation

- Load size
- Structure
- Client's need

Types of electrical power supplies.

Direct current (DC)

Is an electrical charge flow that is unidirectional for example a battery. Rectifiers converts a direct current to an alternating current. DC current is used aluminum and electrochemical processes production. Besides, it is used in railway. DC current voltage is used in transmitting power from the generation site to the end users.

A.C. power

Is either single phase or three phase.

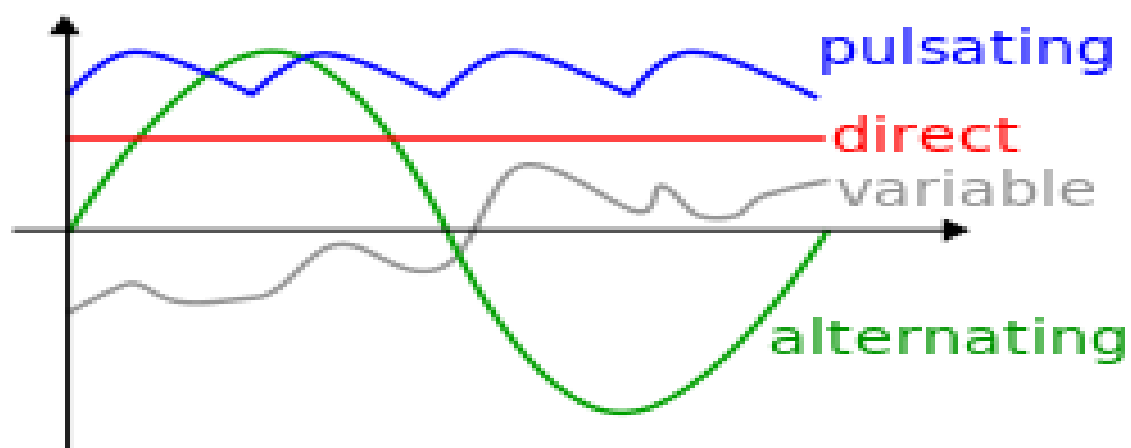
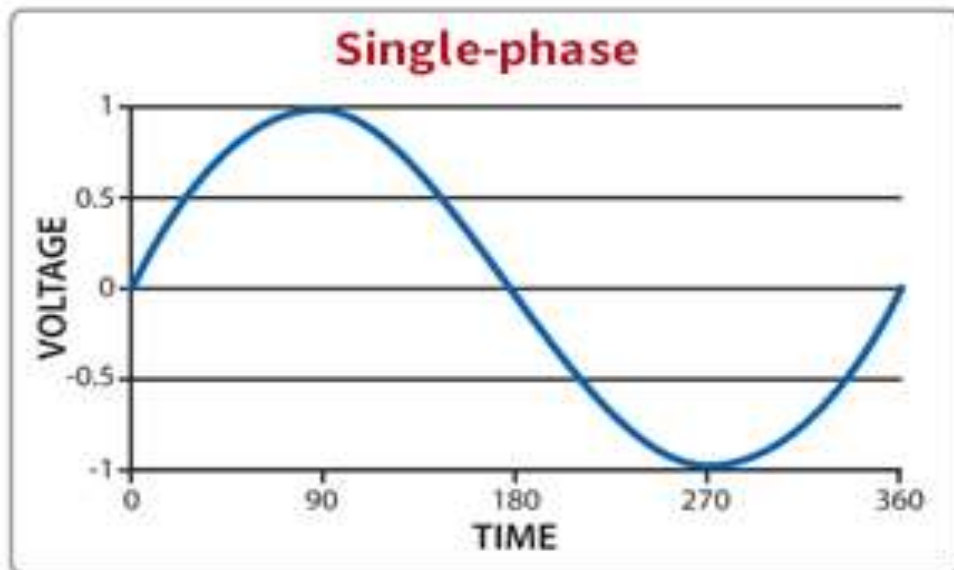


Figure 61: waveforms showing D.C. and A.C.

Single phase and three phase A.C circuits

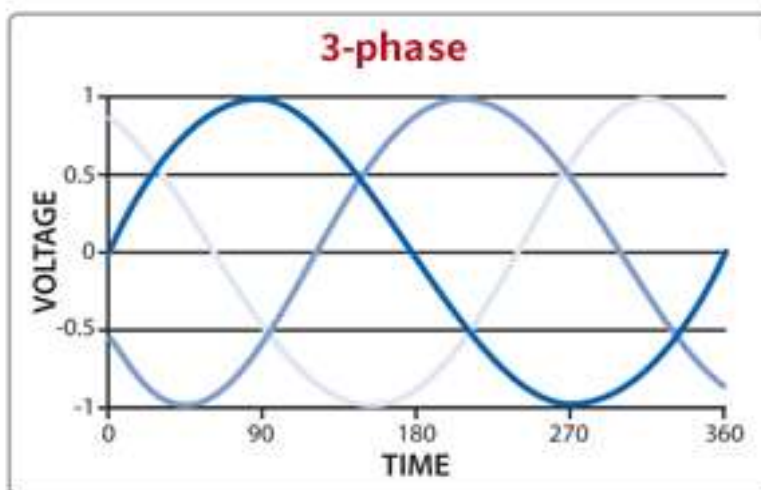
While the single-phase power supply has a single cycle, three phase three distinct cycles. The single phase is 240V while in three phase the voltage is 415V.



With the wave form of single-phase power, when the wave passes through zero, the power supplied at that moment is zero. The wave cycles 50-60 times per second depending on your location.

Figure 62: Single phase supply

Single phase power is majorly used for domestic purpose.



3-phase power has 3 distinct wave cycles that overlap. Each phase reaches its peak 120 degrees apart from the others so the level of power supplied remains consistent.

Figure 63: Three phase supply

3-phase power is majorly used in processing and manufacturing industry.

6.3.4.3 Self-Assessment

1. Explain the difference between trunking and conduit wiring system
2. Differentiate between a fuse and a circuit breaker
3. Explain a wiring system and its types
4. Describe factors to consider in designing electrical installation
5. Which one of the following is not one of the factors to consider in designing electrical installation?
 - a) Load size
 - b) Structure
 - c) Client's need
 - d) Color
6. is an automatic device that stops current flow in an electric circuit
 - a) fuse
 - b) circuit breaker
 - c) contactor
7. Which of the following is a device consisting of a strip of wire that melts and breaks a circuit in case current exceeds limit
 - a) Circuit breaker
 - b) Fuse
 - c) Contactor
8. Differentiate between AC and DC including the wave forms
9. A fuse is an automatic device that stops current flow in an electric circuit.
 - a) True
 - b) False
10. Rectifiers convert a direct current to an alternating current.
 - a) True
 - b) False

Practical exercise

1. Design an electrical installation as per the specific wiring system
2. Demonstrate full understanding of the IEE regulations and Kenya power by laws

6.3.4.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Drawing instruments
- Drawing materials
- Personal Protective Equipment for Drawing

6.3.4.5. References

1. Brian S., IEng, MIET, (2008), Wiring Regulations: Inspection, Testing and Certification 17th Edition IEE, Elsevier Ltd, Corporate Drive, Suite 400, Burlington, MA 01803, USA.
2. Francis G. T., (1972), Electrical installation technology, Longman, London.

3. Christopher K, (2013), Practical Guide to Inspection, Testing and Certification of Electrical Installations, Routledge, New York
4. Brian, S, (1990), Modern Electrical Installation for Craft Students,
5. You Tube Link: <https://youtu.be/52JoONLG12s>

6.3.5. Learning Outcome No. 4. Perform System sizing

6.3.5.1. Learning Activities

Learning Outcome No. 4. Perform System sizing	
Learning Activities	Special Instructions
1. Select the size and type of circuit Protective devices depending on the specific installation design. • Fuses • Circuit breakers • Residual current device 2. Choose the cable sizes for installation design, as per the data sheets provided in the IEE regulations. 3. Record system sizes as per the established procedures. • Circuit breakers • Cable sizes	

6.3.5.2 Information Sheet No 6/ LO4.

This element is intended to equip the trainee with competencies in selecting the correct circuit protective device for the specific installation design. The trainee should also gain knowledge in calculating the correct cable size that will carry the circuit load current safely. The procedures for determining the correct cable size for the circuit and the right circuit protective device should follow the set regulations and standards.

Circuit protective Devices

Circuit conditions requiring protection devices

The conditions that require circuit protection include;

- Short circuits.
- Excessive Current
- Excessive Heat

Types of Circuit Protective Device

The following are the typical circuit proactive devices commonly used in electrical installation designs

1. Fuse
2. MCB – Miniature circuit breaker
3. ELCB – Earth Leakage Circuit Breaker
4. ELCB & MCB
5. Earthing or Grounding

6. Residual Current Device

1. Fuse

A fuse is a short length of wire that melts and breaks in case of excessive current. Characteristics of a good fuse wire

A good fuse wire should possess the following characteristics

- a) Low resistivity
- b) Low melting point
- C) Low conductivity of the metal vapours formed, when the fuse is blown off.

2. Miniature Circuit Breaker

It operates on the principle of magneto thermic release. Its connection is made between the load and the supply.

Advantages of MCB

- Fast mode of operation (less than 5 ms)
- It needs no replacement

3. Earth Leakage Circuit Breaker

It is a safety device that trips in case of any small leakage to the earth hence protecting operator from accidents and shocks.

Residual current device

Is a device that detects problems in power supply and cuts the current flow within 10 to 15 ms. It is important to note that it neither gives safety against overload or short circuit. It is possible to test and reset the residual current device.

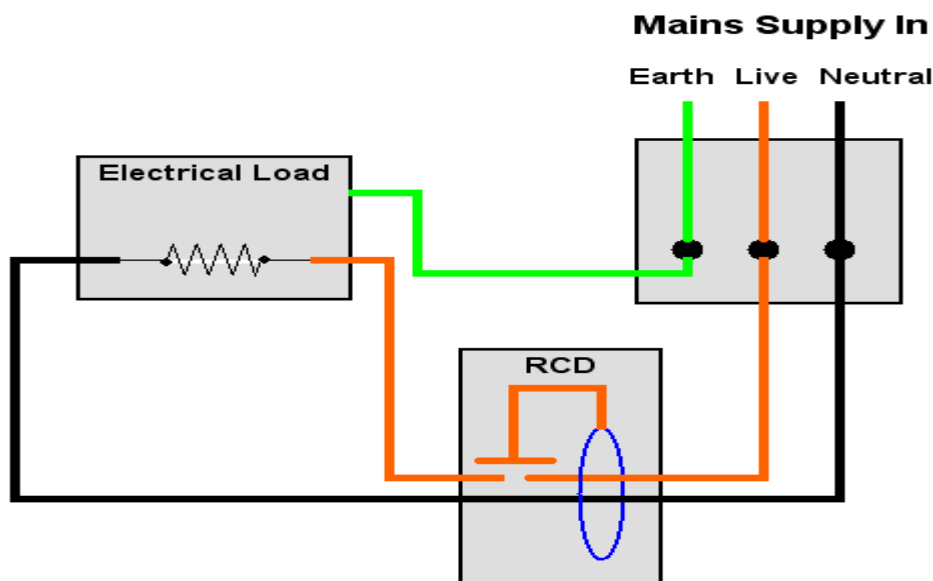


Figure 64: Connection of a residual current device in a circuit

Cable size calculations

General methodology for sizing cables is presented in this element of learning.

The proper sizing of an electrical cable is essential to ensure that the cable can:

- Operate nonstop under full load without being injured
- Survive the worst short circuits currents flowing through the cable
- Deliver the load with a suitable voltage (and avoid excessive voltage drops)
- Ensure operation of protective devices during an earth fault

The general methodology is to follow the following steps

- Collecting data about the cable, its installation conditions and the load that it will carry.
- Determine the minimum cable size based on continuous current carrying capacity
- Determine the minimum cable size based on voltage drop considerations
- Determine the minimum cable size based on short circuit temperature rise
- Determine the minimum cable size based on earth fault loop impedance
- Select the cable based on the sizes calculated.

Step 1: Data collection

The first step is to collate the relevant information that is required to perform the sizing calculation. Typically, you will need to obtain the following data:

Load Details

The characteristics of the load that the cable will supply, which includes:

- Load type: motor or feeder
- Three phase, single phase or DC
- System / source voltage
- Full load current (A) - or calculate this if the load is defined in terms of power (kW)
- Full load power factor (pu)
- Locked rotor or load starting current (A)
- Starting power factor (pu)
- Distance / length of cable run from source to load - this length should be as close as possible to the actual route of the cable and include enough contingency for vertical drops / rises and termination of the cable tails

Cable Construction

The basic characteristics of the cable's physical construction, which includes:

- Conductor material - normally copper or aluminium
- Conductor shape - e.g. circular or shaped
- Conductor type - e.g. stranded or solid
- Conductor surface coating - e.g. plain (no coating), tinned, silver or nickel

- Insulation type - e.g. PVC, XLPE, EPR
- Number of cores - single core or multicore (e.g. 2C, 3C or 4C)

Installation Conditions

How the cable will be installed, which includes:

- Above ground or underground
- Installation / arrangement - e.g. for underground cables, is it directly buried or buried in conduit? For above ground cables, is it installed on cable tray / ladder, against a wall, in air, etc.
- Ambient or soil temperature of the installation site
- Cable bunching, i.e. the number of cables that are bunched together
- Cable spacing, i.e. whether cables are installed touching or spaced
- Soil thermal resistivity (for underground cables)
- Depth of laying (for underground cables)
- For single core three-phase cables, are the cables installed in trefoil or laid flat?

Step 2: Cable Selection Based on Current Rating

Cables have varying current carrying capacity. It is the maximum current that can continuously flow through a particular cable with no damage to its insulation.

6.3.5.3 Self-Assessment

1. The trainee to calculate the cable size of a given electrical design.
2. Explain circuit protection
3. Describe Circuit conditions requiring protection devices
4. Describe type of circuit protective device
5. Describe factors affecting cable size calculations
6. What is the importance of calculating cable size?
7. Which of the following conditions dont require circuit protection?
 - a) Short circuits.
 - b) Excessive Current
 - c) Closed circuit
 - d) Excessive Heat
8. A good fuse wire should possess the following characteristics except
 - a) Low resistivity
 - b) High melting point
 - c) Low melting point
 - d) Low conductivity of the metal vapours formed, when the fuse is blown off.
9. A circuit breaker is a short length of wire that melts and breaks in case of excessive current.
 - a) True
 - b) False

- a) A fuse is breaker is a short length of wire that melts and breaks in case of excessive current.
 - a. True
 - b. False

Practical exercise

- a) Demonstrate ability to select the size and type of circuit Protective devices depending on the specific installation design.
- b) Choose the cable sizes for installation design, as per the data sheets provided in the IEE regulations.

6.3.5.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- 1. Drawing instruments
- 2. Drawing table
- 3. Calculator
- 4. Data sheets.

6.3.5.5. References

- 1. Brian S., IEng, MIET, (2008), Wiring Regulations: Inspection, Testing and Certification 17th Edition IEE, Elsevier Ltd, Corporate Drive, Suite 400, Burlington, MA 01803, USA.
- 2. Thompson F, G., (1972), Electrical installation technology, Longman, London
- 3. Christopher Kitcher, (2013), Practical Guide to Inspection, Testing and Certification of Electrical Installations, Routledge, New York
- 4. Bill Atkinson, (2002), Electrical Installation Designs, Third Edition, Blackwell Publishing Ltd, Osney Mead, Oxford OX2 0EL, UK

6.3.6. Learning Outcome No. 5. Prepare working drawings

6.3.6.1. Learning Activities

Learning Outcome No. 5. Prepare working drawings	
Learning Activities	Special Instructions
1. Draw various types of lines and codes as per the scope. 2. Draw different electrical symbols and diagrams as per the specific installation design. • Tittle block • Block diagrams • Circuit diagrams • Schematic diagrams • Wiring diagrams 3. Use Auto CAD to produce electrical drawings as per the cope 4. Interpret specific electrical diagrams as per the installation design.	

6.3.6.2. Information Sheet No. 6/LO5.

Introduction

This learning element equips the trainee with competencies in using drawing equipment to interpret and draw various electrical drawings as applied to the specific installation design. It also introduces the learner to computer aided designs using the appropriate AutoCAD software.

The trainee will learn how to draw the various types of electrical drawings and use the drawing instruments appropriately.

The following lines are used in technical drawing. They are shown in Fig, TL below.

Orthographic Projection.

Involves parallel projection applied in preparing drawing of an object. The lines are perpendicular to the plane. This plane is faced toward the object whose view is to be prepared as indicated below.

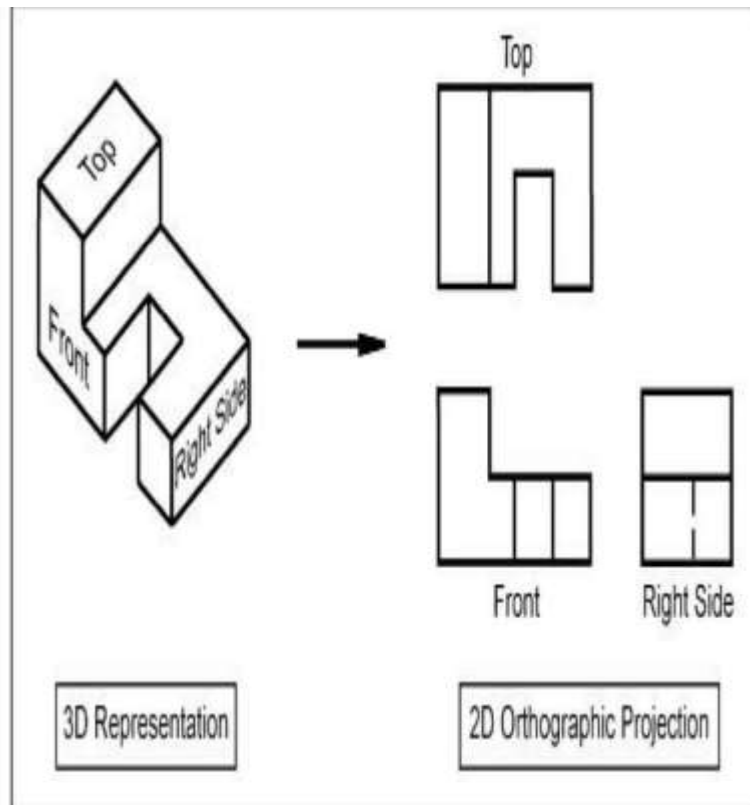


Figure 65: Orthographic drawing.

If the plane is kept in a vertical position, then it is called the vertical plane.

If the plane is kept in a horizontal position, then it is called the horizontal plane.

The following views are formed of an object in Orthographic Projection.

1. Front View.
2. Top View.
3. Back View.
4. Bottom View.
5. Right Side View.
6. Left Side View.

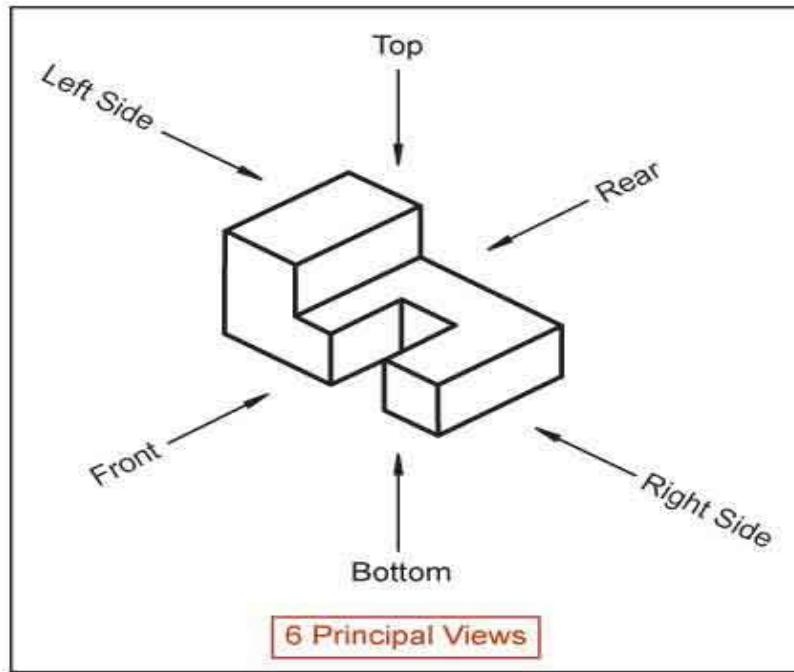


Figure 66: six principle views of orthographic projection.

Block diagrams

A block diagram is a diagram of a system in which the principal parts or functions are represented by blocks connected by lines that show the relationships of the blocks.

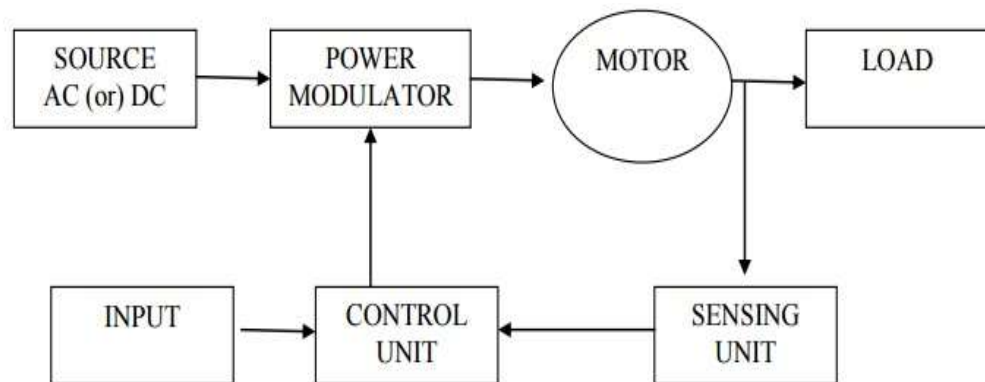


Figure 67: Block diagram of Electrical drives

Block diagrams use very basic geometric shapes, boxes and circles. The principal parts and functions are represented by blocks connected by straight and segmented lines illustrating relationships.

Circuit diagram

A circuit diagram is a visual display of an electrical circuit using either basic images of parts or industry standard symbols. Symbol usage depends on the audience viewing the diagram.

Circuit Diagram Symbols

The following are the various electrical symbols used in electrical schematic diagrams. The symbols conform to BS 3939 standards.

Wiring Diagram

A wiring diagram is a simple visual representation of the physical connections and physical layout of an electrical system or circuit.

Schematic diagram

A schematic is defined as a picture that shows something in a simple way, using symbols.

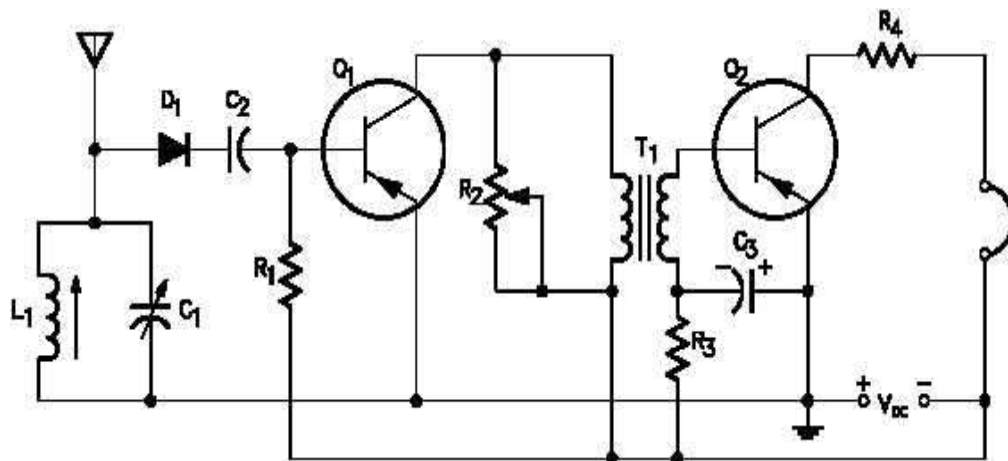


Figure 68: a schematic diagram of an electronic circuit.

Line diagram

In electrical Engineering, a one-line diagram also called a single-line diagram is a simplified notation for representing a three-phase power system.

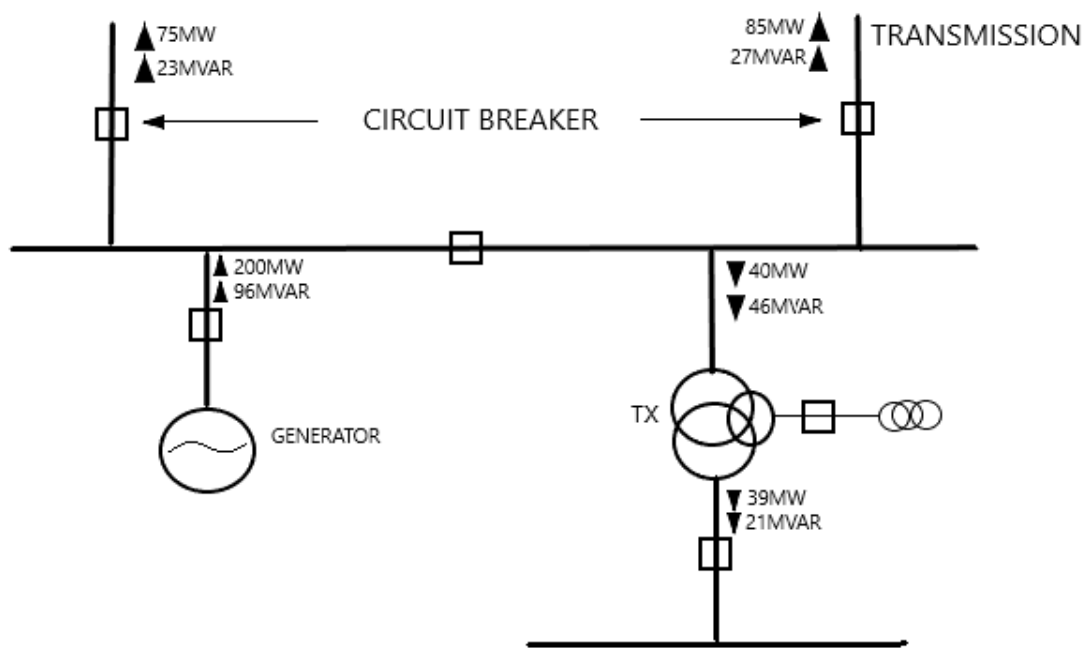


Figure 69: One line diagram of a three phase system

AUTO CAD

Electrical symbols, circuits and drawings can also be drawn using computer programs. CAD stands for computer aided design and describes using computers to create technical drawings. AutoCAD is a specific type of professional CAD software that can create both 2D and 3D drawings and models.

How to make electrical drawings using AutoCAD.

Electrical circuits can be drawn using an AutoCAD. The following is an example of how this can be done using the software

Creating an electrical drawing using our electrical symbol library add-on for AutoCAD.

The following steps are followed when drawing in AutoCAD.

1. After installing the Electrical Symbol Library - start AutoCAD. On the Menu bar, Choose Imperial or Metric symbols.
2. The electrical symbols come in two versions - Imperial and Standard version. In the menu this is shown as "Y32.2 (Imp)" and the Metric version as "Y32.2 (Met)".
3. In case you are using Standard sized drawing sheets, use the Imperial version and if using Metric sized drawing sheets, use the Metric version. Selecting the wrong library will result in tiny electrical symbols if imperial symbols are used on Metric sized sheets. On the other hand, if metric symbols are used on Imperial sized sheets, then they will appear huge.
4. Decide scale and insert drawing sheet. Having decided which symbol library to use, there are now two options. The first one is to import or develop your own drawing sheet, in which case, right click on the appropriate Menu bar heading and from the

dropdown menu, right click on “Parameters”. This will set the correct Snap value and other parameters.

5. The second option is to go to the bottom of the dropdown menu and select the required drawing sheet size and hit ‘Enter’. The displayed sheet is now displayed and is pre-set with the correct parameters
6. Check and adjust your drawing settings
Since the majority of schematic diagrams have connecting lines that run vertically or horizontally, it helps to put “Ortho mode” on. This can be toggled “On” or “Off” by hitting the “F8” key. In addition, check if Snap settings are set correctly to either a 1/4" or 1/2" as this will help align the electrical schematic as well.

6.3.6.3. Self-Assessment

1. Explain Orthographic Projection.
2. Describe various views of Orthographic Projection
3. Describe a block diagram and its features
4. Differentiate between a circuit diagrams, wiring diagram. schematic diagram, line diagram
5. What is the importance of a block diagram?
6. Explain AUTOCAD
7. Student should be able to make various drawings using AUTOCAD
8. Draw the BS electrical symbols of the electrical components in the specific electrical diagram, as per the scope.
9. Draw the block diagram of a specific electrical schematic diagram as per te specific learning element.
10. is a diagram of a system in which the principal parts or functions are represented by blocks connected by lines that show the relationships of the blocks.
 - a) A circuit diagram
 - b) A wiring diagram
 - c) A block diagram
11. is a visual display of an electrical circuit using either basic images of parts or industry standard symbols. Symbol usage depends on the audience viewing the diagram.
 - a) A circuit diagram
 - b) A wiring diagram
 - c) A block diagram
12. is a simple visual representation of the physical connections and physical layout of an electrical system or circuit.
 - a) A circuit diagram
 - b) A wiring diagram
 - c) A block diagram
13. In electrical Engineering, a one-line diagram also called a block diagram is a simplified notation for representing a three-phase power system.

- a) True
 - b) False
14. A circuit diagram is a visual display of an electrical circuit using either basic images of parts or industry standard symbols
- a) True
 - b) False

Practical exercise

1. Draw various types of lines and codes as per the scope.
2. Draw different electrical symbols and diagrams as per the specific installation design such as
 - Tittle block
 - Block diagrams
 - Circuit diagrams
 - Schematic diagrams
 - Wiring diagrams
3. Use Auto CAD to produce electrical drawings as per the cope
4. Interpret specific electrical diagrams as per the installation design.

6.3.6.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

1. Drawing instruments
2. Computer
3. Printer
4. AutoCAD software.

6.3.6.5 References

1. Brian S., IEng, MIET, (2008), Wiring Regulations: Inspection, Testing and Certification 17th Edition IEE, Elsevier Ltd, Corporate Drive, Suite 400, Burlington, MA 01803, USA.
2. Thompson F, G., (1972), Electrical installation technology, Longman, London
3. Christopher Kitcher, (2013), Practical Guide to Inspection, Testing and Certification of Electrical Installations, Routledge, New York
4. Bill Atkinson, (2002), Electrical Installation Designs, Third Edition, Blackwell Publishing Ltd, Osney Mead, Oxford OX2 0EL, UK
5. Brian Scaddan, (1990), Modern Electrical Installation for Craft Students
6. You tube link: <https://youtu.be/q3wa6ZPVWd8>

6.3.7. Learning Outcome No. 6. Plan for logistics

6.3.7.1. Learning Activities

Learning Outcome No. 6. Plan for logistics	
Learning Activities	Special Instructions
1.Planning logistics for an installation project as per the project design 2.Execute the logistics program planned in learning outcome	

6.3.7.2. Information Sheet No 6/LO6.

Planning for logistics is a learning element equipped for the trainee to gain competencies in the logistics involved in transporting the equipment, materials, tools and human resource at the installation site.

Logistics

Once survey for the site has been done, planning for transporting of materials and personnel at the work site has to be planned. One way of doing this is through logistics.

Logistics is defined as the process of planning, implementing and controlling the efficient and cost-effective flow and storage of raw materials, goods, equipment and personnel from the point of origin until the completion of an activity, in accordance with end-user's requirements. In this respect, logistics will involve the following.

1. Transporting materials to the site.
2. Transporting tools to the site.
3. Planning for the storage of the equipment, tools and materials once they arrive on site
4. Making safety arrangements for the materials and tools once they are on site.

In its comprehensive sense, logistics includes all the essentials that institute a delivery infrastructure for electrical materials and equipment

Logistics requirements for the materials, equipment and Tools

The following logistical requirements should be considered for the transportation of materials, equipment and tools to the construction site:

- Packing the consignment

The nature of the goods together with the mode of transportation and the climatic conditions during transit and at the destination, determine the required packaging.

The durability, size and weight of the packages should be considered in relation to the planned means of transportation.

- Packing & transportation instructions

Climatic conditions on transit and at the dispatch end, should be considered to ensure the packaging can withstand heat, cold, rain, humidity, mould, dust, salt water spray, etc.

- Labelling and marking the consignment

The labelling and shipping marks should include:

- consignee
- destination
- project identification
- order number
- Case number.

Contents of the packages should not be included to discourage theft and pilferage.

- Modes of transportation

The mode of transporting the materials and equipment should be decided and planned in advance. The type of transport will depend on the nature of the installation project.

- Insurance during transportation

During transportation and storage, all cargo is vulnerable to a range of risks, such as damage, pilferage and theft, breakage, non-receipt of part of or an entire consignment. Cargo insurance provides protection against potential financial losses resulting from such risks.

- Transportation documents

Complete and appropriate Transportation documents are of critical importance for the timely delivery of goods. The supplier needs documents to move the order from its premises, and to receive payment from the buyer. The transporter requires documents to contract carriage, the consignee requires documents to claim the goods at arrival.

While the particular documents required vary from case to case, every consignment should have documented evidence of:

1. contents of the shipment
2. weight and volume of contents
3. origin of goods (if required)
4. price of the goods
5. Evidence of transport of the goods.

Site storage

Once the installation consignment arrives at the installation site, offloading is done and storage arrangements made.

Human resource requirements are also done to identify the tasks and the personnel to execute those tasks. This includes

- Management of the project
- Remunerations
- Technical assignments
- Risk evaluation

Mode of communication is put in place to ensure efficient and effective execution of the installation project.

6.3.7.3 Self-Assessment

1. Plan and execute a logistic program for an installation site.
2. Explain logistics
3. Describe factors involved in logistics
4. What are the Logistics requirements for the materials, equipment and Tools?
5. What is the importance of labelling and marking the consignment?
6. Explain site storage
7. What are the human resource requirements in site storage?
8. While the particular documents required vary from case to case, every consignment should have documented evidence of the following except
 - a) contents of the shipment
 - b) weight and volume of contents
 - c) size of the goods
 - d) origin of goods (if required)
 - e) Evidence of transport of the goods
9. Human resource requirements are also done to identify the tasks and the personnel to execute those tasks. Which of the following is not a requirement?
 - a) Management of the project
 - b) Remunerations
 - c) Financial requirement
 - d) Risk evaluation
10. logistics includes all the essentials that institute a delivery infrastructure for electrical materials and equipment
 - a) True
 - b) False
11. The durability, size and weight of the packages should be considered in relation to the planned means of transportation.
 - a) True
 - b) False

Practical exercise

- a) Identify planning logistics for an installation project as per the project design
- b) Execute the logistics program planned in learning outcome

6.3.7.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

1. Means for transportation
2. Installation materials as per the installation design
3. Equipment as per the installation design
4. Tools as per the installation design.

6.3.7.5 References (APA)

1. Seema Gupta & Kumar Krishnaan, Logistics management, Knowledge books distributors
2. Michael H. Hugos, (2016), Essentials of Supply Chain Management

6.3.8 Learning Outcome No. 7. Prepare list of tools, equipment and materials

6.3.8.1 Learning Activities

Learning Outcome No. 7. Prepare list of tools, equipment and materials	
Learning Activities	Special Instructions
1. Establish a list of the required tools and materials needed for the project as per the design. • Cutting tools ➤ Electricians knife ➤ Hacksaw ➤ Machete • General working tools ➤ Cable strippers ➤ Pliers ➤ Screwdrivers ➤ hammers ➤ chisels ➤ Bending springs ➤ Steel tapes ➤ Draw wires ➤ Hacksaws ➤ Drills • Measuring tools • Measuring equipment ➤ Oscilloscope ➤ Ammeter ➤ Ohmmeter ➤ voltmeter • materials ➤ cables ➤ cables and conductors ➤ fittings ➤ conduits 2. Assemble tools and materials for the installation work as per the specific installation design.	

6.3.8.2. Information Sheet No. 6/ LO7.

This element equips the trainee with expertise in techniques for handling, care and use of electrical tools and equipment. The trainee will also gain knowledge and skills in ways of handling inventory for materials, tools and equipment.

Tools for the particular installation are checked for specifications and functionality as per the operating procedures.

The most used electrical tools for installation projects are as follows.

1. Fish tape

A fish tape is used to pull stranded or solid wire through metal or PVC conduit. Cable lube is available to assist you in pulling the wires through the pipe.

2. Standard tape measure

A standard tape measure is used for all kinds of field measurements, such as setting heights for switches and outlets, centering lighting fixture boxes, and marking surfaces for cutouts.

3. Non-Contact Voltage Tester

A voltage tester is used for a quick safety check to make sure there's no voltage in an electrical wire or device before you start working on it.

4. Hammer

A hammer is used to secure boxes equipped with nail-on brackets to wall studs and other framing members in a home.

5. Tongue-and-Groove Pliers

Tongue-and-groove pliers are used to remove knockouts from metal electrical boxes, tighten cable clamps, and adjust expansion-type ceiling fan boxes.

6. Wire Strippers

Wire strippers are used to cut and strip insulation from electrical wire.

7. Side-Cutting Diagonal Pliers

Diagonal cutting pliers, sometimes called side snips or dikes, are used to cut wires

8. Pliers

This is an electrician's do-it-all pliers. They cut wires, twist wires together, and grip wires for pulling.

9. Spirit Level

A small level, such as a torpedo level, fits easily in a tool pouch and is used to make sure your work is level and plumb.

10. Flashlight

Electrical work involves a lot of dark places, from attics and basements to wall and ceiling cavities to the insides of electrical boxes.

11. Electricians Knife

A utility knife, or box cutter, is handy for cutting sheathing from non-metallic (Romex) cable, to cut off electrical tape, and to open cardboard boxes.

12. Screwdrivers

Electricians keep screwdrivers with them at all times, for removing and installing cover plates, outlets, switches, and many other devices.

13. Voltmeter or Multimeter

A voltmeter is used to read voltage levels and verify that circuits are indeed “live.” or off. Multimeters can read voltage levels as well as amperage (current), resistance, and DC voltage and amperage.

14. Wire Crimpers

Wire crimpers are used to crimp lugs or terminals onto wires. Many can also be used to strip wire insulation.



Figure 70: Electricians knife



Figure 71: Range of screw drivers



Figure 72: Allen Wrench Set (Image Courtesy: AliExpress)



Figure 73: Hacksaw



Figure 74: Pliers



Figure 75: Wire Stripper



Figure 76: Soldering gun



Figure 77: Multimeter (Image Courtesy: Amazon)

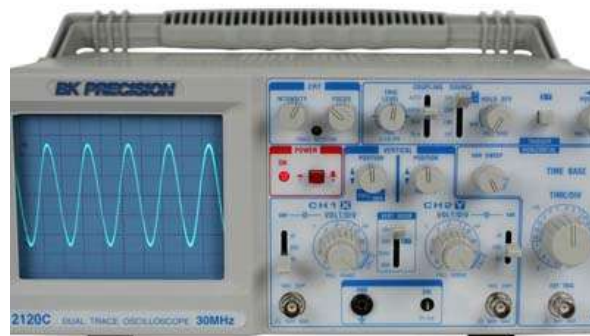


Figure 78: Oscilloscope (Image Courtesy: B&K Precision)



Figure 79: Signal Generator (Image Courtesy: Tektronix)



Figure 80: Tape Measure

6.3.8.3 Self-Assessment

1. Describe electrical tools for installation projects
2. Differentiate between pliers and screw drivers
3. is used to pull stranded or solid wire through metal or PVC conduit. Cable lube is available to assist you in pulling the wires through the pipe.
 - a) fish tape
 - b) voltage tester
 - c) Wire crimpers
 - d) Voltmeter
4. is used for a quick safety check to make sure there's no voltage in an electrical wire or device before you start working on it.
 - a) Fish tape
 - b) Voltage tester
 - c) Wire crimpers
 - d) Standard tape measure
5. is used for all kinds of field measurements, such as setting heights for switches and outlets, centering lighting fixture boxes, and marking surfaces for cutouts.
 - a) Fish tape
 - b) Voltage tester
 - c) Wire crimpers
 - d) Standard tape measure
6. Wire crimpers are used to crimp lugs or terminals onto wires. Many can also be used to strip wire insulation.
 - a) True

- b) False
- 7. Tongue-and-groove pliers are used to remove knockouts from metal electrical boxes, tighten
 - a) True
 - b) False
- 8. Explain safe storage procedures for various tools
- 9. The trainee should have ability to use the various tools appropriately
- 10. Draw the following electrical tools
 - a. Pliers
 - b. Hacksaw
 - c. Screwdriver

Practical exercise

1. Assemble tools and materials for the installation work as per the specific installation design.
2. Establish a list of the required tools and materials needed for the project as per the design.

6.3.8.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Cutting tools
 - Electricians knife
 - Hacksaw
 - Machete
- General working tools
 - Cable strippers
 - Pliers
 - Screwdrivers
 - hammers
 - chisels
 - Allen keys
 - Bending springs
 - Steel tapes
 - Draw wires
 - Hacksaws
 - Drills
- Measuring tools
- Measuring equipment
 - Oscilloscope
 - Ammeter
 - Ohmmeter
 - voltmeter
- materials
 - cables
 - cables and conductors
 - fittings
 - conduits

6.3.8.5 References

1. Brian S., IEng, MIET, (2008), Wiring Regulations: Inspection, Testing and Certification 17th Edition IEE, Elsevier Ltd, Corporate Drive, Suite 400, Burlington, MA 01803, USA.
2. Thompson F, G., (1972), Electrical installation technology, Longman, London
3. Christopher Kitcher, (2013), Practical Guide to Inspection, Testing and Certification of Electrical Installations, Routledge, New York
4. Bill Atkinson, (2002), Electrical Installation Designs, Third Edition, Blackwell Publishing Ltd, Osney Mead, Oxford OX2 0EL, UK
5. Brian Scaddan, (1990), Modern Electrical Installation for Craft Students

6.3.9. Learning Outcome No. 8. Prepare installation work plan

6.3.9.1. Learning Activities

Learning Outcome No. 8. Prepare installation work plan	
Learning Activities	Special Instructions
1. Prepare the work schedule as per the job 2. Assign tasks to be performed to the installation team as per the work schedule. 3. Raise the necessary permit and licenses as per the job. • Gate/Access passes • Name tags • ERC license • Kenya power license	

6.3.9.2 Information Sheet No. 6/ LO8.

This learning element is to equip the trainee with the knowledge, skills and the correct attitude towards performing the actual installation work. The trainee is shown how to perform the actual installation project work.

The installation drawing is acquired as per the established procedures. This includes rules and regulations as stipulated in the Kenya power bylaws and the IEE regulations.

The gate passes or tags for entry are issued if the area for the project is restricted or needs such permits.

Work schedule is prepared based on the scope and the working drawing

An employee's work schedule includes the days and times that he or she is expected to be working. In most cases, this will be a set number of days and hours.

Work Schedule

The most common work schedule requires employees to work from Monday to Friday, from 8 a.m. to 5 p.m.

Shift Work Schedule

Shift work schedules happen when a company divides the day into shifts and assigns employees to work set periods of time.

Flexible Work Schedule

Other work schedules are flexible. Flexible schedules allow employees to vary their arrival and departure, and sometimes even choose the days that they work. For example, a company might allow employees to come in any time they want, as long as they complete 8 hours of work every day.

Part-Time and Full-Time Schedules

A standard definition of a full-time employee is someone who works a 40-hour week, but there is no official, legal guideline. Similarly, there is no legal guideline for the number of hours worked by part-time employees in a week – it's simply defined as

someone who works fewer hours per week than a full-time employee at the same company.

A Gantt chart

A Gantt chart, is commonly used in project management, and is one of the most popular and useful ways of showing activities (tasks or events) displayed against time.

On the left of the chart is a list of the activities and along the top is a suitable time scale. Each activity is represented by a bar; the position and length of the bar reflects the start date, duration and end date of the activity.

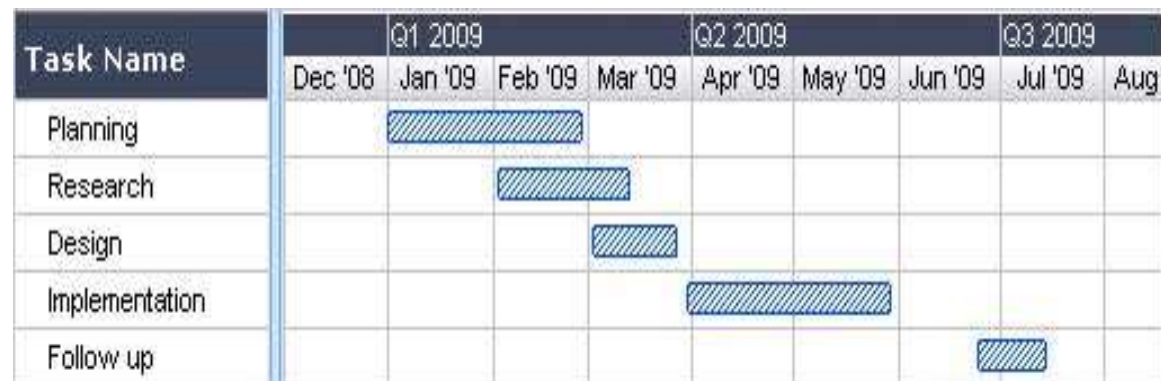


Figure 81: simple Gantt chart.

Energy Regulatory commission (ERC) – Kenya

Class C-2

This class allows the electrician to carry out electrical installation work for connection to a single phase supply at low voltage to up to two storey residential and commercial buildings not used as factories or places of public entertainment;

Class C-1

This class allows the electrician to carry out electrical installation work as in Class C-2, and for connection to a three phase supply at low voltage to up to four storey buildings not used as factories or places of public entertainment.

Class B

This class allows the electrician to carry out electrical installation work as in Class C-1, but without limitation as to number of storeys in the buildings and whether used as factories or places of public entertainment or otherwise, and for connection to supply metered at voltages not exceeding medium.

Class A-1

This class allows the electrician to carry out all kinds of electrical installation work.

Class A-2

This class allows the electrician to carry out specialized electrical installation work.

6.3.9.3. Self-Assessment

1. Explain work schedule
2. Differentiate between work schedule, shift work schedule and flexible work schedule
3. Describe Part-Time and Full-Time Schedules
4. Explain a Gantt chart
5. What is the importance of Gantt chart
6. Describe Energy Regulatory commission (ERC) – Kenya
7. allows the electrician to carry out electrical installation work for connection to a single phase supply at low voltage to up to two storey residential and commercial buildings not used as factories or places of public entertainment;
 - a) Class C-1
 - b) Class C-2
 - c) Class A-1
 - d) Class B
8. allows the electrician to carry out electrical installation work as in Class C-2, and for connection to a three phase supply at low voltage to up to four storey buildings not used as factories or places of public entertainment.
 - a) Class C-1
 - b) Class C-2
 - c) Class A-1
 - d) Class B
9. allows the electrician to carry out electrical installation work as in Class C-1, but without limitation as to number of storeys in the buildings and whether used as factories or places of public entertainment or otherwise, and for connection to supply metered at voltages not exceeding medium.
 - a) Class C-1
 - b) Class C-2
 - c) Class A-1
 - d) Class B
10. allows the electrician to carry out all kinds of electrical installation work.
 - a) Class C-1
 - b) Class C-2
 - c) Class A-1
 - d) Class B
11. Flexible schedules allow employees to vary their arrival and departure, and sometimes even choose the days that they work
 - a) True
 - b) False

12. Class A-1 allows the electrician to carry out all kinds of electrical installation work.

- a) True
- b) False

Practical exercise

- a) Prepare the work schedule as per the job
- b) Assign tasks to be performed to the installation team as per the work schedule.
- c) Explain the IEE regulations for the installation of a domestic installation wiring, and draw the wiring diagram of both the lighting and power circuits

6.3.9.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Cutting tools
 - Electricians knife
 - Hacksaw
 - Machete
- General working tools
 - Cable strippers
 - Pliers
 - Screwdrivers
 - hammers
 - chisels
 - Allen keys
 - Bending springs
 - Steel tapes
 - Draw wires
 - Hacksaws
 - Drills
- Measuring tools
- Measuring equipment
 - Oscilloscope
 - Ammeter
 - Ohmmeter
 - voltmeter
- materials
 - cables
 - cables and conductors
 - fittings

6.3.2.5. References

1. Brian S., IEng, MIET, (2008), Wiring Regulations: Inspection, Testing and Certification 17th Edition IEE, Elsevier Ltd, Corporate Drive, Suite 400, Burlington, MA 01803, USA.
2. Thompson F, G., (1972), Electrical installation technology, Longman, London
3. Christopher Kitcher, (2013), Practical Guide to Inspection, Testing and Certification of Electrical Installations, Routledge, New York
4. Bill Atkinson, (2002), Electrical Installation Designs, Third Edition, Blackwell Publishing Ltd, Osney Mead, Oxford OX2 0EL, UK
5. Brian Scaddan, (1990), Modern Electrical Installation for Craft Students

6.3.10. Learning Outcome No. 9. Establish installation team

6.3.10.1. Learning Activities

Learning Outcome No. 9. Establish installation team	
Learning Activities	Special Instructions
• Design communication procedure for the installation team • Assign responsibilities • Practice team building	

6.3.10.2. Information Sheet No. 6/LO9

This learning element on establishing installation team is intended to equip the training on team building techniques and task distribution for the execution of the project. The contractor will establish the tasks to be performed and the persons to perform the tasks.

The trainee should be able to acquire knowledge and skills on how to build a working team, by hiring and assigning duties to individuals who are competent in the respective field.

Team building

The purpose of team building is to increase trust, improve communication, increase collaboration and increase or maintain motivation. The important thing in team building is to make time and space for co-workers to bond.

The following is the process of team formation.

- Forming – The initial stage is when your team forms. A work team is brought together to achieve a goal. Two important aspects of forming are getting to know the co-workers on your team and getting familiar with your team's purpose as you discuss and plan mission, goals and workflow.
- Storming – As you can guess, the storming stage can be turbulent as team members assess each other's personalities, strengths and weaknesses. During the storming period, it may be a good idea to engage in a team building program. It's vital to come out of this stage successfully; with a good appreciation of your team members.
- Norming – How will your team function on an ongoing basis? Do you acknowledge there may be competition and differences within your team? Can everyone accept colleague's strengths and weaknesses? It's vital to find a path forward in which you all work in a complementary fashion.
- Performing – Every team's goal is to perform as a high functioning team with energy and purpose. This comes when there's mutual respect among team members with boundaries that respect each other's roles. It's important that everyone trusts in each other's competence and expertise.

6.3.10.3. Self-Assessment

1. The installation team to perform a mock team building exercise.
2. Explain team building
3. Describe the process of team formation
4. Differentiate between storming and norming
5. What is the importance of team building
6. Two important aspects of..... stage are getting to know the co-workers on your team and getting familiar with your team's purpose as you discuss and plan mission, goals and workflow.
 - a) Storming
 - b) Forming
 - c) Norming
 - d) Performing
7. In.....team members assess each other's personalities, strengths and weaknesses. It's vital to come out of this stage successfully; with a good appreciation of your team members.
 - a) Storming
 - b) Forming
 - c) Norming
 - d) Performing
8. stage address questions such as how will your team function on an ongoing basis? Do you acknowledge there may be competition and differences within your team? Can everyone accept colleague's strengths and weaknesses? It's vital to find a path forward in which you all work in a complementary fashion.
 - a) Storming
 - b) Forming
 - c) Norming
 - d) Performing
9. At stage it's important that everyone trusts in each other's competence and expertise.
 - a) Storming
 - b) Forming
 - c) Norming
 - d) Performing
10. The important thing in team building is to make time and space for co-workers to bond.
 - a) True
 - b) False
11. During the storming period, it may be a good idea to engage in a team building program.
 - a) True
 - b) False

Practical exercise

- a) Design communication procedure for the installation team and assign responsibilities
- b) Practice team building

6.3.10.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

1. Various sporting balls skipping ropes, and games kits.

6.3.10.5. References

1. Maxwell, J. C, (2013), The 17 Indisputable Laws of Teamwork HarperCollins Leadership

6.3.11. Learning Outcome No. 10. Prepare work site

6.3.11.1. Learning Activities

Learning Outcome No. 10. Prepare work site	
Learning Activities	Special Instructions
1. Identify hazard and safety requirement for the site. 2. Provision of relevant work plan that conforms to relevant regulatory requirements • IEE regulations • OSHA act • County by laws 3. Prepare work site for installation works • Provide water, and telephone facilities • Clear path ways for access to site	

6.3.11.2. Information Sheet No. 6/LO10.

This element provides information on competencies required by the trainee on how to identify and prepare a work site for electrical installation work. It also equips the trainee on knowledge and sound practices on safety

The competencies acquired will help the trainee to control electrical risks and protect workers who use electricity.

As a general practice, you must engage workers and have effective worker participation practices. This means giving workers a reasonable opportunity to express their views and to raise work health or safety concerns. Consider what workers have to say; for example, when identifying electrical hazards and deciding how to eliminate or minimize risks. Their views can help you to improve work health and safety.

Electrical Hazards and related safety issues and mitigation ways as per the Occupational safety and Health Act

- **Overhead Power Lines**

Overhead powered and energized electrical lines have high voltages which can cause major burns and electrocution to workers.

- **Tools and Equipment**

Exposure to damaged electrical tools and equipment can be very dangerous. Do not fix anything unless you are qualified to do so.

- **Inadequate Wiring and Overloaded Circuits**

Using wires with inappropriate size for the current can cause overheating and fires to occur.

- **Exposed Electrical Parts**

Examples of exposed electrical parts include temporary lighting, open power distribution units, and detached insulation parts on electrical cords.

- Improper Grounding

The most common electrical violation as per the OSHA standards is improper grounding of equipment.

- Damaged Insulation

Defective or inadequate insulation is a hazard. Be aware of damaged insulation and report it immediately.

- Wet Conditions

Never operate electrical equipment in wet locations. Water greatly increases the risk of electrocution especially if the equipment has damaged insulation. Have a qualified electrician inspect electrical equipment that has gotten wet before energizing it.

Electricity supply arrangements at the construction site

Electricity can be supplied to the installation construction site through a temporary or permanent connection.

- A builder's temporary (see Figure 1) provides an electricity supply at a worksite where there is no existing connection. Only a licensed electrical worker can install, connect, modify or move a builder's temporary.
- An electrician can install a permanent connection to a mains supply at the beginning of the project.
- Electrical work on properties being renovated typically feeds off the existing permanent switchboard, rather than a builder's temporary.

People working on the same site must, so far as is reasonably practicable, work together (consult, cooperate and coordinate activities) to manage electrical safety risks where you have the same health and safety duty.

- Talk with the people on the construction site about how electricity will be supplied and used in areas where your health and safety duties overlap. This will help to prevent any gaps in managing health and safety risks.
- All contractors who use the electrical supply at the site must make sure their equipment is safe to use and without risks to others.
- All electrical equipment should be protected by a Residual Current Device
- Hiring companies must not hire out equipment that is electrically unsafe.

They are responsible for testing and tagging hire equipment before you hire it.

Temporary supply switchboard

- Temporary supply switchboard gives the electrical technicians at the installation site an electricity supply on a worksite where there is no existing connection to an electricity network

Temporary supply switchboard functions as a main switchboard and has one or more Residual current device protected outlets.

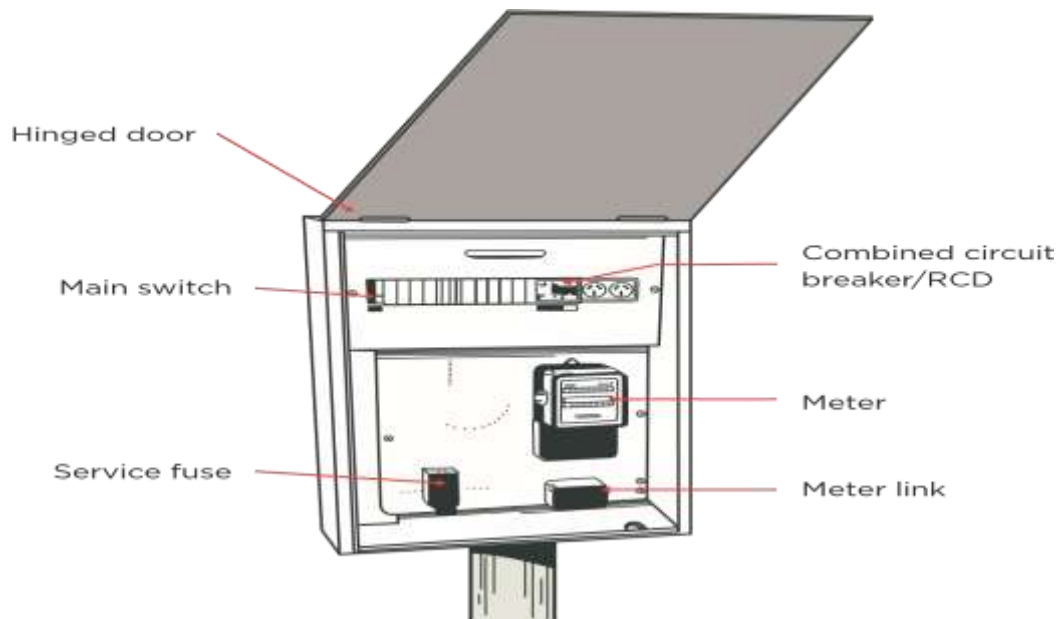


Figure 82: Temporary supply switchboard

Before using a Temporary supply switchboard, an electrician must give you:

- A Certificate of Compliance
- A Record of Inspection
- An Electrical Safety Certificate.

All these certificates should come from the Electricity power supply authority, Kenya power.

6.3.11.3. Self-Assessment

1. Explain the safety requirements at the place of work when dealing with an electrical installation.
2. Explain the IEE regulations regarding temporary installation.
3. Explain OSHA act
4. Explain Electrical Hazards and related safety issues and mitigation ways as per the Occupational safety and Health Act
5. Describe electricity supply arrangements at the construction site
6. Explain temporary switch board and its applications
7. All contractors who use the electrical supply at the site must make sure their equipment is safe to use and without risks to others.
 - a) True
 - b) False
8. gives the electrical technicians at the installation site an electricity supply on a worksite where there is no existing connection to an electricity network
 - a) Temporary supply switchboard
 - b) Socket
 - c) Switch
 - d) Main switch board

9. Before using a Temporary supply switchboard, an electrician must give you the following except
 - a) A Certificate of Compliance
 - b) A Record of Inspection
 - c) Invoice
 - d) An Electrical Safety Certificate.
10. Water greatly increases the risk of electrocution especially if the equipment has damaged insulation
 - a) True
 - b) False
11. Only a licensed electrical worker can install, connect, modify or move a builder's temporary.
 - a) True
 - b) False
12. Connect and test a simple circuit

Practical exercise

1. Identify hazard and safety requirement for the site.
2. Provision of relevant work plan that conforms to relevant regulatory requirements
3. Prepare work site for installation works such as provide water, and telephone facilities and clear path ways for access to site

6.3.11.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Cutting tools
- Measuring tools
- Measuring equipment
- Cables and conductors
- Crimping tools
- Conduits
- Cable strippers
- Pliers
- Screw drivers
- Hammers
- Chisels
- Electrician knives
- Crimping tools
- Bending springs
- Steel tapes
- Draw wires
- Hack saws
- Drills
- Stock and die

- Vice

Materials

- Cables
- Fittings

6.3.11.5. References

1. Francis G Thompson, (1972), Electrical installation technology, Longman, London
2. Christopher Kitcher, (2013), Practical Guide to Inspection, Testing and Certification of Electrical Installations, Routledge, New York

6.3.12 Learning Outcome No. 11. Perform marking, piping and fixing of accessories

6.3.12.1 Learning Activities

Learning Outcome No. 11. Perform marking, piping and fixing of accessories	
Learning Activities	Special Instructions
1. Identify marking piping and fixing tools as per the specific installation to be done. 2. Carry out marking as per the installation design while observing the OSHA act requirements and adhering to the IEE regulations 3. Performing piping of the conduits as per the installation design Fix the electrical accessories in the identified markings as per the design	

6.3.2.2. Information Sheet No. 6/LO11

By the end of the learning outcome, the trainee should be able to perform marking, piping and fixing accessories in an electrical installation as per the design. The trainee should identify the tools and materials needed for these tasks and be able to follow the procedures, standards and regulations as prescribed by the OSHA act, Kenya power by-laws and the IEE regulations.

Marking Piping fixing and accessories in Electrical installation.

Marking, piping and fixing accessories is done when the Concealed Conduit Wiring system is chosen.

In Concealed Conduit Wiring, PVC conduit pipes are placed inside the chiselled brick/block wall before plaster. The wall is later completely plastered and painted. Electrical wires are laid inside the conduits. This type of wiring are beautifully appealing since they are no electrical wires/conduits seen on the top of the wall.



Figure 83: A photograph showing the conduit lay out in concealed conduit wiring system.

Source:

[https://www.google.com/search?q=A+photograph+showing+the+conduit+lay+out+in+concealed+conduit+wiring+system.&tbm=isch&source=iu&ictx=1&fir=qLv4zAML8m2gEM%253A%](https://www.google.com/search?q=A+photograph+showing+the+conduit+lay+out+in+concealed+conduit+wiring+system.&tbm=isch&source=iu&ictx=1&fir=qLv4zAML8m2gEM%253A%253A)

Marking, piping and fixing accessories,

The following procedures show how marking, piping and fixing of accessories is done in concealed conduit systems.

Marking the positions for accessories on the wall and floor.

The positions for installing the accessories are located and marked.

Place the PVC pipes from the given entry holes only.

Marking tools

Bradawl

A bradawl is used to make hollows in wood or other materials in order to ease the insertion of a nail or screw.



Figure 84: Bradawl

Marking gauge

A marking gauge, also known as a scratch gauge, is used in woodworking and metalworking to mark out lines for cutting or other operations.



Figure 85: Marking gauge

Claw hammer

A claw hammer is a tool primarily used for driving nails into, or pulling nails from, some other object. Generally, a claw hammer is associated with installation for driving or removing screws.



Figure 86: Claw hammer

Marking knife

A marking knife is a woodworking layout tool. It is used to scribe a line to be followed by a hand saw or chisel when making woodworking joints and other operations



Figure 87: marking knife.

Other tools needed to carry out the concealed conduit installation and other types of installation include.

- Combinational plies
- Stock-and-die set
- Measuring tape
- Drill machine
- Screw range
- Pipe range
- Side cutter
- Nose plier
- Hack saw
- Wood saw
- Electricians knife
- Hammer
- File

Electrical accessories

Switch

A switch is used to make or break the electric circuit. Or it is used to switch “ON or OFF” the electric supply.

.

Lamp Holder

A lamp holder is used to hold the lamp, and connect it electrically to supply terminals, required for lighting purposes.

Ceiling Rose

These are fixed on walls near the ceiling. Normally these are used to provide tapping to the pendent lamp holder, ceiling fan and fluorescent tube etc through the flexible wire.

Socket

The sockets have insulated base with moulded base having three terminal sleeves. The two terminal sleeves having same cross-section are used to connect phase and neutral wire whereas the third having greater cross-section is used to connect with earth wire.

Main Switch

This switch is used to switch “on or off” the main supply. These switches are used to control the whole supply for a house, office and machine. In single-phase circuit I.C.D.P. main switches are used, whereas in three-phase circuits I.C.T.P. main switches are used to control the supply.

Fuse

It is the most common and important type of safety device used for domestic and commercial installations.

Miniature Circuit Breaker (M.C.B.)

A miniature circuit breaker is an electro-mechanical safety device which operate and disconnect the circuit supply, when the current drawn from the circuit increases to a pre-determined value.



Figure 88: Pattress Box

The following photographs show different types of electrical accessories used final electrical installations.



Figure 89: picture of a Socket outlet



Figure 90: Water proof switch



Figure 91: Industrial Plug



Figure 92: Ceiling Rose.



Figure 93: Straight batten lamp holder



Figure 94: lamp holder



Figure 95: Junction Box



Figure 96: gang surface patch

6.3.12.3. Self-Assessment

1. Carry out a piping exercise as instructed in the specific question.
2. Describe Marking Piping fixing and accessories in Electrical installation.
3. Explain concealed conduit wiring
4. Describe marking tools
5. How are the marking tools applied?
6. Explain electrical accessories
7. is a tool primarily used for driving nails into, or pulling nails from, some other object?
 - a) A miniature circuit breaker
 - b) A marking knife
 - c) A claw hammer
 - d) A contactor
8. is a woodworking layout tool used to scribe a line to be followed by a hand saw or chisel when making woodworking joints and other operations
 - a) A miniature circuit breaker
 - b) A marking knife
 - c) A claw hammer
 - d) A contactor
9. is an electro-mechanical safety device which operate and disconnect the circuit supply, when the current drawn from the circuit increases to a pre-determined value.
 - a) A miniature circuit breaker
 - b) A marking knife
 - c) A claw hammer
 - d) A contactor
10. In Concealed Conduit Wiring, PVC conduit pipes are placed inside the chiselled brick/block wall before plaster
 - a) True
 - b) False
11. A Marking gauge is used to make hollows in wood or other materials in order to ease the insertion of a nail or screw.
 - a) True
 - b) False

Practical exercise

1. Identify marking piping and fixing tools as per the specific installation to be done.
2. Carry out marking as per the installation design while observing the OSHA act requirements and adhering to the IEE regulations
3. Performing piping of the conduits as per the installation design
4. Fix the electrical accessories in the identified markings as per the design

6.3.12.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Materials
- Wood board/meta board/plastic board
- Conduits
- Junction boxes
- Ceiling roses
- Kit Kat fuse
- Lamp holder
- P.V.C holder
- Main switch
- Bushings
- Sockets
- Elbows
- Tees
- Screws
- Tools
- Combinational plies
- Stock-and-die set
- Measuring tape
- Drill machine
- Phase tester
- Screw range
- Pipe range
- Side cutter
- Metal hooks
- Nose plier
- Hack saw
- Wood saw
- Electricians knife
- Hammer
- Megger
- Voltmeter
- Stair
- file

6.3.12.5. References

1. Brian S., IEng, MIET, (2008), Wiring Regulations: Inspection, Testing and Certification 17th Edition IEE, Elsevier Ltd, Corporate Drive, Suite 400, Burlington, MA 01803, USA.
2. Thompson F, G., (1972), Electrical installation technology, Longman, London

3. Christopher Kitcher, (2013), Practical Guide to Inspection, Testing and Certification of Electrical Installations, Routledge, New York
4. Bill Atkinson, (2002), Electrical Installation Designs, Third Edition, Blackwell Publishing Ltd, Osney Mead, Oxford OX2 0EL, UK
5. Brian Scaddan, (1990), Modern Electrical Installation for Craft Students
6. Francis, T.G., (1949), Electrical Installation work, Longman group ltd, Longman house, Harlow, England

6.3.13 Learning Outcome No. 12. Perform electrical Installation

6.3.13.1 Learning Activities

Learning Outcome No. 12. Perform electrical Installation	
Learning Activities	Special Instructions
1. Install the electrical installation design in element 3 as per the drawings while observing the IEE regulations • Lighting circuits • Power circuits • Water heating circuits • Electric cooker circuits • Call and alarm circuits 2. Observe safety procedures as per the OSHA act. 3. Perform the insulation resistance test as per the IEE regulations.	

6.3.13.2 Information Sheet No 6/LO12.

This learning outcome is intended to equip the trainee with competencies in executing the actual electrical installation work. It involves differentiating single phase and three phase installation systems and explaining which specific installation is designed for domestic, commercial or industrial works.

Single Phase wiring installation

In Single Phase supply - 240V in Kenya 230V in United Kingdom and European Union, 120V in United States and Canada- there are 2 (one is Line (Live) and the other one is Neutral) incoming cables from the utility poles to energy meter and then directly connected to the main distribution board (Consumer unit)

The procedure of installing a single phase Main Distribution Board is as follows.

1. Connect the Incoming Live and Neutral (L and N) wires from the electric utility pole to the Single Phase Energy meter
2. Connect the Incoming Live and Neutral (L and N) Wires to the 2 Pole Moulded Case Circuit Breaker (MCCB). It will be used as a main switch for all sections in the home.
3. Connect the MCCB to the Double Pole MCBc, RCD, Single Pole MCBs respectively for each sections and the outgoing wires and cable to the sub circuits and final sub circuits. Do the same steps for each section (3 Switch boards in our case). Keep in mind that proper connection should be done for Neutral and Live wires in the whole system as shown in fig 1. If confused, wiring color codes for IEC and NEC are given below in the info section for both single phase and three phase wiring.

4. Now, connect the electrical devices and appliances with the Earth link terminal which leads to earth electrode in the earthing and grounding system.
5. Do the same steps for all three distribution boards.

Requirements for Three Phase Wiring Installation

Three phase power installation can be done as per the installation design. The following accessories are needed for the installation of a three phase system.

1. 1, Three Phase Energy meter
2. 1, Three Pole MCCB, 63A
3. 3, Double Pole MCBs, 63A
4. 3, Pole, 63A, 30mA Trip Current RCD
5. 6, Single Pole, 10A, MCB
6. 6, Single Pole, 20A, MCB
7. 3, Single Pole, 16A, MCB
8. 3, Distribution board cases
9. Bus bar Link for Neutral Cable Connections
10. Copper strips for MCB common connection
11. Copper strip Bus bar for Earth & Ground Link

Procedure of Three Phase wiring of distribution board & installation

The following is a procedure for wiring a three phase system. All the IEE regulations must be followed to ensure the safety of the building, persons and animals.

1. Connect the three-phase energy meter as shown in fig. (If you don't sure that how to wire a 3-phase energy meter using the standard procedures.
2. Connect the Moulded Case circuit Breaker (M.C.C.B) as main switch to the incoming three phases (R, Y, and B) from 3-phase energy meter. Observe the wiring color code for Red(R), Yellow(Y), and Blue (B).
3. Now connect the outgoing three phases (R, Y, B) from MCCB (Moulded Case circuit Breaker) to the DP (Double Pole MCB , RCD, SP (Single Pole MCBs and load) as shown in fig)
4. Connect the residual current device (RCD) from te distribution board with Phase (Line) and Related Neutral Link. The Outgoing Phase lines should be connected to the final and final sub circuits. The same can be done for Neutral Wires.
5. Finally, Connect the electrical appliances with the Earth link terminal which leads to earth electrode in the earthing and grounding system as shown in fig below.
6. Do the same steps for all three distribution boards for different rooms and areas.

Electrical Cables

- **Non-Metallic Sheathed Cable:** These cables are also known as non-metallic building wire or NM cables. They feature a flexible plastic jacket with two to four wires (TECK cables are covered with thermoplastic insulation) and a bare wire for grounding.

- **Underground Feeder Cable:** These cables are quite similar to NM cables, but instead of each wire being individually wrapped in thermoplastic, wires are grouped together and embedded in the flexible material. Available in a variety of gauge sizes, UF cables are often used for outdoor lighting and in-ground applications.
- **Metallic Sheathed Cable:** Also known as armoured or BX cables, metal-sheathed cables are often used to supply mains electricity or for large appliances.
- **Multi-Conductor Cable:** This is a cable type that is commonly used in homes, since it is simple to use and well-insulated. Multi-conductor or multi-core (MC) cables feature more than one conductor, each of which is insulated individually.
- **Coaxial Cable :** A coaxial (sometimes helix) cable features a tubular insulating layer that protects an inner conductor which is further surrounded by a tubular conducting shield, and might also feature an outer sheath for extra insulation..
- **Unshielded Twisted Pair Cable:** Like the name suggests, this type consists of two wires that are twisted together. The individual wires are not insulated, which makes this cable perfect for signal transmission and video applications.
- **Ribbon Cable:** Ribbon cables are often used in computers and peripherals, with various conducting wires that run parallel to each other on a flat plane, leading to a visual resemblance to flat ribbons. These cables are quite flexible and can only handle low voltage applications.
- **Direct-Buried Cable:** Also known as DBCs, these cables are specially-designed coaxial or bundled fiber-optic cables, which do not require any added sheathing, insulation or piping before being buried underground.
- **Twin-Lead Cable:** These are flat two-wire cables that are used for transmission between an antenna and receiver, like TV and radio.
- **Twin axial Cable:** This is a variant of coaxial cables, which features two inner conductors instead of one and is used for very-short-range high-speed signals.
- **Paired Cable:** With two individually insulated conductors, this cable is normally used in DC or low-frequency AC applications.

Cable ducts.



Figure 97: Photo of a cable duct

Electrical cables are installed via the conduits

Electrical joints and terminations

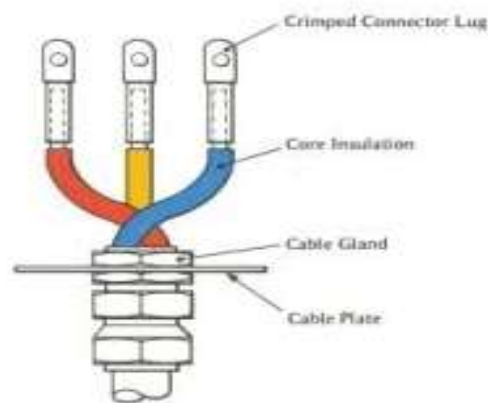


Figure 98: Three phase Electrical cable termination.

The electrical cable termination is the physical and electrical connection of a cable end that connects to another cable, or to the terminal of the equipment.

The methods used to terminate the cables vary according to the type of cable, type of connector and application. The common type of electrical installation joints are:

- **Britannia Joint.**

Britannia joint is suitable for bare overhead conductors. To make this joint, conductors are cleaned with the help of emery paper for a length of 8 to 10 cm.

It is usually used for overhead lines for tapping the electrical energy.

- **Married Joint.**

It is also a straight joint but is used to join stranded cables. a three strand cable is considered.

Follow the steps given below for the joint:

1. Remove the insulation of both cable up to a length of about 6 to 8 cm from one side of each cable in a tapered fashion
2. Remove the also braid if present for about 1 to 2 cm on each cable.
3. Scatter the strands by twisting the conductors in opposite direction leaving about 4 cm from the insulation end and bind it at this point with binding wire
4. Clean each strand neatly with emery paper (sand paper) and cut off the middle strand.
5. Bring both the cables end to end and mix them intersecting with other at alternate strands. Hold one cable in the left hand and wrap the one strand around the twisted portion of the other in opposite direction, and complete the wrapping of other strand also.
6. Repeat the method of wrapping strands on the other side of the conductor. Round off the ends of both the cables with the help of wooden hammer (mallet) or plier.

7. The joint is then soldered and insulated with insulation tape.

- Tee Joint.

It is also known as single branch splice and is used for taking a tapping or connection from a straight through cable or overhead line. Consider a running cable and branch cable. Remove the insulation of the running cable in a tapered fashion for a length of 2 to 3 cm.

Also remove the insulation of the branching cable for a length of 3 to 4 cm as shown in Clean the conductors with the help of a emery paper. Keep the branching wire in quadrature (90°) with the running wire and turn the branching wire around the running wire and complete at least 5 to 8 turns.

Now the joint should be soldered and insulated. Tee joint is shown in *fig: T*

- Western Union Joint.

Western Union Joint (Twisted joint): It is a straight joint and is used to increase the length of single core cables only. The western joint is well explained with the help of fig T and W. It is also known as twisted joint.

- Soldering a Joint

Soldering is a procedure of making joints sandwiched between two metallic surfaces by a metal compound which melts at lower temperature than that of the metals to be jointed.

The material used as a solder for joining of conductors consists of an alloy of lead and tin in the ratio of 1:1 and it melts at 200°.

Typical final circuit wiring in a room

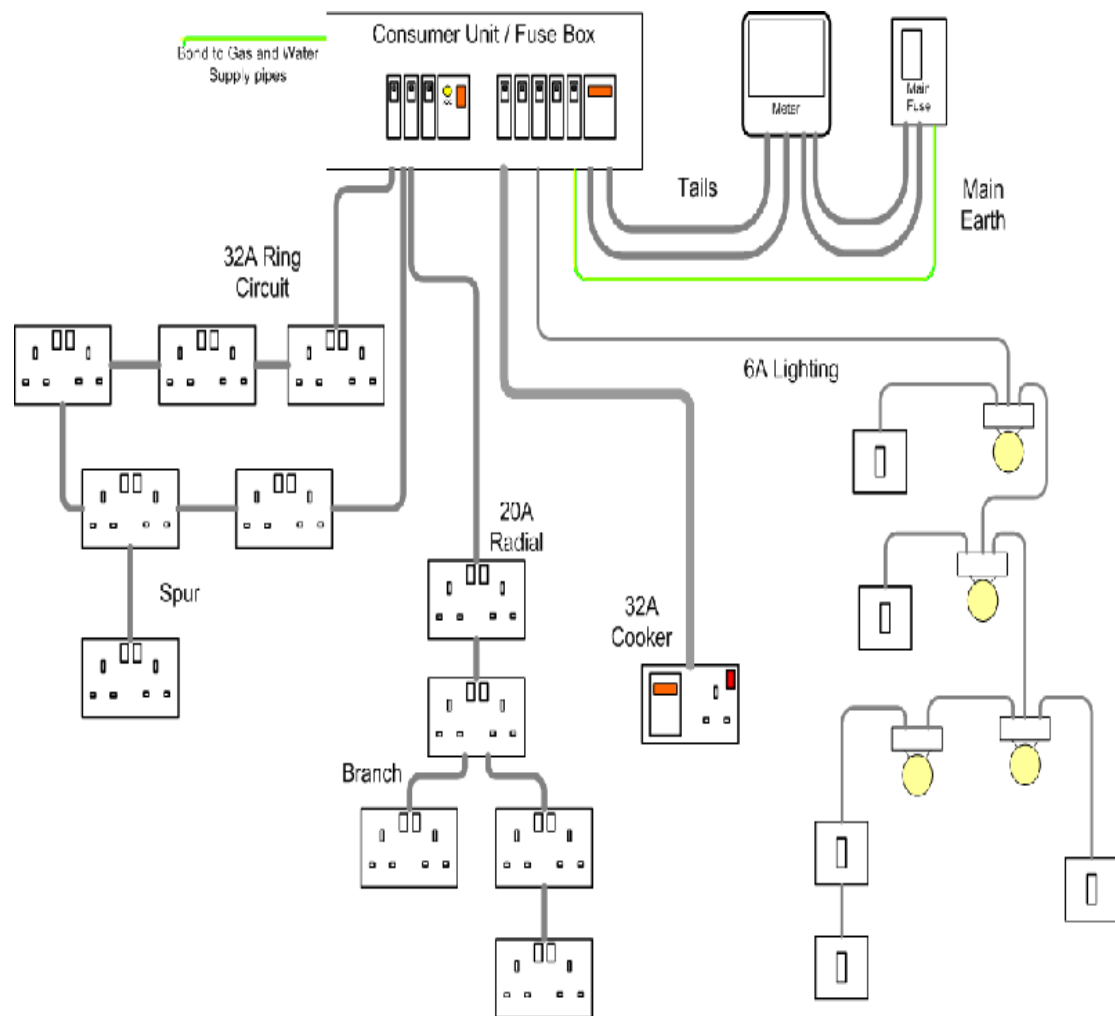


Figure 99: wiring diagram of Final sub circuits for lighting and power sockets

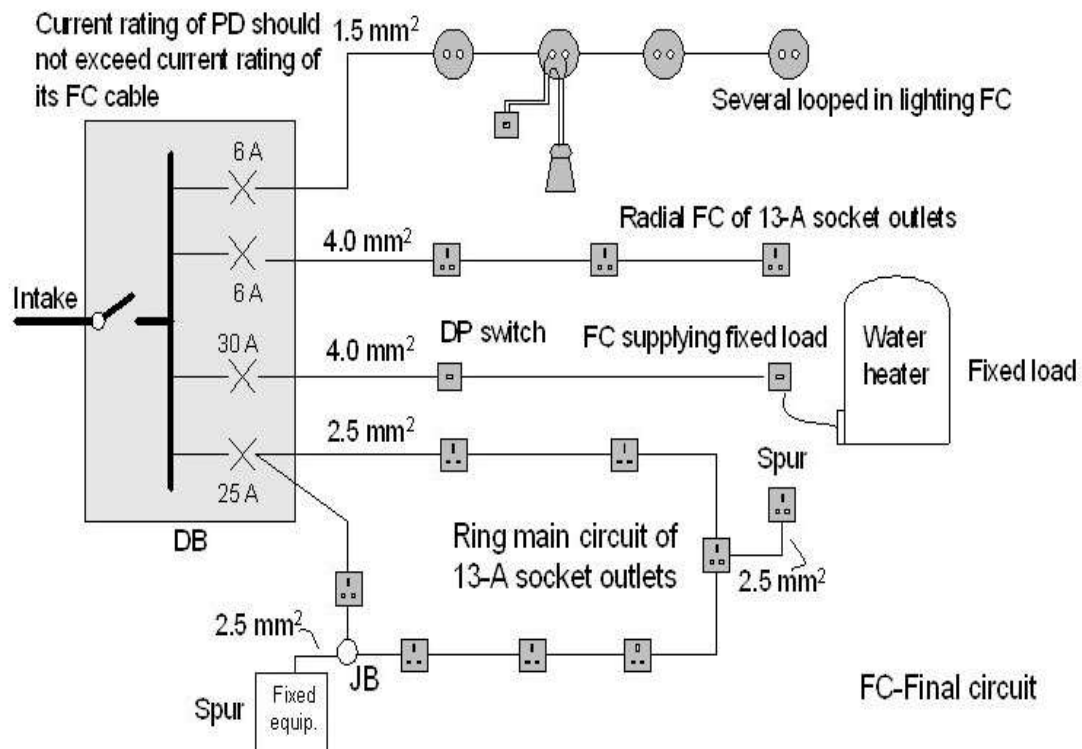


Figure 100: Final sub circuits showing socket, lighting and water heater circuits.

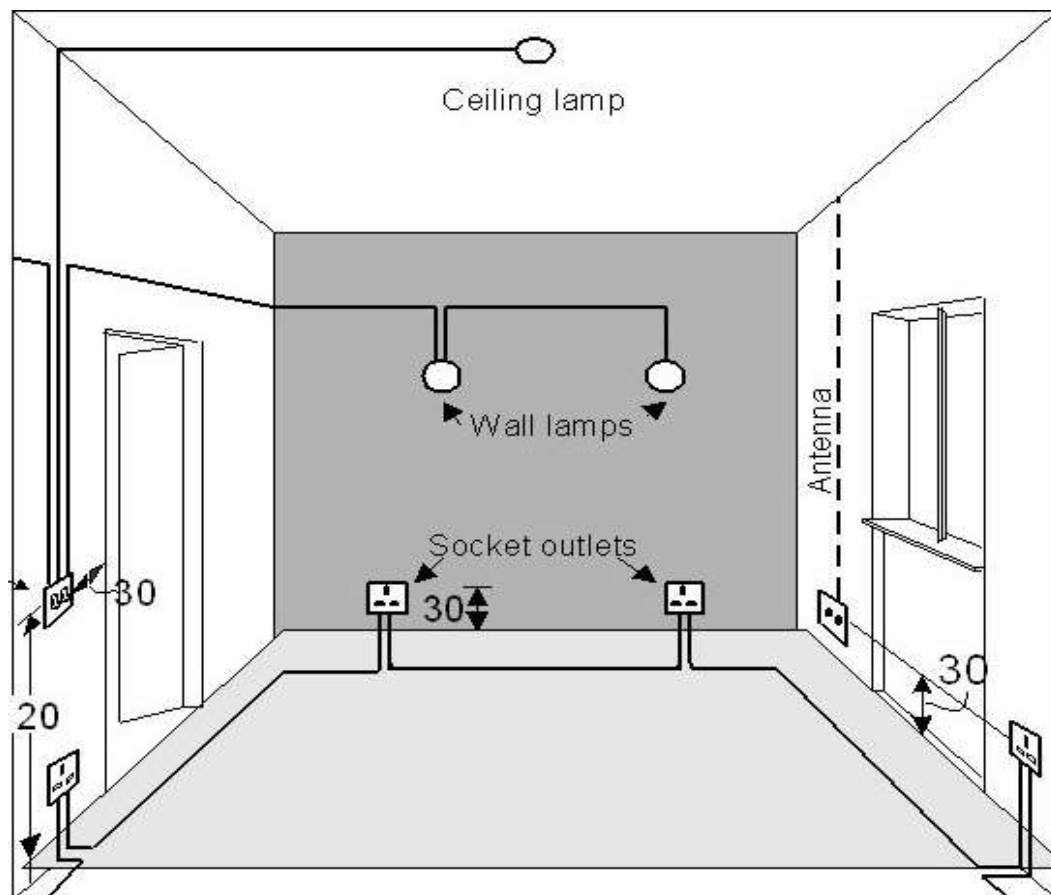


Figure 101: Typical circuit wiring in a room

Types of standard final circuits

- Lighting final circuits
- Power Socket-outlet final circuits
- Radial socket-outlet circuits
- Ring socket-outlet circuits

Basic final circuits serving to a domestic or a small scale industrial premise should be connected to a DB through bus bars using standard protective devices

Lighting final circuits

Lighting circuits used for domestic, commercial and industrial services are simple. A lighting final circuit sets out from a local Distribution board - DB with a circuit protective device connected to the live conductor, and cut off by a single-pole switch connected to the same live conductor.

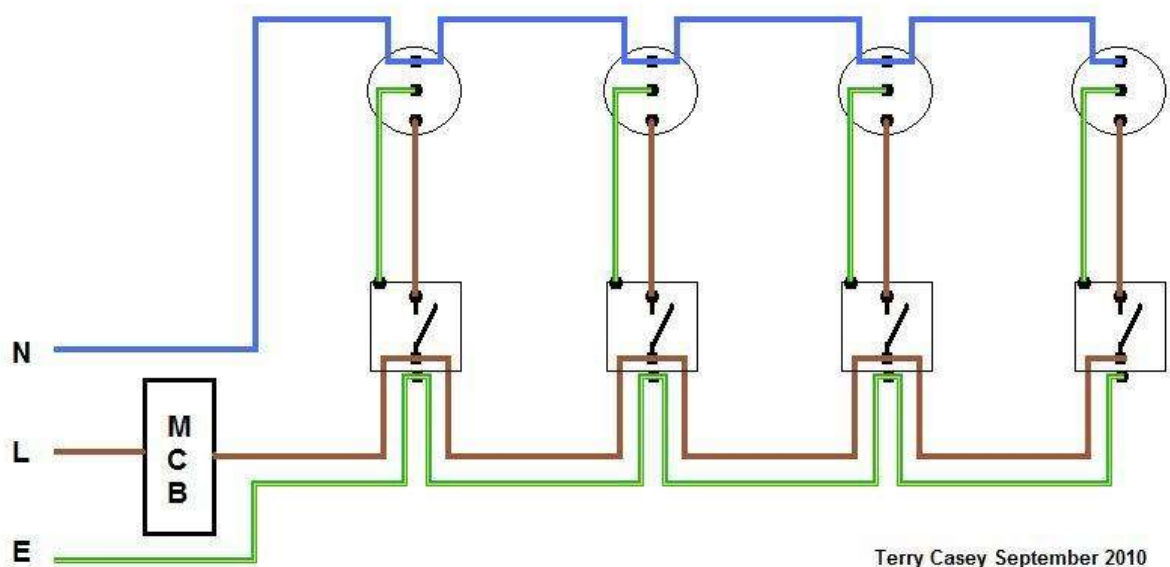


Figure 102: Lighting final circuits

Socket-Outlet final circuits

Socket-outlet for final circuits provide supply to every appliance at its closest point. For most common applications 13-A (BS1363) sockets and plugs wired in the form of radial or ring final circuits supplied from the main or sub-main distribution board are commonly used.

Radial socket outlet circuits

In a radial circuit each socket is fed from the previous one. The phase, neutral and protective conductors are connected to line, neutral and earth terminals at each socket outlet

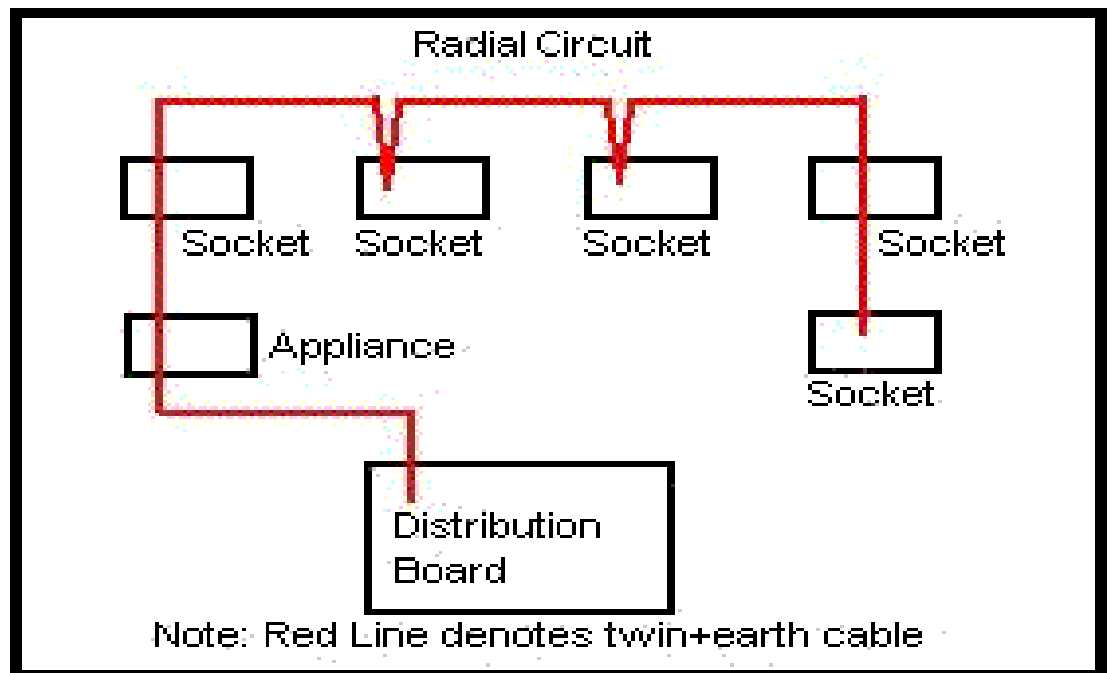


Figure 103: Radial socket outlet circuits

Ring Socket-outlet Circuits

This is made by a cable going from the consumer unit (fuse box) to the first socket, then on to the second socket and then the next socket etc. until the cable returns to the consumer unit.

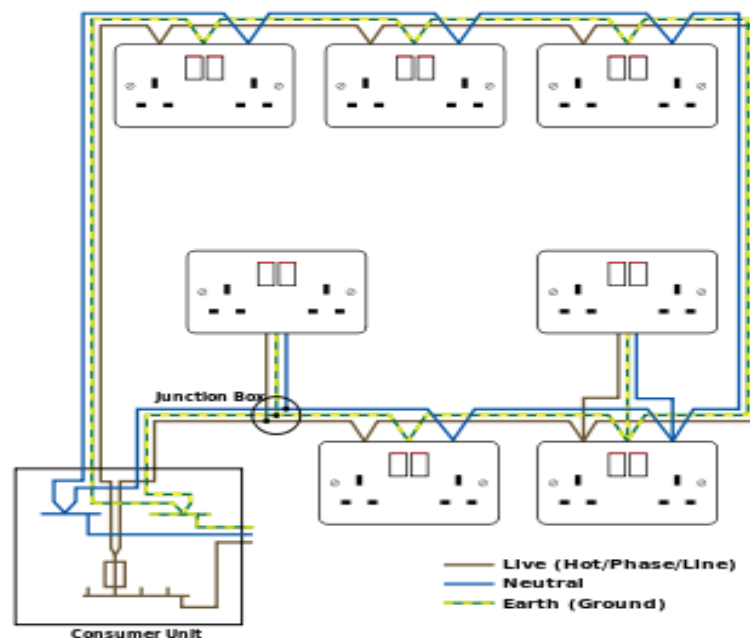


Figure 104: Ring Socket-outlet Circuits

Cooker circuits

Cooker circuits are connected to either the ring or radial sockets in accordance with the IEE standards.

Call and alarm circuits.

The call and alarm circuits are performed in line with the IEE standards.

System Design

Alarm systems for general applications are based on BS5839

1. Heat detectors
2. Smoke detectors

6.3.13.3. Self-Assessment

1. The trainee to carry out insulation resistance test on the specific installation device.
2. Describe Single Phase wiring installation
3. Describe the procedure of installing a single-phase Main Distribution Board as follows.
4. What are the requirements for Three Phase Wiring Installation?
5. Explain the procedure of Three Phase wiring of distribution board & installation
6. Describe electrical cables
7. Explain Electrical joints and terminations
8. Describe socket installation
9. is suitable for bare overhead conductors.
 - a) Britannia joint
 - b) Tee joint
 - c) Married Joint
10. is a straight joint used to join stranded cables
 - a) Britannia joint
 - b) Tee joint
 - c) Married Joint
11. is used for taking a tapping or connection from a straight through cable or overhead line
 - a) Britannia joint
 - b) Tee joint
 - c) Married Joint
12. The methods used to terminate the cables does not depend on.....
 - a) Type of cable
 - b) type of connector
 - c) Color, weight of the cable
13. The methods used to terminate the cables vary according to the type of cable, type of connector and application.
 - a) True
 - b) False
14. The material used as a solder for joining of conductors consists of an alloy of lead and tin in the ratio of 1:1 and it melts at 200°
 - a) True
 - b) False

Practical exercise

1. Install the electrical installation design in element 3 as per the drawings while observing the IEE regulations
2. Observe safety procedures as per the OSHA act.
3. Perform the insulation resistance test as per the IEE regulations.

6.3.13.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Materials
- Wood board/meta board/plastic board
- Conduits
- Junction boxes
- Ceiling roses
- Kit Kat fuse
- Lamp holder
- P.V.C holder
- Main switch
- Bushings
- Sockets
- Elbows
- Tees
- Screws
- Tools
- Combinational plies
- Stock-and-die set
- Measuring tape
- Drill machine
- Phase tester
- Screw range
- Pipe range
- Side cutter
- Metal hooks
- Nose plier
- Hack saw
- Wood saw
- Electricians knife
- Hammer
- Megger
- Voltmeter
- Stair
- File

6.3.13.5. References

1. Brian S., IEng, MIET, (2008), Wiring Regulations: Inspection, Testing and Certification 17th Edition IEE, Elsevier Ltd, Corporate Drive, Suite 400, Burlington, MA 01803, USA.
2. Thompson F, G., (1972), Electrical installation technology, Longman, London
3. Christopher Kitcher, (2013), Practical Guide to Inspection, Testing and Certification of Electrical Installations, Routledge, New York
4. Bill Atkinson, (2002), Electrical Installation Designs, Third Edition, Blackwell Publishing Ltd, Osney Mead, Oxford OX2 0EL, UK
5. Brian Scaddan, (1990), Modern Electrical Installation for Craft Students
6. Francis, T.G., (1949), Electrical Installation work, Longman group ltd, Longman house, Harlow, England
7. You tube link: <http://www.probertencyclopaedia.com/browse/GB.HTM>
8. The methods used to terminate the cables vary according to the type of cable, type of connector and application. TRUE OR FALSE
9. The material used as a solder for joining of conductors consists of an alloy of lead and tin in the ratio of 1:1 and it melts at 200°. TRUE OR FALSE?

6.3.14. Learning Outcome No. 13. Terminate Electrical installation

6.3.14.1. Learning Activities

Learning Outcome No. 13. Terminate Electrical installation	
Learning Activities	Special Instructions
1. Terminate cable as per the scope of the installation design while observing the IEE and Kenya power standards. • Cable lagging • Termination 2. Label the cables used in the installation as per the complexity of the job. 3. Perform insulation resistance test as per the IEE regulations.	

6.3.14.2. Information Sheet No. 6/L013.

This learning outcome should equip the trainee with knowledge, skills and attitude in terminating, lugging and testing a complete electrical installation work.

Electrical termination

Electrical termination is a term that defines the specific point at which a conductive device, such as wire or cable, ends or starts. The conductive device may or may not pass the carried electricity or signal onto another conductive device at this point. A common point of electrical termination is at a terminal block. A wire typically ends, or terminates, at the terminal block; but the electricity or signal may be passed onto the terminal connectors.

The following are types of terminations:

A crimp termination. This is performed when the device requires a contact or terminal. The wire insulation is stripped, and the contact or terminal is attached to the wire using a crimp tool. The tool crimps the contact or terminal onto the wire conductor. This type of termination is most often used on circuit breaker panels.

A solder termination. This is performed when the wire conductors attach directly to the device. This requires stripping off the wire insulation and applying flux and solder to connect the wire to the device

Cable labelling

Cable and wire labelling is critical in the identification, assembly and repair of electrical control panels, wire harnesses, and data/telecommunications systems. It is a cost that saves time and labor expenses when changes or repairs need to occur to the systems you work on.

Cable lugs

Cable lugs are devices used for connecting cables to electrical appliances, other cables, surfaces, or mechanisms.



Figure 105: Photo of different types of cable lugs.

The following tool are used for cable termination;
Cable Benders.



Figure 106: Photo of a cable bender

Cable Cutters.



Figure 107: Cable Cutters.

Cable Strippers.



Figure 108: Photo of a cable stripper

Crimping Tools.



Figure 109: Crimping tool

Other cable termination tools include:

1. Cutting and Crimping Dies.
2. Hydraulic Pumps.
3. Wire stripper

4. Hack saw
5. Strip knife

Other cable termination tools include:

1. Cutting and Crimping Dies.
2. Hydraulic Pumps.
3. Wire stripper
4. Hack saw
5. Strip knife

6.3.14.3. Self-Assessment

1. The trainee to carry out a cable termination exercise as per the specific installation exercise.
2. Explain electrical termination
3. What is the importance of electrical termination?
4. Describe types of electrical termination
5. Explain cable labelling and cable lug
6. Describe tool are used for cable termination.
7. Cable and wire labelling is critical in the identification, assembly and repair of electrical control panels, wire harnesses, and data/telecommunications systems
 - a) True
 - b) False
8. is performed when the device requires a contact or terminal. The wire insulation is stripped, and the contact or terminal is attached to the wire using the tool.
 - a) A solder termination.
 - b) A crimp termination.
9. is performed when the wire conductors attach directly to the device. It requires stripping off the wire insulation and applying flux and solder to connect the wire to the device
 - a) A solder termination.
 - b) A crimp termination.
10. The conductive device may or may not pass the carried electricity or signal onto another conductive device at this point
 - a) True
 - b) False
11. Cable lugs are devices used for connecting cables to electrical appliances, other cables, surfaces, or mechanisms.
 - a) True
 - b) False

Practical exercise

1. Demonstrate ability to terminate cable as per the scope of the installation design while observing the IEE and Kenya power standards.

2. Identify and label the cables used in the installation as per the complexity of the job.
3. Perform insulation resistance test as per the IEE regulations.

6.3.14.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Cable Benders.
- Cable Cutters.
- Cable Strippers.
- Crimping Tools.
- Cutting and Crimping Dies.
- Hydraulic Pumps.
- Wire stripper
- Hack saw
- Strip knife

Materials

- Conduits
- Junction boxes
- Lamp holder
- PVC holder
- Main switch
- Bushings
- Sockets
- Elbows
- Tees
- Screws

6.3.14.5. References

1. Brian S., IEng, MIET, (2008), Wiring Regulations: Inspection, Testing and Certification 17th Edition IEE, Elsevier Ltd, Corporate Drive, Suite 400, Burlington, MA 01803, USA.
2. Thompson F, G., (1972), Electrical installation technology, Longman, London
3. Christopher Kitcher, (2013), Practical Guide to Inspection, Testing and Certification of Electrical Installations, Routledge, New York
4. Bill Atkinson, (2002), Electrical Installation Designs, Third Edition, Blackwell Publishing Ltd, Osney Mead, Oxford OX2 0EL, UK
5. Brian Scaddan, (1990), Modern Electrical Installation for Craft Students
6. Francis, T.G., (1949), Electrical Installation work, Longman group ltd, Longman house, Harlow, England

6.3.15. Learning Outcome No. 14. Test and Inspect electrical Installation

6.3.15.1. Learning Activities

Learning Outcome No. 14. Test and Inspect electrical Installation	
Learning Activities	Special Instructions
1. Perform the installation tests on the finished installation as per the IEE regulations. • Earth continuity test • Ring circuit test • Insulation resistance test • Short circuit test • Open circuit test 2. Establish firmness of the installation through established procedures and standards.	

6.3.15.2. Information Sheet No. 6/LO14

The learning outcome should equip the trainee with competencies in identifying the types of tests, the use the correct instruments to perform the necessary test and carry out the tests in accordance with the IEE regulations, on a complete electrical installation.

After the completion of the installation work, an inspection and test the electrical installation must be done and a certificate of compliance issued.

Additionally, periodic Inspection should be carried to ascertain the condition of an existing electrical installations and to identify in order of priority any deficiencies against BS7671.

In accordance with the IEE's Wiring Regulations, BS 7671, all non-domestic electrical installations should be subject to a regular program of testing and inspection to comply with current legislation. You must ensure that all necessary precautions are being taken to reduce the risk of injury or death through electrical failure.

Periodic testing ensures that the installation is safe, and if there are any problems, they are detected and rectified.

After a physical visual inspection of the installation, the following tests are done in order to establish the safety of the electrical installation

- Earth Continuity: This test is done to establish that the earthing is continuous throughout the circuit.
- Ring Circuit Continuity: The test is done to determine whether or not the ring is complete.
- Insulation Resistance: This test is done to assess whether there has been any breakdown in insulation to the installation.
- Polarity: The test is to check that the installation is correctly wired.
- Earth Fault Loop Impedance - to ascertain the Zs of the installation.
- Short circuit tests

- Open circuit test

The tools for doing the tests include the following:

1. Multimeter
2. Insulation resistance tester
3. Ohmmeter
4. Megger

6.3.15.3. Self-Assessment

1. Carry out the tests on the complete installation using a multimeter in accordance with the established standards and procedures.
2. Explain tests involved in establishing the safety of the electrical installation
3. Describe the tools for doing the tests
4. Differentiate between short circuit test and open circuit test
5. Explain IEE's Wiring Regulations and their importance
6. is done to establish that the earthing is continuous throughout the circuit.
 - a) Polarity test
 - b) Earth Continuity test
 - c) Ring Circuit Continuity test
 - d) Insulation Resistance test
7. is done to determine whether or not the ring is complete.
 - a) Polarity test
 - b) Earth Continuity test
 - c) Ring Circuit Continuity test
 - d) Insulation Resistance test
8. is done to assess whether there has been any breakdown in insulation to the installation.
 - a) Polarity test
 - b) Earth Continuity test
 - c) Ring Circuit Continuity test
 - d) Insulation Resistance test
9. test is to check that the installation is correctly wired.
 - a) Polarity test
 - b) Earth Continuity test
 - c) Ring Circuit Continuity test
 - d) Insulation Resistance test
10. Periodic testing ensures that the installation is safe, and if there are any problems, they are detected and rectified.
 - a) True
 - b) False
11. After the completion of the installation work, an inspection and test the electrical installation must be done and a certificate of compliance issued.
 - a) True
 - b) False

Practical exercise

1. Demonstrate ability to perform the installation tests on the finished installation as per the IEE regulations.
2. Establish firmness of the installation through established procedures and standards.

6.3.15.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

Tools

- Multimeter
- Insulation resistance tester
- Ohmmeter
- Megger
- Cable Benders.
- Cable Cutters.
- Cable Strippers.
- Crimping Tools.
- Cutting and Crimping Dies.
- Hydraulic Pumps.
- Wire stripper
- Hack saw
- Strip knife

Materials

- Conduits
- Junction boxes
- Lamp holder
- P.v.c holder
- Main switch
- Bushings
- Sockets
- Elbows
- Tees
- Screws

6.3.15.5. References

1. Brian S., IEng, MIET, (2008), Wiring Regulations: Inspection, Testing and Certification 17th Edition IEE, Elsevier Ltd, Corporate Drive, Suite 400, Burlington, MA 01803, USA.
2. Thompson F, G., (1972), Electrical installation technology, Longman, London
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6. Francis, T.G., (1949), Electrical Installation work, Longman group ltd, Longman house, Harlow, England

6.3.16. Learning Outcome No. 15. Prepare tenders and service contracts

6.3.16.1. Learning Activities

Learning Outcome No. 15. Prepare tenders and service contracts	
Learning Activities	Special Instructions
1. Prepare a contract for the installation work. 2. Compile tender documents for the contract as per the tender procedures and standards.	

6.3.16.2 Information Sheet No 6/LO15.

This learning outcome should equip the learner with competencies in preparing the electrical contract and tender documents within the confines of the law and standard procedures.

The trainee should understand the meaning of tender document, laws of contract and the types of contracts. In addition, the trainee should be able to explain the meaning of estimation and costing and the statutory documents in contracts and costing.

Source of law

1. The Constitution of Kenya

This is presumably one of the most important sources of law in Kenya. It is common for you to hear a lot of people quoting the constitution as the source of all law. The constitution refers to a formal document that contains the rules, functions, and roles of the constitution. These outlined details are meant to govern and guide the government organizations and state bodies on how to relate with the public. The constitution is the first document that is quoted whenever a law has to be referenced. In fact, it is the sole document used whenever there is a legal emergency. It is therefore crucial for citizens to understand its contents.

2. Acts of parliament

Before enactment of a law, it is referred to as a bill. The chosen and elected members of parliament need to debate on a variety of basic issues affecting the lives of common Kenyans. Once the debates end in suitable conclusions, then a law is made

3. Judicial precedents or common law

These refer to laws that have been made by judges. Judicial precedents occur when a judge looks at a certain law and makes specific conclusions regarding it. These types of laws are mainly in four types according to the legal system. These are:

- the original declaratory
- overruling
- declaration
- distinguishing precedents

4. Acts of UK Parliament

This is a source of Kenyan law that deals with matters concerning foreign tribunal evidence act of 1856. It also has the 1851 evidence as well as the 1857 law of

ascertainment act. This is a crucial source of law since its specifications combine with the international law.

5. Acts of Indian Parliament

This source of law addresses property ownership and transfer acts in the country. It is the law that governs the legal aspect of property. People ought to ensure that their properties are secure as provided by law.

6. Customary law

This refers to the norms and practices/ traditions that are usually unwritten. They have been going on for so long that they are finally considered law. They may have existed before the colonial era but have undergone some thorough transformations over time without necessarily being eroded. The customary law is localized and very diverse as it is dependent on the community involved. However, there are certain principles that are held as consensus principles.

7. Islamic or Sharia law

This source of law is found in article 7 of The Kenyan Constitution. It applies in inheritance and personal status for community members to whom it applies. This kind of law is applied in the Khadhi courts of Kenya and only applies if the parties involved in the case are both Muslims or of the Islamic religion.

8. Subsidiary legislation

This refers to any proclamation, rule, order, proclamation, court ruling or even other instrumental that has a legislative effect. The subsidiary legislation applies to issues needing a general application of the law more so those that contain substantive laws or rules

Law of contract and tort

A tort can be broadly defined as a civil wrong, other than breach of contract. In other words, a tort is any legally recognizable injury arising from the conduct of persons or corporations.

Law of tort.

A tort is a civil breach committed against another in which the injured party can sue for damages. In personal injury cases, the injured party will attempt to receive compensation with the representation of a personal injury lawyer in order to recover from damages incurred. Tort law decides whether a person should be held legally responsible for injury against another, and what type of compensation the injured party is entitled to.

Contract law

In its simplest form, contract law imposes duties on parties who enter into an agreement. Within this agreement, both parties are expected to act reasonably toward one another.

The difference in law of tort and contract law may be explain as;

1. In contract law, only persons that you have a contract with, or you are a third-party-beneficiary, can possibly sue you for breach of contract. In Law of tort, anyone can

sue you, as long as they can establish that you owe them some sort of legally recognized duty.

2. In contract law, damages are usually not difficult to calculate, as contract law seeks to place the parties in the same position as if the bargain had been performed. Compensatory damages also apply in tort law, but they are much more difficult to calculate. Since money cannot bring the dead back to life or regrow a limb, tort law seeks to find a suitable monetary equivalent to those losses, which as you can imagine is a very difficult thing to do.
3. Tort law generally allows for the award of punitive damages, but under contract law, this is not permitted.

Types of contracts.

1. Fixed Price Contract

This contract is also known as lump sum contract. It involves a total fixed price for all construction-related activities. Fixed price contracts can include incentives or benefits for early termination, or can also have penalties, called liquidated damages, for a late termination.

Cost Plus Contracts

A contract agreement where the purchaser agrees to pay the cost of all labour and materials plus an amount for contractor overhead and profit. This amount is usually in form of a percentage of the labour and material cost.

2. Time and Material Contracts When Scope is Not Clear

Time and material contracts are usually preferred if the project scope is not clear, or has not been defined. The owner and the contractor must establish an agreed hourly or daily rate, including additional expenses that could arise in the construction process.

3. Unit Pricing Contracts

Unit pricing contracts are probably another type of contract commonly used by builders and in federal agencies. Unit prices can also be set during the bidding process as the owner requests specific quantities and pricing for a pre-determined amount of unitized items.

Tender estimations and costing

Estimation:

Estimation is the process used by the contractor to establish the cost of carrying out installation and construction works.

Tender and the Tendering Process

A tender is an invitation from the owner to the contractor to execute some work at specified cost in specified time. It is published in the form of tender notice several media.

Types of Tendering Process:

There are four main processes in tendering:

1. Open Tender

In this procedure, the Tenderer is invited by public advertisement and through other media. Then the Tenderer has to demonstrate in his tender, his skills, resources, experience, strength and financial capacity to execute the project. This method is widely used for small projects

2. Selective Tender

In this process only limited numbers of potential Contractor are invited for tender in order to work any specialized work. Tenderers are selected from the list of pre-approved.

3. Expressions of Interest

In this process, Tenderer are invited by public advertisement to quote for particular works that take place intermittently. Examples of such works include maintenance of dams, pipelines and power stations.

4. Invited Tender

This process is used only in emergency situation for some specialist works, where only few Contractors have such experience and capability and they are always less in numbers.

Tender Submission and Opening of the Tender

This is the final stage when Tenderers submits their tender offer before dead line stated in the invitation of the tender document; along with require tender security to the Employer. Tender submissions generally consist of form of tender and covering letter.

Award of the contract

At this stage the Employer issues a Letter of Acceptance to the successful Tenderer who will have won the tender.

6.3.13.3. Self-Assessment

1. The trainee to prepare a contract document for the installation work given
2. Describe sources of law in Kenya
3. What is the importance of these laws?
4. What is Law of contract and tort
5. Explain types of contract
6. A.....is a civil breach committed against another in which the injured party can sue for damages.
 - a) Contract
 - b) Tort'
7. the Tenderer is invited by public advertisement and through other media. Then the Tenderer has to demonstrate in his tender, his skills, resources, experience, strength and financial capacity to execute the project.
 - a) Open Tender
 - b) Selective Tender

- c) Expressions of Interest
 - d) Expressions of Interest
8. In this process only limited numbers of potential Contractor are invited for tender in order to work any specialized work. Tenderers are selected from the list of pre-approved.
- a) Open Tender
 - b) Selective Tender
 - c) Expressions of Interest
 - d) Expressions of Interest
9. In this process, Tenderer are invited by public advertisement to quote for particular works that take place intermittently. Examples of such works include maintenance of dams, pipelines and power stations.
- a) Open Tender
 - b) Selective Tender
 - c) Expressions of Interest
 - d) Expressions of Interest
10. A tort is a civil breach committed against another in which the injured party can sue for damages.
- a) True
 - b) False
11. A tender is an invitation from the owner to the contractor to execute some work at specified cost in specified time. It is published in the form of tender notice several media.
- a) True
 - b) False

Practical exercise

- a) Prepare a contract for the installation work.
- b) Demonstrate ability to compile tender documents for the contract as per the tender procedures and standards.

6.3.15.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Drawing tools
- Drawing equipment
- Writing material
- calculator

6.3.15.5. References

1. Brook, M, (2004), Elsevier Butterworth-Heinemann
2. Smith, A. J., Estimating tendering and bidding for construction Theory and practice, Macmillan publishers, Hong Kong
3. Internet link. <https://www.tuko.co.ke/262861-sources-law-kenya-what-kenyan-law-based.html#262861>

CHAPTER 7: ELECTRICAL TRANSMISSION POWER LINES/ INSTALL ELECTRICAL POWER LINES

7.1. Introduction of the Unit of Learning / Unit of Competency

The training of this course unit attracts the skills on the transmission of produce power to the premises of the consumers from the power station. Use of designed and mounted transmission line, adequate amount of power is transmitted to the consumers from the generating stations. Hence the trainee will design and mount the transmission line. The high voltage usage minimizes voltage drop in the line, resistance and reactance and losses during the transmission. 132 kV or 220 kV or 400 kV or 765 kV are among the standard transmission voltages transmitted along the transmission lines are. Therefore, a step-up transformer is required to step up the generated voltage with the aid of erected transmission lines supports at consistent intervals and transmission towers. The line of transmission terminates in a substation where the distribution starts and the distribution lines terminates at load centers.

The trainee will be able to erect the line supports and terminate the cables at different points in the transmission line. The transmission and distribution system are inspected and tested at every stage. While the current's magnitude determines the cost of copper, voltage determines insulator's cost. At load centers voltage levels are stepped down at appropriate values for supply to various consumers. Examples of consumers include both big and medium industries, offices and domestic consumers. Consumers purchase electricity at specific voltage level. For instance, big industries may purchase 132 kV while domestic consumers at lower voltage of 230V, single phase. Therefore, 400 kV transmission voltages should be stepped down before transmitting power to different consumers with the aid of a step-down transformers. Therefore, finally the trainee will inspect and test the transmission lines (Version 2 EE IIT, Kharagpur).

7.2. Performance Standard

Design the transmission line as per the topography of the installation site, the scope of the load, location of the installation, the type of the materials to be used in line installation and the environmental condition of the location in line with the national and international standards, regulations, legislative requirements and in accordance with IEE regulations.

7.3. Learning Outcome

7.3.1. List of Learning Outcomes

1. Designed a transmission lines
2. Erected a transmission lines support
3. Mounted a transmission line
4. Terminated conductors
5. Inspected and Tested installation

7.3.2. Learning Outcome No. 1. Designed a transmission lines

7.3.2.1. Learning Activities

Learning Outcome No. 1. Designed a transmission lines	
Learning Activities	Special Instructions
• Design transmission lines as per the topography (Hilly, Rocky, Swampy, and Flat) of the installation site. This can be through visiting websites, use video tapes, use charts, maps, visit sites and • Use industrial drawing and design type is the transmission line as per the scope of the load. • Design transmission lines as per location of the installation from the provided use video tapes, use charts, maps, visit sites and. • Design the transmission line Span length as per the weight of the conductor, height and type of the support. From a Visit work site, use industrial standards, use video tapes, case study • Design the transmission line in line with the national and international standards(IEE standard, 17th Edition, British Standard KEBS standard).Visit work site, use industrial standards, use video tapes, case study and • Perform design as per the environmental condition of the location in line with the regulations and legislative requirements through visit work site, use industrial standards, use video tapes, case study	

7.3.2.2. Information Sheet No1 Designed a transmission lines

Definition of Terms

Alternating Current (AC) –Electric current whose flows is reversed manner or alternated at 50HZ in Kenya and60Hz in the U.S.

Conductors (Power Lines) –cables that carry electric current

Corona – Electrical breakdown of the air near high voltage conductors into charged particles.

Current –electricity flow or electrons movement through a conductor typically measured in amperes

Direct Current (DC) – Electric current flowing in a continuous and same direction as contrasted with alternating current.

Distribution Line – A line carrying electricity and distribute power from the generating station to the end-use customers.

Electric Load – appliances that that consumes electricity

Electric Power Transmission –The process of transporting electric power over long distances to the consumers

Energy – The amount of work that can be done by electricity measured in kilowatt-hours (kWh) or megawatt-hours (MWh).

Foundation – System involved in transferring to the ground the various dead and live loads of the transmission structure and conductors.

Generation – The production of electric energy.

Insulators – Used to contain, separate, or support electrical conductors.

Interconnection –Points on a grid or network where two or more transmission lines are connected at a substation or switching station, or where one stage of the energy supply chain meets the next.

Load Center – A particular geographical area where energy is used.

Power – Rate at which electricity does work and measured in watts or kilowatts (kW) or megawatts (MW).

Shield and Ground Wire – Wires for protection from lightning strikes and corresponding surges.

Substation – Part electrical transmission system that either steps up or down voltage.

Switching Station – Part of an electrical transmission system involved in tying two or more electric circuits together through switches hence permitting a circuit to be disconnected, or to change the electric connection between circuits.

Transmission Structures – Are vital in keeping high-voltage conductors that are separated from their surroundings and from each other.

Voltage – Electric “pressure” measured in volts.

Watt – Unit of electrical power.

Transmission Line – A line carrying electricity and transmit electric power from the generating station to the consumers.

Types of transmission lines

Classified as per the amount of voltage it carries

- High Voltage – voltage above 66kv
- Low voltage-voltage below 66kv

Classified as per the type of transmission line

- Overhead transmission line
- Underground transmission line

Classification of transmission line as per the length and voltage it carries

- Short:- Transmission line length is up to 50km
 - Voltage is comparatively low, less than 20kv
 - The capacitance effects are small and hence can be neglected.
 - Only resistance and inductance are considered in the design.

- Medium:- Transmission line length is between 50km and 150km
 -Voltage is comparatively low, greater than 20kv and less than 100kv
 -resistance inductance and capacitance are considered in the design.
- Long:- Transmission line length is over 150km
 -Voltage is very high, greater than 100kv
 -resistance inductance and capacitance are considered in the design.

The elements of a transmission line include; Conductors, supports, insulators, cross arms, Phase plates, Lightning arresters, danger plates, anti-climbing tools, transformers, Isolators bolts and nuts etc

Transmission line designs;

- Transmission line Mechanical design
- When carrying out the Transmission line Mechanical design we establish;
 - The appropriate conductor size and length as per the line voltage
 - The appropriate conductor material as per the line voltage
 - The appropriate line support as per the line voltage
 - The correct size and number of insulators as per the line voltage
 - Allowable sag as per the line voltage
 - Expected corona losses as per the line voltage
 - The string efficiency as per the line voltage
 - The appropriate sag and tension of the line of transmission as per the line voltage

- Transmission line Electrical design

When carrying out the electrical design of the line of transmission we establish;

- The transmission line resistance as per the conductor material.
- The flux linkages around the transmission line as per the line voltage.
- The inductance of the line of transmission as per the line voltage.
- The electric potential around the conductor as per the line voltage.

7.3.2.3. Self-Assessment

1. State any Two transmission line parameters
2. Explain the function of any five elements of a transmission line.
3. Differentiate a long transmission line, medium transmission line and short transmission line.
4. Explain a transmission Line
5. Describe types of transmission line
6. Explain the classification of transmission line as per the length and voltage it carries

7. What are the elements of a transmission line?
8. Develop an understanding of transmission line design
9. transmission line length is up to 50km, Voltage is comparatively low, less than 20kv and the capacitance effects are small and hence can be neglected.
 - a) Short
 - b) medium
 - c) Long
10. transmission line length is between 50km and 150km
 - a) Short
 - b) medium
 - c) Long
11. transmission line length is over 150km, Voltage is very high, greater than 100kv and resistance inductance and capacitance are considered in the design.
 - a) Short
 - b) medium
 - c) Long
12. The elements of a transmission line include the following except;
 - a) Conductors
 - b) Supports
 - c) Contactors
 - d) insulators
13. When carrying out the Transmission line Mechanical design we establish the following except
 - a) The appropriate conductor size and length as per the line voltage
 - b) The appropriate conductor colour as per the line voltage
 - c) The appropriate line support as per the line voltage
 - d) The correct size and number of insulators as per the line voltage
14. The transmission and distribution system are inspected and tested at every stage.
 - a) True
 - b) False

Practical exercise

- a) Demonstrate ability to design transmission lines as per the topography (Hilly, Rocky, Swampy, and Flat) of the installation site. This can be through visiting websites, use video tapes, use charts, maps, visit sites and
- b) see industrial drawing and design type is the transmission line as per the scope of the load.
- c) Demonstrate ability to design transmission lines as per location of the installation from the provided use video tapes, use charts, maps, visit sites and.
- d) Design the transmission line Span length as per the weight of the conductor, height and type of the support. From a Visit work site, use industrial standards, use video tapes, case study

7.3.2.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

1. Cross arm,
2. Transformers
3. Isolators
4. Insulators
5. Danger plates
6. Lightening arrestors
7. Anti-climbing wire
8. Cable
9. Bolts and Nuts

7.3.2.5. References

1. Electric Power Generation, Transmission, and Distribution and Electrical Protective Equipment – Final Rule Updated 2-18-2015 Performance Standard
2. An Introduction to Electric Power Transmission- Western Governors’ Association
3. Version 2 EE IIT, Kharagpur, Principles of power system by v.k mehta

7.3.3. Learning Outcome No. 2. Erected a transmission lines support.

7.3.3.1. Learning Activities

Learning Outcome No. 2. Erected a transmission lines support.	
Learning Activities	Special Instructions
• Use geographical maps, visit site, use video tapes erect Supports as per the location’s soil profile. • Visit websites, use video tapes, manufacturer’s manual sheet, catalogues, actual site visit and erect supports as per the weight of the conductor. • Use manufacturers’ catalogues, working drawings, EMCA Act, OSHA, County by-laws and elect supports as per established procedures and standards • Use manufacturers’ catalogues, working drawings, EMCA Act, • OSHA, County by-laws erect supports as per the conductors’ voltage.	

7.3.2.2. Information Sheet No. 7/LO2

Transmission line support is a structure used to hold the transmission lines above the ground.

Types of supports

- Wooden poles
- Steel poles
- Reinforced concrete poles
- Steel towers

Material used in manufacturing of transmission line supports e.g.

- Concrete
- Steel
- Wood

Erecting of transmission line support

Factors to consider when erecting line support

- Wind load
- Ice load

The materials required are;

- Stays
- Struts
- Cross-arm
- Tie struts
- The supports
- Insulators
- Bolt
- Nuts.

Application of transmission

- Importing of power from another country
- Transmitting power from the generating station to a substation.

7.3.2.3. Self-Assessment

1. Give four types of line supports
2. State four materials used for making line supports
3. Explain the application of the line support
4. State transmission line support
5. Trainee should be able to use geographical maps
6. What is the importance of manufacturers' catalogues?
7. State four types of line support
8. Explain four factors to consider when installing a transmission line
9. Give the applications of transmission line

7.3.2.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Stays
- Struts
- Cross-arm
- Tie struts
- The supports
- Insulators
- Bolt
- Nuts.

7.3.2.5. References

1. Electrical power systems by V.K mehta

7.3.4. Learning Outcome No. 3. Mount a transmission line

7.3.4.1. Learning Activities

Learning Outcome No. 3. Mount a transmission line	
Learning Activities	Special Instructions
• Mount transmission lines in consideration of the balance between tension and sag of the conductors. Visit website, use video tapes, IEE regulations, visit sites and • establish Spacing between conductors as per line voltage Use manufacturers' catalogues, working drawings, EMCA Act, OSHA, County by-laws, make site visit, IEE regulations • mount transmission line as per the type of the conductors. Use manufacturers' catalogues, working drawings, EMCA Act, OSHA, County by-laws, make site visit, IEE regulations and • Perform tension of transmission line as per fluctuations of the weather condition. Visit site, use manufacturer's manual, hold discussions, consultations • Cross arms are mounted in line with the spacing between conductors. • mounted conductors as per the types of insulators used. Use manufacturers' catalogues, working drawings, EMCA Act, OSHA, County by-laws, make site visit, IEE regulations and	

7.3.4.2. Information Sheet No. 3/ LO3

Types of transmission line conductors

- Copper
- Aluminum
- Steel cored aluminum
- Galvanized steel
- Cadmium copper

Equipment's used in mounting transmission line

- Screw drivers
- Pliers kit
- Hand Drill and drill bits selection

<https://www.lowes.com/pl/Pliers-plier-sets-Hand-tools-Tools/4294425055>

- Razor knife for cutting rubber cooler hose
- Hacksaw or small pipe cutter for cutting cooler lines
- A drain pan or small container for capturing fluid
- Climbers
- Drilling Machine
- Transmission-towers-and-substations
 - Hydraulic tensioner
 - Hydraulic pulley
 - Hydraulic pulley Transmission line stringing equipment
 - Hydraulic cable tensioner maximum intermittent tension

Tension and sag in transmission line

The sag and tension analysis help in the continuity and quality of electrical services. Increasing the tension of the conductor is beyond the limit, may break it, and the power transmissions of the system may get erupted.

The conductor dip between the two-level supports is referred to as sag as illustrated below. A span is the horizontal distance between two electrical supports as shown below.

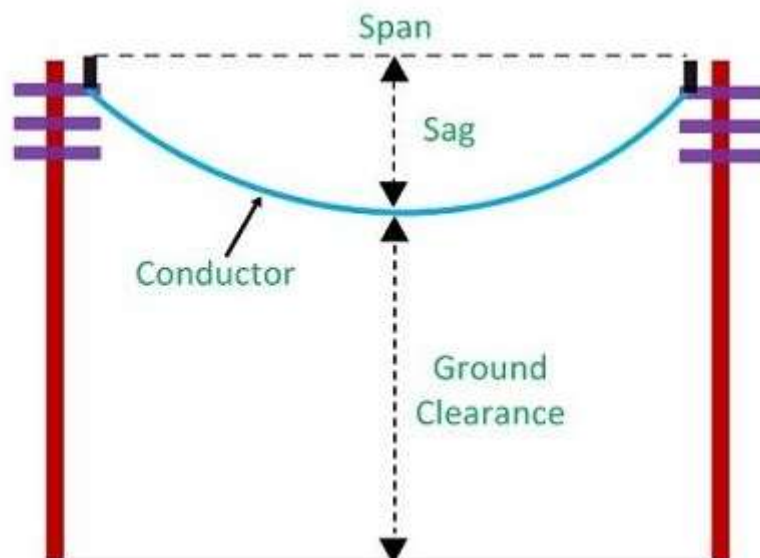


Figure 110: Illustration of Span

Source: <https://circuitglobe.com/calculation-of-sag-and-tension.html>

Factors affecting the sag;

- Conductor weight – the weight of the conductor is directly proportional to the sag. Ice loading increases the weight of the conductor.
- Span – square of the length is directly proportional to the sag. The longer span, the more the sag.
- Tension -The tension in the conductor is inversely proportional to the sag. Increase in tension raises the stress in the insulators that support the structure.
- Wind –sag is increased in the inclined direction.
- Temperature – At low temperatures, sag is reduced while at high temperatures sag is increased.

<https://circuitglobe.com/calculation-of-sag-and-tension.html>

<https://circuitglobe.com/sag-and-tension.html>

Others include; Insulators, Danger plates, Lightning arrestors, Anti-climbing wire, Cables, Bolts and Nuts

Transmission line spacing and corona effects

II. Power Loss

According to Peek's formulas [5], the power loss due to corona under fair weather conditions can be expressed as:

$$P_{ufwc} = \frac{K}{\delta} (f + 25) \sqrt{\frac{R}{d}} \left(\frac{V_L}{\sqrt{3}} - E_{dcv} \right)^2 L \times 10^{-5} \text{ KW / km / phase} \quad (1)$$

The normalized air density correction factor, δ is 1 at 25°C at 76 cm pressure. Table 1 shows the sample of corona loss calculation based on Peek's formula

Under the stormy weather conditions, the disruptive critical voltage (E_{dcv}) is taken as 0.8 times that of the fair weather value. Where the ratio of the phase voltage to the disruptive critical voltage is less than 1.8, Peterson formula [6] is used for determining the corona loss. This is given as:

$$P_{pet} = \frac{21 \times 10^{-6} \times f V^2}{(\log_{10} d / R)^2} \quad (2)$$

Power loss due to Corona on High Voltage Transmission Lines (Enesi ,Asizehi), IOSR Journal of Electrical and Electronics Engineering 2013.

Used in transmission line protection e.g.

- Switch gear
- Fuses used in transmission line
- Isolators

- Circuit breakers

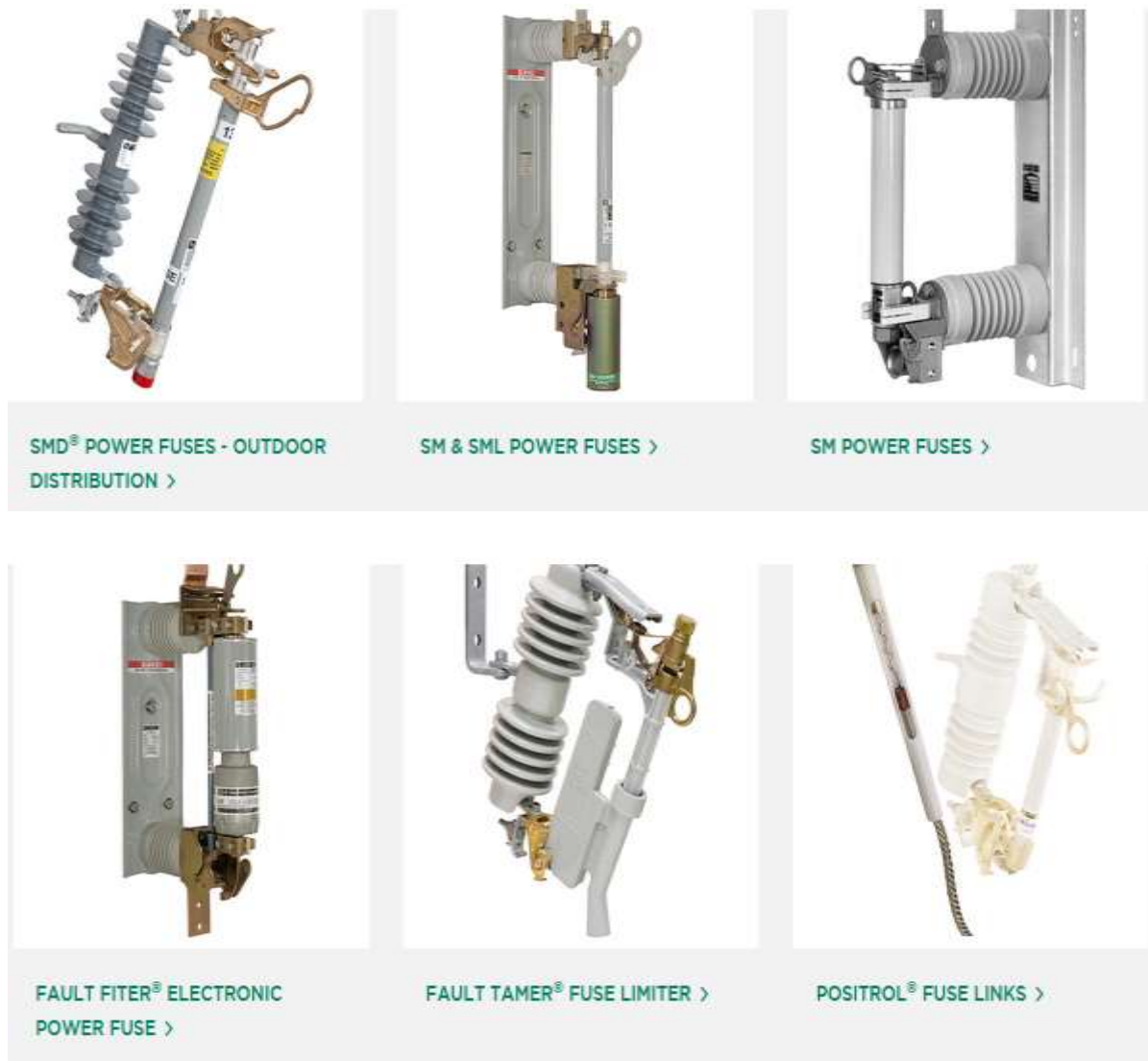


Figure 111: transmission line protection Fuses & Gears

Source: <https://circuitglobe.com/calculation-of-sag-and-tension.html>
<https://circuitglobe.com/sag-and-tension.html>

Definitions

Earthing: Refers to the electrical conduction connection between the construction part and the surrounding soil.

Functional earthing: Earthing to divert lightning currents and 50-periodic fault currents so safe tripping is obtained.

Protective earthing: Earthing a point or points in a system for electrical safety and ensuring protection against electric shock.

Earth conductor

Conductor that forms a part of the fixed installation for the purposes of earthing

Earth electrode: Conductor that provides an electrical connection with the surrounding soil layers.

Shallow earth electrode: Earth electrode that consist of a continuous counterpoise, radial earth electrode or otherwise to the surface parallel located earth conductors down to a depth of about 1 m.

Deep earth electrode: Earth electrode that consist of vertically placed earth electrode buried or driven down in the soil at a greater depth than 1 m.

Radial earth electrode: Horizontally radially placed earth conductors in the soil.

Counterpoise: Conductor or combination of conductors buried in the ground and electrically connecting the footings of the supports of the towers.

Continuous counterpoise: Conductor buried in the ground electrically connecting the footings of the supports of the towers along an overhead line.

Local earth electrode: Earth electrode comprising deep earth electrode, radial earth electrode or a combination thereof.

Protective bonding conductor: Conductor provided for protective-equipotential-bonding.

Potential grading earth electrode: Protective earthing consisting of a protective bonding conductor in the soil around structure and/or stay anchors.

Earthing conductor: Conductor between an earth electrode and an earth terminal or, if such terminal is missing, between an earth electrode and a construction part that shall be earthed.

Down conductor: Conductor for connection of insulator string attachments, cross arm and shield wire to a fixed earth terminal on the tower.

Shield wire: Conductor, horizontally located in an overhead line, usually located above the phase conductors.

Continuous shield wire: Shield wire located along the entire length of overhead lines.

Insulated shield wire: Shield wire electrically separated from the tower with insulators

7.3.2.3 Self-Assessment

1. Differentiate a surge diverter and a surge arrester
2. Explain the parts of a lightning arrester
3. Outline the steps of earthing a transmission line
4. State transmission line conductors
5. Describe types of transmission line conductors
6. Explain tension and sag in transmission line
7. Describe factors affecting the sag
8. Explain components used in mounting transmission lines
9. Perform calculations on power loss
10. Describe transmission line protection
11. consist of vertically placed earth electrode buried or driven down in the soil at a greater depth than 1 m.
 - a) Radial earth electrode

- b) Continuous counterpoise
 - c) Counterpoise
 - d) Deep earth electrode
12. consist of horizontally radially placed earth conductors in the soil.
- a) Radial earth electrode
 - b) Continuous counterpoise
 - c) Counterpoise
 - d) Deep earth electrode
13. Conductor or combination of conductors buried in the ground and electrically connecting the footings of the supports of the towers.
- a) Radial earth electrode
 - b) Continuous counterpoise
 - c) Counterpoise
 - d) Deep earth electrode
14. In the conductor buried in the ground electrically connecting the footings of the supports of the towers along an overhead line.
- a) Radial earth electrode
 - b) Continuous counterpoise
 - c) Counterpoise
 - d) Deep earth electrode
15. The tension in the conductor is inversely proportional to the sag
- a) True
 - b) False
16. At low temperatures, sag is reduced while at high temperatures sag is increased.
- a) True
 - b) False

Practical exercise

- a) Demonstrate ability to use geographical maps, visit site, use video tapes erect Supports as per the location's soil profile.
- b) Visit websites, use video tapes, manufacturer's manual sheet, catalogues, actual site visit and erect supports as per the weight of the conductor.
- c) Identify and use manufacturers' catalogues, working drawings, EMCA Act, OSHA, County by-laws and elect supports as per established procedures and standards

7.3.2.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Multimeter
- Surge arrester
- Surge diverter
- Transmission lines

7.3.2.5. References

1. http://www.weschler.com/_upload/sitepdfs/techref/gettingdowntoearth.pdf

2. https://dam-assets.fluke.com/s3fs-public/1579160_b_w.pdf).
3. <https://www.quora.com/Why-are-cross-arms-used-in-transmission-lines>
4. <https://www.transformertechnologies.com/>
5. <https://www.southernstatesllc.com/applications/transmission-line-circuit-isolation/>
6. SVENSKA KRAFTNAT SWEDISH NATIONAL GRID-Technical guideline-2015.
7. <https://www.svk.se/siteassets/aktorsportalen/tekniska-riktlinjer/tr05/tr05-13e-earthing-revision-2.pdf>
8. <https://www.sandc.com/en/products--services/products/smd-power-fuses-outdoor-transmission/>
9. https://dam-assets.fluke.com/s3fs-public/1579160_b_w.pdf).
10. https://www.ee.iitb.ac.in/course/~emlab/assets/oc_sc.pdf
11. <https://www.instructables.com/id/Basic-Electric-CONTINUITY-TESTER/>

7.3.5. Learning Outcome No. 4. Terminated conductors

7.3.5.1. Learning Activities

Learning Outcome No. 4. Terminated conductors	
Learning Activities	Special Instructions
• Visit work site, use industrial standards, video tapes, case study , manufacturers' catalogues, working drawings, EMCA Act, • OSHA, County by-laws and terminate conductors as per the line voltage. • Use manufacturers' catalogues, working drawings, EMCA Act, • OSHA, County by-laws, visit work site, use industrial standards, use video tapes, case study and terminate transmission lines as per the type of conductors • Visit work site, use industrial standards, use video tapes, case study, manufacturers' catalogues, working drawings, EMCA Act, • OSHA, County by-laws and use appropriate types of joint terminations. • Visit work site, use industrial standards, use video tapes, case study, manufacturers' catalogues, working drawings, EMCA Act, • OSHA, County by-laws and terminate transmission lines as per the IEE regulation • Visit work site, use industrial standards, use video tapes, case study and terminate transmission line as per end point load. • Visit work site, use industrial standards, video tapes, case study and terminate transmission line as per the type of transmission.	

7.3.5.2. Information Sheet No. 7/ LO4

Transmission line termination refers to putting to an end a transmission line with a device with similar characteristic impedance of the line to prevent signals from being reflected off at the end of the transmission line.

Passive

Passive terminators comprise of a single resistor, though reactive loads may need other passive components for example inductors, capacitors, or transformers.

Active

Active terminators comprise of voltage regulator that ensures voltage used for the terminating resistor(s) at a constant level.

Forced Perfect Termination.

Forced perfect termination (FPT) is applicable on a single ended buses in where diodes remove over and undershoot conditions. There is locking of signal between two actively regulated voltage levels, resulting in superior performance over a standard active terminator. Figure below;

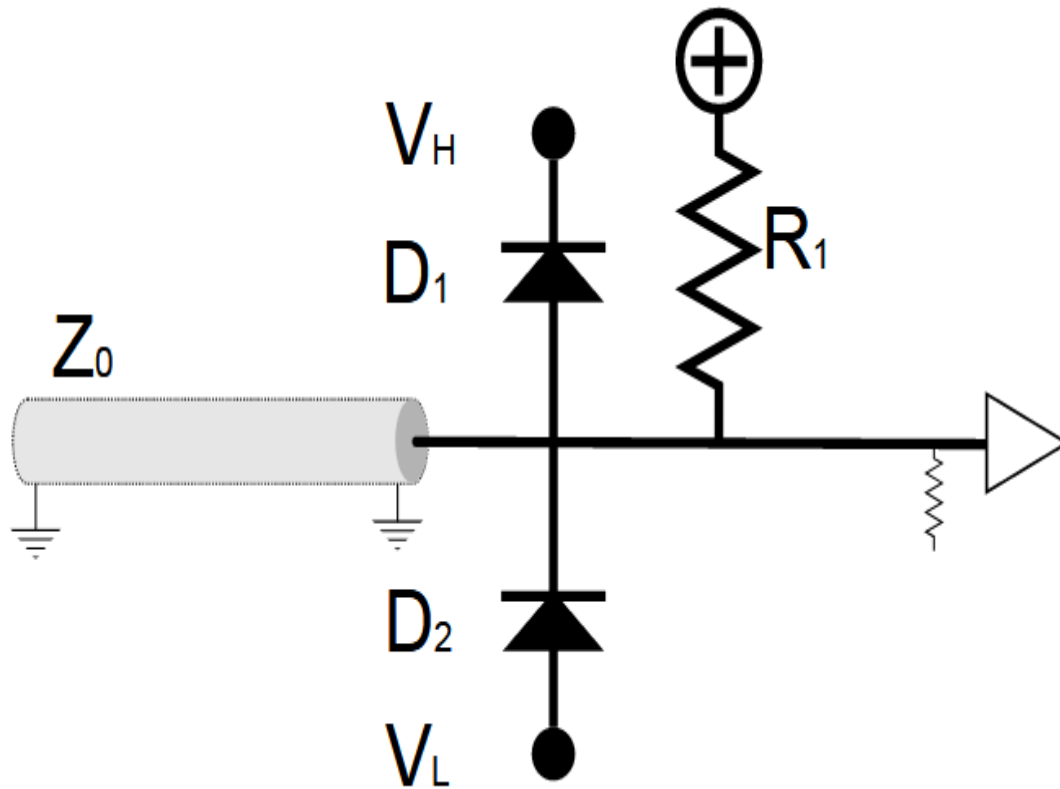


Figure 112: Forced Perfect Termination.

Source: <https://circuitglobe.com/calculation-of-sag-and-tension.html>
<https://circuitglobe.com/sag-and-tension.html>

Some of the termination technique includes:

- Parallel Termination. This technique uses a single resistor from trace to ground and operates appropriately with distributed loads. However, there is a provision of a continuous DC path to ground. Shown below.
- AC Termination. This technique incorporates a capacitor in series with a parallel resistor that terminates to block DC. However, depending on the capacitor used there can be problems with power dissipation or overshoots.

Types of transmission

- i) A.C transmission: It is a transmission line carrying alternating current.
- ii) D.C transmission: It is a transmission line carrying direct current.

Transmission of electric power can be in both AC and DC. They are associated with both advantages and disadvantages as discussed below

DC Transmission

Advantages:

- Only a maximum of two conductors are used in DC transmission -There are no Inductance and Surges in DC transmission.
- Low voltage drop due to absence of inductance
- No skin effect in DC transmission hence only a small cross-sectional area of the conductor is required.
- DC line requires less insulation due to less potential stress.
- No interference with system of communication
- Low Corona losses
- No dielectric losses in high DC transmission.
- No difficulties in synchronizing and stability problems.
- Low insulation required for the Dc systems about 70%).

Disadvantages

- Not possible to produce power at High (DC) Voltage due commutation.
- Not possible to step the level of DC Voltage at high voltage.
- It is not possible to change the level of DC Voltage hence one cannot get desired voltage for Electrical and electronics appliances direct from Transmission system.

AC Transmission

Advantages:

- AC Circuit breakers are cheap
- Easy maintenance and repair of AC sub-station
- It is possible to either increase or decrease AC voltage using transformer

Disadvantages:

- Has skin effect, hence results to losses during transmission.
- Power loss due to capacitance and inductance. along the Corona Losses occur in AC lines,
- There is telecommunication interference in AC System.
- There are problems with stability and synchronization.

Type of loads

Electrical loads such as bug zappers, toasters and refrigerators are the devices connected to the power system. The three types of electrical loads discussed below vary depending on the leading and lagging time relationship between the current and the voltage.

The three load types are

- Resistive
- Inductive
- Capacitive

Components used in line termination e.g.

- Lugs
- Fuses
- Droppers

7.3.5.3. Self-Assessment

1. state four types of electrical joints
2. state the type of electrical load and give an example
3. State transmission line termination
4. Describe types of transmission line termination
5. Explain termination techniques
6. What is the importance of termination?
7. Differentiate between AC and DC transmission
8. Which of the following isn't an advantage of AC transmission?
 - a) AC Circuit breakers are cheap
 - b) Easy maintenance and repair of AC sub-station
 - c) No difficulties in synchronizing and stability problems.
 - d) It is possible to either increase or decrease AC voltage using transformer
9. The three load types include the following except
 - a) Resistive
 - b) Inductive
 - c) Terminative
 - d) Capacitive
10. Components used in line termination include the following except
 - a. Lugs
 - b. Fuses
 - c. Droppers
 - d. Transformer
11. Active terminators comprise of voltage regulator that ensures voltage used for the terminating resistor(s) at a constant level.
 - a) True
 - b) False

12. Thevenin Termination. This technique uses resistor pairs, one for ground, the other for power.

- a) True
- b) False

Practical exercise

- a) Demonstrate ability to use manufacturers' catalogues, working drawings, EMCA Act, OSHA, County by-laws, visit work site, use industrial standards, use video tapes, case study and terminate transmission lines as per the type of conductors
- b) Visit work site, use industrial standards, use video tapes, case study, manufacturers' catalogues, working drawings, EMCA Act, OSHA, County by-laws and use appropriate types of joint terminations.

7.3.5.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- DC generator
- AC generator
- Multimeter
- Electrical cables
- Soldering iron

7.3.5.5. References

1. <https://www.youtube.com/watch?v=puF21Z2hfIM>
2. <http://electriciantraining.tpub.com/14182/css/Terminating-A-Transmission-Line-146.htm>
3. <https://www.falstad.com/circuit/e-tlterm.html>https://en.wikipedia.org/wiki/Electrical_termination
4. https://en.wikipedia.org/wiki/Electrical_termination<https://fenix.tecnico.ulisboa.pt/downloadFile/3779579943588/>

7.3.6. Learning Outcome No. 5. Inspected and Tested installation

7.3.6.1. Learning Activities

Learning Outcome No. 5. Inspected and Tested installation	
Learning Activities	Special Instructions
• Visit work site, use industrial standards, use video tapes, case study, manufacturers' catalogues, working drawings, EMCA Act, OSHA, County by-laws and establish the tests to be carried. • Visit work site, use industrial standards, use video tapes, case study, manufacturers' catalogues, working drawings, EMCA Act, OSHA, County by-laws and perform the test as per the IEE regulations. • Visit work site, use industrial standards, use video tapes, case study, manufacturers' catalogues, working drawings, EMCA Act, OSHA, County by-laws and establish the firmness of the transmission line. • Visit work site, use industrial standards, use video tapes, case study, manufacturers' catalogues, working drawings, EMCA Act, OSHA, County by-laws and perform Continuity test. • Visit work site, use industrial standards, use video tapes, case study, manufacturers' catalogues, working drawings, EMCA Act, OSHA, County by-laws and perform Short circuit test. • Visit work site, use industrial standards, use video tapes, case study, manufacturers' catalogues, working drawings, EMCA Act, OSHA, County by-laws and perform Insulation test as per the IEE regulations	

7.3.6.2. Information Sheet No. 7/ LO5

- Definitions of key terms
- methods, processes/ procedures/ guidelines
- content
- illustrations (photographs, pictures, videos, charts, plans, digital content, simulations)
- case studies

Meaning of testing in line transmission

Testing means using instrument to check the proper operation of the transmission line.

Types of tests in line transmission e.g.

- Continuity test- <https://www.instructables.com/id/Basic-Electric-Continuity-Tester/>

How to test for continuity

1. Turn the dial to Continuity Test mode. It will likely share a spot on the dial with one or more functions, usually resistance (Ω). With the test probes separated, the multimeter's display may show OL and Ω .
2. If required, press the continuity button.
3. First insert the black test lead into the COM jack.
4. Then insert the red lead into the $V\Omega$ jack. When finished, remove the leads in reverse order: red first, then black.
5. With the circuit de-energized, connect the test leads across the component being tested. The position of the test leads is arbitrary. Note that the component may need to be isolated from other components in the circuit.
6. The digital multimeter (DMM) beeps if a complete path (continuity) is detected. If the circuit is open (the switch is in the OFF position), the DMM will not beep.
7. When finished, turn the multimeter OFF to preserve battery life.

Proper insulation is associated with high resistance and poor insulation

The actual values of resistance can either be low or high depending on factors including temperature or the insulation moisture content.

The Megger insulation tester is vital in testing insulation resistance measured in ohms or megohms. It is usually a high-range resistance meter (ohmmeter) with a built-in direct-current generator. It has special current and voltage coils to enable true ohms to be read directly, independent of the actual voltage applied. This method is non-destructive hence does not deteriorate the insulation (https://dam-assets.fluke.com/s3fs-public/1579160_b_w.pdf).

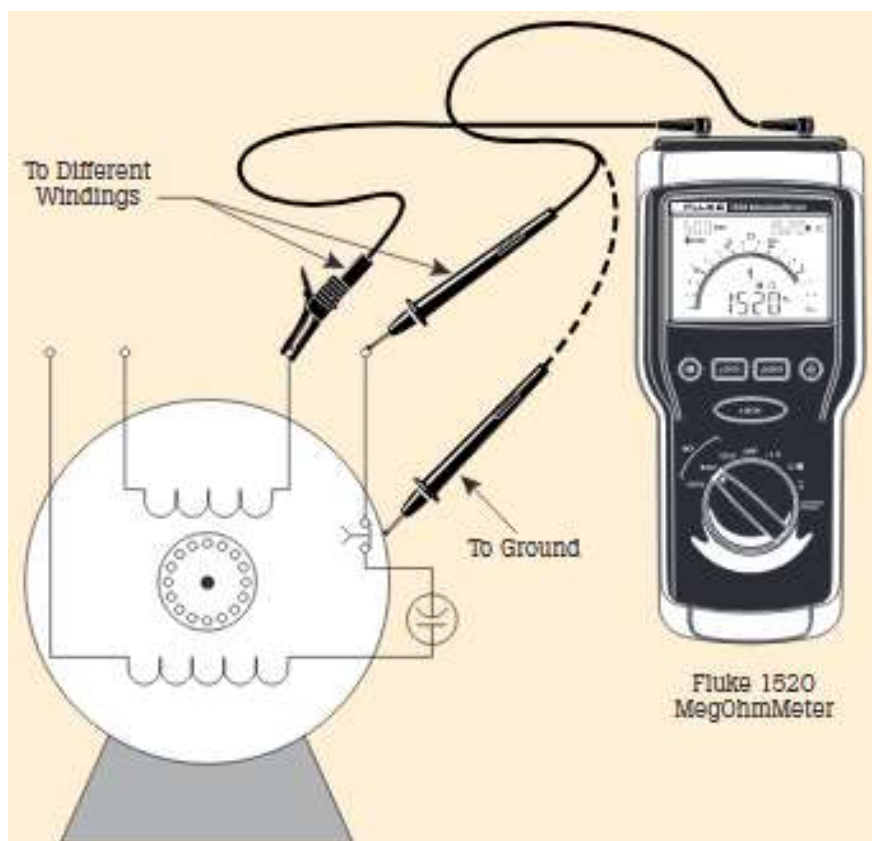


Figure 113: Insulation resistance tester carrying out measurement(https://dam-assets.fluke.com/s3fs-public/1579160_b_w.pdf).

Earth continuity test

Below are drawings showing how to measure earth resistance.

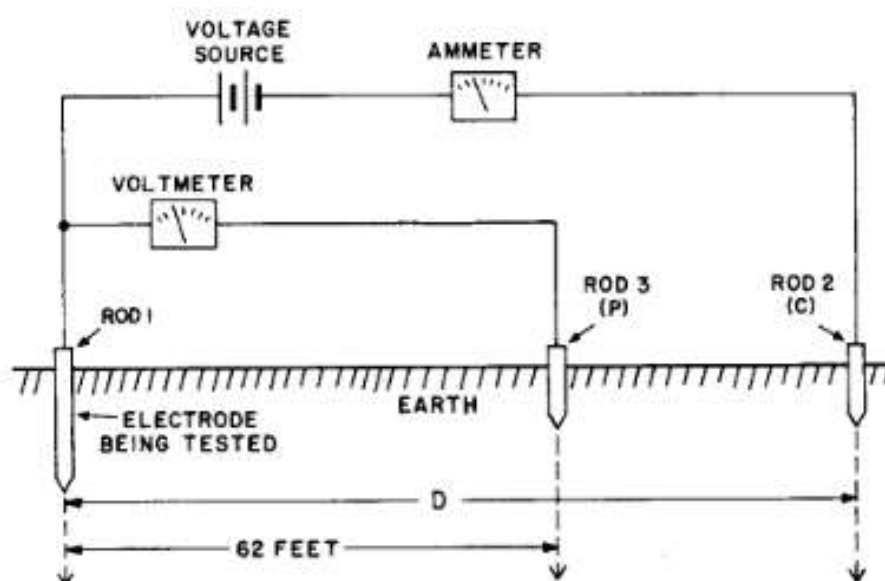


Figure 114: measuring earth resistance
(http://www.weschler.com/_upload/sitepdfs/techref/gettingdowntoearth.pdf)

7.3.6.3 Self-Assessment

- 1) State testing in line transmission
- 2) What is the importance of testing in line transmission?
- 3) Describe types of tests in line transmission
- 4) Explain how to test for continuity
- 5) In the actual values of resistance can either be low or high depending on factors including temperature or the insulation moisture content.
 - a) Continuity test
 - b) Insulation test
 - c) Earth continuity test
- 6) In the digital multimeter (DMM) beeps if a complete path (continuity) is detected.
 - a) Continuity test
 - b) Insulation test
 - c) Earth continuity test
- 7) Which of the following is not a type of test in line transmission?
 - a) Continuity test
 - b) Insulation test
 - c) Earth continuity test
 - d) Speed test
- 8) The Megger insulation tester is vital in testing insulation resistance measured in ohms or megohms.
 - a) True
 - b) False
- 9) Testing means using instrument to check the proper operation of the transmission line.
 - a) True
 - b) False

Practical exercise

- a) Identify and demonstrate how to test continuity
- b) Identify and outline the procedure of carrying out the following tests
 - i) Short circuit test
 - ii) Insulation resistance test

7.3.6.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Insulation resistance test
- Earth resistance test
- Transmission line
- Continuity tester

7.3.6.5 References (APA)

1. http://www.weschler.com/_upload/sitepdfs/techref/gettingdowntoearth.pdf
2. https://dam-assets.fluke.com/s3fs-public/1579160_b_w.pdf).
3. https://dam-assets.fluke.com/s3fs-public/1579160_b_w.pdf).
4. https://www.ee.iitb.ac.in/course/~emlab/assets/oc_sc.pdf
5. <https://www.instructables.com/id/Basic-Electric-CONTINUITY-TESTER/>

CHAPTER 8 ELECTRICAL MACHINE INSTALLATION. / INSTALLATION OF ELECTRICAL MACHINE

8.1. Introduction of the Unit of Learning / Unit of Competency

Electrical machines are used in industrial processes for manufacturing purposes. Proper installation of machine is important to achieve high performance with less breakdown.

This unit is designed to equip the trainee with the necessary knowledge, skills and attitude to understand Electrical machine installation. Competencies in this unit include Observe safety, Electrical machines design, mounting of Electrical machines, mounting of Electrical control panels , Laying of machine cables , Termination of electrical machine installation and testing of electrical machine installation

8.2. Performance Standard

The trainee to observe safety, design , install and mount electrical machine, lay cables, Earth, terminate and test electrical machines as per IEE regulation

8.3 Learning Outcome

8.3.1. List of Learning Outcomes

- a) Design Electrical Machine layout
- b) Mount Electrical Machine
- c) Mount Electrical Machine control panel
- d) Lay Machine cables
- e) Terminate Electrical Machine installation
- f) Test and Inspect Electrical Machine installation

8.3.2 Learning Outcome No. 1. Design electrical machine layout

8.3.2.1 Learning Activities

Learning Outcome No. 1. Design electrical machine layout	
Learning Activities	Special Instructions
• Installing machine cabling in line with IEE regulation. • Installing machine sockets in line with standard operating procedure • Performing Design in line with OSHA • Designing machine layout as per expected loads • Designing machine layout in line with standard operating procedure • Performing Machine design layout in line with OSHA	

8.3.2.2 Information Sheet No. 8/ LO1

Introduction

Layout planning involves making a decision on the best physical structure of the resources consuming space in a facility. Examples of these resources include a cabinet, a desk, a person, a work center and either the entire office or department. Such decisions are not only made in designing a new facility but also made in case there is a change in resources arrangement for instance a new worker being added or change in the implantation of a given procedure. Besides, planning could be done in case either an expansion is done or a space reduced.

Machine Layout

The process of chain system in preparing read made garment in an apparel industry is called production. There are several sewing machines depending on the number of process of garments. The first priority in improving production is the machine layout plan. In the garments industry, the production manager often set up machine layout plan for a particular garment item. The various machine layout plan is unique depending on the garment item. It is largely sewing machine arrangement plan, that is apparent in producing several garments within a limited period with reduced defects of garment.

Types of machine layout

There are Four Key Types of Plant Layout;

- Product or Line Layout: A layout is called product type of layout in case the arrangement of processing equipment and machines are in line with the sequence of operations of the product.
- Process or Functional Layout
- Fixed Position Layout

- Combination Type of Layout

1. Product or Line Layout:

In case all processing equipment and machines arrangement is in line with the sequence of operations of the product, the layout is referred to as product type of layout. In this form of layout, a single product or one form of products is made in an operating area. The product need to be standardized and the production made in huge quantities to justify layout the product.

There is a supply of raw material at one end of the line that goes from one operation to the next quite rapidly with a reduced work in process, storage and handling of material. Fig. 8.3 below illustrates product layout for products A and B.

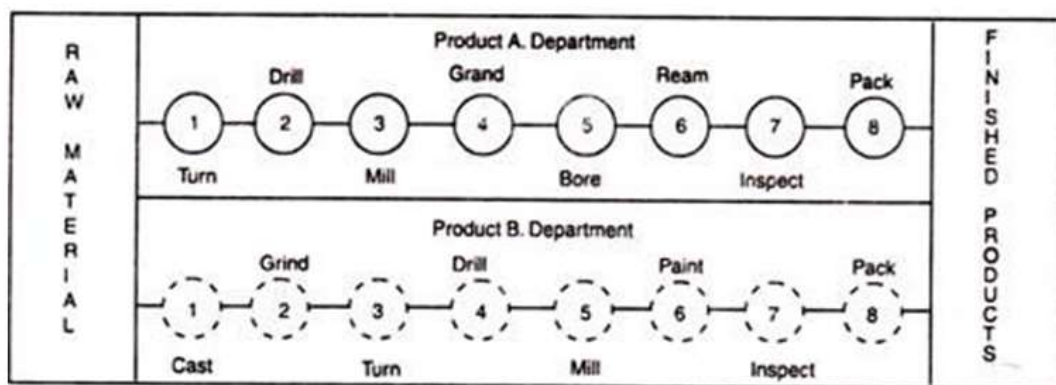


Figure 115: Line Layout:

Product Layout advantages:

- (i) Reduced total material cost of handling.
- (ii) Limited work in processes.
- (iii) Proper use of men and machinery,
- (iv) Limited area of the floor is occupied by transit material and for temporary storages.
- (v) Simple control of production
- (vi) Minimized total production period

Product Layout Limitations:

- (i) Not flexible as what is required is simply to obtained the layout.
- (ii) a fall in volume of production increases manufacturing cost increase
- (iii) There is a considerable machine idleness in case one or two lines are running light,
- (iv) In case a single machine breaks down, the whole production line may shut down
- (v) It is important to ensure specialized and strict supervision

Find more information on

<http://www.yourarticlelibrary.com/industries/plant-layout/four-main-types-of-plant-layout/34604>

Types Electrical Machines

Electric machine is a universal term used in machines using electromagnetic forces, for example electric motors, electric generators, transformers, and Special motors.

These machines have various classification

- Classification based on whether static or dynamic, ie Transformers, Motors and Generators
- Classification based on source of power. AC and DC machine
- Classification based on type of supply. Single phase supply and Three phase supply
- Classification based on principle of operation, Induction motors
- Classification based on their speeds, ie variable speed and constant speed

DC Machines

There are two of DC machines namely DC Motors and DC Generators. While a motor converts an electrical energy to mechanical energy, a Generator converts mechanical energy to electrical energy. There are two main parts in the DC machine, The Yoke and the armature. These machines are classified according to how the armature is connected in relation to the field.

These are

- Separately excited
- Self-excited
- Series and shunt excited
- Compound excited

Factors to Consider In Design If Machine Layout

1. Product nature: The product nature manufactured affects the plant layout. Reduced and less heavy in terms of weight products are possible to move from machine to machine with reduced effort and time hence making the line layout more suitable. Stationary layout is appropriate products that are heavy and bulky. The process layout is ideal for the production of several variety of non-standardized products.

2. Volume of production: For standardized commodities manufactured on a large scale, line layout is highly recommended. In case the production is depended on customers' orders, functional layout is recommended. It is appropriate for low volume job production.

3. The site location: The size and the topology of the site affects the choice of a specific layout. The idea is to maximize the space of utilization. It is vital for the layout to suit the factory building. Besides, the elevators, stairways, parking lots and storage point positions affects the layout.

4. Type of machines: in case the machines are heavy and produce more noise, stationary layout is preferred. It is possible to fit such heavy machines on the floor. Ample space is required for the location of machine and to avoid the occurrence of accidents.

5. Climate: there is need to consider temperature, illumination, ventilation while deciding on layout type to help improve employees' the health and welfare.

6. Service facilities: It is vital for the layout to provide for the employees' comforts and welfare. The requirements include rest rooms, drinking water, lavatory. Besides, sufficient space is required for worker's free movement.

7. Employees' safety: It is vital to give priority the safety of the employees while deciding on a particular type of layout. It needs to provide obstruction free floors, non-slippery floors, protection against dangerous fumes, excess heat, strong odors Etc.

8. Type of production: Layout plans vary depending on the type of production. For job orders, the production of non-standardized products is undertaken, hence functional or process outlet is suitable. When there is mass production of standardized goods, Line layout would be recommended.

9. The process type: For the intermittent production type (bi-cycle manufacturing, electronics), functional layout is applicable. In case synthetic production (cement and automobile industries), line layout is recommended.

10. The policies of management: Such policies that relate to a type of product, quality, scale of production, level of plant integration, type of production, possibility of future expansion etc., influence layout type to be adopted.

8.3.2.3. Self-Assessment

- a) Describe two methods of starting synchronous motors
- b) Differentiate between machine layout and layout planning
- c) Describe types of machine layout
- d) Explain the advantages of the types of machinery layout
- e) State an electrical machine
- f) Describe the classification of electrical machine
- g) Describe factors to consider in design if machine layout

- h) Electric machine is a universal term used in machines using electromagnetic forces. Which of the following is not one of the examples of electrical machines
 - a) electric motors
 - b) electric generators
 - c) transformers
 - d) fuse
- i) Which of the following is not among the factors to Consider in Design If Machine Layout?
 - a) Product nature
 - b) Volume of production
 - c) The site location
 - d) Product color
- j) A layout is called product type of layout in case the arrangement of processing equipment and machines are in line with the sequence of operations of the product.
 - a) True
 - b) False
- k) Layout planning involves making a decision on the best physical structure of the resources consuming space in a facility
 - a) True
 - b) False
- l) DC machines are classified according to how the armature is connected in relation to the field.
 - a) True
 - b) False

Practical exercise

- a) Use a well labeled power diagram of an induction motor and show all power losses
- b) Draw a power and control circuit of a DOL starter
- c) Demonstrate ability to install machine cabling in line with IEE regulation.
- d) Demonstrate ability to install machine sockets in line with standard operating procedure
- e) Performing Design in line with OSHA
- f) Designing machine layout as per expected loads

8.3.2.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Workshop with office, tool store and material store
- Protective goggles
- Dust coat
- Fire extinguishers
- First aid kit
- Portable drilling machine
- Hand drill
- Tape measure, Tin snip, folding bar, Bench vice, Pliers, Screw drivers, Multimeter

8.3.2.5 References

1. [Http://www.yourarticlelibrary.com/industries/plant-layout/four-main-types-of-plant-layout/34604](http://www.yourarticlelibrary.com/industries/plant-layout/four-main-types-of-plant-layout/34604)

8.3.3. Learning Outcome No. 2. Mounting electrical machine

8.3.3.1. Learning Activities

Learning Outcome No. 2. Mounting electrical machine	
Learning Activities	Special Instructions
• Mounting machine as per size, load and OSHA. • Machine Earthing performed as per IEE Regulation. • Mounting machine as per manufacturer manual.	

8.3.3.2. Information Sheet No. 8/LO2.

Machine Mount

Securely mount motors on a firm, flat base, if possible, grout-in larger motors. Motors that are Grease lubricated can be wall or ceiling mounted with the horizontal shaft. Motor that are Grease lubricated in NEMA 140–320 frame ratings are possible to wall mounted with the vertical shaft. For floor mounting, only either the standard transition and/or sliding bases are recommended. In case of mounting positions, it is important refer to the local GE representative. Oil lubrication of sleeving-bearing motors should be mounted with a horizontal shaft. The shield at the end shall be located with the oil ring sight gage in the twelve o'clock position.

The mounting bolts should be tightened to avoid alignment changes and equipment damage for the assembly of base and mounting of motor. A washer should be used under each nut or bolt head to ensure a secure hold on the motor feet. Alternatively, flanged nuts or bolts may be applied. The recommended tightening torques for medium carbon steel mounting bolts, SAE Grade 5, are listed below in Table 1. For recommended tightening torques of other hardware on the motor see tables 4A, and 4B in the Tightening Torque section of this book.

In case of direct coupled applications, the flexible couplings should be applied. It is vital to use accurate mechanical line up to ensure the operation is successful. Signs of poor alignment include mechanical vibration and roughness in running the motor. Generally, lineup by straight edge across, and feeler gauges between coupling halves is not sufficiently accurate. The lineup should be checked with a dial indicator and checking bars connected to the motor and load-machine shafts. The space between coupling hubs need to be maintained as recommended by the coupling manufacturer. Shaft offset should not exceed 0.002". Angular misalignment should be less than 0.002".

Factors to Consider In Machine Mount

Power Supply and Connections

1. Nameplate voltage and frequency should agree with the power supply. Motors will operate satisfactorily on line voltage within $\pm 10\%$ of the nameplate value or frequency within $\pm 5\%$, combined variation not to exceed $\pm 10\%$.

2. Dual voltage motors can be connected for the desired voltage using instructions on the nameplate or the connection diagram.
3. Wiring of motor, control, overload protection and grounding should meet the National and Local codes.
4. When mounting conditions permit, the conduit box may be rotated so that the conduit entrance can be made upward, downward, or from either side. For oversize conduit boxes, the mounting height of the motor may have to be increased for accessibility.

Sleeve Bearing Endplay

The feet need to be located at a suitable distance from the load on sleeve-bearing motors. It will ensure that the rotor of the motor is in the approximate mid-point of its endplay. The rotor's mid-position end play is indicated with a mark on the shaft of the motor. Locate this mark flush with the bearing housing.

Safety in Design of Electrical Machine Layout

Installation

- Avoid contact with energized circuits and rotating parts.
- Avoid bypassing or rendering inoperative any safeguards or protective devices.
- Avoid use of automatic-reset thermal protection where unexpected starting of equipment might be hazardous to personnel.
- Avoid contact with capacitors until safe discharge procedures have been followed.
- Be sure the motor shaft key is captive before the motor is energized.
- Avoid long exposure in close proximity to machinery with high noise levels.
- When the motor is coupled to equipment, ensure that system vibrations are within acceptable limit (per ISO 10816-1) to avoid failure of the motor.
- Use proper protective gear, care and procedures when handling, lifting, installing, operating and maintaining the motor.
- If eyebolts are used for lifting motors, they must be securely tightened, and the direction of the lift must not exceed a 15° angle from the shank of the eyebolt. Do not use eyebolts in an ambient below 0°F. At temperatures below 0° F, the eyebolt could fail resulting in injury to personnel and/or damage to equipment.

Drop-forged eyebolts per American Society of Testing Materials A489 or equivalent must be used.

- Do not use the motor shaft as a means for lifting.
- Do not lift both the motor and driven equipment with the motor lifting means.
- Do not stand on or place objects on the motor.

More information

https://www.gepowerconversion.com/sites/default/files/product/GEI-56128%28NEMA_140-500_HorizMotor%29.pdf

8.3.3.3 Self-Assessment

1. Describe Four factors to consider when mounting a machine
2. State machine mount
3. What is the importance of ensuring safety during machine mount?
4. Describe safety in designing electrical machine layout
5. What should flexible couplings be applied in case of direct coupled applications?
6. If eyebolts are used for lifting motors, they must be securely tightened, and the direction of the lift must not exceed a angle from the shank of the eyebolt
 - a) 60°
 - b) 45°
 - c) 15°
 - d) 180°
7. The space between coupling hubs need to be maintained as recommended by the coupling manufacturer. Shaft offset should not exceed Angular misalignment should be less than
 - a) 0.002", 0.001".
 - b) 0.001", 0.002".
 - c) 0.002", 0.002".
 - d) 0.01", 0.01".
8. Which of the following is not one of the Safety considered in in Design of Electrical Machine Layout?
 - a. Avoid contact with energized circuits and rotating parts.
 - b. Avoid bypassing or rendering inoperative any safeguards or protective devices.
 - c. Make contact with capacitors until safe discharge procedures have been followed
 - d. Avoid use of automatic-reset thermal protection where unexpected starting of equipment might be hazardous to personnel.
9. A washer should be used under each nut or bolt head to ensure a secure hold on the motor feet.
 - a) True
 - b) False
10. In case of mounting positions, it is important refer to the local GE representative. Oil lubrication of sleeving-bearing motors should be mounted with a horizontal shaft.
 - a) True
 - b) False

Practical exercise

- a) Demonstrate ability to Mount machine as per size, load and OSHA.
- b) Machine Earthing performed as per IEE Regulation.
- c) Mounting machine as per manufacturer manual.

8.3.5. Learning Outcome No. 4. Lay machine cables

8.3.5.1. Learning Activities

Learning Outcome No. 4. Lay machine cables	
Learning Activities	Special Instructions
• Laying Machine cables as per IEE regulation • Colour coding cables as per IEE regulation • Installing cables firmly as per standard operating procedure • Segregating cables as per standard operating procedure	

8.3.5.2 Information Sheet No 8/LO4.

Introduction

Types of Cables in motor control

1. Singles
2. Sheathed
3. Coaxial Cable

A cable for motor signal includes coaxial cable that is 75 ohm. We equally offer a combined coaxial and power supply cable to maximize proper operation and cable laying.

Pair-Twisted Signal Cable.

The fire alarms cables are available with either red or grey sheaths depended upon the regulations, aesthetic requirements, etc. The twisted pair cable are recommended for the larger addressable systems.

Factors to consider in machine cable laying

i. Cable installation

For the outdoor or indoor installations, cables can be uses depending on the load served and distribution system. It is vital to understand local conditions, installation crews, and maintenance personnel in assuring the selected cable system functions well! There is frequent damage of cable insulation that is weakened during installation through incorrect application of pulling tensions.

Designing of conduit systems reduces conduit bends numbers and distances between manholes and set particular pulling tensions.

ii. Cable construction

Cable application and selection involves the cable construction type that is required for a given installation. Construction of cable comprise of conductors, insulation, finish

covering and cable arrangement. Copper and aluminum conductor materials need to be given priority in regard with workmanship, maintenance and environmental conditions. The aluminum conductor requirements are more vital as compared to the copper requirements.

iii. Arrangement of cable

The arrangement of conductors may produce either single-conductor or three-conductor cable. Both forms are associated with both merits and demerits. For single conductors it is easier to install, splice, and allow the formation of multiple-cable circuits. Alternatively, the reactance is higher than three-conductor cable. High shield currents are carried by shielded single conductors and need to be considered to avoid cable overheating.

One of important consideration is the ground wire availability in three-conductor cable or a separate ground wire with single-conductor cable. The ground conductor in three-conductor cable construction offers the lowest impedance path hence ensures a proper system ground. Equally, a separate ground in the same conduit as the power conductors provides a better ground return path than a ground path via the equipment or building steel.

iv. Insulation and finish covering

It is normally depended on the installation type, ambient operating temperature, service conditions, type of load served, and other applicable criteria. In several installations uncommon conditions may be predominant, for example corrosive atmosphere, high ambient temperature, insect and rodent hazard, presence of oil and solvents, presence of ozone, and extreme cold. In certain applications, two or more of these unusual conditions may be present, in which case the selection of suitable cables becomes much more difficult.

v. Cable operation (voltage and current)

The cable insulation should be able withstand the voltage stresses produced during normal and abnormal operating conditions. Hence, cable insulation selection needs to be made based on the applicable phase-to-phase voltage and the general system category which are classified as either 100%, 133%, or 173% insulation levels.

vi. Cable size

The cable size selection is based upon the following factors:

- Capacity to carry current
- Voltage regulation
- Short circuit rating

Evaluation of these factors should be done before selecting the size of the cable. However, voltage regulation and factors of short circuit rating are overrated in most cases. It can pose danger to property and personnel including cable destruction.

vii. Shielding requirements

While doing the selection and application of cables at medium voltage, a major concern involves whether the cable should be shielded or non-shielded. Cable shielding conditions cable are discussed below.

- Insulation type of the system
- Whether the system neutral is grounded or ungrounded
- Safety and reliability requirements of the system

In case of the systems that are not shielded or metallic covering, the electric field is partially in the air and partially in the insulation system! For the high electric field for example the case of high and medium voltage, surface discharges would occur causing air particles ionization. Air ionization causes ozone generation that can worsen insulations and destroy coverings.

For the installations that are duck type, non-shielded, and use nonmetallic cable, the external electric field may be considerably high causing a safety hazard to persons working on single cable in multi-circuit installations. For portable cables, cable assemblies, or installations of exposed overhead cable are used and may be handled by personnel, serious safety hazards may exist if non-shielded cable is used.

Cable Laying Arrangement

Multicore cables are laid in “flat formation” arrangement and single core cables may be laid in “trefoil” arrangement or in “flat formation” arrangement. For single core cables “trefoil” arrangement is the most advised method.

Segregation in Cable Laying

No matter what method is used for laying, cables must be segregated taking into account the voltage level and function. Segregation means that cables with different voltage levels and/or different functions must not be laid at the same physical support and must be separated. Segregation of cables must be done in accordance with standards and regulations, as well as local authorities’ recommendations and must consider the following situations:

- Power cables (by voltage level).
- Control cables.
- Communication cables.

Importance Segregations

To evade possible electromagnetic interferences that can interrupt the networks and the signals cables are carrying on

8.3.5.3. Self-Assessment

1. Briefly describe types of cables in motor control system
2. State five factors to consider in cable laying.
3. Define segregation in cable laying
4. State importance of segregation in cable laying.
5. state an electrical cable
6. explain Segregation in Cable Laying
7. Which of the following is not one of the factors to consider in machine cable laying
 - a) Cable installation
 - b) Cable construction
 - c) Cable color
 - d) Cable arrangement
8. The cable size selection is based upon the following factors except?
 - a) Capacity to carry current
 - b) Voltage regulation
 - c) Cable resistance
 - d) Short circuit rating
9. Segregation evade possible electromagnetic interferences that can interrupt the networks and the signals cables are carrying
 - a) True
 - b) False
10. While doing the selection and application of cables at medium voltage, a major concern involves whether the cable should be shielded or non-shielded
 - a) True
 - b) False
11. Segregation of cables must be done in accordance with standards and regulations
 - a) True
 - b) False

Practical exercise

- a) Demonstrate ability to lay Machine cables as per IEE regulation
- b) Perform calculations on electrical cable
- c) Identification and color coding cables as per IEE regulation
- d) Installing and Segregating cables firmly as per standard operating procedure

8.3.5.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Model of cable segregation arrangements
- Cables
- Cable stripper
- Side cutter

8.3.5.5. References

1. Bolotinha, M. (2017). cable laying and pulling.
2. Edvard. (2016). 5 vital factors for cable selection correction and application.

8.3.6. Learning Outcome No. 5. Terminate electrical machine installation

8.3.6.1. Learning Activities

Learning Outcome No. 5. Terminate electrical machine installation	
Learning Activities	Special Instructions
• Performing Cables Lugging as per standard operating procedure • Terminating cables as per IEE regulation • Terminating cables in the connectors as per Load size	

8.3.6.2 Information Sheet No 8/ LO5.

Cable Termination

Termination is used in describing the specific point that a device that conduct electricity, for example wire or cable, ends or starts. At this point, such a device is likely to either pass or not pass the carried electricity or signal to another conductive device.

Terminology in Cable Terminations

1. Isolator termination;
2. Contactor Termination
3. Thermal overload Termination
4. Relay Termination;
5. Start/ stop termination
6. Timer termination
7. Counter termination
8. Circuit breaker termination

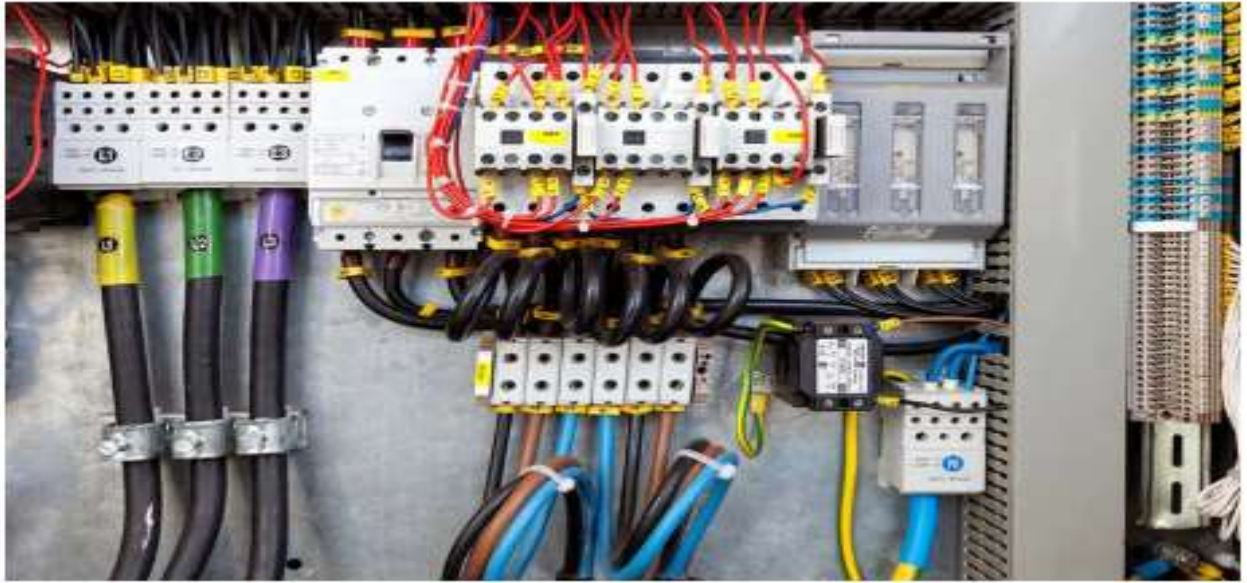


Figure 116: Cable Termination

Cable Lugging

Cable lugging is achieved by use of silver sparkling metal at cables or between wires popularly known as Cable lugs. The devices used in the connection of devices to other electrical appliances, surfaces or mechanisms are called cable lugs. Clamps connecting wires to automotive battery contributes examples of cable lugs. Usually cable lugs are applied in cases where permanent, direct fastening methods are not important. Safety may be provided to cable lugs to prevent shocks, damage to it and connectors and short circuit.

Figure 1 below is popular cable lug images applied to various appliances and places:



Figure 117: cable lugs source: <http://www.mgelectrica.com/what-are-cable-lugs/>

For tool used in cable termination find look at link;
<https://www.toolup.com/electricians-tools/cable-termination>

8.3.6.3. Self-Assessment

1. Define the following terms as used in cable termination.
 - i. Termination.
 - ii. Lugging
2. Briefly explain the key terminologies in cable terminations.
3. State tools in cable termination.
4. Explain the importance of cable termination and lugging
5. State conditions that require cable lugging
6. is achieved by use of silver sparkling metal at cables or between wires popularly known as Cable lugs.
 - a) Termination
 - b) Cable lugging
7. is used in describing the specific point that a device that conduct electricity, for example wire or cable, ends or starts.
 - a) Cable lugging
 - b) Termination
8. Usually cable lugs are applied in cases where permanent, direct fastening methods are not important.
 - a) True
 - b) False
9. Termination is used in describing the specific point that a device that conduct electricity.
 - a) True
 - b) False

Practical exercise

- a) Performing Cables Lugging as per standard operating procedure
- b) Terminating cables as per IEE regulation
- c) Terminating cables in the connectors as per Load size

8.3.2.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Cable bender
- Cable cutter
- Crimping tools
- Cutting and crimping dies
- Hydraulic pumps.

8.3.7 Learning Outcome No. 6. Test electrical machine installation

8.3.7.1 Learning Activities

Learning Outcome No. 6. Test electrical machine installation	
Learning Activities	Special Instructions
• Identifying test types • Performing test as per IEE regulation • Establishing firmness of installation • Performing continuity test as per IEE regulation • Performing continuity resistance test as per IEE regulation • Performing Earth test as per IEE regulation • Performing On load and Offload test as per IEE regulation	

8.3.7.2. Information Sheet No. 8/ LO6.

Introduction

During wiring installations, periodic inspection and internal wiring is vital. It should be done annually to ensure constant safe operations. Therefore, testing is process establishing the correctness electrical installation system by use of measuring instruments. While inspecting and testing installations of the internal wiring, the below points should be taken into consideration:

Incoming Service Line Connection

The below points should be taken into consideration:

1. Proper termination and bringing in of the service line coming to the premises.
2. Checking of the fuse wire rating for the individual phases ensuring it is of proper rating
3. Ensure the wires are of the right size to carry the needed current
4. Ensure the proper earthing and maintenance at the service line side.

Main switch board

Exists at the termination point. Through the board, the supply is provided to the premises.

1. The main switch board should be ensured that it is closer to the supply point in the premises
2. Checking for fuses / circuit breakers used are of the right size for all the phases.
3. Ensure the right ON/OFF working condition of Main Switch. The primary switch safeguards the whole premise during emergency. It needs to be in a proper working condition to ensures proper check of mechanical faults while switching operations that may make it assume the ON state.

4. The Switch board assembly should be ensuring that it is properly covered against rain /weather conditions.
5. Inspection is necessary to ensure clear view of the earthing and neural wires.
6. Inspection of the meter to ensure they are properly fastened.



Figure 118: Testing a control board using instrument

Internal Wiring Circuits

Internal Wiring Circuits are to be checked for following points:

1. Ensure that each circuit branching out of Main Switch board has a connected load of not more than 800 watts or 10 points.
2. Test for insulation resistance of conductor and earth to be as per IEE specifications.
3. Electrical resistance from connection with Earth electrode should not be more than one ohm.
4. Ensure metallic covering of iron clad switches, distribution boards are properly earthed..
5. Test that that leakage current is less than 1/5,000 of maximum supply current.

Types of tests in security system

1. **Insulation Resistance Test:** Testing of the insulation resistance of a wire ensures no leakage current flowing through it. According to IEE regulations, the insulation resistance between wiring and earth do not go beyond 1/5,000 of the current that flows. The test is completed using “Megger” instrument. The main switch is put OFF and the short circuiting of all the lighting connections on the circuit is done. The connection of the merger is done between live and the earth. Later, it is rotation is done to produce voltage and noting down the reading on the dial of Megger.

Figure 1 demonstrates test on insulation resistance

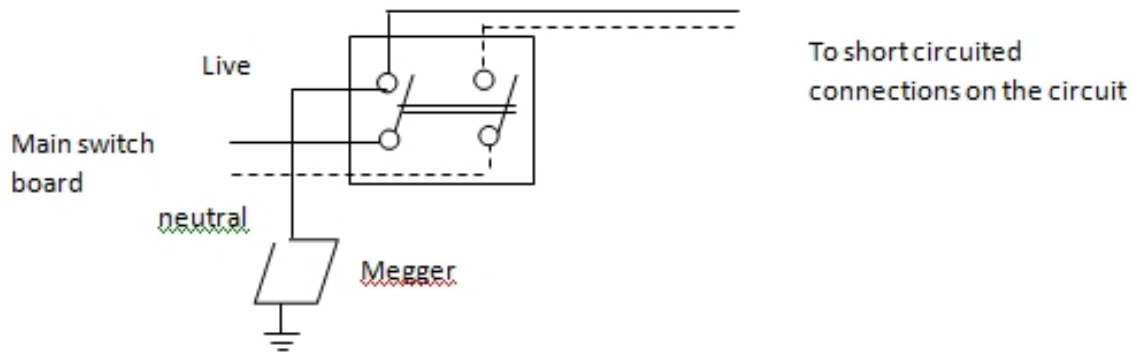


Figure 119: insulation resistance test

2. Earth Continuity Test: Is the second-best safety and installation test. It is important to connect together covers, metal parts, switches and conduits. There is average damage of the whole installation system in case there is absence of this. The leakage current is likely to cause electric shock to those who come into close contact with it. To test this, it is important to put the main switch in an open position. Later, connect the earth continuity tester should be connected between the conduit and independent earth. The value of resistance is indicated by the tester. However, the values don't need to exceed one 1ohm. Otherwise it would indicate the switch is not properly earthed.

For short circuit test and continuity test get information from source:

<http://engineering.electrical-equipment.org/safety/inspection-and-testing-of-wiring-installations.html>

8.3.7.3. Self-Assessment

- a) Differentiate between testing and inspection
- b) Describe Three tests done on a new installation
- c) In..... put the main switch in an open position. Later, connect the earth continuity tester should be connected between the conduit and independent earth. The value of resistance is indicated by the tester.
 - a) Earth Continuity Test
 - b) Insulation Resistance Test
- d) involves testing of the insulation resistance of a wire ensures no leakage current flowing through it.
 - a) Earth Continuity Test
 - b) Insulation Resistance Test
- e) Earth Continuity is the testing of the insulation resistance of a wire ensures no leakage current flowing through it
 - a) True
 - b) False
- f) Earth Continuity Test is the second-best safety and installation test. It is important to connect together covers, metal parts, switches and conduits
 - a) True

- b) False
- g) State incoming Service Line Connection
- h) Describe main switch board
- i) Describe checking of internal Wiring Circuits
- j) Describe types of tests in security system

Practical exercise

- a. Performing continuity test as per IEE regulation
- b. Performing continuity resistance test as per IEE regulation
- c. Performing Earth test as per IEE regulation
- d. Performing On load and Offload test as per IEE regulation

8.3.7.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Workshop with office, tool store and material store
- Protective gear
- Multimeter
- Insulation resistance tester
- New installation or existing installation

8.3.7.5. References

Bolotinha, M. (2017). cable laying and pulling.

Edvard. (2016). 5 vital factors for cable selection correction and application.

CHAPTER 9 ELECTRONICS/DEMONSTRATE UNDERSTANDING OF ELECTRONICS...

9.1. Introduction of the Unit of Learning / Unit of Competency

This unit covers the competencies required to demonstrate understanding of Electronics. The competencies includes; Applying semiconductor theory, Applying semiconductor diodes, demonstrating understanding of transistors and their applications , special semiconductor devices and applications, Performing rectification, applying amplifiers and their applications, demonstrating understanding of oscillators, applying wave shaping and pulse generation circuit and application of electronics..

9.2. Performance Standard

Demonstrate understanding of electronics adhering to the standards on electronics and their design, manufacture, testing, use, and end-of-life procedures as stipulated by International Electro technical Commission (IEC) and the Institute of Electrical and Electronics Engineers (IEEE) standard developing organizations.

9.3. Learning Outcome

9.3.1. List of Learning Outcomes

- a) Apply semiconductor theory
- b) Apply semiconductor diodes
- c) Demonstrate understanding of transistors
- d) Apply Special semiconductor devices
- e) Perform rectification
- f) Apply amplifiers
- g) Demonstrate understanding of oscillators
- h) Apply wave shaping and pulse generation circuits
- i) Apply optic-electronics

9.3.2. Learning Outcome No. 1. Apply semiconductor theory

9.3.2.1. Learning Activities

Learning Outcome No. 1. Apply semiconductor theory	
Learning Activities	Special Instructions
• Explain Meaning of the terms –atom, element, compound, electron, molecule, • Identify Types of materials used in electrical and electronics industry- Insulators, conductors and semiconductors • describe the atomic structure of semiconductor materials 1. intrinsic type 2. extrinsic type	Identify types of electrical materials. 1. Insulators- cable sheathes, plastic conduits 2. Conductors- cables, copper, iron, aluminum, etc 3. Semiconductors- silicon, germanium, N-type, P-type

9.3.2.2. Information Sheet No 9/LO1.

Definitions of key terms

Atom: The *atom* is the smallest object that retains the properties of an element. *Atoms* are composed of electrons and a nucleus. The nucleus contains protons and neutrons. All *atoms* are electrically neutral, because every *atom* has an equal number of electrons and protons.

Element: An *element* is a substance whose all its atoms have the same number of protons: i.e. all atoms of a particular *element's* atoms have the same atomic number. *They* are chemically the simplest substances and hence cannot be broken down using chemical reactions.

Compound: A *compound* is a substance formed when two or more chemical elements are chemically bonded together. ... Example;

Pure water is a *compound* made from two elements - hydrogen and oxygen. The ratio of hydrogen to oxygen in water is always 2:1. Each molecule of water contains two hydrogen atoms bonded to a single oxygen atom. Electron,

An *electron* is a negatively charged particle of charge equal to about 1.602×10^{-19} coulombs. This particle can be either free (not attached to any atom), or bound to the nucleus of an atom. When *Electrons* are in atoms, they exist in spherical shells of various radii, representing energy levels.

Proton

It's a stable subatomic particle occurring in all atomic nuclei. This particle has a positive electric charge equal in magnitude to that of an electron.

Neutron: It's a sub atomic particle of about the same mass as that of a proton but without an electric charge. This particle is present in all atomic nuclei except those of ordinary hydrogen.

ION: *Ion* is as an atom or molecule which has gained or lost one or more of its valence electrons, giving it a net positive or negative electrical charge. In other words, there is an imbalance in the number of positively charged particles and negatively charged particles in an atom or in the chemical union of a molecule.

Molecule: It's a group of atoms bonded together, representing the smallest fundamental unit of a chemical compound that can take part in a chemical reaction.

Classification of electrical materials.

Insulators-

These are the materials that offer high resistance to flow of current through them. Their conduction band is empty at normal room temperature since all the valence electrons are occupying the valence band. The conductivity of an insulator increases with increase in temperature.

Conductors

These are the materials that has very low resistance to flow of current through them. At normal room temperature, their valence electrons are occupying the conduction band while the valence band is empty. The conductivity of a conductor decreases with increase in temperature.

Semiconductors

A semiconductor is a material that has an electrical conductivity value falling between that of a conductor yet higher than that of an insulator. The resistance of a semiconductor decreases as their temperature increases.

Types of semiconductor materials.

There are two types of semiconductors.

- i. Pure semiconductors.
- ii. Impure semiconductors.

Pure semiconductors (INTRINSIC semiconductors).

They are the semiconductors made purely of atoms from group FOUR elements only. The structure of these semiconductor has atoms of group four elements only. Examples are silicon and germanium.

The atomic structure of pure semiconductor material such as silicon is as shown in fig below.

Silicon being a group 4 element, have only four electrons in the outer shell (i.e. it has four valence electrons). It takes eight electrons to fill the outer shell and when the

outer shell of an atom is full, the atom is stable. The atoms of group 4 elements share their valence electrons with neighboring atoms, so that each atom effectively contains eight electrons in the outer shell. This sharing of valence electrons with neighboring atoms forms covalent bonds. It is these covalent bonds that bind the atoms together. The net result is that each atom contains eight electrons in the outer shell tightly bound in the atomic structure.

When pure silicon is at a temperature of absolute ZERO, all the valence electrons are occupying the outer most shell and there are no free electrons for current conduction. Therefore, the valence band is completely full and the conduction band is completely empty. However, valence electrons can ""absorb"" heat or light energy, to enable them to ""jump up"" into the conduction band. Even at typical room temperatures, many electrons will have acquired sufficient energy to jump up into the conduction band and if the temperature increases, the number of electrons in the conduction band also increases.

When an electron moves into the conduction band, it leaves behind a vacant position or hole in the valence band. Thus, when a covalent bond breaks releasing an electron into the conduction band, a hole is also created. I.e. every broken covalent bond results in electron-hole pair generation.

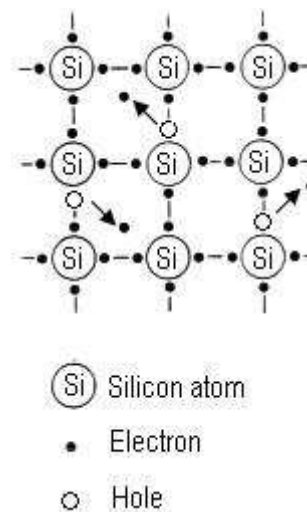


Figure 120: Silicone

The hole will exert a force of attraction to an electron that happen to pass near it and may be forced to move back in to the valence band. If this happen, a broken covalent bond is mend. Also, an electron and hole pair is lost. A hole has a positive charge while the electron has a negative charge. If an external EMF is applied across the semiconductor material, the holes move to the direction of negative charge while the electrons move to the direction of positive charge. The two currents have equal magnitude but opposite in direction.

- Impure semiconductors (extrinsic semiconductor)
- An extrinsic semiconductor or the impure semiconductor is one that has been *doped*.

There are two types of extrinsic semiconductors, the N-type and the P-type.

N- Type Semiconductor:

N-type semiconductors are created by introducing a small controlled amount of impurity atoms into the structure of an intrinsic semiconductor. The impurity atoms introduced are pentavalent atoms i.e. from group 5 elements. Each impurity atom introduces a free electron without a corresponding hole, the semiconductor that is formed have a larger electron concentration than of hole concentration.

The free electron will take part in conduction and increase conductivity just like those electrons created whenever a covalent bond breaks. This semiconductor has electron as majority charge carriers.

Since electrons are negatively charged particles, the semiconductor is called N-type i.e. Negative type Semiconductor.

P-type Semiconductor:

It is formed when the trivalent impurity atoms are added into an intrinsic semiconductor. Each trivalent atom introduces a hole in to the structure of the semiconductor without introducing a corresponding hole in to the structure. Holes are positive charge carriers. Thus, P-type Semiconductors has majority charge carriers as holes and electrons as minority charge carriers. This is the reason it is called P – type semiconductors or Positive Type Semiconductors. Holes are responsible for current conduction in the P-type semiconductor. The trivalent impurity is known as acceptor impurities. They "accept" electrons from the semiconductor's valence band.

9.3.2.3. Self-Assessment

1. Trainee to carry out a practical task to identify and classify materials used in electrical and electronic engineering.
2. Trainee to draw sketches of atomic structure for the different types of semiconductors.
3. Differentiate between an atom, element and a compound
4. State a proton, electron and a neutron
5. Describe the classification of electrical material
6. Describe types of semiconductor materials.
7. Differentiate between intrinsic and extrinsic semiconductors
8. are the materials that offer high resistance to flow of current through them. Their conduction band is empty at normal room temperature since all the valence electrons are occupying the valence band.
 - a) Semiconductors
 - b) Conductors
 - c) Insulators-
9. materials that has very low resistance to flow of current through them. At normal room temperature, their valence electrons are occupying the conduction band while the valence band is empty.

- a) Semiconductors
 - b) Conductors
 - c) Insulators-
10. is a material that has an electrical conductivity value falling between that of a conductor yet higher than that of an insulator.
- a) Semiconductors
 - b) Conductors
 - c) Insulators-
11. is formed when the trivalent impurity atoms are added into an intrinsic semiconductor.
- a) N- Type Semiconductor
 - b) P-type Semiconductor
12. created by introducing a small controlled amount of impurity atoms into the structure of an intrinsic semiconductor.
- a) N- Type Semiconductor
 - b) P-type Semiconductor
13. All *atoms* are electrically neutral, because every *atom* has an equal number of electrons and protons.
- a) True
 - b) False
14. An *element* is a substance who's all its atoms have the same number of protons,
- a) True
 - b) False

Practical exercise

- a) Demonstrate ability to explain Meaning of the terms –atom, element, compound, electron, molecule
- b) Identify Types of materials used in electrical and electronics industry- Insulators, conductors and semiconductors
- c) Describe the atomic structure of semiconductor materials e.g intrinsic type and extrinsic type

9.3.2.4.Tools, Equipment, Supplies

- Multipurpose meter
- Stripping knife.
- Cables
- Assorted electrical materials
- PVC materials
- Standard electronic tool kit

9.3.2.5.References

- 1. https://www.electronics-tutorials.ws/diode/diode_1.html
- 2. <https://en.wikipedia.org/wiki/Semiconductor>

9.3.3. Learning Outcome No. 2. Demonstrate understanding of semiconductor diodes

9.3.3.1 Learning Activities

Learning Outcome No. 2. Demonstrate understanding of semiconductor diodes	
Learning Activities	Special Instructions
1. Trainee to identify types of diodes and state their functions.	Observe safety procedures in the handling of components and test equipment for the semiconductor diodes.
2. <i>Student connect Diodes</i> in an appropriate circuit for investigation of characteristics and determination of properties following the standards established. Follow this link for instruction sheet. ftp://ftp.ni.com/pub/gdc/tut/llab1.pdf	
3. Forward and reverse bias characteristics are established as per the properties of the semiconductor material.	

9.3.3.2. Information Sheet No. 9/LO2.

Definitions of key terms

Semiconductor diodes

It's an electronic device made of semiconductor materials, usually silicon. The device contains a P-type and N-type semiconductors in very close contact forming a P-N junction. This electronic component has the capability to allow electric current to flow through it only in one direction (from anode to cathode) when forward-biased and when the device is reverse biased, it offers very high resistance to the flow of current through it.

Depletion layer.

It's a region of high resistivity that separates the N-Type and the P-Type semiconductors in a diode.

The depletion layer contains neither free electrons nor holes for current conduction.

Charge carriers

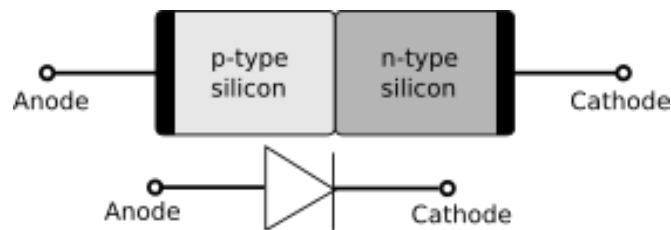
These are the electrons or holes that constitute current conduction in a semiconductor material. Holes are the positive charge carriers while electrons are negative charge carriers.

Potential Barrier:

Potential Barrier is the potential difference required for electrons to pass through the electric field produced by depletion region. After the application of this voltage in proper polarity the electrons from N-region can get into the P-region and likewise the holes from the P-region can cross to the N-region.

The P-N Junction

A p–n junction is the boundary formed by joining p-type and n-type semiconductors when in very close contact. It's the boundary interface where the two regions of the semiconductor meet.



Biasing P-N junction

Biasing is the process of applying potential difference EMF across the P-N junction diode.

Biasing can be of two types –

- Forward biasing
- Reverse biasing

Reverse Biasing condition

Positive voltage is applied to the N-type material and a negative to the P-type material.

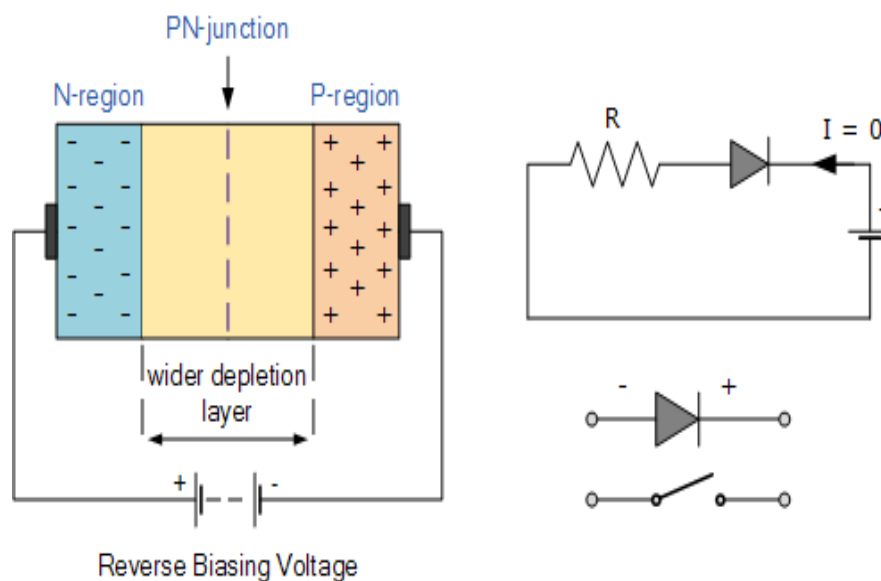


Figure 121: Biasing P-N junction

Source: circuit globe

The positive voltage applied to the N-type material attracts electrons towards the positive electrode and away from the junction, while the holes in the P-type end are also attracted away from the junction towards the negative electrode.

The net result is that the depletion layer grows wider due to a lack of electrons and holes and presents a high impedance path, almost an insulator. The result is that a high potential barrier is created thus preventing current from flowing through the semiconductor material.

Forward Biasing condition.

Negative voltage is applied to the N-type material and a positive to the P-type material.

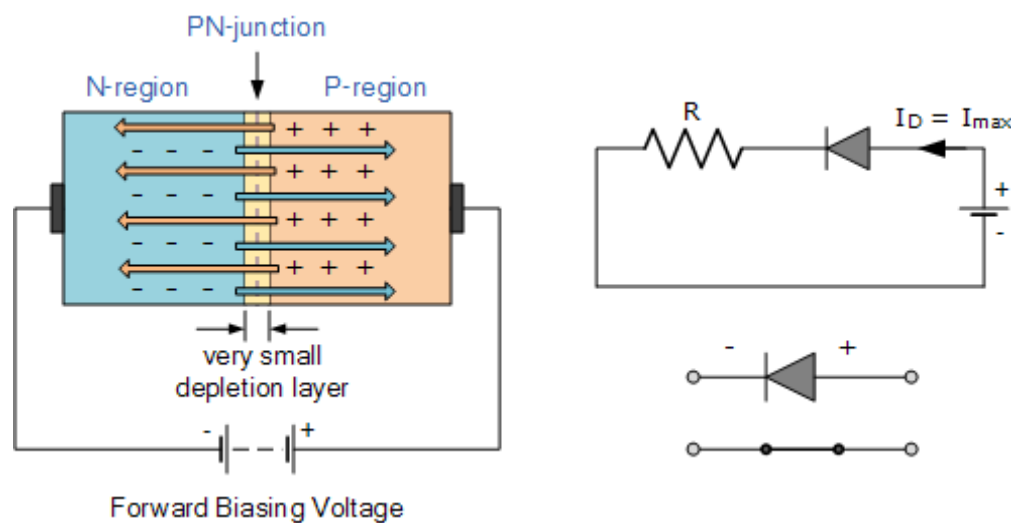


Figure 122: Forward biasing condition.

Source: circuit globe

The application of a forward biasing voltage on the junction diode results in the depletion layer becoming very thin and narrow which represents a low impedance path through the junction thereby allowing high currents to flow through the diode with only a small increase in bias voltage.

Forward and reverse characteristics of a P-N junction diode

Semiconductor Diodes

a. Light Emitting Diodes (Led):

An LED is a P-N junction diode made up of a thin layer of fairly doped semiconductor material of semiconductor compounds such as Gallium Arsenide (GaAs), Gallium Phosphide (GaP), Gallium Arsenide Phosphide (GaAsP), Silicon Carbide (SiC) or Gallium Indium Nitride (GaInN) all mixed together at different ratios to produce a distinct wavelength of colour. When this diode is made, it is then put in a protective encasement that is transparent so that the light it produces can be visible from outside.



Figure 123: LED circuit symbol

Source: circuit globe

Operation Principles.

Whenever a diode is forward biased, electrons cross to the P-side. Likewise, holes cross to the N-side where some combine with opposite charge carriers near the junction. Every recombination results in energy being given out as the electron is moving from the conduction band to the valence band. In those diodes made of silicon or germanium semiconductor materials, a high percentage of the energy released is in the form of heat. In diodes made of gallium arsenide phosphide, a high percentage of the energy given out is in the form of light. The color of the light produced depends on the mixture of the semiconductor material and the amount of doping. Thus when an LED is forward biased, it will conduct and produce light. An LED will not conduct and neither will it produce light when reverse biased.

Most common LEDs require a forward operating voltage of between approximately 1.2 to 3.6 volts with a forward current rating of about 10 to 30 mA, with 12 to 20 mA being the most common range.

Some Applications of LEDs.

- i. In seven segment displays.

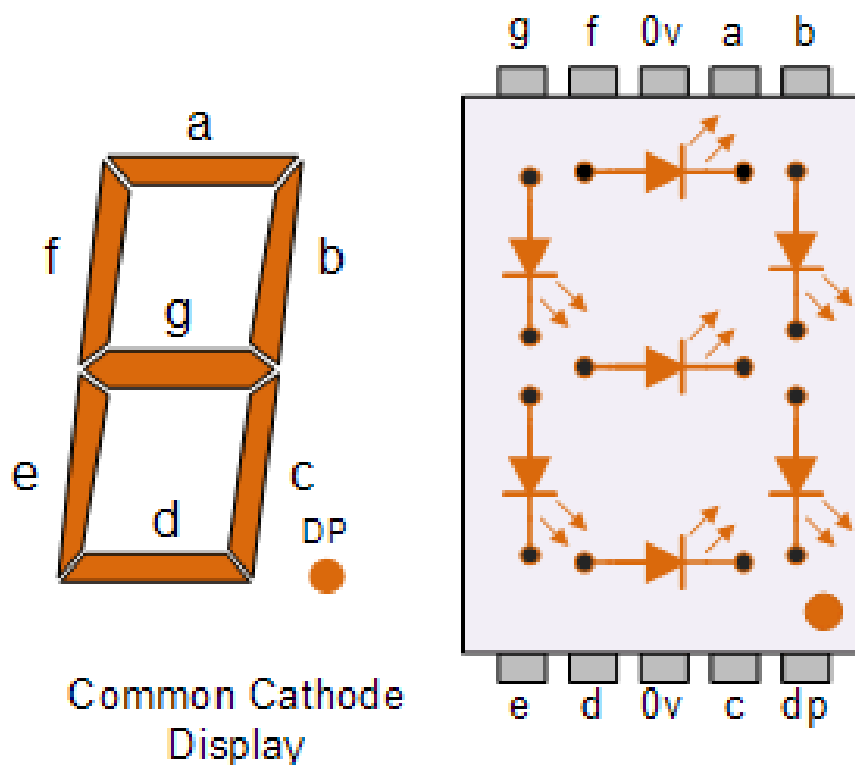


Figure 124 Common cathode display

Source: circuit globe

- ii. Lighting both for domestic and commercial.
- iii. As indicators.
- iv. In remote controls
- v. In optical fiber communication.

- vi. In photo diodes and photo transistor opto-couplers.

The Zener Diode

A Zener Diode is a special PN junction diode made of silicon or germanium. This diode is designed to have a low and specified Reverse Breakdown Voltage. The Zener diode behaves just like the ordinary PN junction diode when biased in the forward direction. The doping level of this diode is higher compared to that of the ordinary diodes.

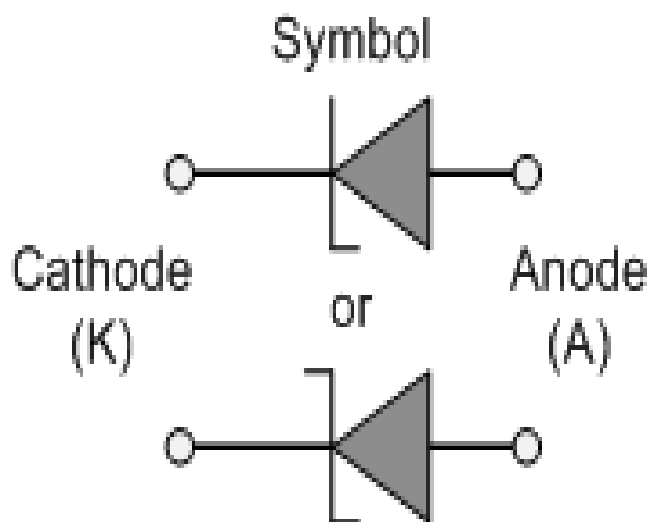
Due to heavy doping, the diode has the following characteristics.

1. Reduces the value of breakdown voltage.
2. Reduces barrier potential.
3. Reduces size of the depletion layer.

When this diode is operating within its breakdown region, the voltage across it remains constant even as the current increases considerably.

Some applications of zener diodes.

1. As voltage regulators
2. In clipping and clamping circuits
3. In wave shaping circuits
4. For meter protection against damage due to accidental application of excess voltage.
5. For setting up a fixed reference voltage in a biasing network of a comparator.



Photograph of a circuit symbols

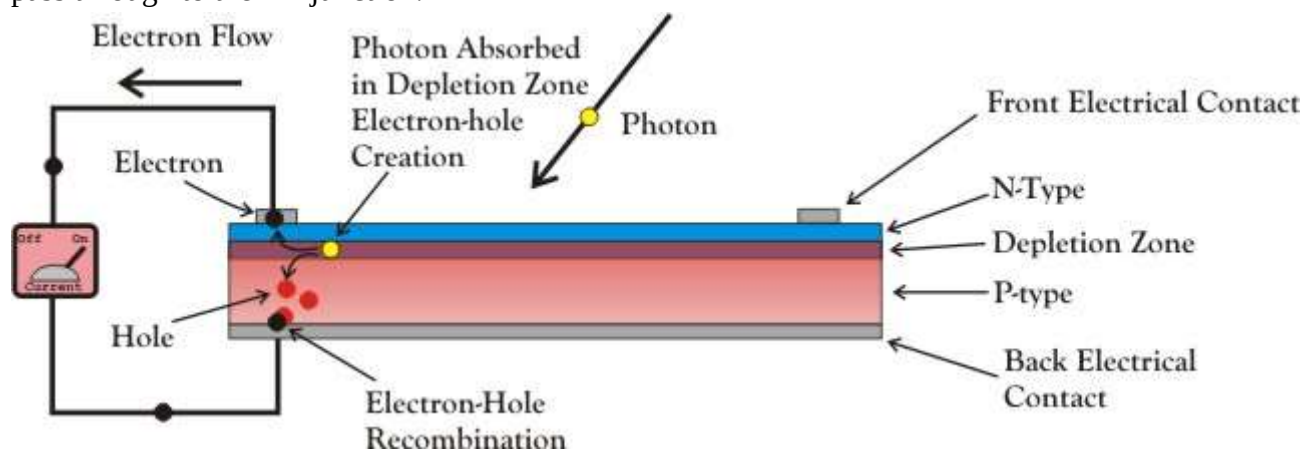
Figure 125: circuit symbols

Source: circuit globe

Photovoltaic diode/ solar Cell

A solar cell consists of p-type and N-type semiconductor materials usually *silicon or selenium* type forming a P-N junction with a large surface area of the cell exposed to sun light. The bottom service of the cell which is always away from the sun is covered with a continuous conductive

This cell has the capability to convert solar energy directly into electrical energy. The semiconductor material facing the direction of the sun is kept thin to allow light to pass through to the PN junction.



OPERATION PRINCIPLE

When light energy strikes atoms in the semiconductor material of the depletion layer, electrons in there absorb this energy and become raised across the energy gap from the valence band to the conduction band. This results in the creation of HOLE-ELECTRON within the depletion layer. This creates an equilibrium state of the P.N junction. The electrons and the holes that have been created move by diffusion outside the depletion layer in response to the electric field outside the depletion layer thus producing a photocurrent that can flow through an external load

The maximum voltage of a silicon cell is about 1.09V and this depends on the intensity of light falling on the cell. Higher voltages can be realized if several cells are connected in series. To obtain higher currents, cells should be connected in parallel.

An efficient cell gives about 108Watts per square meter area. The polarity of the generated E.M.F is; positive on the P-side and negative on the N-side.

Some applications of these cells.

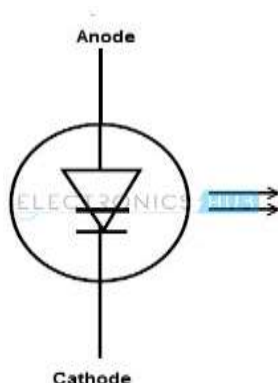
1. Can be used to charge batteries which latter become source of power for domestic or commercial use.
2. For powering satellite equipment such as these used by military or meteorological departments.

Laser Diodes

A laser diode is a semiconductor device that is very similar, in both form and operation, to a light-emitting diode (LED).

The term laser is an acronym: Light Amplification by Stimulated Emission of Radiation. This device emits light through a process of optical amplification based on the stimulated emissions of electromagnetic radiation.

The laser diode is electrically equivalent to a [PIN diode](#).



Laser diode circuit symbol.

Types Of Lasers

Laser diodes can be grouped into two classes:

1. *Edge-emitting lasers (in-plane lasers),*

The laser light in the diodes propagates in a direction along the wafer surface of the semiconductor chip and is reflected or coupled out at a cleaved edge.

2. *Surface-emitting lasers.*

The laser light in these diodes propagates in the direction perpendicular to the semiconductor wafer surface. I.e. at a direction perpendicular to the P-N junction plane. The optical cavity axis is along the direction of current flow rather than perpendicular to the current flow as in edge emitting laser diode.

Laser Diode Theory.

When a light photon enters in to a semiconductor lattice and strikes an electron, the electron releases energy in the form of another light photon. The way in which this occurs can result in the released new photon being of identical wavelength and phase. In this way the light that is generated will be coherent. When the diode is forward biased, the electrons and holes are pumped into the active region from the n and p regions, respectively. When current flows across the p-n junction, some of the holes and the electrons combine near the junction. This releases light energy (photo emission).

If an electromagnetic wave (in this instance light) is made to pass through a P-N junction, it is found that photo-emission process occurs. In the case of the laser diode, when current flows across the p-n junction, some of the holes and electrons combine releasing light energy. Some of these released photons travel in a direction perpendicular to that of the P-N junction and thus strike the reflective surfaces at 90 degrees and are now reflected back. These electromagnetic waves (light rays) will then strike other electrons releasing more photons.

The structure of the laser diode is that it has an optical cavity (*the area between the totally reflecting surface and the partially reflecting surface*) in which the light photons have multiple reflections. When the photons are generated, only a small number are able to leave the cavity. In this way when one photon strikes an electron and enables

another photon to be generated the process repeats itself and the photon density or light level starts to build up (amplification by *Stimulated emission*): The light intensity increases and reaches to a level where a strong beam of light comes out of the diode through the partially reflective surface.

Some Applications of laser diodes.

1. Are used in laser pointers.
2. In bar-code scanners.
3. In CD-ROM and CD players.
4. guidance systems,
5. scanners,
6. metal working,
7. photography,
8. holography, and in medicine
9. Lasers are finding ever increasing military applications -- principally for target acquisition, fire control, and training. These lasers are termed rangefinders, target designators, and direct-fire simulators.
10. In communication systems

Crystal Diode

This is also known as point contact diode. During construction, a metal wire usually of gold, tungsten or phosphor bronze wire is pressed against N-type semiconductor crystal and a high current is briefly passed through the crystal and the metal wire. A small oxide layer is now formed at the point of contact. This layer has the properties of a P-type material and thus a PN junction is formed. The semiconductor crystal acts as cathode and metal wire acts as anode.

The diode has very low junction capacitance about 0.1 to 1pF. This is because the area of contact between the wire and the N-type substrate is very small. Due to the small area of junction, the density of charge carriers near junction is very low. Due to this, the switching ability of this diode is much better than of an ordinary diode.

Applications of Point Contact Diode

1. High-Frequency Circuits: Due to small junction area and low junction capacitance, the diode is suitable for high-frequency applications (about 10 GHz).
2. Radio Frequency Mixers: In communication, Mixers play a crucial role in circuitry and the point contact diode is used extensively in radio frequency mixers.
3. Detector Circuits: For detecting high-frequency signal these diodes play a crucial role in circuitry.
4. Video Detector: It also finds application in video detector.

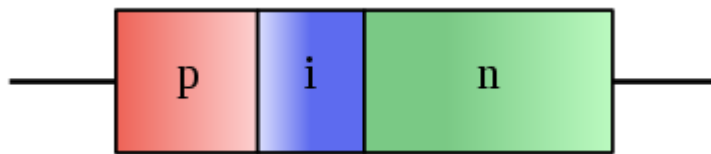
5. Envelope detector and detector circuits of radio and television: Point contact diodes are also used in envelope and television detector circuit because it switches rapidly from one state to another state.

PIN diode.

A PIN diode is a semiconductor diode that has three main layers.

- P-type layer
- Intrinsic layer and the
- N-type layer

The intrinsic layer of the PIN diode causes the diode to change in properties when compared to a normal PN junction diode. The intrinsic region comprises of the un doped semiconductor, and in most PIN diodes it is very thin compared to the other two regions.



block diagram.



circuit symbol.

Source: circuit globe

The working principle of the PIN diode is exactly the same as that of a normal diode. The main difference is that the depletion region that exists between the P & N regions is larger due to the intrinsic layer.

PIN diode characteristics

1. The intrinsic layer between the P-type and N-type regions enables it to have high reverse breakdown voltage compared to ordinary diodes.
2. Has low level of junction capacitance when reverse biased.

PIN diode uses and advantages

The PIN diode is used in a number of areas as a result of its structure and properties.

- *High voltage rectifier:* The PIN diode can be used as a high voltage rectifier. The intrinsic region provides a greater separation between the P and N regions, allowing higher reverse voltages to be tolerated.
- *RF switch:* The PIN diode makes an ideal RF switch. The intrinsic layer between the P and N regions increases the distance between them. This also decreases the capacitance between them, thereby increasing the level of isolation when the diode is reverse biased.

- *Photodetector:* Some photo detector devices like [photo transistors](#) and photodiodes employ an intrinsic region in their construction forming a PIN junction.

As the conversion of light into current takes place within the depletion region of a photodiode, increasing the depletion region by adding the intrinsic layer improves the performance by increasing the volume in which light conversion occurs.

Varactor / Varicap Diode

Varactor diodes or varicap diodes are semiconductor devices that are used in the electronics industry where a voltage controlled variable capacitance is required.

The principle of operation of the varactor diode is that when a diode is operated under reverse bias conditions, three regions are formed. These are

1. The P region where current can be conducted.
2. The N region where current can be conducted.
3. The depletion region where no current carriers are available.

As a result, two good conductors are separated by an insulator. This is exactly the same construction as a capacitor. It has conductive plates separated by an insulating dielectric.

The capacitance of a capacitor is depends on

1. the plate area,
2. the dielectric constant of the insulator between the plates and
3. The distance between the two plates.

In the case of the varactor diode which is always operated when reverse biased, it is possible to increase and decrease the width of the depletion region by simply changing the level of the reverse bias voltage. This has the effect of changing the distance between the plates of the capacitor. The capacitance can thus be varied by changing the bias on the diode as this will vary the width of the depletion region which will accordingly change the capacitance.

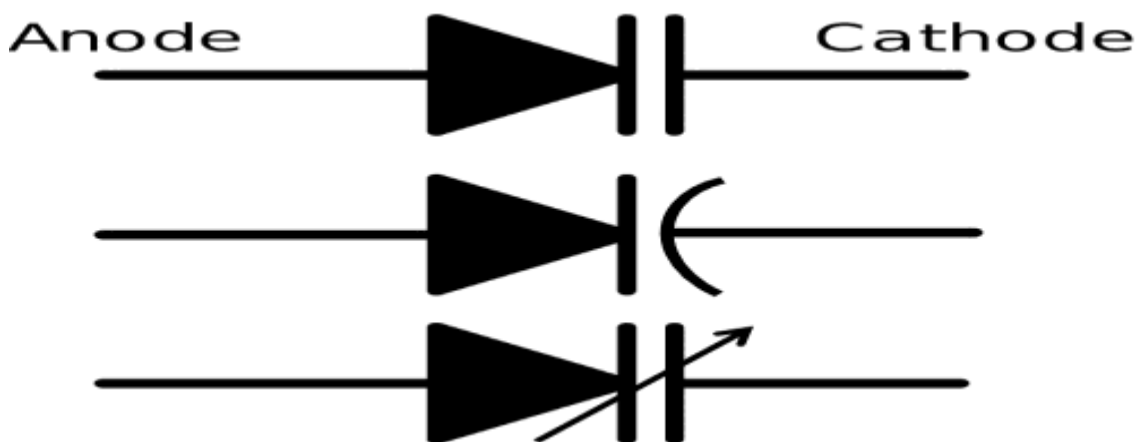


Figure 126: Varactor diode circuit symbols

Source: circuit globe

Types of Varactor Diodes

Abrupt junction varactor diode.

For an abrupt varactor diode, the doping concentration is uniform. I.e. constant doping level. This results in a lower tuning ratio.

I.E. The ratio of maximum capacitance to the minimum capacitance of the diode is lower than that of a hyper abrupt junction diode.

The abrupt varactor exhibits an inverse square law C-V function.

1. Hyper abrupt varactor diode.

The doping profile of this diode is not uniform. The concentration of impurity atoms increases near the junction. This results in a narrower depletion layer and higher capacitance tuning ratio. The diode has a much greater capacitance change for the given voltage change.

Varactor diode applications

Varactor diodes are widely used within the RF design arena. They provide a method of varying the capacitance within a circuit by the application of a control voltage. This gives them an almost unique capability and as a result varactor diodes are widely used within the RF industry.

- *Voltage controlled oscillators, VCOs:*
- *RF filters:* The capacitance for the frequency determining circuit of the filter is provided by the junction capacitance of the varactor diode.

Tunnel Diode

A Tunnel diode is a heavily doped diode which possesses high conductivity due to the higher concentration of impurity atoms. It is different from a conventional P-N junction in terms of doping density. The schematic symbol of Tunnel Diode is as shown below.

Construction of Tunnel Diode

A tunnel diode is usually constructed with Gallium semiconductor material. Compounds of Gallium such as Gallium Arsenide and Gallium Antimonide are preferred for tunnel diode construction.

Working Principle of Tunnel Diode

Due to high doping density, the width of the depletion layer is very small and thus charge carriers can easily cross the junction. Thus, charge carriers require very little kinetic energy to move across the junction; they simply punch through the junction even at very low forward voltage. This is the Tunneling effect and the diode is thus called Tunnel diode.

Due to this effect, a large value of forward current is generated even when the value of forward voltage is low (approximately 100mV).

Heavy doping also causes the diode to have very low reverse breakdown voltage due to the reduction in barrier potential. Any small reverse voltage applied to the diode can lead to the breakdown of the diode. As a consequence of this, a negative resistance region in its volt-ampere characteristics curve is created.

Applications of Tunnel Diode

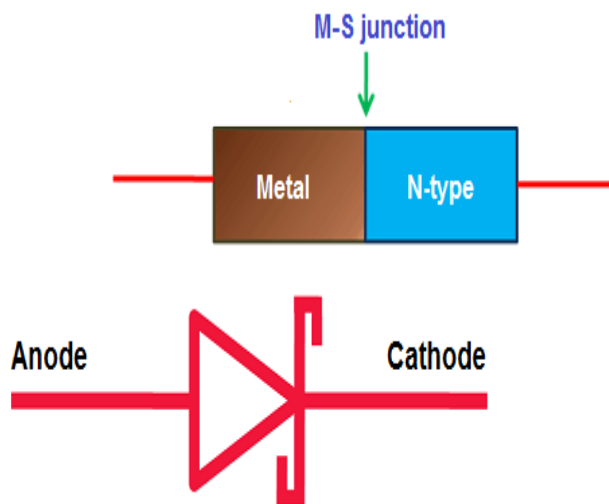
It is used as a high frequency switch.

Oscillator.

Amplifier etc.

Schottky diode

This diode is also known as schottky barrier diode, surface barrier diode, majority carrier device, hot-electron diode, or hot carrier diode. It is a diode made of metal-semiconductor junction unlike a P-N junction.



Source: circuit globe

When aluminium or platinum metal is joined with N-type semiconductor so that the metal replaces the P-type semiconductor, a junction is formed between the metal and N-type semiconductor. This junction is known as a metal-semiconductor junction or M-S junction. The junction formed between the metal and n-type semiconductor creates a barrier or depletion layer known as a schottky barrier.

The diode has less forward voltage drop than the ordinary P-N junction diode.

Applications

1. Useful in high-speed switching power circuits.
2. Schottky diodes are widely used in radio frequency (RF) applications.
3. Schottky diodes are used as general-purpose rectifiers.
4. Schottky diodes are used in radio frequency (RF) applications.
5. Schottky diodes are widely used in power supplies.
6. Schottky diodes are used to detect signals.

7. Schottky diodes are used in logic circuits.

9.3.3.3.Self-Assessment

- a) Explain semiconductor diodes
- b) State a semiconductor diode
- c) Differentiate between PN, NP junctions
- d) Explain forward and reverse biasing
- e) What are the applications of diodes
- f) Which of the following is not one of the applications of laser diodes?
 - a) Are used in laser pointers.
 - b) In bar-code scanners.
 - c) Used in security lighting
 - d) In CD-ROM and CD players.
- g) Which of the following is not one of the applications of point contact diode?
 - a) High-Frequency Circuits
 - b) Radio Frequency Mixers
 - c) Video Detector
 - d) Varactor diode circuit
- h) The capacitance of a capacitor is depends on the following except
 - a) the plate area
 - b) color of the plate
 - c) the dielectric constant of the insulator between the plates and
 - d) The distance between the two plates.
- i) A p–n junction is the boundary formed by joining p-type and n-type semiconductors when in very close contact
 - a) True
 - b) False
- j) The positive voltage applied to the N-type material attracts electrons towards the positive electrode and away from the junction, while the holes in the P-type end are also attracted away from the junction towards the negative electrode.
 - a) True
 - b) False
- k) Describe Zener diodes and its applications
- l) Describe Photovoltaic diode/ solar Cell
- m) Describe laser diode, laser diode theory and its applications
- n) Describe other' types of diode

Practical exercise

- a) Trainee to identify types of diodes and state functions of each.

9.3.3.4 Tools, Equipment, Supplies

- Semiconductor diodes
- Multipurpose meters
- Cables
- DC power supplies
- Electronics tool kits
- Bread boards

9.3.3.7.References

https://www.electronics-tutorials.ws/diode/diode_1.html

<https://en.wikipedia.org/wiki/Semiconductor>

9.3.4. Learning Outcome No. 3. Demonstrate understanding of transistors

9.3.4.1. Learning Activities

Learning Outcome No. 3. Demonstrate understanding of transistors	
Learning Activities	Special Instructions
• <i>Transistors</i> are identified as per their characteristics • NPN and PNP are determined as per their operation • P and N channels are identified as per their operation • <i>Biasing</i> and determination of gain of transistors is performed as per their standard operating procedure Transistor configuration is performed as per their application	Follow the links below for experiments on BJT characteristics • vlabs.iitb.ac.in/vlab/electrical/exp4/Theory.pdf • http://staff.iium.edu.my/adah510/ManualECE1201_SEM%20I%202015_2016.doc

9.3.4.2. Information Sheet No. 9/ LO3

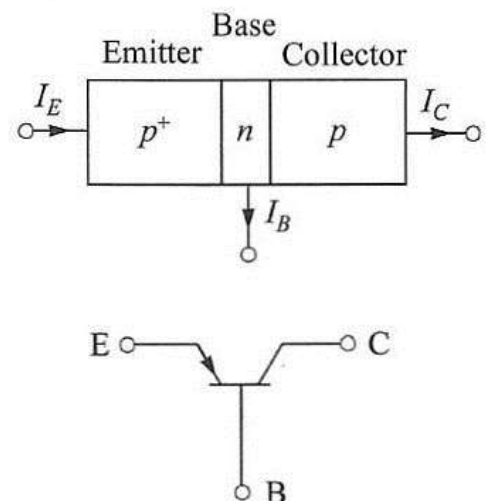
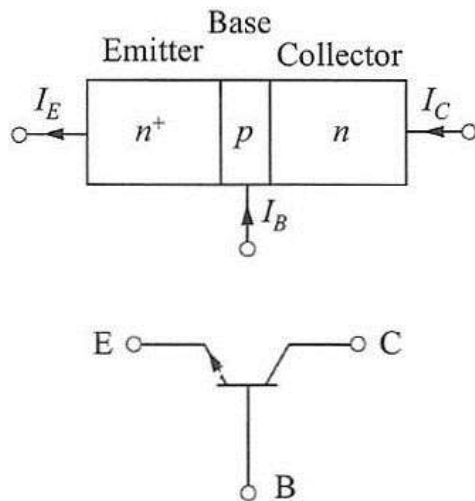
Bipolar Junction Transistor (Bjt)

The BJT is a three terminal semiconductor device whose output current, voltage and power is controlled by its input current. This device is applied in electronic circuits either as

1. A linear Amplifier to boost an electric signal or
2. As electronic switch.

The word transistor was derived from two words combination, transfer –resistance. It is a device that transfers a low resistance into a circuit having a high resistance. This semiconductor device was invented by a team of three scientists at Bell Laboratories, USA in 1947.

Basically, the bipolar junction transistor consists of two back-to-back P-N junctions manufactured in a single piece of a semiconductor crystal. These two junctions are formed by either sandwiching P-Type or N-Type semiconductor layer between a layer of opposite types thus forming either NPN or PNP transistors.



A bipolar junction transistor has three regions called

- Emitter region
- Base region and
- Collector region.

Each of the three regions has a terminal emanating from it and named after the respective region. The circuit symbols for PNP and NPN transistors are also shown in Figure above where the arrow head is always at the emitter and in each case its direction indicates the conventional direction of current flow. For a PNP transistor, arrowhead points from emitter to base meaning that emitter is positive with respect to base. For NPN transistor, the arrow points from base to emitter meaning that base is positive with respect to the emitter.

Characteristics of each region

1. Emitter

It is heavily doped than any of the other regions. It's main function is to supply majority charge carriers (either electrons or holes) to the base region. It second biggest in size.

2. Base

It forms the middle section of the transistor. It is very thin (10–6 m) as compared to either the emitter or collector. It's also very lightly-doped.

3. Collector

Collector region is made physically larger than the emitter region because it has to dissipate much greater power. Its main function is to collect majority charge carriers coming from the emitter and passing through the base region.

Thus,

Due to the difference in construction of collector and Emitter regions, biasing polarities cannot be interchanged and have the transistor function the same way.

Transistor Biasing

For a transistor to operate, working of a transistor, voltages of correct polarity must be applied across its two junctions. A transistor has base-emitter P.N junction and the base collector P.N junction

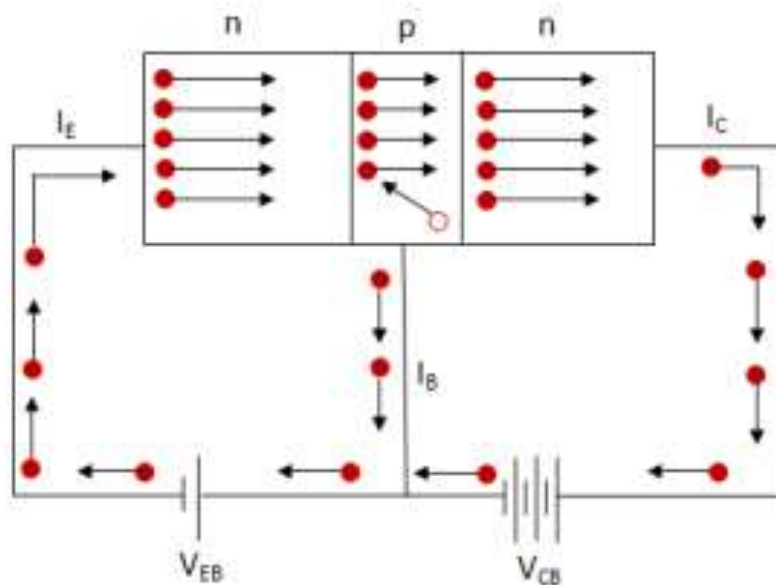
For normal operation;

1. emitter-base junction is always forward-biased while
2. collector-base junction is always reverse-biased.

Transistor Action/ operation

Working of NPN transistor.

When the NPN transistor is biased properly. I.e. applying forward bias to the emitter-base junction and reverse bias to the collector-base junction.

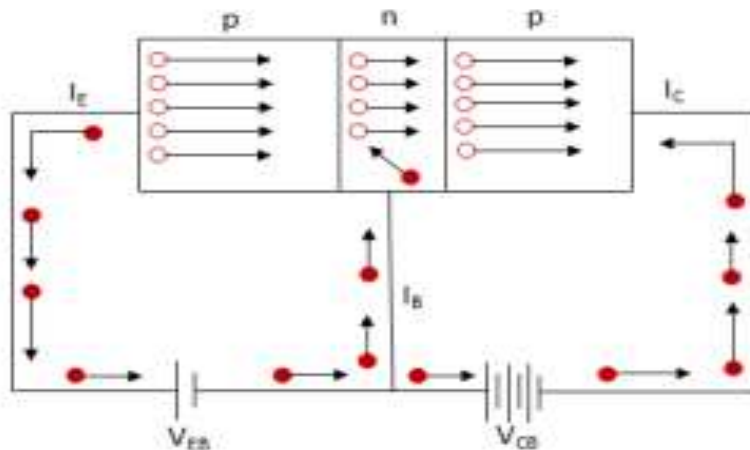


The forward bias cause the electrons in the n-type emitter to flow towards the base. This constitutes the emitter current I_E . As these electrons flow through the p-type base, they tend to combine with holes. As the base is lightly doped and very thin, only a few electrons i.e. less than 5% combine with holes to constitute base current I_B . The remainder i.e. more than 95% cross over into the collector region to constitute collector current I_C . In this way almost entire emitter current flows in the collector circuit.

The emitter current is thus the sum of collector and base current.

$$I_E = I_B + I_C$$

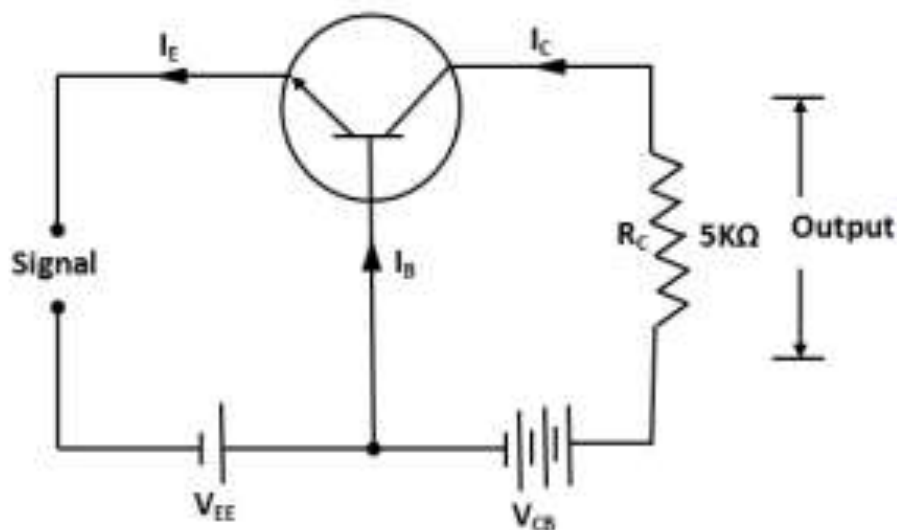
Working of PNP transistor:



The forward bias across the base-emitter PN junction causes the holes in the p-type emitter to flow towards the base. This constitute the emitter current (I_E). As these holes cross into n-type base, some tend to combine with the electrons. As the base is lightly doped and very thin, only a few holes i.e. less than 5% combine with the electrons. This constitute the base current I_B . The remainder holes i.e. more than 95% cross into the collector region to constitute collector current I_C .

Transistor circuit as an Amplifier

As an amplifier, the transistor raises the strength of a weak signal.



The weak signal is applied between the emitter and base while the output is taken across the load R_C , connected between the collector and base.

To achieve faithful amplification, the input circuit should always be forward biased regardless of the polarity of the input signal.

As the input circuit is forward biased, it has low resistance and therefore, a small change in signal voltage causes an appreciable change in emitter current. This causes almost the same change in collector current due to transistor action.

If the collector current is made to flow through a high resistance (R_C), it produces a large voltage across it which is an amplified version of a weak signal at the input.

Thus, a weak signal applied in the input circuit appears in the amplified form in the collector circuit. It is in this way that a transistor acts as amplifier.

Transistor Circuit Configurations/ Transistor Modes Of Connection

There are three types of circuit connections (called configurations) for operating a transistor.

1. common-base (CB),
2. common-emitter (CE),
3. common-collector (CC).

The term 'common' is used to denote the electrode that is common to the input and output

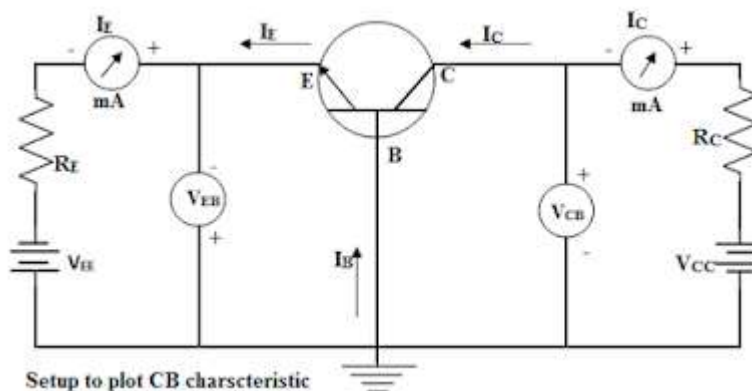
Circuits. Because the common electrode is generally grounded, these modes of operation are

Frequently referred to as grounded-base, grounded-emitter and grounded-collector configurations

Since a transistor is a 3-terminal (and not a 4-terminal) device, when used as an amplifier, one of its terminals has to be common to the input and output circuits.

CB Configuration.

In this configuration, emitter current I_E is the input current and collector current I_C is the output current. The input signal is applied between the emitter and base whereas output is taken out between the base and collector terminal



Common base characteristics.

1. Has low input impedance.
2. High output impedance.
3. The voltage is less than unity, current gain is less than one and the overall power gain is also when compared to the other transistor configurations.
4. The input and output signals are in phase.

Common collector configuration:

This transistor configuration is also known as the emitter follower because the emitter voltage follows that of the base. In this transistor configuration, the collector electrode is common to both input and output circuits.

Common collector characteristics.

1. Has high input impedance due to the reverse biased base –collector PN junction
2. High output impedance
3. The voltage gain is less than one, although current gain is high.
4. The input and output signals are in phase.

In view of these characteristics, the emitter follower configuration is used as a buffer circuit for impedance matching between two stages of common emitter amplifiers.

Common emitter mode of connection:

As can be seen from the diagram, the emitter electrode is common to both input and output circuits. In common emitter mode of connection, the input current is base current (I_B) while the output current is the collector current (I_C).

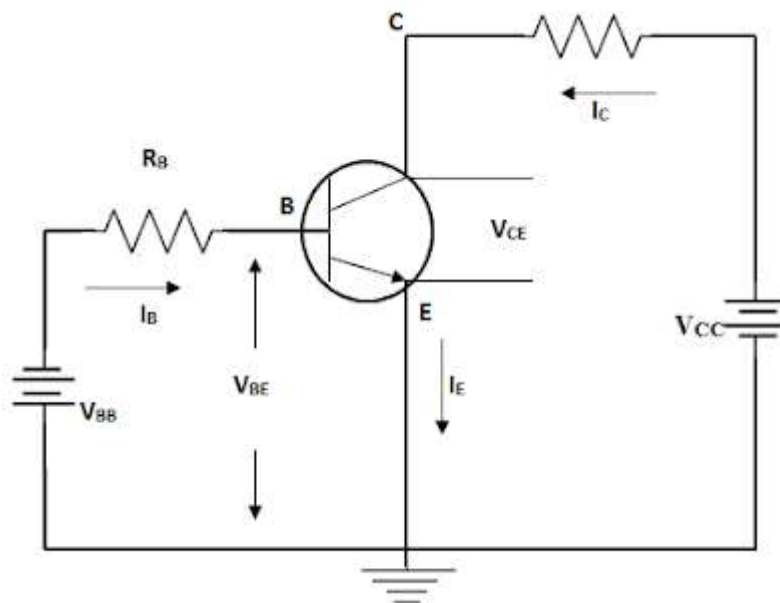


Figure 127: emitter mode

Common emitter characteristics.

1. Has low input impedance
2. Has high output impedance
3. Current gain is greater than one.
4. Voltage gain is greater than one
5. Power gain is greater than one

6. The output is the inverse of the input, i.e. 180° phase change.
This transistor configuration is the most widely used.

Field-Effect Transistor (Fet)

The field-effect transistor (FET) is an [electronic](#) device which uses an [electric field](#) to control the flow of [current](#) through it. FETs have 3-terminals.

- *Source*,
- *gate*, and
- *drain* terminal.

FETs control the flow of current by the application of a voltage to the gate terminal, which in turn alters the [conductivity](#) between the drain and source terminals.

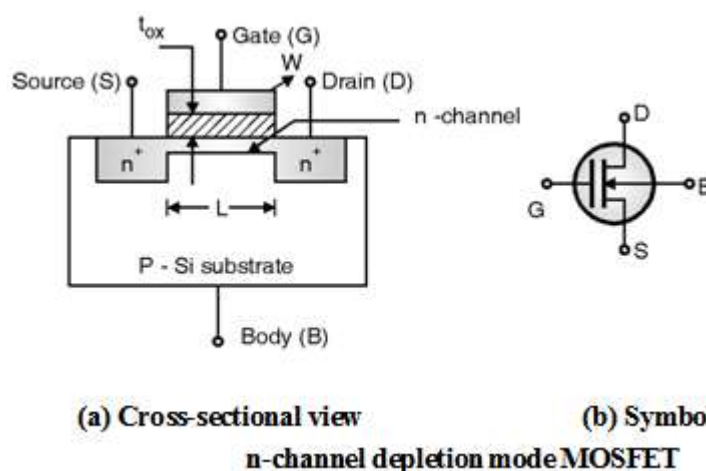
FETs are also known as unipolar transistors since they involve single-carrier-type operation. That is, FETs use electrons or holes as charge carriers in their operation, but not both as is the case with the BJT.

Types of Field Effect Transistors (FETs)

FETs are six different types which are broadly classified in two main groups

1. Junction FET.
 - N channel JFET.
 - P channel JFET.
2. MOSFET or IGFET transistor
 - a. Enhancement MOSFET Transistor.
 - N channel.
 - P channel.
 - b. Depletion mode MOSFET transistor.
 - N channel.
 - P channel

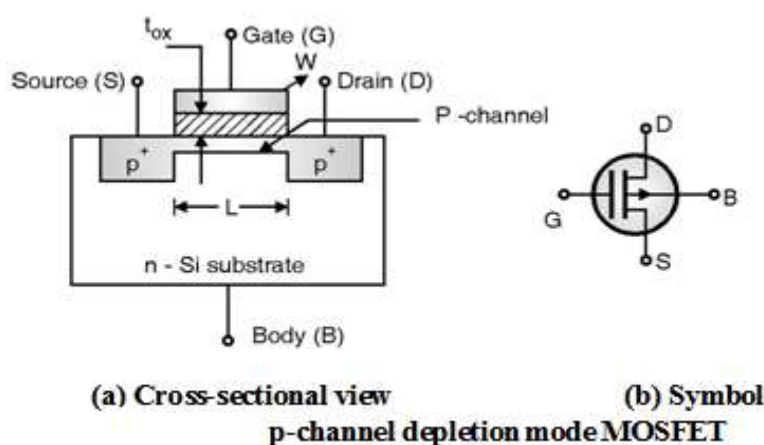
N-Channel Depletion Mode MOSFET



If the gate is connected to a positive voltage with respect to the source, electrons will be attracted from the highly doped N-regions and move into the slightly doped N-region. This reduces the size of the depletion layer since electrons are caused to move into the region of the channel beneath the gate-insulator (the slightly doped N-region). The drain current is increased since the channel resistance has been reduced. The more positive the gate-source voltage, the smaller is the depletion layer and the more the drain current that flows.

A negative voltage at the gate with respect to the source causes the widening of the depletion layer by forcing electrons to move from the slightly doped N-region of the channel beneath the gate-insulator. This results in increase of the channel resistance and hence reduction of drain current. The more negative is the gate-source voltage, the wider is the depletion layer and the less the drain current that flows.

P-Channel Depletion Mode MOSFET



A positive voltage at the gate with respect to the source causes the widening of the depletion layer by forcing electrons to move into the region of the channel beneath the gate-insulator (the slightly doped P-region). This results in reduction of drain current. The more positive is the gate-source voltage, the wider is the depletion layer and the less the drain current that flows.

If the gate is now connected to a negative voltage with respect to the source, HOLES will be attracted from the highly doped P-regions and move into the slightly doped P-region. This reduces the size of the depletion layer since HOLES are caused to move into the region of the channel beneath the gate-insulator (the slightly doped P-region). The drain current is increased since the channel resistance has been reduced. The more negative the gate-source voltage, the smaller is the depletion layer and the more the drain current that flows.

Enhancement Mode Only MOSFET (E-Mosfet)

These types of MOSFETS are off at zero gate–source voltage. The N-channel MOSFET can be turned on by pulling the gate voltage higher than the source voltage while the P–channel MOSFET can be turned on by pulling the gate voltage lower than the source voltage. Thus, pulling an enhancement-mode MOSFET's gate voltage towards its drain voltage turns it *ON*.

Gain of transistor amplifier

When a transistor is to be connected as an amplifier, a signal is connected across the input terminals and then obtained across the output terminals of the amplifier. The ratio of the magnitude of the output signal to that of the input signal defines the gain of an amplifier

DC load line.

A dc load line is a straight line that passes through two points on the output characteristics of a transistor. The two points are cutoff and saturation point. It's on the Dc load line where the transistor operating point is established.

AC load line.

The AC load line is a straight line with a slope equal to the AC impedance the transistor amplifier is experiencing. The ratio of AC voltage to current in the device is defined by this line

9.3.4.3.Self-Assessment

1. Describe a Bipolar Junction Transistor (BJT)
2. Explain regions of Bipolar Junction Transistor (BJT)
3. Define transistor biasing
4. Describe transistor circuit configurations/ transistor modes of connection
5. Describe the operation of field-effect transistor (FET)
6. is a straight line that passes through two points on the output characteristics of a transistor. The two points are cutoff and saturation point.
 - a) Dc load line.
 - b) Ac load line.
7. is a straight line with a slope equal to the AC impedance the transistor amplifier is experiencing.
 - a) Dc load line.
 - b) Ac load line.
8. The BJT is a three terminal semiconductor device whose output current, voltage and power is controlled by its input current
 - a) True
 - b) False

9. the bipolar junction transistor consists of two back-to-back P-N junctions manufactured in a single piece of a semiconductor crystal

- a) True
- b) False

Practical exercises

- a) Identify Transistors as per their characteristics
- b) Determine the operation of P and N channels
- c) Biasing and determination of gain of transistors is performed as per their standard operating procedure

9.3.4.4. Tools, Equipment, Supplies

- Assorted BJT transistors. NPN/PNP types
- Assorted FETS.
- Multipurpose meters
- cables
- dc power supplies
- biasing resistors
- bread boards
- copper strip boards
- standard electronic tool kit

9.3.4.5. References

1. vlabs.iitb.ac.in/vlab/electrical/exp4/Theory.pdf
2. http://staff.iium.edu.my/adah510/ManualECE1201_SEM%20I%202015_2016.doc

9.3.5. Learning Outcome No. 4. Apply special semiconductor devices

9.3.5.1. Learning Activities

Learning Outcome No. 4. Apply special semiconductor devices	
Learning Activities	Special Instructions
-Identify Special semiconductor devices and state operation. -Apply special semiconductors as per their standard operating procedure -identify special semiconductor devices	Demonstrate application of Thyristors in power control circuits. Single phase motor speed control.

9.3.5.2. Information Sheet No 9/ LO4

These are solid-state devices that are not used for signal amplification but have wide application in power supply circuits, device control circuits, and oscillator circuits. These devices have one or more PN junctions and generally are operated in either an "on" or "off" state.

1. Types Of Special Semiconductor Devices

Unijunction Transistors

The *unijunction transistor* (UJT) is a one-PN-junction solid-state device. The device basically consists of a bar of N-type semiconductor material that has a small pellet of P-type material fused into its structure, as shown in Figure below.

Leads are attached to each end of the N-type bar and are referred to as base 1 and base 2. Another lead is then attached to the P-type pellet and is referred to as the *emitter*. As a general rule, the emitter is located closer to base 2 than it is to base 1.

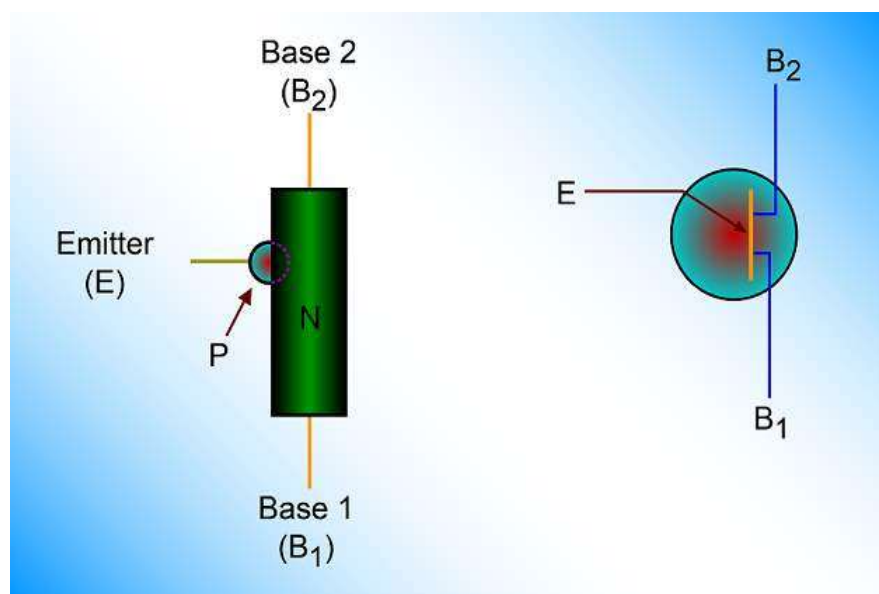


Figure 128: Unijunction Transistors

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

The N-type bar is lightly doped and this makes the resistance between the base 1 and base 2 leads to be quite high. The area in which the P-type pellet and N-type bar meet forms a PN junction that has characteristics similar to those of ordinary PN-junction diode. Therefore, a UJT can be represented with an equivalent circuit that consists of two resistors and a diode that has its cathode end connected between the two resistors.

UJT Operation

The supply voltage for the B1 to B2 circuit (V_{BB}) is normally positive at B2 with reference to emitter. The voltage between the emitter and B ϵ (V_E) is normally positive at the emitter with reference to B ϵ .

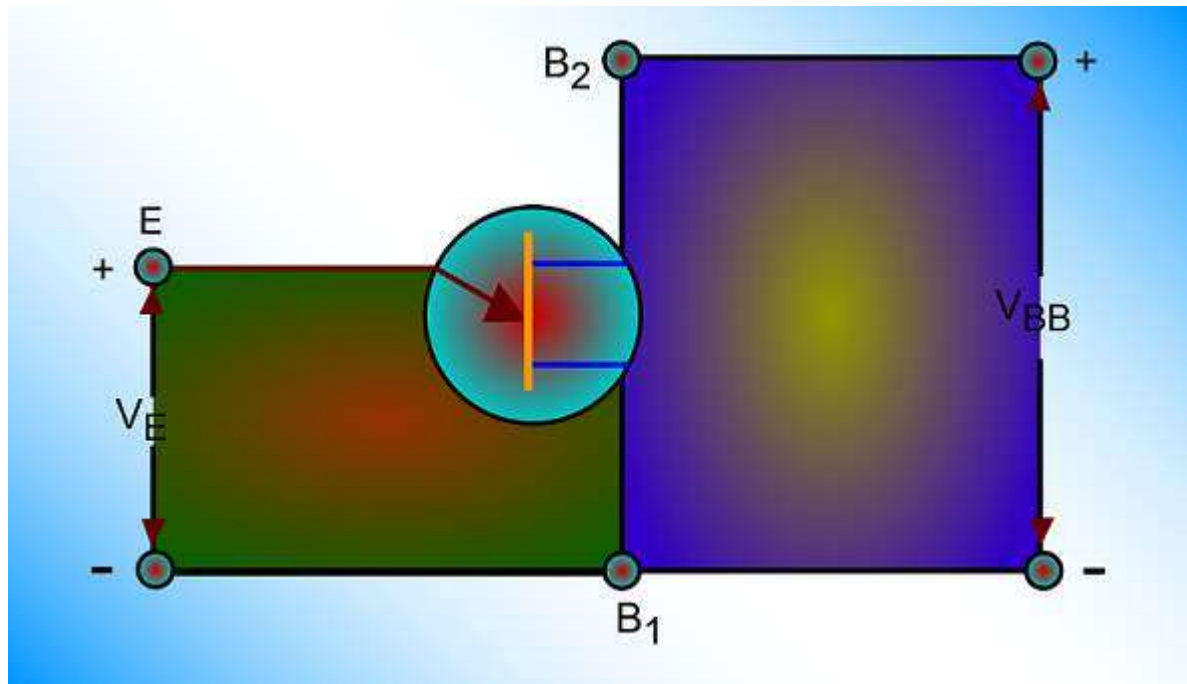


Figure 129: UJT Biasing

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

The operation of an ordinary UJT is more apparent when analyzed using the equivalent circuit shown below. The resistance R_{B2} is a variable resistor since its value will vary with the emitter current (I_E). R_{B1} is a fixed value resistor. The value of resistance between B₂ and B₁ is called the *interbase resistance*.

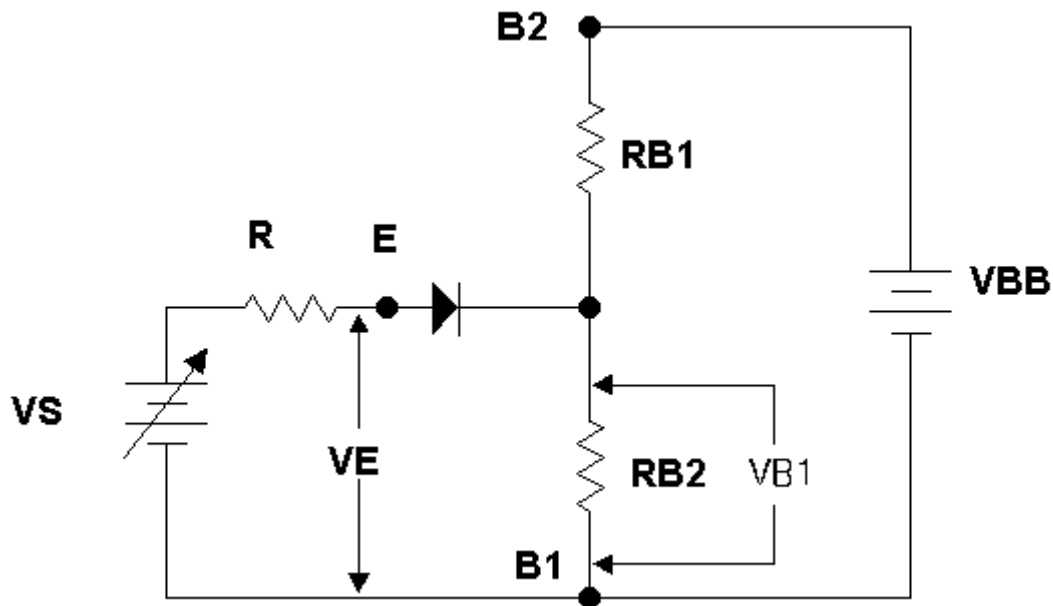


Figure 130: UJT Equivalent Circuit

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

When V_{BB} is applied before V_E has been applied, there is a small flow of current between B2 and B1, which is determined by the magnitude of V_{BB} and the value of the interbase resistance. Since the value of interbase resistance is relatively large, the magnitude of this current is small. Voltages will be developed across RB_2 and RB_1 because of the current flow. The cathode of the diode is positive with reference to B2. As a result, there will not be a flow of current between the emitter and B2 until the emitter voltage is 0.7 V more positive than the voltage across RB_2 .

When the emitter voltage exceeds the voltage across RB_2 by 0.7 V, the diode is forward biased and current will flow between the emitter and base 1. Holes from the P-type emitter region flow toward the N-type base. This produces an increase in the electron flow into RB_2 region. As a result, the density of current carriers in the base 2 region increases and causes the effective opposition of RB_2 to decrease. When the resistance of RB_2 decreases, the voltage across it decreases; therefore, the forward bias between the emitter and B2 is further increased. This produces more emitter-B2 current and RB_2 is further reduced. This regenerative feedback effect continues until RB_2 reaches some minimum value.

Emitter voltage is equal to the drop across RB_2 plus the drop across the PN junction, so the emitter voltage also decreases. This is called the UJT's *negative resistance region* because an increase in B2 to B1 current is produced by an apparent decrease in voltage at the emitter.

The forward bias potential at the emitter quickly reduces the opposition of RB2. RB2 is in series with RB2; consequently, when the opposition of RB2 decreases, the current from B2 to B1 will increase. Once a sufficient amount of forward bias is applied to the emitter, the UJT is switched from a high-resistance "off" state to a low-resistance "on" state.

UJT Applications

The UJT's negative resistance characteristic makes the device useful for generating repetitive signals. A circuit commonly used for this purpose as a *UJT relaxation oscillator*

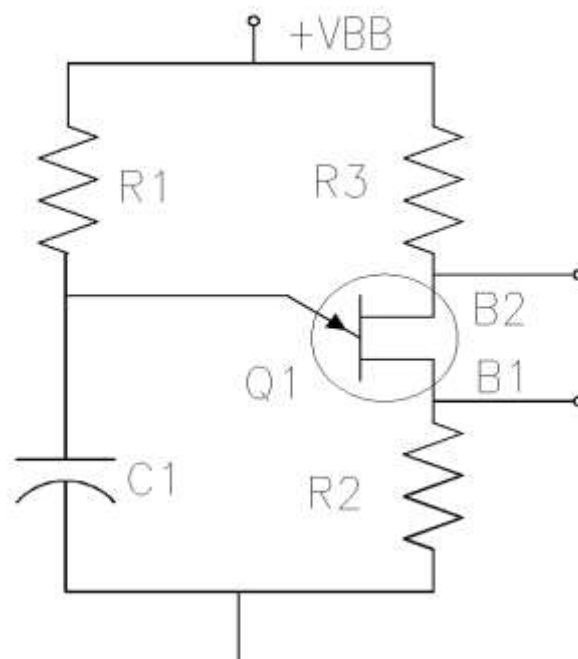


Figure 131: UJT Relaxation Oscillator

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

SCR (silicon controlled rectifier)

An SCR is a four-layer device with three electrodes namely the Anode, cathode and the gate terminal connected internally as shown.

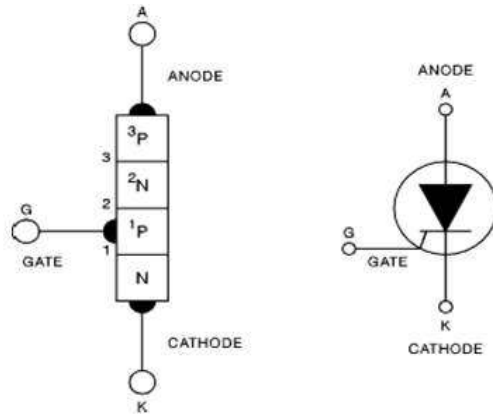


Figure 132: SCR Construction and Schematic Diagram

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

The terminal connected to the outer N-type layer is called the *cathode*. The gate terminal is connected to the inside P-type layer. The gate is physically closer to the cathode and is designated as such in the schematic diagram.

SCR Operation

The theory of operation of an SCR is best explained using the two transistors equivalent circuit as shown.

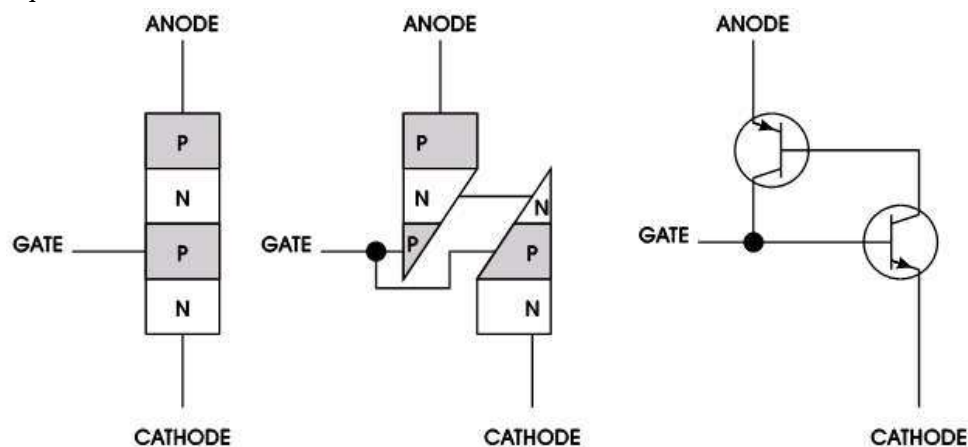


Figure 133: The SCR and Its Equivalent Circuits

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

When the anode of the circuit will be made positive with respect to the cathode, but the gate will be left open. Under these conditions, the NPN transistor will not conduct because its emitter junction will not be subjected to a forward bias voltage, which can produce a base current. This will cause the PNP transistor to turn off because the NPN transistor will not be conducting and, therefore, will not allow a base current to flow through the emitter junction of the PNP transistor. The SCR will not allow current to flow from its anode to its cathode under these conditions.

The SCR is said to be in its *forward blocking region*. It will only switch to its forward conduction region when cathode-anode voltage is increased beyond break over voltage of the device.

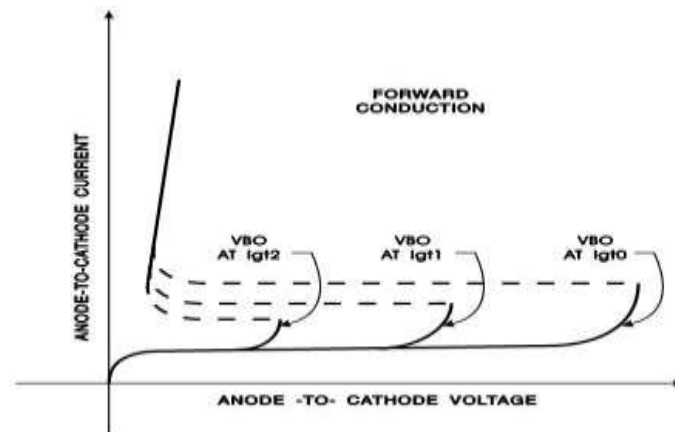


Figure 134: Forward Conduction

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

If the gate is connected to a positive going pulse, the device is triggered in to conduction even before attaining the break over voltage. If this happen, the voltage across its terminals fall to a value below 1 volt as the current increases. The device remains in this conducting state as long as the polarity of the applied voltage is not reversed or the current reduced to a value below the holding current.

When the cathode of the circuit is now made positive with respect to the anode, but the gate left open, The SCR will not allow current to flow from its cathode to anode to under these conditions.

The SCR is said to be in its *reverse blocking region*.

In its second operating state, the SCR is switched to its high conduction region only if the cathode-node voltage is increased beyond the reverse break over voltage.

Application of silicon control rectifier (SCR)

- The silicon controlled rectifier (SCR) is used in AC voltage stabilizers.
- The silicon controlled rectifier (SCR) is used as switch.
- It is used in choppers.
- The silicon controlled rectifier (SCR) is used in inverters.
- The silicon controlled rectifier (SCR) is used for power control.
- It is used for DC circuit breaker.

LASCR

Light Activated SCR (*Photo SCR*)

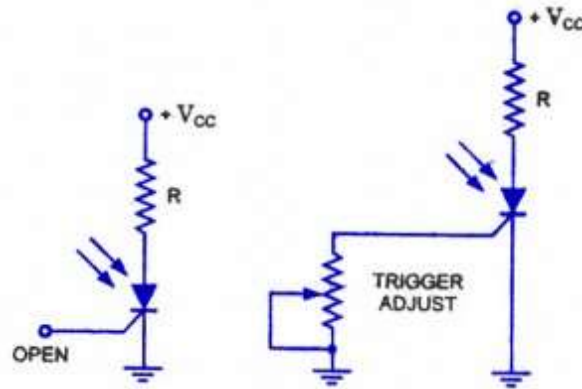


Figure 135: LASCER or Photo SCR

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

This is just like an ordinary SCR except that it can also be light triggered. LASCR is constructed to have a window in the encasement so that light sources from other devices can be coupled to the SCR. The schematic symbols most commonly used for the LASCR are shown in figure. When the light falling on depletion layer is strong enough, valence electrons are dislodged from their orbits and become free electrons. These free electrons flow out of the collector of one transistor into the base of the other.

The positive feedback starts and the LASCR turns on just like a normal SCR, the LASCR will continue to conduct even if the light source is removed.

For maximum sensitivity to light, the gate is usually left open. To alter the sensitivity of the circuit to the incoming light, resistor can be connected to the gate so that it diverts some of the light produced electrons.

LASCR Applications

The LASCRs find many low power applications which includes optical light controls, relays, phase control, motor control and a large number of computer applications. The maximum current (rms) and power (gate) ratings for LASCRs commercially available are about 3 A and 0.1 W. With the increase in junction temperature the light energy required to activate the device is reduced.

TRIAC

The TRIAC consists of two thyristors connected in reverse parallel. For this reason, the triac is able to conduct current irrespective of the voltage polarity of terminals MT1 and MT2. It can also be triggered by either positive or negative gate currents, irrespective of the polarity of the MT2 current. This means that there are four triggering modes or quadrants:

Triac applications

- Lighting control - especially dimmers.
- Control of fans and small motors speed.

- General AC switching and control

DIAC

A DIAC is a full-wave or bi-directional semiconductor switch that can be turned on in both forward and reverse polarities. It is basically a TRIAC without the gate terminal.

DIAC circuit symbols and block diagram

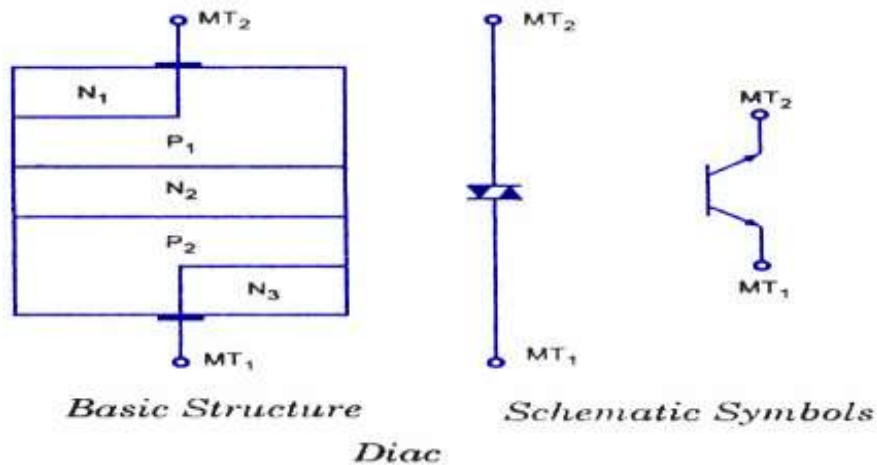


Figure 136: Diac Operation

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

DIAC circuits use the fact that a DIAC conducts current only after a certain breakdown voltage has been exceeded. The actual breakdown voltage will depend upon the specification for the particular component type.

When the DIAC breakdown voltage occurs, the resistance of the component decreases abruptly and this leads to a sharp decrease in the voltage drop across the DIAC, and a corresponding increase in current. The DIAC will remain in its conducting state until the current flowing through it drops below a particular value known as the holding current. When the current falls below the holding current, the DIAC switches back to its high resistance region, or non-conducting state.

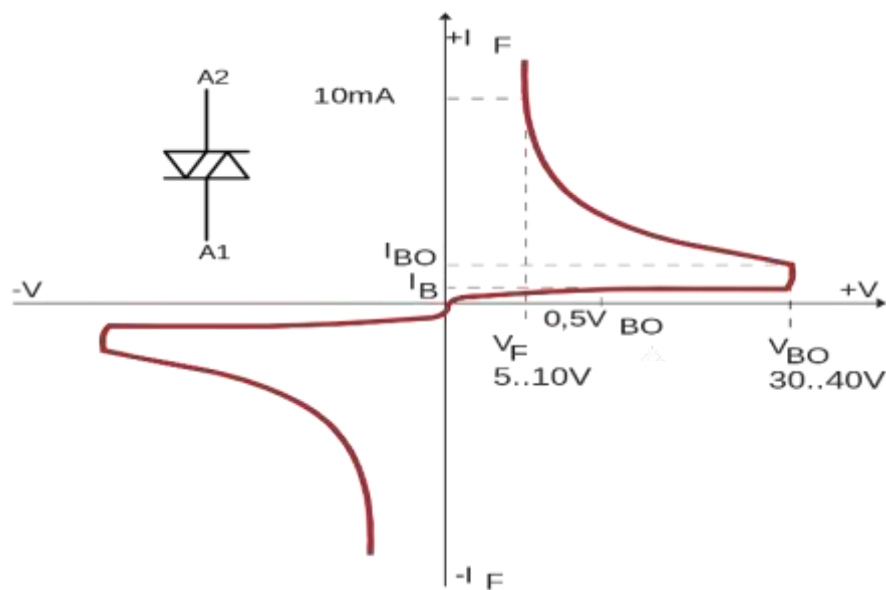


Figure 137: DIAC voltage- current

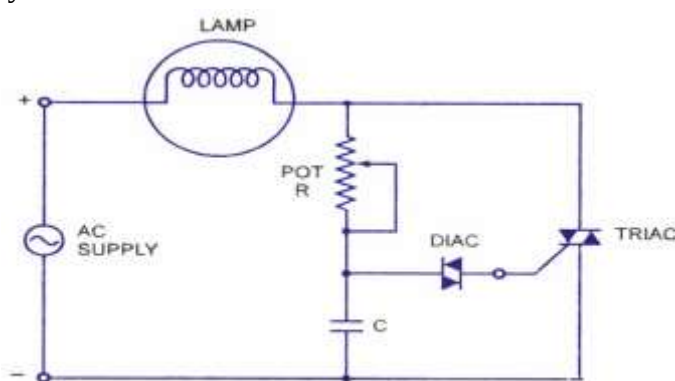
Source: https://www.electronics-tutorials.ws/diode/diode_1.html

DIAC applications

DIACs are mainly used in AC applications. In its applications it utilises the fact that the device is "reset" to its non-conducting state each time the voltage on the cycle falls so that the current falls below the holding current. This behaviour of the device is approximately equal in both directions, and that is what is used as a method of providing equal switching of a TRIAC for both halves of an AC cycle.

Most DIACs have a breakdown voltage of around 30 volts, although this depend upon the particular type of device.

DIACs are mainly used within TRIAC circuits.



Triac Lamp Dimmer Circuit

Figure 138: SCS (silicon controlled switch)

An SCS is fabricated by modifying the SCR. In the SCR, another external terminal is inserted and connected to the base of the top transistor and the collector of the bottom transistor as shown in Figure below. This is the anode-gate terminal.

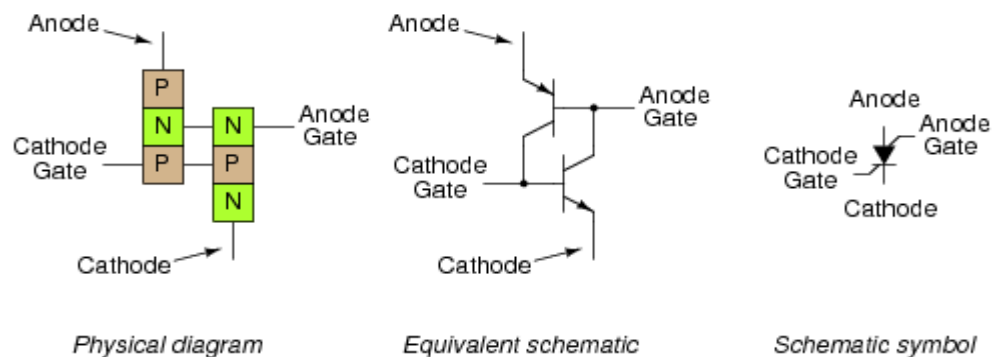
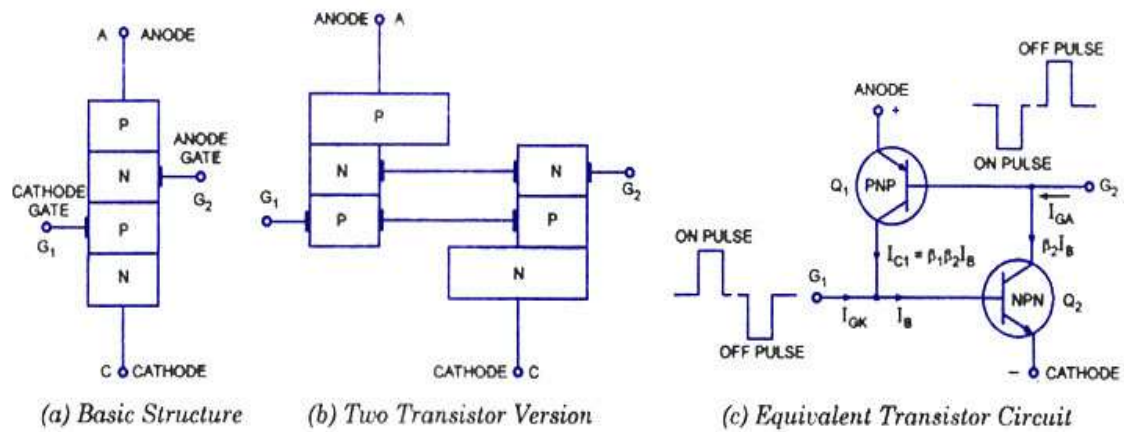
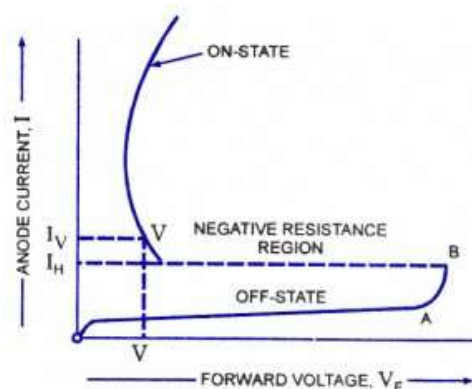


Figure 139: The Silicon-Controlled Switch (SCS)

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

This extra terminal allows more control to be exerted over the device, particularly in the mode of *forced commutation*, where an external signal forces the SCS to turn off while the main current through the device has not yet fallen below the holding current value. Consider an example of

Volt-Ampere Characteristic of SCS.



The volt-ampere characteristic of an SCS is similar to that of an SCR as shown above.

Advantages of SCS over SCR

1. Has reduced turn-off time, typically within the range of 1 to 10 micro seconds for the SCS and 5 to 30 micro seconds for the SCR.
2. Has increased control.
3. Increased triggering sensitivity. It needs small triggering signals.
4. More predictable firing situation.

Disadvantages.

1. SCS is limited to low power, current, and voltage ratings (typical maximum anode currents range from 100 mA to 300 mA with dissipation rating of 100 to 500 mW).
2. It has smaller leakage and holding currents than SCR

A few of the more common areas of application of SCS include a variety of computer circuits (such as counters, registers, and timing circuits) voltage sensors, pulse generators, oscillators etc.

9.3.5.3. Self-Assessment

1. Describe special types of semi-conductor devices
2. Explain the operation of UJT
3. Explain the operation of SCR
4. Draw and label voltage characteristics curve
5. Describe Volt-Ampere Characteristic of SCS.
6. An is a four-layer device with three electrodes namely the Anode, cathode and the gate terminal connected internally as shown.
 - a) TRIAC
 - b) DIAC
 - c) SCR
7. The consists of two thyristors connected in reverse parallel.
 - a) TRIAC
 - b) DIAC
 - c) SCR
8. Which of the following is not an advantages of SCS over SCR
 - a) Has reduced turn-off time, typically within the range of 1 to 10 micro seconds for the SCS and 5 to 30 micro seconds for the SCR.
 - b) Has reduced control.
 - c) Increased triggering sensitivity. It needs small triggering signals.
 - d) More predictable firing situation.
9. The unijunction transistor (UJT) is a one-PN-junction solid-state device.
 - a) True
 - b) False
10. An SCR is a four-layer device with three electrodes namely the Anode, cathode and the gate terminal connected internally
 - a) True
 - b) False

Practical exercise

- a) Identify Special semiconductor devices and state operation.
- b) Apply special semiconductors as per their standard operating procedure
- c) identify special semiconductor devices

9.3.5.4. Tools, Equipment, Supplies

- Assorted special semiconductor devices (DIAC, TRIAC, UJT, LASCR, SCR, SCS)
- Multipurpose meters
- cables
- dc power supplies
- ac power supplies
- biasing resistors
- bread boards
- copper strip boards
- standard electronic tool kit
- oscilloscopes

9.3.6.5. References

1. https://www.electronics-notes.com/articles/electronic_components/scr/what-is-a-diac.php
2. <https://www.oreilly.com/library/view/basic-electronics/9789332512078/xhtml/chapter008.xhtml>
3. <http://www.rgcetpdy.ac.in/Notes/IT/II%20YEAR/ELECTRONIC%20DEVICES%20AND%20CIRCUITS/Unit%202.pdf>

9.3.6. Learning Outcome No. 5. Perform rectification

9.3.6.1. Learning Activities

Learning Outcome No. 5. Perform rectification	
Learning Activities	Special Instructions
1.1 Identify types of rectifiers and their functions 1.2 Classify rectifiers as per their input voltage 1.3 Apply rectifiers 1.4 Identify converters as per their functions 1.5 Apply converters as per their established functions.	Follow the links below for experiments on rectifiers.

9.3.6.2. Information Sheet No. 9/ LO5

Rectification

It's the process of the conversion of an alternating current to direct current and is done by using diodes. A rectifier is an electrical device that converts an Alternating Current (AC) into a Direct Current (DC) by using one or more P-N junction diodes.

Classification of rectifiers

The rectifiers are mainly classified into two types:

- Half wave rectifier
- Full wave rectifier

Half wave rectifier

This is a type of rectifier which converts half of the AC input signal (positive half cycle) into pulsating DC output signal. The remaining half signal (negative half cycle) is blocked or lost. In half wave rectifier circuit, only a single diode is used.

Full wave rectifier

It is a type of rectifier which converts the full AC input signal (positive half cycle and negative half cycle) to pulsating DC output signal. Unlike the half wave rectifier, no input signal is wasted in the rectifier. This makes the efficiency of full wave rectifier to be higher compared to that of half wave rectifier.

Half Wave Rectifier Circuit

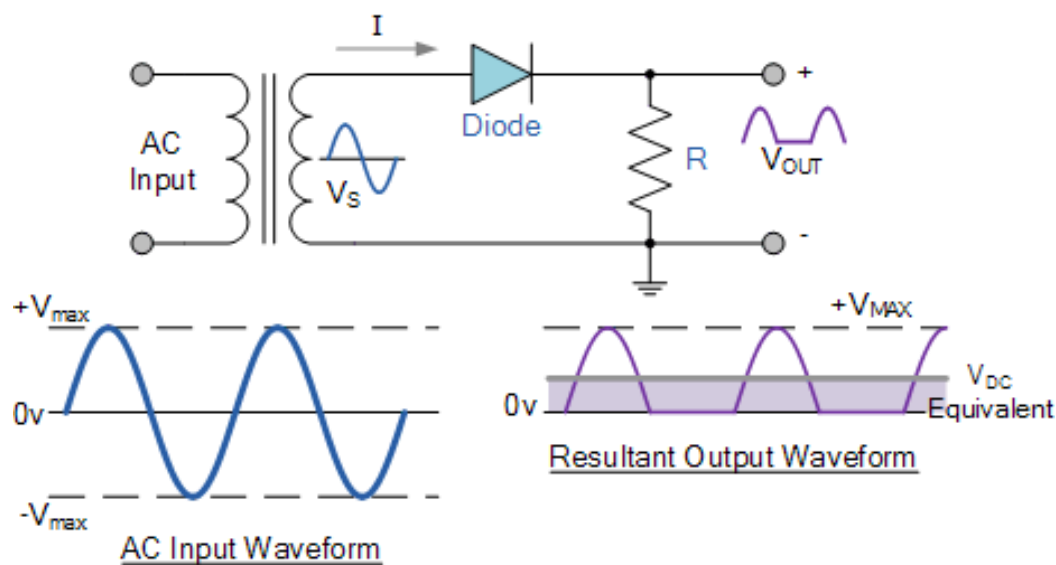


Figure 140: Half Wave Rectifier Circuit

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

During each “positive” half cycle of the AC sine wave, the diode is *forward biased* as the anode is positive with respect to the cathode resulting in current flowing through the diode and through the load. The current flowing in the load resistor is therefore proportional to the voltage (Ohm’s Law), and the voltage across the load resistor will therefore be the same as the supply voltage ($V_{out} = V_s$).

During each “negative” half cycle of the AC sinusoidal input waveform, the diode is *reverse biased* and will not conduct. Therefore, NO current flows through the diode or through the circuit resulting to $V_{out} = 0v$.

The output current flows in one direction only making the circuit Unidirectional. As the load resistor receives from the diode a positive half of the waveform, zero volts, a positive

Full wave rectifier

A full wave rectifier is a type of rectifier which converts both half cycles of the AC signal into pulsating DC signal.

Types of full wave rectifiers

1. Bi-phase rectifier

Theory Of Operation.

During the positive half cycle of the input voltage, diode D1 becomes forward biased and D2 becomes reverse biased. Hence D1 conducts and D2 remains OFF. The load current flows through D1 and the voltage drop across R_L will be equal to the input voltage. During the negative half cycle of the input voltage, diode D1 becomes reverse biased and D2 becomes forward biased. Hence D1 remains OFF and D2 conducts. The load current flows through D2 and the voltage drop across R_L will be equal to the input voltage.

2. Bridge Rectifier

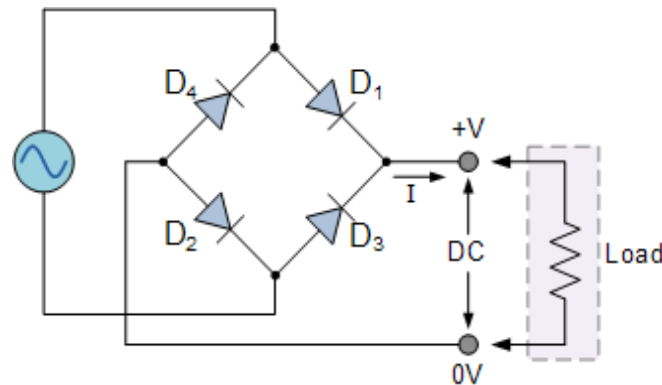


Figure 141: Bridge Rectifier

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

During the positive half cycle of the supply, diodes D1 and D2 conduct in series while diodes D3 and D4 are reverse biased and the current flows through the load as shown below.

3. The Positive Half-cycle

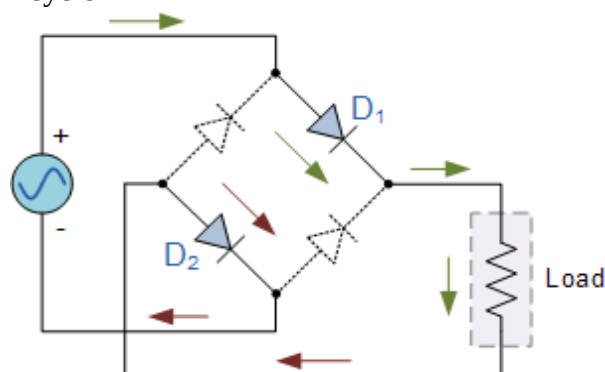


Figure 142: Positive Half-cycle

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

During the negative half cycle of the supply, diodes D3 and D4 conduct in series, but diodes D1 and D2 switch “OFF” as they are now reverse biased. The current flowing through the load is the same direction as before.

The Negative Half-cycle

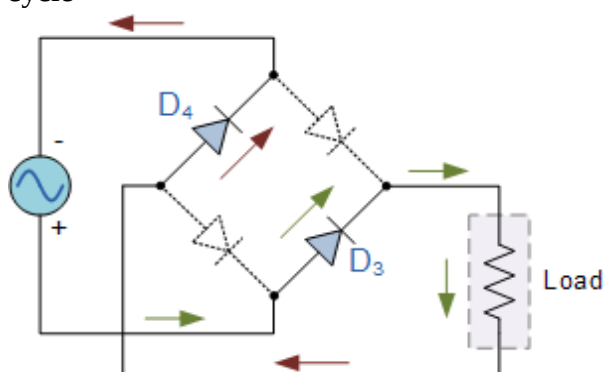


Figure 143: The Negative Half-cycle

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

As the current flowing through the load is unidirectional, so the voltage developed across the load is also unidirectional the same as for the previous two diode full-wave rectifier.

Power Converters

What is a Power Converter?

A power converter is an electrical circuit that changes the electric energy from one form into the desired form optimized for the specific load. A converter may do one or more functions and give an output that differs from the input. It is used to increase or decrease the magnitude of the input voltage, invert polarity, or produce several output voltages of either the same polarity with the input, different polarity, or mixed polarities such as in the computer power supply unit.

Types of power converters

Diode Rectifier.

AC to DC Converter (Controlled Rectifier)

DC to DC Converter (DC Chopper)

AC to AC Converter (AC voltage regulator)

DC to AC Converter (Inverter)

Diode Rectifiers.

A diode rectifier circuit converts AC voltage into a fixed DC voltage. The input voltage to rectifier could be either single phase or three phase.

AC to DC Converters.

An AC to DC converter circuit can convert AC voltage into a DC voltage. The DC output voltage can be controlled by varying the firing angle of the thyristors. The AC input voltage could be a single phase or three phase.

AC to AC Converters.

These converters can convert from a fixed ac input voltage into variable AC output voltage. The output voltage is controlled by varying firing angle of TRIAC. These type converters are known as AC voltage regulator.

DC to DC Converters.

These converters can convert a fixed DC input voltage into variable DC voltage or vice versa. The DC output voltage is controlled by varying of duty cycle.

Static Switch.

Because the power devices can be operated as static switches or contactors, the supply to these switches could be either AC or DC and the switches are called as AC static switches or DC static switches

9.3.6.3. Self-Assessment

1. State rectification
2. Describe classification of rectifiers
3. Differentiate half wave and full wave rectifiers including the circuits
4. Describe theory of operation of rectifiers
5. Define power converters
6. What are the advantages of rectifiers over power converters?
7. Explain types of power converters and their modes of operation
8. is a type of rectifier which converts half of the AC input signal (positive half cycle) into pulsating DC output signal.
 - a) Full wave rectifier
 - b) Half wave rectifier
9. is a type of rectifier which converts the full AC input signal (positive half cycle and negative half cycle) to pulsating DC output signal.
 - a) Full wave rectifier
 - b) Half wave rectifier
10. Which of the following is not a types of power converters?
 - a) Controlled Rectifier
 - b) DC Chopper
 - c) Varactor diode
 - d) Inverter
11. During each “positive” half cycle of the AC sine wave, the diode is *forward biased* as the anode is positive with respect to the cathode resulting in current flowing through the diode and through the load.
 - a) True
 - b) False
12. A full wave rectifier is a type of rectifier which converts both half cycles of the AC signal into pulsating DC signal.
 - a) True

b) False

Practical exercise

- a) Identify types of rectifiers and their functions
- b) Classify rectifiers as per their input voltage
- c) Apply rectifiers and converters and identify converters as per their functions

9.3.6.4. Tools, Equipment, Supplies

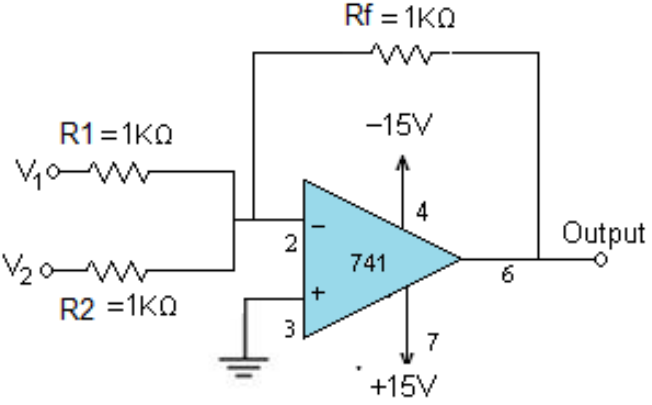
1. Rectifier diodes
2. Capacitors
3. Inductors
4. Power transformers
5. Multipurpose meters
6. cables
7. ac power supplies
8. resistors
9. bread boards
10. copper strip boards
11. standard electronic tool kit
12. oscilloscopes

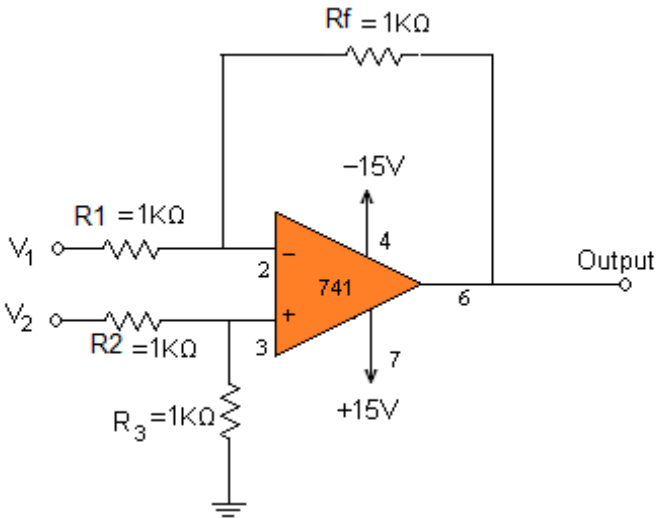
9.3.6.5. References

1. [http://ee.eng.usm.my/eeacad/syafrudin/nota/Lecture%20Note%20Machine%20&%20Drives%20\(Power%20Electronic%20Converter\).pdf](http://ee.eng.usm.my/eeacad/syafrudin/nota/Lecture%20Note%20Machine%20&%20Drives%20(Power%20Electronic%20Converter).pdf)
2. <https://www.efxkits.us/types-of-rectifiers-with-workings/>
3. <https://physicsabout.com/rectification/>

9.3.7. Learning Outcome No. 6. Apply amplifiers

9.3.7.1. Learning Activities

Learning Outcome No. 6. Apply amplifiers	
Learning Activities	Special Instructions
1. Types of <i>amplifiers</i> are identified as per their functions 2. Operational amplifier is identified as per its applications 3. Characteristics of operational amplifiers are determined OP-APM Adder Circuit:-  1. Connect the circuit as per the diagram. 2. Apply the supply voltages of +15V to pin No 7 and -15V to pin No 4 of IC 741 respectively. 3. Apply the inputs V_1 and V_2 as shown. 4. Apply two different signals (DC/AC) to the inputs. 5. Vary the input voltages and note down the corresponding output at pin 6 of the IC 741 adder circuit. 6. Notice that the output is equal to the sum of the two inputs. Subtractor circuit	The trainer to provide assorted amplifier circuits and their diagrams. Calculation: Adder ▪ $V_o = -(V_1 + V_2)$ ▪ If $V_1 = 2V$ and $V_2 = 2V$, then ▪ $V_o = -(2+2) = -4V$. Calculation: Subtractor ▪ $V_o = V_2 - V_1$ ▪ If $V_1 = 4$ and $V_2 = 2$, then ▪ $V_o = 4 - 2 = -2$

 1. Connect the circuit as per the diagram. 2. Apply the supply voltages of +15V to pin7 and pin4 of IC741 Respectively. 3. Apply the inputs V_1 and V_2. 4. Apply two different signals (DC/AC) to the inputs. 5. Vary the input voltages and note down the corresponding output at Pin 6 of the IC 741 subtractor circuit. 6. Notice that the output is equal to the difference of the two inputs.	

9.3.7.2.Information Sheet No. 9/ LO6

Amplifier

An amplifier is an electronic device for increasing the amplitude of electrical signals, it is used mainly in sound reproduction to increase the volume of the sound produced by electric equipment such as guitars, microphones and many other musical instruments.

Types of amplifiers

Transistor Amplifiers:

1. Voltage Amplifiers:
2. Current Amplifiers: ...
3. Power Amplifiers: ...
4. Audio Frequency Amplifiers (A.F. ...
5. Intermediate Frequency Amplifiers (I.F. ...
6. Radio Frequency Amplifiers (R.F. ...
7. Ultrasonic Amplifiers: ...

8. Wideband Amplifiers:

Audio Frequency Amplifiers

Audio frequency amplifiers are used to amplify signals in the range of human hearing that approximately 20 Hz to 20 kHz.

Audio Frequency Amplifier

Audio voltage amplifiers are used to amplify the low level signals from microphones and disk pickups, Etc. By extra circuitry, the audio amplifiers can also perform functions such as tone correction, equalization of signal levels and mixing of different inputs. Audio power amplifiers receive the amplified input from a series of voltage amplifiers and then provide sufficient power to drive loudspeakers.

Intermediate Frequency Amplifiers

These are tuned amplifiers used in radio, TV sets and radar devices. Their Main purpose is to provide the majority of the voltage amplification of a modulated signal, before the audio or video information carried by the signal is separated or demodulated from the radio signal. These amplifiers operate at a frequency lower than that of the received radio waves, but higher than the audio or video signals eventually produced by the system. Example of such an amplifier is shown below.

R.F. Amplifiers

These are tuned amplifiers in which the frequency of operation is governed by a tuned circuit equipment. This circuit may or may not be adjustable depending on the purpose of the amplifier. Its bandwidth also depends on use and may be relatively wide or narrow.

R.F. Amplifier

These amplifiers are used in the earliest stages of a receiver

Wide band Amplifier

Wide band amplifiers are amplifiers with constant gain from DC to several tens of MHz range. These amplifiers are used in measuring equipment such as oscilloscopes. In such equipment, there is need to accurately measure signals over a wide range of frequency range and thus, wide band amplifiers are best suited for this.

DC Amplifiers

DC amplifiers are those types used to amplify DC (0 Hz) voltages or very low frequency signals where the DC level of the signal is an important parameter. They are common in many electrical [control systems and measuring instruments](#).

Video Amplifiers

Video amplifiers are a special type of wide band amplifiers that also preserve the DC level of the signal and are used specifically for signals that are to be applied to CRTs or other video equipment used. Video signals carry all the picture information on TV sets, video and radar systems. Bandwidth of video amplifiers depends on use. In TV receivers it extends from 0 Hz (DC) to 6 MHz and is wider still in radar.

Buffer Amplifiers

Buffer amplifiers are a specialized type of amplifier that can be found within any of the other types of amplifiers. They are primarily used for impedance matching between two stages of amplification. They are placed between two other circuits to prevent the operation of one circuit affecting the operation of the other circuit. I.e. they isolate the circuits from each other.

Buffer amplifiers have a gain of one, i.e. they do not actually amplify the signal, so that their output is the same amplitude as their input wave. Buffer amplifiers have a very high input impedance and a low output impedance and can therefore be used as an impedance matching device. Buffer ensures that signals are not attenuated between circuit parameters, as happens when a circuit with a high output impedance feeds a signal directly to another circuit having a low input impedance.

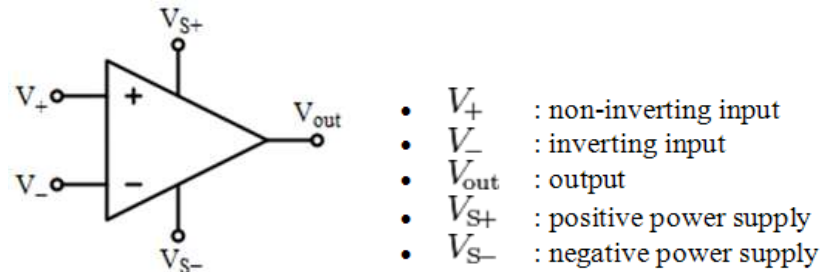
Operational Amplifiers (OP-AMP)

It's a linear integrated circuit amplifier with high gain and high input impedance. The amplifier is used in circuits for performing mathematical operations on an input voltage.

Operational amplifiers were developed for circuits designed for the early analog computers where they were used for mathematical operations such as

1. Adding and subtracting voltages.
2. Differentiation
3. Integration etc.

Block diagram of an op-amp



Applications of op-amps

Characters of an ideal Op Amp:

1. Open Loop gain

Open loop gain is the gain of the Op Amp without a positive or negative feedback. An ideal OP Amp should have an infinite open loop gain but typically it range between 20,000 and 2,000,000.

2. Input impedance

It is the ratio of the input voltage to input current. For an ideal op-amp, it should be infinite without any leakage of current from the supply to the inputs.

3. Output impedance

The ideal Op Amp should have zero output impedance without any internal resistance. So that it can supply full current to the load connected to the output.

4. Band width

The ideal Op Amp should have an infinite frequency response so that it can amplify any frequency from DC signals to the highest AC frequencies.

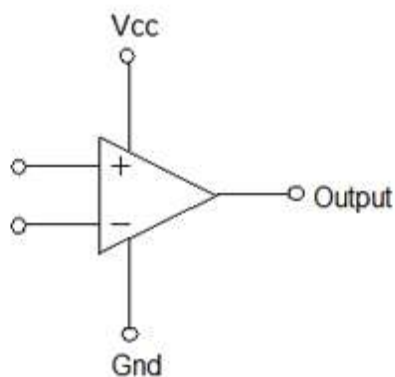
5. Offset

The output of the Op Amp should be zero when the voltage difference between the inputs is zero.

3 OPAMP applications:

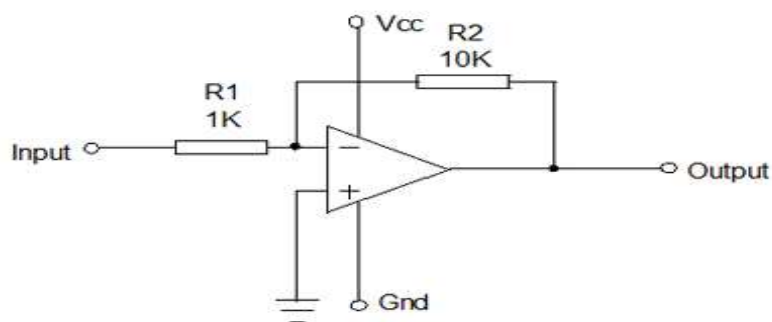
1. Amplification

The amplified output signal from the Op Amp is the difference between the two input signals.

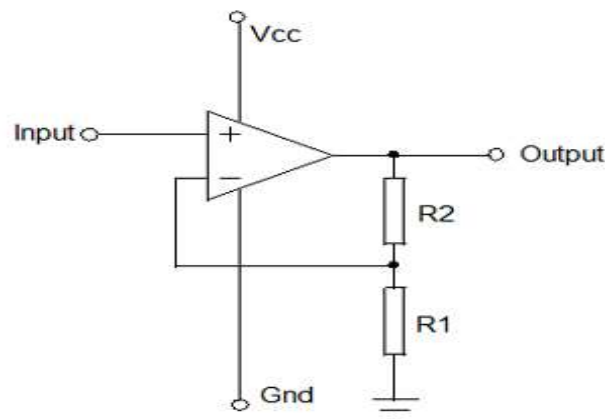


If both the inputs are supplied with the same voltage, the Op Amp will then take the difference between the two voltages and will multiply this with its high gain. The output voltage will be 0v. When 2 volts is given to one input and 1 volt in the other, the Op-Amp will take its difference and multiply with the gain. That is 1 volt x gain. But this gain is very high so to reduce the gain, feedback from the output to the input is usually done through a resistor.

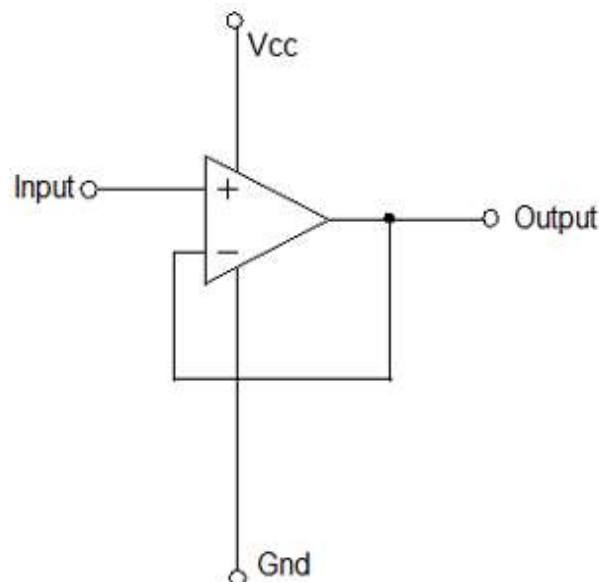
Inverting Amplifier:



2. Non-inverting Amplifier:



2. Voltage Follower



The circuit above is a voltage follower. Here it provides high input impedance, low output impedance. When the input voltage changes, the output and the inverting input will change equally.

3. Comparator

Operational amplifier compares the voltage applied at one input to the voltage applied at the other input. Any difference between the voltages even if it is small drives the op-amp into saturation. When the voltages supplied to both the inputs are of the same magnitude and the same polarity, then the op-amp output is 0Volts

9.3.7.4. Self-Assessment

1. State an amplifier
2. Describe types of amplifier
3. Explain operation of an amplifier
4. Draw and describe a block diagram of an OP-amp

5. State applications of an OP-AMP
6. Provide examples of a commercially available OP-AMP
7. Differentiate a comparator and a voltage follower
8. is a linear integrated circuit amplifier with high gain and high input impedance.
 - a) Operational Amplifiers (OP-AMP)
 - b) Buffer amplifiers
 - c) DC amplifiers
9. have a very high input impedance and a low output impedance and can therefore be used as an impedance matching device.
 - a) Operational Amplifiers (OP-AMP)
 - b) Buffer amplifiers
 - c) DC amplifiers
10. are those types used to amplify DC (0 Hz) voltages or very low frequency signals where the DC level of the signal is an important parameter
 - a) Operational Amplifiers (OP-AMP)
 - b) Buffer amplifiers
 - c) DC amplifiers
11. Which of the following is not true about the characteristic of an ideal Op Amp
 - a) Open loop gain is the gain of the Op Amp without a positive or negative feedback.
 - b) Output impedance is the ratio of the input voltage to input current. For an ideal op-amp, it should be infinite without any leakage of current from the supply to the inputs.
 - c) The ideal Op Amp should have zero output impedance without any internal resistance.
 - d) The ideal Op Amp should have an infinite frequency response so that it can amplify any frequency from DC signals to the highest AC frequencies.
12. Audio power amplifiers receive the amplified input from a series of voltage amplifiers and then provide sufficient power to drive loudspeakers.
 - a) True
 - b) False
13. Their Main purpose is to provide the majority of the voltage amplification of a modulated signal, before the audio or video information carried by the signal is separated or demodulated from the radio signal.
 - a) True
 - b) False

Practical exercise

1. Identify types of amplifiers as per their functions
2. Identified operational amplifier as per its applications
3. Determine characteristics of operational amplifiers

9.3.7.4. Tools, Equipment, Supplies

- Amplifier circuits and diagrams
- Multipurpose meters
- cables
- dc power supplies
- ac power supplies
- biasing resistors
- capacitors
- bread boards
- copper strip boards
- standard electronic tool kit
- signal generators
- OP-amp ICs and pin out diagrams
- oscilloscopes

9.3.5.3. References

1. https://www.tutorialspoint.com/linear_integrated_circuits_applications/linear_integrated_circuits_applications_arithmetic_circuits.htm
2. https://www.tutorialspoint.com/linear_integrated_circuits_applications/linear_integrated_circuits_applications_arithmetic_circuits.htm

9.3.8. Learning Outcome No. 7. Demonstrate understanding of oscillators

9.3.8.1. Learning Activities

Learning Outcome No. 7. Demonstrate understanding of oscillators	
Learning Activities	Special Instructions
-Oscillators are classified as per their operation -Types of oscillators are determined as per their applications -Damped and Undamped oscillation is performed as per oscillator operation	Demonstrate application of Thyristors in power control circuits. Single phase motor speed control.

9.3.8.2. Information Sheet No. 9/LO7

Oscillators

An *oscillator* is an electronic circuit that produces a periodic, oscillating electronic signal, often a sine wave or a square wave. *Oscillators* convert direct current (DC) from a power supply to an alternating current (AC) signal.

Classification of Oscillators:

The oscillator circuits are classified based on the wave forms generated:

- (a) Sinusoidal oscillator
- (b) Relaxation oscillator

a. Sinusoidal Oscillators.

These are the oscillator circuits whose output signal voltage is a sine wave function of time, the oscillator is called as a Sinusoidal oscillator or Harmonic oscillator.

Based on the type of circuit used, sine wave oscillators may be classified as

- (a) LC tuned Oscillator
- (b) RC phase shift oscillator

Transistor based oscillators are classified as follows.

- (a) Tuned collector oscillator
- (b) Colpitt's oscillator
- (c) Hartley oscillator
- (d) Phase shift oscillator
- (e) Wien Bridge oscillator
- (f) Crystal oscillator

All these transistor based oscillators have same function. They provide undamped waveform as the output. The difference between them is the manner in which they provide the energy to the tank circuit to produce the oscillations.

b. Relaxation Oscillators:

This category of oscillator generates voltages or currents which vary abruptly one or more times in a cycle of oscillation.i.e., they generate non-sinusoidal wave forms such as square, rectangular, triangular or saw-tooth waveforms.

Conditions for Oscillation:

The essential conditions for maintaining oscillations are

1. $|A\beta| = 1$, ie, the magnitude of loop gain must be unity or greater than unity.
2. The total phase shift around the closed loop is zero or 360 degrees.

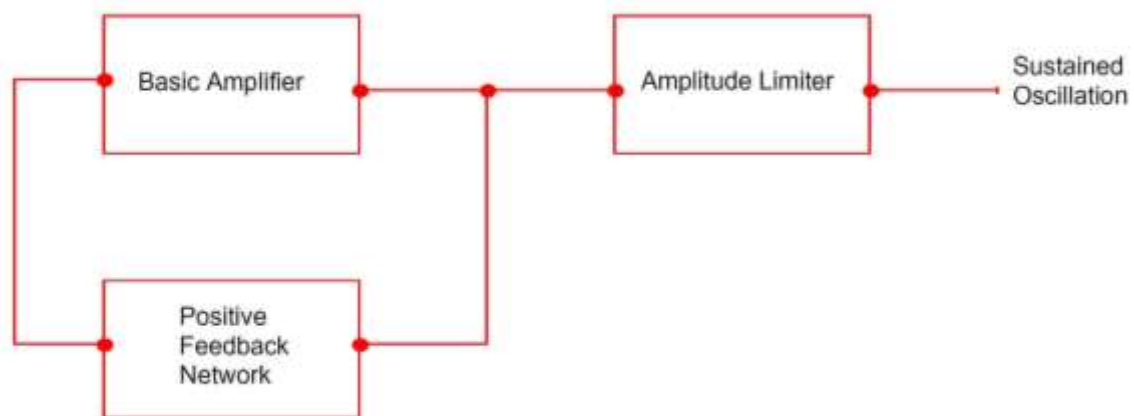
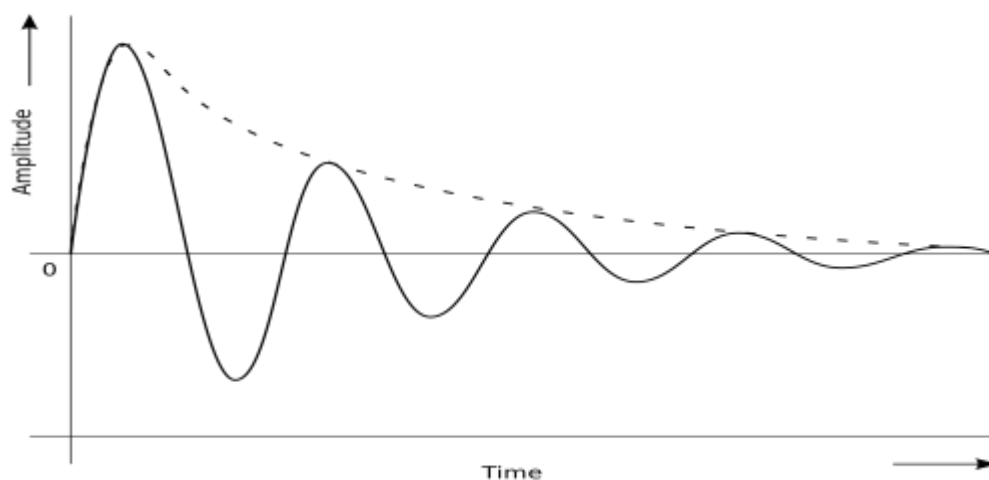


Figure 144: Block diagram of oscillator.

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

Damped oscillation

A damped oscillation is an oscillation that fades away with time. Examples include a swinging pendulum, a weight on a spring.



Undamped Oscillations:

The electrical oscillations whose amplitude remains constant with time are.

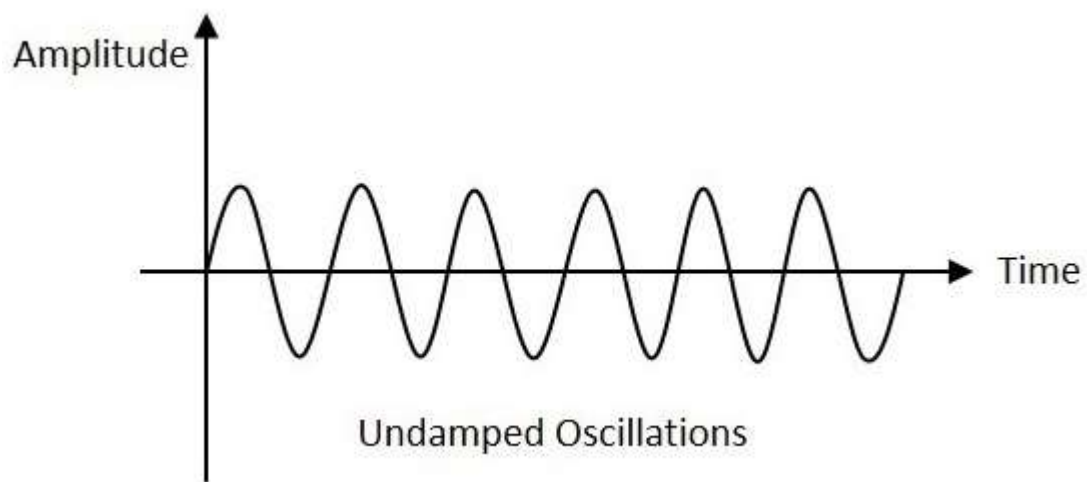


Figure 145: Oscillator circuits

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

Tuned base oscillator.

Tune base oscillator also called “Armstrong oscillator” after the name of its inventor is a type of transistor-based LC oscillator where the tuned circuit (tank circuit) is placed between the base and ground of the transistor. The circuit diagram of a tuned base oscillator is shown in the figure tat follows.

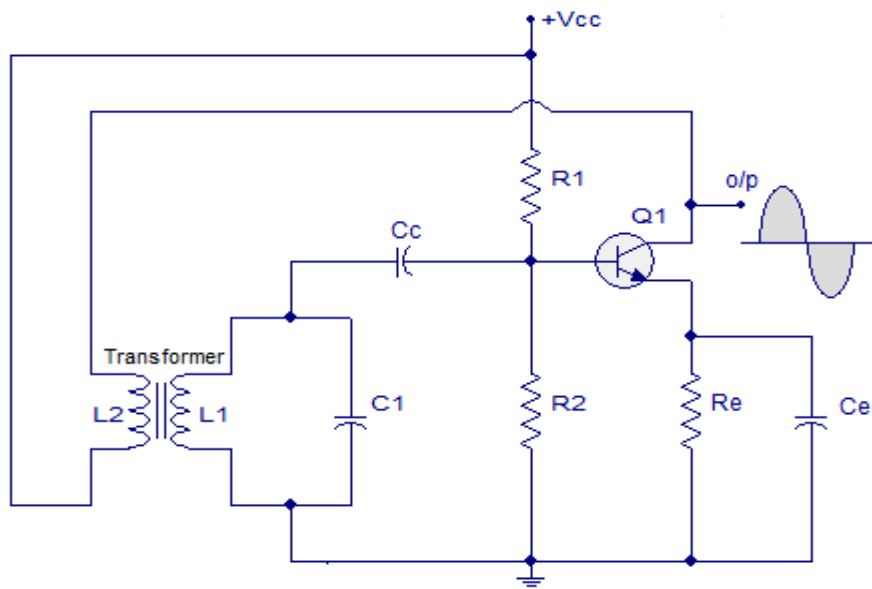


Figure 146: Tuned base oscillator

Source: https://www.electronics-tutorials.ws/diode/diode_1.html

In the circuit diagram, resistors R1 and R2 and R3 are for biasing the transistor Q1. Capacitor Ce is the emitter by-pass capacitor. Its job is to by-pass the amplified AC signals from dropping across Re and thus prevent negative feedback. Capacitor Cc is a DC blocking capacitor. Its job is to prevent DC currents from the tank circuit side from entering the base. The transformer winding coil (L1) and the capacitor C1 forms the tank circuit.

Working of the tuned base oscillator.

When power supply is applied, a current flow through resistor R1 to the base of transistor Q1 causing it to start conducting a collector current. Flow of collector current starts expanding magnetic field through inductor L2 which links inductor L1. This causes an induced EMF in the coil of inductor L1. This induced EMF is the feedback voltage and it causes increase in base current which then further increases the collector current. This increase in collector current expands the magnetic field further causing more induced EMF in L1 and further increase in base current. The action is that of succession of cycles of increased feedback voltage which results to increase in base current which then results to increase of collector current. This continues until the transistor goes to saturation.

Meanwhile, capacitor C1 gets charged to the maximum. As soon as the collector current reaches saturation, the magnetic field of L2 ceases to expand and thus No further induced EMF for feedback. The capacitor C1 now starts to discharge through inductor L1 triggering the following sequence of events.

1. A decrease in base current which the causes a decrease in collector current
 2. Collapsing of magnetic field resulting to an induced EMF in the opposite direction which further decreases the base current.
 3. Decrease in base current will result to further decrease in collector current.
- These sequence of events results in the transistor reaching cutoff. At this time, the capacitor having lost its original charge is now again charged fully in opposite polarity.

The transistor is now at cutoff and hence no further change in magnetic field in L2. The induced EMF in coil L1 is zero. The capacitor starts discharging through inductor L1. As the capacitor discharges, the voltage at the base increases resulting to a base current starting to flow. The transistor starts conducting collector current again. Flow of collector current starts expanding magnetic field through inductor L2 which now causes an induced EMF in the coil L1. This increases the base current which then further increases the collector current. The increase in collector current further expands the magnetic field causing more induced EMF in L1 and further increase in base current. This continues until the transistor goes to saturation again. The cycle keeps on repeating as long as the circuit is supplied with power.

The frequency of oscillations of the tuned base oscillator can be expressed using the equation:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Where

F= the frequency of oscillations.

L= is the inductance of the coil L1 of the transformer and

C =is the capacitance of the capacitor C1 in the tank circuit.

Tuned Collector Oscillator.

The tuned collector oscillator is a kind of transistor LC oscillator where the tank circuit is connected to the collector terminal of the transistor. The tank circuit connected in the collector circuit performs like a simple resistive load at resonance and determines the oscillator frequency. The circuit diagram of a tuned collector oscillator is as shown.

The resistors R1, R2 and Re are biasing resistors form a voltage divider bias. The main role of 'Ce' is to prevent negative feedback from occurring on the amplifier which will affect oscillations. L1 and capacitor C1 forms the tank circuit.

The working principle of the tuned collector oscillator is similar to the tuned base with the frequency of oscillations of the tank circuit being expressed using the following equation:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Where:

- F is the frequency of oscillation.
- L is the inductance of the transformer primary L1 and
- C is the capacitance of capacitor C1.

Some applications of LC oscillator circuits

-In R.F transmitters and receivers (local oscillator of a radio receiver).

Hartley Oscillator

The Hartley oscillator is an LC oscillator which was invented in 1915 by American engineer Ralph Hartley. The tuned circuit consists of a single capacitor in parallel with the two inductors which are in series. The positive feedback signal is taken from the inductor L2. This signal is induced through the auto transformer action. The autotransformer also introduces a phase shift of 180° while the other 180° is introduced by the transistor. Feedback factor is the ratio of turns of L2 and L1

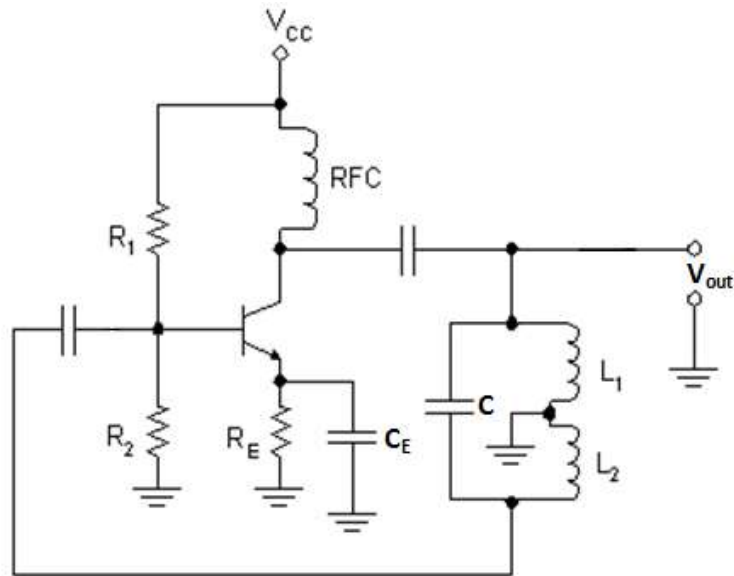


Figure 147 Hartley Oscillator

The frequency of oscillation is given by

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Where

$L = L_1 + L_2 + 2M$. M being the mutual inductance between the two coils L_1 and L_2 .

Colpitts Oscillator

This oscillator is essentially the same as the Hartley oscillator except that it uses tapped capacitance whereas Hartley oscillator uses tapped inductance.

The frequency of oscillations is given by

$$F = \frac{1}{2\pi\sqrt{LC}}$$

.3 Self-Assessment

- Define oscillators
- Explain the operation of oscillators
- Describe the classification of oscillators
- Differentiate between Sinusoidal oscillator and Relaxation oscillator
- Draw and explain the block diagram of oscillator.
- Draw waveform of damped and undamped oscillation
- Explain the equations and calculations
- uses tapped capacitance
 - Colpitts Oscillator
 - Hartley oscillator
 - tuned collector oscillator

- i) The is an LC oscillator which was invented in 1915 by American engineer Ralph Hartley
 - a) Colpitts Oscillator
 - b) Hartley oscillator
 - c) tuned collector oscillator
- j) The is a kind of transistor LC oscillator where the tank circuit is connected to the collector terminal of the transistor.
 - a) Colpitts Oscillator
 - b) Hartley oscillator
 - c) tuned collector oscillator
- k) is a type of transistor-based LC oscillator where the tuned circuit (tank circuit) is placed between the base and ground of the transistor.
 - a) Colpitts Oscillator
 - b) Hartley oscillator
 - c) tuned collector oscillator
- l) *Oscillators* convert direct current (DC) from a power supply to an alternating current (AC) signal.
 - a) True
 - b) False
- m) Tune base oscillator also called “Armstrong oscillator” after the name of its inventor is a type of transistor-based LC oscillator where the tuned circuit (tank circuit) is placed between the base and ground of the transistor
 - a) True
 - b) False

Practical exercise

- a) Classify oscillators as per their operation
- b) Determine types of oscillators as per their applications
- c) Performed Damped and Undamped oscillation as per oscillator operation

9.3.8.3. Tools, Equipment, Supplies

- Transistors and data sheets
- Multipurpose meters
- cables
- dc power supplies
- biasing resistors
- capacitors
- inductors
- RF transformers
- bread boards
- copper strip boards
- standard electronic tool kit

- oscilloscopes

9.3.8.4. References

1. <https://www.slideshare.net/MdNasimhossain/undamped-oscillation-preasentation>
2. <https://electronicspost.com/what-is-an-oscillator-what-do-you-understand-by-damped-and-undamped-oscillations-explain-the-operation-of-a-tank-circuit/>
3. <https://www.slideshare.net/MdNasimhossain/undamped-oscillation-preasentation>

9.3.9 Learning Outcome No. 8. Apply wave shaping and pulse generation circuit

9.3.9.1 Learning Activities

Learning Outcome No. 8. Apply wave shaping and pulse generation circuit	
Learning Activities	Special Instructions
Wave shaping and pulse generation circuits are performed as per their standard operating procedure	

9.3.9.2.Information Sheet No. 9/ LO8

A wave shaping circuit is an electronic circuit that is used to change an input waveform to yield a desired output waveform. The shape can be of different types such as sinusoidal, square, triangular, etc. which vary with respect to time period or they may have some random shapes disregard of the time period.

Types of Wave Shaping

There are two main types of wave shaping. They are –

- Linear wave shaping
- Non-linear wave shaping

Linear Wave Shaping

Linear elements such as resistors, capacitors and inductors are employed to shape a signal in this linear wave shaping.

Filtering is the process of attenuating the unwanted signal or to reproduce the selected portions of the frequency components of a particular signal.

Filters

In the process of shaping a signal, if some portions of the signal are felt unwanted, they can be cut off using a Filter Circuit. A Filter is a circuit that can remove unwanted portions of a signal at its input. The process of reduction in the strength of the signal is also termed as Attenuation. Filters can be made using capacitors and inductors.

- A Capacitor has the property to allow AC and to block DC
- An Inductor has the property to allow DC but blocks AC.

Using these properties, these two components can be used to design filter circuits.

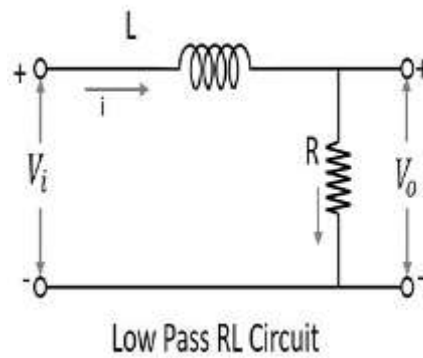
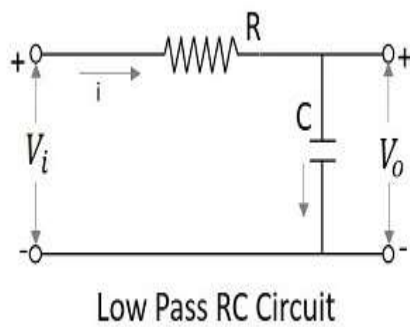
Types of filters –

- Low pass filter
- High pass filter
- Band pass filter
- Band stop filter

Low Pass Filter

This is a Filter circuit which allows a set of frequencies that are below a specified value.

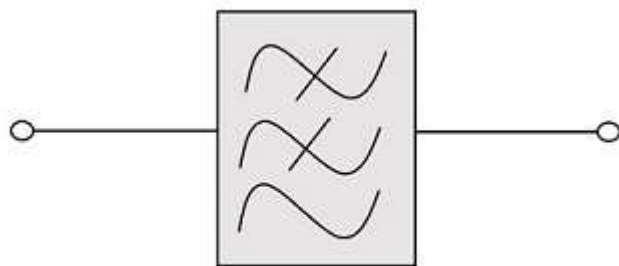
This filter passes the lower frequencies. The circuit diagram of a low pass filter using RC and RL are as shown below.



The capacitor filter or RC filter and the inductor filter or RL filter both act as low pass filters.

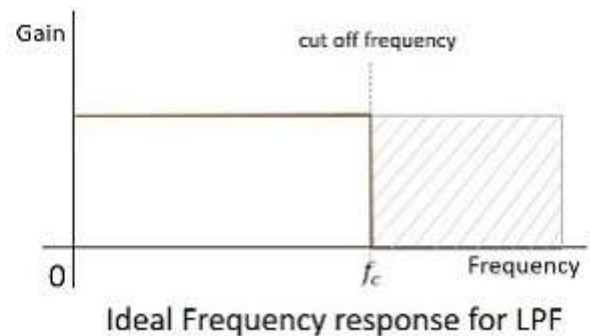
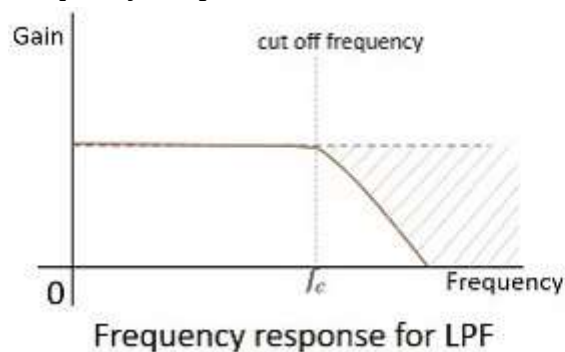
- The RC filter – As the capacitor is placed in shunt, the AC it allows is grounded. This by passes all the high frequency components while allows DC at the output.
- The RL filter – As the inductor is placed in series, the DC is allowed to the output. The inductor blocks AC which is not allowed at the output.

The symbol for a low pass filter (LPF) is as given below.



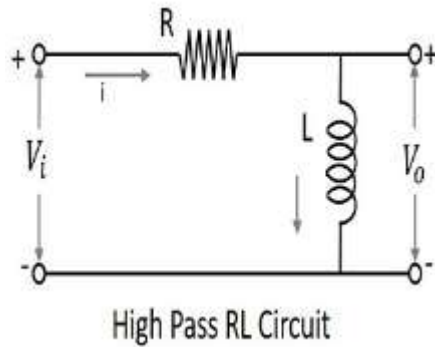
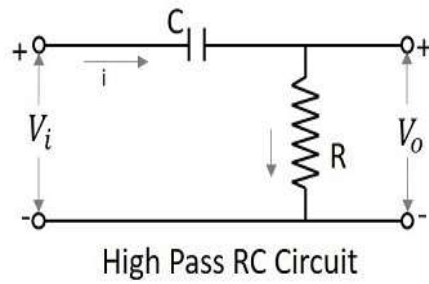
Symbol for LPF

Frequency Response



High Pass Filter

It's a Filter circuit which allows a set of frequencies that are above a specified value. This filter passes the higher frequencies.

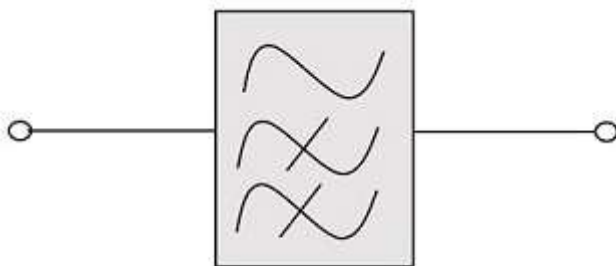


The RC Filter

As the capacitor is placed in series, it blocks the DC components and allows the AC components to the output. Hence the high frequency components appear at the output across the resistor.

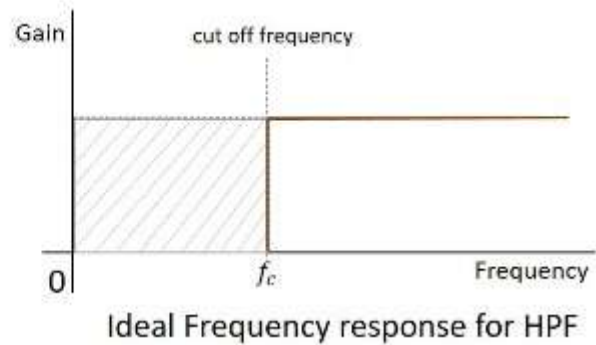
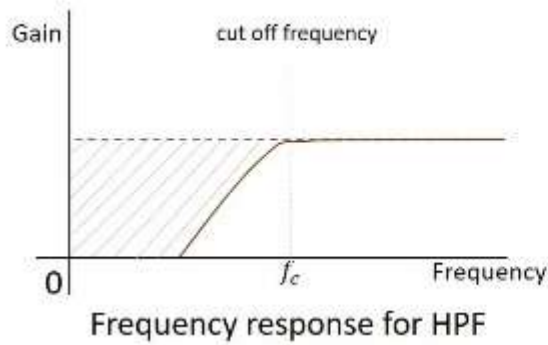
The RL Filter

As the inductor is placed in shunt, the DC is allowed to be grounded. The remaining AC component, appears at the output. The symbol for a high pass filter (HPF) is as given below.



Symbol for HPF

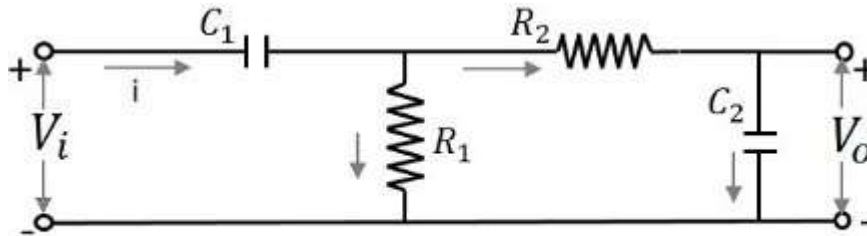
Frequency Response



Band Pass Filter

It's a Filter circuit which allows a set of frequencies that are between two specified values. This filter passes a band of frequencies.

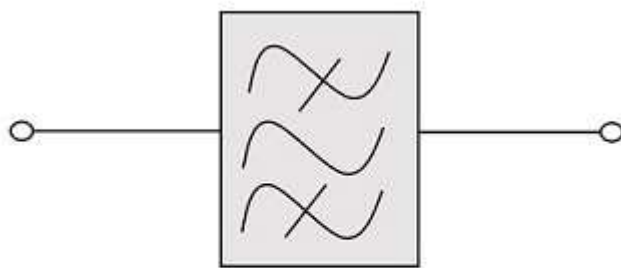
The circuit diagram of a band pass filter is as shown below.



Circuit diagram for Band Pass Filter

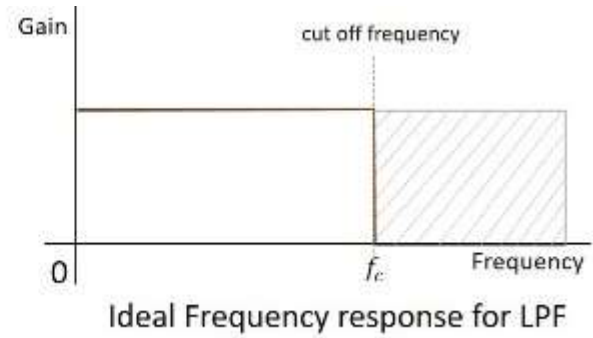
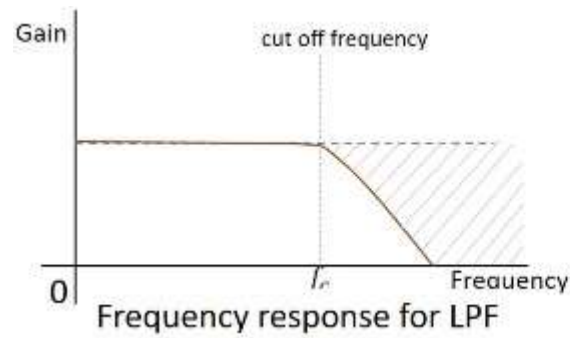
The above circuit can also be constructed using RL circuits or RLC circuits..

The symbol for a band pass filter (BPF) is as given below.



Symbol for BPF

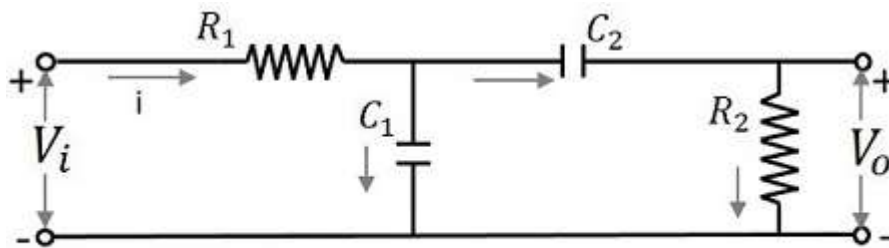
Frequency Response



Band Stop Filter

It's a Filter circuit which blocks or attenuates a set of frequencies that are between two specified values. This filter rejects a band of frequencies and hence can also be called as Band Reject Filter.

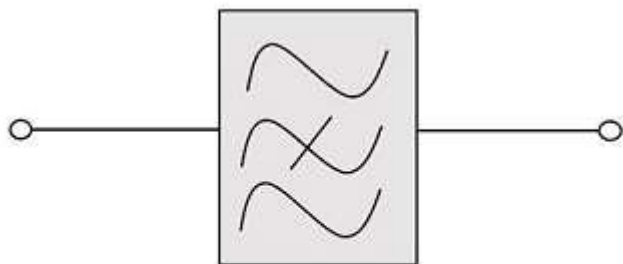
The circuit diagram of a band stop filter is as shown below.



Circuit diagram for Band Stop Filter

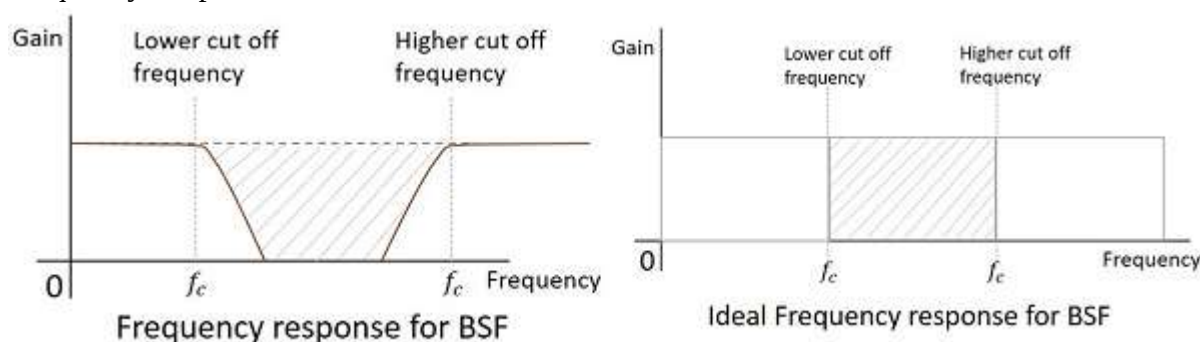
The above circuit can also be constructed using RL circuits or RLC circuits.

The symbol for a band stop filter (BSF) is as given below.



Symbol for BSF

Frequency Response



Multi-vibrators

Multi means ‘‘many ‘ and vibrator is called ‘‘oscillations’’

It is a device consisting of two amplifying transistors or valves, each with its output connected to the input of the other, this device produces an oscillatory signal.

Types of Multi-Vibrators

Monostable Multivibrator

It’s an electronic circuit that generates an output pulse. When triggered, a pulse of pre-defined duration is produced. The circuit then returns to its stable state and produces no more output until triggered again.

Bistable Multivibrator

It’s a type of a multivibrator circuit that has two absolutely stable states. It will remain in the state which it happens to be until a trigger pulse causes it to switch to the other state.

Astable Multivibrator

An Astable Multivibrator or a Free Running Multivibrator is a type of a multivibrator which has no stable states. Its output oscillates continuously between its two unstable states without the aid of external triggering. The time period of each states are determined by Resistor Capacitor (RC) time constant.

Applications of multivibrator.

1. Used as relaxation oscillators,
2. For timers and flip-flops.

9.3.9.3. Self-Assessment

- a) Trainee to carry out a practical that involves connecting wave shaping and pulse generating circuits and analyze the operation of the circuits.
- b) Trainee to connect filter circuits and analyze the operation of the circuits.
- c) State wave shaping
- d) Describe types of wave shaping
- e) What re the importance of wave shaping?
- f) What are the challenges incurred during wave shaping?
- g) Differentiate Linear wave shaping and Non-linear wave shaping

- h) Explain of operation of filters and their operations
- i) Illustrate various filters using RLC circuits
- j) Explain the operation of multivibrator.
- k) is a Filter circuit which allows a set of frequencies that are below a specified value.
 - a) Low Pass Filter
 - b) RC filter
 - c) RL filter
 - d) High Pass Filter
 - e) Band Pass Filter
- l) In the capacitor is placed in shunt, the AC it allows is grounded. This by passes all the high frequency components while allows DC at the output.
 - a) Low Pass Filter
 - b) RC filter
 - c) RL filter
 - d) High Pass Filter
- m) In the inductor is placed in series, the DC is allowed to the output. The inductor blocks AC which is not allowed at the output.
 - a) Low Pass Filter
 - b) RL filter
 - d) High Pass Filter
 - e) Band Pass Filter
- n) is a Filter circuit which allows a set of frequencies that are above a specified value. This filter passes the higher frequencies.
 - a) Low Pass Filter
 - b) RC filter
 - c) RL filter
 - d) High Pass Filter
- o) is a Filter circuit which allows a set of frequencies that are between two specified values. This filter passes a band of frequencies.
 - a) RC filter
 - c) RL filter
 - d) High Pass Filter
 - e) Band Pass Filter
- p) The process of reduction in the strength of the signal is also termed as Attenuation.
 - a) True
 - b) False
- q) High Pass Filter is a Filter circuit which allows a set of frequencies that are above a specified value. This filter passes the higher frequencies.
 - a) True

b) False

Practical exercise

- a) Wave shaping and pulse generation of circuits as per their standard operating procedure
- b) Draw and describe circuit diagrams of the various filters

9.3.9.4. Tools, Equipment, Supplies

- Multivibrators
- Transistors and data sheets
- Multipurpose meters
- cables
- dc power supplies
- biasing resistors
- capacitors
- inductors
- RF transformers
- bread boards
- copper strip boards
- standard electronic tool kit
- oscilloscopes

References

1. https://www.kau.edu.sa/files/0001893/files/35053_31214a.pdf
2. <https://electrosome.com/astable-multivibrator-transistors/>
3. <https://www.electronics-tutorials.ws/waveforms/astable.html>

9.3.10. Learning Outcome No. 9. Apply optic electronics

9.3.10.1. Learning Activities

Learning Outcome Learning Outcome No. 9. Apply optic electronics	
Learning Activities	Special Instructions
1.Types of Opt-electronics semiconductors are identified as per the operation characteristics 2. Diodes are classified as per their operation	Trainer to ensure that the necessary standard safety precautions are taken into consideration while handling LASERS and MASERS

9.3.9.2.Information Sheet No. 9/ LO9

Optoelectronics

Optoelectronics is the study and application of electronic devices and systems that source, detect and control light which includes invisible forms of radiation such as gamma rays, X-rays, ultraviolet and infrared, in addition to visible light.

Optoelectronic devices are electrical-to-optical or optical-to-electrical transducers, or instruments that use such devices in their operation

Optoelectronics is based on the quantum mechanical effects of light on electronic materials, especially semiconductors, sometimes in the presence of electric fields.^[2]

Photodiode

A photodiode is a semiconductor device that converts light into an electrical current. The current is generated when photons are absorbed in the photodiode. Photodiodes may contain optical filters, built-in lenses, and may have large or small surface areas. Photodiodes are similar to regular semiconductor diodes except that they have a window where a focusing lens is mounted to focus incident light to the area around the P-N junction. A photodiode is designed to operate in reverse bias.

Photodiode

A photodiode is a p–n junction or may be having a PIN structure. When a photon of sufficient energy strikes the diode, it creates an electron–hole pair by mechanism known as the photoelectric effect. These carriers are swept from the junction by the built-in electric field of the depletion region. Thus holes move toward the anode, and electrons toward the cathode, and a photocurrent is produced. The total current through the photodiode depends on the light intensity falling in the diode. I.e. the photocurrent is linearly proportional to the irradiance.

Phototransistor

The phototransistor is a three-layer semiconductor device which has a light-sensitive base region. The base senses the light and converts it into the current which flows between the collector and the emitter region.

The construction of phototransistor is similar to the ordinary transistor, except that base terminal is not provided. There is a small hole on the surface of the collector-base junction for placing the lens for focusing the light on the surface of the junction. Instead of the base current, the light energy is taken as the input.

The construction of the phototransistor is quite similar to the ordinary transistor.

Symbol of Phototransistor

The symbol of the phototransistor is similar to that of the ordinary transistor. The only difference is that there are two arrows which show the light incident on the base of the phototransistor. The static characteristics are also similar but show increase in collector current with increase in light intensity.

Light emitting diodes (led):

An LED is a P-N junction diode made up of a thin layer of fairly doped semiconductor material of exotic semiconductor compounds such as Gallium Arsenide (GaAs), Gallium Phosphide (GaP), Gallium Arsenide Phosphide (GaAsP), Silicon Carbide (SiC) or Gallium Indium Nitride (GaInN) all mixed together at different ratios to produce a distinct wavelength of colour. When this diode is made, it is then put in a protective encasement that is transparent so that the light it produces can be visible from outside.

Operation principles

Whenever a diode is forward biased, electrons crosses to the P-side. Likewise, holes crosses to the N-side where some combine with opposite charge carries near the junction. Every recombination results in energy being given out as the electron is moving from the conduction band to the valence band. In those diodes made of silicon or germanium semiconductor materials, a high percentage of the energy released is inform of heat. In diodes made of gallium arsenide phosphide, a high percentage of the energy given out is in form of light. The color of the light produced depends on the mixture of the semiconductor material and the amount of doping. Thus when an LED is forward biased, it will conduct and produce light. An LED will not conduct and neither will it produce light when reverse biased.

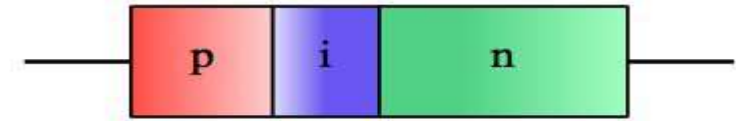
Laser diodes

A laser diode is a semiconductor device that is very similar, in both form and operation, to a light-emitting diode (LED).

The term laser originated as an acronym: Light Amplification by Stimulated Emission of Radiation. Hence, a laser is a device that emits light through a process of optical amplification based on the stimulated emissions of electromagnetic radiation.

The laser diode is electrically equivalent to a PIN diode.

NOTE: A PIN diode as shown below is a diode with an undoped intrinsic semiconductor region sandwiched between a *p*-type semiconductor and an *n*-type semiconductor. Both the *p*-type and *n*-type regions are typically heavily doped.



The laser diodes "active region" resides in the *I*-region (intrinsic region).

Types of lasers

Laser diodes can be grouped into two classes:

1. *Edge-emitting lasers* (also called *in-plane lasers*), the laser light in the diodes propagates in a direction along the wafer surface of the semiconductor chip and is reflected or coupled out at a cleaved edge.

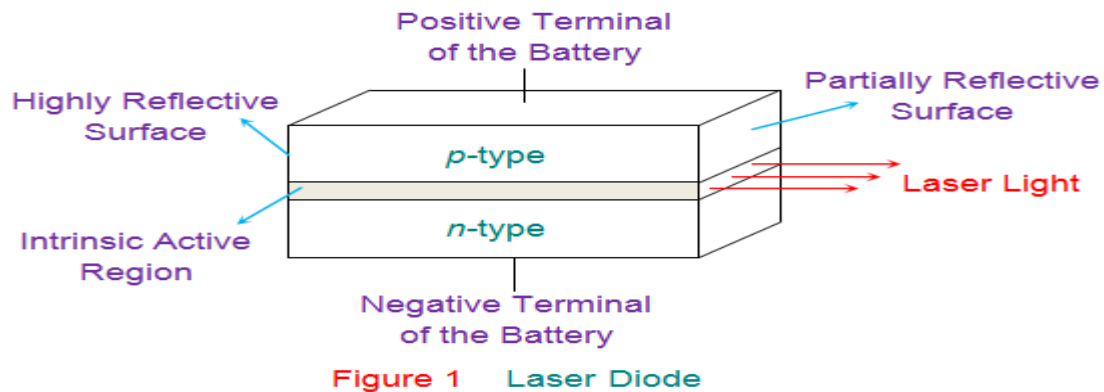


Figure 148: Laser diode

Source: circuit globe

2. *Surface-emitting lasers*. The laser light in these diodes propagates in the direction perpendicular to the semiconductor wafer surface. I.e. at a direction perpendicular to the P-N junction plane. The optical cavity axis is along the direction of current flow rather than perpendicular to the current flow as in edge emitting laser diode.

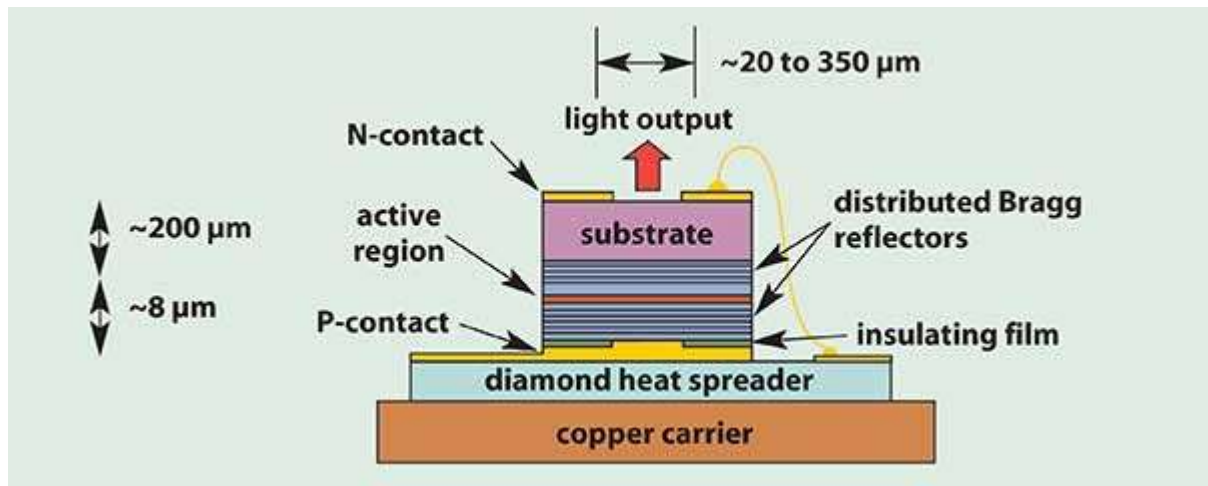


Figure 149: Surface emitting Laser

Source: Circuit globe

Laser DIODE THEORY.

When a light photon enters in to a semiconductor lattice and strikes an electron, the electron releases energy in the form of another light photon. The way in which this occurs can result in the released new photon being of identical wavelength and phase. In this way the light that is generated will be coherent.

The key to the laser diode operation occurs in the region between the highly doped P and N-type regions. When the diode is forward biased, the electrons and holes are pumped into the active region from the *n* and *p* regions, respectively. When current flows across the p-n junction, some of the holes and the electrons combine near the junction. This releases light energy (photo emission).

If an electromagnetic wave (in this instance light) is made to pass through a P-N junction, it is found that photo-emission process occurs.

In the case of the laser diode, when current flows across the p-n junction, some of the holes and electrons combine releasing light energy. Some of these released photons travel in a direction perpendicular to that of the P-N junction and thus strike the reflective surfaces at 90 degrees and are now reflected back. These electromagnetic waves (light rays) will then strike other electrons releasing more photons.

Some Applications of laser diodes.

11. Are used in laser pointers.
12. In bar-code scanners.
13. in CD-ROM and CD players.
14. guidance systems,
15. scanners,
16. metal working,
17. photography,
18. holography, and in medicine

19. Lasers are finding ever increasing military applications -- principally for target acquisition, fire control, and training. These lasers are termed rangefinders, target designators, and direct-fire simulators.
20. In communication systems

Maser

Absorption. According to quantum mechanics, absorption of photons by atoms occurs only if the wavelength of the photon is just the right size (say, of wavelength λ). If it is, the atom will "absorb" it (the photon vanishes) and go to a higher energy state. In physics, this process is called "absorption."

Spontaneous Emission. Atoms don't like to stay in high energy states. So after absorbing a photon and going to a higher energy state, they will move of their own accord to a lower energy state, emitting a photon in the process. This is called "spontaneous emission" because no outside influence triggers the emission.

Normally the average lifetime for spontaneous emissions by excited atoms is around 10^{-8} seconds (that is, the atom or molecule will usually take around 10^{-8} seconds before emitting the photon). Occasionally, however, there are states for which the lifetime is much longer, perhaps around 10^{-3} seconds. These states are called *metastable*. Metastable emission levels are essential for a working MASER.

Stimulated Emission. With stimulated emission, a photon of the absorption wavelength, is fired at an atom *already in its high energy state from prior absorption*. The atom absorbs this photon, and then quickly emits *two* photons to get back to its lower energy state. Thanks to quantum mechanics, both of these newly emitted photons are of same wavelength.

Maser

This is a device that produces and amplifies electromagnetic radiation mainly in the microwave region of the spectrum. The maser operates according to the same basic principle as the laser (the name of which is formed from the acronym for "light amplification by stimulated emission of radiation"). Thus, MASER and shares many of its characteristics with the LASER.

The name MASER is an acronym derived from "microwave (or molecular) amplification by stimulated emission of radiation."

A maser oscillator requires a source of excited atoms or molecules and a resonator to store their radiation. The excitation must force more atoms or molecules into the upper energy level than in the lower, in order for amplification by stimulated emission to predominate over absorption. For wavelengths of a few millimetres or longer, the resonator can be a metal box whose dimensions are chosen so that only one of its modes of oscillation coincides with the frequency emitted by the atoms; that is, the box is resonant at the particular frequency.

The losses of such a resonator can be made quite small, so that radiation can be stored long enough to stimulate emission from successive atoms as they are excited. Thus, all

Liquid Crystals Displays

A liquid crystal is a material (usually, an organic compound) which flows like a liquid at room Temperature but whose molecular structure has some properties normally associated with solids (examples of such compounds are: cholesteryl nonanoate and p-azoxyanisole).

Molecules in ordinary liquids have random orientation but in a liquid crystal they are oriented in a definite crystal pattern. These types of displays have a thin layer of liquid crystal is transparent to incident light. When an electric field is applied across the liquid crystal cell, its molecular arrangement is disturbed causing Liquid Crystal to changes in its optical properties.

When light falls on an activated layer of a liquid crystal, it is either absorbed or else is scattered by the disoriented molecules.

Uses

Field-effect LCDs are normally used in watches and portable instruments for displays

As TV receiver. Screens and desk top LCD monitors.

Note book computer display

Cellular phone display,

etc.

9.3.10.3. Self-Assessment

1. State Optoelectronics
2. Describe the applications of Optoelectronics
3. State a photodiode and draw its symbol
4. Differentiate a photodiode and a phototransistor
5. Explain the operation of LED
6. State the applications of LED
7. Describe LASER and its mode of operation
8. Explain MASER
9. Describe Fiber optics
10. In..... laser light in these diodes propagates in the direction perpendicular to the semiconductor wafer surface
 - a) Edge-emitting lasers
 - b) Surface-emitting lasers
11. In the laser light in the diodes propagates in a direction along the wafer surface of the semiconductor chip and is reflected or coupled out at a cleaved edge.

- a) Edge-emitting lasers
 - b) Surface-emitting lasers
12. Which of the following is not one of the applications of laser diodes
- a) Laser pointers.
 - b) In bar-code scanners
 - c) CD-ROM and CD players
13. Optoelectronic devices are electrical-to-optical or optical-to-electrical transducers, or instruments that use such devices in their operation
- a) True
 - b) False
14. When a photon of sufficient energy strikes the diode, it creates an electron-hole pair by mechanism known as the photoelectric effect.
- a) True
 - b) False
15. The construction of the phototransistor is quite similar to the ordinary transistor.
- a) True
 - b) False

Practical exercise

- a) Trainee to carry out a practical that involves identifying different types of Opto-electronic devices.
- b) Trainee to connect circuits with opto-electronic devices and analyze the operation of the circuits.
- c) Identify types of Opt-electronics semiconductors as per the operation characteristics
- d) Classify diodes as per their operation

9.3.10.4. Tools, Equipment, Supplies

- Photo Transistors and data sheets
- Phot diodes and data sheets
- LASER diode
- MASERs
- Optical fiber cables
- Multipurpose meters
- LCD displays
- dc power supplies
- signal generators
- bread boards
- copper strip boards
- standard electronic tool kit
- oscilloscopes

9.3.10.5. References

1. https://en.wikipedia.org/wiki/Optical_fiber
2. <https://www.explainthatstuff.com/fiberoptics.html>
3. <https://en.wikipedia.org/wiki/Maser>

CHAPTER 10: AUTOMATION OF ELECTRICAL MACHINE / AUTOMATE AN ELECTRICAL MACHINE

10.1. Introduction of the Unit of Learning / Unit of Competency

This unit covers the competencies required to automate an electrical machine. Competencies includes an automation system design, components mountings, programming of an automation system, simulation of an automation system and test running of an automation system. Automation involves robotics, expert system, telemetry, cyber security, wireless applications, measurement and controls among others. This involves the use of programmable logic controllers, microcontrollers and programming.

The trainee should demonstrate the competencies required to design, mount, program automate and test run the system as per the design provided. The resources required to implement this unit of competence include but not limited to, Multimeter, Wattmeter, Insulation resistance tester, Loop impedance tester, Frequency meter, Tachometer, Scientific calculators, drawing tools, Laptops, Measuring tools, Switches, Microcontrollers, Programmable logic controls, source of A.C. power, and D.C. power. The trainee should also have the competencies in regard to work place health and safety, by observing the regulations as stipulated in the OSHA act.

10.2. Performance Standard

Design and mount an automation system as per the scope of the design and program and simulate automation system as per the standard operating procedures based on the IEEE regulations

10.3. Learning outcome

10.3.1. List of Learning Outcomes

- a) Design automation system
- b) Mount Electrical components
- c) Program automation systems
- d) Simulate Automation systems
- e) Test run automation system

10.3.2. Learning Outcome No 1 &2. Design Automation system & Mount Electrical Components

10.3.2.1 Learning Activities

Learning Outcome No 1 &2. Design Automation system & Mount Electrical Components	
Learning Activities	Special Instructions
1. Identify the components needed in the design of an automation system as per the specific design in learning outcome 1 • Sensors • Actuators • Limit switches • Push buttons • Logic gates • Microcontrollers modules - Arduino microcontroller - 8051 microcontroller • PLC • SCADA • Relays • Timers • Contactors 2. Select materials, tools and equipment relative to the job. Materials may include • Solder wire • Jumpers • Printed circuit boards • Bread boards Tools and equipment may include • Pliers • Hammer • Soldering gun 3. Prepare the Bread boards and circuit boards as per the drawing specifications. 4. Mount components to the Bread board or Printed circuit boards as per the job specifications. 5. Apply the IEEE regulations on mounting electronic components on a circuit board.	The trainee to handle Micro-controller and PLC ICs with caution.

10.3.2.2 Information Sheet No 10/LO1.

By the end of this learning outcome, then trainee should define the term automation as used in electrical machines, state factors to consider when designing an automation system and identify the components of an automation system.

Automation System refers to the use of mechanical, electrical and computer technology. This will assists in reducing the human participation in carrying out tasks.

The components in designing an electrical automated machine include;

- i. Sensors
- ii. Actuators
- iii. Limit switches
- iv. Push buttons
- v. Logic gates
- vi. Microcontrollers
- vii. PLC
- viii. SCADA

SENSORS

Are devices that carry out “Input” function. They “sense” a physical change in some characteristic that changes in response to some excitation.

Analogue Sensors

They produce a continuous output signal or voltage which is generally proportional to the quantity being measured.

Thermocouple used in producing an Analogue Signal

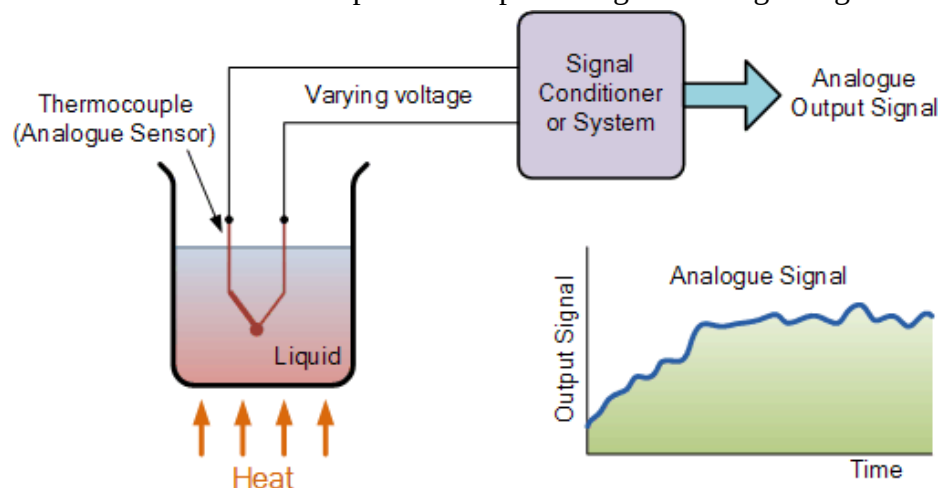


Figure 150: Thermocouple as a sensor

Source: Circuit globe

They output signals produced changes smoothly and continuously with time.

Digital Sensors

They produce a discrete digital output signals or voltages. They produce binary output signal in form of a logic “1” or a logic “0”, (“ON” or “OFF”).

Light Sensor that produces a Digital Signal

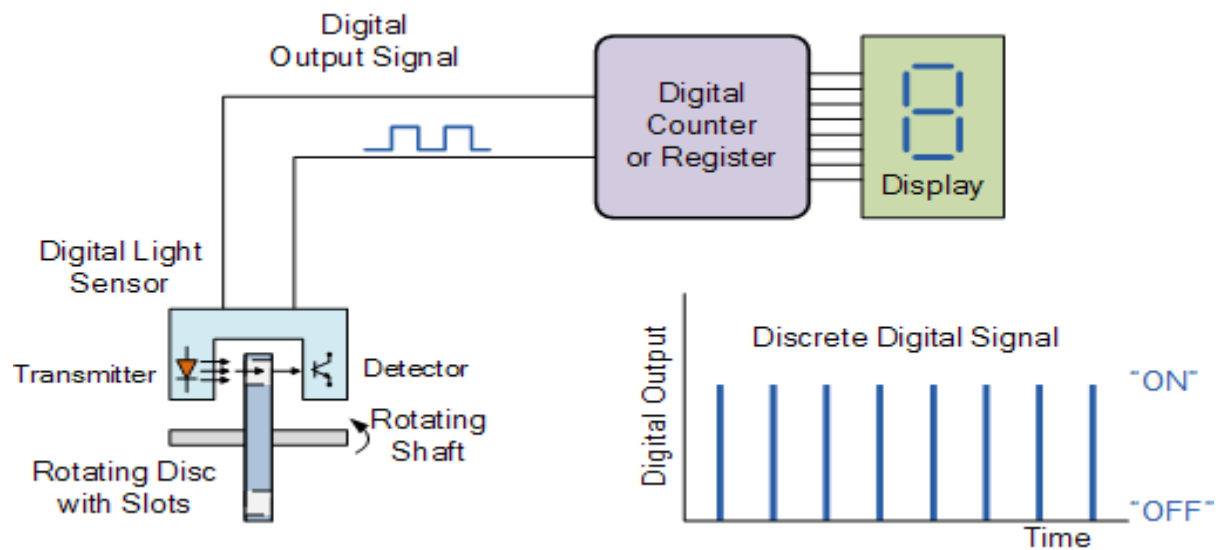


Figure 151: Simple circuit of a digital light sensor

Source: Circuit globe

Actuators

Actuators are hardware devices, machines, or systems that does the conversion of a controller command signal into a change in a physical parameter. Actuators activate the program of instructions. They allow process variables to come into agreement with process parameters. Often the control signal must be amplified if it is to reach sufficient power for the work that is involved. An actuator may be a simple electrical relay, a pneumatic logic circuit of solenoid valves and cylinders, or a robot.

The process and type of control signal amplification generally dictates actuator type. Actuators are best classified according to control signal amplification type. The following are types of actuators.

1. Pneumatic actuators

Compressed air is used to amplify the control signal;

2. Hydraulic actuators.

A pressured fluid is used, typically oil-based, for amplification.

3. Electrical actuators.

Electrical actuators use electricity.

The type and number of sensors and actuators used in a process dictate the type and number of inputs and outputs that should dictate selection of a PLC. This idea is explored in more detail in the next section, as are other PLC considerations.

Limit Switches

Are operated through either motion of a machine part or object presence. Are applied in machine control as a either a safety interlock or counting objects that pass through the particular point.

Limit Switch Operation

Operation starts when any moving machine gets in contact with an actuator. It then regulates electrical circuit controlling the entire machine and the moving parts.

Switch Circuitry

When the switch is opened, the sensor input is pulled to the +5V supply by the pull up resistor.

When the switch is closed, the input is tied to ground, generating a zero voltage signal

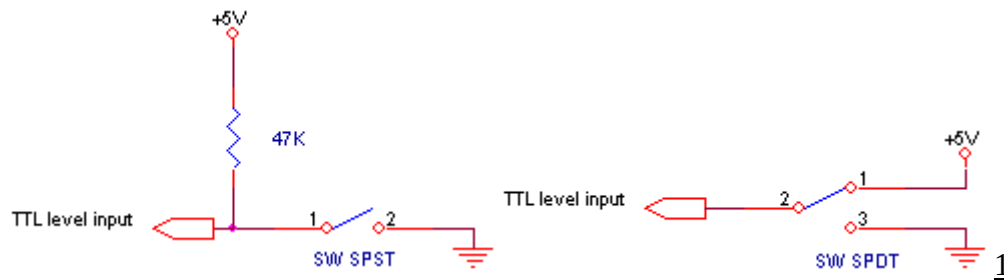


Fig. Micro Switches

LOGIC GATES

Are electronic circuits that have one or more than one input and only one output.

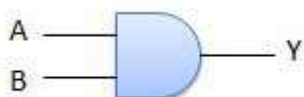
Types of Logic Gates

AND Gate

The circuit below has n input ($n \geq 2$) and one output.

$$\begin{aligned} Y &= A \text{ AND } B \text{ AND } C \dots\dots N \\ Y &= A.B.C \dots\dots N \\ Y &= ABC \dots\dots N \end{aligned}$$

Logic diagram



Truth Table

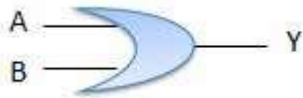
Inputs		Output
A	B	AB
0	0	0
0	1	0
1	0	0
1	1	1

Fig. OR Gate

The circuit below has n input ($n \geq 2$) and one output.

$$\begin{aligned} Y &= A \text{ OR } B \text{ OR } C \dots\dots N \\ Y &= A + B + C \dots\dots N \end{aligned}$$

Logic diagram



Truth Table

Inputs		Output
A	B	A + B
0	0	0
0	1	1
1	0	1
1	1	1

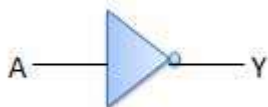
NOT Gate/inverter

The circuit below has one input A and one output Y.

$$Y = \text{NOT } A$$

$$Y = \overline{A}$$

Logic diagram



Truth Table

Inputs	Output
A	B
0	1
1	0

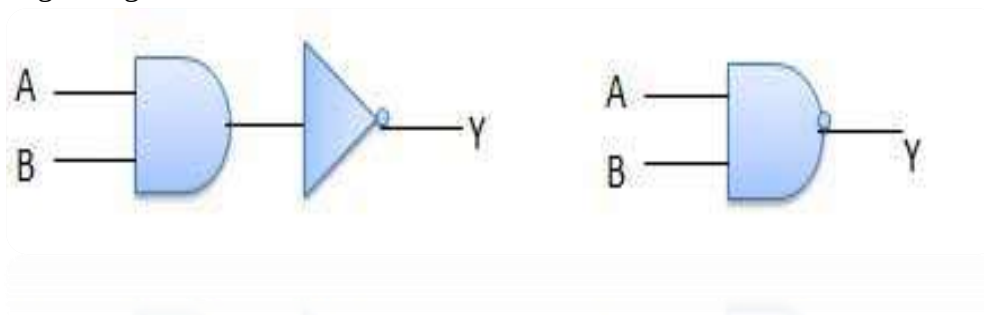
NAND Gate/NOT-AND

The circuit below has n input ($n \geq 2$) and one output.

$$Y = A \text{ NOT AND } B \text{ NOT AND } C \dots\dots N$$

$$Y = A \text{ NAND } B \text{ NAND } C \dots\dots N$$

Logic diagram



Truth Table

Inputs		Output
A	B	$\overline{AB}$
0	0	1
0	1	1
1	0	1
1	1	0

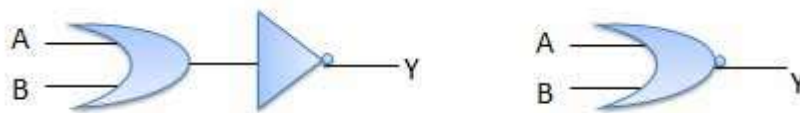
NOR Gate/NOT-OR

The circuit below has n input ($n \geq 2$) and one output.

$$Y = \overline{A \text{ NOT OR } B \text{ NOT OR } C \dots\dots N}$$

$$Y = \overline{A \text{ NOR } B \text{ NOR } C \dots\dots N}$$

Logic diagram



Truth Table

Inputs		Output
A	B	$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

XOR Gate

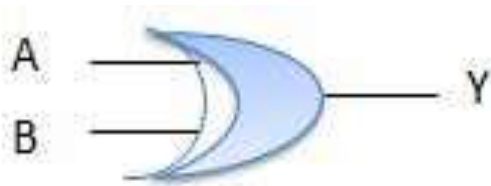
Can be used in the half adder, full adder and subtractor. It has n input ($n \geq 2$) and one output.

$$Y = A \text{ XOR } B \text{ XOR } C \dots\dots N$$

$$Y = A \oplus B \oplus C \dots\dots N$$

$$Y = \overline{A}B + A\overline{B}$$

Logic diagram



Truth Table

Inputs		Output
A	B	$A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

XNOR Gate

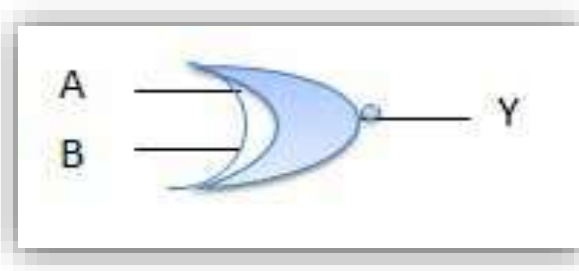
Is applied in the half adder, full adder and subtractor. It has n input ($n \geq 2$) and one output.

$$Y = A \text{ XOR } B \text{ XOR } C \dots\dots N$$

$$Y = A \ominus B \ominus C \dots\dots N$$

$$Y = \overline{A}B + A\overline{B}$$

Logic diagram



Truth Table

Inputs		Output
A	B	$A \oplus B$
0	0	1
0	1	0
1	0	0
1	1	1

Microcontroller

Microcontroller is a tiny computer. You can connect things, like a small display, some buttons, a motor and some sensors. And you can put programs onto it and run them. A microcontroller is an integrated circuit. There are so many things you can do with a microcontroller. You could build a robot. Or an MP3-player. Or a cell phone. Or a door-lock that unlocks your door automatically when you enter a code on your smart phone. For example, if you want to build a robot, you can connect an infrared sensor to use as vision for the robot. And you can connect a motor with some wheels to make it move. You can make a program that reads from the infrared sensor and controls the motor. In your code, you can make sure the robot stops if it sees something in front of it, and make it turn to either left or right before continuing.

To achieve this, you can use a microcontroller by programming it.

A microcontroller has several pins. Most of these pins are so-called input and output pins. And by using these pins, the microcontroller can interact with the outside world. The microcontroller doesn't do anything by itself. You need to tell it what to do, by making a program that you load into it to it. This is often called programming the microcontroller.

From the program you write, you can control the input and output pins.

By connecting a device, such as a Light Emitting Diode (LED) to an output pin, you will be able to switch the light on and off from your program. An input pin could be used to check if a button connected to it has been pushed. Or to read the temperature from a temperature sensor. In your program, you will be able to make decisions based on the input. So you can make a program that will start to blink a light if the temperature goes above or under a certain level. Put this into your beer-brewing room and you will get a visual alarm if the temperature for brewing is not right.

Programming a Microcontroller

These are the three steps necessary to program a microcontroller:

1. Write code
2. Compile your code to machine code
3. Upload the machine code to your microcontroller

Programmable Logic Controller (PLC)

PLC is a digital electronic device that uses a programmable memory to store instructions and to implement specific functions such as logic sequence, timing, counting and arithmetic to control machines

PLC Hardware Components

A PLC consists of the following component hardware:

Processor

Memory unit

Power supply

Input/output (I/O) module

Programming device.

The processor

It examines the status of the input signals, executes the logic and sequencing functions, and operates on the outputs. It consists of one or more microprocessors specifically designed for input and output (I/O) type operations.

Memory.

The memory unit stores the work cycle program, I/O status information, and controller system operation information. It is broken down into two areas: user memory and system memory. The work cycle program is stored in the user memory and the controller operational information is kept in the system memory. The combined processor and memory unit is referred to as the central processing unit, also known as the CPU.

Power Supply

It provides the power to the unit. PLCs are specifically designed to run off a standard 120-volt AC line, a design feature that was part of the specification for the first PLC.

Input/output- (I/O) Module

The controller physically connects with the sensors and actuators through the I/O module. This is the interface to the process application being controlled. Like the power supply, I/O modules were originally specified to accept 120-volt AC signals, intended to enable the PLC to easily connect with standard push buttons and limit switch sensors. However, since the early development of the PLC, I/O module capabilities have greatly expanded. I/O modules are now available in a wide variety of configurations, including, but not limited to:

AC input/AC output

AC input/DC output

AC input/relay output

DC input/DC output

DC input/AC output

DC input/relay output.

Programming devices.

The last hardware component of the PLC is the programming device. This device provides a means of entering the work cycle program into the memory module of the PLC.

Implementing Automation with PLCs

PLCs employ discrete sequential process control of machines, workstations, and work cells. The system is controlled per the program of instructions, which is the sequential list of actions necessary to complete the process.

Following step 1 of the USA principle, we gain an understanding of the process. Most people are familiar with washing machines from a user point of view. However, for implementing automation, one must understand the process from the controller's perspective. To effectively control the machine, one must break the process steps down into a work cycle program. When a designer develops a work cycle program, he or she must put in place appropriate sensors to monitor the process variables (PLC inputs) and select actuators (that act on the process) (PLC outputs). The work cycle program for the washing machine process is shown in Figure 8-34. Clearly, it is a more detailed listing of the process steps listed above. It can also be referred to as an I/O status table; in it, process steps are linked to the corresponding status of PLC inputs and outputs.

Process Steps	PLC Inputs (Sensors)				PLC Outputs (Actuators)			
	Start Button	Stop Button	Tub Empty Sensor	Tub Full Sensor	Solenoid Valve	Agitator Motor	Drain Pump	Spin Motor
Start cycle	ON	off	ON	off	off	off	Off	off
Fill tub to wash	off	off	ON	off	ON	off	Off	off
Wash Agitate tub	off	off	off	ON	off	ON	Off	off
Drain	off	off	off	off	off	off	ON	off
Fill tub for rinse	off	off	ON	off	ON	off	Off	off
Rinse Agitate tub	off	off	off	ON	off	off	Off	off
Drain	off	off	off	off	off	off	ON	off
Spin	off	off	ON	off	off	off	Off	ON
End Cycle	off	off	ON	off	off	off	Off	off

Notice that this work cycle program shows the status of the inputs and outputs at the start of each process step. For example, in the "Fill tub to wash" step, the "Tub Empty Sensor" is marked "ON." Once the tub begins to fill the sensor is switched to "off." The work cycle diagram is a valuable aid in the PLC programming process because it defines the relationship between the process step and I/O status. A timing diagram may also be a beneficial aid when a process is particularly complicated or confusing. In a

timing diagram, the columns and rows of the work cycle diagram are reversed, with process steps across the top and PLC inputs and outputs down the left hand side. The duration of each step's I/O status is visually represented in the length of the bars running under each step of the program. The corresponding timing diagram for the work cycle program listed in Figure 8-34 is shown in Figure 8-35.

Typically, both work cycle program and timing diagram are used to develop the control program, along with other tools, such as process flow charts and state diagrams. All these are crucial to a programmer's clear understanding of the process and the corresponding logic necessary for proper execution. The next is simplifying the process as much as possible. For those familiar with a washing machine cycle, it is obvious that the above work cycle program is already very simple. Options for selecting different wash cycles or water levels are omitted. While these are important options, it is often desirable to oversimplify the process at first by leaving out even necessary options, which can then be added after the basic work cycle program is fully implemented.

Automating the process involves:

Identifying and procuring an appropriate PLC for the application. Designing and developing the control system hardware, including the control panel, electrical cabinet(s), and sensor and actuator mounting brackets. Procuring the sensors and actuators as necessary. Installing the hardware, and wiring the sensors and actuators to the PLC. Converting the work cycle program into the PLC program of instructions. Simulating the program to verify program integrity. Entering the program in the PLC and verifying the program on the machine or workstation.

PLC Selection Considerations

It is vitally important to select the PLC correct to the application at hand. The choice for a particular PLC will depend on the design of the Electrical machine to be automated. Many brands of PLCs are available, and within each brand are many models with a wide range of capabilities and prices. For optimum control of the process the PLC needs to be properly sized. Most manufacturing facilities have a favorite brand of PLC and tend to stick with that brand for new automation projects. Regardless of the brand used, the correct model within the brand must be specified. The four major categories to be considered for PLC model selection include

I/O configuration

I/O configuration refers to the quantity and type of inputs and outputs an application requires. The quantity of the inputs and outputs is critical as it is the primary differentiating factor between PLC model types. For example, an inexpensive PLC model may only have 14 I/O (8 inputs and 6 outputs) whereas a more expensive model may have 36 I/O (20 inputs and 16 outputs). Often during the actual installation and startup of the application, the need for additional inputs and/or outputs is identified.

Therefore, it is good that one selects a PLC capable of expansion or with slightly more I/O than is initially needed to support future process requirements.

CPU performance

CPU performance refers to the capabilities of the main processing unit of the PLC.

The amount of memory, contact execution time, scan time, and the size of the instruction set all fall into this category.

Size of the instruction

This refers to the number of programming commands available. There is a basic set of programming instructions that all PLCs have. However, different PLC brands and models have expanded instruction sets to provide more capabilities

SCADA (supervisory control and data acquisition)

Introduction

SCADA is a central control system which consist of controllers network interfaces, input/output, communication equipment and software.

It takes the reading of the meters and checks the status of sensors in regular interval so that it requires minimal interference of human.

Architecture

1. Hardware Architecture:

SCADA system is made up of two parts:

Client layer: caters for the man machine interaction.

Data server layer: handles most of the process data activities

2. Software Architecture:

It consists of a software program to provide trending, diagnostic data, and manage information such as scheduled maintenance procedure, logistic information, detailed schematics for a particular sensor or machine and expert system troubleshooting guides.

Working Procedure of SCADA system:

The SCADA system performs the following functions:

- Data Acquisitions
- Data Communication
- Information/Data presentation
- Monitoring/Control

These functions are performed by sensors, RTUs, controller, communication network. The sensors are used to collect the important information and RTUs are used to send this information to controller and display the status of the system.

Data Acquisitions:

Real time system consists of thousands of components and sensors. It is very important to know the status of particular components and sensors.

Data Communication:

The SCADA system uses wired network to communicate between user and devices. The real time applications use lot of sensors and components which should be control remotely. The SCADA system uses internet communications. All information is transmitted through internet using specific protocols. Sensor and relays are not able to communicate with the network protocols so RTUs used to communicate sensors and network interface.

Information/Data presentation:

The normal circuit networks have some indicators which can be visible to control but in the real time SCADA system, there are thousands of sensors and alarm which are impossible to be handled simultaneously.

Human machine interface:

The SCADA system uses human machine interface. The information is displayed and monitored to be processed by the human. HMI provides the access of multiple control units which can be PLCs and RTUs. The HMI provides the graphical presentation of the system.

Monitoring/Control:

The SCADA system uses different switches to operate each device and displays the status at the control area. Any part of the process can be turned ON/OFF from the control station using these switches. SCADA system is implemented to work automatically without human intervention but at critical situations it is handled by man power.

Applications of SCADA

Power generation, transmission and distribution

Electrical heating and cooling system.

Generators and turbines

Traffic light control system

Advantages: of SCADA

Can provides on-board mechanical and graphical information

Is expandable, a set of control units and sensors can be added depending on the requirement.

Relays

Relays are switching devices that open and close circuits electromechanically or electronically.

Mode of operation

When a relay contact is normally open (NO), there is an open contact when the relay is not energized.

When a relay contact is Normally Closed (NC), there is a closed contact when the relay is not energized.

Timers

Contactors

Are switches electrically controlled and applied in electric power circuit switching.

When contactors are energized by an alternating current, part of the core gets surrounded with a shading coil that delays magnetic flux slightly in the core. This helps in averaging the magnetic fields' alternating pull, preventing the core from buzzing a double line frequency.

10.3.3.3.Self-Assessment

1. Digital Sensors produce a discrete digital output signals or voltages TRUE OR FALSE?
2. An actuator may be a simple electrical relay, a pneumatic logic circuit of solenoid valves and cylinders, or a robot. TRUE OR FALSE?
3. PLC is a digital electronic device that uses a programmable memory to store instructions and to implement specific functions such as logic sequence, timing, counting and arithmetic to control machines. TRUE OR FALSE?
4. Which of the following does not change in a transformer?
 - a Current
 - b Voltage
 - c Frequency
 - d All of the above
5. In a transformer the energy is conveyed from primary to secondary
 - a through cooling coil
 - b through air
 - c by the flux
 - d none of the above
6. A transformer core is laminated to
 - a reduce hysteresis loss
 - b reduce eddy current losses
 - c reduce copper losses
 - d reduce all above losses

Practical question

1. Perform design as per the scope of the automation system
2. Carry out design done as per the system's functionality
3. Identify design tools and equipment as per the scope of the system
4. Establish complexity as per the scope of the system
5. Identify electrical components to be mounted as per the design
6. Configure components as per the system functionality
7. Mount components as per the standard operating procedure
8. Connect and wire components as per the design

10.3.2.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

1. Laptops
2. Stationeries
3. Drawing boards
4. Solder wire
5. Jumpers
6. Printed circuit boards
7. Bread boards

10.3.2.5 References

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3. Edwin Kiel (2007), Mechatronics for Production and logistics. Germany
4. Fernando E. Valdes- Peres (2009), Microcontrollers. CRC Press, London
5. <http://www.instructables.com/id/How-to-choose-a-MicroController/>
6. <http://www.instructables.com/id/How-to-choose-a-MicroController/>
7. <http://arduino.cc/en/Tutorial/HomePage>
8. <http://stackoverflow.com/questions/78744/how-to-start-programming-a-microcontroller>

10.3.3. Learning Outcome No 3: Program automation System

10.3.3.1. Learning Activities

Learning Outcome No 3: Program automation System	
Learning Activities	Special Instructions
1. Identify the programming language code for the specific job 2. Code the identified programming language • Write a program code on your computer • Compile the code with a compiler for the Microcontroller • Test and debug the program 3. Test and debug the program as per the standard operating procedure • Reproduce the Bug Before You Start Changing Code. • Understand Stack Traces. • Write a Test Case that Reproduces the Bug. • Know Your Error Codes. • Upload the compiled version to the microcontroller 4. Upload the program to the Microcontroller or the PLC as per the Job description. • Verify the program is free of compiling errors (pressing the compile /verify button) • Press the upload button in the menu bar	The trainee to handle Micro-controller and PLC ICs with caution.

10.3.3.2 Information Sheet No. 10/ LO3

Introduction

Automation programming identifies a type of computer programming in which some mechanism generates a computer program to allow human programmers to write the code at a higher abstraction level.

PROGRAMMING:

Microcontrollers are typically programmed in higher-level languages such as C++ or Java. One of the essential tools needed to program a microcontroller is an integrated development environment (IDE). Common tools found in IDE's include, code editors, compilers, and debuggers.

Once a suitable IDE is obtained, you can begin writing code. Below is an example of a simple Arduino program that makes an LED blink on and off at a frequency of 1Hz.

The code is split into 4 unique sections as shown in the following template.

Start any code with a comment section containing a general description of what the code/program does. User instructions, company and copyright information are also commonly placed here as well.

The second section is the Variable declaration. These variables are global, and can be called in any sections that follow.

Thirdly, comes the "Void Setup" section. In this section, the user defines which pins are inputs or outputs, as well as any other parameters that must be initialized.

Lastly, the "Void Loop ()" section. This section is where the function of your microcontroller is written. Any actions that require reading or writing values from pins, or computing the values of different variables is done here.

COMPILING AND UPLOADING:

Once your code is written, it must be uploaded to the microcontrollers. Most have USB interfaces, but some smaller microcontrollers require a special hardware to be programmed.

DEBUGGING:

Not everything will work perfectly on your first attempt. Debugging is an important part of any design process and programming microcontrollers is no exception. Fortunately, there are several methods to help you locate errors in your code without excessive effort. The first most basic method is to hook up your microcontroller to the circuit it's made to control. Often enough you can see what's wrong simply by observing the output and how it differs from the intended functionality. This is called black box testing. While this method is simple and doesn't require any additional tools, it is also very limited, as no knowledge of the inner workings of the microcontroller is available. As mentioned previously, most IDE's contain debuggers that are able to run the code step by step at the user's control while keeping track of variable and register values so the user can learn exactly what point the program behaves differently than as intended. This is a form of white box testing, and provides much more information that can be used to deduce the cause of a faulty program.

CONCLUSION:

Microcontrollers are a practical, affordable, and flexible solution to many challenges of circuit design and modern control systems. While details such as the software used to program the microcontroller can vary, the thought process used to program them is universal. Always keep in mind that online recourses such as the ones listed on the next page are available to you should you require more information.

Circuit Components:

Hardware Components:

- Yellow LED
- Crystal
- Reset
- 8051 microcontroller
- Capacitors
- Resistors

Software Components:

- Keil compiler
- Proteus software
- Embedded C language

Circuit Connections

Step 2: Microcontroller Program Coding

- First open the Kiel uVison2 software. This shows the menu bar with file, edit, view, project and tools option.
- Select the project option and select the 'new project option' from the drop down menu. Give a name to the project and click on 'save' button to save the project. A folder named 'target' is created.
- Select a microcontroller for your project. Here I am selecting 'Atmel'. Select the exact type of Atmel microcontroller from the drop down menu. Here 89C51 microcontroller is selected. A folder with the name 'source group' is created in the 'target' folder.
- Click on the 'File' menu on the menu bar. Select 'new file' from the drop down menu.

Kiel Window

Write the code on the blank space.

The LED Flash Light program:

```
#include<reg51.h>
sbit LED= P0^2;
void delay( unsigned int a);
void main()
{ LED=0;
While (1)
{ LED=0;
delay(600);
```

```
LED=1;
delay(600);
void delay (unsigned int b)
{unsigned int k; for(k=0;k<b;k++);}
```

- Save this code with '.C' extension.
- Right click on the 'source group' folder icon and select 'add files to group' option.
- A window appears. Select the 'C' file to be added.
- Select the 'debug' menu. It checks the program for any errors.
- Right click on the 'target' folder icon.
- Select the 'option for Target' option.
- A target window opens with a menu bar. Click on the 'Target' menu.
- Set the crystal frequency for the microcontroller.
- Click on the 'Output' menu. A window appears
- Click on the 'create hex file' button. A hex file is created.

Step 3: Circuit Drawing

It contains a database of components which we can use to build the circuit. Each and every component is available in the components library.

Proteus Window using the circuit

- Open the Proteus software. A window with a menu bar appears.
- Click on the file menu.
- Select 'new design' from the drop down menu.
- Click on the library menu.
- Select 'pick devices/symbol' from the drop down menu.
- Select the relevant comment by double clicking on it, so that the component appears on the window.
- Add all the components and draw the circuit with proper connections.

10.3.3.3. Self-Assessment

1. Synchronous-induction coupled motors are required for
 - a) high starting torque applications
 - b) high pull out torque applications
 - c) high running torques applications
 - d) none of the mentioned
2. Which of the following can be used for braking purposes in electric trains?
 - a) Induction generator
 - b) Induction motor
 - c) Dc series motor
 - d) Dc differentially compounded generator

3. A synchronous motor absorbing 60 kW is connected in parallel with an continuous load of 240 kW operating at 0.8 power factor lag. What is the kVAR supplied by the synchronous motor to obtain a total power factor of 0.9 lagging?
 - a) 35, leading
 - b) 35, lagging
 - c) 145, leading
 - d) None of the mentioned
4. The most widely used application of ac series motor is
 - a) electric traction upto 1600 kW
 - b) paper mills
 - c) welding
 - d) none of the mentioned

Practical question

1. Identify programming language is identified as per the functionality of the system
2. Perform coding of the identified programming language
3. Upload program in the automation system as per the manufacturers' specifications
4. Configure automation system as per the standard operating procedure

10.3.3.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Laptops
- Stationeries
- Drawing boards
- Solder wire
- Jumpers
- Printed circuit boards
- Bread boards
- Data sheets for the Microcontroller and PLC chips

10.3.3.5. References

1. B.L. Theraja (2008), Basic Electronics S.Chand and Company. RAM NAGAR, NEW DELHI
2. A.K. Sahwney (2007), Electrical and Electronic Measurements and Instrumentation. Dharnpat Rai & Co.Delhi
3. Edwin Kiel (2007), Mechatronics for Production and logistics. Germany
4. Fernando E. Valdes- Peres (2009), Micro controllers. CRC Press, London
5. <http://www.instructables.com/id/How-to-choose-a-MicroController/>
6. <http://www.instructables.com/id/How-to-choose-a-MicroController/>

10.3.4. Learning Outcome No. 4: Simulate Automation system

10.3.2.1. Learning Activities

Learning Outcome No. 4: Simulate Automation system	
Learning Activities	Special Instructions
1. Identify automation system modelling components as per the design in learning activity number 1. 2. Implement the system model 3. Interface the system model with the program 4. Simulate the Circuit • Open the project in the Proteus software. • Click on the 'Debug' menu. • Select the 'start debugging' option. The LED starts blinking, which indicates the circuit is running. • After some time, select the 'stop debugging' option. The LED will now stop blinking. 5. Test run the system as per the job specification. 6. Observe safety and working standards as stipulated in the OSHA act and IEEE regulatio 7. Industrial visit to for more competencies in PLC and SCADA technology.	Follow programming Instructions as per the program's instructions

10.3.4.2 Information Sheet No 10/ LO4.

Introduction

System modeling is the process of developing abstract models of a system, with each model presenting a different view or perspective of that system. System Modeling provides a complete physics model-based design platform for modeling, simulation, validation and verification of early design models and requirements.

Simulation modeling solves real-world problems safely and efficiently. It provides an important method of analysis which is easily verified, communicated, and understood. Across industries and disciplines, simulation modeling provides valuable solutions by giving clear insights into complex systems.

Simulating a Micro-controller in Multisim

NI Multisim microcontroller (MCU) functionality is a simulation program that allows you to co-simulate a microcontroller.

As a part of the Electronics Education platform, the MCU provides an ideal environment for students to learn how a microcontroller works in digital electronics, computer architecture and other design applications.

The MCU functionality also offers a convenient way in which to interface an MCU within an analogue and digital circuit to emulate the behaviour of an entire system.

The following steps offer an explanation on how to use the program

1. Open Multisim and click on the MCU icon, which is located in the component toolbar. After the window opens, select the "805x" family, select the "8051" MCU and click on "OK." The window will disappear and an outline of the 8051 will appear in the workspace.
2. Place the 8051 on the workspace by clicking once. After it is placed, a window titled "MCU Wizard - Step 1 of 3" will appear
3. Name the workspace "test space" and verify the workspace path. Click "Next >" to proceed to the next window. It is not necessary, but you can also "browse" and choose a different workspace path for saving.
4. Click on each drop-down menu, in window "2 of 3." Select "Standard" for project type and select "Assembly" for programming language. Name the project "test MCU" and click "Next >" to proceed. The assembler/compiler tool will automatically be set when the programming language is selected.
5. Click on the radio button for "Add source file" in window "3 of 3." Name the source file "test1." Click "Finish" to close the MCU Wizard and click on the "X" to close the 8051 component window.
6. Construct a circuit using the MCU. This process is similar to constructing any other circuit in Multisim.
7. Click on the tab for the "test1.asm" window (at the bottom of the workspace) to program the 8051. A separate programming window will open. Write the MCU program in the area where it states "; please insert your code here." Include the statements "\$MOD51" and "END" in your program.
8. Run the simulation when programming is complete. Click on "Simulate" and select "Run." This will compile the code and operate the MCU circuit.

10.3.4.3. Self-Assessment

1. Universal motor is used in vacuum cleaners, table fans and portable drilling machine.
 - a) True
 - b) False
2. _____ generator is used in arc welding purposes.
 - a) Differential compound dc
 - b) Dc series
 - c) Cumulative compounded dc

- d) Shunt
- 3. The dc series generator is employed as
 - a) a booster to maintain constant voltage at the end of the feeder.
 - b) for supplying traction load
 - c) for battery bank charging
 - d) none of the mentioned
- 4. If it asked by the customer to provide tapplings on the transformer, the most efficient and economical way to provide it at
 - a) middle of hv winding
 - b) phase end of hv winding
 - c) neutral end of hv winding
 - d) middle of lv winding
- 5. In a single phase induction regulator, the voltage boost is maximum when armature mmf and rotor mmf make an angle of
 - a) zero degrees
 - b) 45 degrees
 - c) 90 degrees
 - d) 180 degrees

Practical question

- 1. Identify automation system modelling components as per the design
- 2. Implement automation system model as per the design
- 3. Interface system model with the program as per the design
- 4. Perform test running of the system for its functionality

10.3.4.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- 1. Drawing boards
- 2. Solder wire
- 3. Jumpers
- 4. Printed circuit boards
- 5. Bread boards
- 6. Data sheets for the Microcontroller and PLC chips
- 7. Keil uVison
- 8. Code Editor
- 9. Assembler
- 8. C compiler
- 9. Burner/Programmer

10.3.4.5 References

1. B.L. Theraja (2008), Basic Electronics. S.Chand and Company, RAM NAGAR, NEW DELHI
2. Edwin Kiel (2007), Mechantronics for Production and logistics. Germany
3. Fernando E. Valdes- Peres (2009), Microcontrollers, CRC Press, London
4. <http://www.instructables.com/id/How-to-choose-a-MicroController/>
5. <http://www.instructables.com/id/How-to-choose-a-MicroController/>
6. <http://arduino.cc/en/Tutorial/HomePage>
7. <http://stackoverflow.com/questions/78744/how-to-start-programming-a-microcontroller>

10.3.5. Learning Outcome No. 5. Test run Automation system

10.3.5.1. Learning Activities

Learning Outcome No. 5. Test run Automation system	
Learning Activities	Special Instructions
1. Identify the type of tests as per the job description • Continuity • Insulation resistance • Polarity • Phase sequence • Accuracy • Efficiency • Earth Electrode resistance • Earth fault loop impedance • Speed • Stability • Resolution 2. Select the test Instruments • Continuity tester - Ohmmeter • Insulation resistance tester • Test lamp • Frequency meter • Digital logic Probe • Tachometer • Oscilloscope 3. Visual inspection is performed as per the job description • Firmness of accessories • Loose connections • Damaged equipment or component • Colour coding 4. Carry out the tests as per then job description • Continuity • Accuracy • Efficiency • Polarity • Phase sequence • Insulation resistance • Frequency • Speed • Earth electrode resistance • Earth loop impedance	Standard safety procedures should be observed as per the IEEE regulations.

10.3.6.2. Information Sheet No 10/ LO5

Introduction

Automation testing is a Software testing technique to test and compare the actual outcome with the expected outcome.

Automated Testing Best Practices involves the following procedure

1. Decide what Test Cases to Automate.
2. Test Early and Test Often.
3. Select the Right Automated Testing Tool.
4. Divide your Automated Testing Efforts.
5. Create Good, Quality Test Data.

The automated electrical machine should be subjected to electrical test to ascertain the electrical soundness of the machine. Electrical testing ensures safety to the operator and the machine. The tests can reveal faults in the system. The tests are carried out with the help of various electrical instruments, some of which are highlighted below.

Tachometer

Is a sensor device used to measure the rotation speed of an object? It indicates the revolutions per minute (RPM) performed by the object.

Frequency meter

It is an instrument that displays the frequency of a periodic electrical signal. Various types of frequency meters are used.

Logic Probes

It is a low cost handheld probe contained within a pen-like tube with indicator lights to show the state of the line being probed.



Picture: Simple logic probe tester

Logic probe measurements

- Logic high state:* The logic probe / digital logic tester is able to detect lines that are at the digital or logic high state. The logic probe will indicate this typically with an LED which is often coloured red.
- Logic low:* The logic probe also is able to indicate a logic or digital low. A common indication is with the use of a green coloured LED.
- Digital pulses:* The logic probe may incorporate some form of pulse detection circuitry. When the line is active and being pulsed a third colour, possibly amber

will be indicated. The logic probe may well incorporate circuitry to detect very short pulses and in this way indicate when the line is active. Sometimes the length of the pulses may be indicated by the brightness of the LED.

- iv. *Line tri-stated:* Some logic probes may also be able to detect when a line has been put into a tri state option.

This is when the output device has its output turned off and no real logical state is defined. Many logic probes are able to indicate this state and they may do this by having all indicators turned off.

Testing parameters in Automation system

Efficiency

Is the ratio of the useful work performed by a machine or in a process to the total energy expended or heat taken in?

Accuracy

Is the degree to which the result of a measurement, calculation, or specification conforms to the correct value or a standard?

Reproducibility

Is the the extent to which consistent results are obtained when an experiment is repeated.

Stability

Is the ability of a substance to remain unchanged over time under stated or reasonably expected conditions of storage and use?

10.3.5.3 Self-Assessment

1. An alternator is to be used for generation purpose in an aircraft. The most suited operating frequency of the alternator should be
 - a. of 400 Hz to remove extra bulk
 - b. of 400 Hz to reduce losses
 - c. of 50 Hz to remove extra bulk
 - d. none of the mentioned
2. A 3-phase synchronous alternator is connected to the infinite bus is over excited, which corresponds to
 - a. capacitor
 - b. inductor
 - c. variable inductor
 - d. any of the mentioned
3. Efficiency is the degree to which the result of a measurement, calculation, or specification conforms to the correct value or a standard? TRUE OR FALSE?
4. The automated electrical machine should be subjected to electrical test to ascertain the electrical soundness of the machine TRUE OR FALSE?

Practical question

1. Identify types of test
2. Identify testing tools and equipments
3. Test for functionality automation system as per the design
4. Test reliability of the system as per the standard operation procedure
5. Test accuracy and efficiency of the system as per design
6. Test automation system parameters as per the design
7. Perform visual inspection

10.3.5.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Logic analyzers
- Digital Multimeter
- Functional generators
- Network and cable tester
- Logic probes

10.3.2.5. References

1. B.L. Theraja (2008), Basic Electronics. S.Chand and Company. RAM NAGAR, NEW DELHI
2. A.K. Sahwney (2007), Electrical and Electronic Measurements and Instrumentation .Dharnpat Rai & Co.Delhi
3. Edwin Kiel (2007), Mechatronics for Production and logistics.Germany
4. Fernando E. Valdes- Peres (2009), Microcontrollers.CRC Press, London

Links:

5. <http://www.instructables.com/id/How-to-choose-a-MicroController/>
6. <http://www.instructables.com/id/How-to-choose-a-MicroController/>
7. <http://arduino.cc/en/Tutorial/HomePage>
8. <http://stackoverflow.com/questions/78744/how-to-start-programming-a-microcontroller>
9. <https://www.fluke.com/en/learn/best-practices/test-tools-basics/portable-oscilloscopes/basic-oscilloscope-functions>
10. <https://whatistechtarget.com/definition/oscilloscope>
11. <https://www.oreilly.com/library/view/digital-electronics-principles/9780470032145/20-chapter16.html>

CHAPTER 11: SECURITY SYSTEM INSTALLATION /INSTALL SECURITY SYSTEMS

11.1. Introduction of the Unit of Learning / Unit of Competency

This unit covers the competencies required in installing of security systems.

Competencies includes; security system design, marking out of security systems zones or call points, laying system cables, mounting accessories, terminate system cables and testing of the system.

11.2. Performance Standard

Design security system, mark out security system zones or call points, lay and mount cables and accessories, terminate system cables and test security system as per the scope of the system and in line with IEE, ERC, NCA and NEMA regulations

11.3. Learning Outcome

11.3.1. List of Learning Outcomes

- a) Design security system
- b) Mark out security system zones
- c) Lay system cables
- d) Mount accessories
- e) Terminate system cables
- f) Test security system

11.3.2. Learning Outcome No .1 Design security system.

11.3.2.1. Learning Activities.

Learning Outcome No .1 Design security system.	
Learning Activities	Special Instructions
• Performing design of various types of security systems i.e CCTV, alarms and electric as per the scope of system and system's functionality. • Identifying the design components of security systems as per system functionality. • Performing wiring design and wiring security system in line with the IEE regulation and with the national and international standards respectively. • Designing security system in line with the expected self-defensive mechanism. • Performing design in adherence to ERC (Energy Regulation Commission). project Design CCTV security system installation	

11.3.2.2 Information Sheet No .1

Introduction

The surveillance capabilities applied in protecting people, assets, and systems is provided by CCTV systems. It majorly serves a security force multiplier, availing surveillance for an extended area, more of the time, than would be feasible with a single security personnel. Such CCTV systems are applied in supporting complex systems of security through video coverage incorporation and security alarms for intrusion detection, barriers and control of access. For instance, a CCTV system is capable in providing the means assessing an alarm generated by detection system intrusion and the event recording.

There are several components CCTV systems with various functions specifications and features. Major components are composed of data distribution, lenses, cameras, power, and lighting. Several technologies in CCTV uninterruptedly are refined to boost in performance mostly in areas including data storage, digital equipment options, wireless communications, component miniaturization and automatic analysis of images. In the current CCTV market, components, options for configuration, and available features have a created a complicated set of purchasing options. Therefore, this handbook provides information on the limitations capabilities of CCTV components necessary in agency procuring of either new CCTV system or upgrade to the current ones.

Definitions of Terminologies in CCTV System;

1. CCTV system: A system that comprises of either electronic or devices with specific construction design or adapted in monitoring or recording images on or in the premises' vicinity.

2. CCTV surveillance installation (installation): An installation that comprises of the hardware and

Software mechanisms of a CCTV system, completely installed and operates in monitoring on or in premises' vicinity.

3. CCTV camera (camera): A unit that contains an imaging device that produces a video signal from an optical image.

4. CCTV camera equipment: A unit that contains a CCTV camera and suitable lens and ancillary equipment.

5. Camera housing: An enclosure that provides protection to the physical and/or environmental of the

Camera, lens and ancillary equipment.

Find more definitions related to CCTV Security system get in the article of requirement for CCTV Installation by the private security authority

Types of CCT Security Systems

1.Simple CCTV System

The CCTV camera simplest form is directly connected to a monitor using a coaxial cable with the power.

2. Main powered CCTV System:

Note that that majorly, the monitor powers the camera. The coaxial cable transmits video signal from the camera to the monitor. Despite simple installation, it is prudent to comply with the relevant regulations to avoid the problems associated with the insurance validity.

3. Systems with Video Recording:

Adding of the video recorder is the next basic development. According to the below arrangement indicated in the figure, the shown pictures during play back will be according to the way the switcher was set up while recording. Therefore, in case the set of sequence was set then there would be a display of same views on the monitor.

4. Movable Cameras

Several fixed cameras would be required in the area to be covered for most applications. Use of cameras fixed to a movable platform is the solution to this and the platform being controlled from a remote location. The platform is likely to rotate in a horizontal plane and is referred to as a scanner. Besides, the platform is likely to be controlled in both horizontal and vertical planes and referred to as a pan, tilt unit.

For alarm and electric fence get information from the following sources (Jahangir, 2016 ;SAID, 2014).

Components of Security System

1 .Smoke Sensor

Is a device with ability to sense smoke, typical indicator of fire. Fire alarm control panel issues signals by a commercial security devices that contributes part of a fire alarm system. For household smoke detectors (smoke alarms) issues a local audible or visual alarm from the specific detector.

For vibration sensors get information from (Guo, 2014)

Factors to consider in design of security system.

For instance in CCTV Security Design the following factors are taken into consideration;

- i. Understand your camera i.e size lens, resolution.
- ii. Consider the terrain i.e obstruction such as trees and buildings.
- iii. Look to the future i.e plan expansion.
- iv. Check your blind i.e size of blind zone to determine mounting height of the camera.

Wiring design of security system.

Electric Fence security system

The conversion of the mains into a high voltage pulse is done using an electric fence energizer. It releases the pulse insulated fence line per second. It usually takes about 150 microseconds.

The pulse is also called "shock" and can be felt through touching an electrified fence by any animal. When it comes to contact with the fence, it completes the circuit and the animal instantly receives the shock. The below diagram indicates the flow of current from the energizer down the fence line and through the animal. Later, it flows through the earth back to the ground system making the circuit complete. The shock prevents the animal from inserting the pressure on the fence line.

For CCTV and Alarms find information from this source (Laboratory National Urban Security Technology Laboratory SAVER Website and www.forgottenbooks.com).

11.3.2.3.Self-Assessment

1. A "Dead Zone" in a PIR motion detectors field of view is
 - A. A zone that has been intentionally masked
 - B. An area of the protection pattern that isn't sensitive
 - C. The area beyond the protective pattern
 - D. An area between PIR motion detectors "beams"
2. A "Pet Alley" is a section of the protection pattern, which has been masked to allow the movement of a small animal
 - A. True
 - B. False
3. A "Pet Proof" detector can ignore any number of real targets in its field of view, as long as their total combined weighs do not exceed the device specifications
 - A. True
 - B. False
4. A 100 Watt 120 Volt CCTV power supply consumes how many amps?
 - A. 120 amps
 - B. 1200 milliwatts
 - C. 0.83 amps
 - D. 1.2 amps
5. A 1000 ohm resistor with 5 volts across it has how much current flowing through it?
 - A. 5.0 A
 - B. 200 mA
 - C. 5.0 mA
 - D. 20 A
6. CCTV system is capable in providing the means assessing an alarm generated by detection system intrusion and the event recording TRUE OR FALSE?
7. The CCTV camera simplest form is directly connected to a monitor using a coaxial cable with the power. TRUE OR FALSE?

Practical question

1. Perform design as per the scope of the system
2. Perform design as per the system's functionality
3. Identify design components as per the system functionality
4. Establish complexity as per the scope of the system
5. Perform wiring design as per the scope of the system
6. Perform wiring system in line with the national and international standards
7. Design system in line with the expected self-defensive mechanism
8. Perform design in adherence to the regulatory bodies requirement

11.3.2.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Model of various design security system i.e CCTV , Alarm and Electric Fence Security System
- Computer with circuit marker software

11.3.2.5 References

- 1.Authority, T. P. (n.d.). Requirements for CCTV Installation.
- 2.Guo, A. (2014). Vibration Sensor Design Research.
- 3.Jahangir, M. (2016). Home automation and Security system.
- 4.SAID, S. B. (2014). AUTOMATED ELECTRIC FENCE. *FINAL YEAR PROJECT REPORT*.

11.3.3. Learning Outcome No .2. Mark out security system zones and call points.

11.3.3.1 Learning Activities.

Learning Outcome No .2. Mark out security system zones and call points.	
Learning Activities	Special Instructions
• Identify marking, piping and fixing tools as per the nature of the job. • Perform marking as per the design drawing (see figure 1 below). • Perform marking in line with established procedure and standard. • Perform marking points and zones as per the design. Project; Mark out security system zones and call points for CCTV security system.	

11.3.3.2 Information Sheet No .2

Introduction

The sensing devices of the security system is assigned to specific “zones”. For instance, the device that senses at entry/exit door may be allocated to zone 01, devices that sense on windows in the master bedroom to zone 02 respectively. In case of any trouble, the numbers are indicated on the display.

Zones in security system

Zones are how a security accomplishes and controls sensors or detectors, in which these sensors are allocated to zones and when a sensor is triggered the security system informs or alerts you which specific zone sensor has been triggered.

Zone Type Summary

Table 1 below is a listing of all the available Zone Types and their behavior. For each Zone Type, we can see whether the sensors would be active or inactive when the alarm system is in different states.

Table 1. Zone Type Summary

Zone Type	Behavior
Immediate	Armed in Away Arm - Active Armed in Home Arm - Active Disarmed - Inactive
Delay	Armed in Away Arm - Active Armed in Home Arm - Active Disarmed - Inactive

	After the alarm is triggered, there is a delay before the alarm goes off.
Emergency	Armed in Away Arm - Active Armed in Home Arm - Active Disarmed - Active
Disable	Armed in Away Arm - Inactive Armed in Home Arm - Inactive Disarmed - Inactive
Away Armed	Armed in Away Arm - Active Armed in Home Arm - Inactive Disarmed - Inactive

Source: <https://www.fortresssecuritystore.com/faq/what-are-zone-types-and-how-do-they-work-in-s02>

Marking Out

It is important for an electrician to decide place and process of fixing to the floor, wall or ceiling when making electrical installation of any equipment. The electrician should have suitable working drawings that indicates the fittings including lighting points, socket points switch points, installation points, systems and / or appliances to be fitted. Use of symbols in the drawing legend indicates the type of fixture and specific region within the premise. Other inclusions are the dimension such as switch drops height and fixtures above the completed floor level. The electrician is required to translate plans of installation into action despite the availability or lack of information in the working drawings. The initial action involves marking out of the exact location for the installation and the route through which the cable follows.

Marking a Vertical Line (Plumb Line)

Plumb lines (plumb bobs) are applied in establishing VERTICAL LINES. The composition of plumb bob includes balanced weight that is attached through its center to one end of a piece of twine. It is possible to hold or suspend it from a point above. It always indicates a true vertical line when stable. See Figure 2. Two pencil marks corresponds to the line of the twine, one at each end. When these two marks are joined, they would establish a true vertical line.

Chalk Lines

The lengths of the chalk lines are usually 3-5 meter of twine fitted with fine chalk powder. Using chalk lines, application of chalk is made to the twine as it is played out from the spool. The shaping of the chalk line makes it possible to be applied as plumb bob as shown in Figure 3 below

In marking a chalk line, using free hand in lifting the tautly held string away from the wall and later releasing it is recommended. The string springs back and deposits a line of chalk on the wall's surface. See Figure 4. It is advisable to fit the line at both ends for long runs and pluck in a same manner close to the Centre

Marking a Horizontal Line (Spirit Level)

The commonly used tool in producing a horizontal line is a spirit level. It is composed of a straight edge, composed of aluminum. Fixing of a tough glass tube is made at the middle and both ends they are usually fully filled with liquid with a small air bubble remaining. The tubes at either end are used for this reason. Specific models are used in marking a 45° line from one end. The variance in sizes is from 250mm to 2 meters in length. It is important to treat a level with care. To accurately mark, it is important to ensure bubble is evenly spaced between the two lines on the glass tube as shown in the See figure 5

Marking Out on a Ceiling

Figures 29 and 30 indicates the process above.

- Set out the fixing points and the direction of the fixtures on an unobstructed floor. The centres of these fixing points should be marked out with crosses that intersect exactly at right angles. Use a plumb line suspended from the ceiling so that the plumb bob is just clear of the floor.
- Move the plumb line until the point of the plumb bob rests exactly over the centre of the mark on the floor, then put a mark on the ceiling at the point of suspension.

Method of Fixing

The fixing rawlnut comprises of a tough natural rubber sleeve with a non-ferrous nut fitted in one end, and a moulded external flange at the other. On tightening the screw is, the rubber sleeve would be compressed into a strong rivet fixing on the reverse side of the partition. See Figure 7.

N.B. In case the screw is removed, the sleeve remains in position and can be re-used.
Method of Use.

- Drill a hole of a suitable diameter in material.
- Insert rawlnut in hole up to external flange.
- Pass fixing screw through fixture and enter into rawlnut.
- Tighten screw to compress rubber sleeve until fixture is secure.

For Marking, piping and fixing tools in security system installation find information from this links:-<https://ipvm.com/reports/installer-tools-guide> and <https://www.securityinfowatch.com/integrators/installation-tools-equipment>

Importance of marking in security system

Marking ensure that the zones sensors, switch points, socket points, lighting points, installation points and system control points are properly located for the efficiency functionality of the security system.

11.3.3.4.Self-Assessment

1. Electrical current is measured in using
 - A. An ohmmeter
 - B. An ammeter
 - C. A voltmeter
 - D. An oscilloscope
2. Electrostatic discharge can damage most modern electronic circuits
 - A. True
 - B. False
3. For an intruder to be sensed by a PIR, it is best if he
 - A. Is wearing summer clothing
 - B. Walks toward the detector
 - C. Walks away from the detector
 - D. Walks across the detector's pattern
4. Four 100 ohm resistors connected in parallel have the equivalent value of
 - A. 33.3 ohm
 - B. 250 ohm
 - C. 333 ohm
 - D. 25.0 ohm
5. Free egress from a building is required
 - A. Only when necessary
 - B. At all times
 - C. When required by the fire marshal
 - D. When the access system is disabled

6. The electrician is required to translate plans of installation into action despite the availability or lack of information in the working drawings TRUE OR FALSE?
7. The composition of plumb bob includes balanced weight that is attached through its center to one end of a piece of twine. It is possible to hold or suspend it from a point above TRUE OR FALSE?

Practical question

1. Identify Marking, piping and fixing tools as per the nature of the job
2. Perform Marking as per the design drawing
3. Perform Marking in line with establishes procedures and standards
4. Perform Marking points and zones as per the design

11.3.3.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Lubricants and screws
- Drill
- Pipe cutter
- Screw driver
- Permanent mark pen.

11.3.3.5. References (APA)

8-18 Zone Intruder Alarm System

(<https://www.zetaalarmsystems.com/media/content/pdfs/EC-P8-Installation-Manual.pdf>)

11.3.4 Learning Outcome No .3 lay system cables

11.3.4.1 Learning Activities.

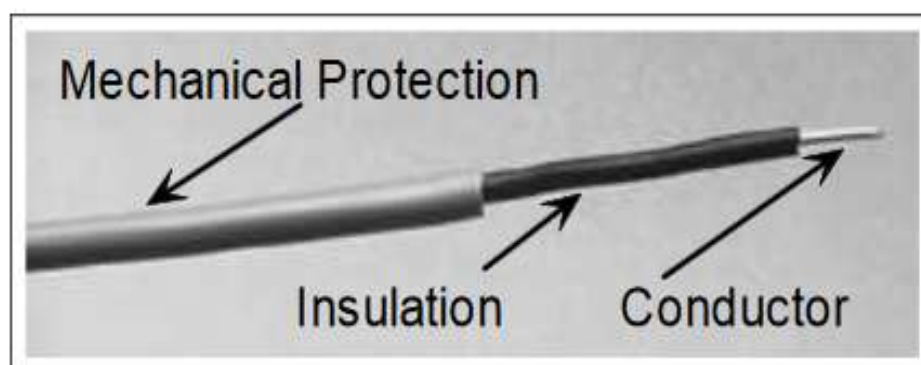
No .3 lay system cables No .3 lay system cables	
Learning Activities	Special Instructions
• Identify cable types. • Laying cables as per the IEE regulations. • Laying cables systems as per the environmental condition. • Installing firmness of the cables as per the standard operating procedure. • Segregating cables as per the standard operating procedure. Project; Lay system cables for alarm security system installation.	

11.3.4.2 Information Sheet No .3

Introduction

At least one conductor is insulated. The insulation may either be provided with an overall covering to enhance mechanical protection. A cable comprises of three parts;

1. Conductor
2. Insulation
3. Sheath (Mechanical Protection)



The commonly used conductor material is copper. For larger cables aluminum is used and is not permitted installation for domestic purposes. PVC is the commonly used insulation. Installing cables is a further protection and is provided in safe regions they are not likely to be damaged. In case this is not possible, cables should be fitted in

trunking, conduit, or ducting. Otherwise an appropriate armored cable must be applied. In case the installation of cables are done in conduit or trunking they don't require any mechanical protection.

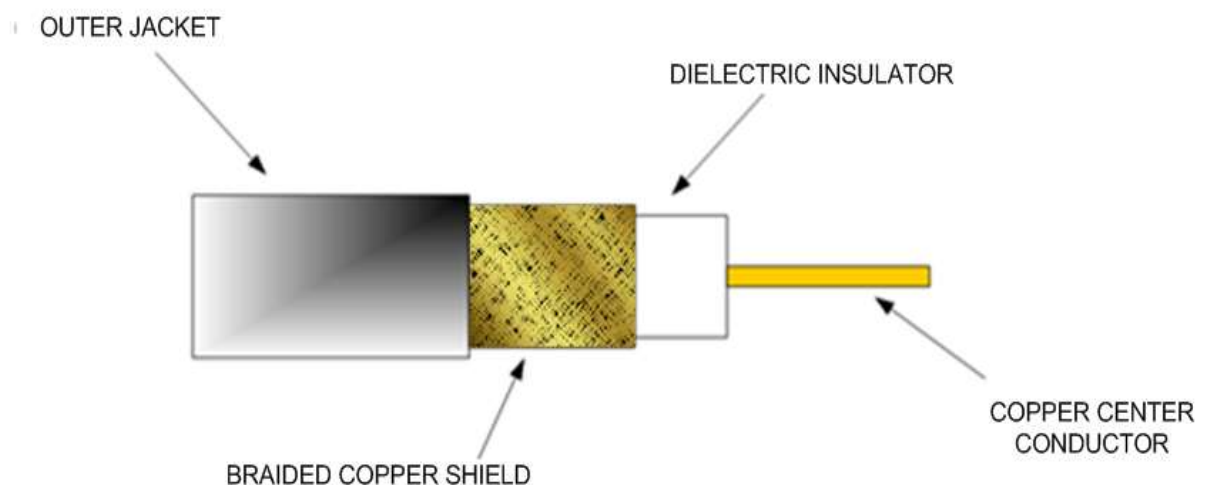
Types of Cables in Security System

1. Coaxial cable

Are applied in the transmission of video signals from either camera to monitor or other components of CCTV. It is made up of wire surrounded by a nonconductive insulating layer also called the dielectric, shielded by the braided wire and covered by a plastic or rubber as shown in the figure below. It is important to note that CCTV applications need highest quality materials. The center conductor and the braided shield should be made of copper. Achieving the direct run distance of about 2000 feet is possible so long as the gauge of the cable is suitable. Cable running across longer distance is possible so long as the amplifier are fitted between the camera and then monitor.

The reliability and quality of the image depends on the quality of the cable.

Transmission through coaxial cable is susceptible to Radio Frequency Interference RFI and EMI since it is electrical. It is important to take great care to ensure proper grounding of the whole CCTV system while using the coaxial cable. Otherwise, it would lead to loss of video, grainy image and poor quality video.



2. Pair-Twisted Signal Cable.

Cables for fire alarms are available with either red or grey sheaths depending on the regulations, aesthetic requirements, etc. In larger addressable systems, twisted pair cable should be used.

For more information of security system cables get from (Cables for alarm and Safety Systems by Nexans).

Factors to consider in security system cable laying

Cable installation

Cables are applied for both the indoor and the outdoor application. It is important to understand the installation screws, local conditions and the maintenance personnel to ensure proper functioning of the cable.

Cable construction

The construction cable involves use of the right conductor, proper arrangement of the cable, installation and cover finishing.

Cable arrangement

Arrangement of conductors ranges from single conductor to three conductors. It is easy to install and splice single conductors to allow for multiple cable circuit installation. Besides, the reactance of the single conductors is higher than that of the three-conductor cable. It is important to consider ground wire in either three conductor cable or single conductor cable. The ground conductor in three conductor cable provides lowest impedance depth hence offering good system ground.

Insulation and finish covering

Is based on installation type, ambient operating temperature, type of load served and service conditions. Abnormal conditions may be prevalent to corrosive atmosphere, high ambient temperature, and insect and rodent hazard, presence of oil and solvents, presence of ozone, and extreme cold.

Cable operation (voltage and current)

Cable selection required for insulation should be based on the phase to phase to phase voltage applicable and the general classification of the system category.

Cable size

The cable size depends on the factors below:

- Current carrying capacity
- Voltage regulation
- Short circuit rating

They need to be evaluated prior to selecting the size of the cable.

Shielding requirement

- Type of insulation system
- Whether the system neutral is grounded or ungrounded
- Safety and reliability requirements of the system

. Cable Laying Arrangement

Multicore cables are laid in “flat formation” arrangement and single core cables may be laid in “trefoil” arrangement or in “flat formation” arrangement. For single core cables “trefoil” arrangement is the most advised method.

Segregation in Cable Laying

No matter what method is used for laying, cables must be segregated taking into account the voltage level and function. . Segregation means that cables with different voltage levels and/or different functions must not be laid at the same physical support and must be separated. Segregation of cables must be done in accordance with standards and regulations, as well as local authorities' recommendations and must consider the following situations:

- Power cables (by voltage level).
- Control cables.
- Communication cables.

Importance Segregations

To evade possible electromagnetic interferences that can interrupt the networks and the signals cables are carrying on

11.3.2.3 Self-Assessment (assessment questions/evaluation question for the learning outcome)

1. In an alarm system installed without an electrical permit, the installer can work after hours installing the transformer only if
Discuss
 - A. Only after phoning the central station and is authorized
 - B. Provided the central station is notified after the technician is finished
 - C. Only if authorized by the client
 - D. May not install outside of normal business hours
2. In an electric door strike, the term "fail secure" means
Discuss
 - A. The door unlocks when power is removed
 - B. The door locks when power is removed
 - C. The unit will never fail
 - D. The strike may be used when part of an alarm system
3. In DC circuits, capacitors are used mainly to
 - A. Isolate a transformer
 - B. Filter fluctuation voltage levels
 - C. Convert to DC to AC
 - D. Reverse series inductance
4. In parallel circuit the voltage across each branch
 - A. Is always equal to the source voltage
 - B. Depends on the current flow and resistance of each branch
 - C. Is inversely proportional to the total current flow
 - D. When totaled equals the source voltage

5. Infrared radiation is a form of
 - A. Sound energy
 - B. Heat energy
 - C. Microwave energy
 - D. Invisible energy
6. Is it permissible to run access control wiring in an elevator shaft?
7. Discuss
 - A. Yes
 - B. No
 - C. Yes, provided the wire is rated FT-4 or higher
 - D. Yes, if the wire is run in conduit
8. Is it permissible to run exposed non-metallic sheathed cable on a vertical wall?
9. Discuss
 - A. Yes
 - B. Yes, provided the cable has a heavy rubber coating to protect it
 - C. Yes, provided the cable is protected from physical damage up to 1.5 m from the floor
 - D. All of the above
10. Is it permissible to run security wire through the same hole as 120V wiring?
 - A. Yes
 - B. No
11. Microwave detectors cannot penetrate through
 - A. Metal and glass
 - B. Metal and fabric
 - C. Concrete
 - D. Metal
12. Explain segregation cable laying
13. Cable selection required for insulation should be based on the phase to phase to phase voltage applicable and the general classification of the system category. TRUE OR FALSE?
14. No matter what method is used for laying, cables must be segregate taking into account the voltage level and function. TRUEOR FALSE?

Practical question

1. Identify cable types
2. Lay cables as per the IEE regulations
3. Cables laying system is as per the environmental condition
4. Install firmness of the cables as per the standard operating procedure
5. Segregate cables as per the standard operating

11.3.2.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

Model of cable segregation arrangements

Cables

11.3.2.5 References (APA)

Cables for alarm and Safety Systems by Nexans.

Bolotinha, M. (2017). cable laying and pulling.

Edvard. (2016). 5 vital factors to correct cable selection and application.

11.3.5 Learning Outcome No .4 Mount accessories.

11.3.5.1 Learning Activities.

Learning Outcome #No 4	
Learning Activities	Special Instructions
• Labelling accessories as per their functions • Wiring accessories as per the design • Mounting control as per the standard operating procedure • Mounting accessories as per the system design • Enclosing control panel with metal case as per the OSHA Project; Mount accessories for CCTV security system	

11.3.5.2 Information Sheet No .4

Introduction

Security is a fundamental aspect of life to which every citizen has a right and is a subject of concern to all. Watchdogs and human guards have been used as a way of protecting property for a very long time despite not being the most effective ways. The introduction of Electric fencing, alarms and CCTV's, protection of property and control animals has become efficient.

Accessories used in security system

Accessories used in alarm security system are listed as follows;

1. Control panels and keypads: - Expansion modules, interface modules, door accessories control modules, transformer, enclosures, power supplies and batteries, cables, switches and programmers, control center and keypad accessories.
2. Detectors and accessories (find information this link:- https://us.boschsecurity.com/en/products/intrusionalarmsystems/detectorsandaccessories/detectorsandaccessories_24#section_3844123787)

Components of CCTV Systems

The following are the components of the CCTV systems

- Cameras;
- Lenses;
- Housings and mounts;
- Monitors;
- Switchers and multiplexers; and
- Video recorders.

Therefore information of electric fence accessories and CCTV accessories find in source:-CCTV Technology Handbook by U.S Department of Homeland Security and linkhttps://www.regalsecurity.co.za/STACH/uploads/2016/01/6_6_Fencing-Accessories.pdf respectively.

Security system control panels

Get information from this source:- <https://www.centurylink.com/asset/home/help/user-guides/2gig-go-control-panel-user-guide.pdf> -Wireless Security system by Nortek Security Control.

Insulation classes of enclosures

Definition of IP Codes (Ingress Protection)

It specifies an international system of classification for the sealing effectiveness of enclosures of electrical equipment from the intrusion into the equipment of foreign bodies (i.e tools, dust, fingers) and moisture.

Degrees of protection-first digit

The initial digit of the IP code shows the degree that a person are protected against contact with movable parts (other than smooth rotating shaft, etc.) and the degree that equipment is protected against solid foreign bodies getting into the enclosure.

Degrees of protection- second digit

Second digit shows the degree of protection of the equipment inside the enclosure against the harmful entry of moisture for example dripping, spraying, submersion.

IP Code Symbols

As illustrated in the chart below, the first digit column note the grid-like symbols next to number 5 and 6. In the second digit columns numbers 3 and 8 are symbolized teardrop shaped symbols, sometimes unenclosed (7-8).

11.3.5.3 Self-Assessment

1. What is the maximum number of bends allowed in a run of conduit?

Discuss

- a. Any combination of bends to a total of 360 degrees
- b. Any combination of bends to a total of 360 degrees, excluding offsets
- c. No more than four 90 degree bends
- d. Any amount is allowed

2. What is the maximum VA output of a class I transformer?

- a. 1000 V
- b. 100 VA
- c. 1.0 KVA

- d. 1000 VA
3. What is the minimum burial depth allowable for a communication cable in a vehicular area?
- 600 mm
 - 300 mm
 - 900 mm
 - 450 mm
4. What is the rule regarding cable penetrating the vapor barrier of a wall?
Discuss
- The cable must be rated FT-1 or higher
 - The cable must be rated FT-4 or higher
 - The cable must be rated CMP
 - The hole around the cable must be sealed
5. The initial digit of the IP code shows the degree that a person are protected against contact with movable parts TRUE OR FALSE?

Practical question

- Label accessories as per their functions.
- Wire accessories as per the design
- Mount control panel as per the standard operating procedure
- Mount accessories as per the system design
- Enclose control panel as per the OSHA

11.3.5.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Computer
- stationary

11.3.5.5 References (APA)

- 1.The Complete Guide To Waterproof IP Rating - IP44, IP54, IP55, IP65, IP66, IPX4, IPX5, IPX7
- 2.CCTV Technology Handbook by U.S Department of Homeland Security

11.3.6 Learning Outcome No .5 Terminate system cables

11.3.6.1 Learning Activities.

Learning Outcome No 5	
Learning Activities	Special Instructions
• Performing cable lugging as per the standards operating procedure. • Terminating cables as per IEE regulations • Terminating cables in the connector as per the design Project; Terminate system cables for alarm security system installation.	

11.3.6.1 Information Sheet No 6/L05

Introduction

It is important for PVC sheath to enter any to provide protection of the conductor insulation from damage. The sheath can easily be removed once in the enclosure since the enclosure offers mechanical protection for the cable insulation. Sufficient cable slack should be available in the ensure to ensure termination and remarking of the cables.

CABLE TERMINATION

Termination describes the particular point where a conductive device ends or starts. It may or not pass the carried electricity or signal onto another device at this point.

TERMINOLOGY IN CABLE TERMINATIONS

9. Indoor Termination–Dry; A termination intended for use where it is protected from solar radiation and precipitation and not subject to periodic condensation, or other excessive humidity (90% RH or more). May be installed in air conditioned or heated areas

10. Indoor Termination–Wet ;A termination intended for use where it is protected from direct exposure to both solar radiation and precipitation, but is subjected to climatic conditions that can cause condensation onto the termination surfaces.

3. Outdoor Termination; A termination intended for use where it is not protected from direct exposure to either solar radiation or precipitation.

Terminating Techniques

1. Screw Terminal

Is among the several methods of terminating conductors. The joint between the conductor and the terminal should be electrically and mechanically sound with no inclusion of pressure on either terminal or the conductor. The cable sheath need to be removed at a distance of 20 mm to prevent leakage of surface current hence enabling the flexibility at the termination and in the identification of the core colour.

If the conductor is small in relation to the terminal, the conductor must be doubled back fully, neatly on itself.

In case the two conductors are to be terminated jointly, it is important to place them side by side in the terminal. Besides, the terminal screw should bear down on both of them. See Figure 5

2. Screw Head and Nut and Washer Terminals

It is important forming the conductor into an eye by the use of round nose pliers when doing the termination of conductors under the screw heads or nuts. The eye needs to be a bit larger than the screw in terms of the diameter but rather smaller than the outside diameter of either the screw head, nut or washer. In case the eye is put in opposite direction way round, the screw's motion will tend to untwist the eye that is likely to lead to poor contact.

See Figure 6

3. Clamp Type Terminal

Used same way as screw type terminal though the clamping for the termination of larger conductors is heavier. Ribbing of the clamping to put small indents into the conductor hence providing better electrical and mechanical support.

Importance of terminations

- Prevents loose connections giving rise to heat.
- Stops heat travelling from its point of origin, along the conductor in both directions.
- Prevents insulation from becoming brittle, delicate and disintegrating.
- Prevents a high resistance joint.
- Prevent possible damage to equipment.
- Prevents possible electric shock.
- Prevents possible fire hazard.

For more information on terminations and its importance read in cables and Cable Terminations course Notes by SOLAS, 2013.

CABLE LUGGING

Cable lugging is achieved by use of silver sparkling metal at cables or between wires popularly known as Cable lugs. The cable lugs are applied when permanent, and direct fastening or not necessary. It is important to provide them with safety to avoid shocks or be covered to avoid damage the cable lugs and connectors hence preventing chances of short circuit.

Figure 7 below is an image of some popular cable lugs used every day in various appliances and places:



Figure 152: cable lugs

Source: <http://www.mgelectrica.com/what-are-cable-lugs/>

For tool used in cable termination find look at link;

<https://www.toolup.com/electricians-tools/cable-termination>

Tools Used in Cable Terminations

1. Electricians Pliers

Are used for gripping (due to serrated jaws), bending and twisting of conductors See Figure 8.

Strip Knife

A good quality one is used in removing the sheath from the various types of cables and flexible cords.

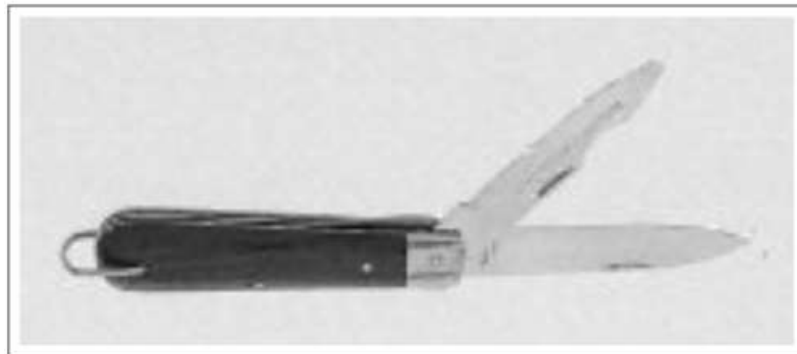
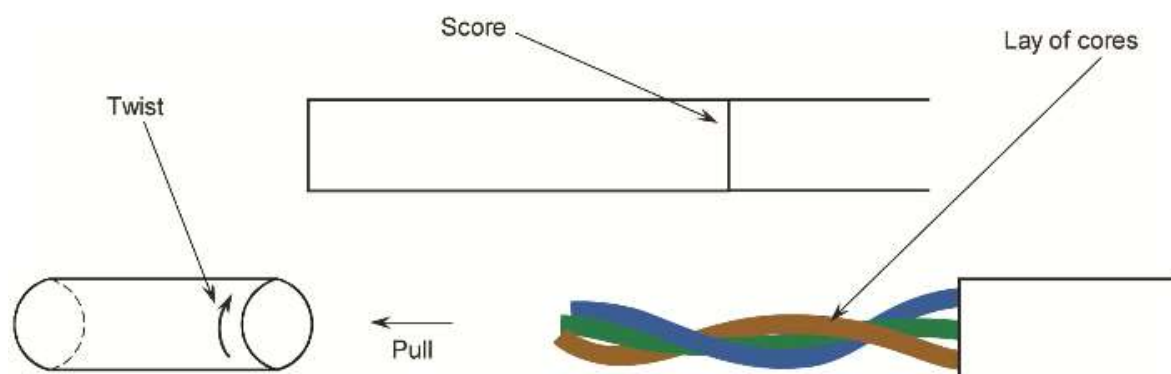


Figure 153:strip knife

Best done through scoring round the sheath at the point at which it must be remove. It is important never to cut through the sheath that could damage the insulation. The sheath may be removed in some cases by gently flexing at the scored point until it yields.



In case the sheath is quite long or tough to be removed, slitting it along its length would help in removing it.

10.3.2.4 Self-Assessment (assessment questions/evaluation question for the learning outcome)

1. What type of network would a cellular alarm back-up transmitter be connected to?
 - A. DVACS
 - B. Intranet

- C. Mutiplex
 - D. All of the above
 - E. None of the above
- 2. When checking the polarity of a phone line, the positive test lead of the meter should be connected to
 - A. Ring
 - B. Does not matter
 - C. Tip
 - D. With the source voltage disconnected
- 3. When correctly measuring a standard alarm power supply voltage your digital VOM reads +6.80 VDC. No devices are connected to the terminals. This means that

Discuss

 - A. The power supply is working
 - B. The positive lead of the meter is connected incorrectly
 - C. The voltage is to low for the system devices to function correctly
 - D. The wire gauge is too small
- 4. When measuring the continuity of an alarm circuit, the circuit should be

Discuss

 - A. Connected to the alarm panel with power on
 - B. Connected to the alarm panel with power off
 - C. Disconnected from the alarm panel
 - D. In alarm
- 5. When running cable in a drop ceiling, if you wish to cross a firewall

Discuss

 - A. You must use metallic sheathed cable
 - B. You must use FT-4 cable
 - C. You may penetrate the fire wall, as long as you seal the hole around the cable
 - D. You may not penetrate the firewall
- 6. When the plug on a properly installed 8 position jack is removed
 - A. The premises telephone lines will be seized
 - B. The premises telephone will operate normally
 - C. The telephone system cannot function properly
 - D. The line seizure function in not affected
- 7. The sheath can easily be removed once in the enclosure since the enclosure offers mechanical protection for the cable insulation TRUE OR FALSE
- 8. The joint between the conductor and the terminal should be electrically and mechanically sound with no inclusion of pressure on ether terminal or the conductor TRUE AND FALSE

Practical question

1. Perform cable lugging as per the standards operating procedure
2. Terminate cables as per the IEE regulations
3. Terminate cables in the connector as per the design

10.3.2.5 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Cable bender
- Cable cutter
- CCX crimper cutter multitool
- Crimping tools
- Cutting and crimping dies
- Hydraulic pumps.

11.3.2.5 References (APA)

SOLAS, 2013 Cable Terminations course Notes.

11.3.7 Learning Outcome No .6 Test and inspect security system

11.3.7.1 Learning Activities.

Learning Outcome #No 6	
Learning Activities	Special Instructions
• Identifying types of tests i.e continuity test, insulation resistance test, short circuit test arming and disarming tests. • Performing test as per IEE regulations. • Establishing firmness of the installation. • Performing continuity test. • Performing insulation resistance as per IEE regulations. Project: Test and inspect alarm security system installation	

11.3.7.2 Information Sheet No .6/LO6

Introduction

It is important to do inspection and testing of internal wiring installations at least every one year. Therefore, testing is process establishing the correctness electrical installation system by use of measuring instruments. While carrying out inspection and testing of internal wiring installations, following points should be checked:

Incoming Service Line Connection

Check and ensure the following:

- a) Service line coming in to the premises is properly terminated and brought in
- b) Check for fuse wire rating on each of the phases so as to ensure it is of correct rating
- c) Check for wire sizes to be of correct size to carry the required current
- d) Check for earthing to be properly maintained at the service line side

Main switch board

A main switch board exists at the point of termination of service line. Supply is provided through this board in to the premises.

- a) Ensure that the main switch board is closer to the point of supply in the premises
- b) Check for fuses / circuit breakers used of adequate sizes for all phases
- c) Check for correct ON/OFF working of Main Switch. A main switch plays a very important role as it helps to switch off the complete supply

of the premises in case of emergency / repairs. It should always be in good working condition. Check for any mechanical faults in switching operations that might cause it to remain continuously in ON state. This may be problematic in emergency cases when the electrician wants to switch the supply off.

- d) Ensure that the Switch board assembly is well covered to protect against rain / weather conditions
- e) Inspect to see that you are clearly able to trace the neutral and earthing wires in different colour.
- f) Inspect the electricity meter connections are properly fastened.

Internal Wiring Circuits

Internal Wiring Circuits are to be checked for following points:

- a) Ensure that each circuit branching out of Main Switch board has a connected load of not more than 800 watts or 10 points.
- b) Test for insulation resistance of conductor and earth to be as per IEE specifications.
- c) Electrical resistance from connection with Earth electrode should not be more than one ohm.
- d) Ensure metallic covering of iron clad switches, distribution boards are properly feathered.
- e) Test that that leakage current is less than $1/5,000$ of maximum supply current.

Types of tests in security system

Insulation Resistance Test: Testing insulation resistance of a wire is done in ensuring that there is no leakage current flowing through it. The test is carried out using “Megger” instrument. The main switch is put in OFF and circuiting of all the lighting connections done. The Megger is connected between live and the earth. Megger is then rotated hence generating voltage and noting of the reading on the dial of Megger done.

Figure 1 shows demonstration of insulation resistance test

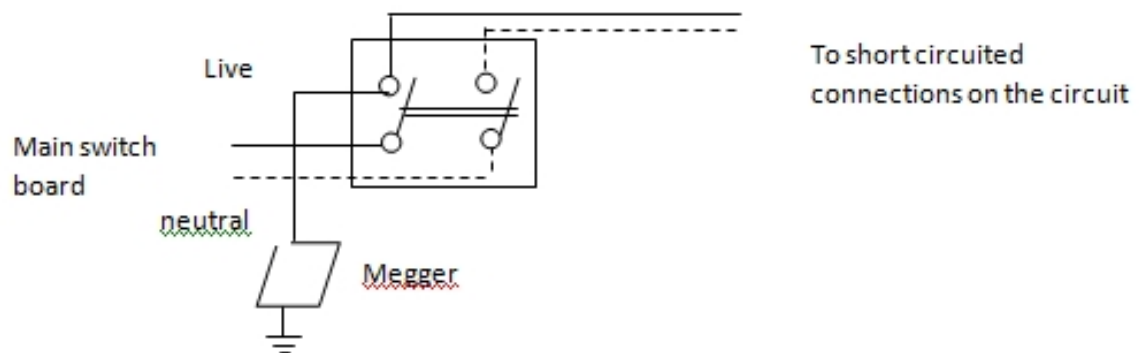


Figure 154 Insulation resistance:

Earth Continuity Test:

In this test, metal parts, metal clad switches and the conduits should be connected to the earth. In case this lacks, there is likelihood of severe damage to the entire installation.

For short circuit test and continuity test get information from source:

<http://engineering.electrical-equipment.org/safety/inspection-and-testing-of-wiring-installations.html>

Arming and Disarming Your Security System

Arming your system means before you can arm you system all your doors and windows must be closed .close all doors and windows and sure no one is present in areas with motion sensors. Press away key to arm all the sensors, including perimeter and interior sensor. The steps of arming your system is as follows;

Arming Prior To Leaving the Building:

1. Verify that the READY light is on.
2. Press the ARM command (key #1) and your Personal Authorization Code (PAC).
3. The control station will begin beeping and the red ARMED light will come on indicating that the System is armed.
4. Leave the building immediately.

Disarming you system means when the system is in the armed stay mode , enter your four-digit security pin to disarm the system ,after you enter PIN , the LCD display will blank and the ready light will be green except panic buttons and smoke sensors.

The steps of disarming your is as follows;

1. After entering through a delay zone, the control station will sound a steady entrance tone

Warning you to disarm the system.

2. Press the ARM command (key # 1) and you're PAC.
3. The red ARMED light should be off indicating that the system is disarmed. If the ARMED light does not go off, press the (star key *) and restart the disarming procedure.

Arming the System Without Leaving The Building and Turning The Interior Protection Off

1. Press the INTERIOR command (key # 4) and your PAC.
2. The yellow INTERIOR OFF light will come on.
3. Arm the system by using the ARM command.

NOTE: When you disarm, the interior automatically returns to INTERIOR ON unless your

Installer has programmed it differently

Monitoring Zones with The System Disarmed: (Chime Mode)

To Turn Monitor On:

1. The system must be disarmed.
2. Press the MONITOR command (key # 6) and your PAC.
3. The control station will beep three times each time a zone is opened.

To Turn Monitor Off:

1. Press the MONITOR command (key # 6) and your PAC.

What to do for A False Alarm:

1. Press the ARM command (key # 1) and your PAC.
2. The alarm should turn off. If it is not, press the (star key *) key and begin again.
3. Notify the appropriate authorities of the alarm immediately.

Diagnosing A Problem Or Open Zone

Zone Status Display:

1. Lift the control station door to reveal the zone location label.
2. Press the ZONE STATUS command (key # 2) and your PAC.
3. The lights on your control station will now become zone status indicators.
4. If a light is on, it is an indication that a zone is open.

Alarm Memory Display:

1. Lift the control station door to reveal the zone location label.
2. Press the ALARM MEMORY command (key # 3) and your PAC.
3. The lights on your control station will now become alarm memory indicators.
4. Any light that is on indicates the zone that caused the most recent alarm.
5. You may reset the blinking ARMED light by pressing the (star key *).

Electrical Power and the Standby Battery:

Manually Testing the Battery:

1. Press the SMOKE/BATT command (key # 7) on your PAC.
2. Wait 5 seconds.
3. If the battery is fully charged, the power light will be on without blinking. If the battery is weak, the POWER light will start blinking and the control station will beep rapidly.
4. The (star key *) key may be pressed to silence the control station.

Arming and disarming tests;

This kind of test entails testing the Protection Sensors, the following steps are followed;

- 1.The system must be disarmed and all zones must be secure.
- 2.. Press the test command (key # 8) and inter your PAC.
- 3.Open any protected door or window. The control station will beep and the green READY light will be off.
4. Close the opened door or window. The control station will stop beeping and the READY light will be back on.
- 5.Begin at step 3 and test the remaining sensors.
6. Press the (star key *) when finished testing

11.3.2.4 Self-Assessment (assessment questions/evaluation question for the learning outcome)

1. Where should an alarm installer keep her licence
 - A. The truck glove box
 - B. Her briefcase
 - C. Safety deposit box
 - D. None of the above
2. Which are the following formats does not support a four digit account number?
 - A. CID
 - B. 4/2
 - C. SIA
 - D. 3/1
3. Which dialer format will transmit information the most quickly?
 - A. DTMF
 - B. JSKY
 - C. FSK
4. Which of the following are the two most common acknowledge tones given by the alarm receiver to the digital dialer?
 - A. 1000 Hz, 1200 Hz
 - B. 1400 Hz, 2300 Hz
 - C. 1000 KHz, 1200 KHz
 - D. 1400 KHz, 2300 KHz
5. Which of the following best describes the rule for running wire in a return-air plenum ceiling? Discuss
 - A. All conductors must be in conduit
 - B. All conductors must be either in conduit or rated for installation in plenum ceilings

- C. Conductors may be run in plenum ceilings provided runs do not exceed 2.50m
 - D. All of the above
- 6. Which of the following does not provide cut-line protection for central station
 - A. Digital dialer
 - B. DVAV
 - C. Direct wire
 - D. Internet
- 7. Which of the following groups of ambient conditions are those to be cautious of when installing PIR motion detectors?

Discuss

 - A. Loose-fitting doors, moving water in pipes, high-pitched noises
 - B. Fluorescent lighting, high humidity or a plasma television
 - C. Objects with rapidly changing temperatures, ie fax machines, heater
 - D. Carpeted areas, sound-absorbing wall covering
- 8. Which of the following is not true
 - A. Insulation thickness determines the current capacity of a wire
 - B. A large conductor can carry more current
 - C. Current flow requires a source voltage
 - D. The polarity of a wire's magnetic field depends on the voltage polarity
- 9. Which of the following is an environmental sensor?

Discuss

 - A. Pull station
 - B. CO detector
 - C. Digital communicator
 - D. Floor stress sensor
- 10. Which of the following is true?
 - A. Only accidents involving blood or penetrating trauma, electrocution, chemical burns or death must be reported to the WCB
 - B. Minor sprains or cuts need not be reported
 - C. All work related injuries must be reported
 - D. All of the above
- 11. Which of the following is true?
 - A. Only non-magnetic materials will shield magnetism
 - B. A magnetic field exists around any current-carrying conductor
 - C. A magnetic field can only be established when a coil is used
 - D. Electromagnetism occurs using only DC and not AC

12. Which of the following is true? (At normal temperatures)
- A. All inanimate objects absorb infrared radiation
 - B. All objects give off infrared radiation
 - C. Only moving objects give off infrared radiation
 - D. Only living beings give off infrared radiation
13. Who is not exempt from having security employee license
- A. You
 - B. Yo mama
14. Testing insulation resistance of a wire is done in ensuring that there is no leakage current flowing through it. TRUE OR FALSE?
15. Switching is process establishing the correctness electrical installation system by use of measuring instruments TRUE OR FALSE?

Practical question

1. Identify type of tests
2. Perform test as per the IEE regulations
3. Establish Firmness of the installation
4. Perform continuity test
5. Perform insulation resistance test as per the IEE regulations

2.3.2.4 Tools, Equipment, Supplies and Materials for the specific learning

outcome

- Multimeter
- Insulation resistance tester(MEGGER)
- Key pads.

11.3.7.5References (APA)

ARMING AND DISARMING YOUR SECURITY SYSTEM

https://www.alarmesecuricom.com/images/produits/pdf/moose_z1100_quick_en.pdf

CHAPTER 12. SOLAR SYSTEM INSTALLATION/INSTAL SOLAR SYSTEM.

12.1 Introduction of the Unit of Learning / Unit of Competency

This unit covers the competencies required by the trainee to install a solar PV system. These includes ; designing solar PV system installation, fixing solar system components, mounting solar panel(s), laying cables, terminating electrical cables and testing the completed solar PV installation.

The solar PV system installation works on the same principles as the electrical installations that are supplied by mains electricity but in this case they use energy derived from the Sun's radiation to generate electricity using photo-voltaic cells to convert the light energy to DC Electricity. The energy from the sun is free and hence the consumer can reduce the cost of electricity paid to the Kenya Power and realize significant savings. Solar PV system installations are ideal for supplying clean and reliable power in OFF-GRID areas where there are no power transmission lines for mains electricity and the alternative of using Diesel generators is too expensive. The unit intends to produce competent solar operators who can install and maintain solar PV systems.

12.2 Performance Standard

Determining the daily energy demand and design a solar PV system installation as per energy demand and IEE regulations. Fix the solar PV system components as per the design. Mount the Solar PV modules with reference to site characteristics. Lay and terminate electrical cables in accordance with the IEE Regulations. Test on the completed solar PV installation in accordance with the IEE Regulations observing safety precautions as per potential hazards and IEE regulation

12.3 Learning Outcome

12.3.1 List of Learning Outcomes

- a) Design Solar system installation
- b) Fix solar system accessories
- c) Mount solar Panel(s)
- d) Layout Electrical cables
- e) Terminate Electrical cables
- f) Test and Inspect Solar PV system installation

12.3.2 Learning Outcome No: 1 Design solar PV system installation

12.3.2.1 Learning Activities

Learning Outcome #No: 1 Design solar PV system Installation						Special Instructions
Learning Activities						
A : <u>DESIGN ACTIVITIES</u>						
1. A hotel in Marsabit away from the grid power supply has the following final circuits to be supplied by a solar PV system:						
Item	Description	Rating	Number	Voltage level	Usage (hours)	
1	Lighting points	10W	10	12V,DC	8	
2	Refrigerator	50W	1	240V,AC	12	
3	Radio	10W	1	12V,DC	8	
4	Colour TV	40W	1	240V,AC	6	
The hotel operates seven days a week. A 5 day system autonomy is required and that a 20% daily depth of discharge is acceptable. An occasional 100% of discharge is acceptable.						
Design the solar PV system of the hotel determining;						
a) The size of solar array						
b) The size of battery bank						
c) The size of charge controller						
d) The size of inverter						
B : <u>PRACTICAL EXERCISE</u>						
Figure 1 shows a domestic solar PV Installation, system layout.						
a) Mount the solar module						
b) Draw a wiring diagram						
c) Complete the wiring of the control gear in the correct sequence						
d) Using PVC Sheathed wiring system, install the circuit such that;						
i) Two lamps L ₁ and L ₂ are controlled by two two-way switches S ₁ and S ₂ from the AC supply.						
ii) Lamp L ₁ is controlled by a switch S ₃ from the D.C supply.						

b) Refer to appliance's power ratings and hours of use

c) Refer to Solar PV Catalogue and data sheets

d) Carry out a site survey

iii) The socket outlets are connected in Ring circuit from the CCU. e) Carry out the following tests; i) Continuity test ii) Insulation resistance test iii) Polarity test	

12.3.2.2 Information Sheet No: 1.

Introduction

This unit covers the competencies required by the trainee to use tools and equipment to install a solar PV system. These includes ; designing solar PV system installation, fixing solar system components, mounting solar panel(s), laying cables, terminating electrical cables and testing the completed solar PV installation.

DEFINITION OF KEY TERMS

Solar resource:

- Solar irradiance is the sun's radiant energy incident on a surface of unit area expressed in units of kW/m^2
- Solar irradiation (energy) or solar insolation is equal to total solar irradiance over time (kWh/m^2)
- Peak sun hours (PSH) are equivalent to the number of hours that the solar irradiance would be at a peak level of 1 kW/m^2

Applications of Solar PV

Consumer electronics

- Calculators, radios and watches

Rural development

- Health care facilities, schools and community centers

Off-grid power for homes

- Lighting and appliances for remote homes and facilities

Agricultural uses

- Water pumping and irrigation
- Fence charging

Lighting

- Signs, street lights, security and parking areas
- Transportation, navigation and aviation aids

Specialty applications

- Remote monitoring, railway signals, and security systems

- Telecommunications facilities
(e.g., cell phone towers)
- Grid-connected systems
 - Residential, commercial and utility-scale

SAFETY HAZARDS IN SOLAR PV INSTALLATION WORK

Three major safety hazards

- Physical hazards (e.g., unprotected falls)
- Electrical hazards (e.g., shocks and sparks)
- Chemical hazards (e.g., burns and explosions)

Workers must apply safe practices when installing and maintaining a PV system to avoid all types of hazards

Methods, processes/procedures/guidelines

A site survey checklist is used to document site conditions:

- Determine locations for installing PV arrays and other equipment
- Assess the condition of roofing and structural support
- Assess the possible causes of shading issues
- Environmental factors
- Determine the daily electrical energy demand for the client's installation.
- Identify relevant building codes and local requirements e.g. county government

Content

All PV modules must be marked with the following information (if not, then they might not be from a reputable source):

1. Open-circuit voltage (V_{oc})
 2. Short-circuit current (I_{sc})
 3. Operating voltage (V_{mp})
 4. Operating current (I_{mp})
 5. Maximum power (P_{mp})
- Polarity of terminals
 - Maximum permissible system voltage

PV modules are connected electrically in series to build voltage output
Series strings of PV modules are connected in parallel to build current and power output

12.3.2.3 Self-Assessment (assessment questions/evaluation question for the learning outcome)

1.



Where is the world's largest solar panel power plant found?

Discuss

- a. Mojave Desert, United States
- b. Sonoran Desert, United States
- c. Sahara Desert, North Africa
- d. Kalahari Desert, South Africa

2.



3.

What is the major element found in a photovoltaic (PV) cell?

- a. Hydrogen
- b. Nitrogen
- c. Silicon
- d. Carbon

4. What is the most common way that solar energy is converted into electricity?

Discuss

- a. Concentrating solar power plants assembled around the world
- b. Photovoltaic (PV) cells that use semiconductor technology

- c. Chemical reactions performed in laboratories that harness energy from the sun
 - d. Through the atmosphere as sunlight crosses the earth's ozone layer
5. What is the purpose of an inverter in an active solar system?
- Discuss
- a. Convert alternating current (AC) to direct current (DC)
 - b. Convert direct current (DC) to alternating current (AC)
 - c. Change the flow of electrons from positive to negative
 - d. Change the flow of electrons from negative to positive
6. Amorphous Silicon (a-Si), Cadmium Telluride (CdTe), Polycrystalline Silicon (Poly-Si), Monocrystalline Silicon (Mono-Si), and Copper Indium Selenide (CIS).
7. What are the five key electrical output parameters for a PV module?
8. Describe open-circuit voltage, short-circuit current and operating voltage, current, power at maximum power point.
9. Describe safety hazards in solar PV installation work
10. What are the Methods, processes/procedures/guidelines involves in PV installation?

Practical question

- 1. Determine Solar panel rating is determined in line with the size of the load
- 2. Determine mounting position in line with the expected output
- 3. Determine Charge controller as per the size of the load and panel output.
- 4. Design Power storage system as per the load size.
- 5. Select inverter size as per the load size
- 6. Perform Cable sizing in line with the IEE regulations

12.3.2.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Module array
- Charge controller
- Battery
- Inverter
- cables and accessories
- AC/DC switches
- Socket outlets
- Lampholders
- Ceiling roses
- Patresses
- Consumer control unit

12.3.2.5 References (APA)

Author, (year), title, publisher, City

Suggested References

- IEE regulations 16th Edition

- Electrical Installation and Workshop Technology Vol. I by F.G. Thomson
- Solar Manuals by Mark Hankins
- Solar PV manuals by KERE A

12.3.3 Learning Outcome No2 Fix solar system accessories

12.3.3.1 Learning Activities

Learning Outcome #No: 2 Fix Solar system accessories	
Learning Activities	Special Instructions
Figure 1 shows a domestic solar PV Installation, system layout. a) Mount the solar module b) Draw a wiring diagram c) Complete the wiring of the control gear in the correct sequence d) Using PVC Sheathed wiring system, install the circuit such that; i) Two lamps L_1 and L_2 are controlled by two two-way switches S_1 and S_2 from the AC supply. ii) Lamp L_1 is controlled by a switch S_3 from the D.C supply. iii) The socket outlets are connected in Ring circuit from the CCU. e) Carry out the following tests; i) Continuity test ii) Insulation resistance test iii) Polarity test	a) Refer to appliances power ratings and hours of use b) Refer to Solar PV Catalogue and data sheets c) Carry out a site survey

2.3.2.2 Information Sheet No: 1.

Introduction

This unit covers the competencies required by the trainee to use tools and equipment to install a solar PV system. These includes ; fixing solar system component such as charge controllers, inverters, mounting solar panel(s), laying cables, terminating electrical cables as per the design.

DEFINITION OF KEY TERMS

1. CONDUIT

A conduit is a tube or pipe in which conductors are run. In effect, the conduit replaces the PVC sheathing of a cable, providing mechanical protection for the insulated conductors. There are three types of conduits: metal, flexible (metal) and non-metallic (PVC).

SAFETY HAZARDS IN FIXING SOLAR PV SYSTEM ACCESSORIES

- Three major safety hazards
 - Physical hazards (e.g., cuts and bruises, burns from contact with hot surfaces, unprotected falls)
 - Electrical hazards (e.g., shocks and sparks)
 - Chemical hazards (e.g., contact with corrosive substances like battery acids, burns and explosions)
- Workers must apply safe practices when installing and maintaining a PV system to avoid all types of hazards.
- The workers must use relevant PPE's like leather gloves, dust coats, rubber soled work boots, clear eye goggles

Methods, processes/procedures/guidelines

- a) The conduit system for each circuit of an installation must be completely erected before any cables are drawn in.
- b) Inspection-type fittings must always be accessible for the removal or addition of cables.
- c) The number of cables drawn into a conduit may be achieved by selecting the size of conduit using the tables shown in the guidance notes to the regulations. The system used applies to trunking as well as conduit. The IEE On-site Guide gives various tables to enable the designer to establish the number of conductors that may be run in conduit or trunking, taking into consideration space factor and the ease of drawing cable in. This system of tables is based on the requirement that, in a conduit run, there should be 40% of cable and 60% of air. In trunking, the cable should only occupy 45% of the available space. So, for example, if eight 2.5 mm 2 stranded conductors were to be installed in a short straight length of conduit, the factor for the cable (43) would be multiplied by the number of conductors (8) to give an overall cable factor of $43 \times 8 = 344$. This overall factor is now used to find a suitable conduit size by comparing it with the conduit factors and selecting a size. In this instance the nearest conduit factor given is (460), giving a conduit size of 20 mm. This method is used for longer lengths with bends, but a different set of tables and factors are used. The same process is also used for trunking capacity.
- d) 4. When conduit is bent, the radius of any bend must not be less than 2.5 times the outside diameter of the conduit
- e) If non-inspection elbows or tees are used, they must be installed only at the end of a conduit immediately behind a luminaire (light fitting) or outlet box, etc., of the inspection type. Alternatively one solid elbow may be located not more than 500 mm from a readily accessible outlet box in a conduit not exceeding 10 m between two outlet points providing that all other bends do not add up to more than 90°C

- f) The ends of conduit must be reamed and entries to boxes and accessories must be bushed in order to prevent damage to cables.
- g) As we have already seen, a conductor carrying a current has a magnetic field around it, and as a.c. causes the field to change direction continually the field will cut across any metal close to it and in doing so induce e.m.f.'s and eddy currents (heating) in that metal. Running another conductor close to the first with its current flowing in the opposite direction will cancel out the fields. Hence cables of a.c. circuits installed in steel conduit should have all lines and neutral (if any) bunched in the same conduit.
- h) Flexible metal conduit must not be used as a circuit-protective conductor; a separate such conductor must be run.
- i) Non-metallic conduits must not be installed where extremes of ambient temperature are likely to occur.
- j) The supports for rigid PVC conduit must allow for expansion and contraction of the conduit.
- k) Drainage points should be provided at the lowest point of a metallic conduit installation to allow moisture due to condensation to drain away.

A site survey checklist is used to document site conditions:

- Determine locations for installing PV arrays and other equipment
- Select the control gear: charge controller, inverter, consumer control unit, switches and circuit breakers as per the design specifications.
- Select the cable as per the ratings indicated in the design
- Observe the safety precautions on use Environmental factors
- Determine the daily electrical energy demand for the client's installation.
- Identify relevant building codes and local requirements e.g. county government

Content

Cables for fixing wiring

In many existing installations, old cables can still be found insulated with rubber with an outer sheathing of lead, cotton or rubber. This type of cable for fixing wiring is no longer manufactured. A modern insulating material for cables is polyvinyl chloride (PVC). Some cables also have a PVC sheath. PVC-insulated single-core cables (singles) are used when the installation is to be run in conduit or trunking. Another type of fixed wiring cable is mineral-insulated metal-sheathed (M.I.M.S.) cable. The most popular version of this cable has copper conductors and a copper sheath (M.I.C.S.) it is also available with an overall PVC covering. This is a very strong and long-lasting type of cable.

Terminations

When a cable conductor is finally connected to the apparatus it is supplying, a safe and effective termination of that conductor must be made.

PVC singles into screw terminals

The insulation should be removed only far enough to allow the conductor to enter the terminal. Do not leave bare conductor showing outside the terminal

Take care not to score the conductor surface when removing the insulation as this may cause the conductor to break if moved.

PVC twin and three-core with earth

In this case, although the final connection into screw terminals is the same as for singles, care must be taken not to damage the conductor insulation when removing the outer sheath.

Two methods used are as follows:

1. using a sharp knife, slice the cable lengthwise, open the cable up and cut off the sheath.
2. With a pair of side cutters, split the end of the cable and hook out the end of the earth conductor. This may then be held with a pair of pliers and pulled backwards along the cable, splitting open the sheath. Excess sheath may then be cut away.

12.3.3.4 Self-Assessment (assessment questions/evaluation question for the learning outcome)

1. What is the purpose of an inverter in an active solar system?

Discuss

- A. Convert alternating current (AC) to direct current (DC)
- B. Convert direct current (DC) to alternating current (AC)
- C. Change the flow of electrons from positive to negative
- D. Change the flow of electrons from negative to positive

2. What is a disadvantage of solar energy?

Discuss

- A. The amount of sunlight that arrives at the earth's surface is not constant
- B. A large surface area is required to collect the sun's energy at a useful rate
- C. Some toxic materials and chemicals are used in the manufacturing process of photovoltaic (PV) cells
- D. All of the above are disadvantages

3. Describe the correct method of cutting a thread on a conduit end.
4. Explain, with the aid of sketches, why all lines and neutral (if any) of a.c. circuits must be drawn into the same metallic conduit or trunking.
5. What is meant by 'segregation' of circuits and how is it achieved in trunking?
6. Cable is a tube or pipe in which conductors are run TRUE OR FALSE?

7. It is not a must for workers to apply safe practices when installing and maintaining a PV system to avoid all types of hazards TRUE OR FALSE?

Practical question

1. Mount Charger controller as per the design
2. Install Solar batteries as per the design
3. Fix Power diodes as per the design
4. Install inverter as per the design

2.3.2.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Module array
- Charge controller
- Battery
- Inverter
- cables and accessories
- AC/DC switches
- Socket outlets
- Lamp holders
- Ceiling roses
- Patresses
- Consumer control unit
- Pliers
- Side cutters
- Screw drivers
- Ball pein hammer
- Cross pein hammer
- Spirit level
- Tape measure
- gimlet

12.3.3.5 References (APA)

Author, (year), title, publisher, City

Suggested References

- IEE regulations 16th Edition
- Electrical Installation and Workshop Technology Vol. I by F.G. Thomson
- Solar Manuals by Mark Hankins
- Solar PV manuals by KEREAA
- Electrical Installation work by Brian Scaddan

12.3.4 Learning Outcome No3. Mount solar panel

12.3.2.1 Learning Activities

Learning Outcome #No: 3 mount solar panel	
Learning Activities	Special Instructions
Select the appropriate tools required in mounting a given solar panel Mount the solar panel as per the given procedure	Guide the learners with procedures

12.3.2.2 Information Sheet No: 1.

Introduction

This unit covers the competencies required by the trainee to use tools and equipment to install a solar PV system. These includes ; fixing solar system component such as charge controllers, inverters, mounting solar panel(s), laying cables, terminating electrical cables as per the design.

DEFINITION OF KEY TERMS

2. CONDUIT

A conduit is a tube or pipe in which conductors are run. In effect, the conduit replaces the PVC sheathing of a cable, providing mechanical protection for the insulated conductors. There are three types of conduits: metal, flexible (metal) and non-metallic (PVC).

Safety hazards in fixing solar pv sytem accessories

- Three major safety hazards
 - Physical hazards (e.g., cuts and bruises, burns from contact with hot surfaces, unprotected falls)
 - Electrical hazards (e.g., shocks and sparks)
 - Chemical hazards (e.g., contact with corrosive substances like battery acids, burns and explosions)
- Workers must apply safe practices when installing and maintaining a PV system to avoid all types of hazards.
- The workers must use relevant PPE's like leather gloves, dust coats, rubber soled work boots, clear eye goggles

TITLE: PV module orientation and tilt angle

OBJECTIVE: To observe the effects of orientation and tilt angle on PV module output

: To understand how the angle of incidence affects the output of a solar PV array

PROCEDURE:

1. Using an inclinometer place a PV module at a tilt angle of 15° on the pole module mount, the module should be oriented to face south.
2. Take the irradiance reading and record.
3. Measure the V_{OC} and I_{SC} output of the PV module using a multimeter/clamp meter. Observe the safety of the meter by setting it to higher respective scale readings.
4. Record the readings.
5. Change the tilt angle from 15° to 30° , 45° and 60° , record the readings.
6. While maintaining the 15° tilt angle change the orientation of the module to east, record the readings.
7. Repeat the above procedure with orientations to the west and north, record the readings.
8. Compare the readings; note the minimum and maximum values.

Module rating.....	Irradiation.....	Orientation.....	Orientation...	Orientation....
Parameter measured/Tilt angle	15° - South	30° - South	45° - South	60° - South
V_{OC} (V)				
I_{SC} (A)				

Module rating...	Irradiation.....	Orientation.....	Orientation...	Orientation...
.....	...			...
Tilt angle	15° - South	15° - East	15° - West	15° - North
V_{OC} (V)				
I_{SC} (A)				

12.3.2.4 Self-Assessment (assessment questions/evaluation question for the learning outcome)

1. Which of the following is a practical use for solar energy?
2. Discuss
 - a. Heating swimming pools
 - b. Cooking hot dogs
 - c. Powering road signs
 - d. All of the above

3. How long does it take for sunlight to travel from the sun to the Earth?

Discuss

- A. 8 seconds
- B. 8 minutes
- C. 8 hours
- D. 8 days

4. More energy from the sunlight falls on the Earth in _____ than the total energy used by the entire population of the planet in one year.

Discuss

- a. 1 hour
- b. 5 hours
- c. 10 hours
- d. 24 hours

5. State any three types of modules

6. Explain the limitations of solar pv systems

7. Describe the effects of temperature on the output of solar modules

8. Explain why the 'tracking' mount is not used in solar home systems

9. Sketch the I-V curve of a solar module

10. A conduit is a tube or pipe in which conductors are run TRUE OR FALSE?

Practical question

- 1. Adhere to slanting angle in solar panel installation
- 2. Determine Solar panel positioning by the expected output
- 3. Determine solar panel connections by the expected output

16. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Module array
- Charge controller
- Battery
- Inverter
- cables and accessories
- AC/DC switches
- Socket outlets
- Patresses
- Pliers
- Side cutters
- Screw drivers
- Ball pein hammer
- Cross pein hammer
- Spirit level
- Tape measure
- gimlet

12.3.4.5 References (APA)

Author, (year), title, publisher, City

Suggested References

- IEE regulations 16th Edition
- Electrical Installation and Workshop Technology Vol. I by F.G. Thomson
- Solar Manuals by Mark Hankins
- Solar PV manuals by KEREAA
- Electrical Installation work by Brian Scaddan

12.3.5 Learning Outcome No4 lay electrical cables

12.3.2.1 Learning Activities

Learning Outcome #No: 4 lay Electrical cables	
Learning Activities	Special Instructions
Identify and select the electrical cables for mounting a job Install PVC Heavy gauge conduct lay cables for the circuit	

12.3.2.2 Information Sheet No: 1.

Introduction

This unit covers the competencies required by the trainee to use tools and equipment to install a solar PV system. These includes; fixing solar system component such as charge controllers, inverters, mounting solar panel(s), laying cables, terminating electrical cables as per the design.

TITLE: LAYING OF ELECTRICAL CABLES

OBJECTIVE: To install PVC Heavy gauge conduit lay cables for the circuit indicated in Fig as per the design.

To mount accessories and

control gear for the circuit as per the layout diagram.

PROCEDURE:

1. Using a chalk, draw the route of the PVC conduit on the installation board.
3. Mark out the location of the accessories and switchgear components on the board as per the dimensions given.
4. Measure the conduit sections and cut to the given dimensions using a hacksaw and smoothen the ends.
5. Make the required 90⁰ bends on the conduit using the 20mm bending spring.
6. Mount the conduits on the board using the spacer bar saddles making sure that they are uniformly spaced and the conduit is firmly fastened.
7. Terminate the conduits to the accessories using the half threads and nuts for a smooth and firm termination.
8. Draw in the cables into the conduits as per the wiring diagram using a steel tape and draw-in wire, ensure that you have 10 cm at each end of the conduit for termination on to the accessories and switch gear.
9. Clear the working area of any waste materials and dispose them in the waste bins.

DEFINITION OF KEY TERMS

3. CONDUIT

A conduit is a tube or pipe in which conductors are run. In effect, the conduit replaces the PVC sheathing of a cable, providing mechanical protection for the insulated conductors.

There are three types of conduits: metal, flexible (metal) and non-metallic (PVC).

Safety hazards in fixing solar pv system accessories

- Three major safety hazards
 - Physical hazards (e.g., cuts and bruises, burns from contact with hot surfaces, unprotected falls)
 - Electrical hazards (e.g., shocks and sparks)
 - Chemical hazards (e.g., contact with corrosive substances like battery acids, burns and explosions)
- Workers must apply safe practices when installing and maintaining a PV system to avoid all types of hazards.
- The workers must use relevant PPE's like leather gloves, dust coats, rubber soled work boots, clear eye goggles
- 1. The type of insulation and sheathing or covering of every cable must be selected so that the cable or Conductor is protected against heat, corrosion or mechanical damage, depending on the situation.
- 2. Cables and conductors must be chosen to suit the voltage and current rating of the circuit.
- 3. Cables and conductors must be chosen such that the voltage drop between the intake position and any point in the installation does not exceed 3% of the supply voltage for lighting and 5% of the supply voltage for power; that is, for a 230 V installation, the voltage drop must not exceed 3% of 230 V $\square$ 6.9 V for lighting and 5% of 230 V $\square$ 11.5 V for power.
- 4. Cables passing through wooden joists should be 50 mm below the top or above the bottom of the joist
- 5. Where cables pass through holes in metalwork, the hole should be bushed to prevent any abrasion of the cable.
- 6. Cables should not be installed in a lift shaft unless they are part of the lift installation.

Methods, processes/procedures/guidelines

1. The type of insulation and sheathing or covering of every cable must be selected so that the cable or conductor is protected against heat, corrosion or mechanical damage, depending on the situation.
2. Cables and conductors must be chosen to suit the voltage and current rating of the circuit.
3. Cables and conductors must be chosen such that the voltage drop between the intake position and any point in the installation does not exceed 3% of the supply voltage for lighting and 5% of the supply voltage for power; that is, for a 230 V installation, the voltage drop must not exceed 3% of 230 V $\square$ 6.9 V for lighting and 5% of 230 V $\square$ 11.5 V for power.

4. Cables passing through wooden joists should be 50 mm below the top or above the bottom of the joist
5. Where cables pass through holes in metalwork, the hole should be bushed to prevent any abrasion of the cable.
6. Cables should not be installed in a lift shaft unless they are part of the lift installation.
7. Cables – sheathed and unsheathed and/or armoured – must be supported according to the requirements shown in the appropriate IEE Regulations On-site Guide tables.
8. Every cable must be selected such that it can withstand the normal ambient temperature of its surroundings.
9. Where cables are to be connected to bus-bars, 150 mm of the insulation should be removed and replaced with heat-resisting insulation. This applies only if the original insulation is of general-purpose rubber or PVC.
10. Care must be taken to select the correct type of cable for use in flammable or explosive situations.
11. In order to ensure that fire cannot spread, any holes through which cables pass must be made good to the full thickness of the floor, wall, ceiling, etc.
12. Cables and conductors must be chosen carefully in order to avoid damage by corrosion.
13. Every core of a cable used for fixed wiring should preferably be identified throughout its length, or if this is not possible, by sleeves or discs at its terminations.
14. All terminations of cable conductors must be mechanically and electrically sound.
15. Care must be taken to avoid contact between aluminium and copper conductors, unless adequate precautions have been taken to prevent corrosion.
16. Cables buried in walls at a depth less than 50 mm must be enclosed in earthed metallic conduit, metallically protected from penetration by nails or screws etc., or protected by a 30 mA RCD.

ISOLATION AND SWITCHING

Part 4 of the IEE Regulations deals with the application of protective measures for safety and with the regulations for switching devices or switchgear required for protection, isolation and switching of a consumer's installation. The consumer's main switchgear must be readily accessible to the consumer and be able to:

- isolate the complete installation from the supply,
- protect against overcurrent,
- cut off the current in the event of a serious fault occurring.

System installation

Once a wiring system has been chosen, decisions must be made as to how the system is to be installed, and such decisions will need to take account of the fabric and structure of the building and the aesthetics. For example, PVC flat cables used to rewire a very old dwelling where the walls are ‘lath and plaster’ (slats of wood covered in a soft lime and sand plaster) are not suitable for chasing out or surface clipping. In this case the best solution is to use an adhesive-backed mini-trunking to enclose the cables. Another example is that of a traditional brick construction premises with wooden joists, some of which may be load-bearing (i.e. walls are resting on them). These timbers should not be penetrated by drilling or notching in such a way as to weaken them. The Building Regulations indicate where a joist may be penetrated.

Clearly, all exposed wiring systems will need supporting either vertically or horizontally to ensure that they are not damaged by undue strain. The IEE Regulations ‘On-site Guide’ includes various tables indicating distances between supports for cables, conduit and trunking systems, together with spans and heights of overhead cables, etc.

12.3.2.5 Self-Assessment (assessment questions/evaluation question for the learning outcome)

1. Domestic lighting circuits are usually wired in:
 - (a) 1.0mm cable
 - (b) 2.5mm cable
 - (c) 4.0mm cable
 - (d) 6.0mm cable.

2. Domestic ring final circuits are usually wired in:
 - (a) 1.0mm cable
 - (b) 2.5mm cable
 - (c) 4.0mm cable
 - (d) 6.0mm cable.

3. The regulations recommend that the flexible cable connecting an appliance to a socket outlet should not exceed:
 - (a) 1m
 - (b) 2m
 - (c) 3m
 - (d) 4m.

4. A 13A plug top always:
 - (a) Has round pins
 - (b) Has copper pins

- (c) Contains a thermal overload
- (d) Contains a cartridge fuse.

5. A radial circuit, wired in 2.5mm PVC insulated and sheathed cable and protected by a 20A fuse, may feed any number of socket outlets, provided that the total floor area does not exceed:

- (a) 10m²
- (b) 20m²
- (c) 50m²
- (d) 100m².

6. A ring circuit wired in 2.5mm PVC insulated and sheathed cable and protected by a 30A fuse, may feed any number of socket outlets, provided that the total floor area does not exceed:

- (a) 10m²
- (b) 20m²
- ©(c) 50m²
- (d) 100m².

7. A non-fused spur to a ring circuit may feed:

- (a) Any number of socket outlets
- (b) Any number of fixed appliances
- ©(c) Only one single- or twin-socket outlet
- (d) Only two fixed appliances.

8. One advantage of a steel conduit installation, compared with a PVC conduit installation, is that it:

- (a) May be easily rewired
- (b) May be installed more quickly
- (c) Offers greater mechanical protection
- (d) May hold more conductors for a given conduit size.

9. The earth continuity of a metallic conduit installation will be improved if:

- (a) Black enamel conduit is replaced by galvanized conduit
- (b) The installation is painted with galvanized paint
- (c) The installation is painted with bright orange paint
- (d) All connections are made tight and secure during installation.

10. The earth continuity of a metallic trunking installation may be improved if:

- (a) Copper earth straps are fitted across all joints
- (b) Galvanized trunking is used
- (c) All joints are painted with galvanized paint
- (d) A space factor of 45% is not exceeded.

11. Describe isolation and switching

12. Explain the process of isolation and switching?
13. What are the safety precaution that should be taken during switching and isolation?
14. Once a wiring system has been chosen, decisions must be made as to how the system is to be installed, and such decisions will need to take account of the fabric and structure of the building and the aesthetics. TRUE OR FALSE?
15. The consumer's main switchgear must be readily accessible to the consumer. TRUE OR FALSE?

Practical question

1. Identify Cable draw- in tools
2. Draw in cables in line with standard operating procedures.
3. Lay number and size of cables in a conduit as per the IEE regulations
4. Perform labelling of the cables as per the complexity of the job.

12.3.2.5 References (APA)

- IEE regulations 16th Edition
- Electrical Installation and Workshop Technology Vol. I by F.G. Thomson
- Solar Manuals by Mark Hankins
- Solar PV manuals by KEREAA
- Electrical Installation work by Brian Scaddan

12.3.6 Learning Outcome No5 Fix solar system accessories

12.3.6.1 Learning Activities

Learning Outcome #No: 5 Terminate Electrical cables	
Learning Activities	Special Instructions
Terminate electrical cables onto accessories and switchgear. Ensure that all joints and terminations are electrically and mechanically sound.	

12.3.2.2 Information Sheet No: 1.

Introduction

This unit covers the knowledge, skills and attitudes required in making cold electrical joints to suit different workplace conditions. These include; Terminating cables onto accessories cable lugs, crimping tools and screw terminals and twisted cable strands.

PVC-insulated PVC-sheathed cable

PVC-insulated PVC-sheathed cable is suitable for all types of domestic and commercial wiring installation where there is little risk of mechanical damage, extremes of temperature or corrosion. It is inexpensive and easy to handle, and no specialized tools are needed for working with it.

PRACTICAL EXERCISE WORKSHEET

TITLE: TERMINATING ELECTRICAL CABLES

OBJECTIVE: To Terminate electrical cables onto accessories and switchgear.

To ensure that all joints and terminations are electrically and mechanically sound.

PROCEDURE:

1. Strip the end of the cable using a stripping Knife and expose the conducting strands for a length of 10mm.
2. Twist the cable strands with a combination plier to ensure the strands are firm to avoid sparking due to looseness.
3. If using a cable lug, fit the strands into the tube end of the lug and ensure that there are no exposed strands.
4. Use a crimping tool and press onto the tube of the cable lug to squeeze the firmly onto the cable strands.
5. Terminate the cable lug onto the appropriate terminal on the accessory/switchgear as per the wiring diagram.
6. Label the cable end with a tag.
7. Repeat for all the cables that require termination as per the wiring diagram.

8. Observe safety precautions when using the hand tools while terminating the cables
9. Clear the working area of any waste materials and dispose them in the waste bins.

DEFINITION OF KEY TERMS

CABLES

A great number of types of cables are available, ranging from the very smallest single-core wire used in electronic circuits to the huge oil- and gas-filled cables used in high-voltage transmission systems. In this book we are concerned only with cables used in low-voltage systems (50–1000 V). A cable comprises two parts: the conductor or conductors and the sheathing and insulation.

CONDUCTORS

A conductor may be defined as the conducting portion of a cable, which consists of a single wire or group of wires in contact with each other.

Terminations

When a cable conductor is finally connected to the apparatus it is supplying, a safe and effective termination of that conductor must be made.

PVC singles into screw terminals

The insulation should be removed only far enough to allow the conductor to enter the terminal. Do not leave bare conductor showing outside the terminal. Take care not to score the conductor surface when removing the insulation as this may cause the conductor to break if moved.

PVC twin and three-core with earth

In this case, although the final connection into screw terminals is the same as for singles, care must be taken not to damage the conductor insulation when removing the outer sheath.

NB.

It is important to note that in any termination and any run of conductor or cable, measures must be taken to avoid any undue strain on that conductor or cable.

SAFETY HAZARDS IN FIXING SOLAR PV SYSTEM ACCESSORIES

- Three major safety hazards
 - Physical hazards (e.g., cuts and bruises, burns from contact with hot surfaces, unprotected falls)
 - Electrical hazards (e.g., shocks and sparks)
 - Chemical hazards (e.g., contact with corrosive substances like battery acids, burns and explosions)

Methods, processes/procedures/guidelines

TYPES OF JOINT/TERMINATION

- Crimp
- Eyelet
- Clamp

LUG TERMINATIONS

There are two types of lugs: crimped lugs and soldered lugs. A crimped lug is fastened to the end of the conductor using the same method as shown in Fig. 14.9. The soldered lug is filled with molten solder and the conductor is pushed into it. Lug terminations are frequently used for connecting a conductor to a bus-bar

SOLDERING

For soldering lugs and joints, a tinman's solder is used in conjunction with a flux. The flux keeps the work clean and prevents it from being oxidized during soldering. For smaller jobs on fine cable, a solder with a flux incorporated in it is used.

TERMINATION INTO APPLIANCES

The methods used to terminate conductors have already been discussed. However, an important aspect of termination of cable into appliances, especially the portable type, is the securing of the cable at or near the point of entry (Fig. 1). A good example of this is the cable clamp in a plug top.

PVC-insulated PVC-sheathed cable

PVC-insulated PVC-sheathed cable is suitable for all types of domestic and commercial wiring installation where there is little risk of mechanical damage, extremes of temperature or corrosion. It is inexpensive and easy to handle, and no specialized tools are needed for working with it.

12.3.2.6 Self-Assessment (assessment questions/evaluation question for the learning outcome)

1. Explain the difference between cable insulation and cable sheathing. What is a flexible cord and when is it used?
2. (a) What precautions should be taken when stripping cable sheaths and insulation and why?
(b) What are the requirements of the IEE with respect to identification of conductors?
3. What is a bus-bar and where is it used? Illustrate your answer with sketches.
4. (a) What is m.i.m.s. cable?
(b) Describe with the aid of sketches one type of termination for m.i.m.s. cable.
5. (a) Describe the correct method of cutting a thread on a conduit end.
(b) What is an inspection fitting and what are the restrictions on the use of solid (non-inspection) elbows and tees?

6. State soldering
7. Describe a PVC
8. PVC-insulated PVC-sheathed cable is suitable for all types of domestic and commercial wiring installation where there is little risk of mechanical damage, extremes of temperature or corrosion. TRUE OR FALSE?
9. When a cable conductor is finally connected to the apparatus it is supplying, a safe and effective termination of that conductor must be made TRUE OR FALSE?
10. For soldering lugs and joints, a tinman's solder is used in conjunction with a flux. TRUE OR FALSE?

Practical question

1. Perform Cable lugging as per the standards operating procedure.
2. Terminate cables as per the IEE regulations

12.3.6.5 Tools, Equipment, Supplies and Materials for the specific learning outcome

	TOOLS	FUNCTION
1	Digital Multi-meter	for Testing and commissioning
2	2 flat screwdrivers (large And small) 2 star screwdrivers (large And small)	For fitting pattress and junction boxes and charge controller terminals and fastening screws Where necessary.
3	Electricians' pliers (large type), Adjustable spanner and or spanner set	For tightening bolts on battery terminals, for fitting module bolts
4	Carpenter's hammer	For fitting cable clips
5	Hard hat(helmet)	Protect the head from injury by falling objects, impact with other objects, debris, and bad weather
6	Hack saw	Protect the head from injury by falling objects, impact with other objects, debris, and bad weather
7	Headlight	For working in ceilings of other dark areas or rooms
8	Cable tie	For binding cables or wires together
9	Crimping tool	To bend, cut, strip and crimp Insulated wiring

10	Cable lugs	Cable lugs are used for connecting cables to electrical appliances, other cables, surfaces, or mechanisms. One end of a cable lug is typically used for connecting a cable, which could be soldered, welded, or crimped depending on the type. The connection end of the lug is then fastened to a matching terminal or connection point by means of a bolt, screw
11	Knife or wire stripper	For cutting and stripping wire
12	Connector strips	For connecting wires
13	Rolls of insulating tape - black	For color-coding wires when necessary.
14	Tape measure	For measuring distances
15	Drill (battery powered or hand drill) and drill bits	For drilling holes where necessary
16	Ladder	For working at heights

12.3.2.5 References (APA)

Author, (year), title, publisher, City

Suggested References

- IEE regulations 16th Edition
- Electrical Installation and Workshop Technology Vol. I by F.G. Thomson
- Solar Manuals by Mark Hankins
- Solar PV manuals by KEREAA
- Electrical Installation work by Brian Scaddan

12.3.7 Learning Outcome No6 Test and inspect solar PV system installation

12.3.7.1 Learning Activities

Learning Outcome #No: 6. Test and inspect solar PV System installation	
Learning Activities	Special Instructions
Identify and select the right measuring Instruments for each test as recommended by IEE Inspect and test a completed Solar PV Installation	

12.3.2.2 Information Sheet No: 1.

Introduction

The purpose and aim of this unit is to enable learners to demonstrate occupational competence. The unit focuses upon the competence required to plan and prepare for, install, Inspect and test a solar photovoltaic systems

PRACTICAL EXERCISE WORKSHEET

TITLE: TESTING AND INSPECTION

OBJECTIVE: To Inspect and test a completed Solar PV Installation

To use the right measuring Instruments for each test as recommended by IEE

PRE-REQUISITES: - skills of using Digital and Analogue measuring instruments
- Knowledge of test procedures and expected readings.
- Safety precautions on use of measuring instruments

PROCEDURE:

Methods, processes/procedures/guidelines

INSULATION RESISTANCE TESTING

Insulation resistance tests are used to verify and demonstrate the integrity of electrical wiring systems and equipment, as required by the NEC [110.7]. These tests can be used to assess degradation or damage to wiring insulation and to locate faults within PV arrays and other system circuits. Insulation tests are an important element of commissioning, acceptance testing and preventative maintenance for PV systems. Electrical conductors are usually insulated with an outer covering to protect them from coming into contact with personnel, equipment or other conductors. Where conductors are exposed at termination points or on busbars, the terminal spacing and air gaps provide insulating properties. Compared to conductors that have very low resistance on the order of a few ohms or less, insulators have very high resistance measured in megohms (MΩ). The quality of conductor insulation can be determined by measuring its resistance. Insulation resistance is determined by applying a constant test voltage to a conductor and measuring the current flow between the conductor and

ground, or between other de-energized system conductors. This is analogous to pressure testing a plumbing system for water leaks. As wiring insulation degrades, its resistance decreases and the small current flow through the insulation increases. The higher its resistance value, the better the conductor insulating quality. Excessive leakage current can present an electrical shock hazard, damage equipment and degrade system performance. Damage to wiring insulation can result from improper installation, or any number of environmental factors, including from impacts or vibration, from animals or insects, or deterioration from temperature or sunlight, or other adverse conditions. Due to the degradation of PV modules and wiring systems over many years of direct exposure to the elements, older PV arrays will naturally have lower insulation resistance than when they were new. Insulation resistance tests are recommended on a 3-year maintenance interval, or more frequently as circumstances dictate. Insulation resistance is measured between the conductors under test and ground, or between other conductors. Insulation resistance and leakage current testing are used to verify the integrity of the following PV system circuits and components:

- Verifying integrity of PV modules and array source and output circuit conductors.
- Measuring the leakage current through overcurrent and disconnect devices, including fuses, switches and circuit breakers.
- measuring the insulation resistance for any equipment with windings, such as motors, generators, transformers and inductors.
- testing the grounding electrode resistance.

DEFINITION OF KEY TERMS

INSPECTION AND TESTING

Circumstances that require an initial verification

New installations or Additions or Alterations are the circumstances that require an *Initial Verification*.

GENERAL REASONS FOR INITIAL VERIFICATION

1. To ensure that the equipment and accessories are to a relevant standard.
2. To prove compliance with BS 7671.
3. To ensure that the installation is not damaged, to impair safety.

SEQUENCE OF TESTS

1. Continuity of all protective conductors.
2. Continuity of ring final circuit conductors.
3. Insulation resistance.
4. Polarity.

TESTING CONTINUITY OF PROTECTIVE CONDUCTORS

All protective conductors, including main and supplementary protective bonding conductors must be tested for continuity using a low-resistance ohmmeter. For main equipotential bonding there is no single fixed value of resistance above which the

conductor would be deemed unsuitable. Each measured value, if indeed it is measurable for very short lengths, should be compared with the relevant value for the length and size of a particular conductor. Such values are shown in Table 19.3. Where a supplementary protective bonding conductor has been installed between simultaneously accessible exposed and extraneous conductive parts, because circuit disconnection times cannot be met, then the resistance (R) of the conductor must be equal to or less than $50/I_a$

The test is conducted in the following manner:

1. Temporarily link together the line conductor and CPC of the circuit concerned in the distribution board (DB) or consumer unit.
2. Test between line and CPC at each outlet in the circuit. A reading indicates continuity.
3. Record the test result obtained at the furthest point in the circuit. This value is (R 1 □ R 2) for the circuit.

3 INSULATION RESISTANCE TEST

The object of the test is to verify that the quality of the insulation is satisfactory and has not deteriorated or short-circuited. The test should be made at the consumer's unit with the mains switch off, all fuses in place and all switches closed. Neon lamps, capacitors and electronic circuits should be disconnected, since they will respectively glow, charge up or be damaged by the test. There are two tests to be carried out using an insulation resistance tester which must supply a voltage of 500V d.c. for 230V and 400V installations. These are phase and neutral conductors to earth and between phase conductors.

The procedures are:

Phase and neutral conductors to earth

- 1 Remove all lamps.
- 2 Close all switches and circuit breakers.
- 3 Disconnect appliances.
- 4 Test separately between the phase conductor and earth, and between the neutral conductor and earth, for every distribution circuit at the consumer's unit.

Record the results on an installation schedule.

Between phase conductors

- 1 Remove all lamps.
- 2 Close all switches and circuit breakers.
- 3 Disconnect appliances.
- 4 Test between phase and neutral conductors of every distribution circuit at the consumer's unit and record the result.

The insulation resistance readings for each test must be not less than $0.5M\Omega$ for a satisfactory result

(IEE Regulation 713–04–02). Where equipment is disconnected for the purpose of the insulation resistance test, the equipment itself must be insulation resistance tested between all live parts (that is, live and neutral conductors connected together) and the exposed conductive parts.

The insulation resistance of these tests should be not less than 0.5M Ω (IEE Regulation 713–04–04).

Although an insulation resistance reading of 0.5M Ω complies with the Regulations, the IEE Guidance

Notes tell us that a reading of less than 2M Ω might indicate a latent but not yet visible fault in the installation.

In these cases each circuit should be separately tested to obtain a reading greater than 2M

SAFETY HAZARDS IN TESTING SOLAR PV INSTALLATIONS

- Three major safety hazards
 - Physical hazards (e.g., cuts and bruises, burns from contact with hot surfaces, unprotected falls, dropping the instruments)
 - Electrical hazards (e.g., shocks and sparks, wrong settings on the instruments which may damage the instruments)
 - Chemical hazards (e.g., contact with corrosive substances like battery acids, burns and explosions during testing)
- Electrical work on stand-alone PV systems and particular hazards
 - Never disconnect the batteries from the charge controller while the PV modules are still connected to the charge controller.
 - The charge controller can be damaged by the high open circuit voltage of the modules.
 - Always disconnect the modules from the charge controller, before disconnecting the batteries.
 - Always connect the batteries to the charge controller before connecting the modules to it.
- Inverters are normally not reverse polarity protected.
 - If an inverter is connected incorrectly to a battery, it can be seriously damaged.
 - This will not be covered by the inverter warranty.
 - Fuses should not be removed when a circuit is under load – to do so can cause arcing.
- Correct DC polarity is to be observed when making all electrical connections.
 - Incorrect polarity can damage appliances and system components.
- All wiring should be inspected and tested before commissioning. This includes:
 - Testing module/array open circuit voltage VOC and short circuit current ISC.
- Verifying polarity.
- Lightning protection

- National codes need to be consulted.
- Modules on roofs or on poles attached to buildings should not be higher than the highest point of the building.
- In regions with frequent thunderstorms, a double pole disconnect / isolator should be installed (even on small systems), so that the PV array can be isolated from the rest of the system, when there is a risk of lightning strike.
- No work should be carried out on PV arrays if there is thunder or lightning in the area.

HOW INSULATION RESISTANCE IS MEASURED

You have seen that good insulation has high resistance; poor insulation, relatively low resistance. The actual resistance values can be higher or lower, depending upon such factors as the temperature or moisture content of the insulation (resistance decreases in temperature or moisture). With a little record-keeping and common sense, however, you can get a good picture of the insulation condition from values that are only relative. The Megger insulation tester is a small, portable instrument that gives you a direct reading of insulation resistance in ohms or megohms. For good insulation, the resistance usually reads in the megohm range.

The Megger insulation tester is essentially a high-range resistance meter (ohmmeter) with a built-in direct-current generator. This meter is of special construction with both current and voltage coils, enabling true ohms to be read directly, independent of the actual voltage applied. This method is nondestructive; that is, it does not cause deterioration of the insulation.

The generator can be hand-cranked or line-operated to develop a high DC voltage which causes a small current through and over surfaces of the insulation being tested (Fig. 2). This current (usually at an applied voltage of 500 volts or more) is measured by the ohmmeter, which has an indicating scale. Fig. 3 shows a typical scale, which reads increasing resistance values from left up to infinity, or a resistance too high to be measured.

12.3.2.7 Self-Assessment (assessment questions/evaluation question for the learning outcome)

1. How does solar panels absorb solar energy?
 - a. By converting photons to electrons
 - b. By converting protons to electrons
 - c. By converting electrons to photons
 - d. By converting electrons to protons

2. What energy is absorbed by the solar panels?

Discuss

- Sound energy
 - Solar energy
 - Kinetic energy
 - Chemical energy
3. Insulation resistance tests are used to verify and demonstrate the integrity of electrical wiring systems and equipment TRUE OR FALSE?
4. All protective conductors, including main and supplementary protective bonding conductors must be tested for continuity using a low-resistance ohmmeter TRUE OR FALSE?
- 5.



What is this?

- Solar box
 - Solar plate
 - Solar panel
 - Solar mirror
6. Describe how insulation resistance is measured
7. Describe safety hazards in testing solar PV installations
8. Describe the procedure for conducting insulation test
9. What is the importance of initial verification before testing?

Practical question

- Perform test as per the IEE regulations
- Identify type of tests
- Establish firmness of the installation
- Perform continuity test
- Perform insulation resistance test as per the IEE regulations
- Perform ring circuit test as per the standard operating procedure
- Perform earth continuity test as per the IEE regulations

12.3.2.8 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Module array

- Charge controller

- Battery
- Inverter
- cables and accessories
- AC/DC switches
- Socket outlets
- Lampholders
- Ceiling roses
- Patresses
- Consumer control unit
- Multimeter
- Insulation resistance tester

2.3.2.5 References (APA)

Author, (year), title, publisher, City

Suggested References

- IEE regulations 16th Edition
- Electrical Installation and Workshop Technology Vol. I by F.G. Thomson
- Solar Manuals by Mark Hankins
- Solar PV manuals by KERE A
- Electrical Installation work by Brian Scaddan

CHAPTER 13: ELECTRICAL EQUIPMENT'S AND SYSTEM MAINTENANCE/ AND SYSTEMS.

13.1. Introduction of the Unit of Learning / Unit of Competency

This unit introduces the trainee to competency to maintain electrical equipment's and system. Electrical equipment's includes, motors, generators, transformers wires, cables, batteries, light fixtures, arrestors and electronic controllers and this equipment need to be maintained. This include preparing maintenance schedule, inspecting and testing electrical equipment and systems, preparing list of maintenance tools and equipment's, performing maintenance activities, system testing and documenting maintenance records. All maintenance must be planned in an efficient way to minimize wastage and obtain full capacity and work as when it was new. Regular maintenance is essential to keep the equipment machines and work environment safe. Observe safety precaution and standards provided in the maintenance service and code of practice.

13.2. Performance Standard

Prepare maintenance schedule, inspect and test electrical equipment and system as the operating procedure. Perform maintenance and document maintenance records as per the expected output and results recorded.

13.3. Learning Outcome

13.3.1. List of Learning Outcomes

- a) Prepare maintenance schedule
- b) Inspect and test electrical equipment and system
- c) Prepare a list of maintenance tools
- d) Perform maintenance activities
- e) Conduct system tests
- f) Document maintenance records

13.3.2 Learning Outcome No 1 prepare maintenance schedule

13.3.2.1 Learning Activities

Learning outcome no 1 prepare maintenance schedule			
Learning activities			Special instructions
Trainee to prepare a maintenance schedule and checklist			
No	Action description	Date assigned	
1	Wipe dust ,dirt and oil		
2	Clean vents, fans and blow out interior		
3	Check commutator brushes		
4	Check brush springs tension		
5	Test field coils		
6	Test armature winding		
7	Check electrical connections		

13.3.2.2 Information Sheet No 13/LO1.....

- Definitions of key terms

Safety Refers to the condition of being safe from undergoing or causing hurt, injury or loss.

1. Preparing Maintenance Schedules

Safety standards are standards prescribed by a regulatory body e.t.c that must be adhered to to ensure a product; event e.t.c is safe and not dangerous.

Maintenance involves all actions appropriate for retaining an item, part, equipment in or restoring it to a given condition.

Maintenance plan a document that outlines the management and technical procedure to be employed to maintain an item, usually describes facilities, tools schedules and resources.

Maintainability refers to the probability that a failed item will be restored to adequately working condition

Safety Standards

1. Noise standards. Addresses many factors involved in preventing injury or discomfort resulting from the effect of sound.
2. Work place standards. Apply to the worker and employer making responsible decisions for their own safety and that of their coworkers.

3. Safety and compliance standards. Involved in management of equipment, maintenance of machinery, procedures for inspection and testing equipment and products.
4. Safety signs and labels. Delineate the proper design, classification and implementation of safety signs and safety labels.
5. Machine risk Assessment standards. Provide guidelines for the assessment and reduction of machine related risk in the workplace.
6. Combustion, explosive or toxic gas detection. Provides guidelines on the selection, use and maintenance of hazardous gas detector.
7. Workplace lighting standards. Addresses a plethora of concerns associated with the principles of design, placement, installations, energy requirements and upgrades to lighting fixtures in various work places.
8. Confined spaces safety standards. Addresses the health and safety of individuals in a confined spaces.
9. Protective clothing standards. Applicable to chemical protective clothing and hot, work, protection from cuts and molten materials as well as other types of hazards.

Definition

Maintenance schedule. Level of maintenance that requires planning, allocation of significant amount of time and a high degree of coordination between different departments and is typically initiated through a work order.

Checklist. A type of job aid used to reduce failure by compensating for partial limits of human memory and attention.

Checklist main function is documentation of the task and auditing against the documentation.

Faulty equipment repaired.

1. Relevant procedures and standards are identified and interpreted for finding the faulty component or fault.
2. Information received and historical information about the faulty component or fault are researched and interpreted.
3. Hazards associated with the fault or faulty component are identified.
4. Relevant tests and inspections to locate the fault or faulty components are carried out.
5. The faulty or faulty component is identified.
6. Safety measures are implemented to carry out the repair.
7. Visual checks of the repaired or replaced faulty component are carried out.
8. Checks and tests required prior to restoring.
9. Report documentation is completed.

Documented Maintenance record

Maintenance of documents requires efficient storage and management paper works is often for extended periods of time for health and safety or compliance purpose. It involves keeping a record of information for each asset together with indexed data for information such as

1. Asset number
2. Maintenance data and times
3. Equipment maintenance details
4. New parts added
5. Manufactures recommendations for maintenance
6. Amount of use
7. Equipment environment conditions
8. User experience and knowledge
9. Risk assessment information

Common documentation includes

1. Electrical certifications
2. Vehicle/ fleet maintenance
3. Building records
4. Equipment maintenance for production/ work equipment
5. Upkeep of medical equipments. Clear data help business to manage their maintenance records efficiently through.
 1. Document scanning
 2. Cloud document management
 3. Secure archive storage services

Types of Maintenance

The purpose of maintenance is to achieve a satisfactory level of system availability

1. Corrective maintenance/ breakdown done when system breakdown and cannot perform its function any longer.

Advantages of corrective maintenance

1. Lower shortterm costs
2. Minimal planning required
3. Simpler process
4. Based solutions in some cases

Disadvantages of corrective Maintenance

1. Unpredictability
2. Paused operations
3. Equipment not maximized
4. Higher longterm costs.

Preventive Maintenance

Its mission is to maintain a level of certain service on equipment, replacing components of parts of a system that are nearing end of their lifespan and therefore likely to fail.

Objectives of preventive maintenance

1. Ensure perfect functioning by replacing weak parts.
2. Detecting weak parts

Advantages of preventive maintenance.

1. Longer equipment life. Regularly checked and maintained equipment, keeps its shape, therefore extending its lifetime.

2. Follows a schedule. Able to keep. To budget while maintaining equipment
3. Less energy wasting. Equipment not kept in best condition drain more energy, hikes up utilities bills.
4. Less disruptions

Disadvantages of preventive maintenance

1. More workers. Because of regular checks.
2. Over maintenance. Because there is regular plan
3. More money upfront

Predictive Maintenance

1. Pursues constantly know and report the status and operational capacity of the installations by knowing the values of certain variables which represent such state and operational ability e.g temperature, vibration, power consumption e.t.c

Advantages of predictive maintenance

1. Reduce equipment costs instead of replacement of the entire piece of equipment due to critical failure and cost is minimized to the piece of equipment.
2. Reduces labour costs
3. Reduces last production time
4. Increases safety
5. Increases revenue
6. Increases efficiency of employee time

Disadvantages of predictive maintenance

1. Cost of the condition monitoring equipment needed is often high
2. Skill level and experience required to accurately intercept condition is also high
3. Periodic maintenance time based maintenance TBM.

This type of maintenance is based on Tpm total productive maintenance

Consists of a series of elementary tasks data collection, visual inspections, lubrication, lightening screws e.t.c for which no extensive training is necessary but perhaps only a brief training.

Advantages of periodic maintenance

1. Usually made up of tasks that don't require extensive training such as lubricating and retightening screws.
2. Lower long term costs compared with breakdown maintenance.

Disadvantages of periodic maintenance

1. Planning time is required
2. Parts are often replaced before end of life, which costs more than waiting until they fail.
3. If a part experiences a serious problem prior to the next inspection assets can fail.
4. Zero hours maintenance overhaul

Set of tasks whose goal is to review the equipment at scheduled intervals before reappearing any failure either the reliability of the equipment has decreased so it is risky to make forecasts of production capacity.

The review is based on leaving the equipment to zero hours of operation. These reviews will replace or repair all items subject to wear.

Trainees trained on safe procedures for working with tools based on the national safety council guidelines for handling of tools when they are in use and when not in use.

Maintenance records

This is a written set of instructions that specifies how a maintenance procedure is to be performed.

It encompasses standards, measurements and specific techniques on how to perform any task.

Procedure of writing maintenance report

1. have a preplan
2. Photograph the job
3. Write down actions step by step
4. Write out a complete parts list
5. Write out a complete supplies tools and expert lists
6. Include drawing and diagrams

Components of a maintenance report

1. Testing
2. Servicing
3. Calibration
4. Inspection
5. Adjustment
6. Alignment
7. Installation

Self -assessment

1. What is the cause for mechanical overloads in the induction motors?

- a) Stalling
- b) Blowing of fuse
- c) Under voltage
- d) Open circuit

2. Which among these uses a low voltage DC source?

- a) Remote indication
- b) Emergency lighting system
- c) Remote position control
- d) All of these
- e) None of these

3. Which sequence is followed first while closing a circuit breaker?

- a) Close the isolator
- b) Open earthing switch

- c) Close circuit breaker
 - d) Any of these
4. Which equipment is used for EHV lines to improve power transferability?
- a) Shunt capacitor
 - b) Shunt reactor
 - c) Series capacitor
 - d) All of these
5. State three disadvantages of periodic maintenance
6. Define the following terms
- Maintenance schedule
 - Maintenance record
7. State four advantages of predictive maintenance
8. Differentiate between predictive and preventive maintenance
9. Explain advantages and disadvantages of predictive and preventive maintenance
10. Between the types of maintenance, which is the most effective type?
11. Maintainability refers to the probability that a failed item will be restored to adequately working condition TRUE OR FALSE?
12. Checklist main function is documentation of the task and auditing against the documentation. TRUE OR FALSE?

Practical questions

1. Identify type of equipment and systems to be maintained
2. Prepare Maintenance checklists referring to manufacturers manual
3. Identify maintenance team as per areas of specialty
4. Identify tools to be used in maintenance
5. Perform maintenance work

Tools, Equipment, supplies and materials

1. Standard screwdriver set
2. Safety glasses
3. Allen screws wrenches
4. Wire strippers
5. Spare test leads
6. Multimeter

References

1. Engineering maintenance, A modern approach By B.S. Dhillon, ph.d
2. Maintenance engineering handbook edited by L.R.Higgins, McGRAW Hillbook company, Newyork 1988.
3. Electrical installation theory and practice, By E.L Donnelly second edition
4. Electrical measurements and instrumentation, By Hawth

13.3.3 Learning Outcome No 2 Inspect and test electrical equipment and system

13.3.3.1 Learning Activities

Learning outcome No 2 Inspect and test electrical equipment and system						Special Instructions Trainer to emphasize on personal safety and correct use of tools.
Learning activities						
Trainee to identify the type of motor and examine its nameplate information.						
No	Area	Description	Date assigned	Date issued	Status	
1.	Running condition	With machine running, check excessive noise and sparking at the brushes.				
2.	Yoke and field windings	Isolate machine from supply, check that the yoke and field windings are in good condition.				
3.	Brushes and brush holders	Check brushes and brush holders are in good condition and that the brushes move freely in their holders.				

4.	Brush springs	Check brush springs are in good condition that spring pressure is adequate and even on all brushes.				
5.	Armatur e Assembl y	Check that the coils are in good condition and held securely at the commutator end by their band. Check the commutator for concentricity, irregularities and cleanliness.				
6.	Bearing	Check bearing for condition and correct lubrication.				
7.	Shaft	Check the shaft for concentricity and general condition.				
8.	Connecti on and wiring	Check that all connections are tight and that wiring is in good condition				

		with no signs of heat damage.				
9.	Insulation test	Carry out insulation test.				

13.3.3.2 Information sheet No. 13/Lo2

Inspect and test electrical equipment and systems

It is the test that is performed to either identify equipment diagnoses equipment problems or to confirm that repair measures have been effective.

i Insulation tests

The purpose of the earth insulation resistance test is to warn of the existence of possible leakages to earth and to pin point the actual leakage.

Preparations for Earth installation resistance test

1. Supply OFF
2. Fuses IN neutral links IN
3. Connect all poles together

Test instrument. The instrument used for insulation resistance testing is a hand driven d.c. generator which should be capable of supplying a d.c voltage not less than twice the voltage normally supplied to the circuit.

The voltage need not exceed 500v for medium voltage circuit's i.e medium voltage range 250v to 650v. The test is carried out at the nearest point to the supply.

Authority's equipment.

Method

1. Connect one wire of insulation tester to earthed metalwork in the case of main switch, trunking, conduit, e.t.c
2. Connect other wire to phase/s and neutral in turn as shown in fig 3.

Reading. The accepted reading will depend upon the size of the installation but should not be less than 50 over number of outlets megohms or 12 and a half over number of socket outlets megohms. 1 Megohms is equivalent to 1,000,000 ohms.

ii No load tests This is an indirect method used to determine the efficiency and the circuit parameters of the equivalent circuit of the three phase induction motors. No load test is same as the open circuit test performed on the transformer.

iii Speed tests indicates and predicts both cognitive and physical function. The speed of motor is usually measured in revolutions per minute, RPM. The one commonly used assessment for motor speed is the finger tapping test FTT, its typically administered as part of a neurological or neuropsychological assessment.

iv Performance tests Many of these tests require a mechanical load to be applied to the motor so the motor has something to “push” against. Such loads are often either a mechanical brake, which converts the motor output energy to frictional heat loss, or a generator, which converts the mechanical energy to electricity which can then be used to drive a resistor load bank (convert to heat) or other means to dump the electrical energy.

(i) Power Usage

For AC motors, use a CT and PT to measure the current (I) and voltage (V) applied to a motor to form the instantaneous power $P=I*V$. For DC motors, rather than a CT, you measure the current with a shunt, and compute power as $I*V$. The amount of power is somewhat proportional to the motor load so tests typically automatically ramp the load to form a curve of input electrical power to output mechanical power

(ii) Condition of Windings

Testing the resistance of each winding can be measured with a standard DMM. These tests help determine issues such as shorts to ground, shorts between phases, and broken windings. A high-pot tester can check for winding insulation breakdown.

(iii) Component Temperature

Sensors used are listed in the table above and applied to various components used to construct the motor, such as the housing, heat sink fins, bearings, and so on. The type of sensor to use is usually chosen based on the required accuracy, with RTDs being the best. Careful calibration and precision signal conditioning is important to get the highest accuracy from temperature sensors due to their small signal output.

(iv) Bearing and Unbalance Vibration

For rotating motors, applying an accelerometer to a motor bearing mount can assess the mechanical integrity of the bearing. Excessive vibration indicates bearing failure and the frequencies of those vibrations are indicative of the types of faults, such as bad roller bearing elements or overall looseness due to worn out elements.

(iv) Shaft Alignment

For rotating motors, placing an accelerometer in the direction of the motor shaft can detect looseness and misalignment in the shaft.

(v) Pull-in Current

A high-bandwidth CT or shunt measures the time response of current draw by the motor when first powered. Since the motor is not moving initially, the power source is driving a very low resistance due almost exclusively to the resistance of the windings. The current in-rush returns to normal levels after the motor starts moving. The shape and peak amplitude of the pull-in current can be used as a pass/fail disposition during manufacturing tests.

i) Run Up Time and Vibrations

The time required for a motor to reach the commanded speed can be an indication of proper motor construction. The typical sensor used for this measurement is an encoder or 1/rev (once per revolution) sensor. Motors that can be speed-controlled often have built-in encoders or 1/rev sensors which the motor controller can use to detect speed

ii) Coast Down Time

The same test methods discussed for run up apply to coast down as well, with the one important fact that during coast down the motor is not being powered. Thus, any torque and other forces present during run up are absent in a coast down.

2.3.2.3 Self-Assessment (assessment questions/evaluation question for the learning outcome)

1. The neutral conductor must:
 - a) Not be connected to a grounding electrode in the second building
 - b) Not be connected to a grounding electrode in either building
 - c) Be bonded to the disconnect enclosure in the second building and connected to a grounding electrode
 - d) Tie into the ungrounded conductor of one of the buildings with a grounding jumper
2. A feeder runs from one part of a building to another under the floor in two parallel sets of rigid non-metallic conduits with type RHW copper conductors size AWG #500 and is protected by 800 ampere fuses. It must have a minimum size copper equipment grounding conductor in each conduit run of no less than which of the following:
 - a) 1/0 AWG
 - b) 20 AWG
 - c) 10 amps
 - d) 5 AWG
3. A surge arrester for a 480 volt electrical system requires a connecting conductor that is #14 copper or larger.
 - a) True
 - b) False
4. Explain the following types of maintenance
 - i. Corrective maintenance
 - ii. Predictive maintenance
5. A new factory machine shop contains electric motors, motor control gear, lighting fittings and small power distribution system. Describe briefly six considerations which should be borne in mind the initial installation in order to provide ideal maintenance.
6. Explain causes of excessive sparking at the commutator.
7. State four objectives of preventive maintenance
8. Maintainability refers to the probability that a failed item will be restored to adequately working condition TRUE OR FALSE?
9. Checklist main function is documentation of the task and auditing against the documentation. TRUE OR FALSE?

Practical questions

1. Inspect equipment and System according to the established procedure
2. Identify main isolation points
3. Identify components in the system

4. Identify and record Maintenance activities of schedule
5. Test the `components and the entire electrical system
6. Perform inspection and tests as per the standard operating procedure

13.3.3.4 Tools and equipment, supplies and materials

1. Standard screwdriver set
2. Safety glasses
3. Allen screws wrenches
4. Wire strippers
5. Spare test leads
6. Multimeter

13.3.3.5 References

1. Engineering maintenance, Amodern approach By B.S. Dhillon, ph.d
2. Maintenance engineering handbook edited by L.R.Higgins, McGRAW Hillbook company, Newyork 1988.
3. Electrical installation theory and practice, By E.L Donnelly second edition
4. Electrical measurements and instrumentation, By Hawth

13.3.4 Learning Outcome No 3 I List of maintenance tools

13.3.4.1 Learning Activities

Learning outcome No. 3, List of maintenance tools				
Learning activity, Trainee identify and classify maintenance tools				
Tools	Materials	Equipment	Reference Materials	Special Instructions Trainer to demonstrate and ask oral questions on maintenance tools.
Set of screw drivers	Stationery	PPE hand gloves, dust coat, dust masks	Service manuals	
Set of spanners and wrenches	Cables	Multimeter	IEE Regulations	
Power tools	Lubricants	Phase sequence meter	Organization Manual	
Cutting tools	Service parts			
Pliers				
Lifting and tensioning tools				
Tool box				
Phase tester				

13.3.4.1 Information sheet No. 13/ Lo3

List of maintenance Tools

Tools and equipment must be properly maintained so that workers are not endangered. Construction regulations require inspections of tools, machines and equipment before use.

Preventive maintenance is the systematic care and protection of tools, equipment, machines in order to keep them in a safe, usable condition, limit downtime and extend productivity.

The degree of detail to include in your company's program regarding equipment maintenance will depend on the kinds of tools/equipment used. Some construction equipment (motors) have very specific inspection and maintenance requirements.

General requirements for equipment maintenance include:

- Obtaining a copy of the maintenance schedule recommended by the manufacturer.
- Ensuring that maintenance is performed as required.
- Ensuring that the trainee performing the maintenance are competent.
- Retaining records of maintenance/service conducted.
- Specifying who is responsible for overseeing equipment maintenance and where the records are kept.
- Set up a system for removal and tagging of damaged or defective tools and equipment.

Specification of maintenance tools

Systems which have been purchased and installed must be operated and maintained for their total life. The cost of this support over the life-cycle is about the same and often even more than the initial acquisition cost.

Aspects in Specifications

In the specifications not only the required primary functions are laid down, but also the required management functions and the grade of performance of the equipment. These aspects, which contribute largely to the costs, can be specified beforehand. These functions are specified for stated conditions. The following aspects can be taken into account when specifying operation or maintenance functions.

Operational aspects

The implementation of operational functions should be done in such a way that they can be carried out easily and no special trained operators are required. Entering modified software in the system must preferably be possible without any effect on the operational mode of the system and of any subscriber. Any interruption must be of short duration only (e.g. no longer than 30 minutes) and must be stated as a maximum value.

Environmental conditions as the reliability of an equipment depends on its environmental conditions, these should be clearly stated in the specification. Reference to Recommendation T/TR 02-03 can be useful for this.

Availability performance normally the “unavailability” will be defined. However this parameter not only depends on aspects for which the manufacturer is responsible (reliability performance and maintainability performance) but also on aspects for which the Administration is responsible (maintenance support performance). So, in defining the unavailability the Administration should state what assumptions have been made on their part (Maintenance Support Performance: e.g. logistic delay time, level of maintenance personnel). The unavailability can be defined e.g. by defining “partial and/or total unavailability” or by introducing weighting factors and so define “cumulative unavailability”. The specification must state if the required value is relative to predicted or operational unavailability.

Reliability performance 2.5. 2.6. 2.7. 2.8. 2.9. 2.10. 2.11. 2.12. a) Failure rate This parameter gives an idea about the expected maintenance effort for the Administration. For this the “Failure rate” and the MTBF (Mean Time Between Failures) can be specified. The specification must state if the required value is relative to predicted or operational failure rate. b) Functional failure rate Protection from the loss of function of an item is often provided by the use of redundant equipment including its software. However the Administrations need to know the frequency with which the function of both normal and redundant equipment, including its software, will be lost simultaneously. The specification must state if the required value is relative to predicted or operational functional failure rate.

Maintainability performance Parameters like “Detection efficiency” or “Localization efficiency” can be specified. The specification must state how these parameters will be tested (e.g. by failure simulation or in the field). Various kinds of test-programs can be required and the ability to schedule various test-programs. Furthermore operations with frequent occurrence must be easy to perform (like e.g. the replacement of fuses and lamps, and adjustments). The specification must state the efficiency of fault detection at component level, attainable when adopting the repair-procedure recommended by the manufacturer.

Requirements for construction and components to be used To assure the Administration that equipment will function well for a certain period of time, requirements on components to be used and on the methods of construction must be stated.

Man-Machine Language (MML) The exchange of information on operational and maintenance matters between men and machines should be specified. The interfaces to terminals (workstations) or other intelligent management systems should be specified.

Standardized consumable articles Articles to be used with the system, like paper, ink-lint, magtapes, etc., must be standardized ones.

System security/authorization In order to protect the system against unauthorized operations an authorization procedure must be required.

Measurements for wrong replacements It must not be possible for interchangeable items to be put in wrong positions where they will be damaged; for this mechanical—or “paper”-keys can be used.

Documentation A specification should state what documentation should be made available and when. Preferably the documentation should be in the native language. ~ Documentation must be structured in such a way that it is easy to read and easy to retrieve information. Edition of February 10, 1988 T/S 52-01 E Page 4 2.13. 2.14. 2.15. 2.16. 2.17. 2.18. 2.19. 2.20. 3. 3.1. 3.2. 3.3.

Programs Requirements should be stated for program-language, structure, modularity, software-documentation, change procedures, etc. Possibility of subsequent delivery the supply of parts and individual components must be guaranteed for a certain period (e.g. 10 years) after the last delivery. After that period substitute functions must be guaranteed. Guarantee on knowledge with the manufacturer

The manufacturer must guarantee that he keeps the knowledge of a certain system for a period (e.g. 20 years) after the latest delivery, for both hardware and software. At any time he must be willing to enable the Administration to obtain this knowledge.

Safety requirements the safety of personnel and other people working with the system must be guaranteed. Energy consumption the allowable consumption of energy (power and air-conditioning) must be specified. Ergonomic requirements

Ergonomic aspects in any area can be essential and can therefore be specified.

Requirements for mobile equipment For equipment which has to be mobile, i.e. which has to be installed several times at different places after transportation, or which has to be stored temporarily several times during its life time, the costs for transportation and storing must be estimated. Therefore the transport- and storing-conditions must be known.

Warranty period of equipment the specification must state what is the duration of the warranty, when the failure rate complies with its specification.

Classification of maintenance tools

Maintenance tools are classified into many categories depending on the nature of the work the tool does:

Cutting tools

These include Snips and shears are used for cutting sheet metal and steel of various thickness and shapes. Normally, the heavier or thicker materials are cut by shears.

Others include Trojan snips, hacksaw blades, chisels, files etc

Fastening tools- these include pliers, pipe wrench, rivets, wire strainer. They used in fastening two parts together.

Measuring tools- these include rulers, meters etc. Some are mechanical while others are electronic

13.3.4.6 Self- assessment

1. Maintenance consist of the following action(s)
 - a. Replace of component
 - b. Repair of component
 - c. Service of component
 - d. All of the above

2. The time elapsed from the point the machine fails to perform its function to the point it is repaired and brought into operating condition is known as
 - a. Down time
 - b. Break Down time
 - c. Both (A) and (B)
 - d. Idle time
3. The down time cost consists of
 - a. Loss of production
 - b. Wages paid to the workers
 - c. Reduction in sales
 - d. All of the above
4. The following is not a classification of maintenance
 - a. Corrective maintenance
 - b. Timely maintenance
 - c. Scheduled maintenance
 - d. Preventive maintenance
5. Belt of an electric motor is broken, it needs
 - a. Corrective maintenance
 - b. Scheduled maintenance
 - c. Preventive maintenance
 - d. Timely maintenance
6. The following is (are) scheduled maintenance
 - a. Overhauling of machine
 - b. Cleaning of tank
 - c. Whitewashing of building
 - d. All of the above
7. Scheduled maintenance is _____ between breakdown maintenance and the preventive maintenance.
 - a. Joint
 - b. Compromise
 - c. Bridge
 - d. In
8. Equipment history cards are meant to record
 - a. The way equipment behaves
 - b. Total down time of the equipment
 - c. The rate at which different components wear off
 - d. All of the above
9. Preventive maintenance is the systematic care and protection of tools, equipment, machines in order to keep them in a safe, usable condition, limit downtime and extend productivity. TRUE OR FALSE?
10. In the specifications not only the required primary functions are laid down, but also the required management?

Practical question

1. Identify Maintenance tools as per the type of maintenance to be carried out
2. Prepare List of maintenance tools as per established procedure
3. Check for specifications and functionality of Maintenance tools as per their standard operating procedure
4. Arrange Maintenance tools as per their functions

13.3.4.4 Tools, equipment, supplies and materials

- Standard screwdriver set
- Safety glasses
- Allen screws wrenches
- Wire strippers
- Spare test leads
- Multimeter

13.3.4.5 References

1. Engineering maintenance, A modern approach By B.S. Dhillon, ph.d
2. Maintenance engineering handbook edited by L.R.Higgins, McGRAW Hillbook company, Newyork 1988.
3. Electrical installation theory and practice, By E.L Donnelly second edition
4. Electrical measurements and instrumentation, By Hawth

13.3.5 Learning Outcome No 4 Perform maintenance activities

13.3.5.1 Learning Activities

Learning outcome No. 4 Perform maintenance activities e.g for a motor					Special Instructions Trainer to give assignment on disposal of waste materials.
Learning activities, Trainee identify faulty component, repair/replace and fill maintenance checklist					
S/NO	Part	Maintenance	Frequency	Status	
1.	Bearings	Correct lubrication			
2.	Shaft	Check for concentric and general condition			
3.	Connections and wirings	Check that all connections are tight and wiring is in good condition.			
4.	Amature assembly	Check coils are held securely and tightened and also check commutator for concentricity, irregularities and clean.			
5.	York and field windings	Check for continuity and rewind			

13.3.5.5 Information sheet No. 13/ L04

Electrical equipment fail to function due to many reasons. These include, mechanical parts and contacts wearing out; overheat of wires as well as burn open or short out; impact and abrasion can also damage parts; etc. thus , electrical equipment can run in a way different from what it was designed to or even fail to function at all.

Identification of faulty components on an electrical system

Troubleshooting-this can be defined as the process of doing an analysis of the behavior of a faulty circuit to establish its problem(s). Thus, defective components are identified and repaired in a circuit. The basic techniques used include;

Split-Half Troubleshooting

In this technique a few measurements are taken and thus the defects are located. This is done by splitting the electrical circuit into two and then trying to troubleshoot the two halves separately, one at a time. This means, in case there are many possible test points, start by measuring at the half way point. If a good signal is recorded at this point, but if you measure here and you have a good reading you know, the problem is probably over here. If the signal is bad, then you would go back and look at this area and then again, you do more tests. The idea is divide and conquer.

Signal Tracing and Signal Injection

These are important techniques when applied along with the split half troubleshooting method previously discussed. The signal is introduced and traced from midpoints within the circuit as opposed to tracing or injecting the signal from the start point of the circuit. In case the output is good when a good signal is injected at the midpoint, then then you rule out the second half of the circuit. The fault must be in the first part of the circuit, and in this specific case we just looked at this one. The idea would be to inject a known good signal at this point where the signal that should be here and then to evaluate; is the signal the signal processed and do we have the correct signal here? In case we don't then we realize that there is a in this point.

Component Substitution

After analysing the system and the source of the fault is identified, the component suspected to be defective is replaced with a new one in order for its status to be ascertained. Substituted components that do not fix the system should be discarded to prevent their reintroduction into the system. Un-installing and installing parts can destroy them and this is even in case you have components that are good, you install them and you take them from the system those components should not be reused

In-circuit Testing of Components

This is the idea that in some cases, components can be tested while they are in the circuit. While the component is still in the circuit, some shorts may be detected using an ohmmeter. Specialized test equipment is also available for a specific component in circuit testing and this is a common practice where you actually measure the components in circuits. It's often a tricky thing though because when you measure a process specific component, often times that component is in parallel with other components and so the reading that you would expect with that out of the circuit and what is in-circuit is often very different.

Repair/replacement of faulty components

Identifying, repair, replacement of faulty components on an electrical machine.

Number	Symptoms	

There are faulty components that cannot be repaired in an electrical system. For instance, a fuse. Such must be replaced with a new one. Others can just be repaired by replacing sub- components.

Care must be taken while either repairing or replacing an electrical component. The general procedure taken is:

- i. Don't modify safety/protective devices in any way without authorization
- ii. protective gear should be put on
- iii. Replace fuses only if the circuit is de-energized. In case a fuse blows, only replace it with another with the same current rating. Whenever possible, check the circuit before you make the replacement because the burned-out fuse often results from a fault in the circuit
- iv. Always move slowly when working around electrical equipment
- v. Don't work on electrical equipment if you are mentally or physically exhausted.
- vi. Don't touch energized electrical equipment when standing on metal, damp, or other well-grounded surfaces
- vii. Never handle energized electrical equipment when you are wet or sweating heavily

Once the faulty component has been identified, de energize the circuit before carefully disassembling it. Identify the causes of the fault and rectify it before replacing the faulty component.

The component to replace with must have similar specifications.

Maintenance activities

Disassembling

While disassembling an electrical component, always ensure that the power is switched off. Dismantling should be step by step and should not be done in a hussy. For instance, for a three phase motor, the following procedure is followed;

- Remove the screws
- remove the cover .
- Pull out the fan
- Remove the tie rods by use of the shield for support
- Remove the key

- Tap the shaft on the fan side in order to loosen the drive end shield by use of a mallet (wooden)
- Remove the rotor shaft and the shield
- Remove the shield on the fan side.
- Take out the preloading washer
- Remove the circle clip from flanged motors
- Separate the shield from the rotor shaft.
- Take out the bearings using a bearing remover

Cleaning

Different components are cleaned using different cleaning agents. For instance, for a three phase motor, the covers should be wiped dry using a dry cloth. Never use water to clean electrical equipment as this may cause short circuit since water is a conductor. Tightening – equipment that are tightened by use of screws and bolts should remain tight. This is because some equipment, especially motors, if not well tightened may fall off due to the torque produced while running.

Oiling- oiling and greasing is important for lubrication. Correct oil should be used. Oil is also used as a cooling agent in many machines and thus they don't suffer overheating. Overheating may reduce the efficiency of a machine and may cause wear and tear.

Motor rewinding - Electric motors are simple mechanical equipment, but rewinding them should be left to the professionals. The process of rewinding varies depending on sheer number of different motors and winding patterns. Nevertheless, it generally involves cutting the original windings out of the motor's stator or armature and replacing them with new coils made from wire of the same basic type and gauge.

Assembling – this should be done slowly, step by step with the power disconnected to avoid electric shock. For instance, in assembling a motor, the following steps are taken;

- Ensure fits and limits on bearing
- Measure bearing clearances of free bearing
- Fit the outer race bearing in bearing housing
- Adjust the rotor into the stator.
- Fit inside grease cups of both side to the rotor shaft.
- Fit the bearings to the rotor shaft by induction heating.
- Fill the grease into the both bearings.
- Fit circlip to rotor shaft at non-driving end side.

- Fit both side end covers.
- Fit steel ring.
- Fit outside grease cups.
- Fit terminal box.
- Put the sleeve to the terminal leads.
- Replace the lugs of terminal leads if required.
- Fit duct jallie of motor.
- Fit the grease nipples.
- Fit the wooden cleat on terminal box.
- Clean and fit the earthing plate.

Filling in maintenance check list

A checklist is a tool which generally lists items, tasks, or points to be considered or acted upon. It is used in helping the human mind on things which are a bit too much for us to remember. It ensures that the task and the things for consideration were completed without missing a thing or two.

A sample checklist is given below

Item	checked	Fault or defect noted	Action taken

Disposal of waste materials

Electrical equipment waste is becoming major threat to the whole world. Its toxic emissions mixed with fertile soil and air and causing harmful effects to plants directly or indirectly. Direct impacts include release of acids, toxic compounds including heavy metals, carcinogenic chemicals and indirect effects such as bio magnification of heavy metals.

Old batteries- disposing of a used-up battery can be a problem since they contain hazardous materials like heavy metals and acids, batteries can lead to serious environmental harm if not properly discarded. Dispose of different types of batteries in appropriate recycling facilities, hazardous waste facilities, or at designated drop-off sites. Properly store and care for used batteries before you dispose of them to mitigate the risk of fire and dangerous chemical leaks

Oils- Keep your used oil in a clean, leak-proof container like a plastic jug or bottle. Make sure the cap is tightly sealed and store in a cool, dry place away from heat, sunlight, children and pets. Used motor oil can't be recycled if it's mixed with other liquids like antifreeze or brake fluid.

Lugs and screws, nuts, bolts- never throw those old nuts and bolts in the trash. It is not likely that any environmental harm will result, but it will take many years for them to rust away once buried in a landfill.

Put them in a container and take them for recycling.

Cable sheaths and offcuts- most metallic wastes can be recycled. The only precaution that should be taken is in handling them before taking them to a recycling plant. One of the best methods is by putting them in containers and ensuring that they are well covered to avoid spillage.

13.3.5.4 Self-assessment

1. What would you use to measure electrical amperage?
 - A. Ohmmeter
 - B. Amp probe
 - C. Megger meter
 - D. Wiggy
2. Choose the primary colors used in single-phase 120/240 volt wiring.
 - A. Brown, orange, yellow, gray, green
 - B. Brown, red, black, green
 - C. Black, red, white, green
 - D. Black, red, white, blue
3. Before working on an electrical subpanel, you should always:
 - A. Wear safety glasses
 - B. Turn off power
 - C. Install a circuit "lock out" tag
 - D. All of the above
4. The maximum over current circuit interrupter breaker for 14-gage wire is which of the following?
 - A. 15 amps
 - B. 20 amps
 - C. 30 amps

- D. 50 amps
- 5. You would not utilize a ground wire to:
 - A. Carry voltage load
 - B. Bond G.F.C.I. plugs
 - C. Bond metal boxes
 - D. Bond pool lights
- 6. A circuit breaker trips off occasionally for no apparent reason. You should:
 - A. Install a smaller circuit breaker
 - B. Keep resetting the breaker
 - C. Investigate the cause
 - D. Install a larger circuit breaker
- 7. Choose the smallest wire:
 - A. #2 gauge
 - B. #6 gauge
 - C. #12 gauge
 - D. #14 gauge
- 8. Usually, the white wire is used for:
 - A. Ground wire
 - B. Common wire
 - C. Hot wire
 - D. Tie wire
- 9. Explain two ways you can use in detecting faulty components in an electrical system
- 10. Describe how you can change the oil of a motor and how you can dispose the used oil
- 11. Explain what a checklist is and state its importance
- 12. Differentiate between Signal Tracing and Signal Injection
- 13. What is the importance of signal tracing?
- 14. While disassembling an electrical component, always ensure that the power is switched off TRUE OR FALSE?
- 15. Oil is also used as a cooling agent in many machines and thus they don't suffer overheating. TRUE OR FALSE?

Practical question

- 1. Identify Components and defective parts to be replaced/repared
- 2. Perform Cleaning, oiling and tightening of components
- 3. Replace/repair Defective components/parts as per established procedures
- 4. Configure replaced and repaired components as per the system operation
- 5. Carry out Maintenance in accordance to health safety and other relevant regulations and standards
- 6. Dispose in accordance in line with EHS regulations

13.3.5.5 Tools, equipment, supplies and materials

1. Standard screwdriver set
2. Safety glasses
3. Allen screws wrenches
4. Wire strippers
5. Spare test leads
6. Multimeter

13.3.5.6 References (APA)

5. Engineering maintenance, A modern approach By B.S. Dhillon, ph.d
6. Maintenance engineering handbook edited by L.R. Higgins, McGRAW Hillbook company, Newyork 1988.
7. Electrical installation theory and practice, By E.L Donnelly second edition
8. Electrical measurements and instrumentation, By Hawth

13.3.6 Learning Outcome No 5 Conduct system tests

13.3.3.1 Learning Activities

Learning Outcome No. 5 conduct system tests	
Learning Activities	Special instruction
Conduct power and speed test of a motor	

Information sheet No. 13/ Lo5

Introduction

Electrical maintenance programs are designed to increase equipment promptness and uptime while lowering capital operating expenses. Thus the benefits of maintenance include;

- increases up-time
- Saves money
- Conserves energy
- Improves safety

Types of tests

Earth insulation test- Connect one wire of insulation tester to earthed metalwork in the case of main switch, trunking, conduit, e.t.c

Connect other wire to phase/s and neutral in turn as shown in fig 3.

Reading. The accepted reading will depend upon the size of the installation but should not be less than 50 over number of outlets megohms or 12 and a half over number of socket outlets megohms. 1 Megohms is equivalent to 1,000,000 ohms

No load tests - This is an indirect method used to determine the efficiency and the circuit parameters of the equivalent circuit of the three This is an indirect method used to determine the efficiency and the circuit parameters of the equivalent circuit of the three phase induction motors. No load test is same as the open circuit test performed on the transformer.

Speed tests- Indicates and predicts both cognitive and physical function. The speed of motor is usually measured in revolutions per minute, RPM. The one commonly used assessment for motor speed is the finger tapping test FTT, it's typically administered as part of a neurological or neuropsychological assessment.

Performance tests- This test requires a mechanical load to be applied to the motor so the motor has something to "push" against. Such loads are often either a mechanical brake, which converts the motor output energy to frictional heat loss, or a generator,

which converts the mechanical energy to electricity which can then be used to drive a resistor load bank (convert to heat) or other means to dump the electrical energy.

Identification of test points and parameters

While carrying out system tests, the crucial points to check are;

- Between turns in a coil
- Between coils in a phase
- Between coils in different phases
- Between a coil or phase and ground

In many cases, faults occur in the above points and it's wise to start diagnostics from the points above.

- Check the motor appearance. Inspect body deterioration or damage to the cooling fan blade or shaft.
- Rotate the shaft manually to check the condition of the bearings. Check for free & smooth rotation.
- From the motor name plate, note the motor data.
- Earth Continuity: Use your ohmmeter to verify the resistance between earth and motor frame is less than 0.5 ohms.
- Power supply, 415 v between L1 to L2, L3 to L1 and L2 to L3.

Basic Parameters to be checked

Current

As line current in all the phases are not equal so the arithmetic mean of the phase currents should be used for evaluating machine performance.

Voltage

this is measured at the motor terminals and at the time of test, it should be approximately balanced. Machine performance can be calculated by using average of the phase voltages.

Power

power input to three phase motor can be calculated by a single watt meters as they are connected in two watt meter method.

Resistance

It is necessary to check the between the motor body and terminals of the machine.

Safe tests procedures

Safety precautions must be observed while carrying out the above tests.

13.3.6.5 Self-assessment

1. Apartment communities prefer one type of fire extinguisher. Which of the below is it?
 - a. Pressurized water
 - b. CO2
 - c. ABC
 - d. Halon
2. Preventative maintenance for a water heater requires it to be drained a refilled how often?
 - a. When it fails
 - b. Annually
 - c. Every 5 years
 - d. Never
3. How often should a smoke detector be checked to see if it is working properly?
 - a. When a service request is received
 - b. Upon move-out of a resident
 - c. Annually
 - d. All of the above
4. If you are called after hours for an emergency, your response should always include:
 - a. Document call and respond in the morning
 - b. Document call and respond in a timely manner
 - c. Phone 911 and then call the property manager
 - d. Call Human Resources and leave a message
5. The ground wire is which color?
 - a. White
 - b. Blue
 - c. Black
 - d. Green
6. A safety ground circuit interrupter is used to protect:
 - a. Receptacles close to water fixtures
 - b. Swimming pool lights
 - c. Outdoor receptacles
 - d. All of the above
7. What is the importance of earth insulation test?
8. The one commonly used assessment for motor speed is the finger tapping test FTT, it's typically administered as part of a neurological or neuropsychological assessment. TRUE OR FALSE?
9. Line current in all the phases are not equal so the arithmetic mean of the phase currents should be used for evaluating machine performance.

TRUE OR FALSE?

Practical question

1. Identify type of tests
2. Identify components to be tested
3. Test replaced/repared components as per the manufacture's manual
4. Perform system tests as per the expected output and results recorded

13.3.6.4 Tools, equipment, supply and materials

The tools used in conducting system tests include;

- Pliers
- Phase tester
- Set of screw drivers
- multimeter

13.3.6.5 References

1. Rex Miller; 2005"Electrician's Pocket Manual" (Pocket References (McGraw-Hill));
2. Engineering maintenance, Amodern approach By B.S. Dhillon, ph.d

13.3.7 Learning Outcome No 6 Document maintenance records

13.3.6.1 Learning Activities

Learning Outcome No. 6 document maintenance records	
Learning Activities	Special instruction
Write a maintenance report of select electrical equipment's such as a motor	

13.3.6.2 Information sheet No. 13/ Lo5

Introduction

Maintenance entails functional checks, servicing, repairing or replacing of necessary devices, equipment, machinery or part of a machine.

Periodic maintenance is needed for all electrical systems as well as non-scheduled maintenance resulting from unpredictable occurrences like storms, accidents as well as equipment failure. The main aim of periodic maintenance is to ensure that the system is operating at an acceptable level of service to the public. Some maintenance activities are common to all systems, regardless of type and they need to be performed on the cycle applicable for the system.

Wiring and Connection Maintenance

- Clean terminals, conductors as well as connectors of all corrosion.
- tighten terminals and connectors like breaker and contactor connectors.
- examine the equipment grounding system including conduit end bushing connections, bonds, equipment grounding conductors, enclosure grounding connections, and pole grounding connections.
- inspect the grounding electrode, grounding electrode conductor, and associated connections.
- examine conductor insulation for damage, and repair if necessary.
- replace deteriorated or missing conductor and terminal identification markings.

Enclosure Maintenance

- Clean enclosure inside and out.
- Repair corroded surfaces, fasteners, and anchor bolts.
- Lubricate lock, latch assembly, and hinges.
- Check door gaskets and base seals.
- Clean vent filter and replace if necessary.

- Clean drain hole

Maintenance report writing

The requirement to report what was accomplished in a day, by whom, and with what equipment and materials is often viewed in the field as not important. Though this reporting may seem excessive, it's the foundation for planning and budgeting. With no correct information on what work is done, it's not possible to come up with the next budget properly. Consequently, with unrealistic budget, planning will suffer and employees, equipment, or materials may be misappropriated.

Procedure of writing a maintenance report

The steps followed in preparing a maintenance report are;

1. have a preplan
2. Photograph the job
3. Write down actions step by step
4. Write out a complete parts list
5. Write out a complete supplies tools and expert lists
6. Include drawing and diagrams

Components of maintenance report

- General information about the department or the person who is preparing the report. It's necessary to note down departments or people's name, complete address, contact number, email etc. data on the person preparing report could be his contact number, address, email etc.
- Detailed report itself: Information related to maintenance report can be;
 - ✓ Date and time of maintenance,
 - ✓ location,
 - ✓ purpose of maintenance,
 - ✓ maintenance nature,
 - ✓ maintenance description,
 - ✓ spare parts replacements,
 - ✓ any major complaint and its replacement,
 - ✓ suggestions for improvement and development for the repaired parts,
 - ✓ extra remarks from maintenance engineer,
 - ✓ Signature and report submission from the maintenance engineer.
- Cost of maintenance incurred- this is important for budgeting and for future references when the same equipment is to be maintained.
-

Other components include

- Testing
- Servicing
- Calibration
- Inspection
- Adjustment

- Alignment
- Installation

Sample maintenance report form

This is a document used in keeping record of maintenance of various things at a different level. This form can be used in factories, workshops and other maintenance shops. The form is an organized way to keep a record for future reference.

Equipment maintenance report prepared by

Name of the equipment					
label					
Serial number					
manufacturer					
date	Maintenance description	Maintenance performed by	Date of validation before put into service	Scheduled date for next maintenance	cost

Tests results documentation

After maintenance has been done, the equipment is tested and the results are documented as per that day. This is important because these results will be used in determining when the equipment needs to be maintained, by checking for deviations. For instance, for a three phase motor, once maintenance has been carried out, normal parameters have to be recorded. These are;

- Current
- Voltages
- Power
- speed
- efficiency
- rotor resistance
- stator resistance

Test results documentation		
parameter	results	comments
current		
voltages		
power		
efficiency		
Rotor resistance		
Stator resistance		
speed		

13.3.7.3 Self-assessment

1. On a 110-volt circuit, the hot wire is normally:
Discuss
 - a. White
 - b. Black or Red
 - c. Green or bare wire
 - d. Yellow
2. What is the purpose of a squirrel cage?
 - a. To move air through the handler
 - b. To cool circulation pump
 - c. None of the above
 - d. All of the above
3. Quality of tools may reflect the quality of work.
Discuss
 - a. True
 - b. False
4. Where is a fuse link located?
Discuss
 - a. In a fuse box
 - b. On a heat coil
 - c. On a stove element
 - d. None of the above
5. Where is a joist found?
 - a. Floor
 - b. Wall
 - c. Stair
 - d. Corner
6. On most garbage disposals, where is the reset button located?
 - a. In the breaker box
 - b. On the outlet nearest the disposal
 - c. On the bottom of the disposal

- d. On the nearest wall
- 7. A copy of the service request should be left in every occupied apartment after completion to let the resident know what service has been completed.
 - a. True
 - b. False

Practical question

- 1. Document the maintenance checklist as per the standard operating procedure
- 2. Document cost, current status of the system and recommendations in a report
- 3. File and submit maintenance report to relevant parties

13.3.7.4 Tools, equipment, supply and materials

- ❖ Stationery
- ❖ Phase tester
- ❖ Tool box

13.3.7.5 References

- 1. Electrical installation theory and practice, By E.L Donnelly second edition
- 2. Electrical measurements and instrumentation, By Hawth

CHAPTER 14 ELECTRICAL PROJECT MANAGEMENT/ MANAGE AN ELECTRICAL PROJECT

14.1. Introduction of the Unit of Learning / Unit of Competency

This unit refers to the practice of initiating, planning, executing, controlling and closing the work of a team of Electricians/Engineers to achieve specified goals within a specified duration. Electrical project management involves preparation of work plans and policies, managing project team, managing materials, tools and equipment. Other areas included are: Managing project budget, Supervising and assessing project implementation, preparing project reports and commissioning.

The trainee should have competencies in preparing a project plan, project budget and write project logistics. The resources required are Finance, personnel, materials, tools, consultancy services, building and storage facilities. The safety of the training is vital. The right tools should be used for the right job. Personal protective equipment should be provided. The trainee is subjected to holistic assessment with other units relevant to his area of specialization.

14.2. Performance Standard

Manage and supervise an Electrical project as per the nature of project, use ISO 21500/2012 to ensure products and processes are of high standard and prepare project report as per project activities.

14.3. Learning Outcome

14.3.1. List of Learning Outcomes

- a) Prepare work plans and policies
- b) Manage project team
- c) Manage materials, tools and Equipments
- d) Manage project budget
- e) Supervise and assess project implementation
- f) Prepare project reports
- g) Project commissioning

14.3.2 Learning Outcome No 1: Prepare work plan and policies

14.3.2.1 Learning Activities

Learning Outcome #No 1 Prepare work plan and policies	
Learning Activities	Special Instructions
Draw a project organizational structure of a hydroelectric power plant.	Trainee to have an academic trip to hydro station prior to drawing

14.3.2.2. Information Sheet No. 17/ LO1

Definition of terms

Project-This is a set of complex, coordinated activities with a clearly defined objective that can be achieved through coordinated efforts within a given time with predetermined amount of human and financial resources.

Planning –This is setting of objectives and determining a course of action to achieve them.

Policy-This is a statement of intent and is implemented as a procedure or protocol.

Deliverables-These are Products or services to deliver to a client.

Milestones-These are key achievements for a project

Optimistic time-Is the shortest time possible, if everything goes perfectly without any complications.

Pessimistic time.-Is the longest time taking into consideration all odds. This is the time estimate if all goes long.

Most likely time-Is the best estimate of the activity time.it lies between optimistic and pessimistic time estimates.

Electrical project management

Project management is the practice of initiating planning, executing work of a team group to achieve specific goals and succeed within a specified time. Electrical project management is a unit in Electrical Engineering that deals with the practice of initiating, planning, executing a task through application of acquired knowledge and skills during the learning process. Effective project management results in a profitable project. It will also lead to good customer satisfaction and good public relation between electrical contractor and the owner. The project will also be completed on time, in good quality and thus the set budget will be achieved. A project is different from other activities in

that it has a beginning and an end. Managing a project means dealing with variables that can be more or less influenced. They include:

- Quality
- Time
- Cost
- resources
- environment

Elements of project planning

These are essential factors that must be there for effective project planning. They are as follows:

- Stakeholders needs identification -This includes all who are affected by the project. They are end users, employees, project sponsors and clients. Prioritize their needs based on urgency and importance.
- Project objectives-The set objectives should be SMART. They should be specific, Measurable, Attainable, Realistic and Time bound. For example, all electrical works should be done but it can be better if said all electrical work should be done by 17th of June 2019.
- Setting clear deliverables and deadlines-The right products or services should be delivered at the required dates and times.
- Project schedule-A detailed project schedule on deliverables, due date for each task and required personnel.
- Deliverable assignments-Take the project as a cake. Break it into pieces. Each piece is a deliverable. Through this, tasks will be easily managed.
- Specify deadlines and personnel in charge-Due dates and those responsible for those tasks are specified to avoid misunderstandings.
- Identify dependencies-Some tasks rely on completion of other tasks for example completed design before taking it for printing.
- Defining roles and responsibilities-This is beyond specifying roles and thus roles are well defined. Who is answerable to who?
- Plan for monitoring and controlling costs-This helps one to remain on budget through regular team meetings and meeting with clients
- Effective communication plan-communication is necessary to all stake holders. When there are project changes they should be informed in order to get their input. It can be daily, through oral or mails.
- Right process and systems-this entails the procedures used to communicate to team members, systems to use to track projects and delivery method to the client.

Project planning is vital and therefore the following factors are considered

1. Safety -This is the first priority in project planning and implementation stage. Any task to be done must be done safely.

The following are considerations for safety.

- Training and certifications-Every team member should be up to date on safety training and that those handling Equipment are certified to do so.
- Protocols and procedures-There should be safety procedures and protocols in place for tool use, material handling, visitors and demolitions.
- Culture –Safety should be a culture within a company and when adhered to it is recognized through an award of safety compliance.
- Third party values.-This deals with contractors or rental companies. It is important to enquire about their safety protocols and training on proper use of their Equipment.

2. Project need awareness

Project needs are well understood from point of view of stakeholders, partners or contractors. Giving attention to every detail can help mitigate errors. It's necessary to create a checklist to ensure that nothing is missed or overlooked. A checklist includes the following:

- Government or industry regulations and restrictions regarding an electrical project for example in Kenya for installation of a generator or installation in a Petro station one requires to have an Energy and Petroleum Regulatory commission Licence class A.This is strictly for special installation.
- Stakeholder's expectations-This concerns project updates and further information that will be relayed to them as project progresses.
- Contractor's scope-This refers to contractor's limitations and what the client can account for.

3. Timelines-There should be set timelines for different tasks.

If an equipment fails, downtime can affect production, thus it is essential to rent or purchase equipment from a Company that offers zero downtime. In the event of any equipment breakdown, they may give equipment. Replacement or support when and whenever it's needed. How to manage timelines,

- Ensure there is a backup-There should be an option if an equipment fails in order for project to move on.
- All necessary legal frameworks should be in place
- Meeting managers to review the project and if there are issues they should be mitigated on time.

4. Hire of Equipments and coordination with third parties

Most projects take off during sunny seasons. Proper mapping of projects requirements and booking equipments in Advance will prevent wasting time searching for equipments at the last minute.

5. Risk management

Policies and procedures should be set in place to make the project run more smoothly. There should be a central data base for ease of accessing information and arising issues reported up the chain of command.

Project policies

A project is governed by various policies from different areas. They include the following:

Occupational Health and Safety Act (OSHA). It ensures that all work activities are done safely. Also all employees are safe. It states that employees have a right to refuse unsafe work, Right to participate in the workplace health and safety activities through the health and safety committees or as a worker health and safety representative. OSHA shows total commitment of employer to employees and public pertaining to the protection of their health and safety.

Environmental health and safety (EHS). It ensures that Employees, other workers and the public are in a safe working environment. ISO 14001 provide guidelines to organizations that hazardous waste materials such as catalysts will be handed back to supplier for specialists' disposal.

To protect Employees from any injury, they should have personal protective Equipments. These includes gloves, goggles especially for those doing welding, safety boots, overalls and nose masks among others.

Workmen compensation Act-This is an Act of parliament that provides for compensation to workmen for injuries suffered in the course of their employment. A worker is compensated for work related injuries and diseases contracted in the course of their working. But an employee is not entitled to compensation if an accident not resulting in serious disablement or death is caused by the deliberate and willful misconduct of the employee.

IEE regulations-All electrical equipments or circuits should be assumed live until proven to be dead.

All equipment's should be as per the BS39

Project life cycle

A Project life cycle entails a four step process which is followed for completion of a project. These steps are:

Initiation-This is starting of a new project. It involves defining objectives, scope, purpose and deliverables to be produced.

Planning –The larger project is broken down into smaller tasks. Smaller goals are created which are achievable within the time frame. This is achieved through preparation of a work plan. (Read further www.cogta.gov.za/toolkit/TOOLBOX). The below figure is an illustration of a project life cycle for recovery project management adapted from the Revised PMBOK (PMI 2013 Pg. 42)

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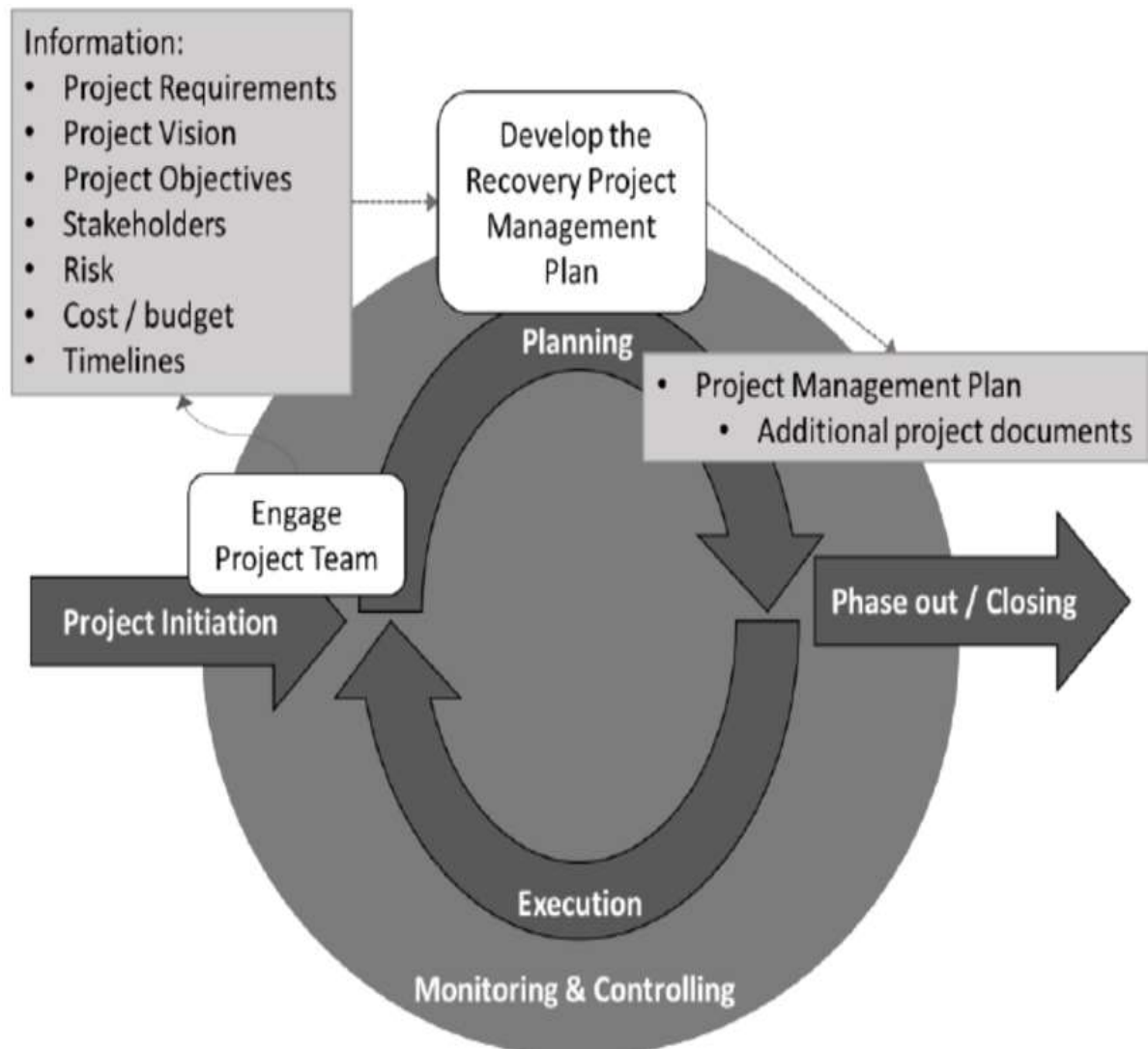


Figure 155: Monitoring project control

Table 9 Annual work plan

YEAR	YEAR	YEAR			
MEETING DATES			15 th jan 2019	15 th june 2019	15 th dec 2019
TOPIC	EXAMPLE				
Strategic review	Strategic aims				
	Charter review				
	consultation				
Regular review	policy				
	Principal performance				
	Curriculum				
	Budget				
	Board process				
Emergence review	National standards				
	New Government initiatives				

Planning is normally done to determine a number of things. There is the issue of time which is determined by pert or cpm. Pert is an acronym for program evaluation review technique. PERT refers to a project management tool used to calculate amount of time it will take to realistically finish a project. It schedules, organizes and coordinates tasks within a project. Pert takes into account the uncertainty of activity times. It is a probalistic model. It makes use of three estimates of time.

- ☐ Optimistic time (t_o)
- ☐ Most likely time (t_m)
- ☐ Pessimistic time (t_p)

Critical path analysis

Critical path method or critical path analysis is the sequence of scheduled activities that determines the duration of the project. It describes the longest sequence of tasks in the project. Activity times are knownwith certainty. For each activity earliest start time (EST) and latest start times (LST) are computed. The path with the longest time sequence is called critical path. The activities on the critical path are called critical Activities.

Execution –This turns the plan into action. Work is done according to original plan.

Closure-This is the last phase. It involves providing Final deliverables, releasing project resources and determining success of the project.

When undertaking an electrical project, the following policies come into place:

14.3.2.3 Self-Assessment

- 1 Electrical engineers use various ways and tools in calculating expected time for project completion. How do they do this?
 - a) Using a program evaluation technique s
 - b) Using critical path analysis
 - c) Using project Budget
 - d) Using the Number of activities to be performed in a project
- 2 Company YX was given a Contract to install electricity in an industry. To ensure quality the manager should adhere to the following except
 - a) Budget
 - b) Scope
 - c) Resources
 - d) Schedule
- 3 During project initiation phase, the manager does the following except
 - a) Define project scope
 - b) Identify and formulate project objective
 - c) Breakdown project tasks into smaller activities
 - d) Describe purpose and deliverables expected from the project
- 4 Pessimistic time is the longest time taking into consideration all odds. This is the time estimate if all goes long. TRUE OR FALSE?
- 5 Critical path analysis is the sequence of scheduled activities that determines the duration of the project TRUE OR FALSE?
- 6 Project life cycle varies by project type and nature of the project?
- 7 True /False
- 8 Explain the importance of planning in project management?
- 9 Describe activities undertaken in the four main project cycle phases?
- 10 Highlight the key components of a project work plan document
- 11 What factors should one consider when formulating project objectives?
- 12 Practical Questions
- 13 You have been given the task of installing electricity in a new hospital building.
 - a. Prepare the work plan for the tasking
 - b. Outline the project objectives
 - c. List down resources you will require in performing the task
 - d. Outline some of the project logistics that you will use in implementing the project
 - e. Develop a work structure showing the various tasks and responsible persons
 - f. Describe some of the policies that will guide or you will observe during the implementation of the project

Prepare a PERT chart showing the project timelines

Conduct a critical path analysis for this project and identify the critical path.

14.3.2.2 Tools, Equipment, Supplies and Materials for the specific learning outcome

14 Drills	.Stationeries
15 Grinders	.Cables
16 Computers	.Trunkings
17 Phones	.Pipes
18 Multimeter	.Accessories
19 Electricians knife	.Panels
20 Pliers	

14.3.2.4 References

Bibliography

Obelender, G. D. (1993). *Project Managemnet for Engineering and Construction*. Boston: Mc Graw Hill.

Telsang Martand (2002), industrial engineering and production management, s.chand & company ltd ram nagar, new delhi

Cole Gerald, (2006) 6th edition management theory and practice, Thomson learning, london

14.3.3 Learning Outcome No 2: Manage Project team

14.3.3.1 Learning Activities

Learning outcome # No 2 Manage project team	
Learning activities	Special instruction
You are the project manager of an upcoming restaurant. Come up with a text outline structure of work breakdown structure (wbs) on the restaurant	

14.3.3.2 Information sheet 2

Definition of terms

Project personnel-This is the staff involved in the project

Work breakdown structure-is a deliverable oriented breakdown of a project into smaller components

Decomposition-Act of breaking down deliverables into successively smaller chunks to be completed within a given time frame.

Managing a project team requires good decision making and communication skills.

The manager has to:

Establish a balanced team. This means employees with technical skills and those with communication skills are integrated together.

The objectives of the project should be clear to ensure that there are no deviations from set standards. Team leaders should be given an opportunity to raise concerns.

There should be good line support.-Different project team leaders from different departments should gain their line managers support in order to be able to identify any potential areas or times of conflict with team members.

Establish a team code

Project leaders and team members come up with their expectations and are placed on a flip chart paper. If there is a variance from this behavior, it is always referred back to the team code.

Recognize stages of team development

Teams go through forming, storming and norming stage before stabilizing. Therefore as a leader you need to adopt from directive to consultative approach of leadership. This will ensure maximum performance.

Use of Neutral facilitator for critical meetings to help in idea generation or decision making .Alternatively develop your own ideas/skills to facilitate groups.

Networking is vital either internally or externally first use the team members, they could be willing to more input through giving opinions or conducting research.

The managers should do review learning on regular basis. This involves asking questions such as

-what success have we achieved so far?

-how could we move more effectively during the rest of the project?

For success of project management, the project manager has to create a work breakdown structure. This helps him to oversee the tasks more effectively than the complex activities.

Purpose of WBS (Work breakdown structure)

- Work breakdown structure helps to define and organize the scope of the total project.
- Assists in assigning responsibilities, resource allocation, monitoring the project and controlling the project.
- Deliverables are made more precise and concrete.

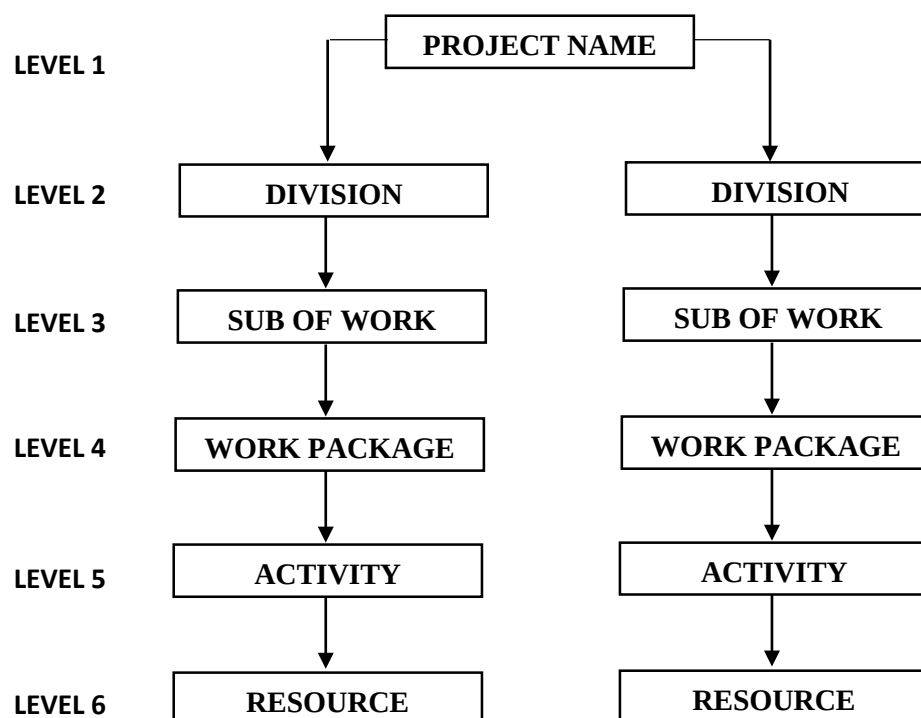
Process of creating a WBS

In order to create a WBS One needs to have the following inputs. The project scope statement, project management plan, organization process assets and Approved change requests.

Also the following tools are necessary, work breakdown structure template and a decomposition.

An example of a WBS

Work breakdown structure



Effective project management requires proper strategic planning. This is achieved through SWOT analysis. This is a planning tool used for evaluating strengths, weaknesses, opportunities and threats to a project. This helps the project manager to improve the project or individual tasks where better efficiency can be gained. A well-organized project will show tasks to be performed and the resources involved. Thus project organization is very vital.

Swot analysis

This is a tool that achieves competitive advantage by comparing ones strengths and competitors weaknesses and analyzing opportunities that are present. It is used by project managers to decide on the most advantageous projects. It involves analyzing internal and external factors. Swot analysis gives focus on the best for the project. SWOT means strengths, weakness opportunities and threats.

Strengths

This refers to the attributes that make a project team to excel. This information can be drawn from customers and clients through questioning.

Sample of strengths

Expertise
Reputation
Cost
Project Management
Speed of Delivery
Communication
Procurement and Supply Management

By using the above as a checklist project manager can ask himself the following questions.

1. What have we excelled at in the past?
2. What do others say that we have excelled at?
3. What resources do we have and others don't

Weaknesses

1. Weaknesses can lead to underperformance in an organization. The table on the strength can be used to analyze weaknesses. The checklist questions are as follows:
2. What was the principal cause of failure of the previous project?
3. How has criticism been?
4. How many customers/project have been lost and why?
5. Which internal conflict has been experienced

Opportunities

These are actions that can lead to achieving organizational goals. They include:

Sample of opportunities

Enter new market Develop new products Add new client Expand to a new geographical area Hire new employees Open new stores/locations Raise morale

Opportunities exist as:

Economic-This concerns future market demand for product or service and also from competitors.

Technological-Better technology increases sales.

Social –This could be demographic such as population shifts, health issues and attitudes for certain problem in a country.

Political-This refers to political stability, no violence within a country. It also touches on taxes, tariffs and regulations.

Threats

These are negative effects which are beyond an organizations control. They are either internal or external.

New competitor Existing competitor Increasing supplier cost Decreasing market demand Decrease quality work Bankruptcy of supplier Check dissatisfaction

Internal threats-Employee turnover rate becomes high, Breakdown of Equipments decrease quality work and poor public relations.

External threats-They include obsolete system, Technological factors, Increase supplier costs, market demand and Act of God.

Questions from threat analysis could be

1. Where did the project fail recently?
2. What are the changes the project is experiencing recently?
3. Which competitors are the greatest threat?
4. Which part of the project is mostly under threat?

The following is an example of a swot analysis template

Strengths	Weakness
Opportunities	Threats

14.3.3.3 Self-Assessment

- Which of the following is correct interpretation of SWOT analysis
 - Scope, Work structure , Opportunity and Time
 - Strength, Weakness Opportunity and Threat
 - Support, Work, Organization and Time
- Work Break down Structure is used for the following purpose except?
 - Work breakdown structure helps to define and organize the scope of the total project.
 - Assists in assigning responsibilities, resource allocation, monitoring the project and controlling the project.
 - Ensure that deliverables are made more precise and concrete.
 - To delegate tasks and duties to the project team
- The following are the responsibility of project manager except
 - Controlling
 - Directing project
 - Organizing Project
 - Defining project output
- Project Organization Structure is used to show work and scope of work to be done in a particular project. True /False
- Effective project management requires proper strategic planning TRUE OR FALSE?
- SWOT analysis gives focus on the best for the project TRUE OR FALSE?
- Explain the purpose of work break down structure
- Discuss the various components of SWOT analysis and their importance to the project
- Explain the importance of training project personnel
- Describe some of the EHS standards used in electrical engineering projects

Practical questions

- You have been tasked to create project team for city electrification project.
 - List down the nature of project team and prepare a project organization structure that will be used for this project.
 - Prepare a job description for each project team members
 - Prepare a work break down structure and use it to show duties and responsibilities to be undertaken by each project team member

14.3.3.4 Tools, Equipment, supplies and materials

- Computers
- Phones
- Stationeries

14.3.2.5References (APA)

1. Obelender, G. D. (1993). *Project Managemnet for Engineering and Construction*. Boston: Mc Graw Hill.
2. Telsang Martand (2002), industrial engineering and production management, s.chand & company ltd ram nagar, new delhi
3. Cole Gerald, (2006) 6th edition management theory and practice, Thomson learning, london
4. <https://www.projectengineer.net>

14.3.4 Learning Outcome No 3: Manage materials tools and equipment's

14.3.4.1 Learning Activities

Learning outcome#3 manage materials, tools and equipment's	
Learning activities	Special instruction
1.Through groups of three trainees Identify five (electrical) power tools 2.Explain the function of each tool 3.Draw the power tools	Open the link https://www.electrical

14.3.2.2Information sheet No 3

Definition of terms

Maintenance-it's any activity designed to keep the resources in good working condition or restore them to operating status.

Inventory-It refers to materials in stock

Material management deals with supporting the complete cycle of material flow, from purchase to the distribution of finished product. It is very vital since it acts as a link to other departments for example marketing and Engineering. Material management objectives are mainly categorized into two:

Primary objectives and secondary objectives.

The primary objective are stated as-Making available supply of materials in specified quantity and quality at economic cost and maintaining the continuity of supply.

Secondary objectives assist in achieving primary objective. They are stated as:

Purchasing items from reliable source at economic price

Reduction of costs by using cost reduction techniques such as variety reduction, standardization and simplification, value analysis, inventory control purchase research etc.

Coordination of the functions such as planning, scheduling, storage and maintenance.

In an electrical project the tools, materials and equipment's used are different from other projects.

They include but not limited to:

Personal protective equipment's.. They enhance personal safety. They include Goggles, safety glasses, gloves, long-sleeve shirts. Common sense is a great essence and a trainee has to protect himself from all hazards before taking on any task. Other tools are:

Circuit testers, screw drivers, electric drill, electrician knife, wire strippers, pliers, hammer, nut drivers, Tape measure, level, electrical tape, flashlight/headlamp among others.

Tools are chosen according to their functions.

Equipments used depends on the project at hand. They may include transformers, control units, motors. Materials for use in an electrical project are but not limited to: Cables, Conduits, Trunkings, cable clips, and conduit saddles, glands (male and female bushes).

Tools can either be classified as hand tools and power tools.

Hand tools include all non-powered tools such as hammers and pliers. Power tools are powered by electricity. For example an electrical drill, circuit breaker. Care should be taken when using electrical equipments to avoid electrocution.

Materials can either be consumables or non-consumables. Consumables have long life span (Distribution board) while non-consumables (conductors) are short lived.

Maintenance

Tools and equipments should be stored well after use. Tools should be kept away from wet or damp areas. All tools and equipments should be well maintained. Maintenance methods could be, planned maintenance, Preventative maintenance, and Breakdown maintenance, predictive and corrective maintenance.

There should be a proper record for tools, equipments and materials in an organization. Therefore inventory control is necessary.

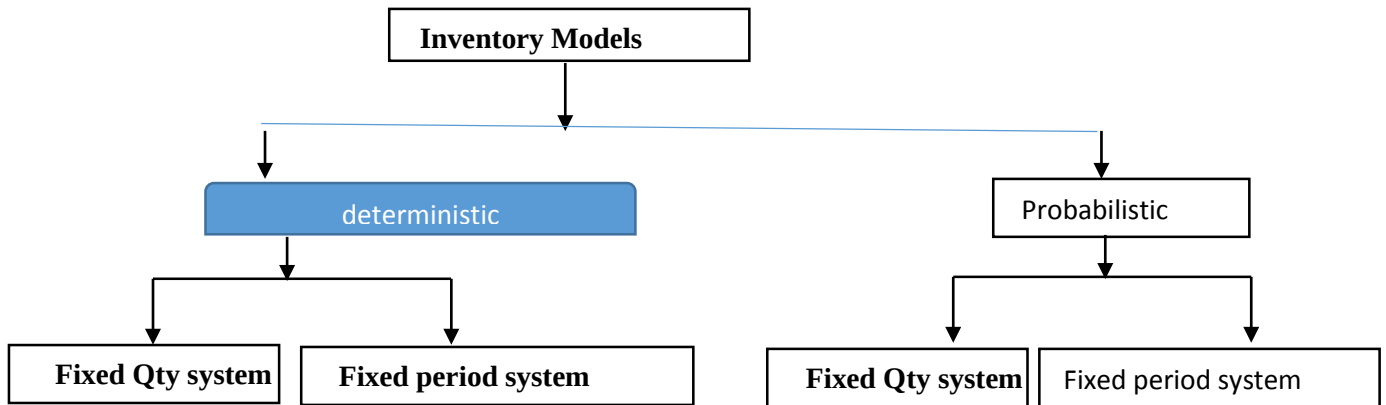
Types of inventories

- Tools inventory-This includes both standard tools and special tools
- Raw Material inventory-It deals with basic fabricated materials

Tools inventory has special tools such as a voltmeter which measures voltage either AC or DC. There is circuit tester which checks wheather a circuit is alive or dead. Earth loop impedance tester measures the effectiveness of earthing in an installation. Insulation resistance tester which measures the resistance between the conductors and conductors and the earth.

Standard tools serve more than one purpose. Pliers are used for cutting cables, they can strip them. A hammer, screw drivers, Electrician knife are multipurpose.

(Do further reading on inventory from Starr and miller, inventory control theory and practice,



14.3.2.3 Self-assessment

1. Project materials refers to
 - a) Man power
 - b) Resources
 - c) Money
 - d) All of the above
2. Productive maintainnce , unplanned down time losses include ;
 - a) Equipment breakdown
 - b) Shift changes
 - c) Unplanned Maintenance
 - d) All of the above
3. Material requirement planning does not include
 - a) Material Price
 - b) Bill of material
 - c) Inventory level
 - d) Production Schedule
4. Electrical engineering project use different and varied tools equipments and materials unlike other projects? True /False
5. Tools equipments and materials do not require maintenance once they have been kept in a safe dry place? True /False
6. Material management deals with supporting the complete cycle of material flow, from purchase to the distribution of finished product. True or False?
7. Describe the various inventory systems used in electrical engineering projects
8. Explain the importance of auditing tools , material and equipments in project?
9. Outline factors to consider when identifying tools, material and equipment to be used in the project

10. Explain the importance of maintain a tools and equipment inventory in project management?

Practical Questions

You have been contracted to install electricity in a super highway in a modern city;

- a) List tools materials and equipment you will use for this project
 - b) Outline the classification you will use for the toola and equipments
 - c) Prepare a maintenance schedule you will use for the equipments and tools
- 1.1 Tools, material and equipment inventory system is developed as per the nature of the project
- 1.2 Tools, materials and equipments are classified as per the project activities
- 1.3 Tools, materials and equipment are maintained in line with project policies.
- d) EHS standards are adhered to in line work place procedures

2.3.2.4 Tools, equipments, supplies and materials

- Circuit tester
- Voltmeter
- Pliers
- Drills
- Trunkings
- Cables
- Conduits
- Control panels
- Hammers
- Soldering gun
- Distribution box
- Circuit breakers

14.3.2.5 References (APA)

Obelender, G. D. (1993). *Project Managemnet for Engineering and Construction*. Boston: Mc Graw Hill.

Telsang Martand (2002), industrial engineering and production management, s.chand & company ltd ram nagar, new delhi

Cole Gerald, (2006) 6th edition management theory and practice, Thomson learning, london

www.iloencyclopaedia.org

14.3.5. Learning Outcome No. 4. Manage project budget

14.3.5.1. Learning activities

Learning Outcome No. 4. Manage project budget	
Learning activities	Special instructions
Activity 1 Assume that you are the new project manager of Wazi holdings who are contracted to install electrical power at the District commissioner's office which has six offices. 1. Determine the budget estimate (electrical works) for the offices. 2. List all the tools, equipment and materials required	

14.3.5.2. Information sheet 4

Definition of terms

Project Budget –This is a tool used by project managers to estimate the total cost of a project.

Project budget management-Is a process of formally identifying, approving and paying the costs and expenses incurred on the project.

Budgeting process –This is an activity of determining cost estimates of individual tasks, or work package to develop total cost estimate that allow setting a formal cost baseline.

Project budgetary process

Project budget consists of the following steps.

1. Defining the project
2. Executing the budget
3. Controlling the budget
4. Updating the budget

For the success of the project budget there are inputs that are required to give information. These are WBS, Project contract or initial budget, Resource cost estimates, Activity duration Estimates, Historical information, Market conditions and donor organization policies and chart of accounts structure. The information given by inputs will be used by project team to develop Cost estimates by activity, the project budget and the budget variance report.

Budget development involves identifying applicable costs factors which are associated with project tasks. The cost could be labor, material and other direct costs. Cost for performance of a task is directly related to personnel assigned to task, time for performance and any other non labor items required by task.

1. Defining the budget

Project manager is responsible for estimating budget requirements for completion of a project. All costs should be allocated to project activities and all aspects of project which includes internal and external cost of human resources, equipment, travel, materials and supplies. The budget should be more detailed and accurate than the proposal budget. The budget can be generated by use of spreadsheets. As budget development proceeds, additional tasks may arise. They include updating WBS and project schedule.

Resource requirements-This involves determining resources required (People, Equipment, Services and Materials) and their quantities.

Human labour resources includes personnel for provision of various services, their quantity and duration of service. For example:

personnel	units	Months
Project manager	1	12
Project staff	2	11
Administrator	1	12
Driver	1	10
Technical adviser	1	8
M & E specialist	1	10
Total	7	

Equipment and material resources-This includes all specialized tools needed by the project. Equipment may include water pumps, Generators, vehicles, computers and printers. Materials would include utility services such as electricity, telephone lines, stationeries, and internet and installation facilities. For example

Account-Training materials

materials	Units
Books and manuals	100
Writing materials	100
notebooks	100

After documenting project requirements then cost estimation is done. This is obtained from people responsible for the work efforts.

Budget development-This is putting all information together from the organization about taxes, shared cost pools, donor regulations and restrictions. This enhances proper allocation of finance for each item. Then finally the budget is set for approval. It is reviewed by project team and various members from finance department. Again it is approved three times during the project life cycle from which a donor negotiates with the finance team and it becomes contact budget. Next is during planning phase when budget is developed into more details and it becomes a baseline budget.

2. Executing the budget

A baseline budget is a time phased budget. It measures and monitors budget. It compares costs incurred by the project as it progresses. Approved budget needs to be communicated to the stakeholders in the project.

Execution of the budget normally starts after budget has been approved and project authorized to start its activities according to project plan

3. Budget control

Budget control is a critical responsibility to the project manager. The organization needs to clarify roles of all stakeholders involved in budget control. The finance manager is charged with recording, tracking the budget and monitoring from a cost accounting perspective and generate reports.

4. Budget update

Many changes are liable to occur in a budget. There could be civil unrest, political interference. Other times the donor may give a small percentage for modifications. There could also be the issue of currency fluctuations. These can affect the budget. The project manager need to understand the donor's clauses and restrictions on specific items. Any approved change to the budget has to be reflected in the accounting system used by the organization and new project budget reports have to reflect this change.

Elements of a budget

These are essentials for a budget. They include:

1. Plan-This refers to future operations of a firm. This involves internal and external factors. Internal factors are within the firms control and discretion, for example promotional programs and manufacturing processes. The external factors are beyond a firms control like General conditions of the project, Government policy and size and composition of population. The budget plan suggests what will happen and should make it happen regardless of the factors involved.
2. Operations and resources
This involves a plan for sourcing funds to finance fixed and current assets. Also the resources of the firm are covered and ways of generating revenue from products and services and expenses to be incurred in generating revenue is factored in the budget.
3. Financial terms
Budgets are prepared in terms of monetary value.
4. Specified future period
A budget is prepared for a fixed duration. It could be monthly or annually.
5. Comprehensiveness
A budget involves all activities and operations within an organization. All the activities from all departments are integrated together and an overall budget is formed which is called Master budget.

Coordination

All activities from various departments are linked together to make the budget more effective and meaningful.

Project cost management

Project cost management (PCM) is concerned with the process of planning and controlling the budget of a project. It also incorporates estimating, budgeting, financing and managing the costs. In order to manage costs effectively, there are three key processes needed. These are:

- Project cost Estimating
- Project cost budgeting
- Project cost control

Project cost estimating

It is a process of estimating how much it will take to complete project activities. All resources to be used by the project are put into considerations. They include Labour, Materials, Equipment, Services and facilities. In some projects one may add inflation allowance.

Project cost budgeting

After all estimation has been done, information is available for projects cost baseline. The approved baseline budget forms the budget for the project. Cost baseline are arrived at by combining cost estimates of individual activities over the life of the project. Cost baseline can be used also for determining and justifying project funding.

Project cost control

This is the execution phase. Project status activities are fully monitored. No deviations should exist on schedules, quality or scope otherwise this will have greater cost impact. Evaluation of the current status against the baseline helps to determine any cost variance for the project. Questions arise for example, is the project progressing well? Is it meeting quality targets? The questions give us information on how the project is performing. It is also possible to determine if there is any corrective action needed in order to be able to forecast the projects total cost at completion

14.3.5.3 Self-assessment

1. Project performance measurement techniques that integrate scope time and cost data is;
 - a) Earned Value
 - b) Cost Variance
 - c) Earned Value management
 - d) Cost Baseline
2. A cost estimate that provides an accurate estimate of project costs is
 - a) Baseline
 - b) Direct cost
 - c) Definitive costs
 - d) Cognitive Reserves

3. Controlling changes on the project budget
 - a) Cost estimate
 - b) Cost Baseline
 - c) Cost Control
 - d) Cost management Plan
4. A cost estimating techniques that uses the actual cost of a previous similar project as the basis for estimating the cost of the current project is called
 - a) Estimate of completion
 - b) Cost estimation
 - c) Analogous estimate
 - d) Definitive estimate
5. Project budget management is a process of formally identifying, approving and paying the costs and expenses incurred on the project. TRUE OR FALSE?
6. Budget development involves identifying applicable costs factors which are associated with project tasks. TRUE OR FALSE?
7. Execution of the budget normally starts after budget has been approved and project authorized to start its activities according to project plan. TRUE OR FALSE?
8. Explain the importance of preparing a project budget
9. Describe the processes followed in budgetary process
10. Outline the various elements included in the budget for an electrical project
11. Discuss the importance of project cost management in completion of projects?

Practical Questions

1. Describe the various techniques used in cost control in project management
2. You have been contracted to install electricity in a secondary school:
 - a) Prepare a budget indicating cost of the project
 - b) Record separately the cost of miscellaneous activities
 - c) Indicate how you will distribute resources as per the master budget

14.3.5.4 Tools, Equipment, supplies and materials for the specific learning outcome

- Computers
- Phones
- Stationeries
- Cables

14.3.5.5. References

1. Obelender, G. D. (1993). *Project Managemnet for Engineering and Construction*. Boston: Mc Graw Hill.
2. Stefano Tonchia (2008) *Industrial Project Management*, Spring Verlag, Berlin
3. Telsang Martand (2002), *industrial engineering and production management*, s.chand & company ltd ram nagar, new Delhi
4. Cole Gerald, (2006) 6th edition *management theory and practice*, Thomson learning, London

14.3.6. Learning Outcome No. 5. Supervise and assess project implementation

14.3.6.1. Learning activities

Learning Outcome No: 5 Supervise and assess project implementation	
Learning activities	Special instructions
Learner to come up with a project of installation of lighting, power and machine circuits in school electrical workshop. He should state what is required at the four phases of a project	Learner to liase with head of electrical workshop

14.3.6.2. Information sheet No.14/ LO5

Monitoring-Monitoring is checking progress against plans

Evaluation-This is assessing as systematically and objectively as possible a completed project or program (or a phase of an ongoing project)

Control-This is checking against set standards to avoid deviations

Monitoring and evaluation (M & E) is a process that helps improve performance and achieve results. It involves a routine collection of information from projects and programs. It purposes to have accountability of resources used and results obtained internally and externally.

It considers past experiences and uses them to forecast. Thus informed decisions are made on the future of the initiative.

Effective project management requires that a well-organized control system be designed, developed and implemented so that effective and efficient feedback on the projects progress can be attained.

The main objective of monitoring is to ensure that various time and cost targets are met and the operational plans prepared for execution of the project are adhered to. Monitoring process ensures that there is no gap between the desired and actual achievements and targets.

Steps in monitoring

1. Setting a monitoring environment –The project manager sets an environment where he exercises his authority and responsibilities.
2. Setting performance standards-This is done by the project monitor on behalf of the project manager. He sets systems and procedures for monitoring the projects.
3. Measuring the progress of the project- Project monitor keeps a close watch on the progress of activities by collecting information regarding on what has been done with regard to. He quantifies them and compares with targets where corrective action can be taken based on feedback.
4. Reviewing-In case of non-permissible activities, he takes corrective decision on how to handle it.

Then he reports to project manager if he fails to take an early action and project manager acts promptly on all unresolved issues.

Effective project management ensures that all materials supplied by the vendors are up to standard. The process of inspecting and verifying the products and services is called control quality. Project quality management is divided into three main processes. Quality Assurance, Quality planning and quality control.

The scope of project control involves:

Scope and progress control-Process of control begins at the last level of WBS.

Expediting and control is a process which ensures the progress-Expediting acts as an external force to do on a project towards its completion.

Performance control-it involves identifying performance parameters and ensure right specifications, right selection of source of suppliers/contractors.

Schedule control-It ensures compliance with time schedule of the project.

Cost control-This monitors all cost components and ensures completion of the project at any optimal cost without lowering the performance.

Project monitoring and evaluation

An organization will always develop its own data regarding its project for ease of analysis. A project is divided into sub phases which determine correct flow of the documents in the project. Cost is monitored through cost control plan. It's normally cost versus financial accounting. Costs include job costs, input cost and target costs. Time is monitored through time control plan. This ensures strict target dates are met for example document planning for design, release of materials for shipment among other activities. Cash flow control is necessary. Cash in cash out is taken care of. All suppliers are paid against their invoices. Concerning technical phase, detailed monitoring concerns designs, procurement, production, shipment, erection, startup and commissioning. The project manager comes up with a master plant list referred to the plant areas to link machines to the plant. Financial management system is used to manage finance Information technology is used to give standardized reports from the company data base according to agreed needs. It updates design document planning and monitoring takes place for single items and in total computation of master plan list and relevant general job schedule. This leads to calculating and restating various phases. If there is need for replanning, it will take place at the end of necessary verifications and consequent analysis and recovery attempts.

Example of project monitoring and reporting

Stake holders	Interest/concerns	results
Top managers/Executives	Company development, Profitability and reputation	Project status issues
Director	Project performance	Cashflow, Earned value
Executive project manager	Time, cost, Quality, Cash flow	Task level, Details. Overall project status
Team leaders	Schedule, Workload	Overall project status and department details
Client	Schedule, Quality	Project status, Schedule, Quality.
Supplies	Exchange of information schedule	Delivery target dates, Technical details
Information management	Data base update	Dedicated information on project

Project monitoring and evaluation in summary

Issues	
Action to be taken	
Action follow up	

Project quality control

Project quality control is an activity used to evaluate whether product and services meet the specified requirements. The process of ensuring procedures have been followed is called Quality Assurance.

Quality Assurance tools ensure there is quality of service in every project level.

The following are tools and techniques for quality assurance.

Forms and templates

These are used as reminders of questions to ask during project planning and status reporting. When are the materials going to be bought, how much quantity is needed for various phases of project. How many personnel's are required?

Checklists-This is turning action plan into a list of things to be done. This could be routine project planning, management task among others. One checklist could consider if one is ready to do a job, another if the job has been finished.

Reviews –This looks at the project process, how communication has been done and more so are there problems that have been encountered and what action has been taken.

Quality control is mostly on technical level of project and its management. Where work has been done repetitively quality assurance can be applied.

Results from quality control are used to,

- Take corrective action –What has deviated from set standards is scrapped off or done again.
- Communicate to QA process so that the action can be taken to prevent similar errors.

14.3.6.3. Self-assessment

1. Results from quality control are used for the following purpose except
 - a) Take corrective action
 - b) Communicate to QA process so that the action can be taken to prevent similar errors.
 - c) Budget for the project
 - d) Improve in execution of similar project
2. Project Monitoring and Evaluation are:
 - a) The same
 - b) Different: Monitoring is the routine collection of information to track progress, evaluation is used to determine the relevance and fulfillment of objectives, developmental efficiency, effectiveness, impact and sustainability
 - c) Different. Monitoring systems are determined during the planning phase while evaluation is determined at the end of the project or program
 - d) The same. Only evaluation suffices in result based management
3. What does a monitoring and evaluation framework include?
 - a) Objectives, assumptions, indicators and a summary of activities
 - b) Objectives and indicators
 - c) Goal and objectives
 - d) Goal, objectives and indicators
4. Effective project management requires that a well-organized control system be designed, developed and implemented so that effective and efficient feedback on the projects progress can be attained. TRUE OR FALSE?
5. The process of inspecting and verifying the products and services is called control quality. TRUE OR FALSE?
6. Explain the various quality control for planning stage of the project
7. Discuss the importance of monitoring and evaluation of an electrical installation project
8. Explain the various aspects one should adhere to in controlling quality of electrical projects?
9. Discuss various challenges encountered in evaluating electrical projects
10. Project quality control
 - Project cycle
 - Project monitoring and evaluation

Practical Question

1. You have been invited to supervise the quality of a hospital electrical installation:

- a) List the activities you will undertake to establish the quality of work done
- b) Form a team to check various quality aspects and develop a check list sheet for them to use in assessing the various project output
- c) Monitoring of project activities as per the project work plan

14.3.6.4. Tools, equipment, supplies and materials for the specific learning outcome

- Consultancy
- Computers
- Phones
- Tape measure
- Stationeries
- Panels
- Accessories

14.3.6.5 References

1. Obelender, G. D. (1993). *Project Managemnet for Engineering and Construction*. Boston: Mc Graw Hill.
2. Cole Gerald, (2006) 6th Edition Management Theory And Practice, Thomson Learning, London
3. Telsang Martand (2002), industrial engineering and production management, s.chand & company ltd ram nagar, new delhi
4. <https://www.glassdoor.com>

14.3.7 Learning Outcome No. 6. Prepare project reports

14.3.2.1 Learning activities

14.3.7 Learning Outcome No. 6. Prepare project reports	
Learning Activities	Special instructions
Write a progress report in your area of specialization dealing with only one unit for a period of one month.	

14.3.7.2 Information sheet No. 14/ LO6

Definition of terms

Progress report-This is a report on activities or process that takes place during project undertaking.

Completion report-These are detailed reports on of completed projects.

Project Progress reports- is an executive summary of the progress that a project team has made on a certain project over a certain time frame.

A project progress report contains the following:

Report Title page

The title page contains the Name of the project, the period that the report covers and who prepared the report. Most of the time, the project manager prepares the report.

The period of coverage is the time taken which could be weekly or monthly.

Executive summary

This is a summary page of the information in progress report. For example, the delays incurred, percentage completed, manpower on site, major activities involved, challenges experienced, delays if any amongst many.

Main sections of the report;

1. Project description-it has the following contents

- Project: Name: and Location
- Project description-Project scope and objectives
- Owner: Name and address (include contact Name, Phone and Fax)
- Financial assistance source: Project No, date of approval and grant amount
- Consultant: Name and address
- Contractor: Name and address

2. Contract details

- Description of contract and amount
- Starting date and duration
- Items under contract
- Advance payment guarantee details and performance bond

3. Progress description

- General progress to date
- General progress since last report

- Progress details by trade (describe progress against planned schedule and percentage accomplished)
- Give a description on materials procured and on site
- State resources available on site during the report period and compare to required numbers

The report may explain the work that has been covered, resources spent, unexpected problems or instances that the project has undergone (if any) and estimated time of completion. Progress report gives the recipient for example supervisors an overview of the overall status report of a specific project. The recipients evaluate the project manager's performance and requests a few changes if necessary. Progress report is important because it makes everyone to know what has been accomplished and how the various departments or teams can collaborate. There is also transparency and accountability on an accomplished task, expected results and why they differed from the expected ones. Once the document is accepted it becomes part of the projects official documentation. This will also help in improving project evaluation and review through shedding light on systematic issues, loopholes and other causes of delay or Failure. A progress report may be written daily, weekly or monthly.

Completion report-This is a formal document of closing a project. It describes results and outcomes of

Summary of work completed to date

Task	deliverable	% of work complete	Date submitted

Example of project completion report

Project identification

Title : Electrical installation at Nairobi city councils office
 Serial Number : 345
 Executing agency- : Nowel Electricals

Host government :Kenya

Starting date :1st August 2018

Actual duration :5 Months

Actual project cost :8 Million

Funding received :10 Million

Part 1-----Executive summary

1. Background information about the project

This section entails all the details about the beginning of the project, what it does, the accomplishments and challenges incurred. Then the conclusion and any recommendations.

Elements of project report Project report must include:

Deliverables-This section lists current status of deliverables for example a product launch such as solar could involve printing t-shirts, trade shows, vendor launch party. Next to each deliverable it should be written completed or ordered.

Timelines –This shows completed tasks, those tasks on schedule and those behind the schedule

Recommendations and Explanations-This shows where additional resource are required, how unexpected reports affected the project, late delivery from vendors, software problems.

After project completion all reports pertaining to the project are compiled together. The electrical designer gives the operational manual to project manager. This is done after testing and inspection have been accomplished.

Documentation of the project report and operational manual

When documenting a project report one must:

1. Write to the reader.

The report is not for oneself but for those reading it (management and clients).A language that can be understood by all is necessary. Avoid technical terms otherwise one has to start by definition of terms.

2. Structure the report.

Every report is different in its own way but there are standards involved such as an executive summary and an abstract of the project contents.

3. Back up data

An effective project report has data to back it up. This is usually used to convince a client or support the project team. It could be Gantt charts, control charts or spreadsheets.

4. Separate facts from opinions

When documenting the project, use facts and not opinions since they are subjective. Document from the available facts.

Operational manual

This refers to the documentation by which an organization provides guidance to its members to perform their operations efficiently and effectively. It documents approved standard procedures for operating safely to give results and compliance with it is approved by the project manager.

It acts as a reminder to employees of how to do their job. The operational manual is either a book or folder of printed documents with standard procedures. A good manual reduces human error and informs everyone precisely what to do and whom they are answerable to and responsible for. It should always be updated.

14.3.7.3. Self-assessment

1. The document that is used to describe project output and results is called
 - a) Completion report
 - b) Progress report
 - c) Work plan

- d) Work Break down structure
- 2. Project completion report is a summary of
 - a) Facts
 - b) Analysis
 - c) Information
 - d) All these
- 3. The project manager will require the following in writing a progress report
 - a) Project schedule
 - b) Material and equipment document
 - c) Suppliers contract
 - d) Project design document
- 4. A good completion report will show the following except
 - a) Costing of the project
 - b) Methods
 - c) Executive summary
 - d) Appendixes
- 5. The section of the report that show the purpose of the project is
 - a) Results
 - b) Methods
 - c) Objectives
 - d) Appendices
- 6. The title page contains the Name of the project, the period that the report covers and who prepared the report. TRUE OR FALSE?
- 7. Differentiate between progress report and completion report.
- 8. Describe the main components detailed in the completion report?
- 9. Explain the various techniques used in sharing completion report for a project
- 10. Discuss the importance of writing a progress report?

Practical question

- 1. Prepare a completion report for a closing project on electrical installation in a hospital
- 3. Provide an outline of operational manual for the completed project
- 4. Prepare a safety and precaution document for project users
- 5. Documentation of the project report and operation manual

14.3.2.4. Tools, Equipment's, supplies, materials for the specific learning outcome

- Computers
- Phones
- Stationeries

14.3.2.5. References

1. Obelender, G. D. (1993). *Project Managemnet for Engineering and Construction*. Boston: Mc Graw Hill.
2. Telsang Martand (2002), industrial engineering and production management, s.chand & company ltd ram nagar, new delhi
3. Cole Gerald, (2006) 6th edition management theory and practice, Thomson learning, London
4. <https://www.sampletemplate.com>

14.3.8 Learning Outcome No. 7. Project Commissioning

14.3.2.1 Learning activities

Learning Outcome No. 7. Project Commissioning	
Learner activities	Special instructions
• Draw a completion certificate on electrical project • Explain the components the completion certificate	• Use the internet or any installation book as your reference

14.3.2.2 Information sheet No. 14/ LO7

Definition of terms

Commissioning-These are activities performed in getting processes running to establish normal operation.

Completion certificate-This is a form that a client signs to certify that a project is complete. Through signing of this Document the client certifies that the project manager has successfully completed all the deliverables concerning the original work agreement and any change orders for the project.

Importance of completion certificate

- It's a mandatory legal document showing that electrical works have been done and completed according to the safety norms and IEE regulations.
- It alerts power supply about the completion of the premises.
- It shows that installation has been done as per the power supply laws and procedures. The Loads to be supplied are also indicated. The electrical contractors License is also attached which shows details of all variables that were inspected and tested.
- Components of completion certificate
- It has address of the power supply company, then the address of the premise and project manager's address. It also shows type of supply-Single phase or three phase it shows the loads to be connected.
- It has plot number of client.
- It has a place for client to sign and the supply company.
- It alerts power supply about the completion of the premises.
- It shows that installation has been done as per the power supply laws and procedures. The Loads to be supplied are also indicated. The electrical contractors License is also attached which shows details of all variables that were inspected and tested.

Hand over Documents

This is a document that contains all that is to be handed over to the owner of a project. It also contains the transition period after which the project will be left to the owner. It contains the following

1. Equipment list-This is available one month before handover of the Equipment. It updates the equipment register and gives them a stock code
2. Equipment specification and certificate-This shows that equipments are of the right standards and have compliance certificate.
3. Maintenance manuals-These assist in making maintenance schedules and identifying tools for maintenance.
4. Recommended spare list. The original equipment must have original spare parts.
5. Operation manuals-These help the management to prepare training packages
6. Drawings and calculations-All drawings and design work is availed prior to handover.

User manuals

These are documents that give instructions on how an Equipment will be operated. It also shows how tools are supposed to be used. It has guidelines on how materials are processed.

1. Self-assessment

1. Functional performance testing for specific components of the project have been successfully been completed. What is the next step in the commissioning process?
 - a) Submit the final commissioning report
 - b) Perform owner training.
 - c) Test inter-relationships between systems and subsystems.
 - d) Recommend beneficial occupancy.
2. Which document is most helpful for identification of acceptance criteria for a project
 - a) Completion certificate
 - b) Commission Plan
 - c) Project design
 - d) Project Contract
3. Completion certificate is issued once the period for certain project is complete. TRUE OR FALSE?
4. Outline the components found within a project completion certificate ?
5. It is advisable to obtain a project completion certificate at the end of the project. Discuss the importance of this document
6. Describe the various hand over documents issued at the completion of project?

Practical Questions

1. Prepare a hand over document for a recently completed project for installing electricity in a secondary school
2. Prepare a training manual for use by the schools

14.3.8.4. Tools, Equipment, supplies and materials

- Insulation resistance tester
- Mega meter
- Earth continuity tester
- Ohmmeter
- Supplies and materials
- Stationeries
- Cable

14.3.8.5. References

1. Obelender, G. D. (1993). *Project Managemnet for Engineering and Construction*. Boston: Mc Graw Hill.
2. F.G.Thompson, (1994) electrical installation technology, elbs, Malaysia
3. Telsang Martand (2002), industrial engineering and production management, s.chand & company ltd ram nagar, new Delhi
4. Cole Gerald, (2006) 6th edition management theory and practice, Thomson learning, London
5. [Https://www.cepl.net.in](https://www.cepl.net.in)

CHAPTER 15: POWER GENERATION/ DEMONSTRATE UNDERSTANDING OF POWER GENERATIONS

15.1. Introduction of the Unit of Learning / Unit of Competency

Power generation entails the use of energy resources to produce electricity. This competency in power generation is applied in electricity generating sectors. This unit of competency covers sources of energy, power plants and their linkages in electrical engineering. The essential resources required in this unit include video tapes of power generation, models of power station, electrical charts of power generating stations, and actual visits to the power generating stations. Upon the completion of this course the trainee is expected to establish the design of a power station, operate and maintain a power station while observing the safety procedures and standards applicable in power generating plants. This course prepares the trainee for a gainful career in power generating sectors.

15.2. Performance Standard

demonstrate understanding of power generating station layout as per the source of energy, expected plant output and the safety involved as per IEEE regulation, demonstrate understanding in the operation of power generating stations constituents as determined by the type of the generating plant and their standard operating procedure Finally, the trainee will demonstrate understanding in the operating sequence of generating station as determined by the energy flow, type of generating stations, and components used in the generating station.

15.3. Learning Outcome

15.3.1. List of Learning Outcomes

- a) Identified types of generating stations
- b) Demonstrated understanding of power generating station layout
- c) Demonstrated understanding in the operation of power generating stations
- d) Demonstrated understanding in the operating sequence of generating stations.

15.3.2 Learning Outcome No. 1. Identified types of generating stations

15.3.2.1 Learning Activities

Learning Outcome No. 1. Identified types of generating stations		
Learning Activities		Special Instructions
i)	Identifying types of generating stations as per their sources of energy form visiting websites ,selecting plants	-visit appropriate website -use appropriate video
ii)	Identifying the appropriate generating station for a given location as in the line with their source of energy. Through visiting websites, using video tapes and visiting potential sites and	tapes -Consult trainers for visits outside the training workshops

15.3.2.2 Information Sheet No. 15/ LO1

Definition of terms

Generation: It is the process of power production by use of an alternator.

Alternator: A device which produces alternating electrical current.

Current: It's the flow of charges in the circuit.

Power station: It is a unit where the alternator, control and protection devices are installed for the purpose of electricity generation.

Transformer: A device for stepping up and stepping down the voltage.

Sources of energy

- water
- wind
- Geothermal
- Solar
- Nuclear
- Diesel
- Waves
- Biomass
- Tides

Factors consider in generating plant setup;

- Availability of the source of power
- The capital available
- The security of the area
- The available technology
- Government policies
- The legal aspect
- The population of the area

Types of generating stations as per their sources of energy

1. Geothermal power station
2. Hydroelectric power station
3. Wind energy power station
4. Solar energy power station
5. Nuclear power stations
6. Diesel engine power station
7. Thermal power station
8. Waves power station
9. Waste water and Bio gas power station
10. Tidal power station

Generating station location as in the line with their source of energy.

- a) Geothermal power station e.g. Olkaria I, Olkaria II, Olkaria III and Olkaria IV located at Olkaria-Naivasha-Kenya where geothermal energy is harvested.
- b) Hydroelectric power station e.g. -Kindaruma, masinga, Kiambere, Gitaru power station and Kamburu power station located along Tana river
 - Wanjii power station along Mathioya River
 - Sondu Miriu power station along Sondu River
- c) Wind energy power station-e.g. –Lake Turkana Wind power project (LTWP) at Loiyangalani District, in Marsabit county-Kenya.
- d) Solar energy power station e.g. Garissa power station(55MW) in Garissa County
- e) Waves power station e.g. 2.5 MW wave farm Aguçadoura of the coast of Portugal(IRENA Ocean Energy Technology Brief 4June 2014)

Tidal power station e.g. Sihwa Lake tidal power station (2 August 2016 by Yun Ha Kim)

15.3.2.3. Self-Assessment

1. Which of the following is the correct equation for the electrical power generated by the hydroelectric power plant?
 - a) $75 \times 0.736 \times wQH\eta$ Watt
 - b) $(7.5/0.736) \times wQH\eta$ Watt
 - c) $0.845 \times wQH\eta$ Watt
 - d) $9.81 \times wQH\eta$
2. Which of the following is not a requirement for site selection of hydroelectric power plant?
 - a) Availability of water
 - b) Large catchment area
 - c) Rocky land
 - d) Sedimentation
3. The amount of electrical energy that can be generated by a hydroelectric power plant depends upon _____
 - a) Head of water

- b) Quantity of water
 - c) Specific weight of water
 - d) Efficiency of Alternator
4. Potential energy of water is used to drive the turbine.
 - a) True
 - b) False
 5. Hydroelectric power plant is _____.
 - a) Non-renewable source of energy
 - b) Conventional source of energy
 - c) Non-conventional source of energy
 - d) Continuous source of energy
 6. Hydroelectric power plant is generally located near load centre.
 - a) True
 - b) False
 7. Hydroelectric power plant is mainly located in _____.
 - a) Flat areas
 - b) Deserts
 - c) Hilly areas
 - d) Deltas
 8. Which statement about hydroelectric power plant is wrong?
 - a) Efficiency of hydroelectric power plant does not reduce with age
 - b) Its construction cost is very high and takes a long time for erection.
 - c) It is very neat and clean plant because no smoke or ash is produced.
 - d) Meeting rapidly changing load demands is not possible in hydroelectric power plant.
 9. Which of the following is not an advantage of hydroelectric power plant?
 - a) no fuel requirement
 - b) low running cost
 - c) continuous power source
 - d) no standby losses
 10. Which of the following statement is true about hydroelectric power plant?
 - a) Hydroelectric power plants are multipurpose.
 - b) Due to non-uniform flow of water frequency control in such plants is very difficult.
 - c) Hydroelectric power plant has high running cost
 - d) Water is used as fuel in hydroelectric power plant
 11. State FIVE types of generating stations
 12. Give five sources of electrical energy
 13. In each case, give the type of generating station and the resource used for power generation
 14. Explain the factors to consider when selecting a site for a power station
 15. Explain factors consider in generating plant setup
 16. Describe types of generating stations as per their sources of energy

Practical exercises

1. Identifying types of generating stations as per their sources of energy form visiting websites ,selecting plants
2. Identifying the appropriate generating station for a given location as in the line with their source of energy. Through visiting websites, using video tapes and visiting potential sites and

15.3.2.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Models of generating station
- Charts
- Actual generating stations
- Video tapes
- Actual of power plant
- OSHA standards
- IEE regulations

15.3.2.5. References

1. Principles of Power systems by V.K Mehta.
2. Sihwa Lake tidal power station (2 August 2016 by yun ha Kim)

15.3.3. Learning Outcome No. 2. Power generating station layout

15.3.3.1. Learning Activities

Learning Outcome No. 2. Power generating station layout	
Learning Activities	Special Instructions
The trainee to observe a video from the following links or any other appropriate link for power generation plant and hence : a) Observing a model power station, charts, video tape and drawing the layouts and generating station as per the source of energy b) Determining the plant output c) Observing model sites, charts, video tapes, visiting potential site for generating station and determining the appropriate plant layout as per the safety involved	-visit a power plant -visit the various links -Observe model power stations -Observe video tapes -Visit different websites -Hold consultations and discussions

15.3.3.2 Information Sheet No 15/L02.

Establishing layout of generating station as per the source of energy

Types of Geothermal power Station

- Dry Steam Power Plant
- Flash Steam Power Plant
- Binary Cycle power plant
- Hydro Power Station
- A Thermal Power Plant
- Wind Power Station
- Nuclear Power Station
- Diesel Engine Power Station
- Solar Power Station
- Tidal Power Station

Determining the plant output for a given layout.

Wind power plant

Equation for wind power is given below;

$$P = \frac{\rho A V^3}{2} \quad \text{where } \rho - \text{Density of air}$$

The more the dense the air, the more energy is received by the turbine.

A-Swept area of the turbine

The large the swept area, the more power the turbine can capture from the wind.

V-Wind speed

The amount of energy in the wind varies with the cube of the wind speed.

Hydro power station

$$P = m \times g \times H_{\text{net}} \times \eta$$

Where:

P- Power measured in Watts (W).

m- Mass flow rate in kg/s (numerically the same as the flow rate in litres/second because 1 litre of water weighs 1 kg)

g - The gravitational constant, which is 9.81m/s^2

H_{net} - the net head. This is the gross head physically measured at the site, less any head losses. To keep things simple head losses can be assumed to be 10%, so

$$H_{\text{net}} = H_{\text{gross}} \times 0.9$$

η - The product of all of the component efficiencies, which are normally the turbine, drive system and generator

For a typical small hydro system the turbine efficiency would be 85%, drive efficiency 95% and generator efficiency 93%, so the overall system efficiency would be: $0.85 \times 0.95 \times 0.93 = 0.751$ i.e. 75.1%

See; <https://www.renewablesfirst.co.uk/hydropower/hydropower-learning-centre/how-much-power-could-i-generate-from-a-hydro-turbine/>

Determining the plant layout as per the safety involved

Seven ways to make a hydropower station a safer workplace (30 September 2015 by Ambrose Canning)

- Designing safety into hydropower stations
- Planning ahead to control risks
- Safety upgrades for older hydropower stations
- Station evacuation
- Flood protection
- Fire and smoke control
- Emergency and crisis management

SEE; <https://www.hydropower.org/blog/seven-ways-to-make-a-hydropower-station-a-safer-workplace>

Summary of standards (Safe Health Work 2016)

Safety and health organization

This section ascertain whether the company has safety departments, committees, and sectional safety committee.

Health and safety policy

The reason for this section is to determine whether the hydroelectric power plant station's safety management has Health and Safety Policies and whether these policies are implemented effectively as required by OSH standard.

Accident reporting, investigation, and analysis

This concerns accident reporting, investigation, and analysis as required by the Occupational Health and Safety Authority

Safety inspection

This captures data from the respondents concerning safety inspection.

Hazard identification and control

This covers company's hazard identification and control as required by Occupational Safety and Health Standard.

Safety operations and procedures

This concerns the company's safety operations and procedures.

Equipment safety

This section of the questionnaire gathered data on equipment safety at the power plant

15.3.3.3 Self-Assessment

1. State the safety requirement in a power station
2. Draw the schematic layouts of the following power stations
 - a) Geothermal power plant
 - b) Nuclear power plant
 - c) Solar power plant
 - d) Wind power plant
3. Write the equations of the power developed in the following types of power plant
 - a) Hydro Power plant
 - b) Wind power plant
4. Explain hazard identification and control
5. Perform calculations in tidal power station

15.3.3.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Actual of power plants
- Models of electric power plant
- OSHA standards
- IEE regulations
- Charts

15.3.3.5. References

1. <https://www.hydropower.org/blog/seven-ways-to-make-a-hydropower-station-a-safer-workplace>
2. <https://openei.org/wiki/wind-energy>
3. Principles of power system by V.K Mehta
4. Quinlan M., Bohle P., Lamm F. 3rd ed. Palgrave Macmillan; South Yarra (Australia): 2010. Managing occupational health and safety: a multidisciplinary approach.
5. Dawson P., Zanko M. Tilde University Press; Prahran (Australia): 2011. Social innovation at work: sustainable OHS in HRM; pp.

6. Nichols T., Walters D., Tasiran A.C. Trade unions, industrial mediation and industrial safety. Evidence from the UK. J Ind Relat. 2007.
7. Environmental, Health, and Safety Approaches for Hydropower Projects - March 2018
8. Employee Safety: Safety at Hydro Plants - 05/01/2009

15.3.4. Learning Outcome No. 3. Demonstrate understanding in the operation of generation station

15.3.4.1 Learning Activities

Learning Outcome No. 3. Demonstrate understanding in the operation of generation station	
Learning Activities	Special Instructions
• Using model power station, visiting links, observing video tapes, visiting actual power station and outline the constituents of the generating station as per the type of generating station. • Using model power station, visit links, observing video tapes, visiting actual power station and establishing the operation of the constituent component in generating stations by their standard operating procedure. • Using model power station, visiting links, observing video tapes, visiting actual power station and outlining energy conversions from one form to another in line with the operation of the constituent components of the plant.	• Visit a power plant • Visit the various links • Observe model power stations • Observe video tapes • Visit different websites • Hold consultations and discussions

15.3.4.2 Information Sheet No. 15/ LO3

The constituents of the generating station as per the type of generating station

a) Hydroelectric power station

It constitutes

- The dam

It is the wall created which stores water and develops the water head

It is made of masonry stone and concrete or concrete alone

- Spill ways

It is an overflow used to discharge the surplus water from the storage reservoir into the river on the downstream side of the dam

- Head work:

It consists of the diversion structure at the head of an intake. They include racks for diverting floating debris, booms, sluices, sediments and valves.

- Surge Tank;

It is tank open at the top in which water level rises or falls to reduce the pressure swings in the penstock

- Pen stock:

It can be open or closed conduits which carry water to the turbines. They are made of steel or reinforced concrete.

- **Water Turbine:-**

Used to convert the energy of falling water into mechanical energy.

In a hydro power station they are either of

- Impulse type
- Reaction type

- **Alternator:**

It converts mechanical energy into electrical energy

- **Transformer:**

It is mainly for stepping up and stepping down voltage

- **Circuit breaker.**

It provides protection to the power plant equipment in case of excess current flowing in a certain circuit

b) Nuclear Power station

- **Heat exchanger**

This is where the steam is developed for driving the turbine

- **Nuclear reactor**

It is the components in which the nuclear fuel is subjected to nuclear fission. It controls the chain reaction that starts after the fission is done

- **Steam turbine:**

It converts the kinetic energy of the steam into mechanical energy which rotates the alternator.

- **Alternator:**

It converts the mechanical energy into electrical energy

c) Gas Turbine Power plant

- **Compressor:-**

A rotary type of compressor is used. It is used to increase the air pressure.

- **Regenerator:**

It is a device which recovers heat from the exhaust gases of the turbine. It consists of a nest of tubes contained in a shell

- **Combustion chamber.**

The heat is added to the air at high pressure by burning oil. This facilitates atomization of oil and its thorough mixing with air.

- **Gas turbine**

Converts the kinetic energy of the gas at high temperature and pressure into turning mechanical energy.

- **Alternator.**

It converts mechanical energy of the turbine into electrical energy.

- **Starting Motor:**

It is meant to start the compressor before starting the turbine.

- The Batteries

For energizing the motor.

d) Solar Power station

- PV module

It converts the solar energy into electrical energy

- Charge controller

It prevents the overcharging and over discharging of the battery.

- Battery

It stores the electrical energy

- Inverter:

It converts the D.C current / voltage into A.C current/voltage.

- Fuel/circuit breaker:

It protects the circuit in case of excess current in the circuit.

e) Diesel Power station

- Fuel supply system:

It has strainers, storage tank, fuel transfer and all day storage tank

- Air Intake System:

It supplies air to the engine for fuel combustion

It has pipes and filters

- Exhaust system:

It assets to remove the engine exhausts gas outside the building and discharge it into atmosphere.

It also incorporates a silencer.

- Cooling system

It provides the cooking in order to keep the temperate of the engine parts within the safe operating limits.

It has the cooling tower, water source and pumps.

- Lubricating system

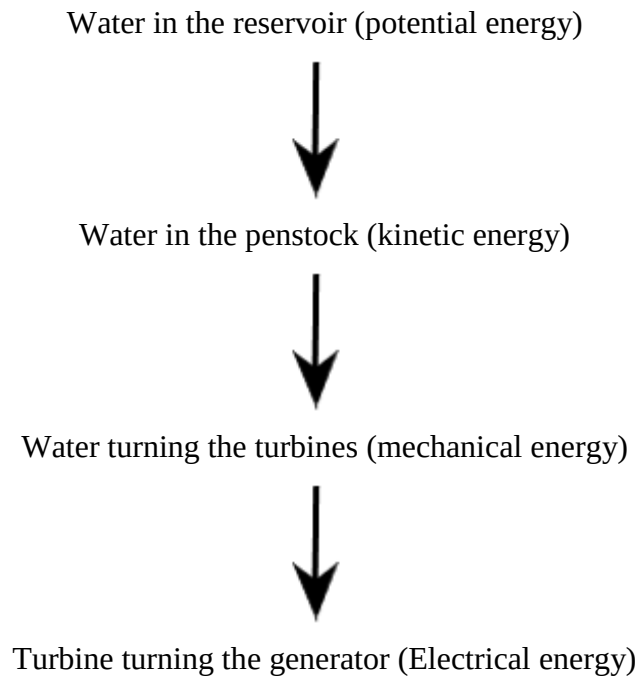
It minimizes the wear of rubbing surfaces of the engine. It consists of lubricating oil tank, the filers and oil cooler.

- Engine starting system:

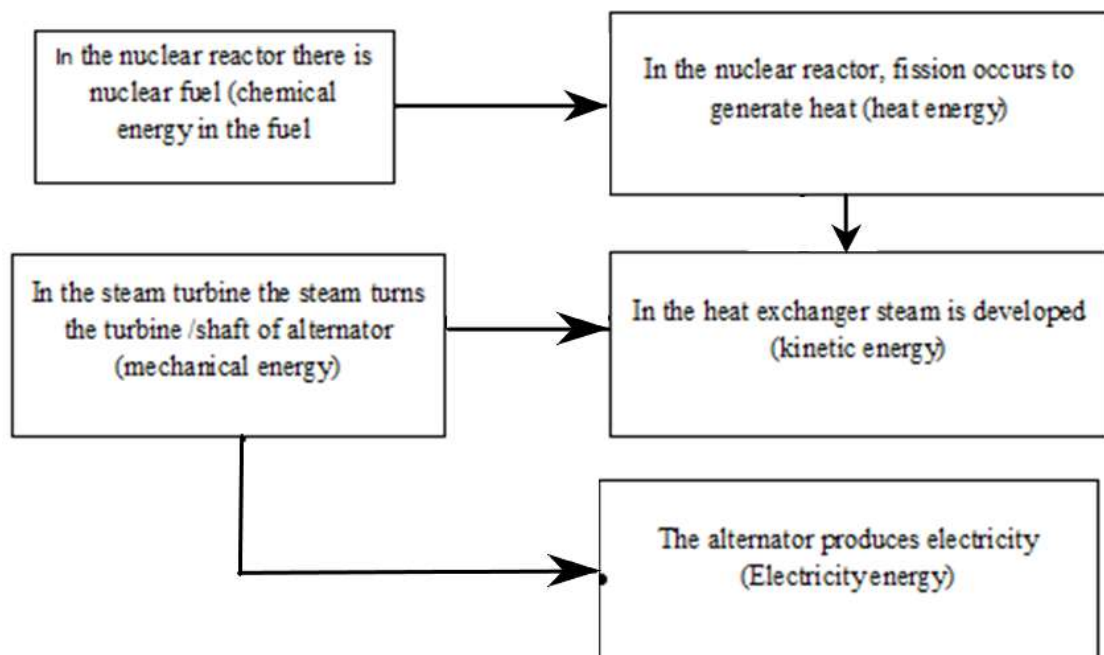
It is an arrangement to rotate the engine initially while starting until firing starts and then with its own power.

Determining Energy conversations from one form to another in line with the operation of the constituents of the plant.

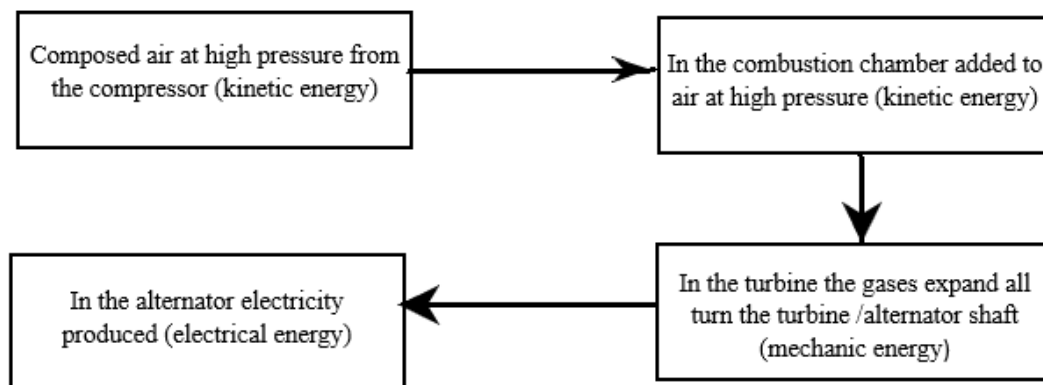
Hydroelectric Power Station



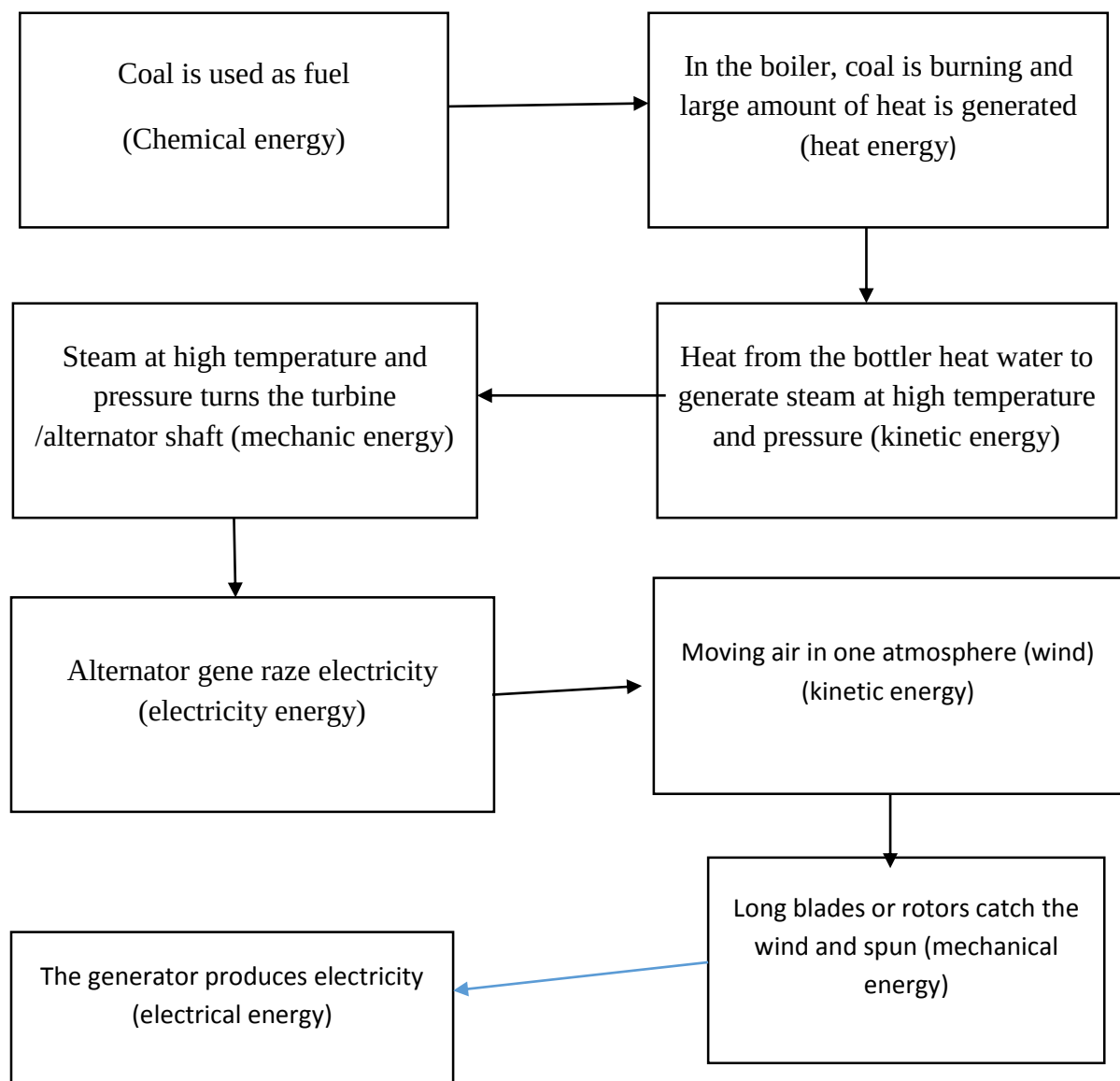
Nuclear Power Station



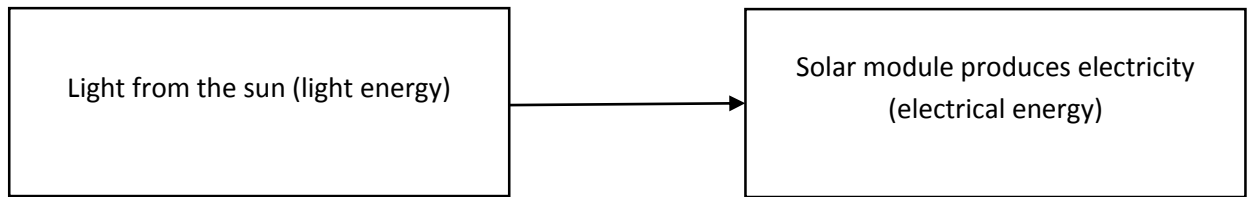
Gas Turbine Power Plant



Thermal power station



Solar power station



$$\text{Power} = (\text{Height of Dam}) \times (\text{River Flow}) \times (\text{Efficiency}) / 11.8$$

2.3.2.3 Self-Assessment

1. What is the advantage of sectionalizing of power plant?
 - a) High reliability
 - b) Low capital cost
 - c) Low maintenance
 - d) Easy operation
2. The area under the load curve represents _____
 - a) the average load on power system
 - b) maximum demand
 - c) number of units generated
 - d) load factor
3. Which of the following is equal to the maximum demand?
 - a) The ratio of area under curve to the total area of rectangle
 - b) The ratio of area under curve and number of hours
 - c) The peak of the load curve
 - d) The area under the curve
4. State a generating station
5. Outline the constituents of the generating station as per the type of generating station.
6. Explain the operation of the constituent component of a geothermal power station.
7. Describe the constituents of the generating station as per the type of generating station
8. Outline energy conversions from one form to another of the following power station.
 - a) Diesel power station
 - b) Nuclear power station
 - c) Solar power station

Practical questions

1. Determine the constituents of the generating station by the type of the generating station
2. Determine Operation of the constituent components in generating stations by their standard operating procedure.

3. Demonstrate the conversion of energy through simulation from one form to another in line with the operation of the constituent components of the plant.

15.3.3.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Actual of power plants
- Models of electric power plant
- OSHA standards
- IEE regulations
- Charts
- Video tapes

15.3.3.5 References

1. <https://www.hydropower.org/blog/seven-ways-to-make-a-hydropower-station-a-safer-workplace>
2. <https://openei.org/wiki/wind-energ>
3. Principles of power system by V.K Mehta

15.3.5 Learning Outcome No. 4. Demonstrate understanding in the operating sequence of generating station

15.3.5.1 Learning Activities

Learning Outcome No. 4. Demonstrate understanding in the operating sequence of generating station	
Learning Activities	Special Instructions
• Determining the operating sequence of the generating plant by the energy flow from model power station, visit links, observing video tapes, visiting actual power station and • Using model power station, visit links, observing video tapes, visiting actual power station and determining the operating sequence of the generating plant by the type of generating station. • Using model power station, visit links, observing video tapes, visiting actual power station and determining the operating sequence by the type of components used in the generating station.	• visit a power plant • visit the various links • Observe model power stations • Observe video tapes • Visit different websites • Hold consultations and discussions

15.3.5.2 Information Sheet No. 15/ LO4

Demonstrate understanding in the operating sequence of generating station

- i. Determining the operating sequence of the generating plant by the energy flow.
- ii. Determining the operating sequence of the generating plant by the type of generating station.
- iii. Determine the operating sequence by the type of components used in the generating station.

- iv. Determining the operating sequence of the generating plant by the energy flow.

Energy flow in a wind power plant

Air moving in the atmosphere (Kinetic energy)

Wind turning the turbine/Generator shaft (mechanical energy)

Generator producing energy (Electrical engineering)

Wind energy is a form of solar energy. Wind turbines convert the kinetic energy in the wind into mechanical energy. Then a generator converts the mechanical power (energy) into electrical energy (electricity).

(<https://openei.org/wiki/wind-energy>)

Nuclear Power Station Layout

Hydro Power Plant

For the energy flow on hydro power station, Diesel power station and others see- principles of power system by V.K Mehta.

Determining the operating sequence of the generating plant by the type of generating station.

Hydro Electrical Power Station.

Hydro-electric power station is, located in hilly places where dams are built and accommodate large water reservoirs.

A water head is formed by making a dam across a river or lake. From the dam water is directed to the water turbine. The water turbine captures the energy in the falling water and changes the hydraulic energy into mechanical energy at the turbine shaft. The turbines turn the alternator and then the alternator converts mechanical energy into electrical energy. Hydro power stations assist in controlling floods, water for irrigation and water for drinking.

See:- For the other types of power stations see- principles of power stations by V. K. Mehta,

15.3.5.3. Self-Assessment

1. Out of the following which one is not an unconventional source of energy?
 - a) Tidal power
 - b) Geothermal energy
 - c) Nuclear energy
 - d) Wind power
2. Out of the following which one is not an unconventional source of energy?
 - a) Tidal power
 - b) Geothermal energy
 - c) Nuclear energy

- d) Wind power
- 3. What is Demand factor?
 - a) Ratio of connected load to maximum demand
 - b) Ratio of average load to connected load
 - c) Ratio of maximum demand to the connected load
 - d) Ratio of kilowatt hour consumed to 24 hour
- 4. Which of the following is not a type of Combined Plant?
 - a) Sodium- mercury-Potassium plant
 - b) Gas turbine-Steam turbine plant
 - c) Thermionic steam plant
 - d) Thermoelectric steam plant
- 5. Which of these is not a component of nuclear reactor?
 - a) reactor core
 - b) refractor
 - c) control rod
 - d) biological shield
- 6. Which of these is not a merit of nuclear power?
 - a) amount of fuel required is small
 - b) plant requires a huge amount of area
 - c) demand for coal and oil is reduced
 - d) most economical in large quantities
- 7. Wind turbines convert the kinetic energy in the wind into mechanical energy.
TRUE OR FALSE?
- 8. This section must be related with the Performance Criteria, Required Knowledge and Skills and the Range as stated in the Occupational Standards.
- 9. Determining the operating sequence of the generating plant by the energy flow.
- 10. Outline the operating sequence of
 - a) Hydro generating station.
 - b) Diesel power station

Practical Exercises

1. Determining the operating sequence of the generating plant by the energy flow from model power station, visit links, observing video tapes, visiting actual power station
2. Demonstrate the operating sequence of the generating plant by the type of generating station. Sources of power generating can be model power station, visit links, observing video tapes, visiting actual power station and
3. Determining the operating sequence by the type of components used in the generating station, using model power station, visit links, observing video tapes, visiting actual power station

14.3.6.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Actual of power plants
- Models of electric power plant
- OSHA standards
- IEE regulations
- Charts
- Video tapes

15.3.5.5. References

1. <https://www.hydropower.org/blog/seven-ways-to-make-a-hydropower-station-a-safer-workplace>
2. <https://openei.org/wiki/wind-energy>
3. Principles of power system by V.K Mehta