Fundamentals of Electrical Engineering (4311101) - Summer 2023 Solution

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Question 1(a) [3 marks]

Define the following term (1) Resistance (2) Electrical energy (3) Electrical Power

Solution

Answer:

Table 1. Definitions of Electrical Terms

Term	Definition
Resistance	The property of a material that opposes the flow of electric current, measured in ohms (Ω)
Electrical Energy	The ability to do work by electrical means, measured in joules (J) or kilowatt-hours (kWh)
Electrical Power	The rate at which electrical energy is transferred or converted, measured in watts (W)

Mnemonic

"RIP: Resistance Impedes Path, Energy Is Potential, Power Is Performance"

Question 1(b) [4 marks]

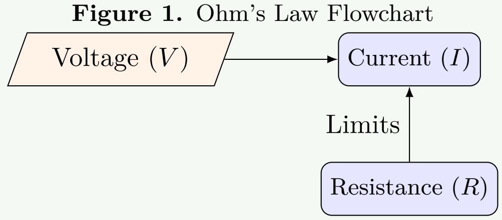
State and Explain Ohm's Law & write limitations of it.

Solution

Answer:
Ohm's Law: The current flowing through a conductor is directly proportional to the voltage across the conductor and inversely proportional to its resistance.
Mathematically: $V = IR$, where:

- V = Voltage (volts)
- I = Current (amperes)
- R = Resistance (ohms)

Figure 1. Ohm's Law Flowchart



Limitations of Ohm's Law:
- Not applicable to non-linear devices (semiconductors, gas discharge tubes)
- Doesn't hold at high temperatures
- Not valid for unilateral elements (diodes)
- Fails for time-varying currents

Mnemonic

"VIRO: Voltage Is Resistance times Output current"

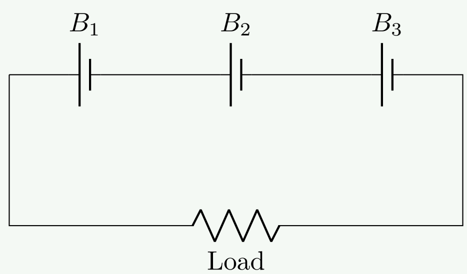
Question 1(c) [7 marks]

Explain series and parallel connection of batteries.

Solution

Answer:
Series Connection of Batteries:

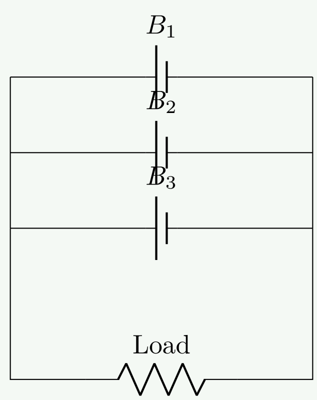
Figure 2. Series Batteries Connection



Characteristics of Series Connection:
- **Total Voltage** = Sum of individual voltages ($V = V_1 + V_2 + ... + V_n$)
- **Current** = Same through all batteries
- **Applications**: Higher voltage requirements
- **Internal Resistance**: Increases ($R_s = r_1 + r_2 + ... + r_n$)

Parallel Connection of Batteries:

Figure 3. Parallel Batteries Connection



Characteristics of Parallel Connection:
- **Voltage** = Same as individual battery (if identical)
- **Total Current** = Sum of individual currents ($I = I_1 + I_2 + ... + I_n$)
- **Applications**: Higher current capacity required
- **Internal Resistance**: Decreases ($1/R_p = 1/r_1 + 1/r_2 + ... + 1/r_n$)

Mnemonic

"VSCP: Voltage Sums in Series, Current Parallels"

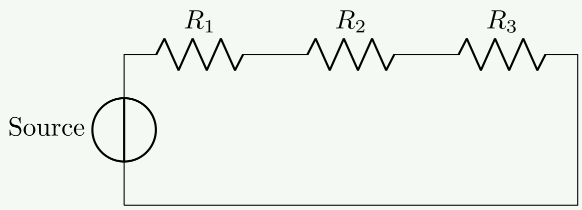
Question 1(c) OR [7 marks]

Explain series and parallel connection of Resistors.

Solution

Answer:
Series Connection of Resistors:

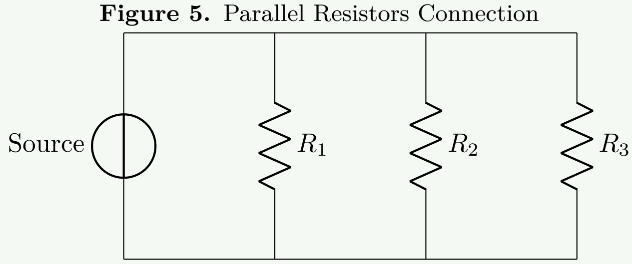
Figure 4. Series Resistors Connection



Characteristics of Series Connection:
- **Equivalent Resistance** = Sum of individual resistances ($R_s = R_1 + R_2 + ... + R_n$)
- **Current** = Same through all resistors
- **Voltage** = Divided across resistors proportional to resistance values
- **Power** divided as per voltage distribution

Parallel Connection of Resistors:

Figure 5. Parallel Resistors Connection



Characteristics of Parallel Connection:
- **Equivalent Resistance**: $1/R_p = 1/R_1 + 1/R_2 + ... + 1/R_n$
- **Voltage** = Same across all resistors
- **Current** = Divided inverse-proportionally to resistance values
- **Total Current** = Sum of individual currents

Mnemonic

"RISE-VICE: Resistance Increases in Series, Voltage Is Constant in Every parallel"

Question 2(a) [3 marks]

Define: (1) Amplitude (2) Frequency (3) Time period

Solution

Answer:

Table 2. Definitions of Waveform Terms

Term	Definition
Amplitude	Maximum displacement of a waveform from its mean position, measured in volts or amperes
Frequency	Number of complete cycles occurring in one second, measured in hertz (Hz)
Time Period	Time taken to complete one cycle of waveform, measured in seconds (s)

Mnemonic

"AFT: Amplitude is the Full height, Time period is the Total cycle"

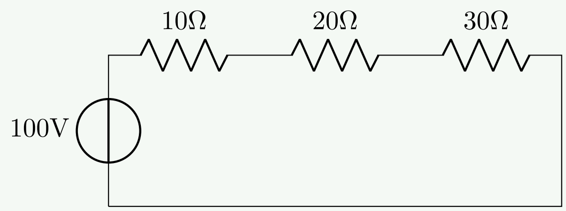
Question 2(b) [4 marks]

10Ω, 20Ω and 30Ω resistors are connected in series and 100V supply is given to them. Find (1) Equivalent resistance (2) Circuit current (3) Voltage drop across each Resistor (4) Power loss in each resistor.

Solution

Answer:

Figure 6. Series Circuit Problem



Solution:

Table 3. Calculations

Parameter	Calculation	Result
Equivalent Resistance	$R = 10\Omega + 20\Omega + 30\Omega$	60Ω
Circuit Current	$I = 100\text{V}/60\Omega$	1.67A
Voltage across 10Ω	$V_1 = 1.67\text{A} \times 10\Omega$	16.7V
Voltage across 20Ω	$V_2 = 1.67\text{A} \times 20\Omega$	33.3V
Voltage across 30Ω	$V_3 = 1.67\text{A} \times 30\Omega$	50.0V
Power in 10Ω	$P_1 = 1.67^2 \times 10$	27.8W
Power in 20Ω	$P_2 = 1.67^2 \times 20$	55.6W
Power in 30Ω	$P_3 = 1.67^2 \times 30$	83.4W

Mnemonic

"REÇVP: Resistances Equivalent Causes Voltage and Power division"

Question 2(c) [7 marks]

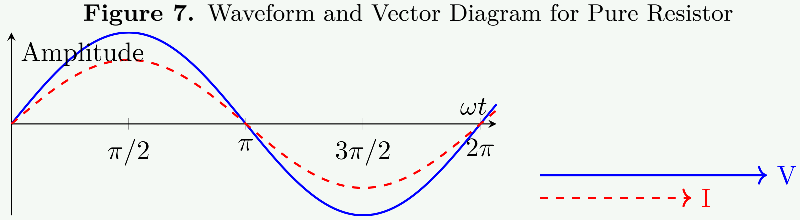
Explain A.C Through pure Resistor with wave form & vector diagram.

Solution

Answer:
In a pure resistive circuit with AC supply:
Key Characteristics:

- Current and voltage are **in phase** with each other
- Circuit follows Ohm's Law: $V = IR$
- Power is always positive ($P = VI$)
- No reactive power consumed
- Power factor = 1 ($\cos\phi = 1$)

Figure 7. Waveform and Vector Diagram for Pure Resistor



Vector Diagram Notes: Matches phase (Parallel vectors).

Mnemonic

"PARVIP: Pure AC Resistor has Voltage In Phase with current"

Question 2(a) OR [3 marks]

Define: (1) cycle (2) Form factor (3) Peak factor

Solution

Answer:

Table 4. AC Term Definitions

Term	Definition
Cycle	One complete repetition of a periodic waveform from start point to same point again
Form Factor	Ratio of RMS value to average value of AC waveform (For sine wave = 1.11)
Peak Factor	Ratio of maximum value to RMS value of AC waveform (For sine wave = 1.414)

Mnemonic

"CFP: Cycle Finishes a Pattern, Form Factor = Vrms/Vavg, Peak Factor = Vmax/Vrms"

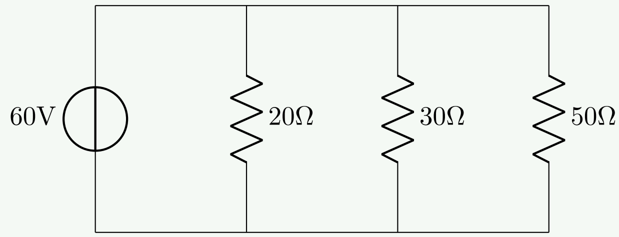
Question 2(b) OR [4 marks]

20Ω, 30Ω and 50Ω resistors are connected in parallel and 60V supply is given to them. Find (1) Current in each Resistor. (2) Total current (3) Equivalent resistance (4) Power loss in each resistor.

Solution

Answer:

Figure 8. Parallel Circuit Problem



Solution:

Table 5. Calculations

Parameter	**Calculation**	**Result**
Current in 20Ω	$I_1 = 60\text{V}/20\Omega$	3A
Current in 30Ω	$I_2 = 60\text{V}/30\Omega$	2A
Current in 50Ω	$I_3 = 60\text{V}/50\Omega$	1.2A
Total Current	$I = 3\text{A} + 2\text{A} + 1.2\text{A}$	6.2A
Equivalent Resistance	$1/R_{eq} = 1/20 + 1/30 + 1/50$	9.68Ω
Power in 20Ω	$P_1 = 60\text{V} \times 3\text{A}$	180W
Power in 30Ω	$P_2 = 60\text{V} \times 2\text{A}$	120W
Power in 50Ω	$P_3 = 60\text{V} \times 1.2\text{A}$	72W

Mnemonic

"VICTIM: Voltage Is Constant, Total current Is the Measure (in parallel)"

Question 2(c) OR [7 marks]

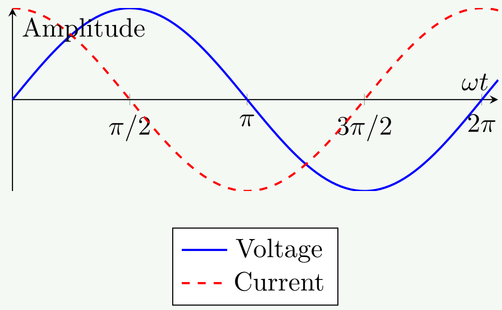
Explain A.C Through pure capacitor with wave form & vector diagram.

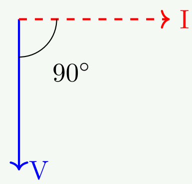
Solution

Answer:
In a pure capacitive circuit with AC supply:
Key Characteristics:

- Current **leads** voltage by 90°
- Capacitive reactance $X_c = 1/(2\pi f C)$
- Only reactive power (no active power)
- Power factor = 0 (lagging)
- Average power over complete cycle = 0

Figure 9. Waveform and Vector Diagram for Pure Capacitor





Note: V lags I by 90°.

Mnemonic

"CLEAR-90: Capacitive Load has Electrical Angle Reaching 90 degrees (current leads voltage)"

Question 3(a) [3 marks]

Define RMS value and average value related to alternating waveform write formula of it.

Solution

Answer:

Table 6. RMS and Average Value Definitions

Term	Definition	Formula
RMS Value	Root Mean Square value - equivalent DC value producing the same heating effect	$V_{rms} = 0.707 \times V_{max}$ for sine wave
Average Value	Mean value of all instantaneous values over half cycle	$V_{avg} = 0.637 \times V_{max}$ for sine wave

Mnemonic

"RAM: RMS Averages the Mean square (RMS = 0.707 Vmax, AVG = 0.637 Vmax)"

Question 3(b) [4 marks]

If A.C. current is represented by equation $i = 25\sin(314t)$. Calculate (1) R.m.s. value (2) Average value (3) Frequency (4) Time period

Solution

Answer:
Given equation: $i = 25\sin(314t)$

Table 7. AC Parameter Calculations

Parameter	Calculation	Result
Maximum value	$I_{max} = 25A$	25A
RMS value	$I_{rms} = I_{max}/\sqrt{2} = 25/1.414$	17.68A
Average value	$I_{avg} = 2I_{max}/\pi = 2 \times 25/3.14$	15.92A
Angular frequency	$\omega = 314$ rad/s	314 rad/s
Frequency	$f = \omega/2\pi = 314/6.28$	50Hz
Time period	$T = 1/f = 1/50$	0.02s

Mnemonic

"SMART: Sine's Maximum divided by root 2 equals RMS Then 2/pi for Average"

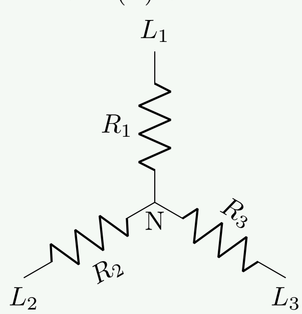
Question 3(c) [7 marks]

Explain star connection of resistors and Derive equation shows relationship between voltage and current in star connection.

Solution

Answer:
Star (Y) Connection:

Figure 10. Star (Y) Connection Diagram



Characteristics of Star Connection:
- Three resistors connected at common point (neutral)
- Line voltage $(V_L) = \sqrt{3}\times$ Phase voltage (V_{ph})
- Line current (I_L) = Phase current (I_{ph})
- For balanced load: $I_L = I_{ph}$
- Total power $= 3\times$ Phase power

Mathematical Relationship:
- Phase voltage: $V_{ph} = V_L/\sqrt{3}$
- Phase current: $I_{ph} = I_L$
- For balanced resistive load: $I_{ph} = V_{ph}/R$
- Therefore: $I_L = V_L/(\sqrt{3} \times R)$

Mnemonic

"SLIP-3: Star Line current Is Phase current, Line voltage is Phase voltage times root-3"

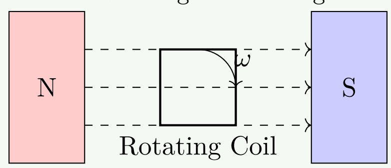
Question 3(a) OR [3 marks]

Explain generation of alternating E.M.F.

Solution

Answer:
Generation of Alternating EMF:

Figure 11. Rotating Coil in Magnetic Field



Process:

- Coil rotates in uniform magnetic field
- Flux linkage changes with angle of rotation
- Rate of change of flux induces EMF
- EMF follows sinusoidal pattern: $e = E_{max} \sin(\omega t)$
- Frequency depends on rotation speed

Mnemonic

"FRAME: Flux Rotation Alternates Magnetic EMF"

Question 3(b) OR [4 marks]

An alternating EMF is expressed by $e = 100 \sin(2\pi 50t)$. Find out (1) Max value of EMF (2) Frequency (3) Time period (4) Angular Frequency

Solution

Answer:
Given equation: $e = 100 \sin(2\pi 50t)$

Table 8. EMF Parameter Calculations

Parameter	Calculation	Result
Maximum EMF	$E_{max} = 100$V	100V
Angular Frequency	$\omega = 2\pi 50 = 314$ rad/s	314 rad/s
Frequency	$f = 50$Hz (directly from equation)	50Hz
Time Period	$T = 1/f = 1/50$	0.02s

Mnemonic

"FAST: Frequency And period are reciprocals, Sin's Top value is maximum"

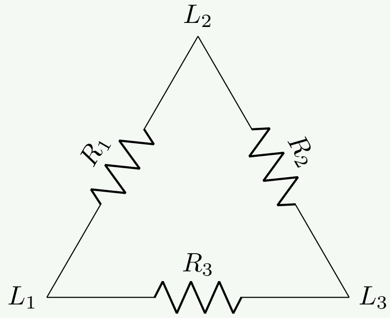
Question 3(c) OR [7 marks]

Explain star connection and Derive equation shows relationship between voltage and current in delta connection.

Solution

Answer:
Delta (Δ) Connection:

Figure 12. Delta Connection Diagram



Characteristics of Delta Connection:

- Three resistors connected in closed loop
- Line voltage (V_L) = Phase voltage (V_{ph})
- Line current (I_L) = $\sqrt{3}\times$ Phase current (I_{ph})
- For balanced load: $V_{ph} = V_L$
- Total power = $3\times$ Phase power

Mathematical Relationship:

- Phase voltage: $V_{ph} = V_L$
- Phase current: $I_{ph} = V_{ph}/R$
- Line current: $I_L = \sqrt{3} \times I_{ph}$
- Therefore: $I_L = \sqrt{3} \times V_L/R$

Mnemonic

"DELVIr3: Delta Equal Line Voltage, Its line current equals phase current times root-3"

Question 4(a) [3 marks]

Define (1) M.M.F. (2) Reluctance (3) flux

Solution

Answer:

Table 9. Magnetic Terms Definitions

Term	**Definition**
M.M.F. (Magnetomotive Force)	The force that produces magnetic flux in a magnetic circuit, measured in ampere-turns (AT)
Reluctance	The magnetic equivalent of resistance, opposition to magnetic flux, measured in AT/Wb
Flux	The total magnetic field passing through a surface, measured in webers (Wb)

Mnemonic

"MFR: MMF Flows against Reluctance like current flows against resistance"

Question 4(b) [4 marks]

Explain Apparent, Active and Reactive power in A.C circuits.

Solution

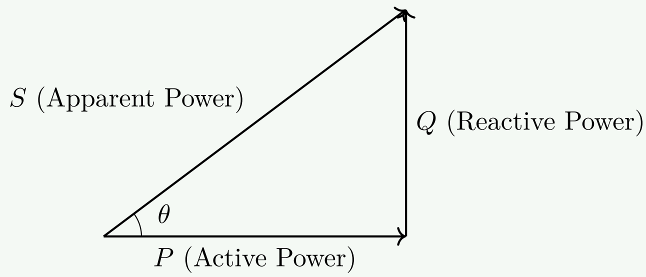
Answer:

Table 10. AC Power Types

Power Type	Symbol & Unit	Definition
Apparent Power	S (VA)	Vector sum of active and reactive power
Active Power	P (W)	Actual work-producing power consumed by the load
Reactive Power	Q (VAR)	Power that oscillates between source and load

Power Triangle:

Figure 13. Power Triangle



Relationships:

- $S = \sqrt{P^2 + Q^2}$
- $P = S \times \cos\theta$
- $Q = S \times \sin\theta$
- Power factor $= \cos\theta = P/S$

Mnemonic

"SPARQ: S is Power Apparent, Real is P, Q is reactive"

Question 4(c) [7 marks]

Compare electric and magnetic circuit.

Solution

Answer:

Table 11. Electric vs Magnetic Circuit

Parameter	Electric Circuit	Magnetic Circuit
Force	EMF (V)	MMF (AT)
Opposition	Resistance (Ω)	Reluctance (AT/Wb)
Flow	Current (A)	Flux (Wb)
Ohm's Law	$V = IR$	MMF $= \Phi \times S$
Medium	Conductor	Ferromagnetic material
Energy	Stored in electric field	Stored in magnetic field
Leakage	Negligible	Significant
Path	Conductors	Usually closed loop
Material Property	Conductivity	Permeability
Current Flow	Electron flow	No particle flow

Mnemonic

"VIRO-MSPhiS: Voltage Is to Resistance as MMF is to Reluctance, Our phi flows Similar"

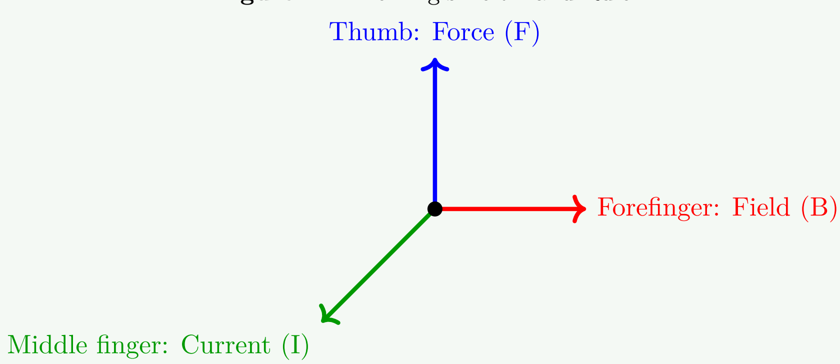
Question 4(a) OR [3 marks]

State and explain Fleming's left hand rule.

Solution

Answer:
Fleming's Left Hand Rule: Used to find the direction of the force experienced by a current-carrying conductor placed in a magnetic field.

Figure 14. Fleming's Left Hand Rule



Application:
- Thumb → Direction of Force (F)
- Forefinger → Direction of magnetic Field (B)
- Middle finger → Direction of Current (I)
- Only works when fingers are perpendicular to each other

Mnemonic

"FBI-Left: Force, B-field, and I-current directions are shown by the Left hand"

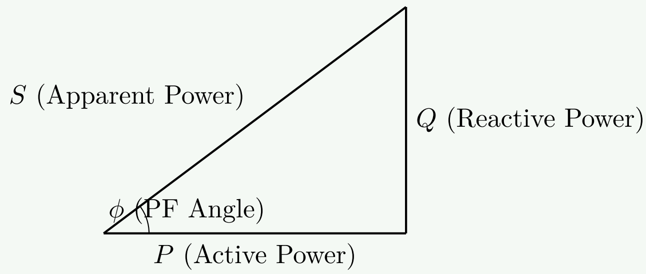
Question 4(b) OR [4 marks]

Draw power triangle and explain each component of it.

Solution

Answer:
Power Triangle:

Figure 15. Power Triangle Components



Components:

Table 12. Power Triangle Components

Component	Symbol	Unit	Meaning
Active Power	P	Watt (W)	Real power doing useful work
Reactive Power	Q	VAR	Power oscillating between source and load
Apparent Power	S	VA	Vector sum of P and Q
Power Factor	$\cos\phi$	-	Ratio of active to apparent power (P/S)

Relationships:
- $S^2 = P^2 + Q^2$
- $P = S \times \cos\phi$
- $Q = S \times \sin\phi$

Mnemonic

"SPQR: S is Pythagoras of P and Q, Ratio of P/S is power factor"

Question 4(c) OR [7 marks]

Differentiate statically and dynamically induced E.M.F.

Solution

Answer:

Table 13. Statically vs Dynamically Induced EMF

Parameter	Statically Induced EMF	Dynamically Induced EMF
Definition	EMF induced due to change in current in the primary coil	EMF induced due to relative motion between conductor and magnetic field
Mechanism	Change in linkage flux	Cutting of magnetic flux
Movement	No physical movement required	Requires relative motion
Examples	Transformer, inductor	Generator, motor
Faraday's Law	$e = -N(d\Phi/dt)$	$e = Blv$
Application	Power transfer without motion	Power generation through motion
Energy Conversion	Electrical to magnetic and back	Mechanical to electrical or vice versa

Mnemonic

"STIM-DMOV: STatically Induced needs Magnetic flux change, Dynamically needs MOVement"

Question 5(a) [3 marks]

Define (1) solar cell (2) solar panel (3) solar array

Solution

Answer:

Table 14. Solar Term Definitions

Term	Definition
Solar Cell	Basic photovoltaic unit that converts sunlight directly into electricity through semiconductor material
Solar Panel	Collection of solar cells connected in series/parallel in a frame
Solar Array	Multiple solar panels connected together to form a larger electricity-generating unit

Mnemonic

"CPA: Cell Produces electricity, Panel Arrays cells, Array is collection of panels"

Question 5(b) [4 marks]

Differentiate HAWT and VAWT.

Solution

Answer:

Table 15. HAWT vs VAWT

Parameter	Horizontal Axis Wind Turbine (HAWT)	Vertical Axis Wind Turbine (VAWT)
Axis Orientation	Parallel to ground	Perpendicular to ground
Efficiency	Higher (35-45%)	Lower (15-30%)
Wind Direction	Needs to face the wind	Works with wind from any direction
Generator Location	At the top of tower	Can be placed at ground level
Space Required	More	Less
Noise	Higher	Lower
Examples	Propeller-type, widely used commercially	Darrieus, Savonius designs

Mnemonic

"HAVE: Horizontal Aligns with wind, Vertical Enjoys omnidirectional wind"

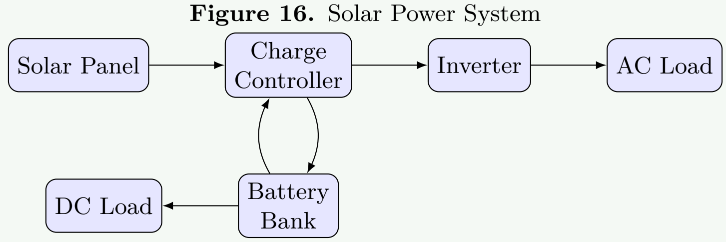
Question 5(c) [7 marks]

Draw and explain the Block diagram of solar power system.

Solution

Answer:
Solar Power System Block Diagram:

Figure 16. Solar Power System



Components:

1. **Solar Panels**: Convert sunlight to DC electricity
2. **Charge Controller**: Regulates battery charging, prevents overcharging
3. **Battery Bank**: Stores energy for use when sunlight isn't available
4. **Inverter**: Converts DC to AC power for household appliances
5. **Loads**: AC loads (appliances) and DC loads (LED lights, etc.)

Optional Components:

- **Monitoring System**: Tracks power generation/consumption
- **Grid Connection**: Allows selling excess electricity

Mnemonic

"SCBIL: Solar Collects, Battery Inverts for Loads"

Question 5(a) OR [3 marks]

Explain the need of green energy for our planet.

Solution

Answer:
Need for Green Energy:

1. **Sustainability**: Renewable sources won't deplete unlike fossil fuels
2. **Pollution Reduction**: Minimizes air and water pollution from burning fossil fuels
3. **Climate Change**: Reduces greenhouse gas emissions that cause global warming
4. **Energy Security**: Decreases dependence on imported fuels
5. **Economic Benefits**: Creates jobs and reduces health costs related to pollution

Mnemonic

"SPECS: Sustainable, Pollution-free, Economic, Climate-friendly, Secure"

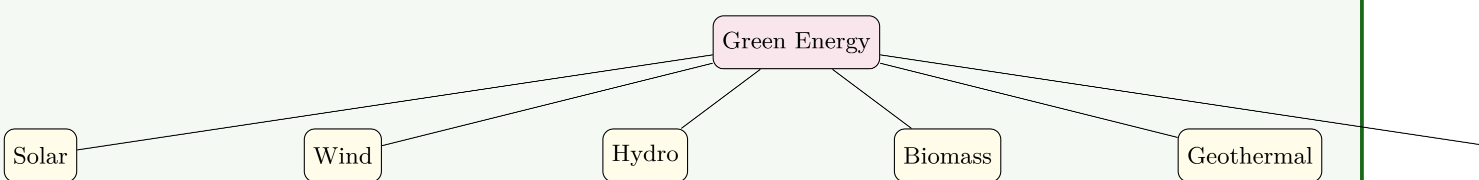
Question 5(b) OR [4 marks]

Classify green energy and explain any one in detail.

Solution

Answer:
Classification of Green Energy Sources:

Figure 17. Green Energy Classification



Solar Energy in Detail:

- **Working Principle**: Photovoltaic effect converts sunlight to electricity
- **Components**: Solar cells, panels, inverters, batteries
- **Applications**: Residential power, industrial use, transportation
- **Advantages**: No pollution, abundant source, low maintenance
- **Limitations**: Weather dependent, requires storage, initial cost

Mnemonic

"SWHBGT: Sun Wind Hydro Biomass Geothermal Tidal are green energy types"

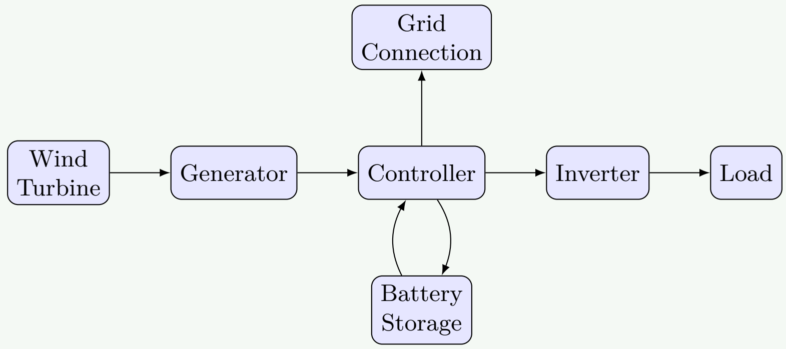
Question 5(c) OR [7 marks]

Explain block diagram of wind power system and explain the operation of wind power system.

Solution

Answer:
Wind Power System Block Diagram:

Figure 18. Wind Power System



Operation:

1. **Wind Turbine**: Converts wind's kinetic energy to mechanical energy
2. **Generator**: Transforms mechanical rotation to electrical energy
3. **Controller**: Regulates power output and protects from high winds
4. **Battery**: Stores excess energy (for off-grid systems)
5. **Inverter**: Converts DC to AC for consumption
6. **Grid Connection**: Feeds excess power to grid or draws when needed

Types of Wind Turbines:

- Horizontal Axis (HAWT): Main commercial type
- Vertical Axis (VAWT): Better for urban settings

Wind Speed Requirements:

- Cut-in speed: 3-5 m/s
- Rated output: 12-15 m/s
- Cut-out speed: 25 m/s (for safety)

Mnemonic

"WGCBIL: Wind Generates, Controller Balances, Inverter Loads"