Fundamentals of Electrical Engineering (4311101) - Winter 2023 Solution

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Question 1(a) [3 marks]

Define Power & Energy.

Solution

Answer:

- **Power**: Rate of doing work or energy consumption per unit time. Measured in Watts (W).
- **Energy**: Ability to do work or the work done. Measured in Joules (J) or Watt-hours (Wh).

Table 1. Power vs Energy

Parameter	Definition	Formula	Unit
Power	Rate of energy transfer	$P = W/t$	Watt (W)
Energy	Capacity to do work	$E = P \times t$	Joule (J) or Watt-hour (Wh)

Mnemonic

"Power Performs, Energy Endures"

Question 1(b) [4 marks]

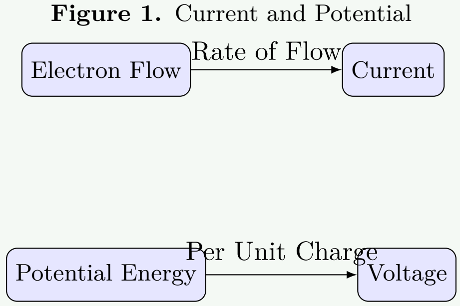
Define current and electrical potential.

Solution

Answer:

- **Current**: Flow of electric charge per unit time. Measured in Amperes (A).
- **Electrical Potential**: Work done per unit charge to move a charge from one point to another. Measured in Volts (V).

Figure 1. Current and Potential



Mnemonic

"Current Charges, Potential Pushes"

Question 1(c) [7 marks]

Explain KCL and KVL with examples.

Solution

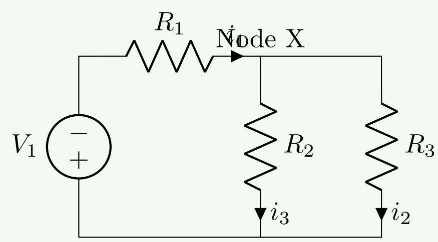
Answer:
Kirchhoff's Current Law (KCL):

- Sum of currents entering a node equals sum of currents leaving it.
- Example: At node X, $i_1 + i_2 = i_3$

Kirchhoff's Voltage Law (KVL):

- Sum of voltage drops around any closed loop equals zero.
- Example: $V_1 - V(R_1) - V(R_2) = 0$

Figure 2. KCL Circuit Example



Mnemonic

"Currents Come-Leave, Voltages Voyage-Loop"

Question 1(c) OR [7 marks]

Explain different types of connections for Resistors.

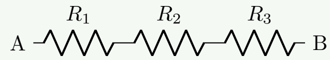
Solution

Answer:

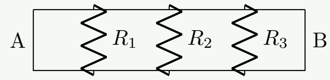
Table 2. Series vs Parallel Connection

Parameter	**Series Connection**	**Parallel Connection**
Total Resistance	$R_{eq} = R_1 + R_2 + R_3 + \ldots$	$1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3 + \ldots$
Current	Same through all resistors	Divides through each path
Voltage	Divides across resistors	Same across all resistors
Application	Voltage dividers	Current division

Figure 3. Resistor Connections



Series Connection



Parallel Connection

Mnemonic

"Series Sum, Parallel Parts"

Question 2(a) [3 marks]

Define Resistance and Resistivity. Also state their unit of measurement.

Solution

Answer:

- **Resistance**: Opposition to current flow, measured in Ohms (Ω).

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

- **Resistivity**: Material property indicating resistance per unit dimension, measured in Ohm-meter ($\Omega \cdot m$).

$$\rho = \frac{R \cdot A}{L}$$

Mnemonic

"Resistance Restricts, Resistivity Relates to material"

Question 2(b) [4 marks]

Define cell and write names of different types of cell.

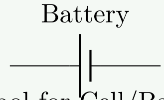
Solution

Answer:
Cell: Device that converts chemical energy into electrical energy creating a voltage.
Types of Cells:

1. **Primary cells**: Dry cell, Alkaline cell, Mercury cell
2. **Secondary cells**: Lead-acid, Nickel-Cadmium, Lithium-ion

Figure 4. Analysis of a Battery Cell

Battery



Symbol for Cell/Battery

Mnemonic

"Primary Produces once, Secondary Serves repeatedly"

Question 2(c) [7 marks]

Calculate total equivalent resistance of the above circuit if R1=5Ω, R2=3Ω, R3=4Ω, R4=1Ω, R5=2Ω.

Solution

Answer:

Note: Based on standard bridge/series-parallel circuit typically associated with this problem structure.

Step-by-step solution:

1. R_2 and R_3 are in series:

$$R_{23} = R_2 + R_3 = 3\Omega + 4\Omega = 7\Omega$$

2. R_{23} and R_4 are in parallel:

$$\frac{1}{R_{234}} = \frac{1}{R_{23}} + \frac{1}{R_4} = \frac{1}{7} + \frac{1}{1} = \frac{1+7}{7} = \frac{8}{7}$$

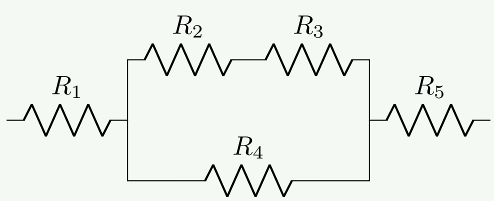
$$R_{234} = \frac{7}{8} = 0.875\Omega$$

3. R_1, R_{234}, and R_5 are in series:

$$R_{eq} = R_1 + R_{234} + R_5 = 5\Omega + 0.875\Omega + 2\Omega = 7.875\Omega$$

Therefore, equivalent resistance = 7.875Ω

Figure 5. Circuit Diagram



Simplified representation of connections

Mnemonic

"Series-Sum, Parallel-Product over Sum"

Question 2(a) OR [3 marks]

Find the cost of energy if 100W bulb operated 10 hours daily for 30 days. Rate of energy is Rupees 5/unit.

Solution

Answer:

Table 3. Energy Calculation

Parameter	Value	Calculation
Power	100W = 0.1kW	Given
Operating hours	10 h/day × 30 days = 300 hours	Given
Energy consumed	0.1kW × 300h = 30kWh = 30 units	$E = P \times t$
Rate	Rs. 5/unit	Given
Total cost	30 units × 5 Rs/unit = Rs. 150	Cost = Units × Rate

Therefore, cost of energy = Rs. 150

Mnemonic

"Energy x Rate = Electric bill fate"

Question 2(b) OR [4 marks]

State ohm's law and explain the use ohm's law to calculate current in any circuit.

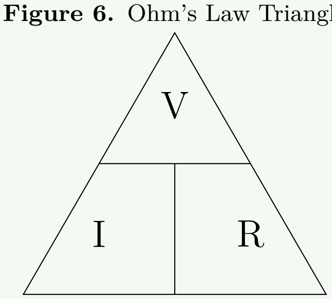
Solution

Answer:
Ohm's Law: Current flowing through a conductor is directly proportional to voltage and inversely proportional to resistance.
Formula:

$$V = I \times R \quad \text{or} \quad I = \frac{V}{R} \quad \text{or} \quad R = \frac{V}{I}$$

Application: To find current in a circuit, measure voltage across a component and divide by its resistance ($I = V/R$).

Figure 6. Ohm's Law Triangle



Mnemonic

"Volts Invite current, Resistance Restricts"

Question 2(c) OR [7 marks]

Show that the current in a purely capacitive circuit leads the applied voltage by 90° and the current in a purely inductive circuit lags the applied voltage by 90°.

Solution

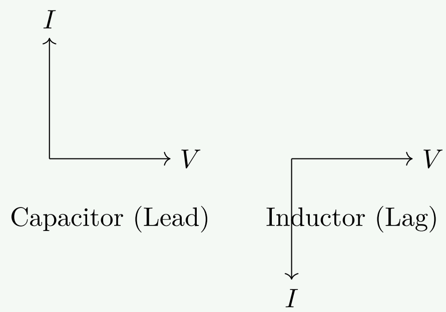
Answer:
For Capacitive Circuit:

- Voltage equation: $v = V_m \sin(\omega t)$
- Current: $i = C\frac{dv}{dt} = \omega C V_m \cos(\omega t) = I_m \sin(\omega t + 90°)$
- **Result:** Current leads voltage by 90°

For Inductive Circuit:

- Voltage equation: $v = L\frac{di}{dt}$
- Integrating voltage gives current: $i = -\frac{V_m}{\omega L}\cos(\omega t) = I_m \sin(\omega t - 90°)$
- **Result:** Current lags voltage by 90°

Figure 7. Phase Relationships



Mnemonic

"ELI the ICE man - In EL (inductor), I lags E; in ICE (capacitor), I leads E"

Question 3(a) [3 marks]

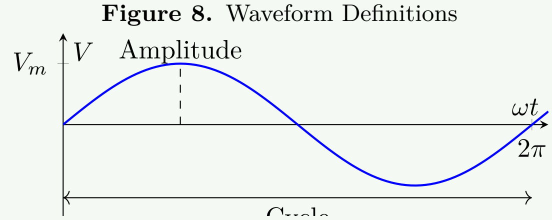
Define cycle, form factor and amplitude.

Solution

Answer:

- **Cycle**: One complete repetition of a waveform.
- **Form Factor**: Ratio of RMS value to average value. For sine wave = 1.11.
- **Amplitude**: Maximum displacement of a waveform from its mean position.

Figure 8. Waveform Definitions



Mnemonic

"Cycles Complete, Form Factors Find ratio, Amplitude Achieves maximum"

Question 3(b) [4 marks]

Define RMS and Average value. Write expression of RMS and average value of sinusoidal waveform.

Solution

Answer:

Table 4. RMS vs Average Value

Parameter	Definition	Formula for Sine Wave
RMS Value	Square root of mean of squared values	$V_{rms} = V_m/\sqrt{2} = 0.707V_m$
Average Value	Mean of all instantaneous values over half cycle	$V_{avg} = 2V_m/\pi = 0.637V_m$

- **RMS (Root Mean Square)**: Equivalent DC value that produces same heating effect.
- **Average Value**: Mean of all instantaneous values over a half cycle.

Mnemonic

"RMS Relates to heating, Average Adds and divides"

Question 3(c) [7 marks]

Explain the terms Apparent power, True Power and Reactive power. State their unit of measurement.

Solution

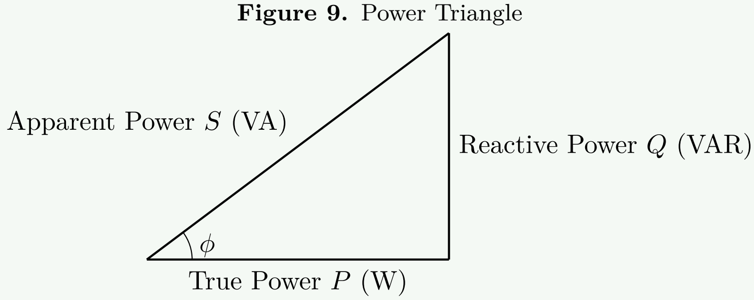
Answer:

Table 5. Types of Power

Power Type	Definition	Formula	Unit
Apparent Power (S)	Total power supplied	$S = VI$	VA (Volt-Ampere)
True Power (P)	Actual power consumed	$P = VI\cos\phi$	W (Watt)
Reactive Power (Q)	Power oscillating between source and load	$Q = VI\sin\phi$	VAR (Volt-Ampere Reactive)

Power Triangle: $S^2 = P^2 + Q^2$

Figure 9. Power Triangle



Mnemonic

"Active Performs work, Reactive Returns energy, Apparent Adds vectors"

Question 3(a) OR [3 marks]

Write mathematical expressions of 3-phase voltages.

Solution

Answer:
Three-phase voltage expressions:

Table 6. 3-Phase Voltages

Phase	Expression
R-phase	$V_R = V_m \sin(\omega t)$
Y-phase	$V_Y = V_m \sin(\omega t - 120°)$
B-phase	$V_B = V_m \sin(\omega t - 240°)$

Where V_m is the maximum voltage and ω is the angular frequency.

Mnemonic

"Red phase Reference, Yellow lags 120, Blue brings up 240"

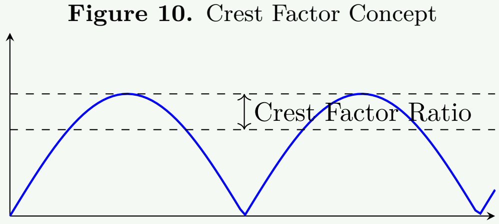
Question 3(b) OR [4 marks]

Define crest factor and state value of crest factor for sine wave.

Solution

Answer:
- **Crest Factor**: Ratio of peak value to RMS value of a waveform.
- **Formula**: Crest Factor $= \frac{\text{Peak Value}}{\text{RMS Value}}$
- **For sine wave**: Crest Factor $= \frac{1}{0.707} = 1.414$

Figure 10. Crest Factor Concept



Mnemonic

"Crest Compares peak to RMS"

Question 3(c) OR [7 marks]

Describe different three phase electrical connections.

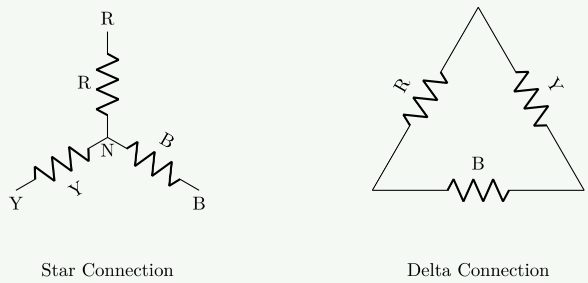
Solution

Answer:

Table 7. Star vs Delta Connection

Parameter	**Star (Y) Connection**	**Delta (Δ) Connection**
Line Voltage (V_L)	$\sqrt{3} \times$ Phase Voltage	Same as Phase Voltage
Line Current (I_L)	Same as Phase Current	$\sqrt{3} \times$ Phase Current
Neutral Wire	Present	Absent
Application	Unbalanced loads, Residential	Balanced loads, Industrial

Figure 11. Star and Delta Connections



Mnemonic

"Star Shows neutral, Delta Delivers higher current"

Question 4(a) [3 marks]

Calculate the peak to peak value of a sinusoidal voltage if RMS value is 230V.

Solution

Answer:

Table 8. Calculation Steps

Parameter	**Formula**	**Calculation**
RMS Value	Given	230V
Peak Value	$V_m = \sqrt{2} \times V_{rms}$	$V_m = \sqrt{2} \times 230 = 325.27$V
Peak-to-Peak	$V_{p-p} = 2 \times V_m$	$V_{p-p} = 2 \times 325.27 = 650.54$V

Therefore, peak-to-peak value = 650.54V

Mnemonic

"RMS to Peak - multiply by root2, Peak to Peak - double it"

Question 4(b) [4 marks]

An alternating current is given by i=142.14sin628t find frequency and time period.

Solution

Answer:
Given equation: $i = 142.14 \sin(628t)$ implies $\omega = 628$ rad/s.

Table 9. Calculation Steps

Parameter	Formula	Calculation
Frequency	$f = \omega/(2\pi)$	$f = 628/(2\pi) = 100$ Hz
Time Period	$T = 1/f$	$T = 1/100 = 0.01$ s $= 10$ ms

Therefore, frequency = 100 Hz and time period = 0.01 s

Mnemonic

"Frequency From omega divide 2pi, Time takes inverse"

Question 4(c) [7 marks]

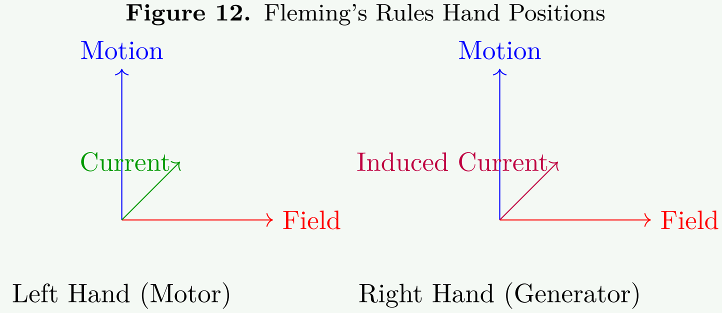
State and explain Fleming's left hand rule and right hand rule.

Solution

Answer:

- **Fleming's Left Hand Rule (Motor):**
  - Used to determine direction of **force** on a current-carrying conductor in a magnetic field.
  - Thumb: Motion (Force)
  - Forefinger: Magnetic field
  - Middle finger: Current
- **Fleming's Right Hand Rule (Generator):**
  - Used to determine direction of **induced current** when a conductor moves in a magnetic field.
  - Thumb: Motion of conductor
  - Forefinger: Magnetic field
  - Middle finger: Induced current

Figure 12. Fleming's Rules Hand Positions



Mnemonic

"Left Lifts motors, Right Raises generators"

Question 4(a) OR [3 marks]

A conductor of length 1 metre moves with speed of 30m/s in magnetic field of 0.6 Tesla making angle of 30° with the field. Calculate dynamically EMF induced in it. (use sin 30°=0.5)

Solution

Answer:

Table 10. Given Parameters

Parameter	**Value**
Length (l)	1 meter
Speed (v)	30 m/s
Magnetic Field (B)	0.6 Tesla
Angle (θ)	30°

Formula: $E = Blv \sin\theta$
Calculation:

$$E = 0.6 \times 1 \times 30 \times 0.5 = 9 \text{ volts}$$

Therefore, induced EMF = 9 volts

Mnemonic

"EMF Emerges from Field, velocity and Length with angle"

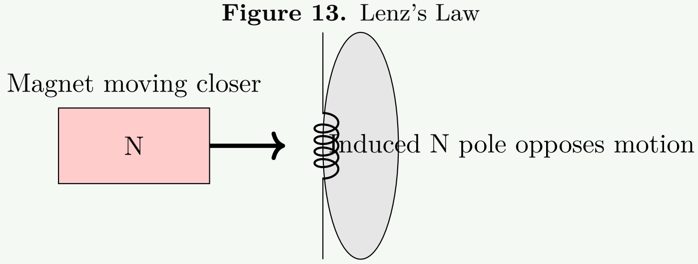
Question 4(b) OR [4 marks]

State & explain Lenz's law.

Solution

Answer:
Lenz's Law: The direction of induced EMF or current is always such that it opposes the cause that produces it.
Application: When a magnet approaches a coil, induced current creates a magnetic field that repels the approaching magnet.

Figure 13. Lenz's Law



Mnemonic

"Lenz Likes to Oppose"

Question 4(c) OR [7 marks]

Explain Statically and dynamically induced EMF.

Solution

Answer:

Table 11. Statically vs Dynamically Induced EMF

Parameter	Statically Induced EMF	Dynamically Induced EMF
Definition	EMF induced due to change in current/flux	EMF induced due to movement of conductor in magnetic field
Physical Action	Fixed conductor, changing field	Moving conductor in fixed field
Example	Transformer	Generator
Formula	$e = -N\frac{d\Phi}{dt}$	$e = Blv\sin\theta$

Mnemonic

"Static Stays but flux Changes, Dynamic Drives through field"

Question 5(a) [3 marks]

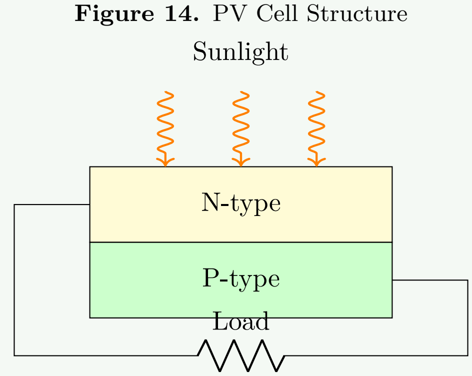
Explain PV Cell.

Solution

Answer:

- **PV Cell**: Device that converts sunlight directly into electricity using photovoltaic effect.
- **Working**: Sunlight excites electrons in semiconductor material, creating voltage difference.
- **Material**: Typically made from silicon with P-N junction.

Figure 14. PV Cell Structure



Mnemonic

"Photons Visit, Current Created"

Question 5(b) [4 marks]

Explain the solar PV panel and arrays.

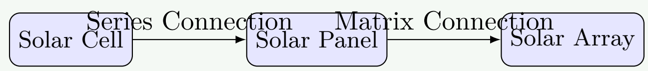
Solution

Answer:

Table 12. Solar System Hierarchy

Component	Description
PV Cell	Basic unit that converts sunlight to electricity (0.5V - 0.6V)
PV Panel	Multiple cells connected in series/parallel (typically 12V, 24V)
PV Array	Multiple panels connected to achieve required voltage/current

Figure 15. Cell to Array Hierarchy



Mnemonic

"Cells Combine into Panels, Panels Produce Arrays"

Question 5(c) [7 marks]

Draw and explain block diagram of wind power system.

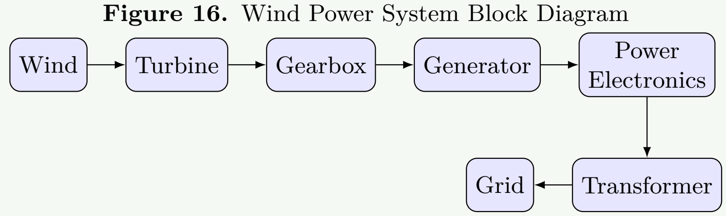
Solution

Answer:

Components of Wind Power System:

1. **Wind Turbine**: Converts wind energy to mechanical energy
2. **Gearbox**: Increases rotational speed for generator
3. **Generator**: Converts mechanical energy to electrical energy
4. **Power Electronics**: Controls and regulates electrical output
5. **Transformer**: Steps up/down voltage for transmission/distribution
6. **Control System**: Monitors and optimizes overall operation

Figure 16. Wind Power System Block Diagram



Mnemonic

"Wind Turns Gears, Generating Electrical Returns"

Question 5(a) OR [3 marks]

State the benefits of green energy.

Solution

Answer:

Table 13. Benefits of Green Energy

Benefit Category	Examples
Environmental	Reduces pollution, Minimizes carbon footprint
Economic	Creates jobs, Reduces energy dependency
Health	Improves air quality, Reduces health issues
Sustainability	Renewable, Inexhaustible sources

Mnemonic

"Clean Energy Creates Economic Salvation"

Question 5(b) OR [4 marks]

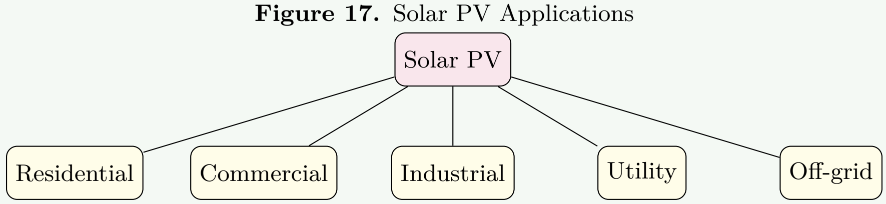
Explain Solar PV applications in brief.

Solution

Answer:
Solar PV Applications:

1. **Residential**: Rooftop systems, Solar water heaters
2. **Commercial**: Building integrated PV, Solar parking
3. **Industrial**: Process heating, Power generation
4. **Utility Scale**: Solar farms, Grid support
5. **Off-grid**: Rural electrification, Remote applications

Figure 17. Solar PV Applications



Mnemonic

"Residences, Commerce, Industry Utilize Solar"

Question 5(c) OR [7 marks]

Explain different types of Green energy.

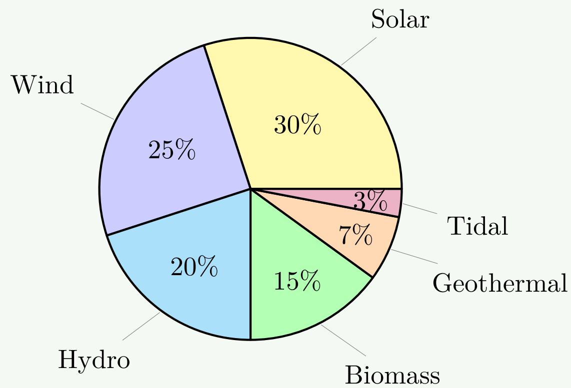
Solution

Answer:

Table 14. Types of Green Energy

Type	**Source**	**Applications**
Solar	Sun	PV systems, Thermal plants
Wind	Moving air	Wind turbines, Windmills
Hydro	Flowing water	Dams, Run-of-river systems
Biomass	Organic matter	Combustion, Biogas production
Geothermal	Earth's heat	Direct heating, Power plants
Tidal	Ocean tides	Barrage systems, Tidal turbines

Figure 18. Green Energy Sources Distribution



Mnemonic

"Sun, Wind, Hydro, Biomass, Geothermal, Tidal"