



**K. K. Wagh Institute of Engineering Education and Research,
Nashik**
(An Autonomous Institute from A.Y. 2022-23)

Model Answer
End-Sem Examination-I, Winter 2025

Academic Year: 2025-2026	Semester: I
Class: F Y B Tech	Program: B Tech
Branch Code: CIV/MEC/CHE	Pattern: 2023
Name of Course: Basic Electrical Engineering	Course Code: 2300106A

Q. No	Answer Details	Max. Marks																								
1a	<p>Calculation of Insulation Resistance of a Cable</p> <p>Insulation resistance of a cable is the resistance offered by the insulating material between the conductor and the earth.</p> <p>Formula:</p> $R = \frac{\rho}{2\pi l} \ln\left(\frac{D}{d}\right)$ <p>Derivation (brief): Consider a single-core cable of length l with conductor diameter d and inner sheath diameter D. For a thin cylindrical layer of insulation at radius r and thickness dr, the elemental resistance is</p> $dR = \frac{\rho dr}{2\pi r l}$ <p>Integrating from $r = \frac{d}{2}$ to $r = \frac{D}{2}$,</p> $R = \int \frac{\rho}{2\pi l} \frac{dr}{r} = \frac{\rho}{2\pi l} \ln\left(\frac{D}{d}\right)$ <p>where ρ is resistivity of insulation ($\Omega \cdot m$).</p>	6																								
2a	<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 25%; text-align: center;">Feature</th> <th style="width: 35%; text-align: center;">SMPS (Switch Mode Power Supply)</th> <th style="width: 40%; text-align: center;">UPS (Uninterruptible Power Supply)</th> </tr> </thead> <tbody> <tr> <td>Function</td> <td>Converts AC to regulated DC voltage for electronic devices</td> <td>Provides backup AC power during mains failure</td> </tr> <tr> <td>Primary Purpose</td> <td>Voltage conversion and regulation</td> <td>Power continuity and protection from outages</td> </tr> <tr> <td>Input/Output</td> <td>AC input, DC output (usually)</td> <td>AC input and AC output (some UPS provide DC internally)</td> </tr> <tr> <td>Backup</td> <td>No backup; stops if mains fail</td> <td>Provides power backup for a limited time (battery-based)</td> </tr> <tr> <td>Components</td> <td>Rectifier, high-frequency inverter, filter, regulator</td> <td>Battery, inverter, rectifier, charger, control circuitry</td> </tr> <tr> <td>Applications</td> <td>Computers, TVs, LED drivers, electronics</td> <td>Computers, servers, medical equipment, telecom systems</td> </tr> <tr> <td>Power Handling</td> <td>Low to medium power (few watts to kW)</td> <td>Medium to high power (kVA range)</td> </tr> </tbody> </table>	Feature	SMPS (Switch Mode Power Supply)	UPS (Uninterruptible Power Supply)	Function	Converts AC to regulated DC voltage for electronic devices	Provides backup AC power during mains failure	Primary Purpose	Voltage conversion and regulation	Power continuity and protection from outages	Input/Output	AC input, DC output (usually)	AC input and AC output (some UPS provide DC internally)	Backup	No backup; stops if mains fail	Provides power backup for a limited time (battery-based)	Components	Rectifier, high-frequency inverter, filter, regulator	Battery, inverter, rectifier, charger, control circuitry	Applications	Computers, TVs, LED drivers, electronics	Computers, servers, medical equipment, telecom systems	Power Handling	Low to medium power (few watts to kW)	Medium to high power (kVA range)	6
Feature	SMPS (Switch Mode Power Supply)	UPS (Uninterruptible Power Supply)																								
Function	Converts AC to regulated DC voltage for electronic devices	Provides backup AC power during mains failure																								
Primary Purpose	Voltage conversion and regulation	Power continuity and protection from outages																								
Input/Output	AC input, DC output (usually)	AC input and AC output (some UPS provide DC internally)																								
Backup	No backup; stops if mains fail	Provides power backup for a limited time (battery-based)																								
Components	Rectifier, high-frequency inverter, filter, regulator	Battery, inverter, rectifier, charger, control circuitry																								
Applications	Computers, TVs, LED drivers, electronics	Computers, servers, medical equipment, telecom systems																								
Power Handling	Low to medium power (few watts to kW)	Medium to high power (kVA range)																								



**K. K. Wagh Institute of Engineering Education and Research,
Nashik**

(An Autonomous Institute from A.Y. 2022-23)

	<p>Response to Power Failure Device shuts down immediately</p> <p>Cost Relatively low</p>	<p>Supplies power instantly or within milliseconds</p> <p>Higher due to battery and inverter system</p>	within
3a	<ul style="list-style-type: none"> • Amplitude: Maximum value of an AC waveform • Frequency: Number of cycles per second (Hz) • Form Factor: Ratio of RMS value to average value of AC • Cycle: One complete repetition of AC waveform • Instantaneous Value: Value of AC at a specific instant • Time Period: Time taken for one complete cycle ($T = 1/f$) • Crest Factor: Ratio of peak value to RMS value of AC 		8
3b	<p>Instantaneous Current in Series RC Circuit</p> <p>Given: Series RC circuit across AC supply $v(t) = V_m \sin \omega t$</p> <p>Impedance: $Z = \sqrt{R^2 + \frac{1}{\omega^2 C^2}}$</p> <p>Phase angle: $\phi = \tan^{-1} \left(\frac{1}{\omega RC} \right)$</p> <p>Peak current: $I_m = \frac{V_m}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}}$</p> <p>Instantaneous current: $i(t) = I_m \sin(\omega t - \phi)$</p> <p>Circuit Diagram: AC source in series with R and C</p> <p>Phasor Diagram: Voltage V as reference, voltage across R in phase with current, voltage across C lags current by 90°, current leads voltage across capacitor by ϕ</p> <p>Waveforms: $v(t) = V_m \sin(\omega t)$, $i(t) = I_m \sin(\omega t - \phi)$, $v_R = iR$ in phase with current, v_C lags current by 90°, current leads applied voltage by ϕ</p>		8



3c	<p>Given three-phase supply 400 V, 50 Hz and delta-connected load $R = 15 \Omega$, $X_L = 30 \Omega$</p> <p>Phase impedance $Z_\phi = R + jX_L = 15 + j30 \Omega$ $Z_\phi = \sqrt{15^2 + 30^2} = \sqrt{1125} \approx 33.54 \Omega$ Phase angle $\theta = \tan^{-1}(X_L/R) = \tan^{-1}(30/15) \approx 63.43^\circ$</p> <p>Phase voltage $V_\phi = V_L = 400 \text{ V}$</p> <p>Phase current $I_\phi = V_\phi / Z_\phi = 400 / 33.54 \approx 11.93 \text{ A} \angle -63.43^\circ$</p> <p>Line current $I_L = \sqrt{3} * I_\phi \approx 20.67 \text{ A}$</p> <p>Power factor $\cos \theta = \cos 63.43^\circ \approx 0.447$</p> <p>Total power $P = \sqrt{3} * V_L * I_L * \cos \theta = \sqrt{3} * 400 * 20.67 * 0.447 \approx 6390 \text{ W} \approx 6.39 \text{ kW}$</p> <p>Answer: Phase current $\approx 11.93 \text{ A}$, Line current $\approx 20.67 \text{ A}$, Total power $\approx 6.39 \text{ kW}$</p>	
3d	<p>Step 1: Phase voltage in Star connection</p> $V_\phi = \frac{V_L}{\sqrt{3}} = \frac{440}{\sqrt{3}} \approx 254 \text{ V}$ <p>Step 2: Phase current</p> $I_\phi = \frac{V_\phi}{R} = \frac{254}{35} \approx 7.26 \text{ A}$ <p>Step 3: Line current In Star connection, line current = phase current</p> $I_L = I_\phi \approx 7.26 \text{ A}$ <p>Step 4: Line voltage</p> $V_L = \sqrt{3}V_\phi = 440 \text{ V}$ <p>Step 5: Active power</p> $P = \sqrt{3}V_L I_L \cos \theta$ <p>Purely resistive load $\rightarrow \cos \theta = 1$</p> $P = \sqrt{3} \cdot 440 \cdot 7.26 \cdot 1 \approx 5525 \text{ W}$ <p>Step 6: Reactive power</p> $Q = \sqrt{3}V_L I_L \sin \theta$ <p>Purely resistive $\rightarrow \sin \theta = 0$</p> $Q = 0 \text{ VAR}$ <p>Step 7: Apparent power</p> $S = \sqrt{3}V_L I_L = \sqrt{3} \cdot 440 \cdot 7.26 \approx 5525 \text{ VA}$	8
4a	A DC generator is an electrical machine that converts mechanical energy into direct current (DC) electrical energy using the principle of electromagnetic	8



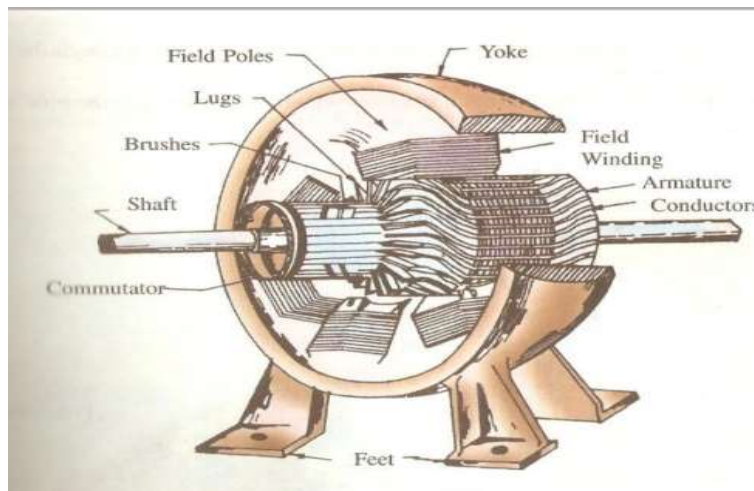
induction.

Construction of a DC Generator:

The main parts of a DC generator are:

Part	Function
Yoke (Magnetic Frame)	Provides mechanical support and acts as the outer frame.
Pole Cores and Pole Shoes	Carry field windings and spread the magnetic flux uniformly.
Field Windings	Wound on the poles, they produce a magnetic field when excited with DC.
Armature Core	Cylindrical soft iron core with slots to hold armature conductors. Reduces reluctance and carries flux.
Armature Windings	Conductors placed in the armature slots in which emf is induced.
Commutator	Converts the alternating emf induced in armature conductors into direct current.
Brushes	Usually made of carbon, they maintain electrical contact between the rotating commutator and external circuit.

Labeled Diagram of DC Generator:



Working Principle:

- The working of a DC generator is based on Faraday's Law of Electromagnetic Induction, which states:

Whenever a conductor cuts the magnetic field lines, an emf is induced in the conductor.

In the generator:

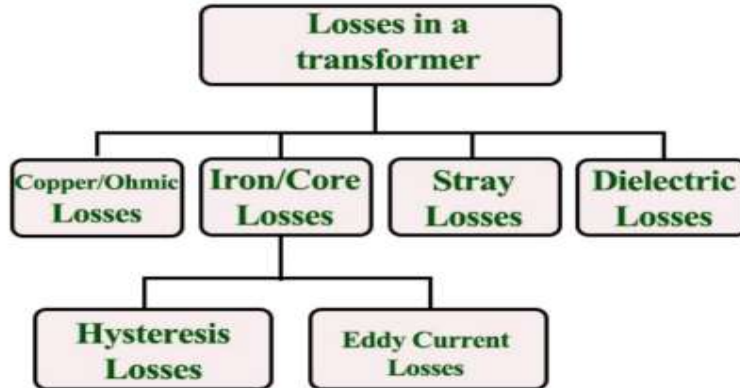


	<ol style="list-style-type: none">1. Mechanical energy is supplied to rotate the armature.2. The armature conductors rotate within the magnetic field created by field windings.3. As a result, an emf is induced in the armature conductors.4. This induced emf is alternating in nature.5. The commutator rectifies this alternating emf into unidirectional (DC) emf.6. The brushes collect the current from the commutator and supply it to the external circuit. <p>5. Equation of Induced EMF (for reference):</p> $E=(P \cdot \phi \cdot N \cdot Z)/(60 \cdot A)$ <p>Where:</p> <ul style="list-style-type: none">• E = EMF generated (in volts)• P = Number of poles• ϕ = Flux per pole (in Weber)• N = Armature speed (in RPM)• Z = Total number of armature conductors• A = Number of parallel paths in armature <p>Applications:</p> <ul style="list-style-type: none">• Battery charging• Electroplating• Small-scale power supply	
4 b	<p>Rewirable Fuse (KitKat Fuse):</p> <p>A rewirable fuse is a type of protective device used in electrical circuits to prevent overcurrent. It consists of a strip or wire of a low melting point material (usually tin or lead alloy) housed in an insulated casing. When the current exceeds the rated value, the wire melts, breaking the circuit and protecting the appliances from damage. The fuse can be “rewired” by replacing the melted wire after the fault is cleared.</p> <p>Advantages of MCBs over traditional fuses:</p> <ol style="list-style-type: none">1. Automatic reset: MCBs can be easily reset after tripping without replacing any parts, unlike fuses which need replacement.2. Faster response: MCBs react quickly to overcurrent, providing better protection.3. No wastage: No need to buy and replace fuses repeatedly.4. Safety: MCBs reduce the risk of fire and electric shocks compared to fuses.5. Indication: MCBs clearly indicate tripped condition, making fault	

	<p>identification easier.</p> <p>6. Multiple protection: MCBs provide protection against overload and short circuits simultaneously.</p>													
4c	<p>A stepper motor is a special type of DC motor that moves in discrete steps instead of continuous rotation. Each step is a fixed angular displacement, allowing precise control of position and speed without requiring feedback systems.</p> <p>Working Principle of Stepper Motor:</p> <ul style="list-style-type: none"> • Stepper motors work on the principle of electromagnetism. • When a stator phase winding is energized, it develops a magnetic field. • The rotor, which is typically a permanent magnet or toothed iron core, aligns itself with the stator field. • By sequentially energizing the stator windings, the rotor moves in steps, providing controlled rotation. • The speed of rotation depends on the frequency of the pulses given to the stator <p>Diagram: Basic Stepper Motor (Conceptual)</p> <div style="text-align: center;"> </div> <p>fig.1 Structure of Permanent Magnet Stepper Motor</p> <p>Types of Stepper Motors:</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 25%;">Type</th> <th style="width: 45%;">Description</th> <th style="width: 30%;">Diagram Sketch</th> </tr> </thead> <tbody> <tr> <td>a) Permanent Magnet (PM) Stepper Motor</td> <td>Uses a permanent magnet rotor and operates based on attraction/repulsion between stator poles and rotor poles.</td> <td>Rotor has distinct N-S poles. Stator is wound with field coils.</td> </tr> <tr> <td>b) Variable Reluctance (VR) Stepper Motor</td> <td>Rotor is made of soft iron without permanent magnets. It rotates to align with minimum reluctance path.</td> <td>Rotor with multiple teeth. Stator coils energized in sequence.</td> </tr> <tr> <td>c) Hybrid</td> <td>Combines features of both PM and VR types. Offers high accuracy and</td> <td>Rotor with permanent magnet</td> </tr> </tbody> </table>	Type	Description	Diagram Sketch	a) Permanent Magnet (PM) Stepper Motor	Uses a permanent magnet rotor and operates based on attraction/repulsion between stator poles and rotor poles.	Rotor has distinct N-S poles. Stator is wound with field coils.	b) Variable Reluctance (VR) Stepper Motor	Rotor is made of soft iron without permanent magnets. It rotates to align with minimum reluctance path.	Rotor with multiple teeth. Stator coils energized in sequence.	c) Hybrid	Combines features of both PM and VR types. Offers high accuracy and	Rotor with permanent magnet	8
Type	Description	Diagram Sketch												
a) Permanent Magnet (PM) Stepper Motor	Uses a permanent magnet rotor and operates based on attraction/repulsion between stator poles and rotor poles.	Rotor has distinct N-S poles. Stator is wound with field coils.												
b) Variable Reluctance (VR) Stepper Motor	Rotor is made of soft iron without permanent magnets. It rotates to align with minimum reluctance path.	Rotor with multiple teeth. Stator coils energized in sequence.												
c) Hybrid	Combines features of both PM and VR types. Offers high accuracy and	Rotor with permanent magnet												



	<p>Stepper Motor better performance.</p>	<p>and toothed structure.</p>	
<p>4d</p>	<p>Key Parameters:</p> <ul style="list-style-type: none"> • Step Angle: Angular movement per pulse (e.g., 1.8°, 7.5°) • Holding Torque: Torque required to move the motor when stationary • Resolution: Total number of steps per revolution <p>Applications of Stepper Motors:</p> <ul style="list-style-type: none"> • Printers and plotters • CNC machines • Robotics and automation • Camera platforms • Textile and medical equipment 	<p>Importance of Earthing in Electrical Installations:</p> <ol style="list-style-type: none"> 1. Safety of human life: Earthing prevents electric shocks by providing a low-resistance path for fault currents to flow to the ground. 2. Equipment protection: Protects electrical appliances and devices from damage due to overvoltages or lightning strikes. 3. Stability of voltage: Maintains system voltage at a reference level, ensuring proper operation of electrical equipment. 4. Fault current path: Provides a path for fault currents, enabling protective devices like fuses and MCBs to operate correctly. 5. Fire prevention: Reduces the risk of fire caused by insulation failure or leakage currents. <p>Method of Earthing – Plate Earthing:</p> <ul style="list-style-type: none"> • A copper or galvanized iron plate is buried vertically in the ground, usually 2–3 meters deep. • The plate is connected to the electrical system with a thick copper conductor. • The surrounding soil is kept moist or conductive to ensure low resistance. • This method is suitable for substations and industrial installations. 	<p>8</p>
<p>5a</p>	<p>A transformer is an electrical device used to transfer electrical energy from one circuit to another through electromagnetic induction. While doing so, certain power losses occur, which reduce the efficiency of the transformer.</p> <p>Types of Losses in Transformer:</p>		<p>8</p>



Methods to Minimize Transformer Losses:

Type of Loss	Minimization Technique
Hysteresis Loss	Use high-grade silicon steel with low hysteresis coefficient
Eddy Current Loss	Laminate the core with thin insulated sheets to restrict eddy currents
Copper Loss	Use conductors of lower resistance (e.g., copper with proper cross-section)
Stray Losses	Proper placement of magnetic shielding and core geometry design
Dielectric Loss	Use high-quality insulation and regular maintenance

5 b

- N = number of turns in a winding
- ϕ_m = maximum flux in the core (Weber)
- f = frequency of AC supply (Hz)

The alternating flux is sinusoidal:

$$\phi = \phi_m \sin \omega t, \quad \omega = 2\pi f$$

The induced EMF in one turn:

$$e = \frac{d\phi}{dt} = \frac{d}{dt}(\phi_m \sin \omega t) = \omega \phi_m \cos \omega t$$

The RMS value of EMF in one turn:

$$E_1 = 4.44 f N \phi_m$$

For a winding with N turns, the induced EMF:

$$E = 4.44 f N \phi_m \quad \text{Volts}$$

Explanation of each term:

- E = RMS value of induced EMF (V)
- f = frequency of AC supply (Hz)
- N = number of turns in the winding
- ϕ_m = maximum magnetic flux in the core (Weber)
- 4.44 = a constant derived from the RMS value of a sinusoidal waveform



5c	<p>1. Efficiency at full load, unity power factor</p> <p>Full-load output power:</p> $P_{out,FL} = S \cdot PF = 1200 \times 1000 \cdot 1 = 1,200,000 \text{ W}$ <p>Total losses at full load:</p> $P_{loss,FL} = P_{cu,FL} + P_{fe} = 1850 + 950 = 2800 \text{ W}$ <p>Efficiency:</p> $\eta_{FL} = \frac{P_{out,FL}}{P_{out,FL} + P_{loss,FL}} = \frac{1,200,000}{1,200,000 + 2800} \approx 0.9977 \approx 99.77\%$ <hr style="width: 50%; margin: 10px auto;"/> <p>2. Efficiency at 75% full load, 0.85 power factor</p> <p>Half-load copper loss (varies with square of load):</p> $I = 0.75 \text{ load} \Rightarrow P_{cu,75\%} = P_{cu,FL} \cdot (0.75)^2 = 1850 \cdot 0.5625 \approx 1040.6 \text{ W}$ <p>Output power at 75% load:</p> $P_{out,75\%} = 0.75 \cdot 1200,000 \cdot 0.85 = 765,000 \text{ W}$ <p>Total losses:</p> $P_{loss,75\%} = P_{fe} + P_{cu,75\%} = 950 + 1040.6 \approx 1990.6 \text{ W}$ <p>Efficiency:</p> $\eta_{75\%} = \frac{765,000 \downarrow}{765,000 + 1990.6} \approx 0.9974 \approx 99.74\%$	8
5d	<p>Step 1: Full-load currents</p> $I_2 = S / V_2 = 1,100,000 / 220 \approx 5000 \text{ A}$ $I_1 = S / V_1 = 1,100,000 / 2200 \approx 500 \text{ A}$ <p>Step 2: Equivalent resistance referred to secondary</p> $R_{eq} = R_2 + R_1 \cdot (V_2/V_1)^2 = 0.0068 + 0.68 \cdot (220/2200)^2 \approx 0.0071 \Omega$ <p>Step 3: Full-load copper loss</p> $P_{cu,FL} = I_2^2 \cdot R_{eq} \approx 5000^2 \cdot 0.0071 \approx 177,500 \text{ W}$ <p>Step 4: Total full-load loss</p> $P_{loss,FL} = P_{iron} + P_{cu,FL} = 2500 + 177,500 \approx 180,000 \text{ W}$ <p>Step 5: Full-load output power</p> $P_{out,FL} = S \cdot PF = 1,100,000 \cdot 0.8 = 880,000 \text{ W}$ <p>Step 6: Full-load efficiency</p> $\eta_{FL} = P_{out,FL} / (P_{out,FL} + P_{loss,FL}) = 880,000 / (880,000 + 180,000) \approx 0.830 \approx 83\%$ <p>Step 7: Half-load copper loss</p> $P_{cu,HL} = P_{cu,FL} \cdot 0.5^2 = 177,500 \cdot 0.25 \approx 44,375 \text{ W}$ <p>Step 8: Total half-load loss</p> $P_{loss,HL} = P_{iron} + P_{cu,HL} = 2500 + 44,375 \approx 46,875 \text{ W}$ <p>Step 9: Half-load output power</p> $P_{out,HL} = 0.5 \cdot S \cdot PF = 0.5 \cdot 1,100,000 \cdot 0.8 = 440,000 \text{ W}$ <p>Step 10: Half-load efficiency</p> $\eta_{HL} = P_{out,HL} / (P_{out,HL} + P_{loss,HL}) = 440,000 / (440,000 + 46,875) \approx 0.904 \approx 90.4\%$	8



**K. K. Wagh Institute of Engineering Education and Research,
Nashik**
(An Autonomous Institute from A.Y. 2022-23)
