PAPER ID-311340

Subject Code: BEE101

Roll No: | | | | | | | | | | | | |

BTECH
(SEM I) THEORY EXAMINATION 2023-24
FUNDAMENTALS OF ELECTRICAL ENGINEERING

TIME: 3HRS **M.MARKS: 70**

Note: 1. Attempt all Sections. If require any missing data; then choose suitably.

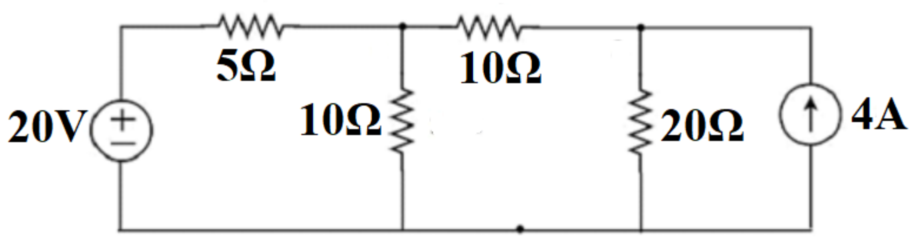
SECTION A

1. Attempt *all* questions in brief. 2 x 7 = 14

Q no.	Question	Marks	CO
a.	Differentiate between ideal voltage source and practical voltage source.	2	1
b.	Describe briefly the following elements with examples: (i) Unilateral and Bilateral elements. (ii) Active and Passive elements.	2	1
c.	Derive that the average power consumed by a pure inductor is zero.	2	2
d.	In a series RLC circuit, R =2Ω, L = 2mH, C = 10μF. Find the resonant frequency and Q-factor.	2	2
e.	Find the inductance of a coil in which a current of 0.2A increasing at a rate of 0.4 A/sec represents a power flow of 0.4 watt.	2	3
f.	What is the function of slip rings in 3-ϕ induction motor?	2	4
g.	What are the common problems that occur during electrical installations?	2	5

SECTION B

2. Attempt any *three* of the following: 7 x 3 = 21

Q no.	Question	Marks	CO
a.	Calculate the current across 20Ω resistor using nodal analysis in the following circuit:  	7	1
b.	Calculate the form factor and peak factor for a half-wave rectified voltage signal.	7	2
c.	A 100 kVA, 1-ϕ transformer has iron loss of 600 W and a copper loss of 1.5 kW at full-load current. Calculate the efficiency at (i) full load and 0.8 pf (lagging), and (ii) half load and unity pf?	7	3
d.	Describe the working principle and torque-slip characteristics of 3-ϕ induction motor.	7	4
e.	Discuss briefly the types of batteries and explain any one type of secondary battery with the necessary diagram.	7	5

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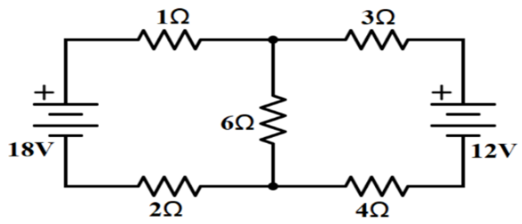
SECTION C

3. Attempt any *one* part of the following: 7 x 1 = 7

Q no.	Question	Marks	CO
a.	Calculate the current across 6Ω resistor in the following circuit using: (i) Mesh Analysis (ii) Nodal Analysis 	7	1
b.	Explain the procedure of mesh analysis with the help of an example.	7	1

4. Attempt any *one* part of the following: 7 x 1 = 7

a.	Derive an expression of bandwidth, upper and lower half power frequency of a series resonating circuit.	7	2
b.	Derive the relation between line and phase voltages in a 3-ϕ, star-connected circuit. A balanced star-connected load of (3+j4) Ω/phase is connected to a 3-ϕ, 400 V supply. Calculate the line current, power factor, active and reactive power drawn from the supply.	7	2

5. Attempt any *one* part of the following: 7 x 1 = 7

a.	A 20 kVA, 2000V/200V, 1-ϕ, 50 Hz transformer has a primary resistance of 1.5 Ω and reactance of 2 Ω. The secondary resistance and reactance are 0.015 Ω and 0.02 Ω respectively. The no-load current of transformer is 1A at 0.2 power factor. Determine: (i) Equivalent resistance and reactance referred to primary. (ii) Total copper loss.	7	3
b.	Draw the phasor diagram of ideal and practical transformer at no-load conditions.	7	3

6. Attempt any *one* part of the following: 7 x 1 = 7

a.	Derive the expression of torque for DC motor. A 6 pole lap wound DC shunt motor has 500 conductors in the armature. The resistance of the armature path is 0.05 Ω. The resistance of the shunt field is 25 Ω. Find the speed of the motor when it takes 120 A from DC mains of 100 V. Flux per pole is 0.02 Wb.	7	4
b.	Why 1-ϕ induction motor is not self-starting? What are the methods of starting? Explain any one of them.	7	4

7. Attempt any *one* part of the following: 7 x 1 = 7

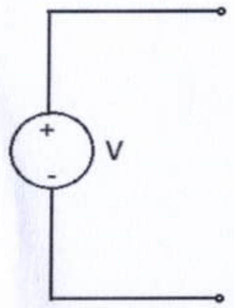
a.	Explain the following with neat and labelled diagram: (i) Earth Leakage Circuit Breaker (ii) Miniature Circuit Breaker	7	5
b.	What is the difference between earthing and grounding? Also discuss the different methods of earthing?	7	5

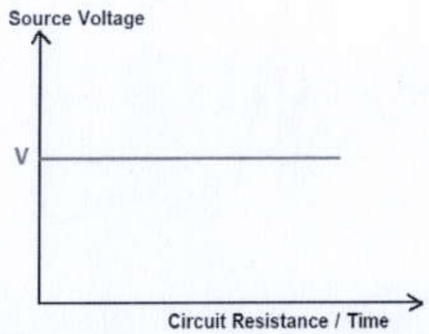
SOLUTION OF FUNDAMENTALS OF ELECTRICAL ENGINEERING (BEE 101)

BTECH (SEM I) THEORY EXAMINATION 2023-24

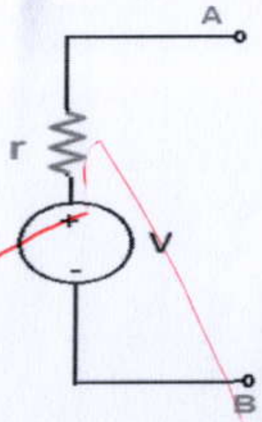
SECTION A

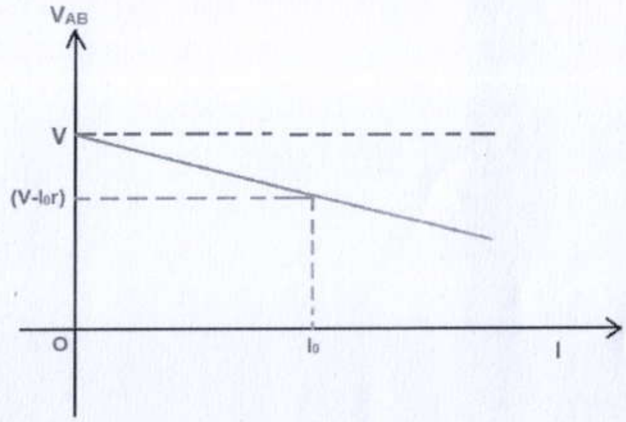
1(a) Ideal Voltage Source: An ideal voltage source is defined as the two terminal device capable of providing a constant voltage across its terminals. The voltage across the terminals of an ideal voltage source remains constant and is independent of load current. The internal resistance of ideal voltage source is zero.





Practical Voltage Source: The internal resistance of practical voltage source is non-zero.





(b) (i) Unilateral and Bilateral Elements:

Unilateral Elements: These are components that allow the flow of current in only one direction. Examples include diodes, which conduct current in one direction (forward bias) and block it in the opposite direction (reverse bias).

Bilateral Elements: These are components that allow the flow of current in both directions. Examples include resistors, capacitors, and inductors, which do not exhibit any directional preference for current flow.

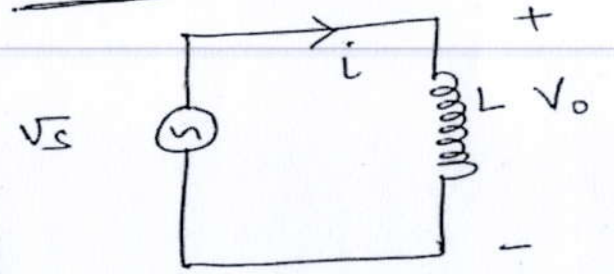
(ii) Active and Passive Elements:

Active Elements: These are components that can generate or amplify electrical signals. They require an external source of energy to operate. Examples include transistors, operational amplifiers (op-amps), and voltage regulators.

Passive Elements: These are components that do not require an external source of energy and cannot amplify electrical signals. They can only attenuate or dissipate energy. Examples include resistors, capacitors, inductors, and diodes.

(c) <u>Average power in purely inductive circuit</u>

<u>Pure inductive Circuit</u>



$v_s = V_m \sin \omega t$

$v_o = L \dfrac{di}{dt}$

but $[v_s = v_o]$

so

$$v_s = L \frac{di}{dt}$$

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

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

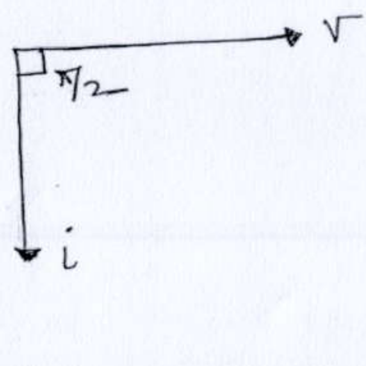
$$i = \int \frac{V_m}{L} \sin \omega t \, dt \qquad (3)$$

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

$\omega L = X_L \rightarrow$ inductive reactance

$$\left[i = \frac{V_m}{X_L} \sin(\omega t - \pi/2) \right] \qquad (2)$$

<u>NOTE:</u>→ On comparing eqn (1) & (2), eqn current lags the voltage by $\pi/2$.



Power in pure inductive circuit

$$P = vi = V_m \sin\omega t \, I_m \sin(\omega t - \pi/2)$$

$$= -V_m I_m \sin\omega t \cos\omega t$$

$$= -\frac{V_m I_m}{2}(2 \sin\omega t \cos\omega t)$$

$$= -\frac{V_m I_m}{2} \sin 2\omega t$$

$$P_{avg} = \frac{1}{2\pi}\int_0^{2\pi} -\frac{V_m I_m}{2} \sin 2\omega t \, d(\omega t)$$

$\sin 2\omega t \, d(\omega t) \to 0$ [av. value of complete cycle is zero]

$$\boxed{P_{av} = 0}$$

(d) In a series RLC circuit, R =2Ω, L = 2mH, C = 10μF.

Resonating frequency (F_r)

$$F_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times 3.14 \times \sqrt{2\times 10^{-3} \times 10 \times 10^{-6}}}$$

$$\boxed{F_r = 1126 \, Hz}$$

Quality Factor (Q_o)

$$Q_o = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{2}\sqrt{\frac{2\times 10^{-3}}{10\times 10^{-6}}} = 7.07$$

(e) power flow, p = 0.4watt
Current, i = 0.2 A
Induced EMF, e = p/i = 0.4/0.2 = 2V
Rate of change of current, di/dt = 0.4 A/s
Inductance of coil, L = e/(di/dt) = 2/0.4 = 5H

(f) ***The function of slip rings*** in a wound rotor induction motor is to provide external electrical connections to the rotor windings. These slip rings allow for the rotor windings to be connected to external resistors or other control devices. By varying the resistance or impedance connected to the rotor windings through the slip rings, the speed-torque characteristics of the motor can be adjusted.

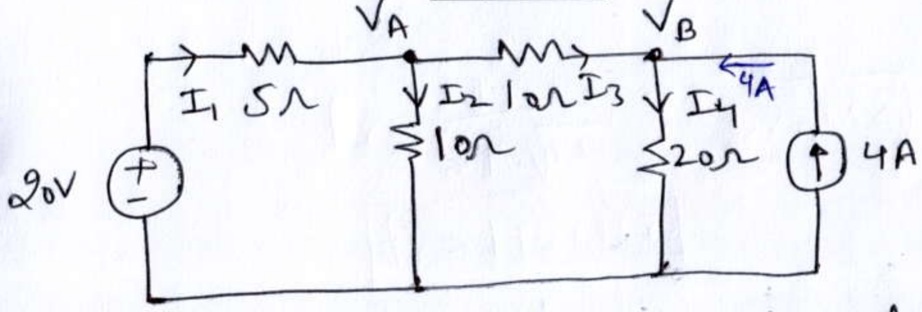
Additionally, slip rings facilitate the transfer of electrical power and signals between the stationary part (stator) and the rotating part (rotor) of the motor. This allows for external control and monitoring of the motor's operation, such as speed control, braking, and starting torque adjustment.

(g) During electrical installations, several common problems may occur, leading to safety hazards, equipment damage, and operational issues. Some of these common problems include:

- Overloaded Circuits
- Short Circuits
- Ground Faults
- Improper Wiring Connections
- Overvoltage or Undervoltage
- Poor Grounding
- Insufficient Conduit Sizing
- Inadequate Circuit Protection
- Poor Cable Management
- Insufficient Voltage Drop Consideration

SECTION B

2(a)



at node (A)

$I_1 = I_2 + I_3$

$\frac{20-V_A}{5} = \frac{V_A}{10} + \frac{V_A-V_B}{10}$

$\frac{20-V_A}{\cancel{5}} = \frac{2V_A-V_B}{\cancel{10}\,2}$

$40 - 2V_A = 2V_A - V_B$

$4V_A - V_B = 40$ —— (1)

at node (B)

$I_3 + 4 = I_4$

$\frac{V_A-V_B}{10} + 4 = \frac{V_B}{20}$

$\frac{V_A-V_B+40}{\cancel{10}} = \frac{V_B}{\cancel{20}\,2}$

$2V_A - 2V_B + 80 = V_B$

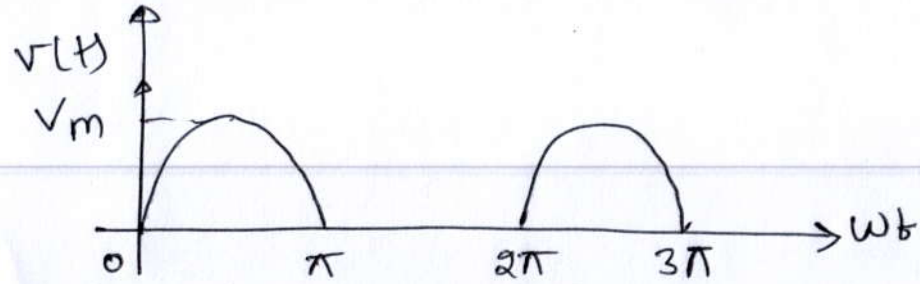
$2V_A - 3V_B = -80$ —— (2)

By solving (1) & (2) $\boxed{V_A = 20V}$ $\boxed{V_B = 40V}$

current across 20Ω resistor

$$I_4 = \frac{V_B}{20} = \frac{40}{20} = \underline{\underline{2A}}.$$

2(b) Half wave Rectified Signal



$$v(t) = V_m \sin\omega t \quad \text{——— (1)}$$

Average voltage (V_{avg})

$$V_{avg} = \frac{1}{2\pi}\int_0^{\pi} V_m \sin\omega t \, d(\omega t)$$

$$= \frac{V_m}{2\pi}\left[-\cos\omega t\right]_0^{\pi}$$

$$= \frac{V_m}{2\pi}\left[1+1\right]$$

$$= \frac{V_m}{\pi}$$

RMS voltage (V_{rms})

$$V_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} V_m^2 \sin^2\omega t \, d(\omega t)}$$

$$V_{rms} = \sqrt{\frac{V_m^2}{2\pi}\int_0^{\pi}\left(\frac{1-\cos2\omega t}{2}\right)\omega t}$$

$$V_{rms} = \sqrt{\frac{V_m^2}{4\pi}\left[[\omega t]_0^{\pi} - \underbrace{\left[\frac{\sin2\omega t}{2}\right]_0^{\pi}}_{0}\right]}$$

$$V_{rms} = \sqrt{\frac{V_m^2}{4\cancel{\pi}} \times \cancel{\pi}}$$

$$\left[V_{rms} = \frac{V_m}{2}\right]$$

$$\text{form factor} = \frac{V_{rms}}{V_{avg}}$$

$$= \frac{\frac{\cancel{V_m}}{2}}{\frac{\cancel{V_m}}{\pi}} = \frac{\pi}{2}$$

$$= \underline{\underline{1.57}}$$

$$\text{Peak factor} = \frac{V_m}{V_{rms}}$$

$$= \frac{V_m}{\frac{V_m}{2}}$$

$$= 2$$

for a half wave rectified signal

$\boxed{K_f = 1.57}$ $\boxed{K_p = 2}$

2(c) (i) Efficiency at full load & 0.8 pf (lagging)

$$\% \eta = \frac{x \cdot Q \cdot \cos\phi}{x \cdot Q \cdot \cos\phi + P_i + x^2 P_{cFL}} \times 100 = \frac{1 \times 100 \times 10^3 \times 0.8}{100 \times 10^3 \times 0.8 + 600 + (1)^2 \times 1500} \times 100$$

$$\boxed{\% \eta = 97.44\%}$$

(ii) Efficiency at half load & UPF

$$\% \eta = \frac{0.5 \times 100 \times 10^3 \times 1}{0.5 \times 100 \times 10^3 + 600 + (0.5)^2 \times 1500} \times 100 = \frac{50000}{50975} \times 100$$

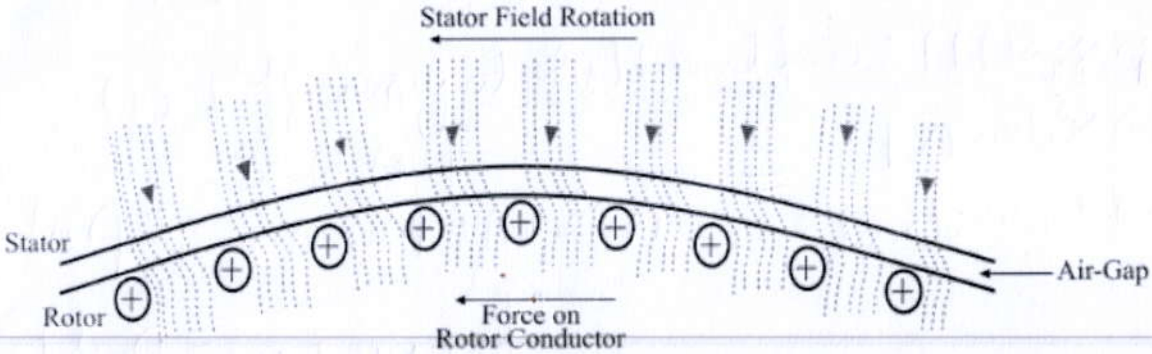
$$\boxed{\% \eta = 98.08\%}$$

2(d) **Working principle of 3-ϕ induction motor:** The working principle of a three-phase induction motor is based on electromagnetic induction. When a three-phase alternating current (AC) is applied to the stator windings of the motor, a rotating magnetic field is produced. This rotating magnetic field interacts with the rotor conductors, inducing an electromotive force (EMF) and generating currents within the rotor.

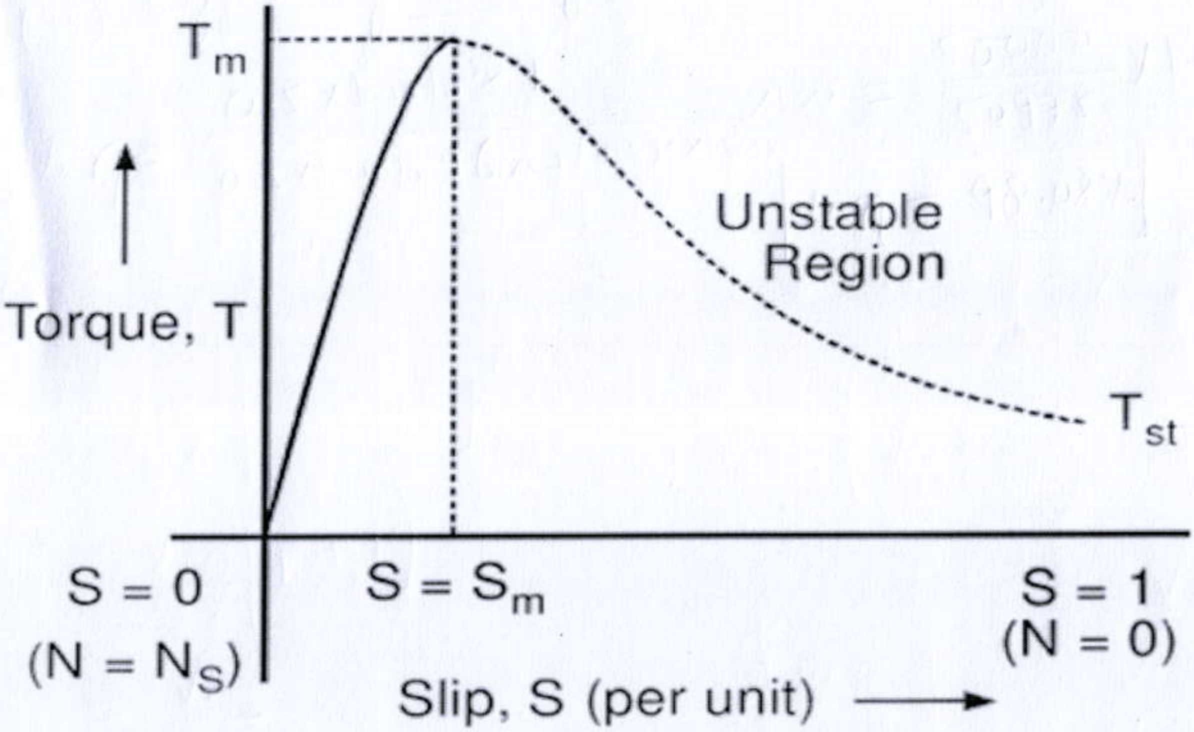
The rotor currents produce a magnetic field that interacts with the stator magnetic field, resulting in electromagnetic forces that cause the rotor to rotate. The rotation of the rotor follows the synchronous speed of the rotating magnetic field produced by the stator, but with a slight lag known as slip.

The slip is necessary for the motor to develop torque and overcome mechanical losses. As the rotor rotates, it experiences electromagnetic drag due to the interaction between the stator and rotor magnetic fields. This drag causes the rotor speed to lag behind the synchronous speed of the rotating magnetic field.

The difference between the synchronous speed and the actual rotor speed is known as slip. The amount of slip determines the amount of torque developed by the motor. Higher slip results in higher torque production, allowing the motor to handle increased loads.



Torque-slip characteristics of 3-ϕ induction motor



2(c) Batteries are energy storage devices that convert chemical energy into electrical energy through electrochemical reactions. There are several types of batteries, each with unique characteristics and applications. Some common types of batteries include:

Lead-Acid Batteries: Lead-acid batteries are one of the oldest and most widely used types of rechargeable batteries. They are commonly used in automotive applications, uninterruptible power supplies (UPS), and stationary backup power systems.

Lithium-Ion Batteries: Lithium-ion batteries are lightweight, high-energy-density batteries widely used in portable electronic devices, such as smartphones, laptops, and electric vehicles (EVs). They offer high energy density, long cycle life, and fast charging capabilities.

Nickel-Cadmium (NiCd) Batteries: Nickel-cadmium batteries are rechargeable batteries known for their robustness and reliability. They are commonly used in applications where high discharge rates and durability are required, such as power tools and emergency lighting.

Nickel-Metal Hydride (NiMH) Batteries: Nickel-metal hydride batteries offer higher energy density and lower toxicity compared to nickel-cadmium batteries. They are commonly used in portable electronic devices, hybrid vehicles, and rechargeable AA or AAA batteries.

Lithium Polymer (LiPo) Batteries: Lithium polymer batteries are a type of lithium-ion battery that uses a solid polymer electrolyte instead of a liquid electrolyte. They offer higher energy density, lighter weight, and greater flexibility in shape and size, making them suitable for use in drones, remote-controlled vehicles, and wearable electronics.

One type of secondary battery that can be explained in detail is the Lead-Acid Battery:

Lead-Acid Battery:

Lead-acid batteries consist of lead dioxide (PbO2) as the positive electrode (cathode), sponge lead (Pb) as the negative electrode (anode), and sulfuric acid (H2SO4) electrolyte. During discharge, sulfuric acid dissociates into ions, allowing for the flow of electrons between the electrodes and producing electrical energy.

The working of a lead-acid battery is as follows:

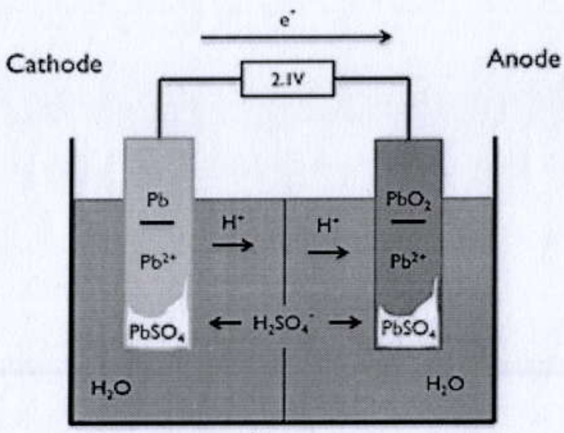
Charging: During charging, an external voltage source is applied to the battery, causing a flow of current through the battery in the opposite direction of discharge. This reverses the chemical reactions that occurred during discharge, converting lead sulfate (PbSO4) back into lead dioxide and sponge lead.

Discharging: During discharge, the lead dioxide electrode reacts with sulfuric acid to form lead sulfate and water, releasing electrons in the process. At the same time, the sponge lead electrode reacts with sulfuric acid to form lead sulfate and water, consuming electrons. This flow of electrons constitutes the electrical current produced by the battery.

Overall Reaction: The overall chemical reaction during discharge can be represented as:

$PbO2 + Pb + 2H2SO4 \rightarrow 2PbSO4 + 2H2O$

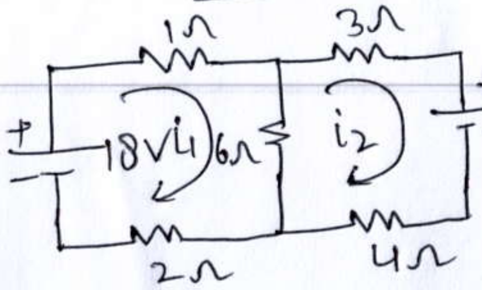
Rechargeability: Lead-acid batteries are rechargeable, allowing them to be reused multiple times by reversing the chemical reactions through the application of an external charging voltage.



SECTION C

3(a)

(i) Mesh Analysis



Mesh ①

$i_1 + 6(i_1 - i_2) + 2i_1 - 18 = 0$

$3i_1 + 6i_1 - 6i_2 = 18$

$9i_1 - 6i_2 = 18$ —— ①

Mesh ②

$3i_2 + 12 + 4i_2 + 6(i_2 - i_1) = 0$

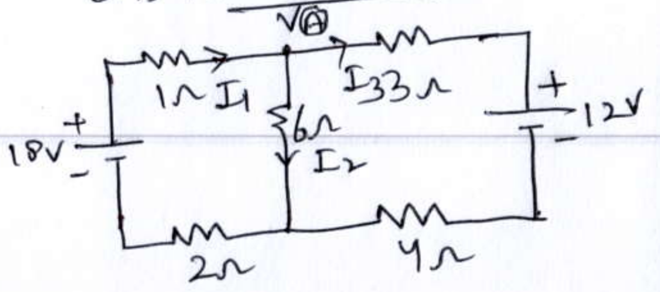
$-6i_1 + 13i_2 = -12$ —— ②

from ① & ②

$\boxed{i_1 = 2A}$ $\boxed{i_2 = 0A}$

$i_{6\Omega} = i_1 - i_2 = \underline{\underline{2A}}$

(ii) Nodal Analysis



at node Ⓐ

$I_1 = I_2 + I_3$

$\frac{18 - V_A}{3} = \frac{V_A}{6} + \frac{V_A - 12}{7}$

$\frac{18 - V_A}{\cancel{3}} = \frac{7V_A + 6V_A - 72}{\cancel{42}\,14}$

$252 - 14V_A = 13V_A - 72$

$252 + 72 = 27V_A$

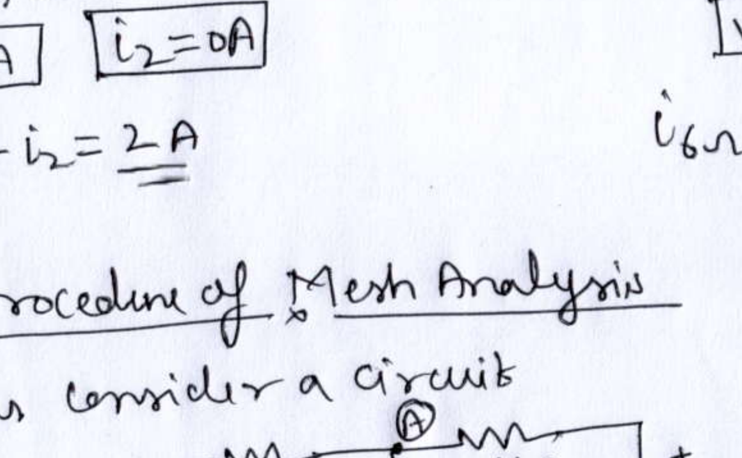
$324 = 27V_A$

$\boxed{V_A = 12V}$

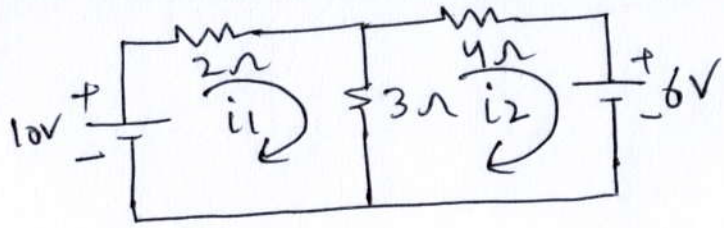
$i_{6\Omega} = I_2 = \frac{V_A}{6} = \underline{\underline{2A}}.$

3(b) Procedure of Mesh Analysis

let us consider a circuit



In this circuit, we have to find out current in 3Ω resistor using mesh Analysis.



In Mesh ①

$2i_1 + 3(i_1 - i_2) = 10$

$5i_1 - 3i_2 = 10$ — ①

In mesh ②

$4i_2 + 6 + 3(i_2 - i_1) = 0$

$-3i_1 + 7i_2 = -6$ — ②

Solving ① & ②

$[i_1 = 2A]$ $[i_2 = 0A]$

$i_{3\Omega} = i_1 - i_2 = \underline{\underline{2A}}$

Procedure

①. Identify the no. of mesh in the ckt.

②. Assume current direction in each mesh.

③. Develop the KVL eqn for each mesh.

④. Solve the KVL eqn to calculate the current.

4(a)

The plot of the frequency response of series circuit is as shown in Figure 1.2. At resonant frequency ω_r the current is maximum.

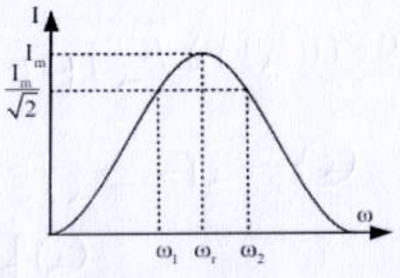


Figure 1.2: Frequency response of series circuit

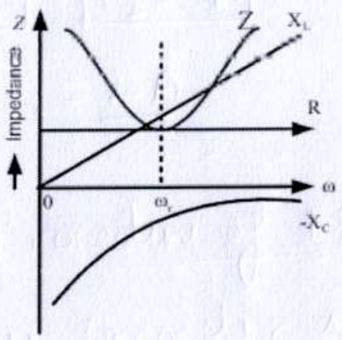


Figure 1.3: Frequency response of impedance of series circuit

$$a = 1,\ b = \frac{R}{L},\ c = -\frac{1}{LC}$$

$$\omega_1 = \frac{-\frac{R}{L} \pm \sqrt{\left(\frac{R}{L}\right)^2 + \frac{4}{LC}}}{2} = -\frac{R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$$

Frequency is always positive

$$\omega_1 = -\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$$

In terms of frequency f_1

$$f_1 = \frac{1}{2\pi}\left[-\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}\right]$$

At frequency ω_2 the circuit impedance $X_L > X_C$

$$\begin{aligned} X_L - X_C &= R \\ \omega_2 L - \frac{1}{\omega_2 C} - &= R \\ \frac{\omega_2^2 LC - 1}{\omega_2 C} &= R \\ \omega_2^2 LC - R\omega_2 C - 1 &= 0 \\ \omega_2^2 - \frac{R}{L}\omega_2 - \frac{1}{LC} &= 0 \end{aligned}$$

$$a = 1,\ b = -\frac{R}{L},\ c = -\frac{1}{LC}$$

At resonance frequency f_r $Z = R$ and current is I_m
At half power frequencies f_1 and f_2 the current is $\frac{I_m}{\sqrt{2}}$

$$Z = \sqrt{2}R$$

$$Z = R + jX_L - JX_C = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\begin{aligned}
\sqrt{R^2 + (X_L - X_C)^2} &= \sqrt{2}R \\
R^2 + (X_L - X_C)^2 &= 2R^2 \\
(X_L - X_C)^2 &= R^2 \\
X_L - X_C &= R
\end{aligned}$$

At frequency ω_1 the circuit impedance $X_C > X_L$

$$\begin{aligned}
X_C - X_L &= R \\
\frac{1}{\omega_1 C} - \omega_1 L &= R \\
\frac{1 - \omega_1^2 LC}{\omega_1 C} &= R \\
R\omega_1 C - 1 + \omega_1^2 LC &= 0 \\
\omega_1^2 + \frac{R}{L}\omega_1 - \frac{1}{LC} &= 0
\end{aligned}$$

$$\omega_2 = \frac{\frac{R}{L} \pm \sqrt{\left(\frac{R}{L}\right)^2 + \frac{4}{LC}}}{2} = \frac{R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$$

Frequency is always positive

$$\omega_2 = \frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$$

In terms of frequency f_2

$$f_2 = \frac{1}{2\pi}\left[\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}\right]$$

Relation between ω_r , ω_1 and ω_2

$$\begin{aligned}
\omega_1 \times \omega_2 &= \\
&= \left[\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}\right] \times \left[\frac{-R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}\right] \\
&= \frac{1}{LC}
\end{aligned}$$

$$\begin{aligned}
\omega_r &= \sqrt{\frac{1}{LC}} \\
\omega_r^2 &= \frac{1}{LC} = \omega_1.\omega_2 \\
\omega_r &= \sqrt{\omega_1.\omega_2} \\
f_r &= \sqrt{f_1 f_2}
\end{aligned}$$

Relation between Bandwidth Quality factor

Bandwidth is $B = \omega_2 - \omega_1$

$$\begin{aligned}
B &= \omega_2 - \omega_1 \\
&= \left[\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}\right] - \left[\frac{-R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}\right] \\
&= \frac{R}{L} \quad radians
\end{aligned}$$

$$B = \frac{1}{2\pi}.\frac{R}{L} = \frac{R}{2\pi L}\ Hz$$

$$\omega_r = \sqrt{\frac{1}{LC}}$$

$$\omega_1 = -\frac{B}{2} + \sqrt{\left(\frac{B}{2}\right)^2 + \omega_r^2}$$

$$\omega_2 = \frac{B}{2} + \sqrt{\left(\frac{B}{2}\right)^2 + \omega_r^2}$$

4(b)

$V_L = 400V$

$Z_p = (3 + j4)\Omega/\text{phase}$

In 3-ϕ star connection

$$\begin{bmatrix} I_p = I_L \\ V_L = \sqrt{3}V_p \end{bmatrix}$$

$$I_p = \frac{V_p}{Z_p} = \frac{\frac{400}{\sqrt{3}}}{(3+j4)} = 46.18 \angle -53.13 A$$

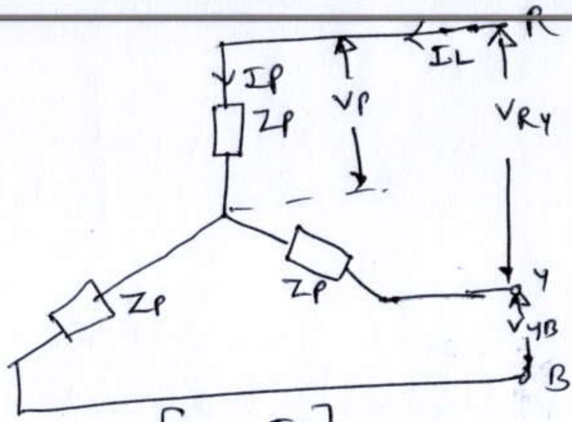
$$\left[I_p = 46.18 \angle -53.13 A \right]$$

(i) $I_L = I_p = 46.18A$

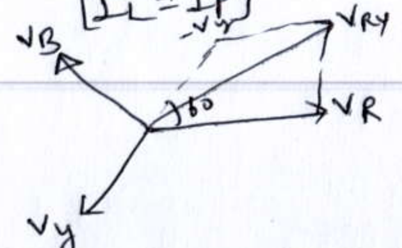
(ii) $P.f = \cos\phi = \cos 53.13$
$= 0.6$ (lag.)

(iii) $P_{3-\phi} = \sqrt{3} V_L I_L \cos\phi$
$= \sqrt{3} \times 400 \times 46.18 \times 0.6$
$= 19.19$ KW

$Q_{3-\phi} = \sqrt{3} V_L I_L \sin\phi$
$= \sqrt{3} \times 400 \times 46.18 \times \sin 53.13$
$= 25.59$ KVAR



$[I_L = I_P]$

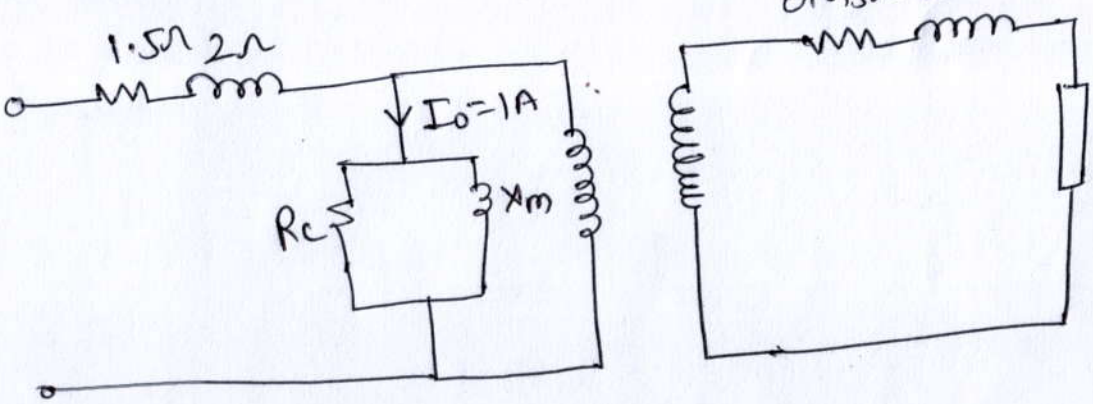


$$V_{RY} = \sqrt{V_R^2 + V_y^2 + 2V_R \cdot V_y \cdot \cos 60}$$

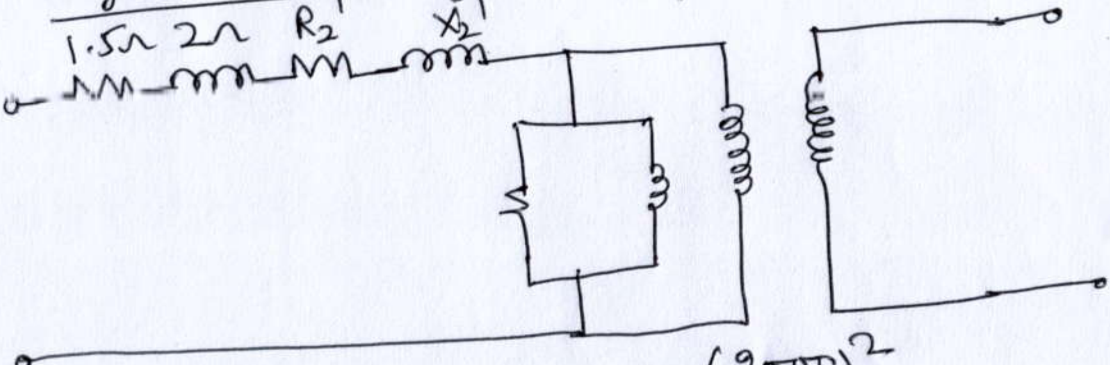
$$V_L = \sqrt{V_P^2 + V_P^2 + 2V_P \cdot V_P \times \tfrac{1}{2}}$$

$$\boxed{V_L = \sqrt{3} V_P}$$

5(a)



(i) Referred to primary



$$R_{01} = R_1 + R_2' = 1.5 + 0.015\left(\frac{2000}{200}\right)^2$$
$$= 3\Omega$$

$$X_{01} = X_1 + X_2' = 2\Omega + 0.02\left(\frac{2000}{200}\right)^2 = 4\Omega$$

(ii) Total copper loss, $\underline{\underline{P_c}} = I_p^2 R_{01} = I_s^2 R_{02}$

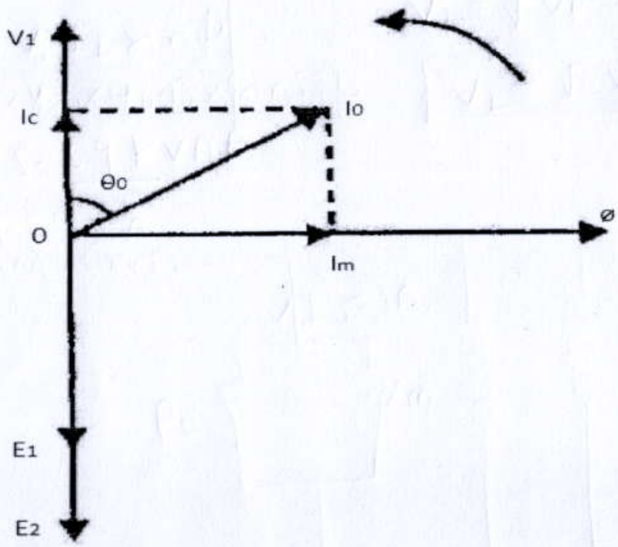
$\boxed{P = 20\,kVA}$ $V_p = 2000V$ $\cancel{20}^{1}\times 1\cancel{0^3} = \cancel{2000}\times I_p$

$\boxed{I_p = 10A}$

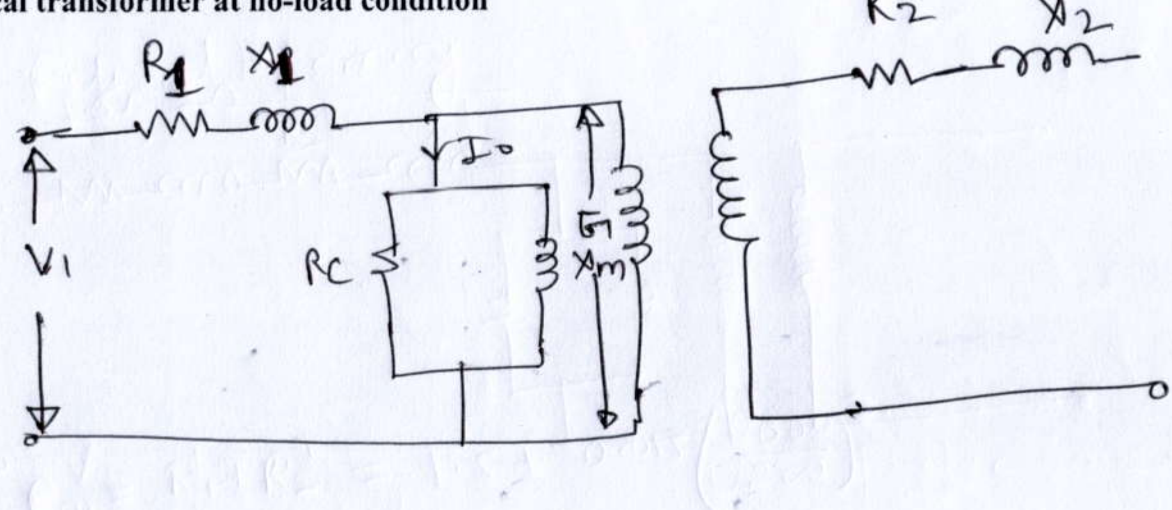
$P_c = I_1^2 R_{01} = 10^2 \times 3 = 100\times 3 = \underline{\underline{300W}}$

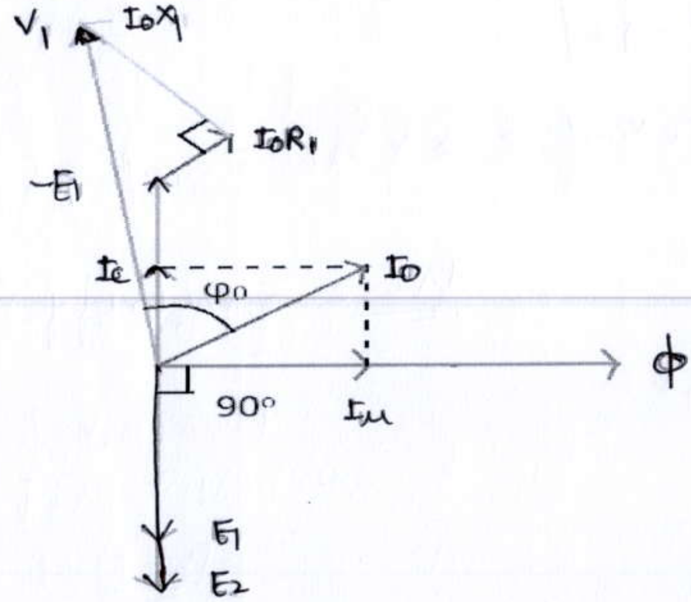
Total copper loss $= \underline{\underline{300W}}$

5(b) Ideal transformer at no-load condition



Practical transformer at no-load condition





6(a) <u>Torque Eq. of DC motor</u>

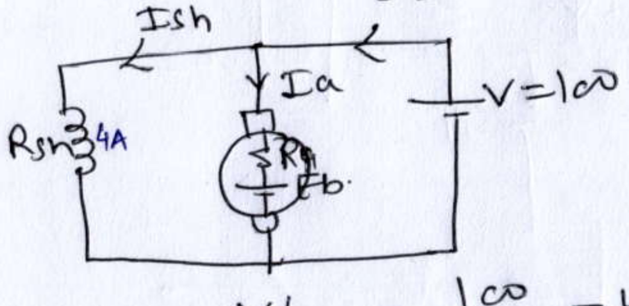
$$P = T\omega = E_b I_a$$

$$T \times \frac{2\pi \cancel{N}}{\cancel{60}} = \frac{P\phi \cancel{N} Z}{\cancel{60} A} \times I_a$$

$$T = \frac{1}{2\pi} \cdot \frac{PZ}{A} \cdot \phi I_a$$

$$\boxed{T = 0.159 \frac{PZ}{A} \cdot \phi I_a}$$

<u>Numerical:-</u>



$$I_{sh} = V/R_{sh} = \frac{100}{25} = 4A$$

$$I_a = I_L - I_{sh} = 120 - 4A$$
$$= 116A$$

$$I_a R_a + E_b = V$$

$$E_b = V - I_a R_a$$
$$= 100 - 116 \times 0.05$$

$$\boxed{E_b = 94.2V}$$

$$E_b = \frac{P\phi NZ}{60A}$$

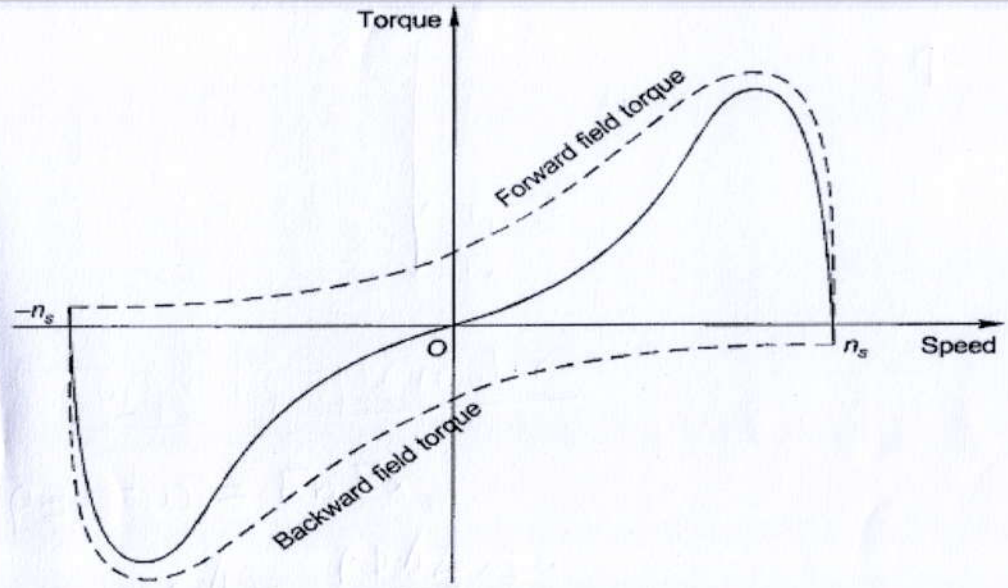
for lap wound $(A = P)$

$$N = \frac{94.2 \times 60 \times \cancel{A}}{\cancel{P} \times 0.02 \times 500}$$

$N = 565.2 \simeq 566\ rpm$

$\boxed{N = 566\ RPM}$

6(b) A single-phase (1-ϕ) induction motor is not self-starting because it lacks a rotating magnetic field, which is necessary for the motor to develop torque and begin rotating. Unlike three-phase induction motors, which produce a rotating magnetic field with the help of three-phase AC power, single-phase induction motors rely on a single-phase AC power supply, resulting in a pulsating magnetic field that does not produce sufficient starting torque.



To overcome this limitation and start a single-phase induction motor, various starting methods are employed. One common method is the split-phase starting method, which involves the use of a split-phase winding arrangement to create a rotating magnetic field and provide starting torque to the motor.

The working of split-phase starting method is as follows:

Split-Phase Winding: The stator winding of the single-phase induction motor is divided into two separate windings: the main winding and the auxiliary winding. These windings are spatially displaced from each other to create a phase shift between the magnetic fields they produce.

Phase Shift: The main winding is connected directly to the single-phase AC power supply, while the auxiliary winding is connected in series with a starting capacitor. The starting capacitor introduces a phase shift between the currents in the main and auxiliary windings, creating a rotating magnetic field during starting.

Starting Sequence: When the single-phase AC power is applied to the motor, current flows through both the main and auxiliary windings. Due to the phase shift introduced by the starting capacitor, the magnetic fields produced by the two windings are out of phase with each other, resulting in a rotating magnetic field.

Starting Torque: The rotating magnetic field generated by the split-phase winding arrangement produces starting torque, causing the motor to begin rotating. As the motor accelerates, the starting capacitor is disconnected from the circuit by a centrifugal switch or other means to prevent excessive current flow and overheating.

Operation: Once the motor has reached a sufficient speed, it operates as a standard single-phase induction motor, with the main winding alone providing the magnetic field required for continuous rotation.

The other starting methods are:

Split phase motor

Capacitor start motor

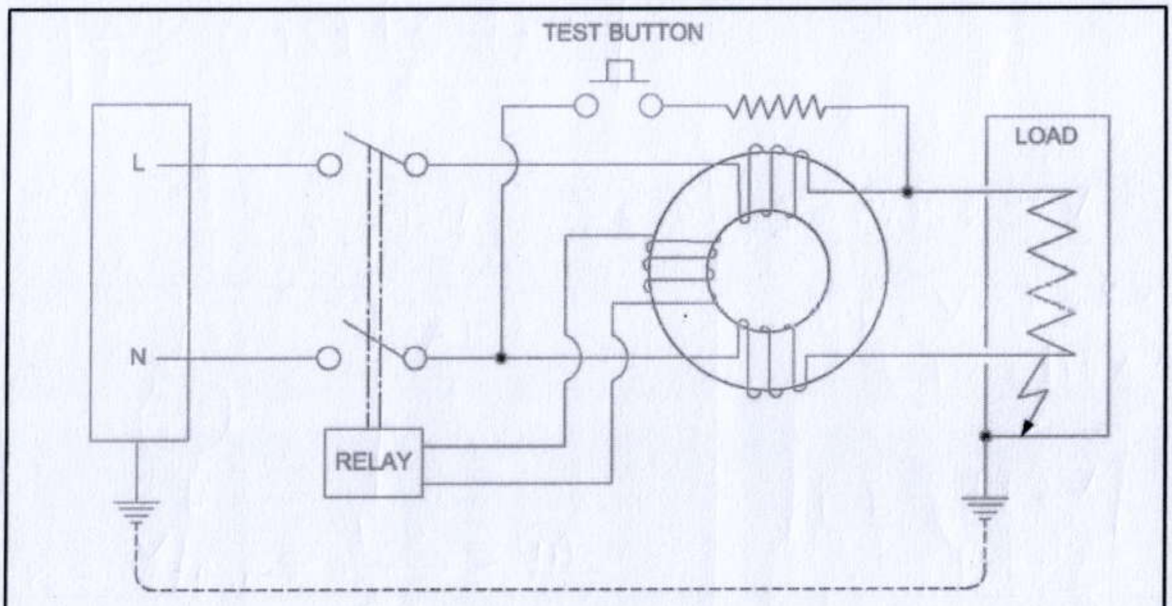
Capacitor start capacitor run motor

Shaded pole motor

7(a) (i) Earth Leakage Circuit Breaker (ELCB): An Earth Leakage Circuit Breaker (ELCB) is a protective device used to detect earth faults or leakages in electrical circuits and disconnect power to prevent electric shock and fire hazards.

The diagram shows the internal configuration of an ELCB. It consists of a voltage coil connected in series with the live wire (Phase) and a current coil connected in series with the load.

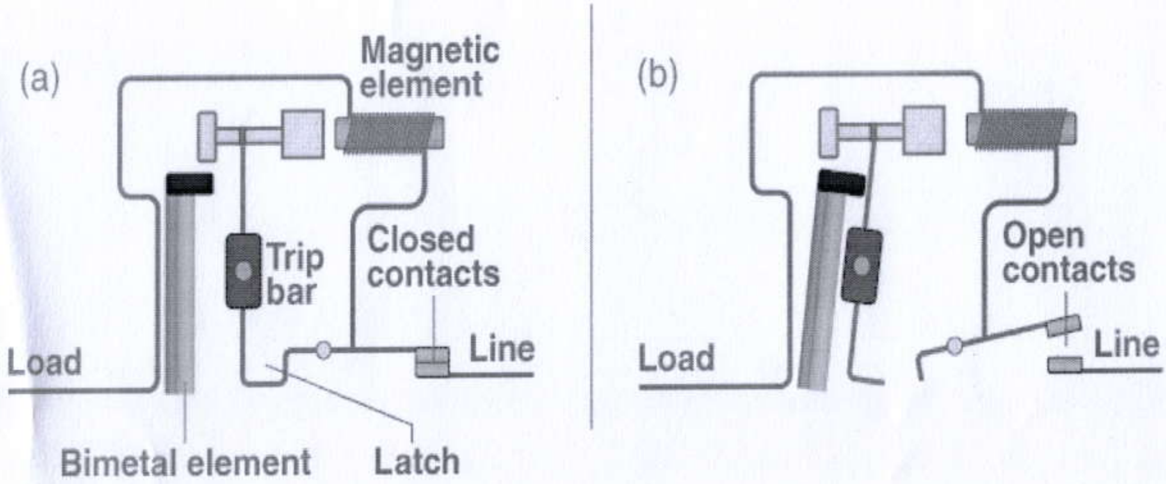
Operation: When there is no earth fault, the currents flowing through the voltage and current coils are equal and opposite, resulting in zero net current. However, in the event of an earth fault, some current flows through the earth path due to leakage. This creates an imbalance between the currents in the voltage and current coils, causing the ELCB to trip and disconnect power.



WORKING PRINCIPLE OF ELCB

Mechanism: The tripping mechanism of an ELCB can be either electromagnetic or electronic, depending on the design. In an electromagnetic ELCB, the imbalance in currents creates a magnetic field that actuates a tripping mechanism, while in an electronic ELCB, the imbalance is detected by electronic circuits, triggering the tripping mechanism.

(ii) Miniature Circuit Breaker (MCB): A Miniature Circuit Breaker (MCB) is a protective device used to automatically disconnect electrical circuits in case of overcurrents or short circuits to prevent damage to equipment and electrical fires.



Components: The diagram shows the components of an MCB, including the operating mechanism, trip mechanism, and contacts. It consists of a thermal-magnetic trip unit and a toggle mechanism for manual operation.

Operation: The MCB operates based on two principles: thermal and magnetic. In case of overcurrents (due to overload), the bimetallic strip heats up, causing it to bend and trip the circuit breaker. In case of short circuits, the magnetic trip unit detects the high magnetic field generated by the fault current and trips the MCB instantaneously.

Resetting: After tripping, the MCB can be manually reset by toggling the handle to the "off" position and then back to the "on" position. This resets the thermal-magnetic trip unit and restores power to the circuit.

Both ELCBs and MCBs play crucial roles in electrical safety by protecting against electrical faults, but they operate based on different principles and offer distinct features for circuit protection.

7(b) The terms "earthing" and "grounding" are often used interchangeably, but they refer to slightly different concepts in the context of electrical systems:

Earthing: Earthing, also known as "grounding" in some regions, is the process of connecting metallic parts of electrical equipment and installations to the earth (ground) to ensure safety and proper operation. The primary purpose of earthing is to provide a low-resistance path for fault currents to flow to the earth, preventing the buildup of dangerous voltages and reducing the risk of electric shock and fires.

Grounding: Grounding typically refers to the connection of electrical systems or circuits to the earth (ground) for safety and functional purposes. It involves establishing a reference point (ground) that is at zero potential voltage relative to other points in the system. Grounding helps stabilize voltages, provide a return path for fault currents, and mitigate electromagnetic interference (EMI).

Different methods of earthing:

Plate Earthing: In plate earthing, a copper or galvanized iron plate is buried vertically in the ground, typically in a moist location with good conductivity. The plate is connected to the electrical system's neutral point and provides a low-resistance path for fault currents to dissipate into the earth.

Pipe or Rod Earthing: In pipe or rod earthing, a metal pipe or rod made of copper or galvanized iron is driven vertically into the ground. The pipe or rod is connected to the electrical system's neutral point and serves as an electrode for dissipating fault currents into the earth.

Strip Earthing: Strip earthing involves burying a wide metallic strip made of copper or galvanized iron horizontally in the ground. The strip is typically buried at a shallow depth and connected to the electrical system's neutral point. Strip earthing is suitable for rocky or dry soil conditions where driving rods or pipes may be challenging.

Plate and Pipe Combination Earthing: This method combines the advantages of plate and pipe earthing by using both a buried plate and a driven pipe or rod. The plate provides a large contact area with the earth, while the pipe or rod offers deeper penetration and lower resistance.

Chemical Earthing: Chemical earthing involves enhancing the conductivity of the earth electrode by surrounding it with a conductive compound, such as bentonite or salt. This method improves the contact between the electrode and the surrounding soil, reducing the earth resistance and improving the efficiency of earthing systems.

Concrete Encased Electrode (CEE): CEE involves burying a metal conductor, such as copper or steel, encased in concrete. The concrete provides mechanical protection and stability for the electrode, while the metal conductor ensures electrical conductivity.

Each method of earthing has its advantages and suitability depending on factors such as soil conditions, space availability, and local regulations. Proper earthing is essential to ensure the safety and reliability of electrical systems by effectively dissipating fault currents and minimizing the risk of electric shock and equipment damage.