Fundamentals of Electrical Engineering (DI01000101) - Winter 2024 Solution

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Question 1(a) [3 marks]

Explain ohm's law with its limitation and application.

> **Solution**
>
> **Answer:**
> **Ohm's Law Summary:**
>
> **Table 1.** Ohm's Law Summary
>
> | Aspect | Description |
> |---|---|
> | **Statement** | Current through conductor is directly proportional to voltage |
> | **Formula** | $V = I \times R$ |
> | **Units** | V (Volts), I (Amperes), R (Ohms) |
>
> **Limitations:**
> - **Temperature dependency**: Resistance changes with temperature
> - **Non-linear materials**: Does not apply to semiconductors, diodes
> - **AC circuits**: Modified form needed for reactive components
>
> **Applications:**
> - **Circuit analysis**: Calculate unknown voltage, current, or resistance
> - **Power calculations**: $P = V^2/R$, $P = I^2R$

> **Mnemonic**
>
> ""Voltage Is Really Important" (V = I × R)"

Question 1(b) [4 marks]

Explain faraday's law of electromagnetic induction with necessary figure.

> **Solution**
>
> **Answer:**
> **Faraday's Laws:**
> - **First Law**: EMF is induced when magnetic flux changes through conductor
> - **Second Law**: Magnitude of EMF equals rate of flux change
>
> **Mathematical Expression:**
>
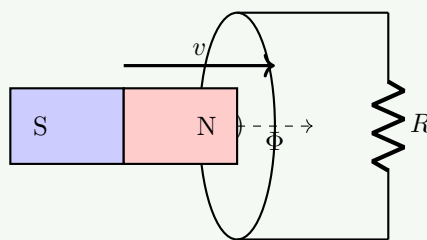> $$e = -N \times \frac{d\Phi}{dt}$$
>
> **Diagram:**

Figure 1. Faraday's Law Illustration

Applications:
- **Transformers**: Mutual induction principle
- **Generators**: Mechanical to electrical energy conversion
- **Inductors**: Self-induced EMF opposes current changes
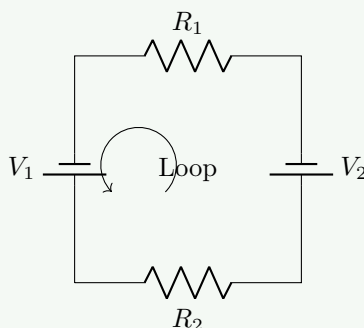
Mnemonic

""Flux Change Generates EMF" (dΦ/dt = EMF)"

Question 1(c) [7 marks]

Explain kirchhoff's voltage law and kirchhoff's current law with necessary diagram.

Solution

Answer:
Kirchhoff's Laws Comparison:

Table 2. Kirchhoff's Laws Comparison

Law	Statement	Mathematical Form	Application
KVL	Sum of voltages in closed loop = 0	$\Sigma V = 0$	Series circuits
KCL	Sum of currents at node = 0	$\Sigma I = 0$	Parallel circuits

KVL Diagram:

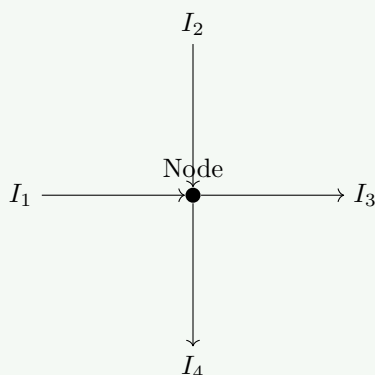**Figure 2.** KVL Closed Loop

KCL Diagram:

Figure 3. KCL Node

Key Points:
- **KVL**: Algebraic sum considers voltage polarities
- **KCL**: Considers current directions (incoming vs outgoing)
- **Applications**: Circuit analysis, finding unknown values

Mnemonic

""Voltage Loops, Current Nodes" (KVL for loops, KCL for nodes)"

Question 1(c OR) [7 marks]

Differentiate statically induced emf and dynamically induced emf

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Solution

Answer:
Static vs Dynamic EMF:

Table 3. Static vs Dynamic EMF

Parameter	Statically Induced EMF	Dynamically Induced EMF
Cause	Changing magnetic field	Relative motion between conductor and field
Field	Time-varying, conductor stationary	Steady field, conductor moving
Examples	Transformer, inductor	Generator, motor
Formula	$e = -N(d\Phi/dt)$	$e = BLv$
Applications	AC circuits, power supplies	Power generation, motors

Static EMF Types:
- **Self-induced**: Same coil creates and experiences flux change
- **Mutually induced**: One coil affects another coil

Dynamic EMF Factors:
- **Magnetic field strength (B)**: Tesla
- **Conductor length (L)**: Meters
- **Velocity (v)**: m/s

Mnemonic

""Static Stays, Dynamic Dances" (Static = stationary, Dynamic = motion)"

Question 2(a) [3 marks]

Explain various types of losses in transformer.

> **Solution**
>
> **Answer:**
> **Transformer Losses:**
>
> **Table 4.** Transformer Losses
>
> | Loss Type | Cause | Location | Characteristics |
> |---|---|---|---|
> | **Iron Loss** | Hysteresis + Eddy currents | Core | Constant, frequency dependent |
> | **Copper Loss** | I^2R heating | Windings | Variable with load |
> | **Stray Loss** | Leakage flux | Overall | Minimal |
>
> **Iron Losses:**
> - **Hysteresis loss**: Magnetic domain reversal energy
> - **Eddy current loss**: Circulating currents in core
>
> **Copper Losses:**
> - **Primary winding**: $I_1^2 R_1$
> - **Secondary winding**: $I_2^2 R_2$

> **Mnemonic**
>
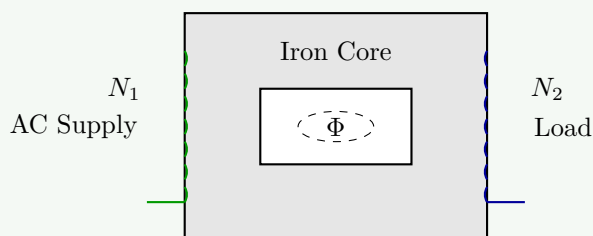> ""Iron Core, Copper Coil" (Location of main losses)"

Question 2(b) [4 marks]

Explain working principle of transformer.

> **Solution**
>
> **Answer:**
> **Working Principle: Mutual electromagnetic induction** between primary and secondary windings through common magnetic core.
> **Diagram:**
>
>
>
> **Figure 4.** Transformer Principle
>
> **Operation Steps:**
> - **Step 1**: AC current in primary creates alternating flux
> - **Step 2**: Flux links secondary through core
> - **Step 3**: Changing flux induces EMF in secondary
> - **Step 4**: Secondary EMF drives current through load
>
> **Key Relations:**
> - **Voltage ratio**: $V_2/V_1 = N_2/N_1$
> - **Current ratio**: $I_1/I_2 = N_2/N_1$

> **Mnemonic**
>
> ""Primary Produces, Secondary Supplies" (Energy transfer direction)"

Question 2(c) [7 marks]

Derive emf equation of transformer.

> **Solution**
>
> **Answer:**
> **Given Parameters:**
> - N_1: Primary turns, N_2: Secondary turns
> - Φ_m: Maximum flux, f: Frequency
>
> **EMF Derivation:**
> **Step 1: Flux Variation**
> $$\Phi = \Phi_m \sin(2\pi ft)$$
>
> **Step 2: Rate of Flux Change**
> $$\frac{d\Phi}{dt} = 2\pi f \Phi_m \cos(2\pi ft)$$
>
> **Step 3: Maximum Rate**
> $$\left(\frac{d\Phi}{dt}\right)_{max} = 2\pi f \Phi_m$$
>
> **Step 4: RMS EMF Formula**
> $$E_1 = 4.44 \times f \times N_1 \times \Phi_m$$
> $$E_2 = 4.44 \times f \times N_2 \times \Phi_m$$
>
> **EMF Equation Components:**
>
> **Table 5.** EMF Equation Components
>
> | Symbol | Parameter | Units |
> |--------|-----------|-------|
> | E | RMS EMF | Volts |
> | f | Frequency | Hz |
> | N | Number of turns | - |
> | Φ_m | Maximum flux | Weber |
> | 4.44 | Form factor constant | - |
>
> **Transformation Ratio:**
> $$K = \frac{E_2}{E_1} = \frac{N_2}{N_1}$$

> **Mnemonic**
>
> ""Four-Forty-Four Flux Formula" (4.44 factor)"

Question 2(a OR) [3 marks]

Write application of transformer.

> **Solution**
>
> **Answer:**
> **Transformer Applications:**
>
> **Table 6.** Transformer Applications
>
> | Application | Purpose | Voltage Level |
> |---|---|---|
> | **Power transmission** | Reduce transmission losses | Step-up (400kV) |
> | **Distribution** | Safe voltage for consumers | Step-down (230V) |
> | **Isolation** | Electrical isolation | 1:1 ratio |
> | **Electronic circuits** | DC power supplies | Step-down |
>
> **Industrial Applications:**
> - **Welding transformers**: High current, low voltage
> - **Instrument transformers**: Measurement and protection
> - **Audio transformers**: Impedance matching

> **Mnemonic**
>
> ""Power Distribution Isolation Electronics" (Main application areas)"

Question 2(b OR) [4 marks]

Write equation for back emf and torque of D.C motor.

> **Solution**
>
> **Answer:**
> **Back EMF Equation:**
> $$E_b = \frac{\phi Z N P}{60 A}$$
>
> **Simplified Form:**
> $$E_b = K \phi N$$
>
> **Torque Equation:**
> $$T = \frac{\phi Z I_a P}{2 \pi A}$$
>
> **Simplified Form:**
> $$T = K \phi I_a$$
>
> **Symbol Definitions:**
>
> **Table 7.** Symbol Definitions
>
> | Symbol | Parameter | Units |
> |---|---|---|
> | E_b | Back EMF | Volts |
> | T | Torque | N-m |
> | ϕ | Flux per pole | Weber |
> | N | Speed | RPM |
> | I_a | Armature current | Amperes |
> | K | Motor constant | - |

> **Mnemonic**
>
> ""Back EMF opposes, Torque proposes" (EMF opposes supply, torque drives rotation)"

Question 2(c OR) [7 marks]

Explain construction and working of D.C. motor with necessary figure
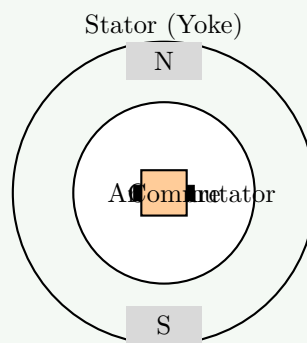
> **Solution**
>
> **Answer:**
> **Construction Components:**
>
> **Table 8.** DC Motor Parts
>
> | Component | Function | Material |
> |---|---|---|
> | **Stator** | Provides magnetic field | Cast iron/steel |
> | **Rotor/Armature** | Rotating part | Silicon steel laminations |
> | **Commutator** | Current direction reversal | Copper segments |
> | **Brushes** | Current collection | Carbon |
> | **Field windings** | Electromagnets | Copper wire |
>
> **Construction Diagram:**
>
>
>
> **Figure 5.** DC Motor Construction
>
> **Working Principle:**
> - **Step 1**: Current flows through armature conductors
> - **Step 2**: Magnetic field interacts with current
> - **Step 3**: Force generated by Fleming's left-hand rule
> - **Step 4**: Commutator reverses current direction
> - **Step 5**: Continuous rotation maintained
>
> **Force Equation:**
> $$F = B \times I \times L$$

> **Mnemonic**
>
> ""Current Creates Circular motion" (Current interaction produces rotation)"

Question 3(a) [3 marks]

Explain construction of transformer.

> **Solution**
>
> **Answer:**
> **Transformer Construction:**
>
> **Table 9.** Transformer Construction
>
> | Component | Material | Function |
> |---|---|---|
> | **Core** | Silicon steel laminations | Magnetic flux path |
> | **Primary winding** | Copper/Aluminum | Input energy |
> | **Secondary winding** | Copper/Aluminum | Output energy |
> | **Insulation** | Varnish/Paper | Electrical isolation |
> | **Tank** | Steel | Oil containment & cooling |
>
> **Core Types:**
> - **Shell type**: Windings surrounded by core
> - **Core type**: Core surrounded by windings
>
> **Cooling Methods:**
> - **Air cooling**: Small transformers
> - **Oil cooling**: Large transformers with radiators

> **Mnemonic**
>
> ""Core Carries Current Carefully" (Core design importance)"

Question 3(b) [4 marks]

Explain application of DC motor

> **Solution**
>
> **Answer:**
> **DC Motor Applications:**
>
> **Table 10.** DC Motor Applications
>
> | Motor Type | Speed Characteristic | Applications |
> |---|---|---|
> | **Shunt** | Constant speed | Fans, pumps, lathes |
> | **Series** | Variable speed | Traction, cranes |
> | **Compound** | Moderate variation | Elevators, compressors |
>
> **Industrial Applications:**
> - **Shunt motors**: Machine tools requiring constant speed
> - **Series motors**: Electric vehicles, starting heavy loads
> - **Compound motors**: Rolling mills, punch presses
>
> **Advantages:**
> - **Easy speed control**: Voltage/field control
> - **High starting torque**: Series motors
> - **Reversible operation**: Change field/armature polarity

> **Mnemonic**
>
> ""Shunt Stays, Series Speeds" (Speed characteristics)"

# Question 3(c) [7 marks]

Explain different types of DC motor.

Solution

Answer:
DC Motor Classification:

Table 11. DC Motor Classification

Type	Field Connection	Speed-Torque	Applications
Shunt	Parallel to armature	Constant speed, low starting torque	Fans, pumps
Series	Series with armature	Variable speed, high starting torque	Traction
Compound	Both series & shunt	Moderate characteristics	General purpose

Shunt Motor Diagram:
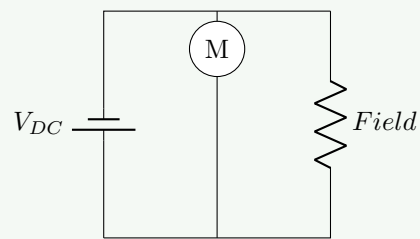
Figure 6. DC Shunt Motor

Characteristics:
- **Shunt**: Speed $\propto (V - I_a R_a)/\phi$
- **Series**: High starting torque, speed varies with load
- **Compound**: Combines advantages of both types

Speed Control Methods:
- **Armature control**: Vary armature voltage
- **Field control**: Vary field current
- **Resistance control**: Add external resistance

Mnemonic

""Shunt Steady, Series Strong, Compound Combined" (Key characteristics)"

Question 3(a OR) [3 marks]

Explain transformation ratio of transformer.

Solution

Answer:
Definition: Transformation ratio (K) is the ratio of secondary to primary voltage or turns.
Mathematical Expression:

$$K = \frac{N_2}{N_1} = \frac{E_2}{E_1} = \frac{V_2}{V_1}$$

Transformation Ratio Types:

Table 12. Transformation Ratio Types

Ratio	Type	Voltage Change	Applications
$K > 1$	Step-up	Increases	Power transmission
$K < 1$	Step-down	Decreases	Distribution
$K = 1$	Isolation	Same	Safety isolation

Current Relationship:

$$\frac{I_1}{I_2} = \frac{N_2}{N_1} = K$$

Power Relationship:

$$P_1 = P_2 \text{ (Ideal transformer)}$$

Mnemonic

""Turns Tell Transformation" (Turns ratio determines voltage ratio)"

Question 3(b OR) [4 marks]

Write application of autotransformer.

Solution

Answer:
Autotransformer Applications:

Table 13. Autotransformer Applications

Application	Advantage	Voltage Range
Motor starting	Reduced starting current	50-80% of rated
Voltage regulation	Fine voltage adjustment	$\pm 10\%$ variation
Laboratory	Variable voltage source	0-110% of input
Power systems	Economic transmission	Close voltage ratios

Advantages:
- **Economy**: Less copper and iron required
- **Efficiency**: Higher than two-winding transformer
- **Size**: Compact design
- **Regulation**: Better voltage regulation

Limitations:
- **No isolation**: Common electrical connection
- **Safety**: Higher fault current

Mnemonic

""Auto Adjusts Advantageously" (Automatic voltage adjustment benefit)"

Question 3(c OR) [7 marks]

Explain speed control of DC shunt motor

Solution

Answer:
Speed Control Methods:

Table 14. Speed Control Methods

Method	Range	Efficiency	Applications
Armature control	Below rated speed	High	Precise speed control
Field control	Above rated speed	High	Constant power drives
Resistance control	Below rated speed	Low	Simple applications

Armature Control Diagram:
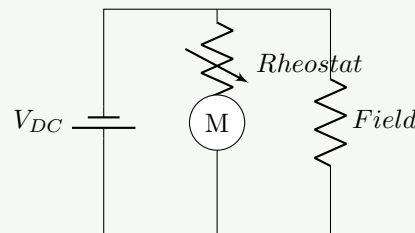
Figure 7. Armature Control Method

Speed Equations:
- **Armature control**: $N \propto (V - I_a R_a)/\phi$
- **Field control**: $N \propto V/\phi$
- **Resistance control**: $N \propto (V - I_a(R_a + R_{ext}))/\phi$

Modern Methods:
- **Chopper control**: PWM voltage control
- **Ward-Leonard system**: Motor-generator set
- **Electronic control**: Thyristor/IGBT drives

Characteristics:
- **Smooth control**: Stepless speed variation
- **Efficiency**: Armature control most efficient
- **Cost**: Field control economical

Mnemonic

""Armature Accurate, Field Fast, Resistance Rough" (Control characteristics)"

Question 4(a) [3 marks]

Explain vector representation of alternating EMF.

Solution

Answer:
Vector Representation: Alternating EMF can be represented as a rotating vector (phasor) with constant magnitude and angular velocity.
Mathematical Form:
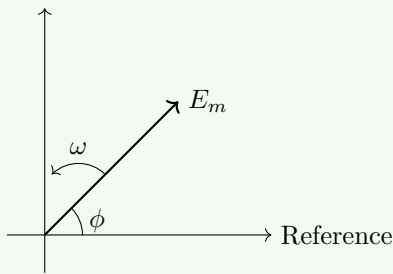
$$e = E_m \sin(\omega t + \phi)$$

Diagram:

Figure 8. EMF Phasor Diagram

Vector Parameters:

Table 15. Vector Parameters

Parameter	Symbol	Units	Description
Magnitude	E_m	Volts	Maximum EMF
Angular velocity	ω	rad/s	Rotation speed
Phase angle	ϕ	Degrees	Initial phase
Frequency	$f = \omega/2\pi$	Hz	Cycles per second

Advantages:
- **Visual representation**: Easy to understand phase relationships
- **Mathematical simplification**: Complex calculations made easier

Mnemonic

""Vectors Visualize Voltage Variation" (Phasor representation benefits)"

Question 4(b) [4 marks]

Define following terms w.r.t Alternating current: RMS value, Average value, Frequency, Time period

Solution

Answer:
AC Parameters Definition:

Table 16. AC Parameters Definition

Term	Definition	Formula	Units
RMS Value	Effective value producing same heating	$I_m/\sqrt{2}$	Amperes
Average Value	Mean value over half cycle	$2I_m/\pi$	Amperes
Frequency	Number of cycles per second	$f = 1/T$	Hz
Time Period	Time for one complete cycle	$T = 1/f$	Seconds

Mathematical Relations:
- **Form Factor**: RMS/Average $= \pi/2\sqrt{2} = 1.11$
- **Peak Factor**: Peak/RMS $= \sqrt{2} = 1.414$
- **Angular frequency**: $\omega = 2\pi f$

Mnemonic

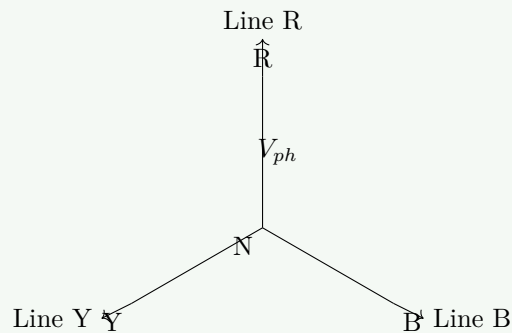""Really Mean Square, Average Frequency Time" (Key AC parameters)"

Question 4(c) [7 marks]

Derive equation for relation between line and phase voltage and current in star connection

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Solution

Answer:
Star Connection Diagram:

Figure 9. Star Connection

Voltage Relations:
- **Phase Voltages**: V_R, V_Y, V_B (with respect to neutral)
- **Line Voltages**: V_{RY}, V_{YB}, V_{BR} (between lines)

Phasor Analysis:

$$V_{RY} = V_R - V_Y$$

For balanced system:
- Phase voltages are equal in magnitude: $V_R = V_Y = V_B = V_{ph}$
- Phase difference $= 120°$

Vector Addition: Using phasor diagram and cosine rule:

$$V_L = \sqrt{V_{ph}^2 + V_{ph}^2 - 2V_{ph}V_{ph}\cos(120°)}$$

$$V_L = \sqrt{2V_{ph}^2 + V_{ph}^2} = \sqrt{3} \times V_{ph}$$

Final Relations:
Star Connection Relations:

Table 17. Star Connection Relations

| Parameter	Relationship
Line Voltage	$V_L = \sqrt{3} \times V_{ph}$
Line Current	$I_L = I_{ph}$
Power	$P = \sqrt{3}V_L I_L \cos\phi$

Mnemonic

""Star Scales Voltage, Same current" ($\sqrt{3}$ factor for voltage, current unchanged)"

Question 4(a OR) [3 marks]

Explain vector representation of alternating current.

Solution

Answer:
Vector Representation: AC current represented as rotating phasor with magnitude and phase angle.
Mathematical Expression:

$$i = I_m \sin(\omega t + \phi)$$

Phasor Diagram:
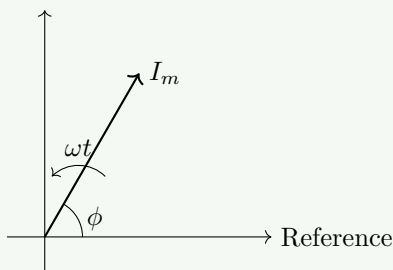
Figure 10. Current Phasor Diagram

Current Vector Elements:

Table 18. Current Vector Elements

Element	Symbol	Description
Magnitude	I_m	Peak current value
Phase	ϕ	Leading/lagging angle
Angular velocity	ω	Rotation speed
RMS value	$I = I_m/\sqrt{2}$	Effective current

Mnemonic

""Current Circles Continuously" (Rotating phasor concept)"

Question 4(b OR) [4 marks]

Define following terms w.r.t Alternating current: Form factor, Peak factor, Angular velocity, Amplitude

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Solution

Answer:
AC Current Parameters:

Table 19. AC Current Parameters

Term	Definition	Formula	Typical Value
Form Factor	RMS/Average value ratio	I_{rms}/I_{avg}	1.11 (sine wave)
Peak Factor	Peak/RMS value ratio	I_m/I_{rms}	1.414 (sine wave)
Angular Velocity	Rate of phase change	$\omega = 2\pi f$	314 rad/s (50Hz)
Amplitude	Maximum instantaneous value	I_m	Peak current

Practical Significance:
- **Design considerations**: Peak factors for insulation
- **Waveform analysis**: Form factors for distortion
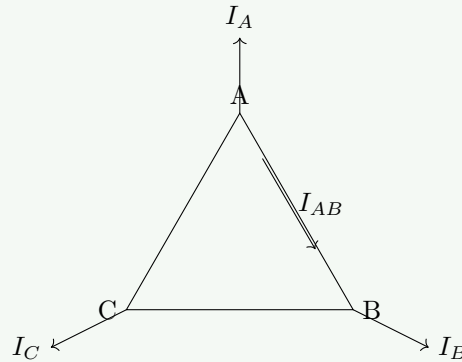- **Synchronization**: Angular velocity for timing

---

Question 4(c OR) [7 marks]

Derive equation for relation between line and phase voltage and current in delta connection

Solution

Answer:
Delta Connection Diagram:

Figure 11. Delta Connection

Voltage Relations: In delta connection, line voltage equals phase voltage:

$$V_L = V_{ph}$$

Current Analysis: Each line current is vector sum of two phase currents.
For Line Current I_A:

$$I_A = I_{AB} - I_{CA}$$

Phasor Analysis: For balanced system with phase currents equal in magnitude:

- $I_{AB} = I_{CA} = I_{CB} = I_{ph}$
- Phase difference between currents $= 120°$

Vector Subtraction:

$$I_A = I_{AB} - I_{CA} = I_{AB} - (-I_{CA})$$

Using phasor diagram:

$$I_L = \sqrt{I_{ph}^2 + I_{ph}^2 - 2I_{ph}I_{ph}\cos(60°)}$$

$$I_L = \sqrt{2I_{ph}^2 - I_{ph}^2} = \sqrt{3} \times I_{ph}$$

Delta Connection Relations:

Table 20. Delta Connection Relations

Parameter	Relationship
Line Voltage	$V_L = V_{ph}$
Line Current	$I_L = \sqrt{3} \times I_{ph}$
Power	$P = \sqrt{3}V_L I_L \cos\phi$

> **Mnemonic**
>
> ""Delta Doubles current, Same voltage" ($\sqrt{3}$ factor for current, voltage unchanged)"
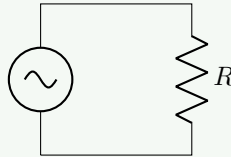
Question 5(a) [3 marks]

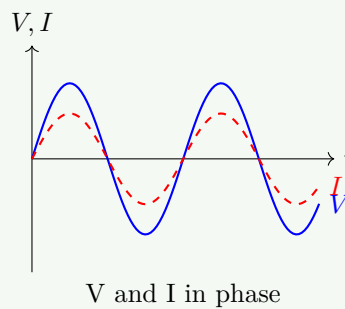**Explain AC through pure resistor with necessary circuit and waveform.**

> **Solution**
>
> **Answer:**
> **Circuit Diagram:**
>
>
>
> **Figure 12.** AC through Resistor
>
> **Waveform:**
>
>
>
> V and I in phase
>
> **Figure 13.** Resistive Waveforms
>
> **AC through Resistor:**
>
> **Table 21.** AC through Resistor
>
> | Parameter | Relationship | Phase |
> |-----------|--------------|-------|
> | **Ohm's Law** | $V = IR$ | Same phase |
> | **Power** | $P = VI = I^2R$ | Always positive |
> | **Impedance** | $Z = R$ | Purely resistive |

> **Mnemonic**
>
> ""Resistor Refuses phase Shift" (No phase difference)"

Question 5(b) [4 marks]

Define following terms w.r.t Alternating current: Impedance, Phase angle, Power factor, Reactive power

---

Solution

Answer:
AC Circuit Parameters:

Table 22. AC Circuit Parameters

Term	Definition	Formula	Units
Impedance	Total opposition to AC current	$Z = \sqrt{R^2 + X^2}$	Ohms
Phase Angle	Angle between V and I	$\phi = \tan^{-1}(X/R)$	Degrees
Power Factor	Cosine of phase angle	$PF = \cos\phi = R/Z$	-
Reactive Power	Power in reactive components	$Q = VI\sin\phi$	VAR

**Power Triangle:**

$$S^2 = P^2 + Q^2$$

Mnemonic

""Impedance Phase Power Quadrature" (Four key AC parameters)"

Question 5(c) [7 marks]

Enlist different protective device and explain construction and working of any one protective device.

Solution

Answer:
Protective Devices:

Table 23. Protective Devices

Device	Protection Against	Application
Fuse	Overcurrent	Low/Medium voltage
MCB	Overload, Short circuit	Domestic/Commercial
ELCB	Earth leakage	Safety protection
Relay	Various faults	Industrial systems
Surge arrester	Overvoltage	Transmission lines

MCB (Miniature Circuit Breaker) - Detailed Explanation:
Construction:
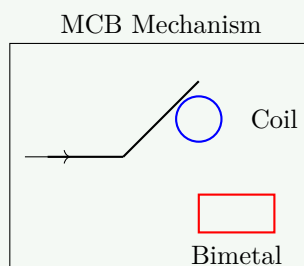
Figure 14. MCB Simplified Internal Structure

Components:
- **Fixed and moving contacts**: Current carrying parts
- **Bimetallic strip**: Thermal protection
- **Electromagnetic coil**: Magnetic protection

- **Arc quenching chamber**: Arc extinction
- **Operating mechanism**: Manual/automatic operation

Working Principle:
- **Overload Protection**: Current heats bimetallic strip → Strip bends → Trips mechanism.
- **Short Circuit Protection**: High current → Strong magnetic field in coil → Instantaneous trip.

Advantages:
- **Reusable**: Reset after fault clearance
- **Reliable operation**: Dual protection mechanism
- **Easy maintenance**: Accessible contacts

Mnemonic

""MCB Magnetically Controls Both" (Thermal and magnetic protection)"

Question 5(a OR) [3 marks]

Derive equation of AC current passing through pure inductor

Solution

Answer:
Given: Pure inductor with inductance L, applied voltage $v = V_m \sin(\omega t)$
Voltage-Current Relationship:

$$v = L \times \frac{di}{dt}$$

Substituting applied voltage:

$$V_m \sin(\omega t) = L \times \frac{di}{dt}$$

Integration:

$$di = \frac{V_m}{L} \sin(\omega t) dt$$

$$i = -\frac{V_m}{\omega L} \cos(\omega t) + C$$

At steady state, $C = 0$:

$$i = -\frac{V_m}{\omega L} \cos(\omega t)$$

$$i = \frac{V_m}{\omega L} \sin(\omega t - 90°)$$

Pure Inductor Characteristics:
- **Current amplitude**: $I_m = V_m/\omega L$
- **Phase**: Current lags voltage by 90°
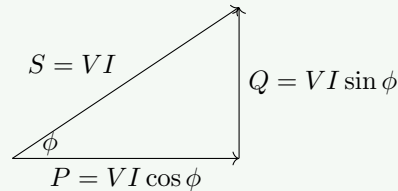- **Power**: $P = 0$ (average)

Mnemonic

""Inductor Impedes, Current lags" (XL opposes current, 90 degree lag)"

Question 5(b OR) [4 marks]

Explain concept of power and power triangle in AC circuit.

Solution

Answer:
AC Power Components:

Table 24. AC Power Components

Power Type	Symbol	Formula	Units
Active Power	P	$VI\cos\phi$	Watts
Reactive Power	Q	$VI\sin\phi$	VAR
Apparent Power	S	VI	VA

Power Triangle:

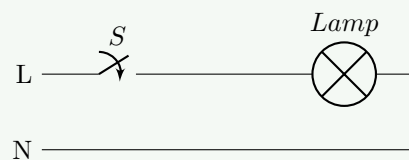**Figure 15.** Power Triangle

Significance:
- **Active power**: Does useful work
- **Reactive power**: Maintains fields
- **Power factor**: Efficiency indicator (P/S)

Mnemonic

""Power Triangle: Please Qualify Students" (P, Q, S components)"

Question 5(c OR) [7 marks]

Explain wiring of lamp control from one place and staircase type.

Solution

Answer:
1. Lamp Control from One Place:
Circuit Diagram:

Figure 16. One-way Control

Components:
- **SPST Switch**: Single pole, single throw
- **Live wire control**: Switch in live wire for safety
2. Staircase Wiring (Two-Way Control):
Circuit Diagram:

Figure 17. Two-way Staircase Wiring

Switch Positions:

Table 25. Staircase Logic

S1 Position	S2 Position	Lamp Status
Up	Up	ON
Up	Down	OFF
Down	Up	OFF
Down	Down	ON

Applications:
- **Staircase lighting**: Control from top and bottom
- **Long corridors**: Control from both ends
- **Bedroom lighting**: Control from bed and door

Mnemonic

""Two-way Toggles, Two places" (Two switches, two locations)"