Fundamentals of Electrical Engineering (4311101) - Summer 2024 Solution

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June 15, 2024

Question 1(a) [3 marks]

Define EMF, electric current and power. Also write their units.

Solution

Answer:

Table 1. Definitions and Units

Term	Definition	Unit
EMF (Electromotive Force)	The energy supplied by a source per unit charge	Volt (V)
Electric Current	The rate of flow of electric charge	Ampere (A)
Power	The rate at which electrical energy is transferred	Watt (W)

Mnemonic

"EVA: EMF in Volts, Current in Amperes, Power in Watts"

Question 1(b) [4 marks]

Three resistors having resistances of 1000 Ω, 2000 Ω and 3000 Ω respectively are connected in series. Find the equivalent resistance of this series connection. Now these three resistors are connected in parallel. Find the equivalent resistance of this parallel connection.

Solution

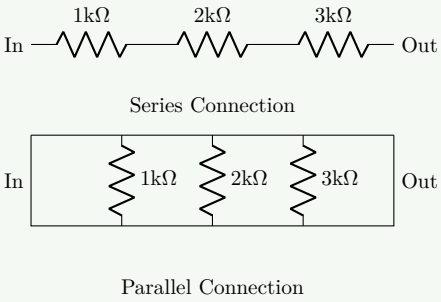
Answer:
For Series Connection:

$$R_{eq} = R_1 + R_2 + R_3$$
$$R_{eq} = 1000\Omega + 2000\Omega + 3000\Omega$$
$$R_{eq} = 6000\Omega$$

For Parallel Connection:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$
$$\frac{1}{R_{eq}} = \frac{1}{1000} + \frac{1}{2000} + \frac{1}{3000}$$
$$\frac{1}{R_{eq}} = 0.001 + 0.0005 + 0.00033$$
$$\frac{1}{R_{eq}} = 0.00183$$
$$R_{eq} = 545.45\Omega$$

Figure 1. Resistor Connections



Mnemonic

"Series Sum, Parallel Product/Sum: In series add directly, in parallel take reciprocal sum"

Question 1(c) [7 marks]

Write the definition of Resistor, Capacitor and Inductor. Draw their symbols and write their units. Also write the use of each device in electrical circuit.

Solution

Answer:

Table 2. Circuit Components

Component	Definition	Symbol	Unit	Use in Circuit
Resistor	A component that opposes the flow of electric current		Ohm (Ω)	Limits current, divides voltage, generates heat
Capacitor	A component that stores electric charge		Farad (F)	Blocks DC, passes AC, energy storage, filtering
Inductor	A component that stores energy in magnetic field		Henry (H)	Blocks AC, passes DC, energy storage, filtering

Mnemonic

"RCI: Resistor Controls current, Capacitor stores charge, Inductor stores magnetic energy"

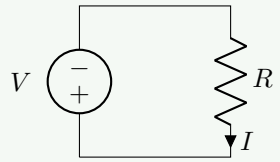
Question 1(c) OR [7 marks]

State Ohm's law and write the equation of Ohm's law with circuit diagram. Write applications of Ohm's law. Also write the limitation of Ohm's law.

Solution

Answer:
Ohm's Law: The current flowing through a conductor is directly proportional to the voltage across it and inversely proportional to its resistance.
Equation: $V = I \times R$

Figure 2. Ohm's Law Circuit



Applications of Ohm's Law:
- Calculating current, voltage, or resistance in circuits
- Designing electrical and electronic circuits
- Power calculations ($P = V \times I = I^2 \times R = V^2/R$)
- Circuit analysis using voltage divider and current divider

Limitations of Ohm's Law:
- Not applicable for non-linear devices (diodes, transistors)
- Not valid for high-frequency AC circuits
- Not valid for non-metallic conductors
- Does not apply during transient conditions

Mnemonic

"VIR: Voltage equals current times resistance"

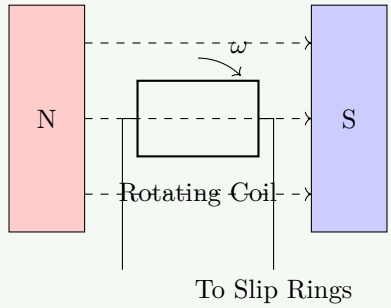
Question 2(a) [3 marks]

Explain the generation of alternating EMF with the help of necessary diagram and equation.

Solution

Answer:
Alternating EMF is generated when a conductor rotates in a magnetic field.
Equation: $e = E_0 \sin(\omega t) = E_0 \sin(2\pi f t)$
Where:
- e = instantaneous EMF
- E_0 = maximum EMF
- ω = angular velocity ($2\pi f$)
- f = frequency
- t = time

Figure 3. AC Generation Principle



Mnemonic

"RCBS: Rotation of Coil in magnetic field produces sinusoidal EMF"

Question 2(b) [4 marks]

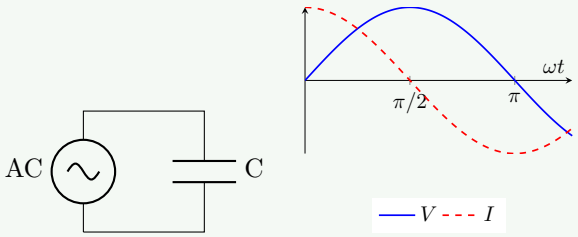
Explain the behavior of pure capacitor with AC supply with necessary circuit diagram and equation.

Solution

Answer:
Behavior of Pure Capacitor with AC:

- Current leads voltage by 90° in a pure capacitor
- Capacitive reactance (X_c) = $1/(2\pi fC)$
- As frequency increases, reactance decreases
- Stores energy in electric field during charging

Figure 4. Capacitor Circuit and Waveform



Equation: $I = C \times \frac{dV}{dt}$

Mnemonic

"CIVIC: Capacitor's current Is ahead of Voltage by 90 In Circuit"

Question 2(c) [7 marks]

An AC voltage is expressed as 300 Sin (628t) V. Find (i) Amplitude (ii) Frequency (iii) Time period (iv) Average value (v) RMS Value (vi) Form Factor and (vii) Peak Factor for this AC voltage.

Solution

Answer:
Given: $v = 300\sin(628t)$ V

Table 3. Calculated Parameters

Parameter	Formula	Calculation	Result
Amplitude	V_m	300 V	300 V
Angular Frequency	ω	628 rad/s	628 rad/s
Frequency	$f = \omega/2\pi$	628/6.28	100 Hz
Time Period	$T = 1/f$	1/100	0.01 s
Average Value	$V_{avg} = 2V_m/\pi$	$2 \times 300/3.14$	191 V
RMS Value	$V_{rms} = V_m/\sqrt{2}$	300/1.414	212.16 V
Form Factor	$FF = V_{rms}/V_{avg}$	212.16/191	1.11
Peak Factor	$PF = V_m/V_{rms}$	300/212.16	1.414

Mnemonic

"FART FAFP: Frequency, Angular, RMS, Time; Form factor, Average, Peak factor"

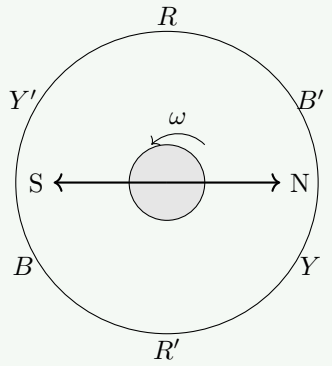
Question 2(a) OR [3 marks]

Explain the generation of 3-phase alternating EMF.

Solution

Answer:
3-phase alternating EMF is generated using three separate coils placed 120° apart in a magnetic field.
Key Points:
- Three identical coils are placed 120° apart
- Each coil produces sinusoidal EMF
- Phases are labeled as R, Y, and B
- Phase difference between any two phases is 120°

Figure 5. 3-Phase Generation



Mnemonic

"THREE: Three coils Have 120 Rotating EMF Each"

Question 2(b) OR [4 marks]

Explain the behavior of pure inductor with AC supply with necessary circuit diagram and equation.

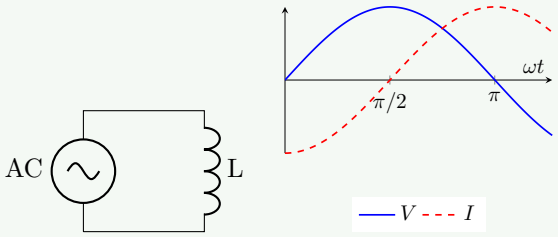
Solution

Answer:

Behavior of Pure Inductor with AC:

- Current lags voltage by 90° in a pure inductor
- Inductive reactance (X_L) = $2\pi fL$
- As frequency increases, reactance increases
- Stores energy in magnetic field

Figure 6. Inductor Circuit and Waveform



Equation: $V = L \times \frac{dI}{dt}$

Mnemonic

"VLIC: Voltage Leads current by 90 In inductor Circuit"

Question 2(c) OR [7 marks]

Define phase voltage, line voltage, phase current and line current for 3-phase AC. (i) Calculate the line voltage for star (Y) connection if the phase voltage is 100V. Also find the line current for star (Y) connection if the phase current is 5A (ii) Calculate the line voltage for delta (Δ) connection if the phase voltage is 100V. Also find the line current for delta (Δ) connection if the phase current is 5A.

Solution

Answer:

Table 4. 3-Phase Definitions

Term	Definition
Phase Voltage	Voltage across a single phase element
Line Voltage	Voltage between any two lines
Phase Current	Current flowing through a phase element
Line Current	Current flowing through a line

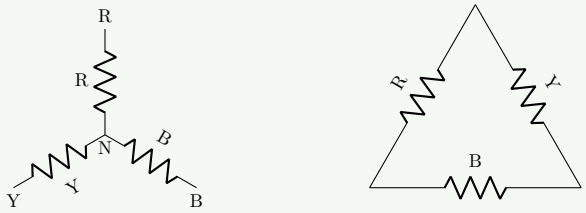
Star (Y) Connection:

- Line voltage = $\sqrt{3}\times$ Phase voltage = $\sqrt{3} \times 100 = 173.2$ V
- Line current = Phase current = 5 A

Delta (Δ) Connection:

- Line voltage = Phase voltage = 100 V
- Line current = $\sqrt{3}\times$ Phase current = $\sqrt{3} \times 5 = 8.66$ A

Figure 7. Star and Delta Connections



Star Connection Delta Connection

Mnemonic

"SLIP: Star Line voltage is root3 Phase, In Delta Phase equals Line voltage"

Question 3(a) [3 marks]

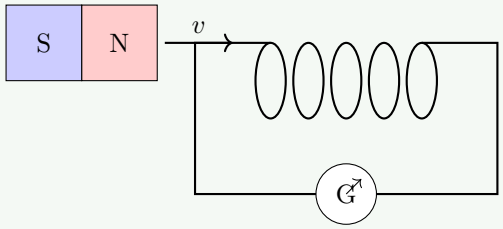
State and explain Faraday's laws of electromagnetic induction with necessary diagram and equations.

Solution

Answer:
Faraday's Laws:
1. **First Law:** When a conductor cuts magnetic flux, EMF is induced.
2. **Second Law:** The magnitude of induced EMF is proportional to the rate of change of magnetic flux.

Equation: $e = -N\frac{d\Phi}{dt}$

Figure 8. Faraday's Experiment



Mnemonic

"FIRE: Flux change Induces Rapid EMF"

Question 3(b) [4 marks]

Define amplitude, frequency, time duration and RMS value for alternating quantity.

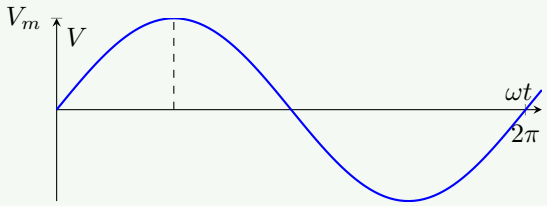
Solution

Answer:

Table 5. AC Definitions

Parameter	Definition	Formula
Amplitude	Maximum value of the alternating quantity	V_m
Frequency	Number of complete cycles per second	$f = 1/T$
Time Period	Time taken to complete one cycle	$T = 1/f$
RMS Value	Effective value, equivalent to DC causing same heating	$V_{rms} = 0.707V_m$

Figure 9. Waveform Parameters



Mnemonic

"AFTR: Amplitude is peak, Frequency is cycles, Time is period, RMS is effective"

Question 3(c) [7 marks]

Explain self inductance and mutual inductance. (i) Find the self induction of the coil if total magnetic flux linked with the coil is 5 μWb-turns for 2 A current given to the coil (ii) Find the self induction of the coil, if the parameters of the coils are as follows: number of turns is 10, relative permeability of the material used for coil is 3, length of the coil is 5 cm and cross sectional area of coil is 2 cm^2.

Solution

Answer:
Self Inductance: Property of a coil to oppose change in current through it by inducing EMF in itself.
Mutual Inductance: Property of one coil to induce EMF in another coil due to change in current in the first coil.
Part (i):

$$L = \frac{\text{Flux Linkage}}{\text{Current}}$$
$$L = \frac{5\mu\text{Wb-turns}}{2\text{A}} = 2.5\mu\text{H}$$

Part (ii):

$$L = \frac{\mu_0 \mu_r N^2 A}{l}$$
$$L = \frac{4\pi \times 10^{-7} \times 3 \times 10^2 \times 2 \times 10^{-4}}{5 \times 10^{-2}}$$
$$L = 15.07\mu\text{H}$$

Figure 10. Self vs Mutual Inductance

Self Inductance Mutual Inductance

Mnemonic

"SLIM: Self Linked with own flux, Induction Mutual between two coils"

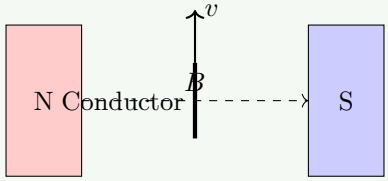
Question 3(a) OR [3 marks]

Define dynamically induced EMF. Explain it with the help of necessary diagram and equation.

Solution

Answer:
Dynamically Induced EMF: EMF induced in a conductor due to relative motion between the conductor and magnetic field.
Equation: $e = Blv \sin\theta$ where B is flux density, l is length, v is velocity.

Figure 11. Dynamic EMF



Mnemonic

"MOVE: Motion Of conductor in magnetic field produces Voltage Effect"

Question 3(b) OR [4 marks]

Define cycle, Form Factor and Peak Factor for alternating quantity. Write the value of Form Factor and Peak Factor for sinusoidal alternating quantity.

Solution

Answer:

Table 6. AC Parameters

Term	Definition	Value (Sine)
Cycle	One complete oscillation of an alternating quantity	-
Form Factor	Ratio of RMS value to average value (V_{rms}/V_{avg})	1.11
Peak Factor	Ratio of maximum value to RMS value (V_m/V_{rms})	1.414

Mnemonic

"CFP: Cycle Finishes Pattern, Form Factor 1.11, Peak Factor 1.414"

Question 3(c) OR [7 marks]

State and explain Lenz's law. State and explain Fleming's right hand rule for generator. Find the energy stored in inductor having self inductance of 4 μH, if 3 A of current is flowing through the inductor.

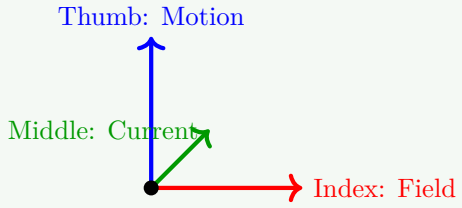
Solution

Answer:
Lenz's Law: The direction of induced EMF is such that it opposes the change in magnetic flux that produces it.
Fleming's Right Hand Rule:
- **Thumb:** Direction of motion
- **Forefinger:** Direction of magnetic field
- **Middle finger:** Direction of induced current

Energy Calculation:

$$E = \frac{1}{2}LI^2$$
$$E = \frac{1}{2} \times 4 \times 10^{-6} \times 3^2$$
$$E = 18 \times 10^{-6} \text{ J} = 18\mu\text{J}$$

Figure 12. Fleming's Right Hand Rule



Mnemonic

"LOF: Lenz Opposes Flux, Fleming Right for Generators"

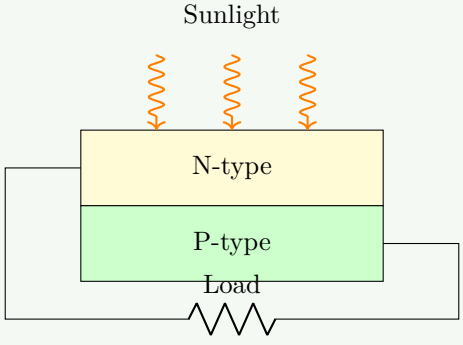
Question 4(a) [3 marks]

Define PV cell. Explain the function of PV cell.

Solution

Answer:
PV Cell: A photovoltaic cell is a semiconductor device that converts light energy directly into electrical energy.
Function:
- Absorbs photons from sunlight
- Creates electron-hole pairs
- Generates potential difference at p-n junction
- Produces DC electricity

Figure 13. PV Cell Operation



Mnemonic

"PASE: PV Absorbs Sunlight, produces Electricity"

Question 4(b) [4 marks]

Explain the classification of green energy.

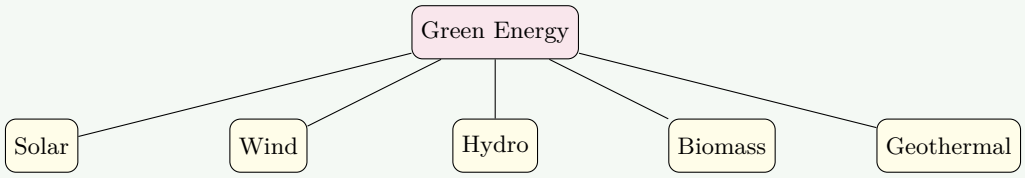
Solution

Answer:

Table 7. Green Energy Sources

Type	Source
Solar	Sunlight (PV, Thermal)
Wind	Air currents (Turbines)
Hydro	Flowing water (Dams, Tidal)
Biomass	Organic matter (Biofuels)
Geothermal	Earth's heat

Figure 14. Green Energy Classification



Mnemonic

"SWHBG: Sun, Wind, Hydro, Biomass, Geothermal"

Question 4(c) [7 marks]

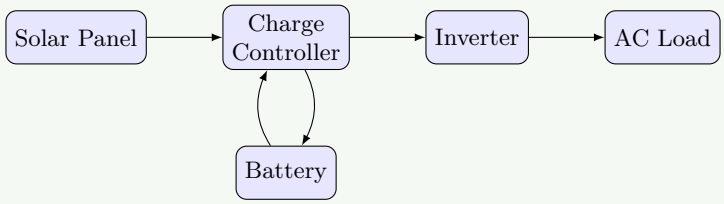
Draw and explain the block diagram of solar power system.

Solution

Answer:
Components:

- **Solar Panel:** Converts sunlight to DC
- **Charge Controller:** Regulates battery charging
- **Battery Bank:** Stores energy
- **Inverter:** Converts DC to AC
- **Loads:** Consumes power

Figure 15. Solar Power System Block Diagram



Mnemonic

"SCBIL: Solar Collects, Battery Inverts for Loads"

Question 4(a) OR [3 marks]

Define green energy, conventional energy and renewable energy.

Solution

Answer:

Table 8. Energy Definitions

Term	Definition
Green Energy	Energy from eco-friendly sources with minimal impact
Conventional Energy	Traditional non-renewable sources like fossil fuels
Renewable Energy	Sources naturally replenished on human timescale

Mnemonic

"GCR: Green is Clean, Conventional is Carbon, Renewable is Replenished"

Question 4(b) OR [4 marks]

Explain the need of green energy.

Solution

Answer:
Need for Green Energy:

- **Environmental Protection:** Reduces pollution
- **Resource Conservation:** Saves fossil fuels
- **Energy Security:** Reduces import dependence
- **Economic Benefits:** Job creation
- **Sustainability:** For future generations

Mnemonic

"ERESS: Environment, Resources, Energy security, Savings, Sustainability"

Question 4(c) OR [7 marks]

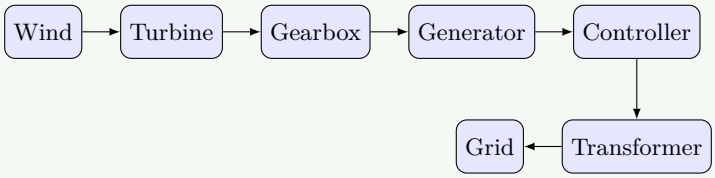
Draw and explain the block diagram of wind power system with types of turbines.

Solution

Answer:
Components:
- **Wind Turbine:** Converts wind to mechanical energy
- **Gearbox:** Increases speed
- **Generator:** Produces electricity
- **Controller:** Manages system
- **Transformer:** Steps up voltage

Types: HAWT (Horizontal Axis) and VAWT (Vertical Axis).

Figure 16. Wind Power System



Mnemonic

"WGGTC: Wind, Gearbox, Generator, Transformer, Controller"

Question 5(a) [3 marks]

Explain the factors affecting the value of resistance of a resistor.

Solution

Answer:
Factors Affecting Resistance ($R = \rho l/A$):
- **Length (l):** Directly proportional ($R \propto l$)
- **Area (A):** Inversely proportional ($R \propto 1/A$)
- **Temperature:** Increases for metals
- **Material (ρ):** Depends on resistivity

Mnemonic

"TLAM: Temperature, Length, Area, Material"

Question 5(b) [4 marks]

Define active power, reactive power, apparent power and power factor with the help of power triangle. Write their units.

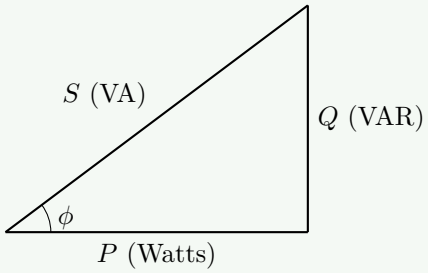
Solution

Answer:

Table 9. Power Definitions

Term	Formula	Unit
Active Power (P)	$P = VI\cos\phi$	Watt (W)
Reactive Power (Q)	$Q = VI\sin\phi$	VAR
Apparent Power (S)	$S = VI$	VA
Power Factor	$\cos\phi = P/S$	-

Figure 17. Power Triangle



Mnemonic

"ARSP: Active, Reactive, S-Apparent, Power Factor"

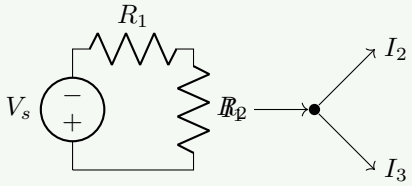
Question 5(c) [7 marks]

State and explain Kirchhoff's Voltage Law (KVL) and Kirchhoff's Current Law (KCL) with the help of circuit diagram.

Solution

Answer:
KVL: Algebraic sum of voltages in a closed loop is zero ($\sum V = 0$).
KCL: Algebraic sum of currents at a node is zero ($\sum I = 0$).

Figure 18. KVL and KCL



KVL: $V_s - IR_1 - IR_2 = 0$ KCL: $I_1 = I_2 + I_3$

Mnemonic

"VCL: Voltage Closed Loop, Current Node Sum"

Question 5(a) OR [3 marks]

Write the difference between EMF and potential difference. Also write the difference between cell and battery.

Solution

Answer:

Table 10. Differences

EMF	Potential Difference
Energy supplied per unit charge	Energy Consumed
Exists in open circuit	Exists in closed circuit
Cause of current	Effect of current

Cell vs Battery: Cell is a single unit; Battery is a combination of cells.

Mnemonic

"ESOP: EMF Source, Potential Operating"

Question 5(b) OR [4 marks]

Write the relation between AC voltage and AC current for pure resistor, pure capacitor and pure inductor. Draw the vector diagram of AC voltage and AC current for pure resistor, pure capacitor and pure inductor. Also write the value of power factor for pure resistor, pure capacitor and pure inductor.

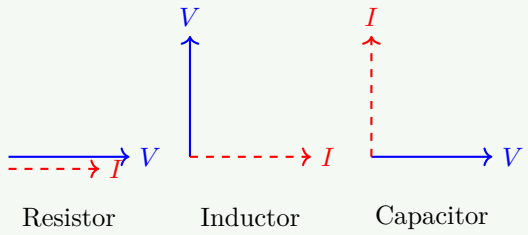
Solution

Answer:

Table 11. Component Comparisons

Component	Relation	Phase	PF
Resistor	$V = IR$	In Phase (0°)	1
Inductor	$V = L(dI/dt)$	I lags V by 90°	0 (lag)
Capacitor	$I = C(dV/dt)$	I leads V by 90°	0 (lead)

Figure 19. Vector Diagrams



Mnemonic

"RCI: Resistor Constant, Inductor lags, Capacitor leads"

Question 5(c) OR [7 marks]

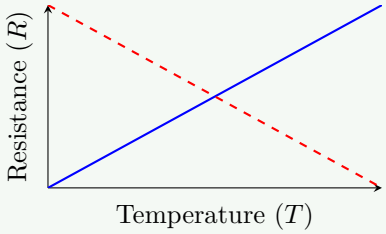
Define temperature coefficient of material and write its unit. Explain the effect of temperature on resistance of conductor with the help of temperature coefficient of conductor.

Solution

Answer:
Temperature Coefficient (α): The fractional change in resistance per degree change in temperature. **Unit:** Per degree Celsius ($^\circ C^{-1}$).
Effect on Conductors:
- Resistance increases with temperature (Positive α)
- $R_2 = R_1[1 + \alpha(T_2 - T_1)]$

Effect on Semiconductors: Resistance decreases (Negative α).

Figure 20. Temperature Effect



Mnemonic

"TRIP: Temperature Raises resistance In Proportion"