071306T4EEN

Electrical Engineering (Power Option)

Level 6 ENG/OS/PO/CC/02/6

Apply Electrical

Principles

July/August 2024

Time: 3 Hours

TVET CURRICULUM DEVELOPMENT, ASSESSMENT AND CERTIFICATION COUNCIL (TVET CDACC)

WRITTEN

ASSESSMENT 3

HOURS

Answers

1. Calculate the time for which the current flowed. (3 marks)

Using the formula: $Q=I\times t$ Where:

- Q = charge (Coulombs)
- I = current (Amperes)
- t = time (seconds)

Given:

- $Q=80\,C$
- $I=0.5\,A$

Rearranging the formula gives:

$$t = \frac{Q}{I} = \frac{80\,C}{0.5\,A} = 160\,s$$

2. Calculate the total resistance in Series and Parallel. (3 marks)

a) Series: Rtotal=R1+R2+R3=10 Ω+20 Ω+30 Ω=60 Ω*Rtotal*=*R*1+*R*2+*R*3=10Ω+20Ω+30Ω=60Ω

b) Parallel: 1Rtotal=1R1+1R2+1R3=110+120+130*Rtotal*1=*R*11+*R*21+*R*31=101+201+301
Finding a common denominator (60): 1Rtotal=660+360+260=1160*Rtotal*1=606+603+602=6011
Thus, Rtotal=6011≈5.45 Ω*Rtotal*=1160≈5.45Ω

3. Calculate the resistance of the resistor and the new value of the current. (4 marks)

Using Ohm's Law:

$$R = \frac{V}{I}$$

Given:

- $V = 100\,V$
- $I = 5\,mA = 0.005\,A$

Calculating resistance:

$$R = \frac{100\,V}{0.005\,A} = 20000\,\Omega = 20\,k\Omega$$

Now, for the new voltage:

$$I_{new} = \frac{V_{new}}{R} = \frac{25\,V}{20000\,\Omega} = 0.00125\,A = 1.25\,mA$$

4. Calculate the terminal potential difference (p.d). (6 marks)

Using the formula: Vp.d=emf−I×r*Vp.d*=emf−*I*×*r*

Where:

- r=0.15 Ω*r*=0.15Ω

a) For 0.5A0.5*A*: Vp.d=6V−(0.5A×0.15Ω)=6V−0.075V=5.925V*Vp.d*=6*V*−(0.5*A*×0.15Ω)=6*V*−0.075*V*=5.925*V*

b) For 2A2*A*: Vp.d=6V−(2A×0.15Ω)=6V−0.3V=5.7V*Vp.d*=6*V*−(2*A*×0.15Ω)=6*V*−0.3*V*=5.7*V*

c) For 10A10*A*: Vp.d=6V−(10A×0.15Ω)=6V−1.5V=4.5V*Vp.d* =6*V*−(10*A*×0.15Ω)=6*V*−1.5*V*=4.5*V*

5. State two methods of rectifying armature reaction in motors. (2 marks)

1. **Using Compensating Windings:** Additional windings are placed on the pole faces to counteract the effects of armature reaction.
2. **Using Interpole Windings:** Small auxiliary windings are placed between the main poles to maintain the uniformity of the magnetic field.

6. State Kirchhoff's current and voltage laws. (4 marks)

- **Kirchhoff's Current Law (KCL):** The total current entering a junction equals the total current leaving the junction.
- **Kirchhoff's Voltage Law (KVL):** The sum of the electrical potential differences (voltage) around any closed circuit is zero.

7. Differentiate variation in resistance with temperature in conductors and semiconductors. (4 marks)

- **Conductors:** Resistance increases with temperature due to increased lattice vibrations, which impede electron flow.
- **Semiconductors:** Resistance decreases with temperature as more charge carriers (electrons and holes) become available, enhancing conductivity.

8. State four basic quantities used in engineering and science and indicate their corresponding SI units. (4 marks)

1. **Current (I)** - Ampere (A)
2. **Voltage (V)** - Volt (V)
3. **Resistance (R)** - Ohm (Ω)
4. **Power (P)** - Watt (W)

9. List five types of Single-phase machines. (5 marks)

1. **Single-phase Induction Motor**
2. **Single-phase Transformer**
3. **Single-phase Synchronous Motor**
4. **Single-phase Universal Motor**
5. **Single-phase AC Generator**

10. Explain why lights in power systems are connected in parallel. (4 marks)

- **Independent Operation:** Each light can operate independently; if one fails, the others remain lit.
- **Consistent Voltage:** All lights receive the same voltage, ensuring uniform brightness.
- **Ease of Maintenance:** Lights can be replaced or maintained without affecting others in the circuit.
- **Load Distribution:** Parallel connections allow for better load distribution across the circuit, reducing the risk of overload.

11. (a) A moving coil meter is rated 10 kΩ/V. The coil has a resistance of 50Ω. Calculate the value of multiplier required for: (6 marks)

i. The 10V d.c. range:

To find the multiplier M for the 10V range:

1. The total resistance R_t needed for a 10V range is: $R_t = 10\ k\Omega = 10{,}000\ \Omega$
2. The multiplier is given by: $M = R_t - R_{coil} = 10{,}000\ \Omega - 50\ \Omega = 9{,}950\ \Omega$

ii. The 10V a.c. range:

The calculation is the same for the a.c. range since the meter is rated the same: $M = 10{,}000\ \Omega - 50\ \Omega = 9{,}950\ \Omega$

(b) You are asked by your technical supervisor to carry out maintenance of the company earthing system.

(i) List three components of an earthing system. (3 marks)

1. **Earth Electrode:** The physical component buried in the ground to disperse electrical energy.
2. **Earthing Conductor:** The wire connecting the electrode to the electrical system.
3. **Earthing System Bonding:** Connections that ensure all parts of the installation are at the same potential.

(ii) Outline the procedure you would use to carry out 'insulation resistance test'. (5 marks)

1. **Preparation:** Disconnect the equipment from the supply and any sensitive components.
2. **Select the Tester:** Use an insulation resistance tester (megger).
3. **Connect the Tester:** Connect one lead to the conductor and the other to the earth or ground.
4. **Apply Voltage:** Set the tester to the appropriate voltage (usually 250V or 500V) and apply it.
5. **Record the Reading:** Check the reading on the tester; a high resistance (typically above 1 MΩ) indicates good insulation.

6. **Re-test:** Repeat the test for all conductors and ensure to record all readings for maintenance records.

12. (a) The resistance of the field winding of a shunt generator is 200Ω. When the machine is delivering 80kW the generated emf and terminal voltage are 475V and 450V respectively. Calculate:

i. The armature resistance; (6 marks)

1. **Calculate the armature current I_a:** $P = V \times I \implies I_a = \frac{P}{V} = \frac{80{,}000\,W}{450\,V} \approx 177.78\,A$
2. **Use the formula for terminal voltage:** $V_t = E - I_a \times R_a \implies 450 = 475 - 177.78 \times R_a$
   Rearranging gives: $R_a = \frac{475-450}{177.78} \approx 0.140\,\Omega$

ii. The value of generated e.m.f when the output is 50kW, the terminal voltage then being 460V.

1. **Calculate the new armature current I_a:** $I_a = \frac{50{,}000\,W}{460\,V} \approx 108.70\,A$
2. **Use the formula for terminal voltage:** $V_t = E - I_a \times R_a \implies 460 = E - 108.70 \times 0.140$ Thus,
   $E = 460 + 15.18 \approx 475.18\,V$

(b) Classify D.C machines according to methods of excitation.

1. **Separately Excited:** The field winding is powered from an independent source.
2. **Self-Excited:** The field winding is powered from the machine's own output.

- **Shunt Excited:** Field winding connected in parallel with the armature.
- **Series Excited:** Field winding connected in series with the armature.
- **Compound Excited:** Combination of both shunt and series excitation.

13. (a) List three methods of power factor correction. (6 marks)

1. **Capacitor Banks:** Adding capacitors in parallel to offset inductive loads.
2. **Synchronous Condensers:** Using synchronous motors to provide reactive power.
3. **Phase Advancers:** Devices used in induction motors to improve power factor.

(b) A coil of resistance 5Ω and inductance 120mH in series with a 100μF capacitor is connected to a 300V, 50 Hz supply. Calculate the current flowing in the circuit. (8 marks)

1. **Calculate the inductive reactance X_L:** $X_L = 2\pi f L = 2\pi(50)(0.120) \approx 37.7\,\Omega$
2. **Calculate the capacitive reactance X_C:** $X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(50)(100\times10^{-6})} \approx 31.83\,\Omega$
3. **Calculate the total impedance Z:** $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{5^2 + (37.7 - 31.83)^2} \approx \sqrt{5^2 + 5.87^2} \approx \sqrt{25 + 34.56} \approx \sqrt{59.56} \approx 7.72\,\Omega$
4. **Calculate the current I:** $I = \frac{V}{Z} = \frac{300}{7.72} \approx 38.87\ A$

(c) In the network shown in figure 1, find using Thevenin's theorem the current flowing in the 10Ω resistor. (11 marks)

1. **Identify the circuit components and remove the 10Ω resistor.**
2. **Calculate the Thevenin equivalent voltage Vth*Vth*:**

- For the circuit, calculate the open-circuit voltage at the terminals where the 10Ω resistor was connected.

3. **Calculate the Thevenin equivalent resistance Rth*Rth*:**

- Deactivate all sources (replace voltage sources with short circuits).
- Find the equivalent resistance seen from the terminals.

4. **Reattach the 10Ω resistor:**

- Use Vth*Vth* and Rth*Rth* to find the current through the 10Ω resistor using Ohm's Law: I=VthRth+10*I*=*Rth*+10*Vth* (Note: Actual calculations will depend on the specific values of R1,R2,R3*R*1,*R*2,*R*3 in the circuit.)

14. (a) Define the term 'lightning arrestor' and explain five types of lightning arrestors. (10 marks)

Definition: A lightning arrestor is a device used to protect electrical equipment from lightning strikes by diverting the surge of electrical energy safely to the ground.

Types of Lightning Arrestors:

1. **Rod Type Arrestor:** A simple metal rod that intercepts lightning strikes.
2. **Gap Type Arrestor:** Uses a spark gap to allow the lightning to jump and be directed to ground.
3. **Non-Gapped Arrestor:** Utilizes semiconductor technology to absorb surges without a gap.
4. **Composite Arrestor:** Combines multiple technologies for enhanced protection.
5. **Surge Protective Device (SPD):** Protects against transient voltage spikes in electrical systems.

(b) A series motor has an armature resistance of 0.2Ω and a series field resistance of 0.3Ω. It is connected to a 240V supply and at a particular load runs at 1440 r.p.m when drawing 15 A from the supply.

i. Determine the back e.m.f at this load. (4 marks)

1. **Calculate the total resistance:** Rtotal=Ra+Rf=0.2 Ω+0.3 Ω=0.5 Ω*Rtotal*=*Ra*+*Rf* =0.2Ω+0.3Ω=0.5Ω
2. **Calculate the voltage drop across the resistance:** Vdrop=I×Rtotal=15 A×0.5 Ω=7.5 V*Vdrop* =*I*×*Rtotal*=15*A*×0.5Ω=7.5*V*
3. **Calculate the back e.m.f E*E*:** E=V−Vdrop=240 V−7.5 V=232.5 V*E*=*V*−*Vdrop* =240*V*−7.5*V*=232.5*V*

ii. Calculate the speed of the motor when the load is changed such that the current is increased to 30A (assume that this causes a doubling of flux). (6 marks)

1. **New total resistance remains the same:** $R_{total} = 0.5\,\Omega$
2. **Calculate the new voltage drop:** $V_{drop} = 30\,A \times 0.5\,\Omega = 15\,V$
3. **Calculate the new back e.m.f E_{new}:** $E_{new} = V - V_{drop} = 240\,V - 15\,V = 225\,V$
4. **Using the relationship between speed and back e.m.f:** $\frac{E}{N} = \text{constant} \implies \frac{232.5}{1440} = \frac{225}{N_{new}}$
   Rearranging gives: $N_{new} = \frac{225\times1440}{232.5} \approx 1350\,\text{r.p.m}$