Question 1(a) [3 marks]

Explain ohm's law with its limitation and application.

Answer:

Table: Ohm's Law Summary

Aspect	Description
Statement	Current through conductor is directly proportional to voltage
Formula	V = I × 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.

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 × (dΦ/dt)
```

Diagram:

```
   +-------+
   |   N   |  Coil with N turns
   |       |
   +---+---+
       |
       |  Moving magnet
   +---v---+
   | S | N |
   +-------+
      ↕
  Motion direction
```

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]

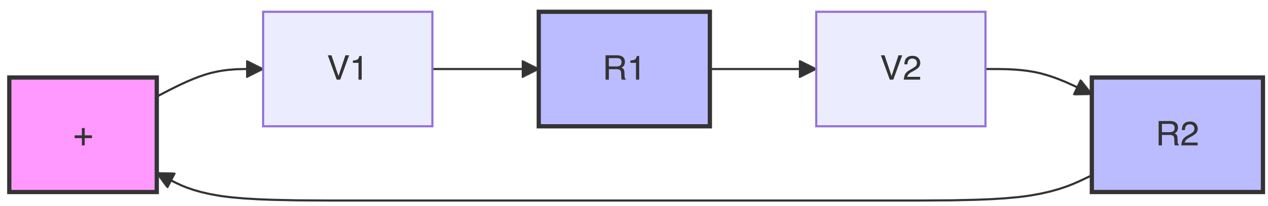
Explain kirchhoff's voltage law and kirchhoff's current law with necessary diagram.

Answer:

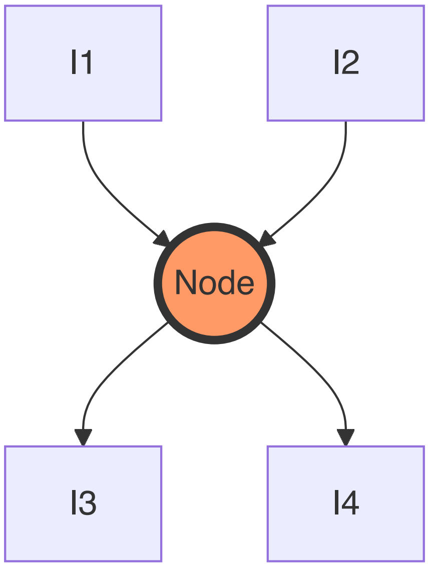
Table: Kirchhoff's Laws Comparison

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:



KCL Diagram:



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

Answer:

Table: 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.

Answer:

Table: 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**: $I_1^2R_1$
- **Secondary winding**: $I_2^2R_2$

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

Question 2(b) [4 marks]

Explain working principle of transformer.

Answer:

Working Principle:
Mutual electromagnetic induction between primary and secondary windings through common magnetic core.

Diagram:

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.

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

$$d\Phi/dt = 2\pi f\Phi_m \cos(2\pi ft)$$

Step 3: Maximum Rate

$$(d\Phi/dt)_{max} = 2\pi f\Phi_m$$

Step 4: RMS EMF Formula

$$E_1 = 4.44 \times f \times N_1 \times \Phi_m$$
$$E_2 = 4.44 \times f \times N_2 \times \Phi_m$$

Table: 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 = E₂/E₁ = N₂/N₁
```

Mnemonic: "Four-Forty-Four Flux Formula" (4.44 factor)

Question 2(a OR) [3 marks]

Write application of transformer.

Answer:

Table: 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.

Answer:

Back EMF Equation:

```
Eb = (φ × Z × N × P) / (60 × A)
```

Simplified Form:

```
Eb = K × φ × N
```

Torque Equation:

```
T = (φ × Z × Ia × P) / (2π × A)
```

Simplified Form:

```
T = K × φ × Ia
```

Table: Symbol Definitions

Symbol	Parameter	Units
Eb	Back EMF	Volts
T	Torque	N-m
φ	Flux per pole	Weber
N	Speed	RPM
Ia	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

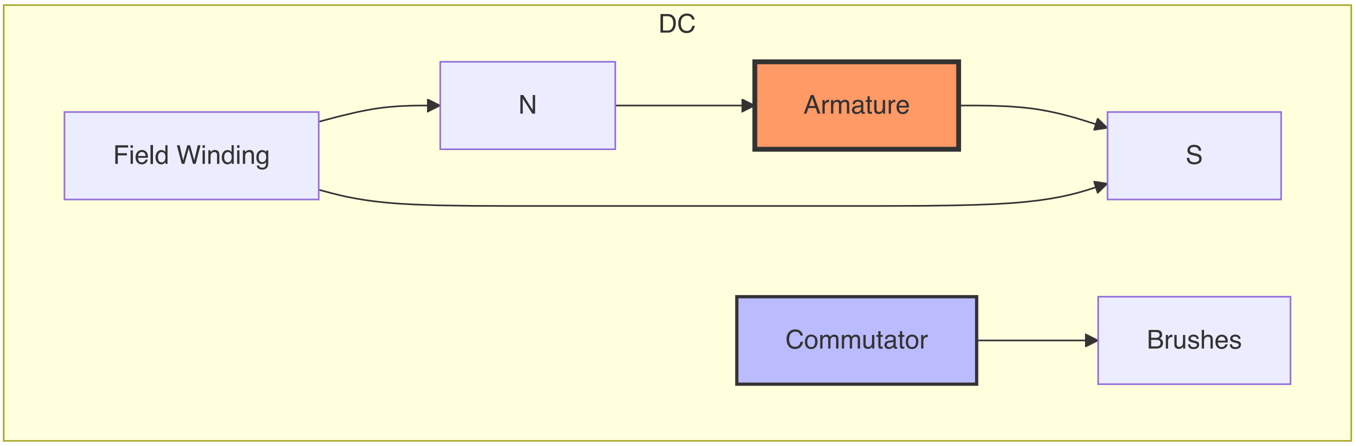
Answer:

Construction Components:

Table: 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:



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 × I × L
```

Mnemonic: "Current Creates Circular motion" (Current interaction produces rotation)

Question 3(a) [3 marks]

Explain construction of transformer.

Answer:

Table: 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

Answer:

Table: 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]

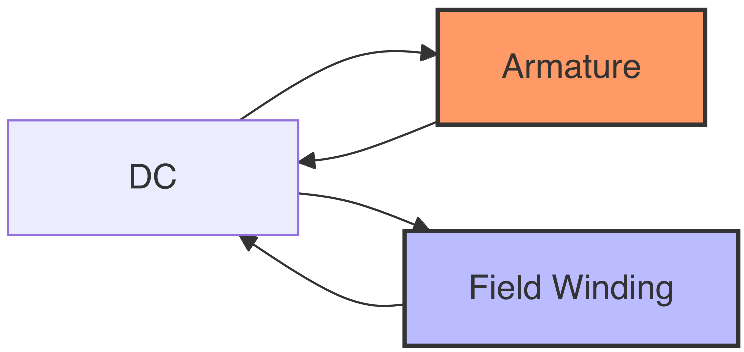
Explain different types of DC motor.

Answer:

Table: 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:



Characteristics:

- **Shunt**: Speed ∝ (V - IaRa)/φ
- **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.

Answer:

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

Mathematical Expression:

```
K = N₂/N₁ = E₂/E₁ = V₂/V₁
```

Table: 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:

```
I₁/I₂ = N₂/N₁ = K
```

Power Relationship:

```
P₁ = P₂ (Ideal transformer)
```

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

Question 3(b OR) [4 marks]

Write application of autotransformer.

Answer:

Table: Autotransformer Applications

Application	Advantage	Voltage Range
Motor starting	Reduced starting current	50-80% of rated
Voltage regulation	Fine voltage adjustment	±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]

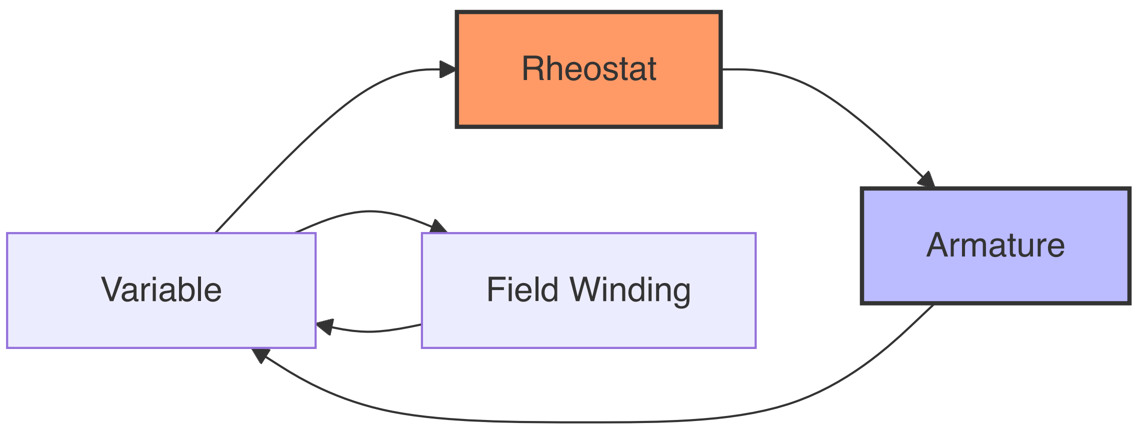
Explain speed control of DC shunt motor

Answer:

Table: 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:



Speed Equations:

- **Armature control**: $N \propto (V - I_aR_a)/\phi$
- **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.

Answer:

Vector Representation:
Alternating EMF can be represented as a rotating vector (phasor) with constant magnitude and angular velocity.

Mathematical Form:

```
e = Em sin(ωt + φ)
```

Diagram:

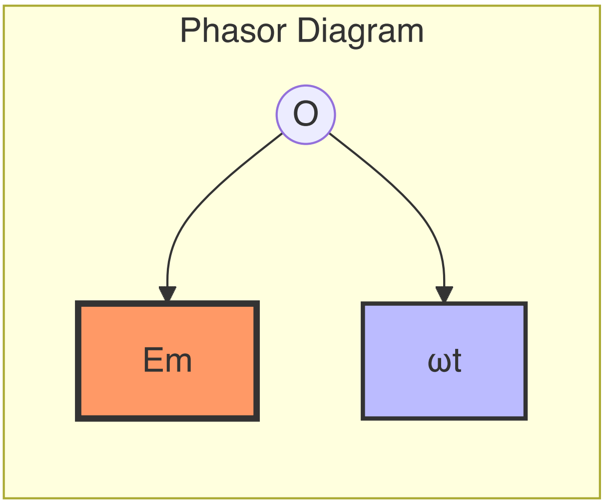


Table: Vector Parameters

Parameter	Symbol	Units	Description
Magnitude	Em	Volts	Maximum EMF
Angular velocity	ω	rad/s	Rotation speed
Phase angle	φ	Degrees	Initial phase
Frequency	f = ω/2π	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

Answer:

Table: AC Parameters Definition

Term	Definition	Formula	Units
RMS Value	Effective value producing same heating	Im/√2	Amperes
Average Value	Mean value over half cycle	2Im/π	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 = π/2√2 = 1.11
- **Peak Factor**: Peak/RMS = √2 = 1.414
- **Angular frequency**: ω = 2πf

Practical Values:

- **RMS current**: Used for power calculations
- **Average current**: Used for DC equivalent
- **Frequency**: 50 Hz (India), 60 Hz (USA)

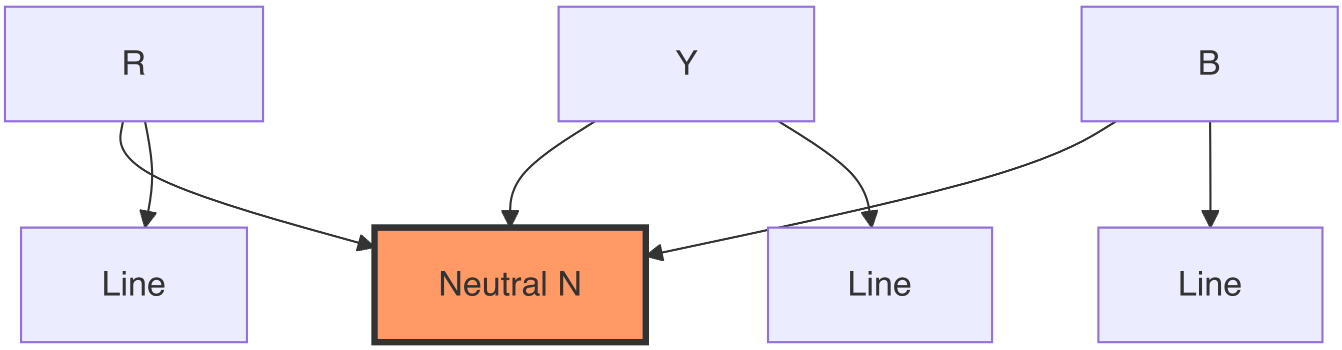
Mnemonic: "Really Mean Square, Average Frequency Time" (Key AC parameters)

Question 4(c) [7 marks]

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

Answer:

Star Connection Diagram:



Voltage Relations:

Phase Voltages: VR, VY, VB (with respect to neutral)
Line Voltages: VRY, VYB, VBR (between lines)

Phasor Analysis:

```
VRY = VR - VY
```

For balanced system:

- Phase voltages are equal in magnitude: VR = VY = VB = Vph
- Phase difference = 120°

Vector Addition:
Using phasor diagram and cosine rule:

```
VL = √(Vph² + Vph² - 2Vph·Vph·cos(120°))
VL = √(2Vph² + Vph²) = √3 × Vph
```

Final Relations:

Table: Star Connection Relations

Parameter	Relationship
Line Voltage	$VL = \sqrt{3} \times Vph$
Line Current	IL = Iph
Power	$P = \sqrt{3} \times VL \times IL \times \cos\phi$

Current Relations:
In star connection, line current equals phase current:

```
IL = Iph
```

Mnemonic: "Star Scales Voltage, Same current" (√3 factor for voltage, current unchanged)

Question 4(a OR) [3 marks]

Explain vector representation of alternating current.

Answer:

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

Mathematical Expression:

```
i = Im sin(ωt + φ)
```

Phasor Diagram:

```
      Im
       ↗
      /|
     / |
    /  |φ
  O---+---→ Reference
      ωt
```

Table: Current Vector Elements

Element	Symbol	Description
Magnitude	Im	Peak current value
Phase	φ	Leading/lagging angle
Angular velocity	ω	Rotation speed
RMS value	I = Im/√2	Effective current

Applications:

- **Circuit analysis**: Phase relationships between voltage and current
- **Power calculations**: Real and reactive power components

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

Answer:

Table: AC Current Parameters

Term	Definition	Formula	Typical Value
Form Factor	RMS/Average value ratio	Irms/Iavg	1.11 (sine wave)
Peak Factor	Peak/RMS value ratio	Im/Irms	1.414 (sine wave)
Angular Velocity	Rate of phase change	ω = 2πf	314 rad/s (50Hz)
Amplitude	Maximum instantaneous value	Im	Peak current

Mathematical Relations:

- **Form factor**: Indicates waveform shape
- **Peak factor**: Shows crest factor
- **Angular velocity**: Links frequency and phase
- **Amplitude**: Determines RMS and average values

Practical Significance:

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

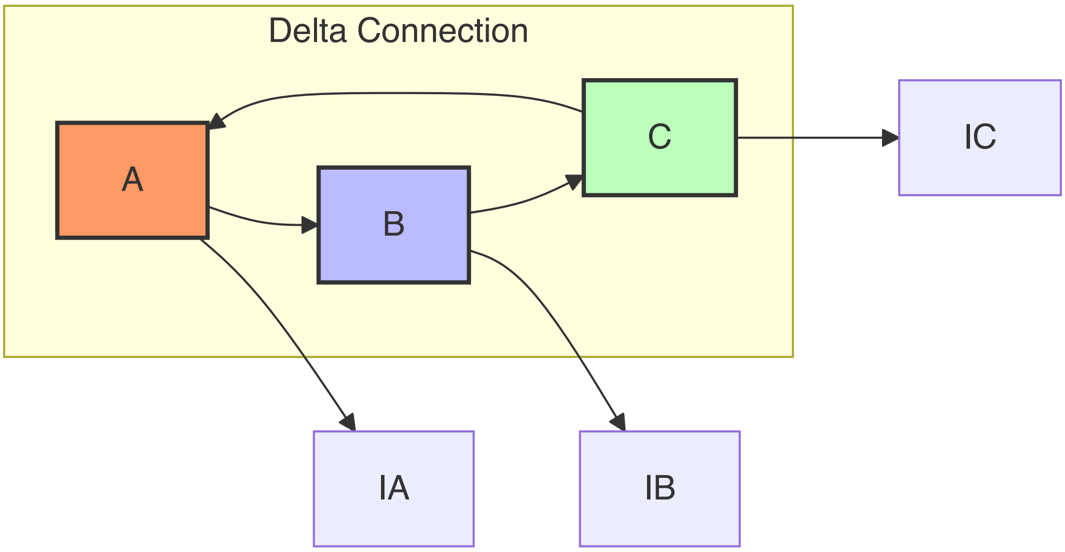
Mnemonic: "Form Peak Angular Amplitude" (Four key factors)

Question 4(c OR) [7 marks]

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

Answer:

Delta Connection Diagram:



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

```
VL = Vph
```

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

For Line Current IA:

```
IA = IAB - ICA
```

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

- IAB = ICA = ICB = Iph
- Phase difference between currents = 120°

Vector Subtraction:

```
IA = IAB - ICA = IAB - (-ICA)
```

Using phasor diagram:

```
IL = √(Iph² + Iph² - 2Iph·Iph·cos(60°))
IL = √(2Iph² - Iph²) = √3 × Iph
```

Final Relations:

Table: Delta Connection Relations

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

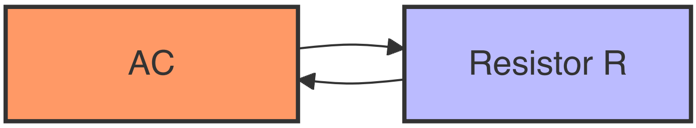
Mnemonic: "Delta Doubles current, Same voltage" (√3 factor for current, voltage unchanged)

Question 5(a) [3 marks]

Explain AC through pure resistor with necessary circuit and waveform.

Answer:

Circuit Diagram:



Waveform:

```
   V,I
    ↑
    |    /\       /\
    |   /  \     /  \
    |  /    \   /    \
 ---+--------\/------\/-→ t
    |        /\      /
    |       /  \    /
    |      /    \  /

 V and I in phase
```

Table: 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

Characteristics:

- **Current and voltage in phase**: No phase difference
- **Power consumption**: Continuous power dissipation

- **Resistance unchanged**: Same as DC value

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

Answer:

Table: 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 Relations:

- **Active Power**: $P = VI \cos\phi$ (Watts)
- **Reactive Power**: $Q = VI \sin\phi$ (VAR)
- **Apparent Power**: $S = VI$ (VA)

Power Triangle:

```
S² = P² + Q²
```

Practical Significance:

- **High power factor**: Efficient power utilization
- **Low power factor**: Higher current for same power
- **Reactive power**: No net energy transfer

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.

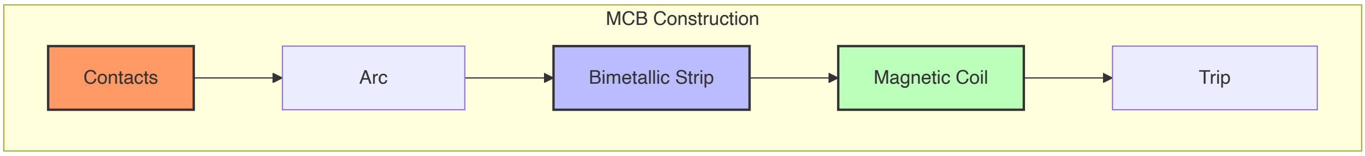
Answer:

Table: 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:



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 and trips mechanism
- Time-delay characteristic protects against temporary overloads

Short Circuit Protection:

- High fault current creates strong magnetic field
- Electromagnetic force operates trip mechanism
- Instantaneous operation for safety

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

Answer:

Given: Pure inductor with inductance L, applied voltage v = Vm sin(ωt)

Voltage-Current Relationship:

```
v = L × (di/dt)
```

Substituting applied voltage:

```
Vm sin(ωt) = L × (di/dt)
```

Integration:

```
di = (Vm/L) sin(ωt) dt
i = -(Vm/ωL) cos(ωt) + C
```

At steady state, C = 0:

```
i = -(Vm/ωL) cos(ωt)
i = (Vm/ωL) sin(ωt - 90°)
```

Table: Pure Inductor Characteristics

Parameter	Value	Phase Relationship
Current amplitude	Im = Vm/ωL	Current lags voltage by 90°
Inductive reactance	XL = ωL = 2πfL	Frequency dependent
Power	P = 0 (average)	No net power consumption

Mnemonic: "Inductor Impedes, Current lags" (XL opposes current, 90° lag)

Question 5(b OR) [4 marks]

Explain concept of power and power triangle in AC circuit.

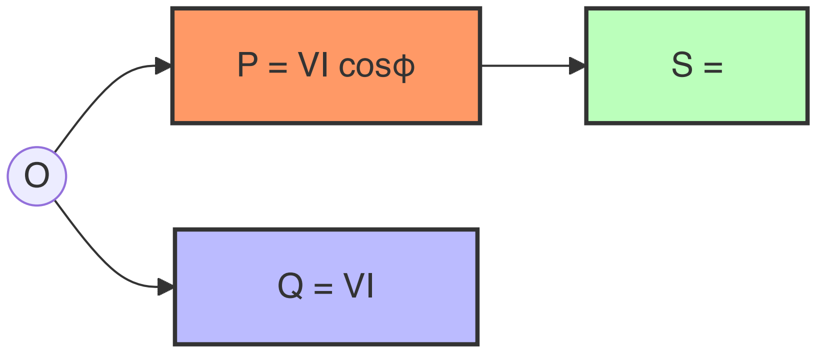
Answer:

Types of Power:

Table: AC Power Components

Power Type	Symbol	Formula	Units	Description
Active Power	P	VI cosφ	Watts	Useful power
Reactive Power	Q	VI sinφ	VAR	Circulating power
Apparent Power	S	VI	VA	Total power

Power Triangle:



Mathematical Relations:

```
S² = P² + Q²
Power Factor = P/S = cosφ
```

Significance:

- **Active power**: Does useful work (heating, mechanical)
- **Reactive power**: Maintains magnetic/electric fields
- **Power factor**: Efficiency indicator

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.

Answer:

1. Lamp Control from One Place:

Circuit Diagram:

```
Live ----[S]----[Lamp]----+
                          |
Neutral ------------------+

S = Single Pole Single Throw Switch
```

Components:

- **SPST Switch**: Single pole, single throw
- **Live wire control**: Switch in live wire for safety
- **Simple on/off**: Basic control mechanism

2. Staircase Wiring (Two-Way Control):

Circuit Diagram:

```
Live ----[S1]----+----[S2]----[Lamp]----+
            \    |    /                 |
             \   |   /                  |
              \  |  /                   |
               \ | /                    |
                \|/                     |
Neutral --------------------------------+

S1, S2 = Two-way switches (SPDT)
```

Table: Switch Positions for Staircase Control

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

Working Principle:

- **Two-way switches**: SPDT (Single Pole Double Throw)
- **Common terminal**: Connected to live and lamp
- **Strappers**: Link switches together
- **Toggle action**: Either switch can control lamp

Applications:

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

Advantages:

- **Convenience**: Control from multiple locations
- **Energy saving**: Easy switching reduces wastage

- **Safety**: No need to walk in dark

Installation Points:

- **Proper earthing**: All metal parts earthed
- **Cable rating**: Adequate current capacity
- **Switch height**: Standard 4 feet from floor

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