Question 1(a) [3 marks]

Define current, electric Power and energy.

Answer:

Term	Definition
Current	The rate of flow of electric charge through a conductor (measured in amperes, A)
Electric Power	The rate at which electrical energy is transferred or consumed (measured in watts, W)
Energy	The capacity to do work, measured as power multiplied by time (measured in joules or watt-hours)

Mnemonic: "CPE: Charge-Per-second, Product-of-VI, Energy-over-time"

Question 1(b) [4 marks]

Explain the effect of temperature on the value of resistance of pure metal, alloys and insulators.

Answer:

Material Type	Temperature Effect	Equation
Pure Metals	Resistance increases with temperature	$R_2 = R_1[1 + \alpha(T_2-T_1)]$
Alloys	Slight increase with temperature (low α)	$R_2 = R_1[1 + \alpha(T_2-T_1)]$
Insulators	Resistance decreases with temperature	$R_2 = R_1e^{\wedge}(\beta(1/T_2-1/T_1))$

where α is temperature coefficient, T is temperature, and R is resistance

Mnemonic: "MAI: Metals Add, Alloys Increase-little, Insulators Invert"

Question 1(c) [7 marks]

State and explain KCL and KVL with examples.

Answer:

Kirchhoff's Laws:

Law	Statement	Equation	Example Circuit
KCL	Sum of currents entering a node equals sum of currents leaving the node	∑Iin = ∑Iout	`mermaid graph TD; A((Node)); I1-->A; I2-->A; A-->I3; A-->I4;`
KVL	Sum of voltage drops equals sum of voltage rises in a closed loop	∑V = 0	`mermaid graph LR; A((+))-->B((-))); B-->C((+)); C-->D((+)); D-->A; linkStyle 0 stroke:red,stroke-width:2px; linkStyle 1 stroke:green,stroke-width:2px; linkStyle 2 stroke:blue,stroke-width:2px; linkStyle 3 stroke:orange,stroke-width:2px;`

Example:

- **KCL**: At node A, if I_1 = 5A and I_2 = 3A entering, then $I_3 + I_4$ = 8A must be leaving
- **KVL**: In a loop with battery 12V and resistors R_1(4Ω) and R_2(8Ω), 12V = I×(4Ω+8Ω)

Mnemonic: "CLAN: Currents Leave And eNter equally, Voltage Around Loop is Null"

Question 1(c) OR [7 marks]

Explain series and parallel connections of resistors with necessary equations.

Answer:

Connection	Circuit Diagram	Equation	Current/Voltage Relation
Series	`mermaid graph LR; A---B[(R1)]---C[(R2)]---D[(R3)]---E;`	Req = $R_1 + R_2 + R_3 + ... + Rn$	Same current through all resistors
Parallel	`mermaid graph TD; A---B; A---C[(R1)]---B; A---D[(R2)]---B; A---E[(R3)]---B;`	1/Req = $1/R_1 + 1/R_2 + 1/R_3 + ... + 1/Rn$	Same voltage across all resistors

- **Series**: Total resistance increases, current decreases
- **Parallel**: Total resistance decreases, current increases

Mnemonic: "SPARC: Series Plus All Resistors, parallel Combines with reciprocals"

Question 2(a) [3 marks]

Write factors affecting the Resistance value.

Answer:

Factor	Effect on Resistance	Relation
Length (l)	Directly proportional	$R \propto l$
Cross-sectional Area (A)	Inversely proportional	$R \propto 1/A$
Material (ρ)	Depends on resistivity	$R \propto \rho$
Temperature (T)	Usually increases with temperature	$R \propto T$

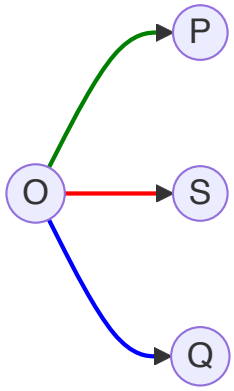
Mnemonic: "LAMT: Length Adds, Area Minimizes, Material matters, Temperature transforms"

Question 2(b) [4 marks]

Draw power triangle and define active and reactive power.

Answer:

Power Triangle:



Power Type	Definition	Unit	Formula
Active Power (P)	Actual power consumed by device	Watt (W)	$P = VI \cos \phi$
Reactive Power (Q)	Power oscillating between source and load	VAR	$Q = VI \sin \phi$
Apparent Power (S)	Vector sum of active and reactive power	VA	$S = VI$

Mnemonic: "PAWS: Power Active Works, Apparent is Slant-hypotenuse, reactive Qoscillates"

Question 2(c) [7 marks]

Explain concept of cell and battery. List out various rating and types of battery.

Answer:

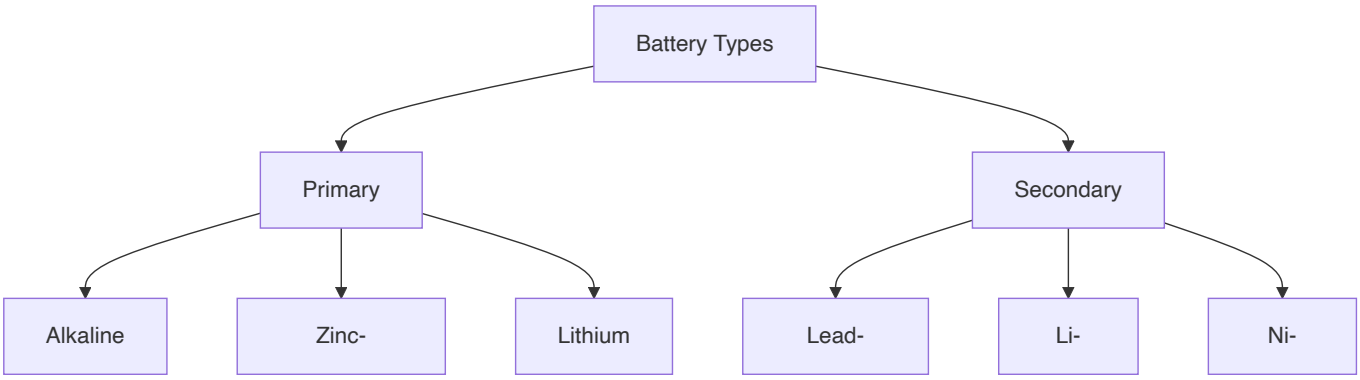
Cell vs Battery:

Term	Definition
Cell	Basic electrochemical unit that converts chemical energy to electrical energy
Battery	Collection of one or more cells connected in series or parallel

Battery Ratings:

Rating	Description	Unit
Voltage	Potential difference	Volts (V)
Capacity	Amount of charge stored	Ampere-hour (Ah)
Energy	Total energy available	Watt-hour (Wh)
C-Rate	Discharge/charge rate	C
Cycle Life	Number of charge/discharge cycles	-

Battery Types:



Mnemonic: "CAVE: Cells Are Voltage Elements, batteries Bundle And TallY Energy"

Question 2(a) OR [3 marks]

Define the terms resistance, conductance and conductivity.

Answer:

Term	Definition	Unit	Formula
Resistance (R)	Opposition to current flow	Ohm (Ω)	$R = \rho l/A$
Conductance (G)	Ease of current flow	Siemens (S)	$G = 1/R$
Conductivity (σ)	Material property of allowing current flow	S/m	$\sigma = 1/\rho$

where ρ is resistivity, l is length, and A is cross-sectional area

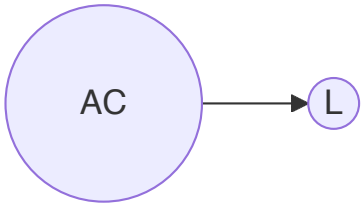
Mnemonic: "RCG: Resist Current Gladly, Conduct Generously, σ Gets current through"

Question 2(b) OR [4 marks]

Prove that for pure inductive circuit, the current lags applied voltage by 90°.

Answer:

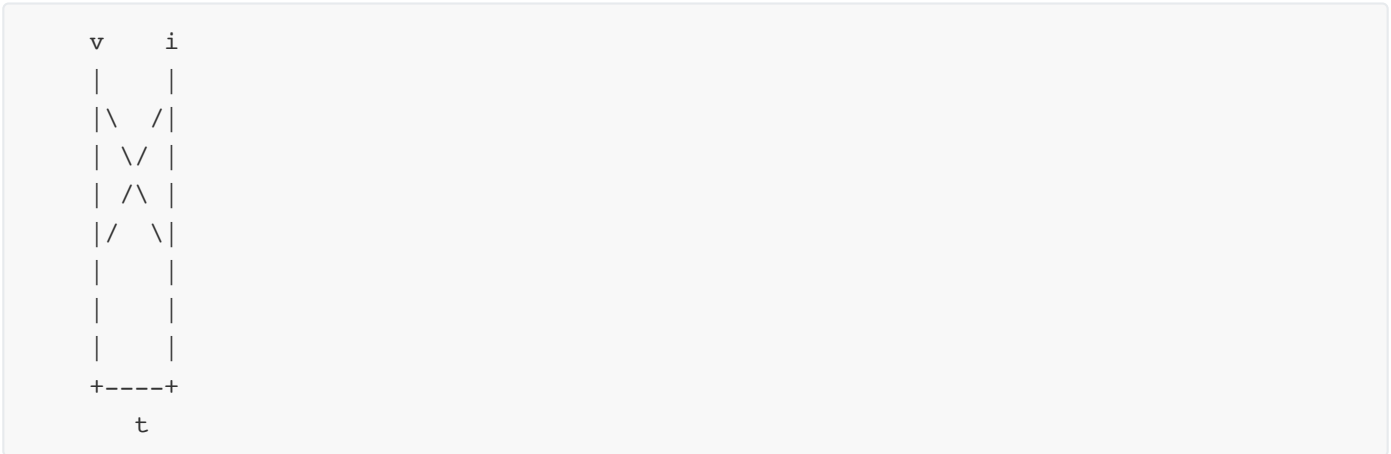
For pure inductive circuit:



Mathematical Proof:

- Applied voltage: v = Vm sin(ωt)
- For inductor: v = L(di/dt)
- Therefore: L(di/dt) = Vm sin(ωt)
- Integrating: i = -(Vm/ωL)cos(ωt) = (Vm/ωL)sin(ωt-90°)

Waveform:



Mnemonic: "ELI: Voltage Leads current In inductor by 90 degrees"

Question 2(c) OR [7 marks]

Describe Resistor, Inductor and Capacitor with their formula.

Answer:

Component	Symbol	Description	Formula	Energy Storage
Resistor	`mermaid graph LR; A---B[(___/\/\/\___)]---C`	Opposes current flow	V = IR	No storage
Inductor	`mermaid graph LR; A---B[(_mmmmm_)]---C`	Opposes change in current	V = L(di/dt)	E = ½LI²
Capacitor	`mermaid graph LR; A---B[(_||_)]---C`	Opposes change in voltage	I = C(dv/dt)	E = ½CV²

Effect on AC Circuit:

- **Resistor**: Current in phase with voltage (cos θ = 1)
- **Inductor**: Current lags voltage by 90° (cos θ = 0)
- **Capacitor**: Current leads voltage by 90° (cos θ = 0)

Mnemonic: "RIC: Resistor Impedes Current, Inductor Catches current-changes, Capacitor Controls voltage-changes"

Question 3(a) [3 marks]

Define and explain R.M.S value and average value of AC signal.

Answer:

Value	Definition	Formula for Sine Wave	Relation
RMS Value	Square root of mean of squared values	Vrms = Vmax/√2 = 0.707Vmax	Gives equivalent heating effect of DC
Average Value	Mean of rectified signal over half cycle	Vavg = 2Vmax/π = 0.637Vmax	Used for battery charging applications

Mnemonic: "RAM: Rms-Average Method: Root-mean-square And Mean-of-absolute"

Question 3(b) [4 marks]

With necessary diagrams explain how alternating EMF is generated?

Answer:

Alternating EMF Generation:

Diagram:

```
N       S
|       |
+-------+
  |   |
  |   |
  |___|
   \ /
    |
    v
```

- Coil rotates in uniform magnetic field
- EMF = NBAlω sin(ωt)
- As coil rotates, cutting flux changes direction
- Generating sinusoidal waveform e = Emax sin(ωt)

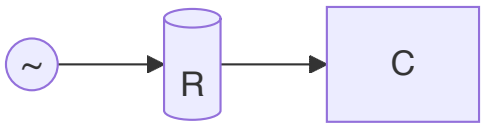
Mnemonic: "FARM: Flux And Rotation Make alternating voltage"

Question 3(c) [7 marks]

Explain A.C analysis of purely resistive AC circuit.

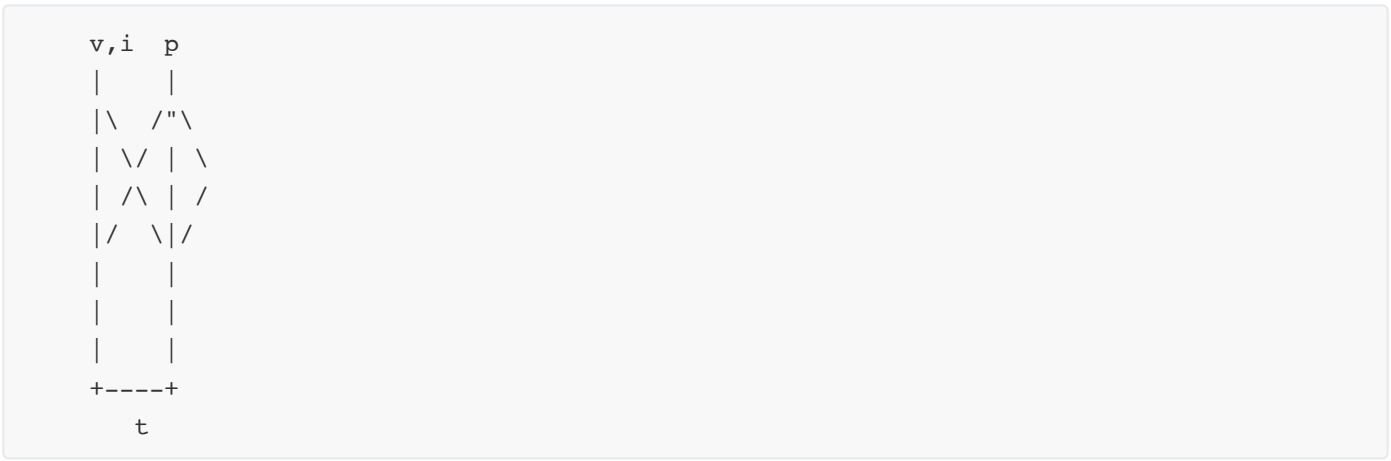
Answer:

Purely Resistive Circuit:



Parameter	Formula	Waveform Relationship
Applied Voltage	v = Vm sin(ωt)	Current and voltage in phase
Current	i = v/R = (Vm/R)sin(ωt)	Follows Ohm's Law
Power	p = vi = Vm Im sin²(ωt)	Always positive
Average Power	P = Vrms × Irms = V²/R	Constant value

Waveform:



Mnemonic: "VIPS: Voltage In-Phase with current, Same waveform, Power always Positive"

Question 3(a) OR [3 marks]

Alternating current is given by I = 28.28sin(2Π50t). Find R.M.S value of current.

Answer:

Given:

- I = 28.28sin(2Π50t)
- Therefore, Im = 28.28A

Solution:

Step	Calculation
1. Identify peak value	Im = 28.28A
2. Apply RMS formula	Irms = Im/√2
3. Calculate	Irms = 28.28/√2 = 28.28/1.414 = 20A

Therefore, RMS value of current = 20A

Mnemonic: "PER: Peak to Effective by Root-2"

Question 3(b) OR [4 marks]

Find maximum value and R.M.S value of sinusoidal voltage if Vav=60V.

Answer:

Given:

- Average value (Vav) = 60V

Solution:

Step	Formula	Calculation
1. Relation between Vav and Vm	Vav = 2Vm/π = 0.637Vm	Vm = Vav/0.637 = 60/0.637
2. Calculate maximum value	Vm = Vav × (π/2)	Vm = 60 × (π/2) = 60 × 1.57 = 94.2V
3. Calculate RMS value	Vrms = Vm/√2 = 0.707Vm	Vrms = 0.707 × 94.2 = 66.6V

Therefore, maximum value = 94.2V and RMS value = 66.6V

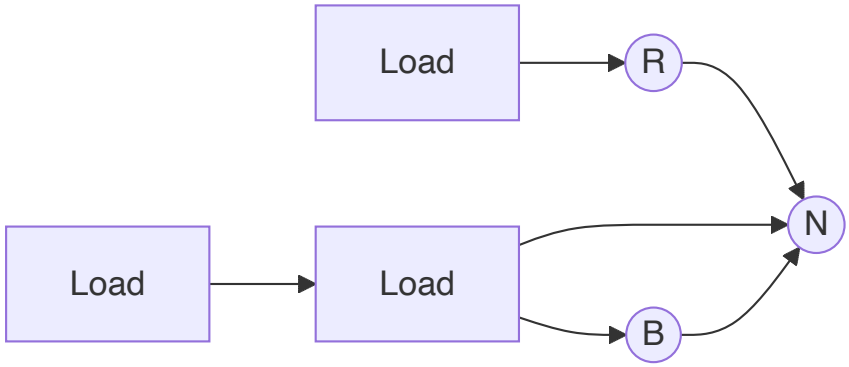
Mnemonic: "AVR: Average to peak Via multiplying by (π/2), Rms is peak/√2"

Question 3(c) OR [7 marks]

Derive equation of line and phase voltage for balanced star connected load with help of phasor diagram.

Answer:

Star Connection:



Phasor Diagram:

Derivation:

- Phase voltages: VRN, VYN, VBN (120° apart)
- Line voltages: VRY = VRN - VYN
- For balanced system with magnitude Vp for phase voltage:
- VRY = VRN - VYN = Vp∠0° - Vp∠-120° = Vp(1 - ∠-120°) = √3Vp∠30°

Relation:

- Line voltage (VL) = √3 × Phase voltage (Vp)
- Line voltage leads phase voltage by 30°

Mnemonic: "PALS: Phase to Line in Star: multiply by Square-root-3"

Question 4(a) [3 marks]

Write statement of Faraday's law and Lenz's law with expression.

Answer:

Law	Statement	Expression
Faraday's Law	EMF induced is directly proportional to rate of change of magnetic flux	e = -N(dΦ/dt)
Lenz's Law	Induced EMF opposes the cause producing it (negative sign in formula)	Direction opposes flux change

Mnemonic: "FORC: Faraday's flux Over Rate Change, Lenz Opposes the Reason for Change"

Question 4(b) [4 marks]

State any four advantage of 3-phase supply over single-phase supply.

Answer:

Advantages of 3-Phase Over Single-Phase	Explanation
Higher Power Density	3-phase delivers 1.732 times more power with same wire size
Constant Power Delivery	No pulsation in power as in single-phase
Smaller Conductors	Less copper required for same power transfer
Self-Starting Motors	No starting mechanism needed for motors

Additional: More efficient transmission, reduced harmonics, balanced loading

Mnemonic: "PCCS: Power higher, Constant delivery, Copper less, Self-starting motors"

Question 4(c) [7 marks]

Explain Fleming's right-hand rule for generators and left-hand rule for motors.

Answer:

Fleming's Hand Rules:

Rule	Application	Hand Position	Diagram
Right-Hand Rule (Generator)	Determines direction of induced EMF	**Thumb**: Motion **Forefinger**: Field **Middle finger**: Current/EMF	```goat

```
F ^
  |
--+-- > M
  |
  v
  C
``` |

| **Left-Hand Rule (Motor)** | Determines direction of motion/force | **Thumb**: Motion/Force
Forefinger: Field
Middle finger: Current | `goat`

```
    F ^
      |
    --+-- > M
      |
      v
      C |
```

- **Generator**: Mechanical energy converted to electrical energy
- **Motor**: Electrical energy converted to mechanical energy

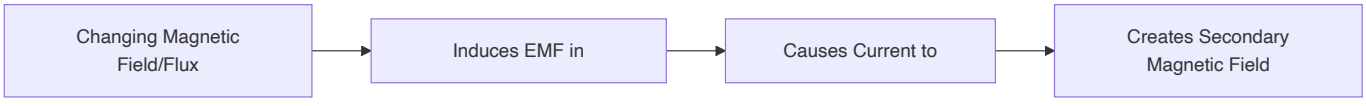
Mnemonic: "FBI-MFC: Field-B-Induced current for right hand, Motion-Field-Current for left"

Question 4(a) OR [3 marks]

Describe phenomenon of electromagnetic induction.

Answer:

Electromagnetic Induction:



Key Factors:

- Requires relative motion or changing flux
- EMF proportional to rate of change of flux
- Direction determined by Lenz's law

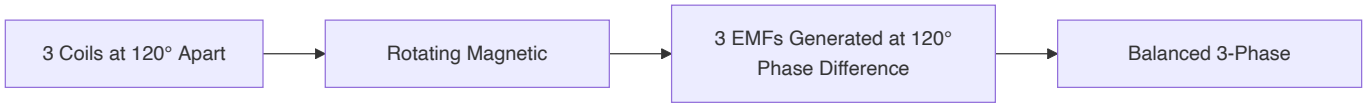
Mnemonic: "MICE: Motion Induces Current via Electromagnetic induction"

Question 4(b) OR [4 marks]

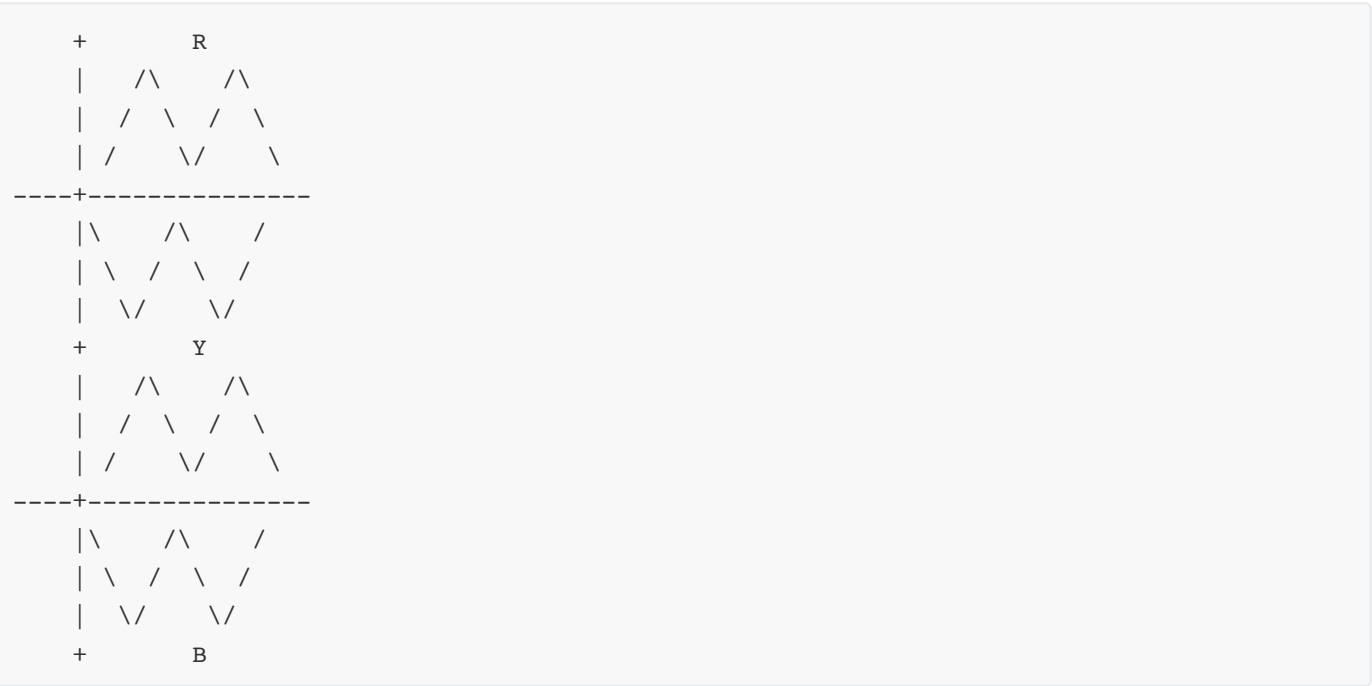
Explain the generation of 3-phase alternating EMF.

Answer:

3-Phase EMF Generation:



Three Phase Waveform:



- Three identical coils displaced 120° spatially
- Produces three identical EMFs displaced 120° in time
- EMFs: eR = Emax sin(ωt), eY = Emax sin(ωt-120°), eB = Emax sin(ωt-240°)

Mnemonic: "CPS: Coils Produce Shifted waveforms at 120 degrees"

Question 4(c) OR [7 marks]

Differentiate statically and dynamically induced E.M.F.

Answer:

Parameter	Statically Induced EMF	Dynamically Induced EMF
Definition	EMF induced due to change in flux linking with stationary conductor	EMF induced due to conductor moving in a magnetic field
Movement	No relative motion between conductor and field	Relative motion exists
Change Source	Changing current in primary circuit	Physical movement of conductor
Examples	Transformer, inductor	Generator, alternator
Mathematical Expression	e = -N(dΦ/dt) due to changing current	e = Blv (B=flux density, l=length, v=velocity)

Mnemonic: "SMCE: Static-Moving, Change-External: static has changing flux, moving has constant flux"

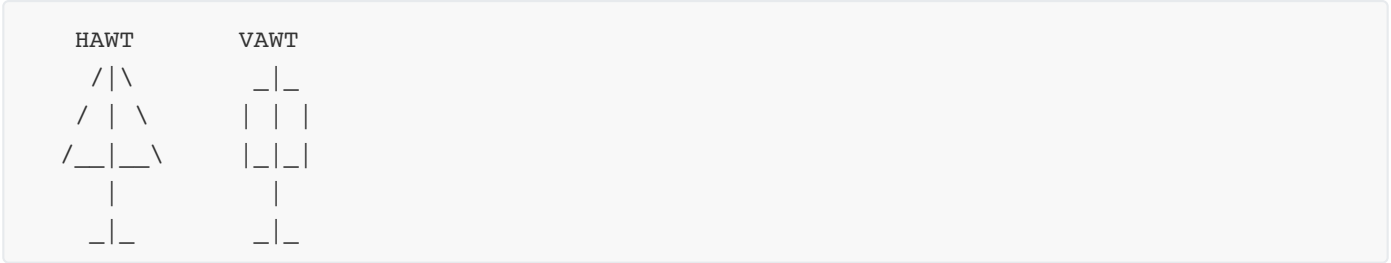
Question 5(a) [3 marks]

Differentiate HAWT and VAWT.

Answer:

Parameter	HAWT (Horizontal Axis Wind Turbine)	VAWT (Vertical Axis Wind Turbine)
Orientation	Blades rotate on horizontal axis	Blades rotate on vertical axis
Wind Direction	Needs to face wind direction	Works with wind from any direction
Installation	Tall tower, high off ground	Lower to ground, easier access

Diagram:



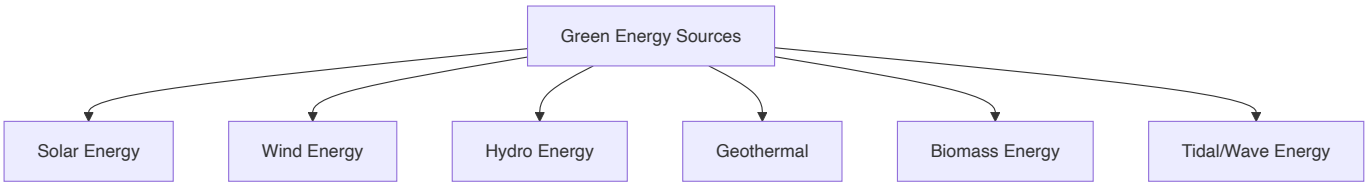
Mnemonic: "HV-DIT: Horizontal-Vertical, Directional-Independent, Tall-lower"

Question 5(b) [4 marks]

Classification of green energy.

Answer:

Green Energy Classifications:



Source	Primary Principle	Application
Solar	Photovoltaic effect	Solar panels, thermal collectors
Wind	Kinetic energy of air	Wind turbines
Hydro	Potential energy of water	Dams, run-of-river
Geothermal	Earth's internal heat	Heat pumps, power plants

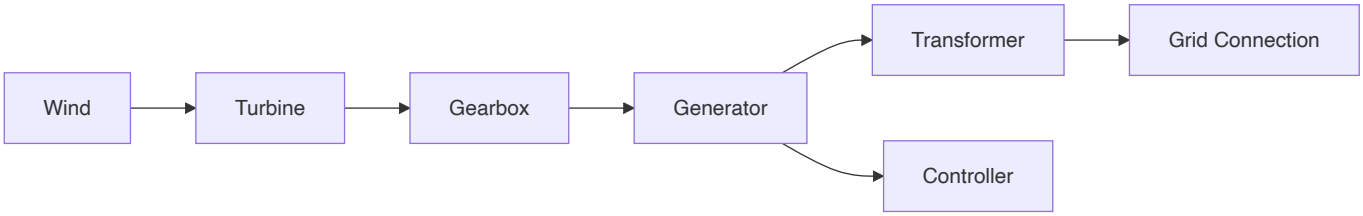
Mnemonic: "SWHGBT: Sun Wind Hydro Geo Bio Tidal - Sources With Huge Green Benefits Today"

Question 5(c) [7 marks]

Explain wind power system.

Answer:

Wind Power System:



Components:

- **Wind Turbine**: Converts wind energy to mechanical rotation
- **Gearbox**: Increases rotation speed for generator
- **Generator**: Converts mechanical to electrical energy
- **Controller**: Regulates output and safety functions
- **Transformer**: Steps up voltage for transmission
- **Tower**: Elevates turbine to capture stronger winds

Working Principle:

1. Wind turns blades (kinetic to mechanical)
2. Gearbox increases RPM
3. Generator produces AC power
4. Controller regulates output

5. Transformer prepares for grid connection

Mnemonic: "WINGER: Wind In, Gearbox Enhances Rotation, Generator outputs"

Question 5(a) OR [3 marks]

List any three needs of green energy.

Answer:

Need for Green Energy	Explanation
Environmental Protection	Reduces pollution and greenhouse gas emissions
Resource Conservation	Preserves finite fossil fuel resources
Energy Security	Reduces dependence on imported fuels and price volatility

Other Needs: Climate change mitigation, sustainable development, economic benefits

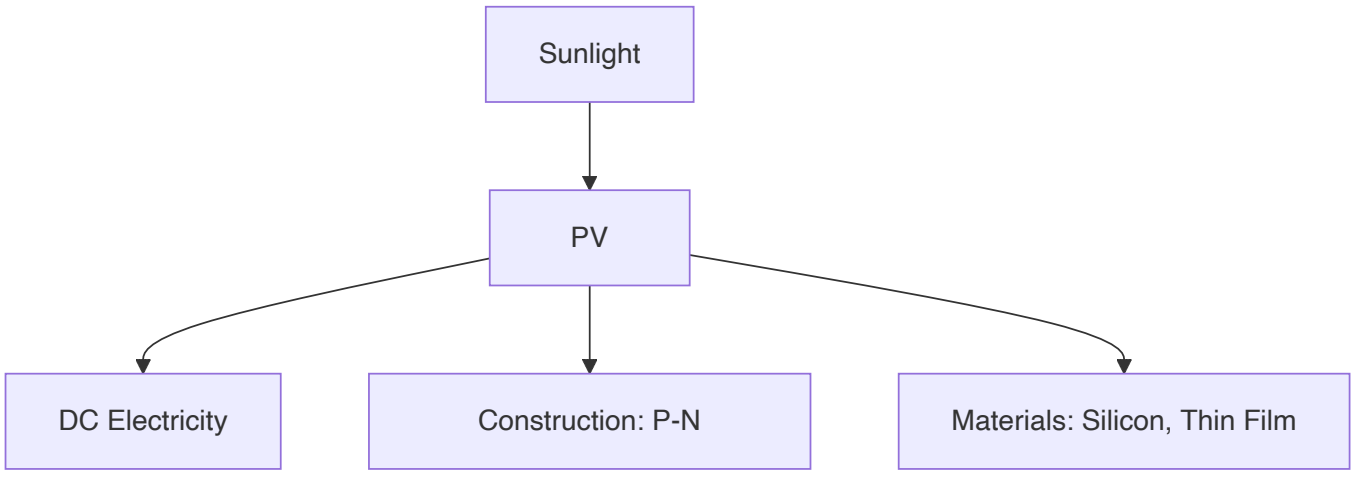
Mnemonic: "ECO: Environment protected, Conservation of resources, Oil-independence"

Question 5(b) OR [4 marks]

Write short note on PV cell.

Answer:

Photovoltaic (PV) Cell:



Working Principle:

- Based on photovoltaic effect
- Converts sunlight directly to electricity
- Uses semiconductor material (usually silicon)
- Creates electron flow when photons hit P-N junction

Types: Monocrystalline, Polycrystalline, Thin-film

Efficiency: Typically 15-22% for commercial cells

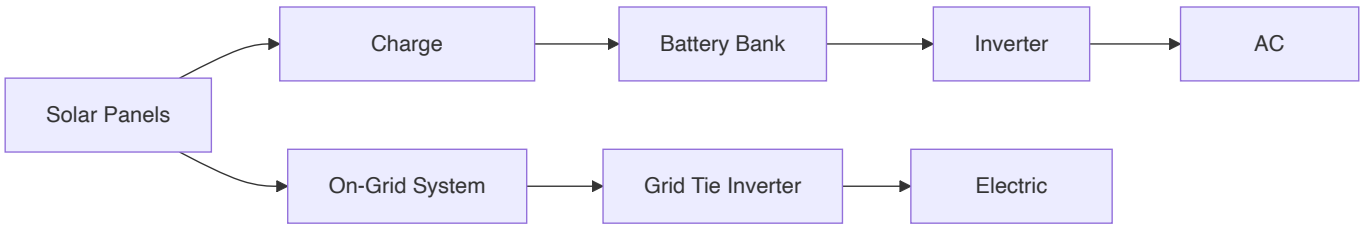
Mnemonic: "SPEC: Sunlight Produces Electricity through Cells with p-n junctions"

Question 5(c) OR [7 marks]

Explain solar system.

Answer:

Solar Power System:



Components:

- **Solar Panels**: Convert sunlight to DC electricity
- **Charge Controller**: Regulates battery charging
- **Battery Bank**: Stores electrical energy (off-grid)
- **Inverter**: Converts DC to AC for household use
- **Distribution Panel**: Connects to home electrical system

Types:

- **Grid-Connected**: Feeds excess power to grid
- **Off-Grid**: Independent with battery storage
- **Hybrid**: Combination of both systems

Applications: Home power, water pumping, street lighting, industrial use

Mnemonic: "SCBID: Solar Cells produce, Battery stores, Inverter converts, Distribution supplies"