

# 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 ( $\Omega$ )
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

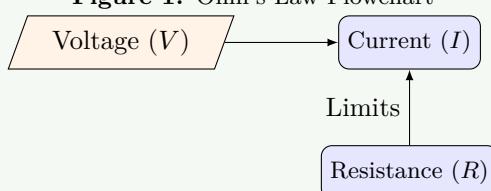
Answer:

**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**

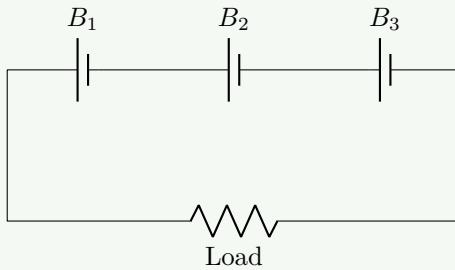
“VIRO: Voltage Is Resistance times Output current”

**Question 1(c) [7 marks]**

Explain series and parallel connection of batteries.

**Solution****Answer:****Series Connection of Batteries:**

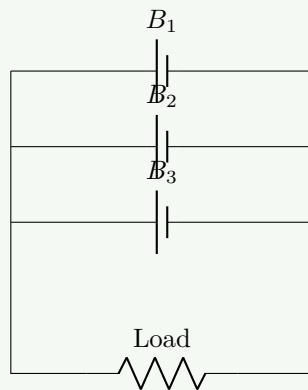
**Figure 2.** Series Batteries Connection

**Characteristics of Series Connection:**

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

**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 ( $I = I_1 + I_2 + \dots + I_n$ )
- **Applications**: Higher current capacity required
- **Internal Resistance**: Decreases ( $1/R_p = 1/r_1 + 1/r_2 + \dots + 1/r_n$ )

**Mnemonic**

“VSCP: Voltage Sums in Series, Current Parallels”

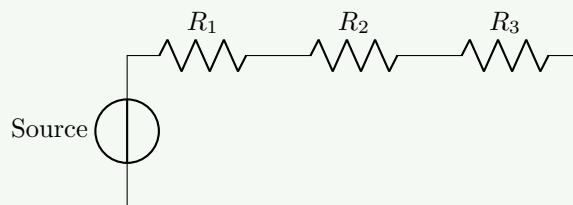
**Question 1(c) OR [7 marks]**

Explain series and parallel connection of Resistors.

**Solution****Answer:**

**Series Connection of Resistors:**

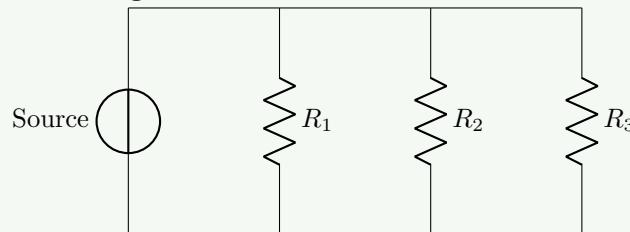
**Figure 4.** Series Resistors Connection

**Characteristics of Series Connection:**

- **Equivalent Resistance** = Sum of individual resistances ( $R_s = R_1 + R_2 + \dots + R_n$ )
- **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:**  $1/R_p = 1/R_1 + 1/R_2 + \dots + 1/R_n$
- **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

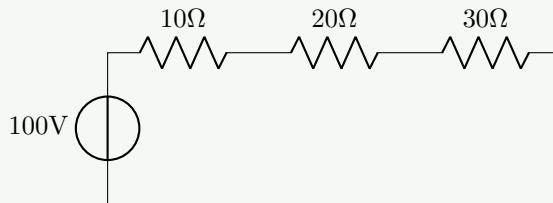
Term	Definition
<b>Amplitude</b>	Maximum displacement of a waveform from its mean position, measured in volts or amperes
<b>Frequency</b>	Number of complete cycles occurring in one second, measured in hertz (Hz)
<b>Time Period</b>	Time taken to complete one cycle of waveform, measured in seconds (s)

**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	$I = 100V/60\Omega$	1.67A
Voltage across 10Ω	$V_1 = 1.67A \times 10\Omega$	16.7V
Voltage across 20Ω	$V_2 = 1.67A \times 20\Omega$	33.3V
Voltage across 30Ω	$V_3 = 1.67A \times 30\Omega$	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**

“RECV: Resistances Equivalent Causes Voltage and Power division”

## Question 2(c) [7 marks]

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

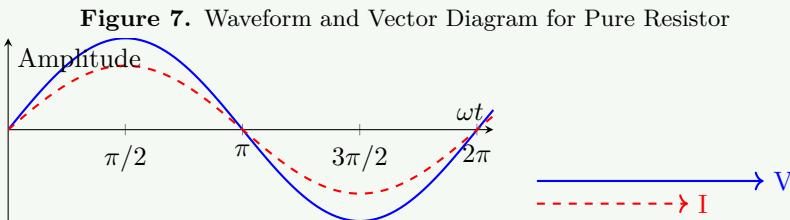
### Solution

#### 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 ( $\cos \phi = 1$ )



**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

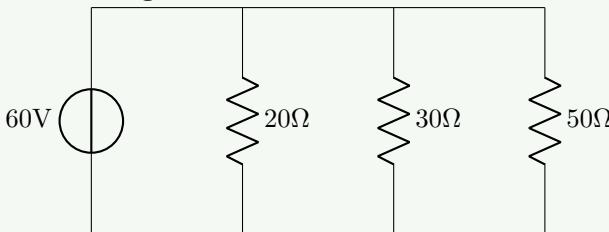
Term	Definition
Cycle	One complete repetition of a periodic waveform from start point to same point again
Form Factor	Ratio of RMS value to average value of AC waveform (For sine wave = 1.11)
Peak Factor	Ratio of maximum value to RMS value of AC waveform (For sine wave = 1.414)

### Mnemonic

“CFP: Cycle Finishes a Pattern, Form Factor =  $V_{rms}/V_{avg}$ , Peak Factor =  $V_{max}/V_{rms}$ ”

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

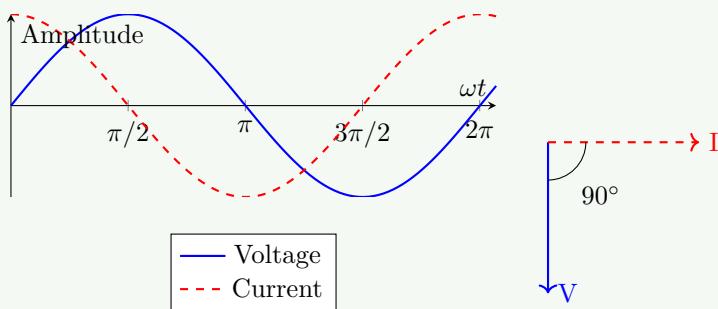
**Solution****Answer:**

In a pure capacitive circuit with AC supply:

**Key Characteristics:**

- Current **leads** voltage by  $90^\circ$
- Capacitive reactance  $X_c = 1/(2\pi fC)$
- 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  $90^\circ$ .

### 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
<b>RMS Value</b>	Root Mean Square value - equivalent DC value producing the same heating effect	$V_{rms} = 0.707 \times V_{max}$ for sine wave
<b>Average Value</b>	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	$I_{max} = 25\text{A}$	25A
RMS value	$I_{rms} = I_{max}/\sqrt{2} = 25/\sqrt{2} = 25/1.414$	17.68A
Average value	$I_{avg} = 2I_{max}/\pi = 2 \times 25/3.14$	15.92A
Angular frequency	$\omega = 314 \text{ rad/s}$	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]**

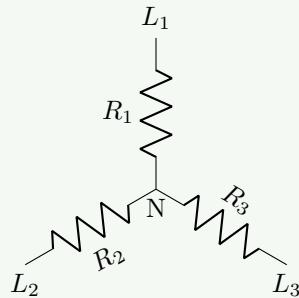
Explain star connection of resistors and Derive equation shows relationship between voltage and current in star connection.

**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]

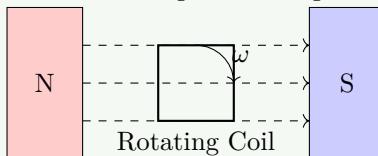
Explain generation of alternating E.M.F.

### 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	$E_{max} = 100V$	100V
Angular Frequency	$\omega = 2\pi 50 = 314 \text{ rad/s}$	314 rad/s
Frequency	$f = 50\text{Hz}$ (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]

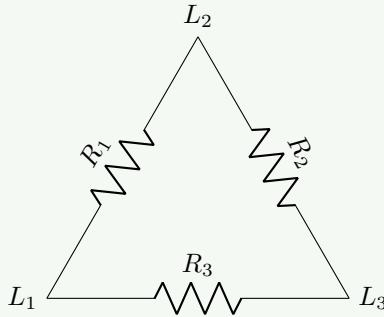
Explain star connection and Derive equation shows relationship between voltage and current in delta connection.

## Solution

**Answer:**

**Delta ( $\Delta$ ) 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

“DELV<sub>ir</sub>3: 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
<b>M.M.F. (Magnetomotive Force)</b>	The force that produces magnetic flux in a magnetic circuit, measured in ampere-turns (AT)
<b>Reluctance</b>	The magnetic equivalent of resistance, opposition to magnetic flux, measured in AT/Wb
<b>Flux</b>	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

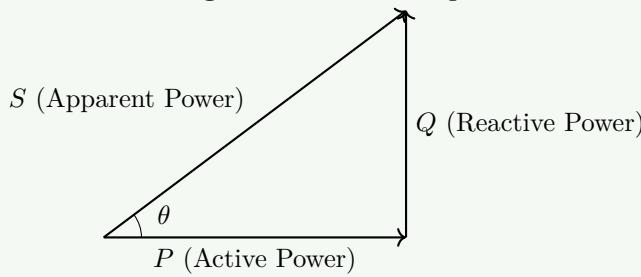
**Answer:**

**Table 10.** AC Power Types

Power Type	Symbol & Unit	Definition
<b>Apparent Power</b>	$S$ (VA)	Vector sum of active and reactive power
<b>Active Power</b>	$P$ (W)	Actual work-producing power consumed by the load
<b>Reactive Power</b>	$Q$ (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
<b>Force</b>	EMF (V)	MMF (AT)
<b>Opposition</b>	Resistance ( $\Omega$ )	Reluctance (AT/Wb)
<b>Flow</b>	Current (A)	Flux (Wb)
<b>Ohm's Law</b>	$V = IR$	$MMF = \Phi \times S$
<b>Medium</b>	Conductor	Ferromagnetic material
<b>Energy</b>	Stored in electric field	Stored in magnetic field
<b>Leakage</b>	Negligible	Significant
<b>Path</b>	Conductors	Usually closed loop
<b>Material Property</b>	Conductivity	Permeability
<b>Current Flow</b>	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.

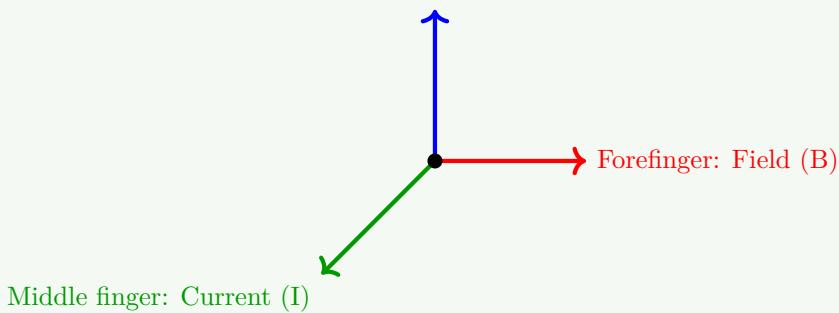
**Solution**

**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

Thumb: Force (F)



**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]

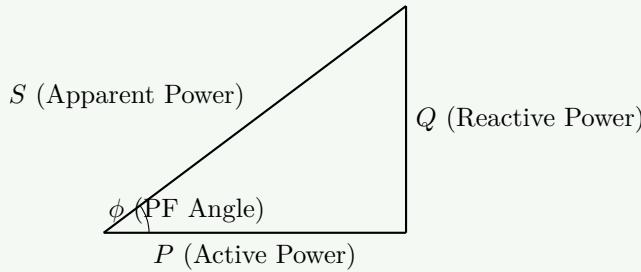
Draw power triangle and explain each component of it.

### Solution

**Answer:**

**Power Triangle:**

**Figure 15.** Power Triangle Components



**Components:**

**Table 12.** Power Triangle Components

Component	Symbol	Unit	Meaning
<b>Active Power</b>	$P$	Watt (W)	Real power doing useful work
<b>Reactive Power</b>	$Q$	VAR	Power oscillating between source and load
<b>Apparent Power</b>	$S$	VA	Vector sum of $P$ and $Q$
<b>Power Factor</b>	$\cos \phi$	-	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
<b>Definition</b>	EMF induced due to change in current in the primary coil	EMF induced due to relative motion between conductor and magnetic field
<b>Mechanism</b>	Change in linkage flux	Cutting of magnetic flux
<b>Movement</b>	No physical movement required	Requires relative motion
<b>Examples</b>	Transformer, inductor	Generator, motor
<b>Faraday's Law</b>	$e = -N(d\Phi/dt)$	$e = Blv$
<b>Application</b>	Power transfer without motion	Power generation through motion
<b>Energy Conversion</b>	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
<b>Solar Cell</b>	Basic photovoltaic unit that converts sunlight directly into electricity through semiconductor material
<b>Solar Panel</b>	Collection of solar cells connected in series/parallel in a frame
<b>Solar Array</b>	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”

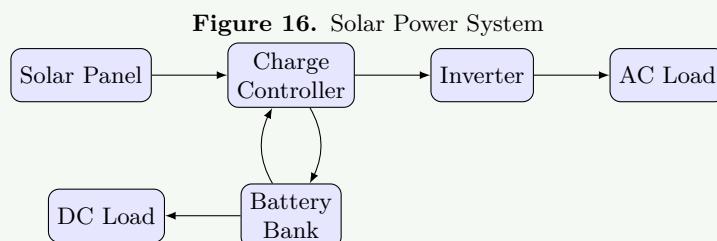
**Question 5(c) [7 marks]**

Draw and explain the Block diagram of solar power system.

**Solution**

**Answer:**

**Solar Power System Block Diagram:**

**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]

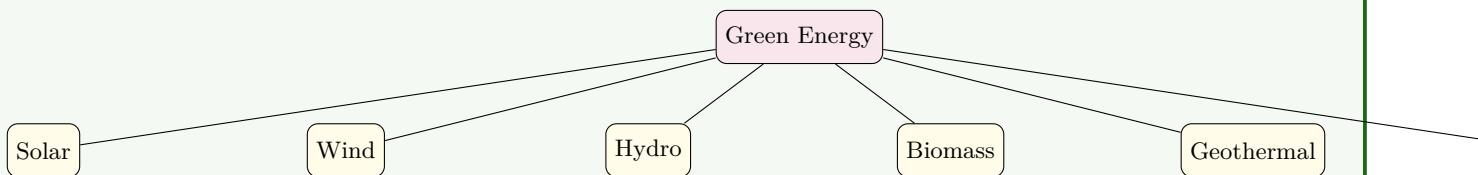
Classify green energy and explain any one in detail.

### 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]

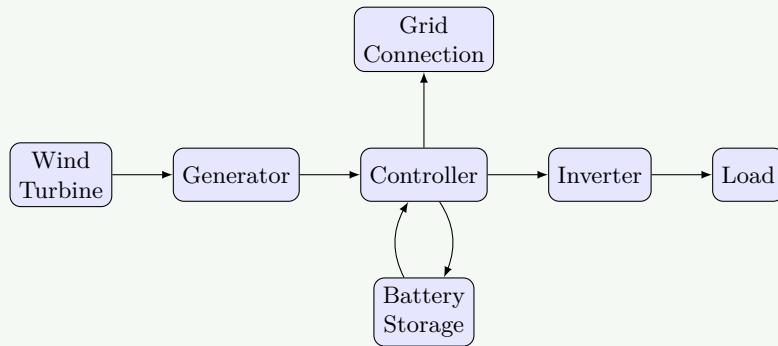
Explain block diagram of wind power system and explain the operation of wind power system.

### 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”