Subject Name Solutions

4311101 – Summer 2024

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

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

Solution

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

For Series Connection:

```
Req = R1 + R2 + R3
Req = 1000 Ω + 2000 Ω + 3000 Ω
Req = 6000 Ω
```

For Parallel Connection:

```
1/Req = 1/R1 + 1/R2 + 1/R3
1/Req = 1/1000 + 1/2000 + 1/3000
1/Req = 0.001 + 0.0005 + 0.00033
1/Req = 0.00183
Req = 545.45 Ω
```

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Input] {-{-}{-} B[1000 Ω]}
    B {-{-}{-} C[2000 Ω]}
    C {-{-}{-} D[3000 Ω]}
    D {-{-}{-} E[Output]}

    F[Input] {-{-}{-} G[1000 Ω] {-}{-}{-} H[Output]}
    F {-{-}{-} I[2000 Ω] {-}{-}{-} H}
    F {-{-}{-} J[3000 Ω] {-}{-}{-} H}
{Highlighting}
{Shaded}
```

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

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

Diagram:

```
+{-{-}{-}{-}{-}+    +{-}{-}{-}{-}{-}+     +{-}{-}{-}{-}{-}+}
|      |    |      |      |     |
|    |    |    |      |     |
|      |    |      |      |     |
+{-{-}{-}{-}{-}+    +{-}{-}{-}{-}{-}+     +{-}{-}{-}{-}{-}+}
Resistor    Capacitor    Inductor
```

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

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 $\times R$
Circuit Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Voltage Source V] {-{-}{-} B[Resistor R]}
    B {-{-}{-} C[Current I]}
    C {-{-}{-} A}
{Highlighting}
{Shaded}
```

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

Alternating EMF is generated when a conductor rotates in a magnetic field.

Equation: e = $E_0 sin(t) = E_0 sin(2ft)$

Where:

- e = instantaneous EMF
- $E_0 = maximum EMF$
- = angular velocity (2 f)
- f = frequency
- t = time

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Magnetic Field] {-{-}{-} B[Rotating Coil]}
    B {-{-}{-} C[Slip Rings]}
    C {-{-}{-} D[Brushes]}
    D {-{-}{-} E[AC Output]}
{Highlighting}
{Shaded}
```

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

Behavior of Pure Capacitor with AC:

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

Circuit and Waveform:

```
    +       +
    |       |
 AC |       | C
```

```
    |       |
    +       +


 Voltage
    |    /{}
    |   /  {}
    |  /    {    Current}
    | /      {    /}
    |/        {  /  }
{-{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}/{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}}
    |{        /|        /}
    | {      / |       /}
    |  {    /  |}
    |   {  /   |}
    |    {/    |}
```

Equation: I = C $\times dV/dt$

Mnemonic

"CIVIC" - Capacitor's current Is ahead of Voltage by 90$°InCircuit$

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

Given: v = 300 Sin(628t) V

Parameter	Formula	Calculation	Result
Amplitude	V_0	300 V	300 V
Angular Frequency		628 rad/s	628 rad/s
Frequency	f = /2	628/2 = 628/6.28	100 Hz
Time Period	T = 1/f	1/100	0.01 s
Average Value	Vavg = $2V_0/$	2×300/ = 600/3.14	191 V
RMS Value	Vrms = $V_0/\sqrt{2}$	300/1.414	212.16 V
Form Factor	FF = Vrms/Vavg	212.16/191	1.11
Peak Factor	PF = $V_0/Vrms$	300/212.16	1.414

Mnemonic

"FART FAFP" - Frequency is Angular frequency divided by 2 , RMS is peak divided by root 2, Time period is 1/f, Form factor is 1.11, Average is $2V_m/, Peak factor is 1.414$

Question 2(a OR) [3 marks]

Explain the generation of 3-phase alternating EMF.

Solution

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 (or U, V, W)
- Phase difference between any two phases is 120°

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Rotating Magnet] {-{-}{-} B[Three Coils 120^ Apart]}
    B {-{-}{-} C[Three{-}Phase Output]}
    D[Time] {-{-}{-} E[Three Phase Waveforms]}
{Highlighting}
{Shaded}
```

Mnemonic

"THREE" - Three coils Have 120° $RotatingEMFEach$

Question 2(b OR) [4 marks]

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

Solution

Behavior of Pure Inductor with AC:

- Current lags voltage by 90° $inapureinductor$
- Inductive reactance (XL) = 2 fL
- As frequency increases, reactance increases
- Stores energy in magnetic field

Circuit and Waveform:

```
    +       +
    |       |
 AC |       | L
    |       |
    +       +

 Voltage
    |    /{}
    |   /  {}
    |  /    {}
    | /      {    Current}
    |/        {    /}
{-{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}/{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}}
    |{          /      /}
    | {         /|     /}
    |  {       / |}
    |   {     /  |}
    |    {   /   |}
    |     { /    |}
    |      V     |
```

Equation: V = L $\times dI/dt$

Mnemonic

"VLIC" - Voltage Leads current by 90° $IninductorCircuit$

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

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 = $\sqrt{3} \times Phasevoltage$
- Line current = Phase current

Calculations:

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

Delta (Δ) Connection:

- Line voltage = Phase voltage
- Line current = $\sqrt{3} \times Phasecurrent$

Calculations:

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

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph Star Connection
    A1((R)) {-{-}{-} B1((Y))}
    B1 {-{-}{-} C1((B))}
    C1 {-{-}{-} A1}
    D1((N)) {-{-}{-} A1}
    D1 {-{-}{-} B1}
    D1 {-{-}{-} C1}
    end

    subgraph Delta Connection
    A2((R)) {-{-}{-} B2((Y))}
    B2 {-{-}{-} C2((B))}
    C2 {-{-}{-} A2}
    end
{Highlighting}
{Shaded}
```

Mnemonic

"SLIP" - Star: Line voltage is $\sqrt{3} times Phasevoltage, In Delta : Phasevoltage equals Linevoltage$

Question 3(a) [3 marks]

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

Solution

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 $\times (d/dt) Where : e = induced EMF, N = number of turns, d/dt = rate of change of flux$

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Moving Magnet] {-{-}{-} B[Coil]}
    B {-{-}{-} C[Galvanometer]}
    D[Changing Magnetic Field] {-{-}{-} E[Induced EMF]}
{Highlighting}
{Shaded}
```

Mnemonic

"FIRE" - Flux change Induces Rapid EMF

Question 3(b) [4 marks]

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

Solution

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	Vrms = $V_m/\sqrt{2} = 0.707V_m$

Diagram:

```
    Amplitude
        \^{}
        |    /|{}
        |   / | {}
        |  /  |  {}
        | /   |   {}
        |/    |    {}
{-{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}}
        |{    |     /      |}
        | {   |    /       |}
        |  {  |   /        |}
        |   { |  /         |}
        |    {|/           |}
        |                { |}
        |                 {|}
        |
        |{{-}Time Period T {-}|}
```

Mnemonic

"AFTR" - Amplitude is peak, Frequency is cycles per second, Time period is 1/f, RMS is 0.707 times peak

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 Wb-turns (micro Wb-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

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.
Part (i):

```
Self inductance (L) = Flux linkage / Current
L = 5  Wb-turns / 2 A
L = 2.5  H
```

Part (ii):

```
L = ( _{o} \times   \times N^{2} \times A) / l
L = (4  \times 10^{-}^{7} \times 3 \times 10^{2} \times 2 \times 10^{-}^{4}) / (5 \times 10^{-}^{2})
L = (4  \times 3 \times 100 \times 2 \times 10^{-}^{7}) / (5 \times 10^{-}^{2})
L = (24  \times 10^{-}^{5}) / (5 \times 10^{-}^{2})
L = 24  \times 10^{-}^{3} / 5
L = 4.8  \times 10^{-}^{3}
L = 15.07  H
```

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph Self Inductance
    A[Current in Coil] {-{-}{} B[Magnetic Field]}
    B {-{-}{} C[EMF in Same Coil]}
    end

    subgraph Mutual Inductance
    D[Current in Coil 1] {-{-}{} E[Magnetic Field]}
    E {-{-}{} F[EMF in Coil 2]}
    end
{Highlighting}
{Shaded}
```

Mnemonic

"SLIM" - Self inductance 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

Dynamically Induced EMF: EMF induced in a conductor due to relative motion between the conductor and magnetic field.
Equation: e = Blv Where: e = induced EMF, B = magnetic flux density,
l = length of conductor,
v = velocity of conductor
Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Magnetic Field B] {-{-}{-} B[Moving Conductor]}
    B {-{-}{-} C[Induced EMF e]}
```

```
    D[Motion with velocity v] {-{-}{-} B}
{Highlighting}
{Shaded}
```

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

Term	Definition	Value for Sinusoidal Wave
Cycle	One complete oscillation of an alternating quantity	-
Form Factor	Ratio of RMS value to average value	1.11
Peak Factor	Ratio of maximum value to RMS value	1.414

Diagram:

```
    \^{}
    |    /|{}
    |   / | {     One Cycle}
    |  /  |  {    {-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}}
    | /   |   {}
    |/    |    {}
{-{-}{-}{-}+{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}}
    |{    |     /      |}
    | {   |    /       |}
    |  {  |   /        |}
    |   { |  /         |}
    |    {|/           |}
    |                { |}
    |                 {|}

    Form Factor = Vrms/Vavg = 1.11
    Peak Factor = Vm/Vrms = 1.414
```

Mnemonic

"CFP" - Cycle is one oscillation, Form factor is 1.11, Peak factor is 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 H, if 3 A of current is flowing through the inductor.

Solution

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 of conductor
- Index finger: Direction of magnetic field
- Middle finger: Direction of induced current

Energy Calculation:

```
Energy stored in inductor (W) = (1/2) \times L \times I^{2}
W = (1/2) \times 4 \times 10^{-}^{6} \times 3^{2}
W = (1/2) \times 4 \times 10^{-}^{6} \times 9
W = 18 \times 10^{-}^{6} / 2
W = 9 \times 10^{-}^{6} Joules
W = 9  J
```

Diagram:

```
Fleming{s Right Hand Rule:}

Thumb (Motion)
Index (Field) ↑
Middle (Current)

Lenz{s Law:}

N[==={]S    (Conductor)}
Induced current opposes motion
```

Mnemonic

"LOF" - Lenz's law Opposes Flux change, Fleming's rule - thumb Motion, index Field, middle Current

Question 4(a) [3 marks]

Define PV cell. Explain the function of PV cell.

Solution

PV Cell: Photovoltaic cell is a semiconductor device that converts light energy directly into electrical energy.

Function:

- **Absorbs photons from sunlight**
- **Creates electron-hole pairs in semiconductor**
- **Generates potential difference at p-n junction**
- **Converts solar energy to electrical energy**

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Sunlight] {-{-}{} B[PV Cell]}
    B {-{-}{} C[DC Electricity]}
    D[P{-type Silicon] {-}{-}{-} E[N{-}type Silicon]}
{Highlighting}
{Shaded}
```

Mnemonic

"PASE" - PV cell Absorbs Sunlight to generate Electricity

Question 4(b) [4 marks]

Explain the classification of green energy.

Solution

Green Energy Type	Source	Example Applications
Solar Energy	Sun	PV panels, solar thermal
Wind Energy	Air currents	Wind turbines
Hydro Energy	Flowing water	Dams, tidal, wave
Biomass Energy	Organic matter	Biofuels, biogas
Geothermal Energy	Earth's heat	Geothermal plants

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Green Energy] {-{-}{} B[Solar]}
    A {-{-}{} C[Wind]}
    A {-{-}{} D[Hydro]}
    A {-{-}{} E[Biomass]}
    A {-{-}{} F[Geothermal]}
{Highlighting}
{Shaded}
```

Mnemonic

"SWHBG" - Sun, Wind, Hydro, Biomass, Geothermal energy sources

Question 4(c) [7 marks]

Draw and explain the block diagram of solar power system.

Solution

Solar Power System Components:

Component	Function
Solar Panel	Converts sunlight to DC electricity
Charge Controller	Regulates battery charging and prevents overcharging
Battery Bank	Stores electricity for later use
Inverter	Converts DC to AC for household appliances
Distribution Panel	Distributes electricity to loads
Grid Connection	Optional connection to utility grid

Block Diagram:

```
flowchart LR
    A[Solar Panels] {-{-} B[Charge Controller]}
    B {-{-} C[Battery Bank]}
    C {-{-} D[Inverter]}
    D {-{-} E[Distribution Panel]}
    E {-{-} F[Home Appliances]}
    E {-.{-} G[Grid Connection]}
```

Mnemonic

"SCBIDG" - Solar panels, Charge controller, Batteries, Inverter, Distribution, Grid

Question 4(a OR) [3 marks]

Define green energy, conventional energy and renewable energy.

Solution

Term	Definition
Green Energy	Energy from naturally replenished sources with minimal environmental impact
Conventional Energy	Energy from traditional fossil fuel sources like coal, oil, and natural gas
Renewable Energy	Energy from sources that are naturally replenished on a human timescale

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Energy Sources] {-{-}{} B[Green/Renewable]}
    A {-{-}{} C[Conventional/Non{-}renewable]}

    B {-{-}{} D[Solar, Wind, Hydro, etc.]}
    C {-{-}{} E[Coal, Oil, Natural Gas]}
{Highlighting}
{Shaded}
```

Mnemonic

"GCR" - Green is Clean, Conventional is Carbon-emitting, Renewable is Replenished

Question 4(b OR) [4 marks]

Explain the need of green energy.

Solution

Need for Green Energy:

Need	Explanation
Environmental Protection	Reduces pollution and greenhouse gas emissions
Resource Conservation	Preserves limited fossil fuel resources
Energy Security	Reduces dependence on imported fuels
Economic Benefits	Creates jobs and reduces energy costs long-term
Sustainable Development	Meets present needs without compromising future generations

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Need for Green Energy] {-{-}{} B[Environmental Protection]}
    A {-{-}{} C[Resource Conservation]}
    A {-{-}{} D[Energy Security]}
    A {-{-}{} E[Economic Benefits]}
    A {-{-}{} F[Sustainable Development]}
{Highlighting}
{Shaded}
```

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

Wind Power System Components:

Component	Function
Wind Turbine	Converts wind energy to mechanical energy
Gearbox	Increases the rotational speed
Generator	Converts mechanical energy to electrical energy
Controller	Monitors and controls the system
Transformer	Steps up voltage for transmission
Grid Connection	Connects to the utility grid

Types of Wind Turbines:

1. **Horizontal Axis Wind Turbine (HAWT) - Blades rotate around horizontal axis**
2. **Vertical Axis Wind Turbine (VAWT) - Blades rotate around vertical axis**

Block Diagram:

```
flowchart LR
    A[Wind] {-{-} B[Wind Turbine]}
    B {-{-} C[Gearbox]}
    C {-{-} D[Generator]}
    D {-{-} E[Controller]}
    E {-{-} F[Transformer]}
    F {-{-} G[Grid]}

    subgraph "Types of Turbines"
    H[Horizontal Axis]
    I[Vertical Axis]
    end
```

Mnemonic

"WGGTC" - Wind turns turbine, Gearbox speeds up, Generator produces electricity, Transformer steps up, Controller manages

Question 5(a) [3 marks]

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

Solution

Factors Affecting Resistance:

Factor	Effect
Temperature	Resistance increases with temperature in metals
Length	Resistance is directly proportional to length
Cross-sectional Area	Resistance is inversely proportional to area
Material	Different materials have different resistivities

Equation: R = $\times(l/A)$
Where:

- R = Resistance
- = Resistivity
- l = Length
- A = Cross-sectional area

Mnemonic

"TLAM" - Temperature, Length, Area, Material affect resistance

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

Power Type	Definition	Formula	Unit
Active Power (P)	Actual power consumed	P = VI cos	Watt (W)
Reactive Power (Q)	Power oscillating between source and load	Q = VI sin	Volt-Ampere Reactive (VAR)
Apparent Power (S)	Product of voltage and current	S = VI	Volt-Ampere (VA)
Power Factor (PF)	Ratio of active power to apparent power	PF = P/S = cos	No unit (0 to 1)

Power Triangle:

```
            Q (VAR)
            |
            |
            |
            |       S (VA)
            |     /
            |   /
            | /
            +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-} P (W)}
           /|
      PF=cos
```

Mnemonic

"ARSP" - Active is Real power in Watts, Reactive is Stored power in VAR, S is total VA, PF is cos

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

Kirchhoff's Voltage Law (KVL): The algebraic sum of all voltages around any closed loop in a circuit is zero.
Kirchhoff's Current Law (KCL): The algebraic sum of all currents entering and leaving a node is zero.

Law	Equation	Application
KVL	$= 0$	Finding voltage in complex circuits
KCL	$= 0$	Finding current distribution

Circuit Diagrams:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph KVL
    A1(({+)) {-}{-}{-} B1[R1]}
    B1 {-{-}{-} C1[R2]}
    C1 {-{-}{-} D1[R3]}
    D1 {-{-}{-} A1}
    end

    subgraph KCL
    A2((Node)) {-{-}{-} B2[I1]}
    A2 {-{-}{-} C2[I2]}
    A2 {-{-}{-} D2[I3]}
    A2 {-{-}{-} E2[I4]}
    end
{Highlighting}
{Shaded}
```

KVL Example: $\mathbf{V}_1 + V_2 + V_3 = 0$
KCL Example: $\mathbf{I}_1 + I_2 = I_3 + I_4$

Mnemonic

"VCL" - Voltage around Closed Loop is zero, Currents at a point sum to zero

Question 5(a OR) [3 marks]

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

Solution

EMF vs. Potential Difference	Cell vs. Battery
EMF: Energy supplied by source per unit charge	Cell: Single unit that converts chemical energy to electrical energy
Potential Difference: Energy consumed in external circuit	Battery: Collection of two or more cells connected in series or parallel

EMF exists even in open circuit	**Cell has lower voltage (typically 1.5V or 2V)**
Potential difference exists only in closed circuit	**Battery has higher voltage output**

Diagram:

```
EMF Source          Cell vs Battery
  +{-{-}{-}+              +{-}{-}{-}+    +{-}{-}{-}+{-}{-}{-}+{-}{-}{-}+}
  |   |              |   |    |   |   |   |
  | E |              | 1 |    | 1 | 2 | 3 |
  |   |              |   |    |   |   |   |
  +{-{-}{-}+              +{-}{-}{-}+    +{-}{-}{-}+{-}{-}{-}+{-}{-}{-}+}
                      Cell     Battery (Series)
```

Mnemonic

"ESOP" - EMF is Source energy, Open circuit too; Potential difference is Operating energy

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

Component	Relation	Phase Difference	Power Factor
Pure Resistor	V = IR	In phase (0°)	1
Pure Capacitor	I = C(dV/dt)	Current leads voltage by 90°	0 (leading)
Pure Inductor	V = L(dI/dt)	Current lags voltage by 90°	0 (lagging)

Vector Diagrams:

```
   Resistor         Capacitor        Inductor
     V,I              I               V
      \^{              \^{}                \^{}}
      |                |               |
      |                |               |
      |                |               |
     +{-{-}{-}{-}{-}{-}       {-}+{-}           {-}{-}+{-}{-}}
                       V               I
```

Mnemonic

"RCI" - Resistor Current In phase, Capacitor current leads, Inductor current lags

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

Temperature Coefficient: The fractional change in resistance per degree change in temperature.
Unit: per degree Celsius ($^{-1})orperKelvin(K^{-1})$
Effect of Temperature on Resistance:
Equation: R$_2 = R_1[1 + (T_2 - T_1)]$

Where:

- $\mathbf{R}_1 = Resistance at temperature T_1$
- $\mathbf{R}_2 = Resistance at temperature T_2$
- = Temperature coefficient
- $\mathbf{T}_1, T_2 = Initial and final temperatures$

For Conductors (Metals):

- Resistance increases with temperature (positive)
- Resistance decreases when temperature decreases

For Semiconductors:

- Resistance decreases with temperature (negative)

Material	Temperature Coefficient ( ) per	Behavior
Copper	0.0043	Resistance increases with temperature
Aluminum	0.0039	Resistance increases with temperature
Nichrome	0.0004	Small change with temperature
Silicon	-0.07	Resistance decreases with temperature

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Temperature Increase] {-{-}{} B[Increased Atomic Vibrations]}
    B {-{-}{} C[More Electron Collisions]}
    C {-{-}{} D[Increased Resistance in Metals]}
{Highlighting}
{Shaded}
```

Mnemonic

"TRIP" - Temperature Raises resistance In Proportion to coefficient