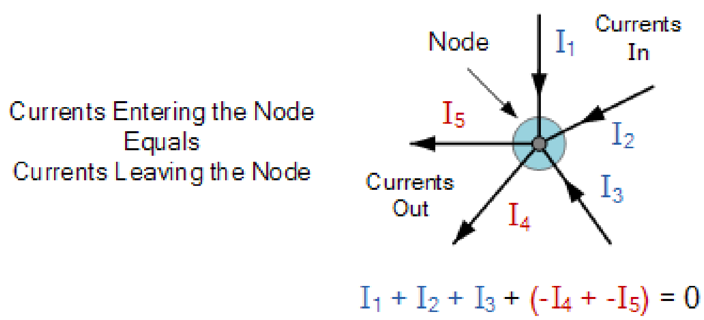
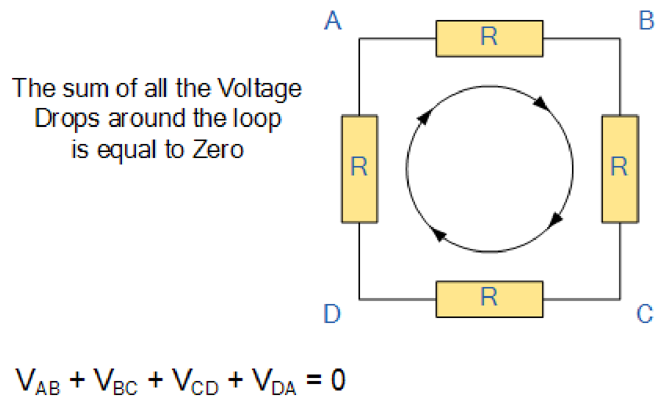
UNIT-1: DC Circuits

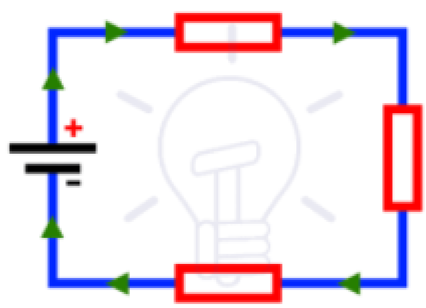
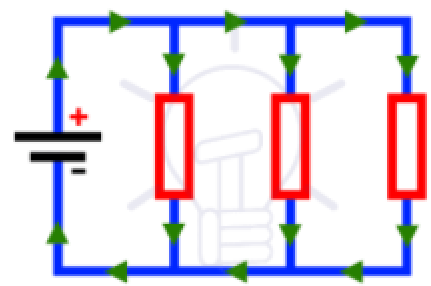
GTU End Sem Exam Solution

Exam	Question	Marks
Jan-2020	**Que: State Ohm's law and Kirchhoff's Laws in context with DC circuits** **Solution:** • **Ohm's Law** - Ohm's law states that the current ***I*** flowing in a circuit is directly proportional to the applied voltage ***V*** and inversely proportional to the resistance ***R***, provided the temperature remains constant. • **Kirchhoff's Current Law** – The algebraic sum of all branch current meeting at a junction or node is Zero. • **Kirchhoff's Voltage Law** – The algebraic sum of all branch Voltage around in a closed loop is Zero	3
Nov-2020 June-2019	**Que: State and explain Kirchhoff's Laws in context with DC circuits** **Solution:** • **Kirchhoff's Current Law** – **Kirchhoffs Current Law** or KCL, states that the "total current or charge entering a junction or node is exactly equal to the charge leaving the node as it has no other place to go except to leave, as no charge is lost within the node". In other words the algebraic sum of ALL the currents entering and leaving a node must be equal to zero, $I_{(exiting)} + I_{(entering)} = 0$. This idea by Kirchhoff is commonly known as the **Conservation of Charge**.  • **Kirchhoff's Voltage Law** – **Kirchhoffs Voltage Law** or KVL, states that "in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop" which is also equal to zero. In other words the algebraic sum of all voltages within the loop must be equal to zero. This idea by Kirchhoff is known as the **Conservation of Energy**.	3



June-2019 **Que: Compare the resistive series and parallel circuit.** **3**

Solution:

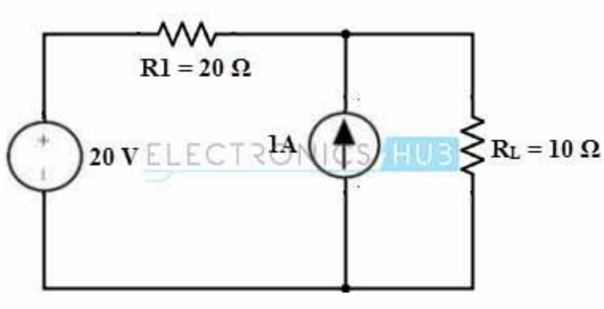
Series Circuit	Parallel Circuit
	
A circuit is said to be a series circuit when the flow of current is the same throughout all the components in the circuit.	A parallel circuit refers to a circuit with two or more two paths for the current to flow.
If a fault occurs at one point, the total circuit will break.	In a parallel circuit, if any one component gets damaged, the current does not stop and continues to flow through the other components; hence other components work efficiently.
If V is the total voltage across the total components in the series circuit, it is equal to V1+V2+V3.	f V is the total voltage across the total components in the parallel circuit, it is equal to V1=V2=V3
If I is the total current through all the component of series circuit then It is equal to I = I1 = I2 = I3	If I is the total current through all the component of parallel circuit then It is equal to I = I1 + I2 + I3
The equivalent resistance is always more than highest value of resistance in the series connection.	The equivalent resistance always has a less value than any of the single resistors connected parallely.
R = R1 + R2 + R3 + ……+ RN	R = 1/R1 + 1/R2 + 1/R3+…….+1/RN

Nov-2020

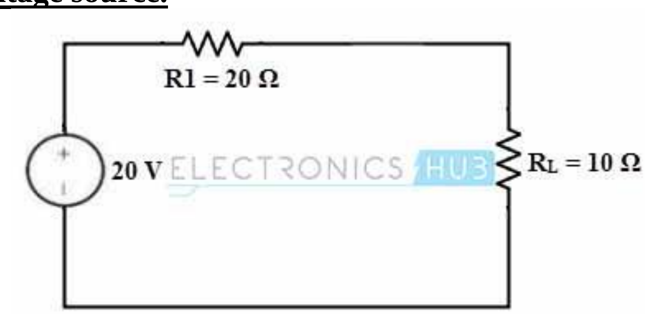
Que: State the superposition theorem with suitable example. **4**

Solution:

- The superposition theorem states that in any linear bilateral network that consisting of two or more independent sources, current through (or voltage across) an element is the algebraic sum of the currents through (voltages across) that element caused by each independent source acting alone with all other sources are replaced by their internal resistances.
- Example:- Find the current through 10ohm By using superposition theorem.

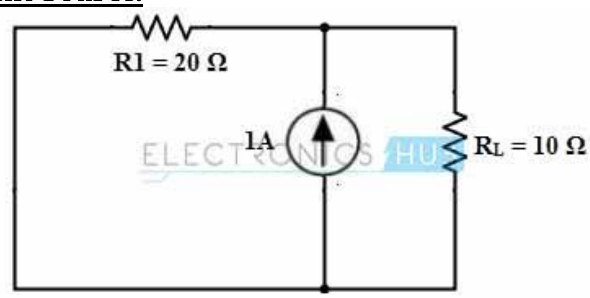


- **<u>Case - 1 Only Voltage source.</u>**



So the Current of the circuit I_{L1} = 20/ (20+10) = 20/30 = 2/3 = 0.66A which is the same current passing through 10 ohm.

- **<u>Case -2 Only Current Source.</u>**



By using current divider rule current through 10 ohm resistor is

I_{L2} = (20/20+10) x 1 = 20/30 = 0.666A

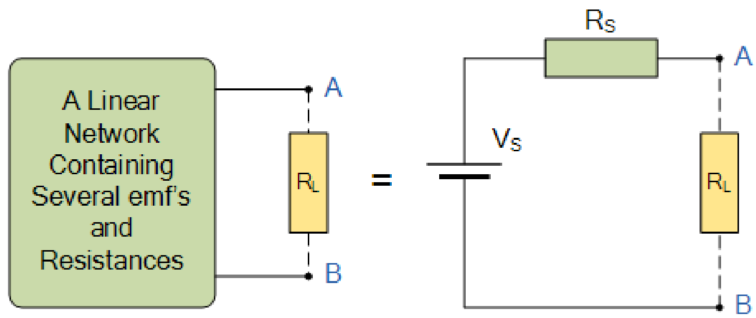
So Total I_L = I_{L1} + I_{L2} = 0.666 + 0.666 = 1.333A

Jan-2020

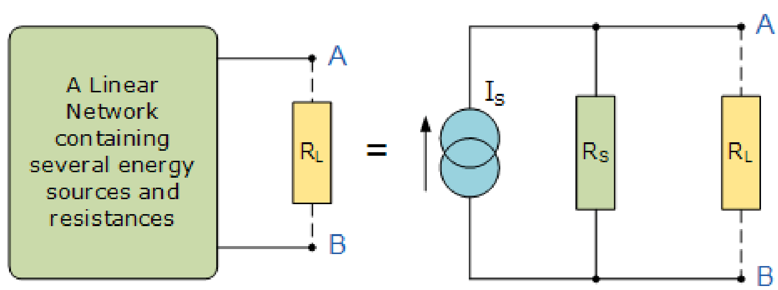
Que: State Thevenin's and Norton's Theorem. **3**

Solution:

- **Thevenin's Theorem**
- "Any linear circuit containing several voltages and resistances can be replaced by just one single voltage in series with a single resistance connected across the load".
- In other words, it is possible to simplify any electrical circuit, no matter how complex, to an equivalent two-terminal circuit with just a single constant voltage source in series with a resistance (or impedance) connected to a load.



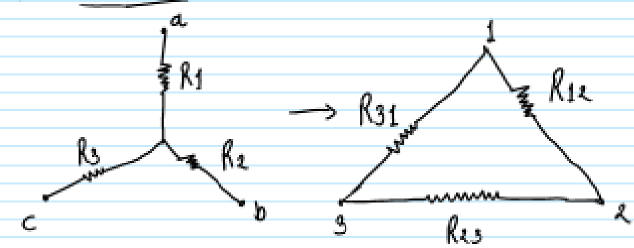
- **Norton's Theorem**
- "Any linear circuit containing several energy sources and resistances can be replaced by a single Constant Current generator in parallel with a Single Resistor".
- As far as the load resistance, R_L is concerned this single resistance, R_S is the value of the resistance looking back into the network with all the current sources open circuited and I_S is the short circuit current at the output terminals.



Jan-2020 **Que: Derive an expression for equivalent resistances of a star connected network to transform into a Delta connected network.** **7**

Solution:

Star - Delta transformation:-



$$\therefore R_1 = \frac{R_{12} R_{31}}{R_{12} + R_{23} + R_{31}} \quad \text{--- (1)}$$

$$R_2 = \frac{R_{12} R_{23}}{R_{12} + R_{23} + R_{31}} \quad \text{--- (2)}$$

$$R_3 = \frac{R_{23} R_{31}}{R_{12} + R_{23} + R_{31}} \quad \text{--- (3)}$$

Now eqn(1) × eqn(2) + eqn(2) × eqn(3) + eqn(3) × eqn(1)

$$\therefore R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_{12}^2 R_{23} R_{31} + R_{12} R_{23}^2 R_{31} + R_{12} R_{23} R_{31}^2}{(R_{12} + R_{23} + R_{31})^2}$$

Taking $R_{12}, R_{23}, \& R_{31}$ common

$$\therefore R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_{12} R_{23} R_{31} (R_{12} + R_{23} + R_{31})}{(R_{12} + R_{23} + R_{31})^2}$$

$$\therefore R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_{12} R_{23} R_{31}}{R_{12} + R_{23} + R_{31}} \quad \text{----- eqn (4)}$$

Now eqn(4) ÷ eqn(1)

$$\therefore \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1} = \frac{\dfrac{R_{12} R_{23} R_{31}}{R_{12} + R_{23} + R_{31}}}{\dfrac{R_{12} R_{31}}{R_{12} + R_{23} + R_{31}}}$$

$$\therefore R_{23} = R_2 + R_3 + \frac{R_2 R_3}{R_1}$$

Same as eqn(4) ÷ eqn(2)

$$R_{31} = R_3 + R_1 + \frac{R_3 R_1}{R_2}$$

& eqn(4) ÷ eqn(3)

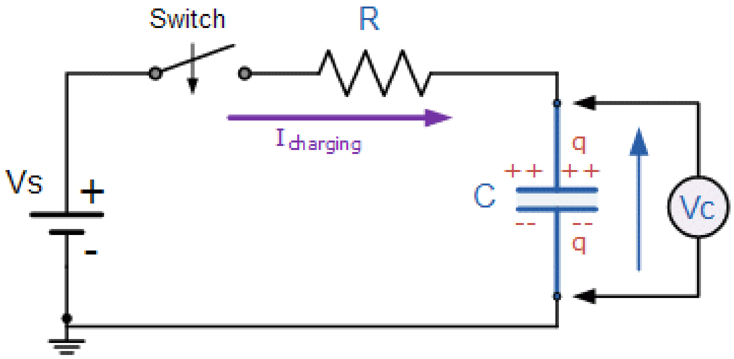
$$R_{12} = R_1 + R_2 + \frac{R_1 R_2}{R_3}$$

Jan-2020 **Jan-2019** **Que: Derive an expression for the voltage across the capacitor during charging through the resistor at any instant $V_C = V(1-e^{-t/RC})$. Assume that RC series circuit is connected across a DC supply of voltage V.** **7**

OR

Derive the equations of capacitor voltage and circuit current in a series R-C circuit connected to a DC supply through a switch. Assume that switch is initially open and it is closed at time t=0 second.

Solution:



- Consider a circuit consisting of resistance of R ohms and a capacitor of capacitance C farads connected in series with switch S and a battery of V volts.
- At the instant of closing the switch, No charge on the capacitor and Potential difference across the capacitor is zero.
- As a result, the entire voltage V acts momentarily across the resistors R and charging current is maximum say I_m.
- Initial charging current, $I_m = V/R$
- Let at any instant during charging,
- V_c = p.d. across the capacitor
- i = charging current
- q_c = charge on the capacitor = CV_c
- According to KVL, Applied voltage = Voltage across capacitor+ voltage across resistor

$$V = V_c + iR$$

$$V = V_c + R\frac{dq_c}{dt}$$

$$V = V_c + R\frac{d(CV_c)}{dt}, \qquad V = V_c + RC\frac{d(V_c)}{dt}$$

$$V - V_c = RC\frac{d(V_c)}{dt}$$

$$\therefore \frac{-dV_c}{V-V_c} = -\frac{dt}{RC}, \qquad \therefore \frac{-dV_c}{V-V_c} = -\frac{dt}{RC}$$

- Integrating both the side

$$\int \frac{-dV_c}{V-V_c} = \int -\frac{dt}{RC}$$

$$\log_e^{(V-V_c)} = \frac{-t}{RC} + K$$

- Where, K is a constant of integration. Its value can be determined from the initial conditions. At the instant of closing the switch S,

$$t = 0, \quad V_c = 0$$

$$\log_e^{V} = K$$

- Putting the value of K= $\log_e V$

$$\log_e^{(V-V_c)} = \frac{-t}{RC} + \log_e^V \qquad \log_e^{(V-V_c)} - \log_e^V = \frac{-t}{RC}$$

$$\log_e\left(\frac{V-V_c}{V}\right) = \frac{-t}{RC} \qquad \frac{V-V_c}{V} = e^{\frac{-t}{RC}}$$

$$V_c = V\left[1-e^{\frac{-t}{RC}}\right] \qquad V_c = V\left[1-e^{\frac{-t}{\lambda}}\right]$$

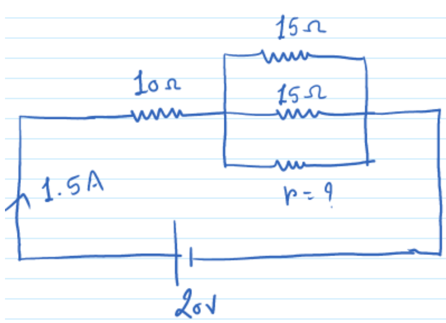
- Where λ = CR is known as time constant.
- **Variation of charging current with time**

$V - V_c = iR$ $\qquad i = \frac{V-V_c}{R}$

$$i = \frac{V - V\left[1-e^{\frac{-t}{\lambda}}\right]}{R} \qquad i = \frac{V}{R}e^{\frac{-t}{\lambda}} \qquad i = I_m e^{\frac{-t}{\lambda}}$$

Nov - 2020 **A resistance of 10Ω is connected in series with two resistances each of the 15Ω arranged in parallel. What resistance must be shunted across this parallel combination so that total current taken shall be 1.5 A with 20 V applied.** **3**

Solution:



Total Resistance of the ckt.

$R = \frac{V}{I} = \frac{20}{1.5} = 13.33\ \Omega$

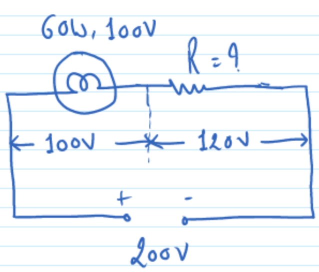
& also $R_{equ} = 10 + (15 \| 15 \| r)$

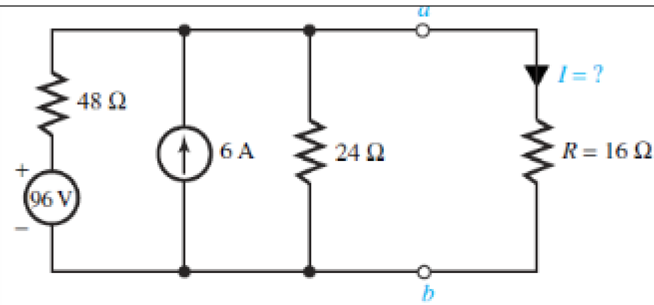
$\therefore 13.33 = 10 + (7.5 \| r)$ $\left(\because 15\|15 = \frac{15\times15}{30} = 7.5 \right)$

$\therefore 13.33 - 10 = \frac{7.5 \times r}{7.5 + r}$ $\qquad \therefore 3.33(7.5 + r) = 7.5r$

$\therefore 24.95 + 3.33r = 7.5r$ $\qquad \therefore 24.95 = 7.5r - 3.33r = 4.17r$

$\therefore \boxed{r = \frac{24.95}{4.17} = 5.98\ \Omega}$

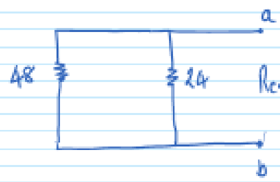
Nov – 2020	**Calculate the resistance of a 100 m length of wire having a uniform cross sectional area of 0.02 mm^2 and having resistivity of 40 μΩcm** **Solution** $l = 100m,\ a = 0.02\,mm^2$ & $\rho = 40\mu\Omega\,cm = 40\times10^{-6}\,\Omega\,cm$ $\therefore R = \frac{\rho l}{a}$ $\therefore l = 100m,\ a = 0.02\,mm^2 = 0.02\times10^{-6}\,m^2$ & $\rho = 40\times10^{-6}\times10^{-2}\,m \therefore 40\times10^{-8}\,m$ $\therefore R = \frac{40\times10^{-8}\times100}{0.02\times10^{-6}} = \boxed{2000\Omega}$	**3**
Jan - 2020	**A 100V,60 Watt bulb is to be operated from a 220V supply. What is the resistance to be connected in series with the bulb to glow normally?** **Solution**  Power of the bulb = 60W Voltage of the bulb = 100V $\therefore$ Current of the bulb = $I = \frac{P}{V}$ $\therefore I = \frac{60}{100} = 0.6A$ Now as lamp & Resistance R connected in series Current Remain same. Now Voltage across Resistance R = Supply Voltage − Voltage across bulb $= 220 - 100 = 120V$ $\therefore$ So, $R = \frac{V}{I} = \frac{120}{0.6} = \boxed{200\,\Omega}$	**4**
June - 2019	**Consider the circuit shown in Figure. Reduce the portion of the circuit to the left of terminals a–b to (a) Thévenin equivalent and (b) a Norton equivalent. Find the current through R = 16 Ohm.**	**7**



Solution

⇒ Step-1 Find R_{th} or R_N (∵ open all current source & short all voltage source)

Remove the load resistance across the terminal ab & find Requivalent

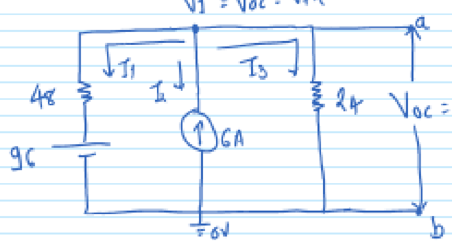


$R_{eq} = R_{th} = R_N$

$\therefore R_{th} = (48 \| 24) = \frac{48 \times 24}{48 + 24}$

$\therefore \boxed{R_{th} = R_N = 16\Omega}$

Step-2 Find V_{th} (∵ Find the open circuit voltage across terminal ab by removing load resistance)



Apply KCL at Node-1

$I_1 + I_2 + I_3 = 0$

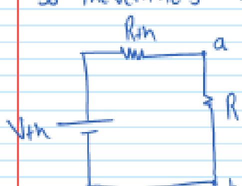
(∵ You can also apply mesh or Superposition)

$\frac{V_1 - 96}{48} - 6 + \frac{V_1}{24} = 0$

take LCM = 48

$\therefore V_1 - 96 - 288 + 2V_1 = 0$ $\therefore 3V_1 = 384$ $\therefore \boxed{V_1 = 128V = V_{th}}$

So thevenine's equivalent ckt.



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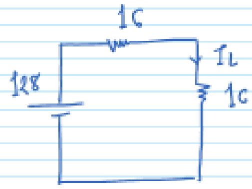
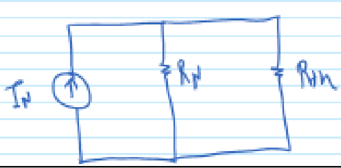


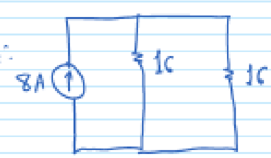
$\therefore I_L = \frac{V_{th}}{R_{th} + R_L} = \frac{128}{32} = \boxed{4A}$

& Norton's Equivalent ckt.



$\therefore I_N = \frac{V_{th}}{R_{th}} = \frac{128}{16} = 8A$

∴



Nov - 2020	**For the Wheatstone bridge diagram shown in Figure 1, obtain the current flowing through the 20Ω resistance using Thevenin's equivalent network.**	7

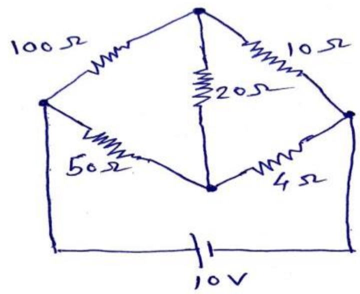
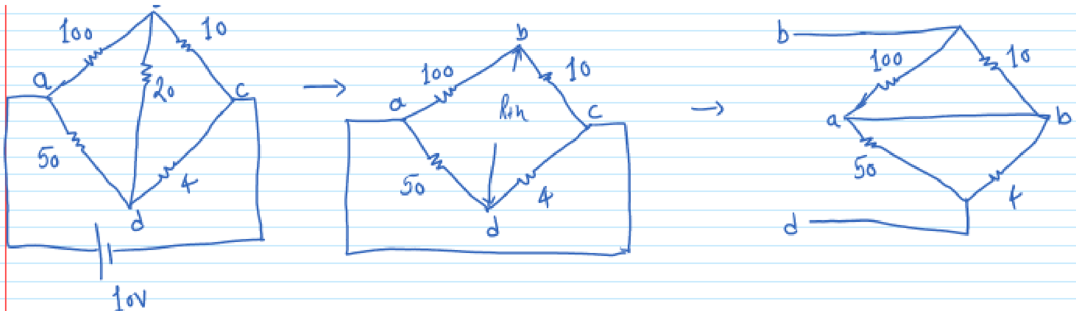


Figure - 1

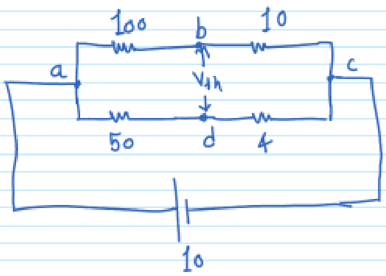
Solution



So $R_{th} = (100 \| 10) + (50 \| 4) = \frac{100 \times 10}{110} + \frac{50 \times 4}{50+4} = 9.09 + 3.70$

$\therefore$ $\boxed{R_{th} = 12.79\,\Omega}$

& V_{th} =



Apply Voltage divider Rule:

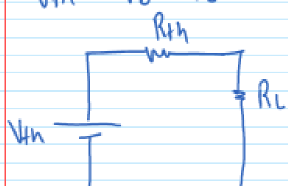
Potential of b wrt c

$= \frac{10}{100+10} \times 10 = 0.909V$

& potential of d wrt c

$= \frac{4}{50+4} \times 10 = 0.74V$

$V_{th} = V_b - V_d = 0.909 - 0.74 = 0.169\ V$



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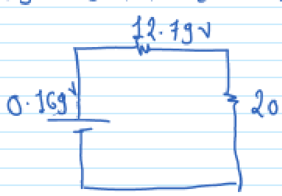

$\therefore I_L = \frac{V_{th}}{R_{th} + R_L}$

$= \frac{0.169}{12.79 + 20} = \boxed{5.15\,mA}$

UNIT-2: AC Circuits

GTU End Sem Exam Solution

<table>
<tr><th>Exam</th><th>Question</th><th>Marks</th></tr>
<tr><td>Nov 2020</td><td>

Define the following terms for AC (alternating current) signal:
(i) Crest Factor (ii) Form Fator (iii) Average Value (iv) RMS Value.

(i) Crest Factor/Peak Factor:

Crest factor is defined as the ratio of peak value to rms value of an alternating quantity (current or voltage).

It is defined as the ratio $K_a = \dfrac{\text{maximum value}}{\text{r.m.s. value}}$

(ii) Form Factor:

The ratio of the rms value to the average value of an alternating quantity (current or voltage) is called Form Factor.

It is defined as the ratio, $K_f = \dfrac{\text{r.m.s. value}}{\text{average value}}$

(iii) Average Value:

The average value I_a of an alternating current is expressed *by that steady current which transfers across any circuit the same charge as is transferred by that alternating current during the same time.*

(iv) RMS Value:

The r.m.s. value of an alternating current *is given by that steady (d.c.) current which when flowing through a given circuit for a given time produces the same* heat *as produced by the alternating current when flowing through the same circuit for the same time.*

</td><td>04</td></tr>
<tr><td>NOV 2020</td><td>

A current of 5 A flows through a non-inductive resistance in series with a choking coil when supplied at 250V,50Hz. If the voltage across the resistance is 125 V and across the coil 200V, calculate (i) impedance, reactance and resistance of the coil (ii) the power absorbed by the coil (iii) and total power.

Solution. As seen from the vector diagram of Fig. 13.17 (*b*).

$BC^2 + CD^2 = 200^2$ ...(*i*) $(125 + BC)^2 + CD^2 = 250^2$ ...(*ii*)

Subtracting Eq. (*i*) from (*ii*), we get, $(125 + BC)^2 - BC^2 = 250^2 - 200^2$

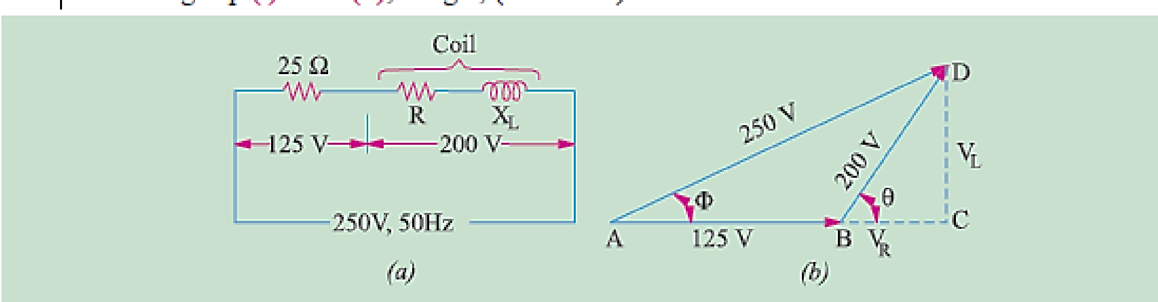

Fig. 13.17

$\therefore \quad BC = 27.5$ V; $CD = \sqrt{200^2 - 27.5^2} = 198.1$ V

(*i*) Coil impedance $= 200/5 = \mathbf{40\ \Omega}$

$V_R = IR = BC$ or $5R = 27.5 \quad \therefore P = 27.5/5 = \mathbf{5.5\ \Omega}$

Also $V_L = I \cdot X_L = CD = 198.1 \quad \therefore X_L = 198.1/5 = \mathbf{39.62\ \Omega}$

or $X_L = \sqrt{40^2 - 5.5^2} = \mathbf{39.62\ \Omega}$

</td><td>07</td></tr>
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(*ii*) Power absorbed by the coil is $= I^2 R = 5^2 \times 5.5 = 137.5$ W

Also $P = 200 \times 5 \times 27.5/200 =$ **137.5 W**

(*iii*) Total power $= VI\cos\phi = 250 \times 5 \times AC/AD = 250 \times 5 \times 152.5/250 =$ **762.5 W**

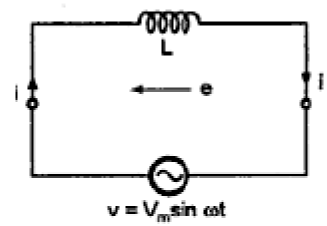
The power may also be calculated by using $I^2 R$ formula.

Series resistance $= 125/5 = 25\ \Omega$

Total *circuit* resistance $= 25 + 5.5 = 30.5\ \Omega$

$\therefore$ Total power $= 5^2 \times 30.5 =$ **762.5 W**

NOV 2020 — **Prove that the current in purely inductive circuit lags its voltage by 90° and average power consumption in pure inductor is zero.** — 07



Consider a simple circuit consisting of a pure inductance of L henries, connected across a voltage given by the equation, $v = V_m \sin \omega t$. The circuit is shown in the Fig. 7.4.

Pure inductance has zero ohmic resistance. Its internal resistance is zero. The coil has pure inductance of L henries (H).

When alternating current 'i' flows through inductance 'L', it sets up an alternating magnetic field around the inductance. This changing flux links the coil and due to self inductance, e.m.f. gets induced in the coil. This e.m.f. opposes the applied voltage.

The self induced e.m.f. in the coil is given by,

Self induced e.m.f., $e = -L\dfrac{di}{dt}$

At all instants, applied voltage, V is equal and opposite to the self induced e.m.f., e

$$\therefore \quad v = -e = -\left(-L\frac{di}{dt}\right)$$

$$\therefore \quad v = L\frac{di}{dt} \quad \text{i.e. } V_m \sin \omega t = L\frac{di}{dt}$$

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

$$\therefore \quad i = \int di = \int \frac{V_m}{L}\sin \omega t\, dt = \frac{V_m}{L}\left(\frac{-\cos \omega t}{\omega}\right)$$

$$= -\frac{V_m}{\omega L}\sin\left(\frac{\pi}{2} - \omega t\right) \quad \text{as } \cos \omega t = \sin\left(\frac{\pi}{2} - \omega t\right)$$

$$\therefore \quad i = \frac{V_m}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right) \quad \text{as } \sin\left(\frac{\pi}{2} - \omega t\right) = -\sin\left(\omega t - \frac{\pi}{2}\right)$$

$$\therefore \quad \boxed{i = I_m \sin\left(\omega t - \frac{\pi}{2}\right)}$$

Where $I_m = \dfrac{V_m}{\omega L} = \dfrac{V_m}{X_L}$

Where $\boxed{X_L = \omega L = 2\pi f L\ \Omega}$

The expression for the instantaneous power can be obtained by taking the product of instantaneous voltage and current.

$$\therefore \quad P = v \times i = V_m \sin \omega t \times I_m \sin\left(\omega t - \frac{\pi}{2}\right)$$

$$= -V_m I_m \sin(\omega t) \cos(\omega t) \quad \text{as } \sin\left(\omega t - \frac{\pi}{2}\right) = -\cos \omega t$$

$$\therefore \quad \boxed{P = -\frac{V_m I_m}{2} \sin(2\omega t)} \quad \text{as } 2 \sin \omega t \cos \omega t = \sin 2\omega t$$

Key Point : *This power curve is a sine curve of frequency double than that of applied voltage.*

The average value of sine curve over a complete cycle is always zero.

$$P_{av} = \int_0^{2\pi} -\frac{V_m I_m}{2} \sin(2\omega t)\, d(\omega t) = 0$$

The Fig. 7.7 shows voltage, current and power waveforms.

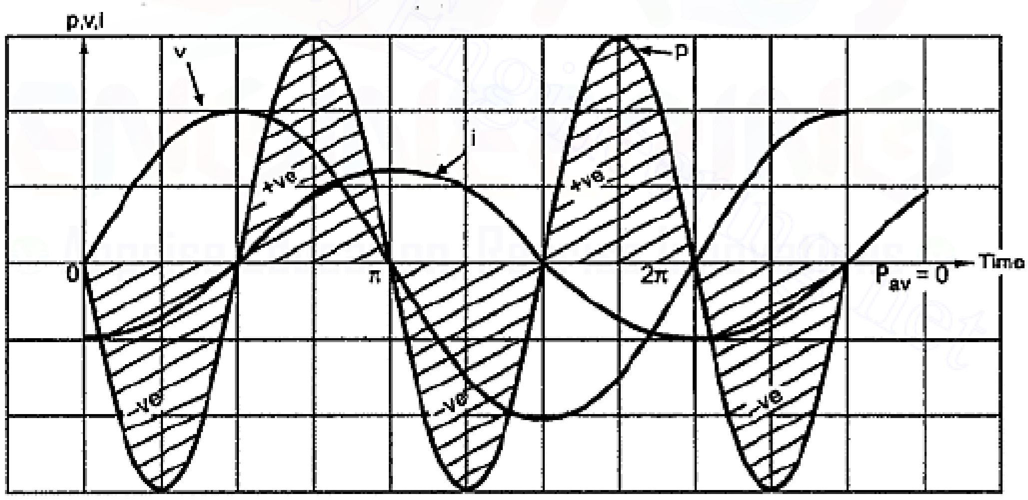
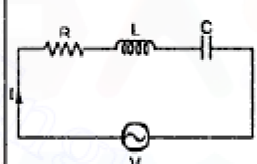
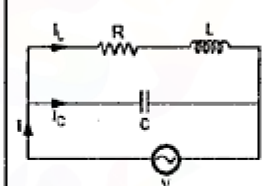


Fig. 7.7 Waveforms of voltage, current and power

NOV 2020/ JAN 2020

Write the comparison between series resonance and parallel resonance condition in AC circuit. 03

No.	Parameter	Series resonant	Parallel resonant
1.	Circuit		
2.	Type of circuit	Purely resistive	Purely resistive
3.	Power factor	Unity	Unity
4.	Impedance	Minimum Z = R	Dynamic but maximum $Z_D = \frac{L}{RC}$

5.	Frequency	$f_r = \frac{1}{2\pi\sqrt{LC}}$	$f_r = \frac{1}{2\pi\sqrt{LC}}$
6.	Current	Maximum $I = \frac{V}{R}$	Minimum $I = \frac{V}{Z_0}$
7.	Magnification	Voltage magnification	Current magnification
8.	Quality factor	$Q = \frac{\omega_r L}{R} = \frac{\omega_r}{B.W.}$	$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$
9.	Nature	Acceptor	Rejector
10.	Practical use	Radio circuits sharpness of tunning circuit	Impedance for matching, tuning, as a filter

NOV 2020/ JAN 2020

Derive the relation between line-voltage and phase-voltage for three-phase four wire star connection network. Also, prove that the total three-phase power consumption in star connection is PT = √3 V_L I_L cos ϕ. 07

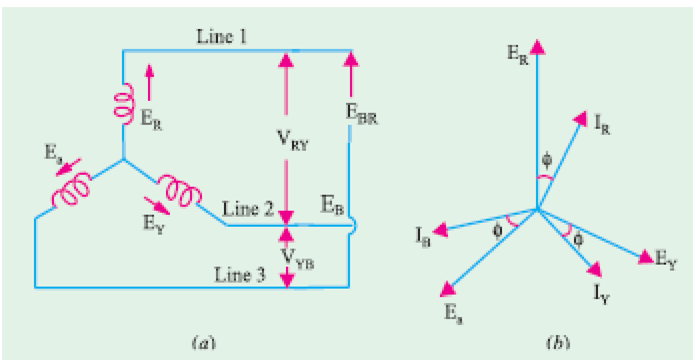


Fig. 19.12

The voltage induced in each winding is called the *phase* voltage and current in each winding is likewise known as *phase* current. However, the voltage available between any pair of terminals (or outers) is called *line* voltage (V_L) and the current flowing in each *line* is called *line* current (I_L).

As seen from Fig. 19.12 (*a*), in this form of interconnection, there are two phase windings between each pair of terminals but since their *similar* ends have been joined together, they are in opposition. Obviously, the *instantaneous* value of p.d. between any two terminals is the *arithmetic difference* of the two phase e.m.fs. concerned. However, the r.m.s. value of this p.d. is given by the *vector difference* of the two phase e.m.fs.

The vector diagram for phase voltages and currents in a star connection is shown in Fig. 19.12.

(*a*) Line Voltages and Phase Voltages

The p.d. between line 1 and 2 is $V_{RY} = E_R - E_Y$ ... vector difference.

Hence, V_{RY} is found by compounding E_R and E_Y reversed and its value is given by the diagonal of the parallelogram of Fig. 19.13. Obviously, the angle between E_R and E_Y reversed is 60°. Hence if $E_R = E_Y = E_B =$ say, E_{ph} – the phase e.m.f., then

$$V_{RY} = 2 \times E_{ph} \times \cos(60°/2)$$

$$= 2 \times E_{ph} \times \cos 30° = 2 \times E_{ph} \times \frac{\sqrt{3}}{2} = \sqrt{3}\, E_{ph}$$

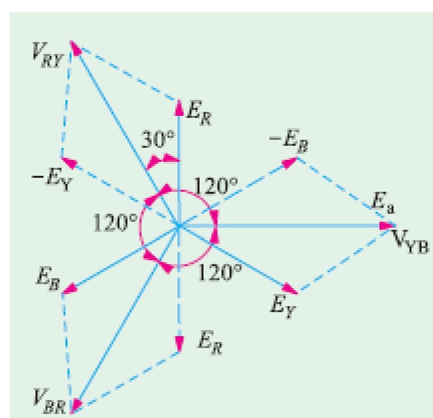


Fig. 19.13

Similarly, $V_{YB} = E_Y - E_B = \sqrt{3} \cdot E_{ph}$ ...vector difference

and $V_{BR} = E_B - E_R = \sqrt{3} \cdot E_{ph}$

Now $V_{RY} = V_{YB} = Y_{BR} =$ line voltage, say V_L. Hence, in star connection $V_L = \sqrt{3} \cdot E_{ph}$

It will be noted from Fig. 19.13 that

1. Line voltages are 120° apart.

2. Line voltages are 30° ahead of their respective *phase* voltages.

3. The angle between the line currents and the corresponding line voltages is $(30 + \phi)$ with current lagging.

(*b*) Line Currents and Phase Currents

It is seen from Fig. 19.12 (*a*) that each line is in series with its individual phase winding, hence the line current in each line is the same as the current in the phase winding to which the line is connected.

Current in line 1 = I_R ; Current in line 2 = I_Y; Current in line 3 = I_B

Since $I_R = I_Y = I_B$ = say, I_{ph} – the phase current

$\therefore$ line current $I_L = I_{ph}$

(*c*) Power

The total active or true power in the circuit is the sum of the three phase powers. Hence,

total active power = 3 × phase power or $P = 3 \times V_{ph} I_{ph} \cos \phi$

Now $V_{ph} = V_L / \sqrt{3}$ and $I_{ph} = I_L$

Hence, in terms of line values, the above expression becomes

$$P = 3 \times \frac{V_L}{\sqrt{3}} \times I_L \times \cos\phi \text{ or } P = \sqrt{3}\, V_L\, I_L \cos\phi$$

JAN 2020 **A single phase R-L-C circuit having resistance of 8Ω, inductance of 80mH and capacitance of 100µF is connected across single phase ac 150 V , 50Hz supply. Calculate the current, power factor and voltage drop across inductance and capacitance.** 07

Calculations

The inductive reactance,

$$X_L = 2\pi f L$$

$$\Rightarrow X_L = 2 \times 3.14 \times 50 \times 80 \times 10^{-3}$$

$$\Rightarrow X_L = 25.12\,\Omega$$

The capacitive reactance,

$$X_c = \frac{1}{2\pi f C}$$

$$\Rightarrow X_c = \frac{1}{2 \times 3.14 \times 50 \times 100 \times 10^{-6}}$$

$$\Rightarrow X_c = 31.84\,\Omega$$

The Impedance,

$$Z = \sqrt{R^2 + (X_c - X_L)^2}$$

$$\Rightarrow Z = \sqrt{8^2 + (31.84 - 25.12)^2}$$

$$\Rightarrow Z = \sqrt{8^2 + (6.72)^2}$$

$$\Rightarrow Z = \sqrt{64 + 45.15}$$

RMS current,

$$\frac{V}{Z} = \frac{150}{10.44} = 14.36\ A$$

Power Factor,

$$\frac{R}{Z} = \frac{8}{10.44} = 0.766$$

Voltage across the Inductor,

$$I\,X_L = 14.36 \times 25.12 = 360.72\ V$$

Voltage across the Capacitor ,

$$I\,X_C = 14.36 \times 31.84 = 457.22\ V$$

JAN 2020

Define the following terms in connection with AC waveforms: 03

1. Q-Factor 2. Power Factor 3. Form factor.

1. Q-Factor:

The Q-factor of an R-L-C series circuit can be defined in the following different ways.

(i) it is given by the voltage magnification produced in the circuit at resonance.

$\therefore$ Q − factor, $$Q_0 = \frac{\omega_0 L}{R} = \frac{2\pi f_0 L}{R} = \tan\phi$$

2. Power Factor:

It is the ratio of active (true) power to apparent power. It is also defined as the cosine of the angle between voltage and current signals.

3. Form Factor:

The ratio of the rms value to the average value of an alternating quantity (current or voltage) is called Form Factor.

It is defined as the ratio, $K_f = \dfrac{\text{r.m.s. value}}{\text{average value}}$

<table>
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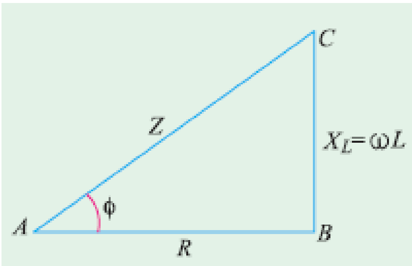
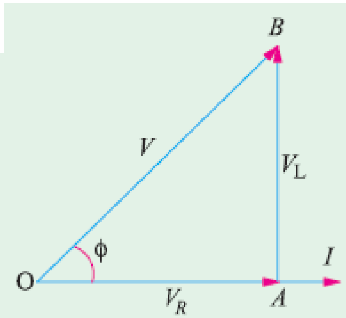
Draw impedance triangle, Voltage triangle, Power triangle for single phase R-L series circuit.

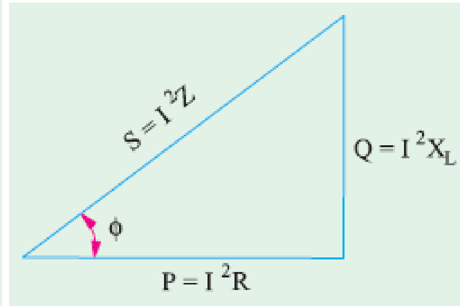
Impedance Triangle:



(i) Impedance Triangle



(ii) Voltage Triangle



(ii) Power Triangle

</td><td>04</td></tr>
<tr><td>JAN 2020</td><td>

Define the terms:- 1. Real power 2. Reactive power 3. Apparent power.

Let a series *R-L* circuit draw a current of *I* when an alternating voltage of r.m.s. value *V* is applied to it. Suppose that current lags behind the applied voltage by ϕ. The three powers drawn by the circuit are as under :

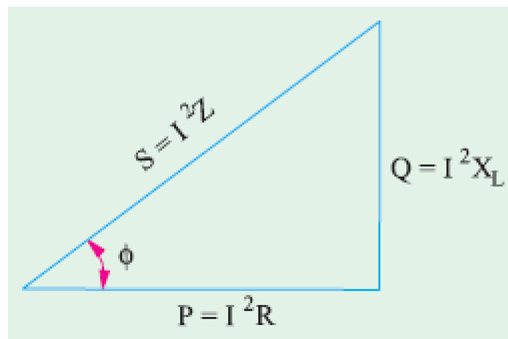


Fig. 13.11

(i) apparent power (S)

It is given by the product of r.m.s. values of applied voltage and circuit current.

$\therefore \quad S = VI = (IZ) \cdot I = I^2 Z$ volt-amperes (*VA*)

(ii) active power (P or W)

It is the power which is actually dissipated in the circuit resistance. $P = I^2 R = VI \cos\phi$ watts

(iii) reactive power (Q)

It is the power developed in the inductive reactance of the circuit.

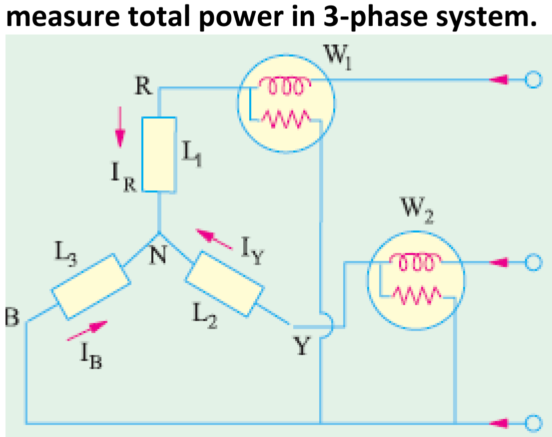
$Q = I^2 X_L = I^2 \cdot Z \sin\phi = I \cdot (IZ) \cdot \sin\phi = VI \sin\phi$ volt-amperes-reactive (VAR)

These three powers are shown in the power triangle of Fig. 13.11 from where it can be seen that

$$S^2 = P^2 + Q^2 \text{ or } S = \sqrt{P^2 + Q^2}$$

</td><td>03</td></tr>
<tr><td>JAN 2020/ JUNE 2019</td><td>

With neat circuit diagram and a phasor diagram prove that two watt meters are sufficient to measure total power in 3-phase system.



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</table>

19.18. Two Wattmeter Method– *Balanced Load*

If the load is balanced, then power factor of the load can also be found from the two wattmeter readings. The Y-connected load in Fig. 19.47 (b) will be assumed inductive. The vector diagram for such a balanced Y-connected load is shown in Fig. 19.48. We will now consider the problem in terms of r.m.s. values instead of instantaneous values.

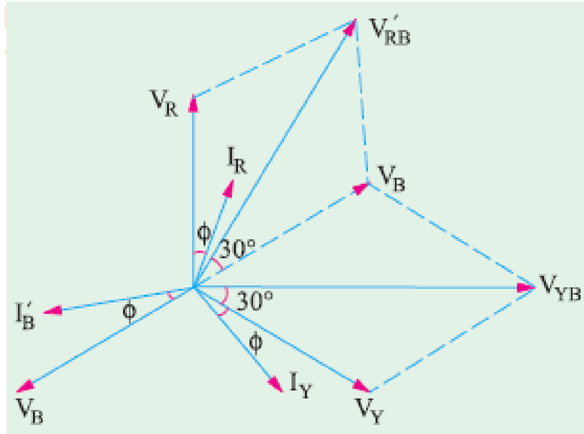


Fig. 19.48

Let V_R, V_Y and V_B be the r.m.s. values of the three phase voltages and I_R, I_Y and I_B the r.m.s. values of the currents. Since these voltages and currents are assumed sinusoidal, they can be represented by vectors, the currents lagging behind their respective phase voltages by ϕ.

Current through wattmeter W_1 [Fig. 19.47 (b)] is = I_R.

P.D. across voltage coil of W_1 is

$$V_{RB} = V_R - V_B \quad \text{... vectorially}$$

This V_{RB} is foundby compounding V_R and V_B reversed as shown in Fig. 19.42. It is seen that phase difference between V_{RB} and I_R = $(30° - \phi)$.

$\therefore$ Reading of $W_1 = I_R\, V_{RB} \cos(30° - \phi)$

Similarly, as seen from Fig. 19.47 (b). Current through $W_2 = I_Y$

P.D. across $W_2 = V_{YB} = V_Y - V_B$ ... vectorially

Again, V_{YB} is found by compounding V_Y and V_B reversed as shown in Fig. 19.48. The angle between I_Y and V_{YB} is $(30° + \phi)$. Reading of $W_2 = I_Y V_{YB} \cos(30° + \phi)$

Since load is balanced, $V_{RB} = V_{YB}$ = line voltage V_L; $I_Y = I_R$ = line current, I_L

$$\therefore \quad W_1 = V_L I_L \cos(30° - \Phi) \text{ and } W_2 = V_L I_L \cos(30° + \phi)$$

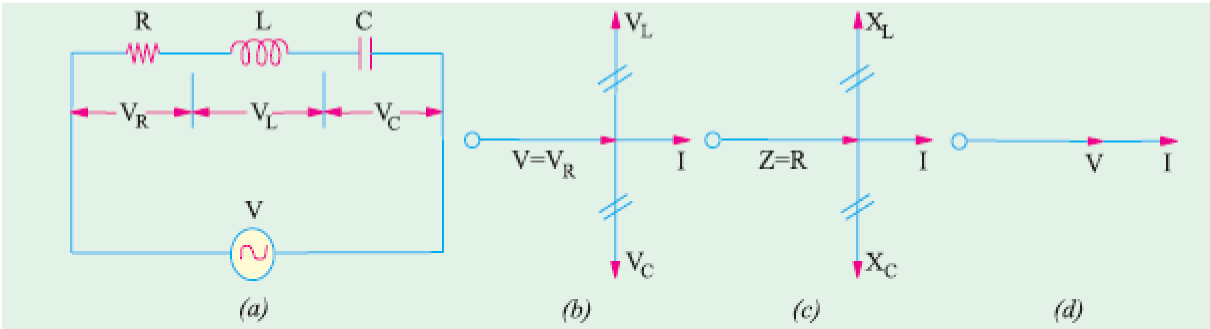
$$\therefore \quad W_1 + W_2 = V_L I_L \cos(30° - \phi) + V_L I_L (\cos(30° + \phi)$$

$$= V_L I_L [\cos 30° \cos\phi + \sin 30° \sin\phi + \cos 30° \cos\phi - \sin 30° \sin\phi]$$

$$= V_L I_L (2\cos 30° \cos\phi) = \sqrt{3} V_L I_L \cos\phi = \text{total power in the 3-phase load}$$

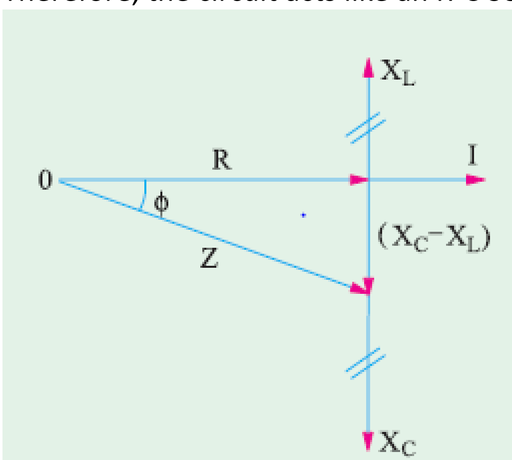
Hence, the sum of the two wattmeter readings gives the total power consumption in the 3-phase load.

JUNE 2019	**For series resonant circuit with brief description draw the phasor diagrams for following conditions (i) At resonant (ii) Below resonant (iii) Above resonant.** **(i) At Resonance:** At the resonance condition X_L=X_C. The net impedance of the circuit is only resistance. Therefore, R-L-C circuit behaves like a purely resistive circuit. The power factor of the circuit is Unity.	03



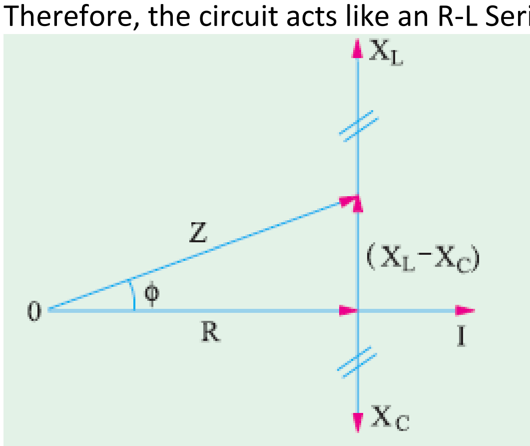
(ii) Below resonance:

At the frequencies below resonant frequency, $X_L<X_C$. The net impedance is capacitive in nature. Therefore, the circuit acts like an R-C Series circuit. The power factor of the circuit is leading.



(iii) Above resonance:

At the frequencies below resonant frequency, $X_L>X_C$. The net impedance is inductive in nature. Therefore, the circuit acts like an R-L Series circuit. The power factor of the circuit is lagging.



JUNE 2019

A series RLC circuit with L= 160 mH, C= 100 µF and R = 40 Ω is connected to a sinusoidal voltage V(t) = 40 Sinωt, with ω= 200 rad/sec. Find (i) What is the Impedance of the circuit. (ii) Let the current at any instant in the circuit be I(t) = I0 Sin(ωt-Φ). Find I0 (iii) What is the Phase Φ ? 07

Solution:

Given Data: L=160 mH, C=100 µF, R=40 Ohm, Vm=40 V, ω= 200 rad/sec

$X_L = \omega L = 200*160*10^{-3} = 32$ Ohm

$Xc = 1/\omega C = 1/(200*100*10^{-6}) = 50$ Ohm

$Z = \sqrt{40^2 + (32-50)^2} = 43.86\ \Omega$

I0 = Vm/Z = 0.911 Amp

Phase angle Φ = Cos^{-1}(R/Z) = Cos^{-1}(40/43.86) = 24.21° (leading)

JUNE 2019 | 07

A balanced star connected load of (4+j3) Ω per phase is connected to a balance 3 phase 400 V supply. Find the line current, power factor, active power and reactive power.

Solution:

Impedance per phase Zph = $(R_2^2+X_L^2)^{1/2}$= (16+9)^{½} = 5 Ohm.

In star connection Line voltage = 1.732*Phase Phase Voltage V_L = 1.732*Vph

Therefore, Vph = V_L/1.732 = 400/1.732 = 230.94 V

In star connection Line current = Phase Current = Vph/Zph = 230.94/5 = 46.18 Amp

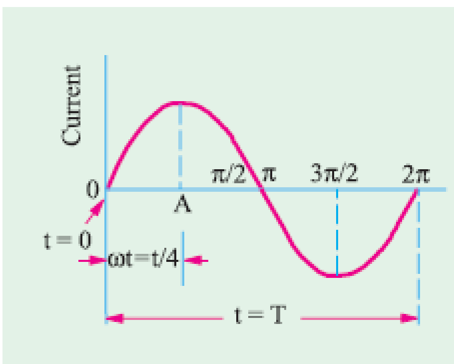
Power factor Cos Φ = R/Z = 4/5 = 0.8 (lagging)

Active power = 1.732*V_L*I_L*Cos Φ = 1.732*400*46.18*0.8 = 25594.80 Watt

Reactive Power = 1.732*V_L*I_L*Sin Φ = 1.732*400*46.18*0.6 = 19196.10 VAR

JUNE 2019 | 03

For A.C. sinusoidal current prove that Irms = 0.707 Im.



The standard form of a sinusoidal alternating current is $i = I_m \sin \omega t = I_m \sin \theta$.

The mean of the squares of the instantaneous values of current over one complete cycle is (even the value over half a cycle will do).

$$= \int_0^{2\pi} \frac{i^2 \, d\theta}{(2\pi - 0)}$$

The square root of this value is $= \sqrt{\left(\int_0^{2\pi} \frac{i^2 \, d\theta}{2\pi}\right)}$

Hence, the r.m.s. value of the alternating current is

$$I = \sqrt{\left(\int_0^{2\pi} \frac{i^2 d\theta}{2\pi}\right)} = \sqrt{\left(\frac{I_m^2}{2\pi}\int_0^{2\pi} \sin^2\theta \, d\theta\right)} \qquad (\text{put } i = I_m \sin\theta)$$

Now, $\cos 2\theta = 1 - 2\sin^2\theta \quad \therefore \; \sin^2\theta = \frac{1-\cos 2\theta}{2}$

$$\therefore \qquad I = \sqrt{\left(\frac{I_m^2}{4\pi}\int_0^{2\pi}(1-\cos 2\theta)\, d\theta\right)} = \sqrt{\left(\frac{I_m^2}{4\pi}\left|\theta - \frac{\sin 2\theta}{2}\right|_0^{2\pi}\right)}$$

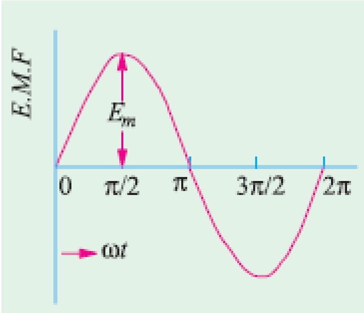
$$= \sqrt{\frac{I_m^2}{4} \; 2} \qquad \sqrt{\frac{I_m^2}{2}} \qquad \therefore \; I = \frac{I_m}{\sqrt{2}} = 0.707\, I_m$$

Hence, we find that for a symmetrical sinusoidal current

r.m.s. value of current = 0.707 × max. value of current

JAN 2019

Define Amplitude, Frequency and Time period for alternating quantities. 03



Amplitude:

The maximum value, positive or negative, of an alternating quantity is known as its amplitude.

Frequency:

The number of cycles/second is called the frequency of the alternating quantity. Its unit is hertz (Hz).

Time period:

The time taken by an alternating quantity to complete one cycle is called its time period T.

$T = 1/f$

JAN 2019

The maximum values of voltage and current in a circuit are 400 V and 20 A respectively. Both the quantities are sinusoidal with 50 Hz frequency. The instantaneous values of voltage and current at time t=0 second are 283 V and 10 A respectively (both increasing and positive). Obtain the equations of voltage and current in this circuit at time 't' second. Also find out the active power consumption in the circuit. 07

Solution:

Data given $V_m = 400V$, $I_m = 20A$, $f = 50Hz \rightarrow \omega = 2\pi f = 314$

at $t=0$ $v(t) = 283V$ and $i(t) = 10A$

Let us consider the equation for $v(t)$ & $i(t)$ as follow

$v(t) = V_m \sin(\omega t + \phi_v)$ ϕ_v = Phase angle of voltage

$i(t) = I_m \sin(\omega t + \phi_i)$ ϕ_i = Phase angle of current

Now.

at $t=0$ $v(t) = 283V$ $\therefore$ $283 = 400 \sin(0 + \phi_v)$

calculate ϕ_v in radians → $\therefore$ $\phi_v = 0.707$ radians

$\therefore \phi_v = 0.707 \times \frac{180}{\pi} = 45°$

$\therefore$ Equation of instantaneous voltage $v(t)$

$v(t) = 400 \sin(314t + 0.707)$ V

Similarly at $t=0$ $i(t) = 20A$ $\therefore 20 = 40 \sin(0 + \phi_i)$

$\therefore \sin\phi_i = 0.5$

calculate ϕ_i in radians → $\therefore \phi_i = 0.523$ radians

$\phi_i = 0.523 \times \frac{180}{\pi} = 30°$

$\therefore$ Equation of instantaneous current $i(t)$

$$i(t) = 40 \sin(314t + 0.523) \text{ Amp}$$

Now to find power $P = V_{rms} \times I_{rms} \times \cos\phi$

ϕ = phase angle between V & I $= \phi_v - \phi_i$

$$= 45^\circ - 30^\circ$$
$$= 15^\circ$$

$$\therefore P = \frac{400}{\sqrt{2}} \times \frac{20}{\sqrt{2}} \times \cos(15^\circ) = 3863.7 \text{ watt}$$

JAN 2019	**In a series R-L circuit, a voltage of 10 V at 50 Hz frequency produces a current of 750 mA. In the same circuit with same magnitude of applied voltage with a frequency of 75 Hz produces a current of 500 mA. Find out the values of R and L in the circuit.**	07

Given Data.

Case-1 $V = 10$, $I_1 = 750mA$ $f_1 = 50Hz$

$$\therefore X_{L_1} = 2\pi f_1 L = (314L)\ \Omega$$

Now.

$$Z_1 = \frac{V}{I_1} = \frac{10}{750 \times 10^{-3}} = 13.33\ \Omega$$

$$\therefore Z_1 = \sqrt{R^2 + X_{L_1}^2} = 13.33$$

$$\therefore R^2 + (314L)^2 = (13.33)^2$$

$$\therefore R^2 + 98596L^2 = 177.69 \quad \text{——(1)}$$

Case-2 $V = 10V$, $I_2 = 500mA$ $f_2 = 75Hz$

$$\therefore X_{L_2} = 2\pi f_2 L = (471L)\ \Omega$$

Now $Z_2 = \frac{V}{I_2} = \frac{10}{500 \times 10^{-3}} = 20\ \Omega$

$$Z_2 = \sqrt{R^2 + X_{L_2}^2} = 200 \quad \therefore R^2 + X_{L_2}^2 = 400$$

$$\therefore R^2 + (471L)^2 = 400 \quad \text{——(2)}$$

Using eq^n (1) and (2)

$$R^2 + 98596 L^2 = 177.69 \quad —(1)$$

$$R^2 + 221814 L^2 = 400 \quad —(2)$$

subtracting eq^n (1) from eq^n (2)

$$\therefore 123218 L^2 = 222.31$$

$$\therefore 351.02 L = 14.91$$

$$\therefore L = 0.042 \text{ H}$$

$$\therefore L = 42 \text{ mH}$$

Now using eq^n (1) $R^2 = 177.69 - 98596 \times (42 \times 10^{-3})^2$

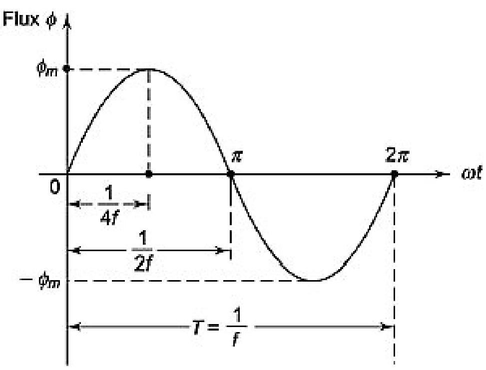
$$R^2 = 177.69 - 174.55$$

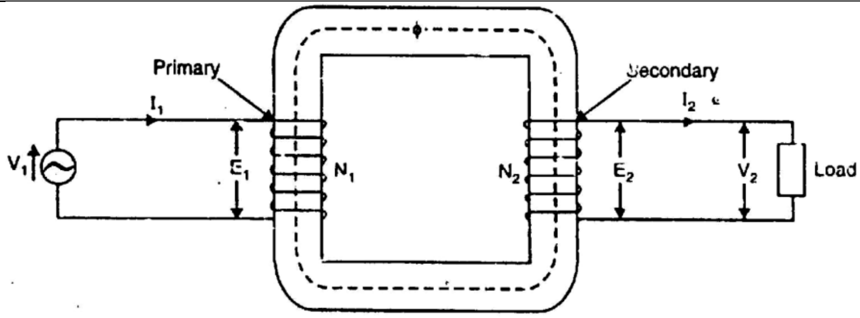
$$\therefore R^2 = 3.14$$

$$\therefore R = 1.77 \Omega$$

UNIT-3: Transformers

GTU End Sem Exam Solution

Exam	Question	Marks
Jan/2021 Nov/2020 June/2019	**Que: Derive the EMF equation of single-phase transformer.** **<u>Solution:</u>** ➢ The magnitude of induced emf is equal to the product of number of turns and the rate of change of flux. $e = -N\frac{d\phi}{dt}$  ➢ As, shown in the fig., the flux rises sinusoidally to its maximum value Φ_m from 0. It reaches to the maximum value in one quarter of the cycle i.e in T/4 sec (where, T is time period of the sin wave of the supply = 1/f). ➢ average rate of change of flux $= \frac{\phi_m}{T/4} = \frac{\phi_m}{1/4f}$ average rate of change of flux = $4f\,\Phi_m$ .... (Wb/s). ➢ Induced emf per turn = rate of change of flux per turn ➢ Average emf per turn = $4f\,\Phi_m$ ....(Volts). ➢ RMS value of emf per turn = Form factor × average emf per turn. ➢ As, the flux Φ varies sinusoidally, form factor of a sine wave is 1.11 ➢ RMS value of emf per turn = $1.11 \times 4f\,\Phi_m = 4.44f\,\Phi_m$ RMS value of induced emf in whole primary winding (E_1) = RMS value of emf per turn × Number of turns in primary winding $E_1 = 4.44f\,N_1\,\Phi_m$ Similarly, RMS induced emf in secondary winding (E_2) can be given as $E_2 = 4.44f\,N_2\,\Phi_m$	04
Jan/2021	**Que: Explain working principle of single-phase Transformer.** **<u>Solution:</u>** ➢ Principle of Single-Phase Transformer: ➢ The single-phase transformer works on the principle of Faraday's Law of Electromagnetic Induction. Typically, mutual induction between primary and secondary windings is responsible for the transformer operation in an electrical transformer.	03



- When an alternating voltage V1 is applied to the primary, an alternating flux f is set up in the core. This alternating flux links both the windings and induces e.m.f.s E_1 and E_2 in them according to Faraday's laws of electromagnetic induction. The e.m.f. E_1 is termed as primary e.m.f. and e.m.f. E_2 is termed as secondary e.m.f.

$$E_1 = -N_1 \frac{d\phi}{dt}$$

$$E_2 = -N_2 \frac{d\phi}{dt}$$

$$\frac{E_2}{E_1} = \frac{N_2}{N_1}$$

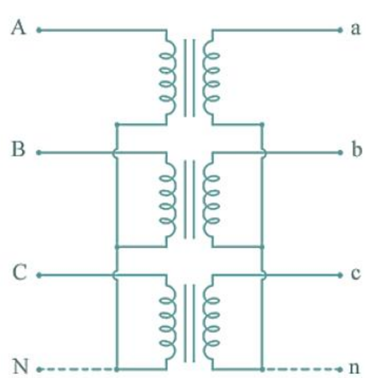
- magnitudes of E_2 and E_1 depend upon the number of turns on the secondary and primary respectively. If $N_2 > N_1$, then $E_2 > E_1$ (or $V_2 > V_1$) and we get a step-up transformer. On the other hand, if $N_2 < N_1$, then $E_2 < E_1$ (or $V_2 < V_1$) and we get a step-down transformer. If load is connected across the secondary winding, the secondary e.m.f. E_2 will cause a current I_2 to flow through the load. Thus, a transformer enables us to transfer a.c. power from one circuit to another with a change in voltage level.

Nov/2020 June/2019 **Explain various connections of three phase transformer with diagram.** 07

Solution:

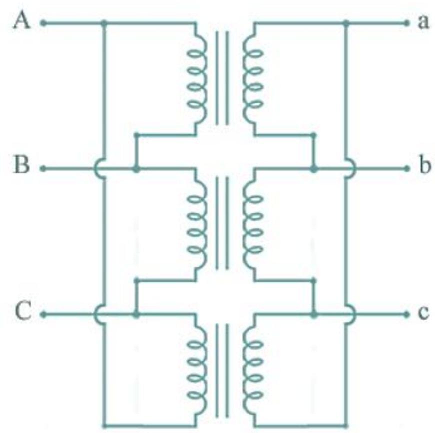
- Windings of a three-phase transformer can be connected in various configurations as (i) star-star, (ii) delta-delta, (iii) star-delta, (iv) delta-star

(i) star-star



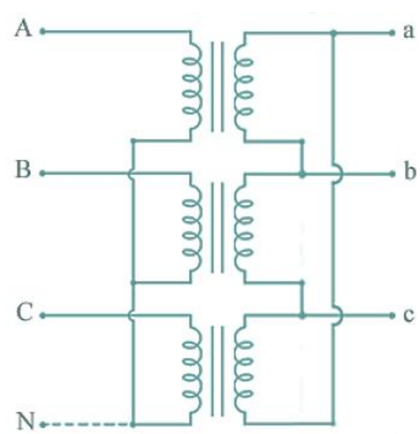
- Star-star connection is generally used for small, high-voltage transformers. Because of star connection, number of required turns/phase is reduced (as phase voltage in star connection is 1/√3 times of line voltage only). Thus, the amount of insulation required is also reduced.
- The ratio of line voltages on the primary side and the secondary side is equal to the transformation ratio of the transformers.
- Line voltages on both sides are in phase with each other.
- This connection can be used only if the connected load is balanced.

(ii) delta-delta



- This connection is generally used for large, low-voltage transformers. Number of required phase/turns is relatively greater than that for star-star connection.
- The ratio of line voltages on the primary and the secondary side is equal to the transformation ratio of the transformers.
- This connection can be used even for unbalanced loading.
- Another advantage of this type of connection is that even if one transformer is disabled, system can continue to operate in open delta connection but with reduced available capacity.

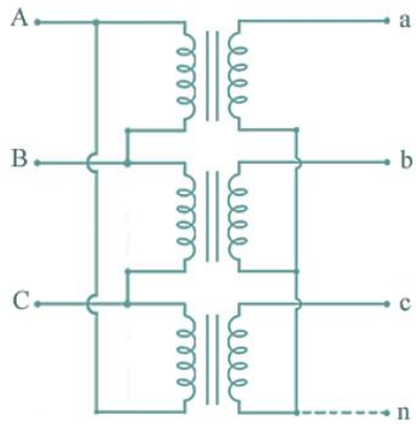
(iii) star-delta



- The primary winding is star star (Y) connected with grounded neutral and the secondary winding is delta connected.
- This connection is mainly used in step down transformer at the substation end of the transmission line.

- The ratio of secondary to primary line voltage is 1/√3 times the transformation ratio.
- There is 30° shift between the primary and secondary line voltages.

(iv) delta-star

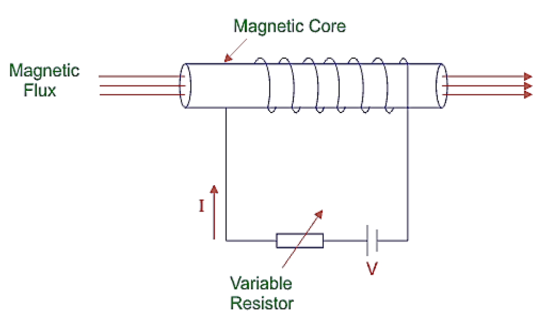


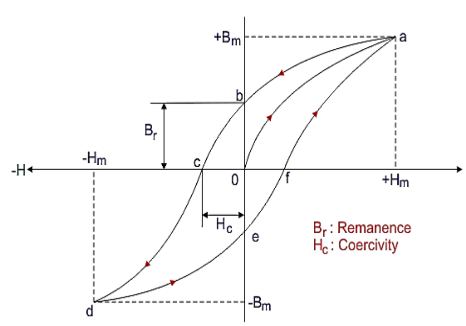
- The primary winding is connected in delta and the secondary winding is connected in star with neutral grounded. Thus, it can be used to provide 3-phase 4-wire service.
- This type of connection is mainly used in step-up transformer at the beginning of transmission line.
- The ratio of secondary to primary line voltage is √3 times the transformation ratio.
- There is 30° shift between the primary and secondary line voltages.

Nov/2020 **Explain magnetic hysteresis.** 03

Solution:

- The phenomenon of lagging behind of induction flux density (B) behind the magnetizing force (H) in magnetic material is called magnetic hysteresis.
- Hysteresis loop is a four quadrant B – H graph from where the hysteresis loss, coercive force and retentively of magnetic material are obtained.
- To understand hysteresis loop, we suppose to take a magnetic material to use as a core around which insulated wire is wound. The coils is connected to the supply (DC) through variable resistor to vary the current I.





- When supply current I = 0, so no existence of flux density (B) and magnetizing force (H).

- When current is increased from zero value to a certain value, magnetizing force and flux density both are set up and increased following the path o to a.
- For a certain value of current, flux density becomes maximum (B_m). The point indicates the magnetic saturation or maximum flux density of this core material. All element of core material get aligned perfectly.
- When the value of current is decreased from its value of magnetic flux saturation, H is decreased along with decrement of B not following the previous path rather following the curve a to b. The point b indicates H = 0 for I = 0 with a certain value of B. This lagging of B behind H is called hysteresis.

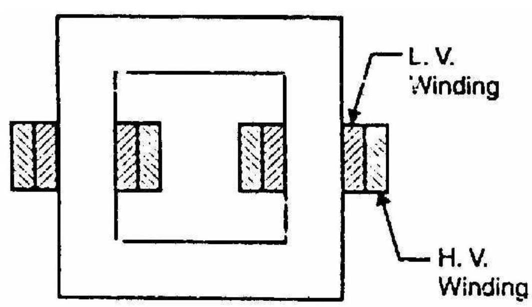
Nov/2020 June/2019 **State the difference in core type and shell type transformer with neat and clean construction diagram.** 07

Solution:

- Depending upon the manner in which the primary and secondary are wound on the core, transformers are of two types viz., (i) core-type transformer and (ii) shell-type transformer.

(i) Core-type transformer:

- In a core-type transformer, half of the primary winding and half of the secondary winding are placed round each limb as shown in Fig.
- This reduces the leakage flux. It is a usual practice to place the low-voltage winding below the high-voltage winding for mechanical considerations.

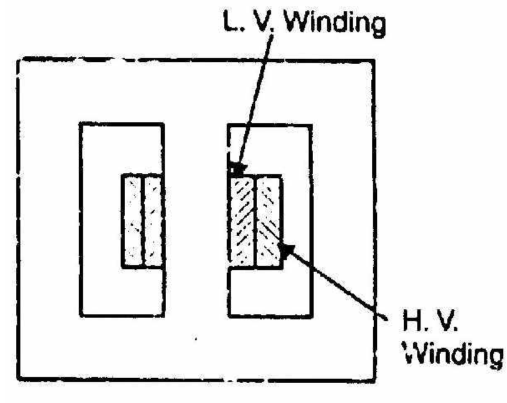


Core-type transformer

(ii) shell-type transformer:

- Shell-type transformer. This method of construction involves the use of a double magnetic circuit. Both the windings are placed round the central limb the other two limbs acting simply as a low-reluctance flux path.

- The choice of type (whether core or shell) will not greatly affect the efficiency of the transformer. The core type is generally more suitable for high voltage and small output while the shell-type is generally more suitable for low voltage and high output.



Shell-type transformer

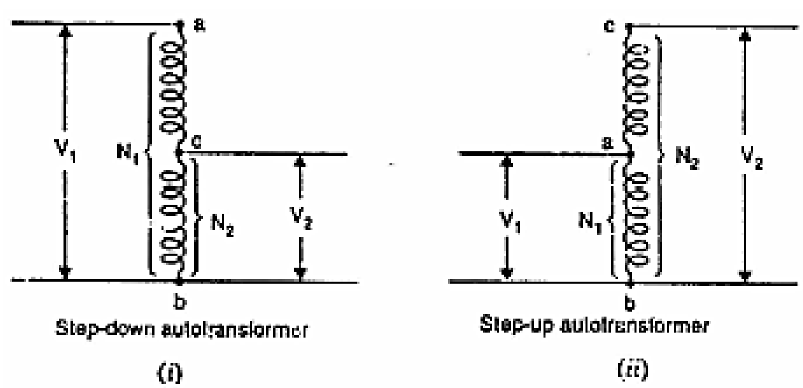
June/2019	**Explain voltage step-up and step-down operation in autotransformer with diagram.**	04

Solution:

- An autotransformer is a transformer where a part of the winding belongs to both the primary winding and secondary winding of the transformer. Its operating principle is the same as the conventional transformer, then the relation between input and output voltages, input and output currents and the ratio of number of turns between the primary and the secondary winding is the same.

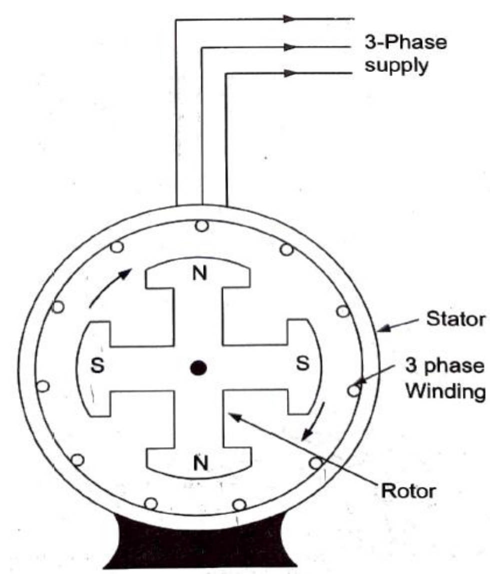
- **Step-down autotransformer**
- If an alternating voltage is applied to points A and B, and the output voltage is measured at points B and C, a lower voltage is obtained. This transformer is a step-down auto transformer. In this case, the turn ratio = Ns/Np < 1.

- **Step-up autotransformer**
- If an alternating voltage is applied to points A and B, and the output voltage is measured at points B and C, a higher voltage is obtained. This transformer is a step-up autotransformer. In this case, the turns ratio is: Ns/Np > 1.



UNIT-4: Electrical Machines

GTU End Semester Exam Solution

Exam	Question	Marks
Nov 2020	**Que: Why single-phase induction motor is not self starting while three-phase induction motor is self starting. Explain in brief.** **Solution:** A single-phase induction motor consists of a squirrel cage rotor and a stator carrying a single-phase winding. When a single phase supply provide to stator winding, it produces a flux (or field) which only alternating i.e. one which alternates along one space axis only. It is not a synchronously revolving (or rotating) flux, as in the case of a two or three phase stator winding, fed from a 2 or 3 phase supply. Now, alternating or pulsating flux acting on a stationary squirrel cage rotor cannot produce rotation. That is why a single phase motor is not self-starting. Three-phase induction motor is self-starting, because winding displacement is 120 degrees for each phase and supply also has 120 phase shift for 3-phase. It results in a unidirectional rotating magnetic field is developed in air gap which causes 3-phase induction motor to self-start.	4
Nov 2020 Jan 2020 June 2019	**Que: Explain construction of Alternator with neat diagram.** **Solution:**  A synchronous generator (alternator) is a machine which produces 3 phase AC power when it receives mechanical input. It thus converts mechanical energy to electrical energy. It consists of a stator which carries a 3 phase winding and rotor which carries the field winding as shown in the fig. **Construction:** 1. Stator: It is the stationary part of the machine and is built up of sheet-steel laminations having slots on its inner periphery. A 3-phase winding is placed in these slots and serves as the armature winding of the alternator. The armature winding is always connected in star and the neutral is connected to ground.	7

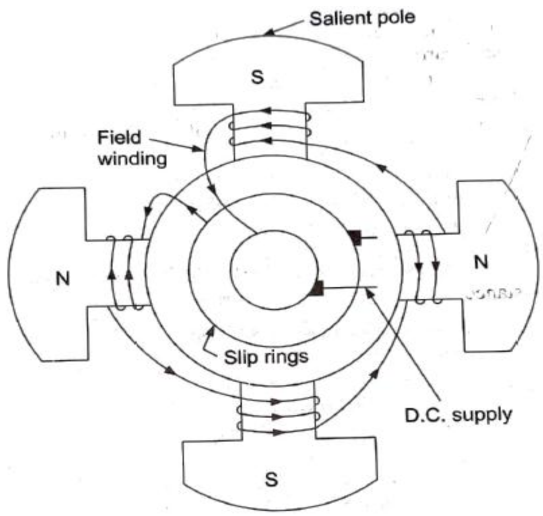
2. Rotor: The rotor carries a field winding which is supplied with direct current through two slip rings by a separate d.c. source. This d.c. source (called exciter) is generally a small d.c. shunt or compound generator mounted on the shaft of the alternator. Rotor construction is of two types, namely;

(i) Salient (or projecting) pole type

(ii) Non-salient (or cylindrical) pole type

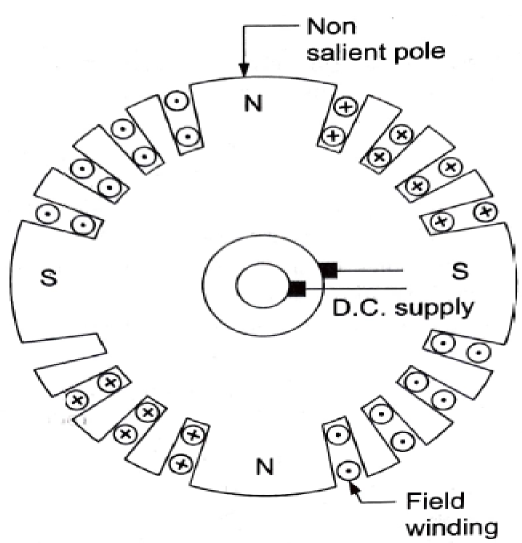
(i) Salient pole type

In this type, salient or projecting poles are mounted on a large circular steel frame which is fixed to the shaft of the alternator as shown in Fig. The individual field pole windings are connected in series in such a way that when the field winding is energized by the d.c. exciter, adjacent poles have opposite polarities. Low and medium synchronous generators are driven by diesel engines or water turbines that use salient pole rotors.



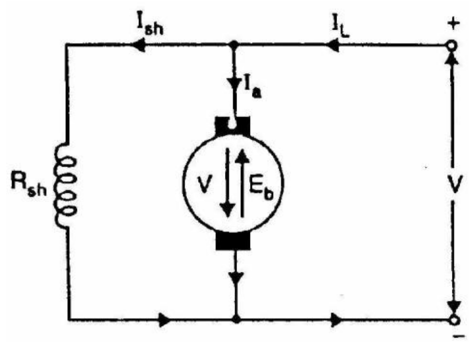
(ii) Non-Salient pole type:

In this type of rotor, smooth solid steel is used to form a radial cylinder. This cylinder has a number of slots along its outer periphery. These slots carry the field windings which in turn are connected in series to the slip rings through which they are energized by the d.c. exciter. The regions which form the poles are left un-slotted. The non-salient rotor is shown in the fig. High-speed alternators (1500 or 3000 r.p.m.) are driven by steam turbines and use non-salient type rotors



Nov 2020 **Que: Justify that how back e.m.f. in DC motor acts like a governor.** **3**

Solution:

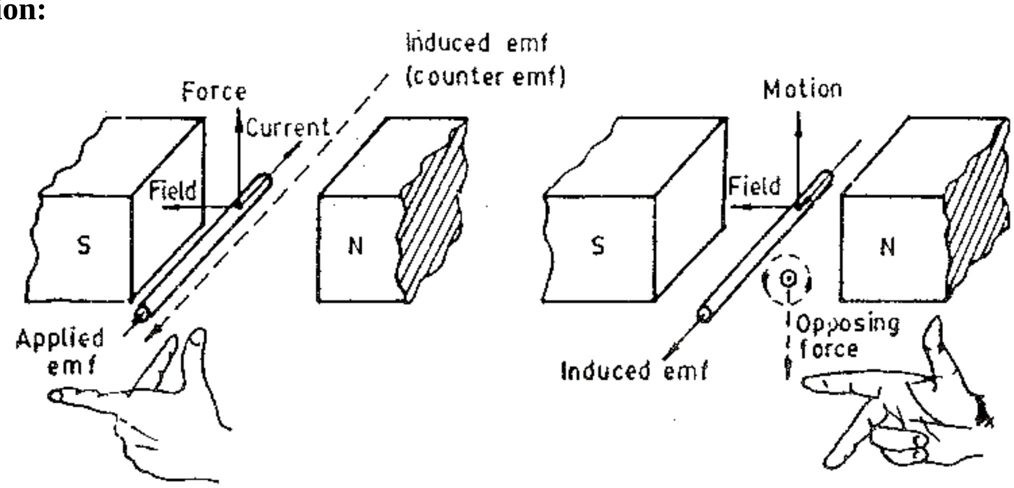


When the armature of a d.c. motor rotates under the influence of the driving torque, the armature conductors move through the magnetic field and hence e.m.f. is induced in them as in a generator The induced e.m.f. acts in opposite direction to the applied voltage V(Lenz's law) and in known as back or counter e.m.f. Eb.

The back e.m.f. Eb (= PΦZN/60 A) is always less than the applied voltage V, although this difference is small when the motor is running under normal conditions. Consider a shunt wound motor shown in Fig. When d.c. voltage V is applied across the motor terminals, the field magnets are excited and armature conductors are supplied with current. Therefore, driving torque acts on the armature which begins to rotate. As the armature rotates, back e.m.f. Eb is induced which opposes the applied voltage V. The applied voltage V has to force current through the armature against the back e.m.f. Eb. The electric work done in overcoming and causing the current to flow against Eb is converted into mechanical energy developed in the armature. It follows, therefore, that energy conversion in a d.c. motor is only possible due to the production of back e.m.f. Eb.
Net voltage across armature circuit = V – Eb
If Ra is the armature circuit resistance, then, $I_a = (V - E_b)/R_a$

Nov 2020 **Que: State the comparison of generator and motor action with respect to design and working principle. Draw the necessary diagram.** **4**

Solution:



(a) Left-hand motor rule (b) Right-hand generator rule

Sr. No.	Differentiating Property	Motor	Generator
1	Definition	An electric motor is a machine that converts electrical energy to mechanical energy.	An electric generator is a machine that converts mechanical energy to electrical energy.
2	Rule	Electric motor follows Fleming's left-hand rule.	Electric generator follows Fleming's right-hand rule.
3	Principle	The working principle of a motor is based on the current-carrying conductor that experiences a force when it is kept in the magnetic field.	The working principle of generator is based on electromagnetic induction.
4	Driving force for shaft	The shaft of an electric motor is driven by a magnetic force which is developed between the armature and field.	The shaft of an electric generator is connected to the rotor which is driven by a mechanical force.
5	Current Usage	In a motor, current is supplied to the armature winding.	In a generator, current is produced in the armature winding.
6	Example	Ceiling fans, cars, etc. are all examples of motor.	In power stations, generator is used to generate electricity.

Nov 2020 Jan 2020

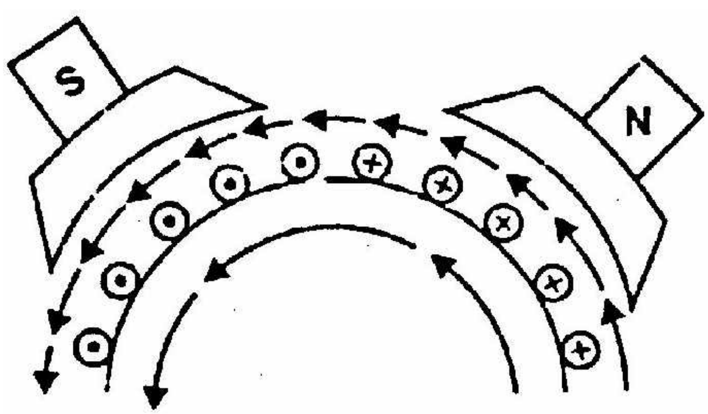
Que: Write working principle of DC motor with neat diagram. **7**

Solution:

Basic principle: A machine that converts d.c. power into mechanical power is known as a d.c. motor. Its operation is based on the principle that when a current carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force. The direction of this force is given by Fleming's left hand rule and magnitude is given by;

F = BIl newtons

Basically, there is no constructional difference between a d.c. motor and a d.c. generator. The same d.c. machine can be run as a generator or motor.



Consider a part of a multipolar d.c. motor as shown in Fig. When the terminals of the motor are connected to an external source of d.c. supply:
(i) the field magnets are excited developing alternate N and S poles;
(ii) the armature conductors carry currents. All conductors under N-pole carry currents in one direction while all the conductors under S-pole carry currents in the opposite direction.

Suppose the conductors under N-pole carry currents into the plane of the paper and those under S-pole carry currents out of the plane of the paper as shown in Fig. Since each armature conductor is carrying current and is placed in the magnetic field, mechanical force acts on it. Referring to Fig. and applying Fleming's left hand rule, it is clear that force on each conductor is tending to rotate the armature in anticlockwise direction. All these forces add together to produce a driving torque which sets the armature rotating. When the conductor moves from one side of a brush to the other, the current in that conductor is reversed and at the same time it comes under the influence of next pole which is of opposite polarity. Consequently, the direction of force on the conductor remains the same.

Nov 2020

Que: A d-c generator has an e.m.f of 200 volts and provides a current of 10 amps. How much energy does it provide each minute? **3**

Solution:
Energy = Power x Time
Power = V x I
= 200 x 10
= 2000 watts
Energy = 2000 x 60
= 120,000 Joules or 120 kJ

Jan 2020

Que: Give Merits, Demerits and Applications of Induction Motor. **4**

Solution:
Merits:
1) The working of an induction motor is very simple. It can operate in any environmental condition. The construction of an induction motor is robust and sturdy.
2) It is very cheap in cost to compare the other motors.
3) It is a highly efficient motor. The efficiency of IM is varying from 85 to 95%.
4) The brushes are not used in an induction motor. So, there are no sparks in the motor and it can be used in polluted and hazards environment.
5) The maintenance of IM is very less compared to the DC motor and synchronous motor.
6) 3 phase induction motor is the self-starting motor. So, any special starting arrangement or extra starting motor is not required. However, single-phase induction motors do not have self-starting torque, and it uses some auxiliaries to rotate.
7) In this motor, only one AC source requires to operate. It does not require DC excitation like a synchronous motor.
8) The speed variation from no-load to rated load is very less.

Demerits:
1) The power factor of the motor is very low during the light load condition.
2) The three-phase induction motor is constant speed motor. The change in speed of the motor is very low during different loading conditions. So, the speed control of IM is difficult.
3) Single-phase induction motor is not self-starting. It requires some auxiliary for stating.
4) The motor cannot use in such applications where high starting torque is necessary like

traction and lifting weight.

Applications of Induction Motor:

1. Lifts
2. Cranes
3. Hoists
4. Large capacity exhaust fans
5. Driving lathe machines
6. Crushers
7. Oil extracting mills
8. Pumps
9. Compressors
10. Small fans
11. Mixers
12. Toys
13. High speed vacuum cleaners
14. Electric shavers
15. Drilling machines

Jan 2020

Que: Compare poly phase Induction Motor and single phase Induction Motor. **4**

Solution:

Basis	**Single phase induction motor**	**Three phase induction motor**
Supply	Single Phase induction motor uses single phase supply, for its operation.	Three Phase induction motor uses three phase supply, for its operation.
Starting torque	The starting torque is low.	The starting torque is high.
Maintenance	They are easy to repair and maintain.	Difficult to repair and maintain.
Features	Simple in construction, reliable and economical as compared to three phase induction motors.	Complex in construction and costly.
Efficiency	Efficiency is less	Efficiency is high
Power factor	Power factor is low	Power factor is high
Examples	They are mostly used in domestic appliances such as mixer grinder, fans, compressors etc	Three phase induction motors are mostly used in industries.

Nov 2020 Jan 2020 June 2019

Que: Explain Generation of Rotating Magnetic Field in 3-phase Induction Motor with diagrams and equations. **7**

Solution:

When a 3-phase winding is energized from a 3-phase supply, a rotating magnetic field is produced. This field is such that its poles do no remain in a fixed position on the stator but go on shifting their positions around the stator. For this reason, it is called a rotating Held. It can be shown that magnitude of this rotating field is constant and is equal to 1.5 Φm where Φm is the maximum flux due to any phase.

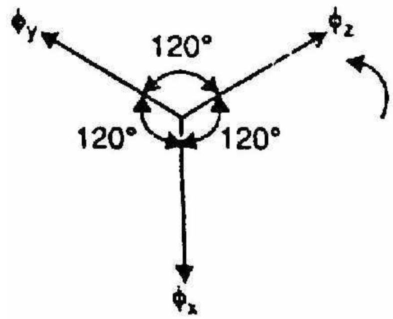
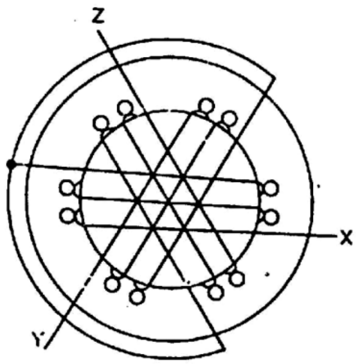
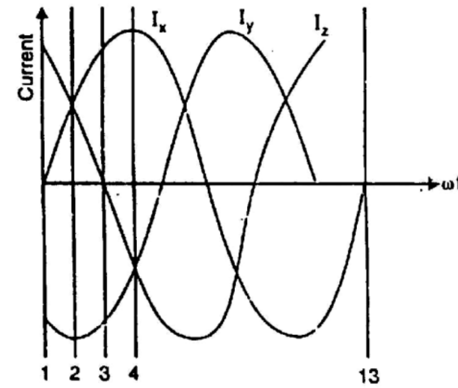


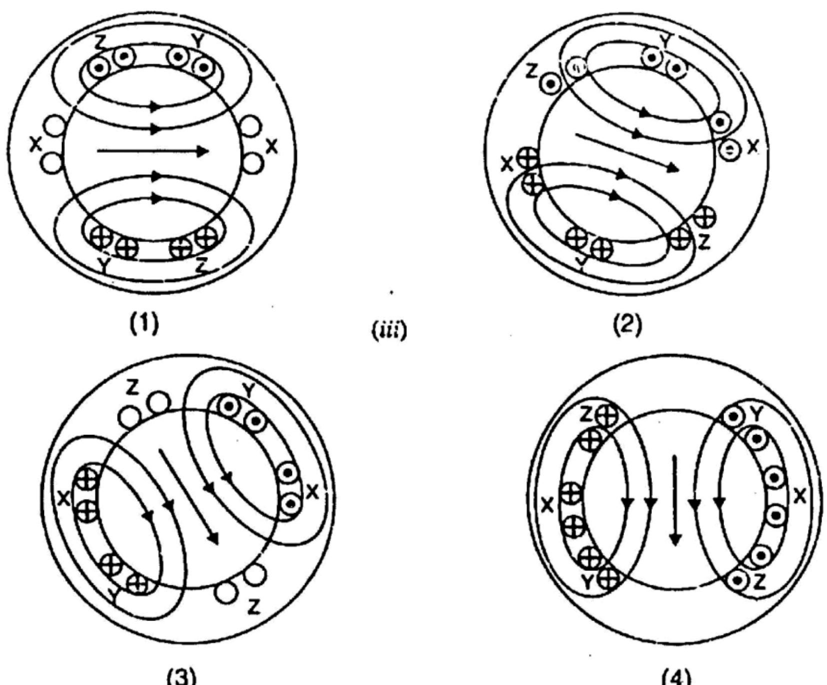
Fig. 1.



(i)



(ii)



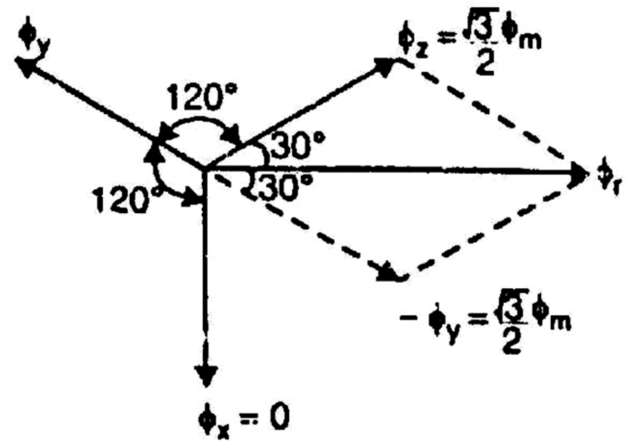
(iii)

To see how rotating field is produced, consider a 2-pole, 3-phase winding as shown in Fig. (i). The three phases X, Y and Z are energized from a 3-phase source and currents in these phases are indicated as Ix, Iy and Iz [See Fig. (ii)]. Referring to Fig. (ii), the fluxes produced by these currents are given by:

$$\phi_x = \phi_m \sin \omega t$$
$$\phi_y = \phi_m \sin (\omega t - 120°)$$
$$\phi_z = \phi_m \sin (\omega t - 240°)$$

Here Φm is the maximum flux due to any phase. Fig. (1) shows the phasor diagram of the three fluxes. We shall now prove that this 3-phase supply produces a rotating field of constant magnitude equal to 1.5 Φm.

(i) At instant 1 [See Fig. (ii) and Fig. (iii)], the current in phase X is zero and currents in phases Y and Z are equal and opposite. The currents are flowing outward in the top conductors and inward in the bottom conductors. This establishes a resultant flux towards right. The magnitude of the resultant flux is constant and is equal to 1.5 Φm as proved under:



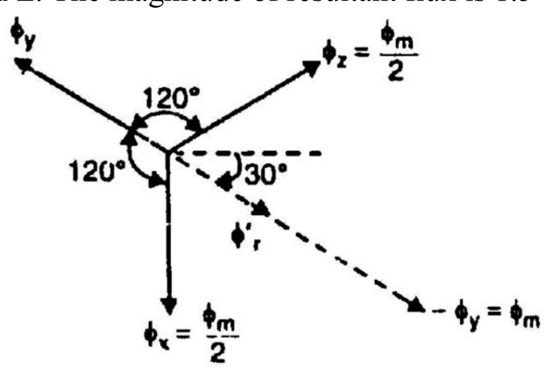
At instant 1, ωt = 0°. Therefore, the three fluxes are given by;

$$\phi_x = 0; \qquad \phi_y = \phi_m \sin(-120°) = -\frac{\sqrt{3}}{2}\phi_m;$$
$$\phi_z = \phi_m \sin(-240°) = \frac{\sqrt{3}}{2}\phi_m$$

The phasor sum of - Φy and Φz is the resultant flux Φr [from above phasor diagram]. It is clear that:

$$\text{Resultant flux,} \quad \phi_r = 2 \times \frac{\sqrt{3}}{2}\phi_m \cos\frac{60°}{2} = 2 \times \frac{\sqrt{3}}{2}\phi_m \times \frac{\sqrt{3}}{2} = 1.5\ \phi_m$$

(ii) At instant 2, the current is maximum (negative) in Φy phase Y and 0.5 maximum (positive) in phases X and Z. The magnitude of resultant flux is 1.5 Φm as proved under:



At instant 2, ωt = 30°. Therefore, the three fluxes are given by;

$$\phi_x = \phi_m \sin 30° = \frac{\phi_m}{2}$$

$$\phi_y = \phi_m \sin(-90°) = -\phi_m$$

$$\phi_z = \phi_m \sin(-210°) = \frac{\phi_m}{2}$$

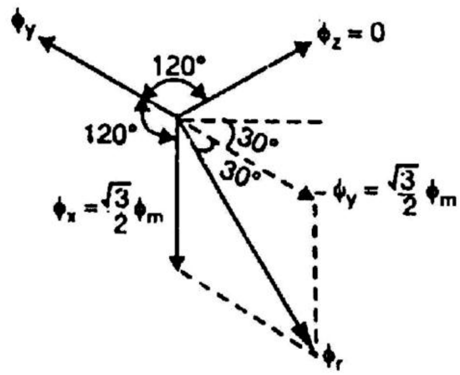
The phasor sum of Φx, - Φy and Φz is the resultant flux Φr

Phasor sum of ϕ_x and ϕ_z, $\phi'_r = 2 \times \frac{\phi_m}{2} \cos\frac{120°}{2} = \frac{\phi_m}{2}$

Phasor sum of ϕ'_r and $-\phi_y$, $\phi_r = \frac{\phi_m}{2} + \phi_m = 1.5\,\phi_m$

Note that resultant flux is displaced 30° clockwise from position 1.

(iii) At instant 3, current in phase Z is zero and the currents in phases X and Y are equal and opposite (currents in phases X and Y are 0.866 × max. value).



The magnitude of resultant flux is 1.5 Φm as proved under:
At instant 3, ωt = 60°. Therefore, the three fluxes are given by;

$$\phi_x = \phi_m \sin 60° = \frac{\sqrt{3}}{2}\phi_m;$$

$$\phi_y = \phi_m \sin(-60°) = -\frac{\sqrt{3}}{2}\phi_m;$$

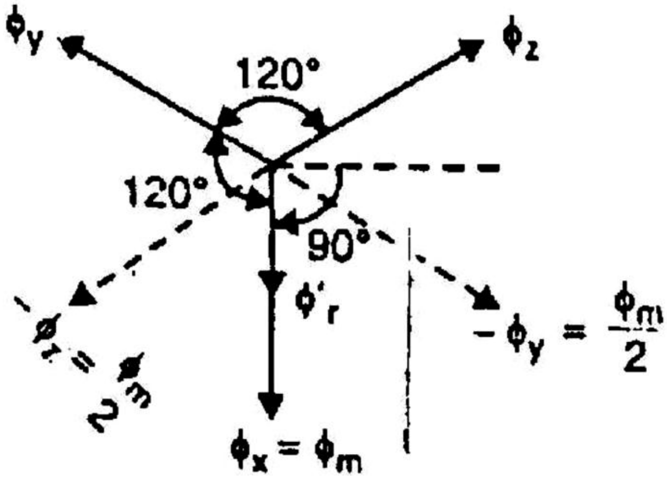
$$\phi_z = \phi_m \sin(-180°) = 0$$

The resultant flux Φr is the phasor sum of Φx and - Φy (Φz = 0).

$$\phi_r = 2 \times \frac{\sqrt{3}}{2}\phi_m \cos\frac{60°}{2} = 1.5\,\phi_m$$

Note that resultant flux is displaced 60° clockwise from position 1.

(iv) At instant 4, the current in phase X is maximum (positive) and the currents in phases Y and Z are equal and negative (currents in phases Y and Z are 0.5 × max. value).



This establishes a resultant flux downward as shown under:

At instant 4, ωt = 90°. Therefore, the three fluxes are given by;

$$\phi_x = \phi_m \sin 90° = \phi_m$$

$$\phi_y = \phi_m \sin(-30°) = -\frac{\phi_m}{2}$$

$$\phi_z = \phi_m \sin(-150°) = -\frac{\phi_m}{2}$$

The phasor sum of Φx, - Φy and - Φz is the resultant flux Φr

$$\text{Phasor sum of } -\phi_z \text{ and } -\phi_y,\ \phi'_r = 2 \times \frac{\phi_m}{2} \cos\frac{120°}{2} = \frac{\phi_m}{2}$$

$$\text{Phasor sum of } \phi'_r \text{ and } \phi_x,\ \phi_r = \frac{\phi_m}{2} + \phi_m = 1.5\ \phi_m$$

Note that the resultant flux is downward i.e., it is displaced 90° clockwise from position 1.

June 2019	**Que: Classify and compare various DC motor.**	4

Solution:

There are three types of d.c. motors characterized by the connections of field winding in relation to the armature viz.:

(i) **Shunt-wound motor** in which the field winding is connected in parallel with the armature [See Fig. 1]. The current through the shunt field winding is not the same as the armature current. Shunt field windings are designed to produce the necessary m.m.f. by means of a relatively large number of turns of wire having high resistance. Therefore, shunt field current is relatively small compared with the armature current.

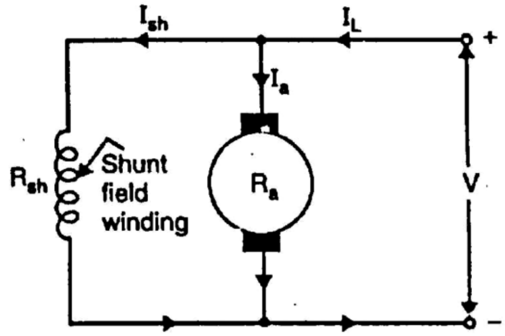


Fig.1

(ii) **Series-wound motor** in which the field winding is connected in series with the armature [See Fig. 2]. Therefore, series field winding carries the armature current. Since the current passing through a series field winding is the same as the armature current, series field windings must be designed with much fewer turns than shunt field windings for the same m.m.f. Therefore, a series field winding has a relatively small number of turns of thick wire and, therefore, will possess a low resistance.

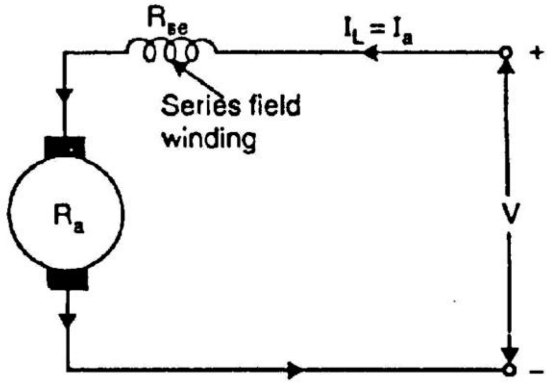


Fig. 2.

(iii) **Compound-wound motor** which has two field windings; one connected in parallel with the armature and the other in series with it. There are two types of compound motor connections (like generators). When the shunt field winding is directly connected across the armature terminals [See Fig. 3], it is called short-shunt connection. When the shunt winding is so connected that it shunts the series combination of armature and series field [See Fig. 4], it is called long-shunt connection.

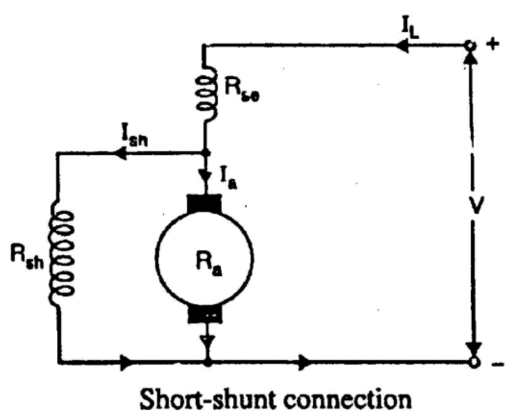


Fig. 3

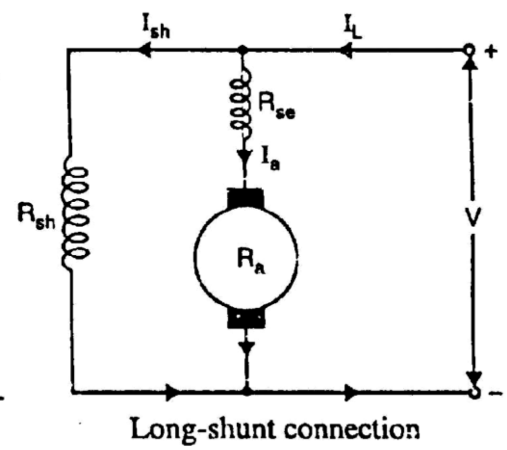


Fig. 4

June 2019 **Que: Give the classification of Induction motor.** **3**

Solution:

There are mainly two types of induction motor on the basis of power supply, Single Phase Induction Motor and Three Phase Induction Motor.

i. Single phase induction motor may be classified on the basis of their construction and starting methods. On this basis, they can be further categorized into following types:

1. Split Phase Induction Motor
2. Capacitor Start Induction Motor
3. Capacitor Start Capacitor Run Induction Motor

4. Shaded Pole Induction Motor

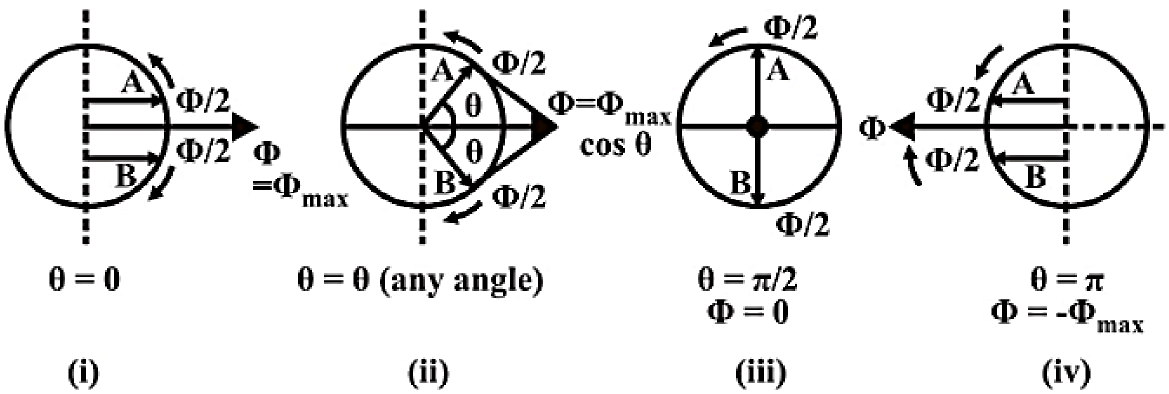
ii. A three phase induction motor classified on the basis of its rotor construction. On this basis, they can be further categorized into following types:

1. Squirrel Cage Induction Motor
2. Wound Rotor or Slip Ring Induction Motor

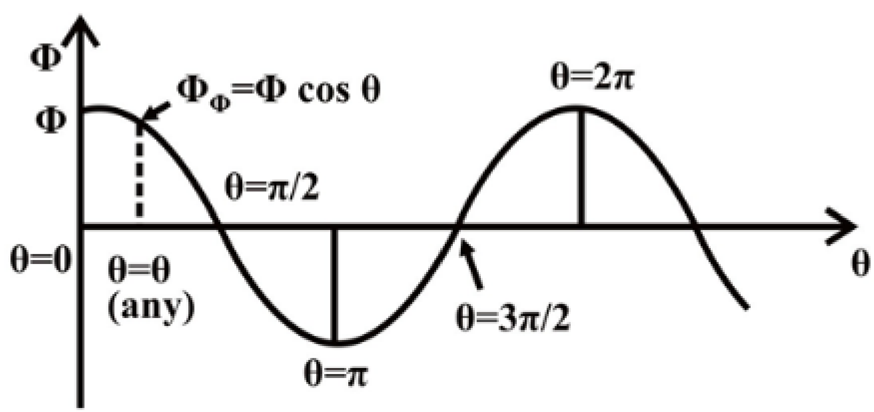
June 2019 **Que: Explain the working of single phase induction motor with diagram.** **7**

Solution:

When the stator winding (distributed one as stated earlier) carries a sinusoidal current (Being fed from a single-phase supply), a sinusoidal space distributed mmf, whose peak or maximum value pulsates (alternates) with time, is produced in the air gap. This sinusoidal varying flux (φ) is the sum of two rotating fluxes or fields, the magnitude of which is equal to half the value of the alternating flux (φ / 2), and both the fluxes rotating synchronously at the speed, in opposite directions.



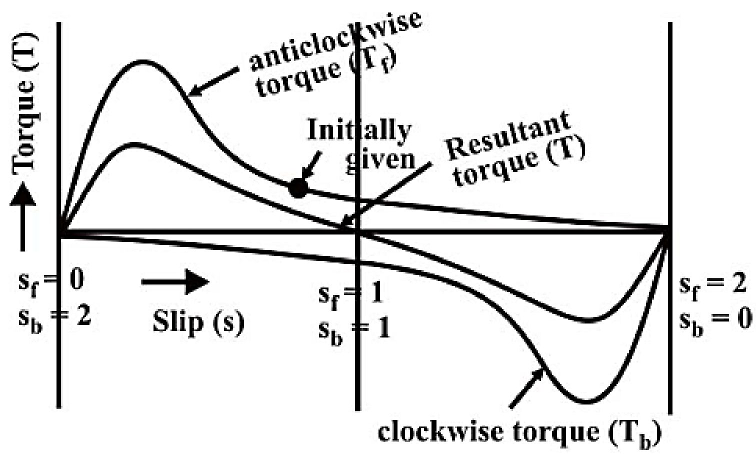
The first set of figures show the resultant sum of the two rotating fluxes or fields, as the time axis (angle) is changing from θ = 0° to π°(180).



The above figure shows the alternating or pulsating flux (resultant) varying with time or angle.

The flux or field rotating at synchronous speed, say, in the anticlockwise direction, i.e. the same direction, as that of the motor (rotor) taken as positive induces EMF (voltage) in the rotor conductors. The rotor is a squirrel cage one, with bars short circuited via end rings. The current flows in the rotor conductors, and the electromagnetic torque is produced in the same direction as given above, which is termed as positive (+ve). The other part of flux or field rotates at the same speed in the opposite (clockwise) direction, taken as negative. So, the torque produced by this field is negative (-ve), as it is in the clockwise direction, same as that of the direction of rotation of this field. Two torques are in the opposite direction, and the resultant (total) torque is the difference of the two torques produced.

Let the flux φ1 rotate in anti clockwise direction and flux φ2 in clockwise direction. The flux φ1 will result in the production of torque T1 in the anti clockwise direction and flux φ2 will result in the production of torque T2 In the clockwise direction.



At standstill, these two torques are equal and opposite and the net torque developed is zero. Therefore, single-phase induction motor is not self-starting. Note that each rotating field tends to drive the rotor in the direction in which the field rotates.

Now assume that the rotor is started by spinning the rotor or by using auxiliary circuit, in say clockwise direction. The flux rotating in the clockwise direction is the forward rotating flux (φf) and that in the other direction is the backward rotating flux (φb). The slip w.r.t. the forward flux will be

$$Sf = \frac{Ns - N}{Ns} = 1 - \frac{N}{Ns} \; or \; \frac{N}{Ns} = 1 - S$$

The rotor rotates opposite to the rotation of the backward flux. Therefore, the slip w.r.t. the backward flux will be

$$Sb = \frac{Ns - (-N)}{Ns} = \frac{Ns + N}{Ns} = 1 + \frac{N}{Ns} = 1 + (1 - S) = 2 - S$$

Thus for forward rotating flux, slip is s (less than unity) and for backward rotating flux, the slip is 2 − s (greater than unity). Since for usual rotor resistance/reactance ratios, the torques at slips of less than unity are greater than those at slips of more than unity, the resultant torque will be in the direction of the rotation of the forward flux. Thus if the motor is once started, it will develop net torque in the direction in which it has been started and will function as a motor.

June 2019

Que: State significance of the back emf in DC motor. **3**

Solution: The presence of back e.m.f. makes the d.c. motor a self-regulating machine i.e., it makes the motor to draw as much armature current as is just sufficient to develop the torque required by the load.

Armature current, $I_a = (V - E_b)/R_a$

(i) When the motor is running on no load, small torque is required to overcome the friction and windage losses. Therefore, the armature current Ia is small and the back e.m.f. is nearly equal to the applied voltage.

(ii) If the motor is suddenly loaded, the first effect is to cause the armature to slow down. Therefore, the speed at which the armature conductors move through the field is reduced and hence the back e.m.f. Eb falls. The decreased back e.m.f. allows a larger current to flow through the armature and larger current means increased driving torque. Thus, the driving torque increases as the motor slows down. The motor will stop slowing down when the armature current is just sufficient to produce the increased torque required by the load.

(iii) If the load on the motor is decreased, the driving torque is momentarily in excess of the requirement so that armature is accelerated. As the armature speed increases, the back e.m.f. Eb also increases and causes the armature current Ia to decrease. The motor will stop accelerating when the armature current is just sufficient to produce the reduced torque required by the load.

It follows, therefore, that back e.m.f. in a d.c. motor regulates the flow of armature current i.e., it automatically changes the armature current to meet the load requirement.

UNIT-5: Electrical Installations

GTU End Sem Exam Solution

Exam	Question	Marks
June 2019	**Que: State function of various parts of HT cable** **Answer:** **Cores/Conductors** – It consists of one central core or a number of cores of tinned stranded copper or aluminum conductors. Conductors are used in stranded form to provide flexibility Conductor numbers are 3, 7, 19, 37 and so on. **Insulation** The satisfactory operation of cable depends to a great extent upon the characteristics of insulation. The insulation is provided according to voltage to be withstood by cable. **Metallic sheath (Al)** – As cable is placed underground, the soil may present moisture, gases and some other liquids. Therefore, a metallic sheath is applied over the insulation for protecting the conductor from moisture, gases, and alkalies in soil. **Bedding (jute)**- It is used to protect metallic sheet against corrosion and mechanical injury from armouring. **Armouring (Galv. Steel)** - It protects cable from mechanical injury while laying and handling. **Serving (jute)** – It protects armoring from atmosphere conditions.	03

June 2019, Jan 2019

Que: Give the comparison of fuse and MCB.

04

MCB	***FUSE***
• MCB trips off in case of excessive load. • MCB is to be just put-on after correcting the fault in wiring • Since we do not change the MCB, there is no risk of putting on the MCB/switch even if the fault is not correctly repaired. • Compact, small equipment. • Works on Bi-metal expansion or induced magnetism. • Relatively costlier than fuse.	• Fuse melts/fuses in case of excessive load. • Fuse needs to be replaced with a new one. • There is a risk of putting on the switch in case; due to ignorance higher capacity fuse-wire is positioned. • It has Porcelain base and top. • Works on melting/fusing due to high temperature. • Relatively cheaper than MCB.

June 2019

Que: Explain plate earthing with diagram

07

Answer:

This is one of the common methods of earthing. In this case, the earthing is done by embedding GI or copper plate in the earth sufficiently deep. The size of the plate used should not be less than 60 cmx 60 cm x 6.35 mm in case of GI plate and 60 cm x 60 cm x 3.18 mm in case of copper plate. The copper on account of its high cost is not used nowadays.

A pit is dug about 4 meters deep, and the earth electrode is placed in such a way that its face is vertical. The space around the plate is filled with layers of charcoal and salt for a minimum thickness of 15 cm. The electrode or plate is connected to GI pipe of 12.7 mm diameter for carrying GI each wire for connection to earth electrode. The earth wire is securely bolted to the earth plate with the help of bolt, nut, washer and GI thimble, the details of which is shown in the diagram.

It should be remembered that the nut and bolts thimble and washers must be of copper for copper plate and GI for galvanized earth plate or electrode. The pit filled with charcoal and salt is also connected with a pipe for carrying water from concrete work so that area for the purpose of increasing dampness and moisture which ultimately reduces earth resistance. The cement work is covered with iron plate for periodic opening. It is better to have an independent earth plate in domestic installation.

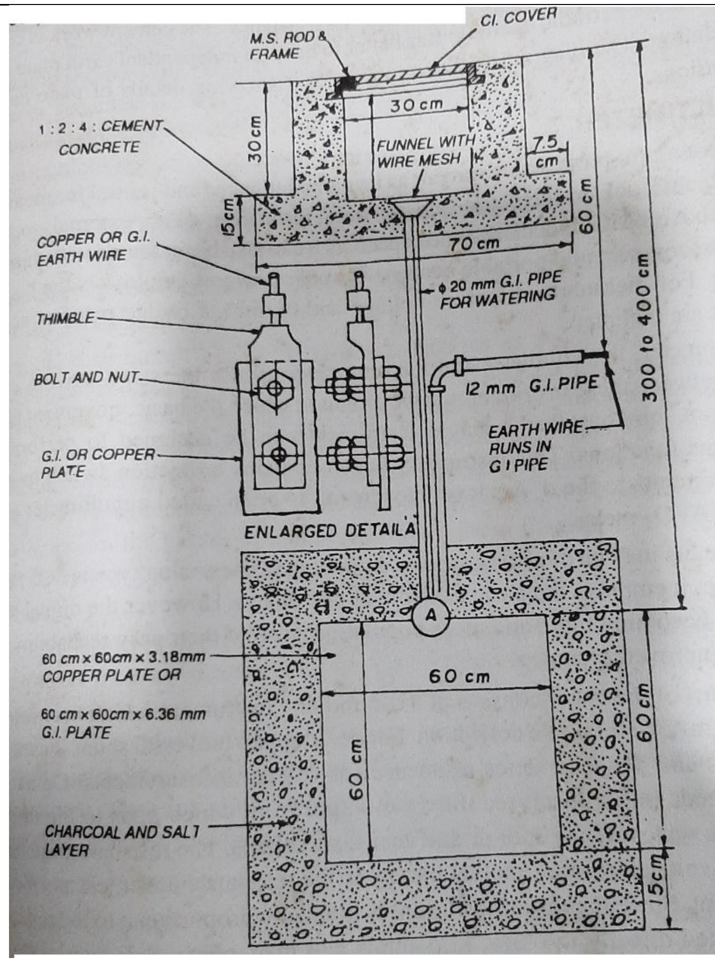


Figure: Diagram of Plate Earthing

June 2019

Que: What is power factor and why improvement is required in that? 03

Answer:

Power factor is the ratio of active power consumed by the load to the apparent power demanded by the load.

The poor power factor leads to increased current in the conductor.

The increased current causes more losses in the current carrying conductor resulting into poor efficiency.

Due to this, the utility imposes additional charges on certain consumer as a penalty of poor power factor.

Hence, it is necessary to improve the power factor for certain consumers.

The improvement of power factor is very important for both consumers and generating stations as discussed below :

(i) For consumers. A consumer* has to pay electricity charges for his maximum demand in kVA plus the units consumed. If the consumer imporves the power factor, then there is a reduction† in his maximum kVA demand and consequently there will be annual saving due to maximum demand charges. Although power factor improvement involves extra annual expenditure on account of p.f. correction equipment, yet improvement of p.f. to a proper value result in the net annual saving for the consumer.

(ii) For generating stations. A generating station is as much concerned with power factor improvement as the consumer. The generators in a power station are rated in kVA but the

	useful output depends upon kW output. As station output is kW = kVA × cos ϕ, therefore, number of units supplied by it depends upon the power factor. The greater the power factor of the generating station, the higher is the kWh it delivers to the system. This leads to the conclusion that improved power factor increases the earning capacity of the power station	
June 2019	**Que: State and explain in brief important electrical characteristics of battery.** **Answer:** There are three important characteristics of an accumulator (or storage battery) are: 1. Voltage 2. Capacity 3. Efficiency 1. Voltage: The value of emf of a cell does not remain constant but varies with the change in specific gravity of electrolyte, temperature, and the length of time since it was last charged. 2. Capacity: There are two types of capacities of a battery. (i) Ampere – hour capacity: It is the amount of energy which can be supplied by it. It applies only to a certain range of load current. Thus, it is the product of the rated current during discharge and the number of hours. Mathematically, $$A - h\ capacity = I_d T_d$$ (ii) Watt-hour capacity: The product of the average battery voltage during the discharge and ampere -hour capacity is called the watt-hour capacity of the battery. Mathematically, $$W - h\ capacity = V_d I_d T_d$$ Where Vd is the average voltage of the battery during discharge 3. Efficiency: The efficiency of the battery is the ration of output of the battery during discharging to the input to the battery during discharging. There are two ways of defining the efficiency of the battery. (i) Ampere-hour efficiency: The ratio of output ampere-hour during discharging to the input ampere-hour during charging of the battery is called ampere-hour efficiency of the battery. $$\eta_{A-h} = \frac{I_d T_d}{I_c T_c} \times 100$$ (ii) Watt-hour efficiency: The ratio of output watt-hour during discharging to the input watt-hours during charging of the battery is called watt-hour efficiency of the battery. It is also known as the energy efficiency of the battery. Mathematically, $$\eta_{W-h} = \frac{I_d V_d T_d}{I_c V_c T_c} \times 100$$	04

<table>
<tr><td>June 2019</td><td>

Que: Calculate the electricity bill amount for a month of April, if 4 bulbs of 40 W for 5 h, 4 tube lights of 60 W for 5 h, a TV of 100 W for 6 h, a washing machine of 400 W for 3 h, a water pump of 0.5 HP for 15 minutes are used per day. The cost per unit is Rs 3.50. Consider 1 HP = 746 watts
Answer:
Let us calculate the energy utilization per day.
Energy utilized by bulbs = no. of bulb x wattage of bulb x duration of operation
Energy utilized by bulbs = 4 x 40 x 5 = 800 Wh
Energy utilized by tube lights = 4 x 60 x 5 = 1200 Wh
Energy utilized by TV = 100 x 6 = 600 Wh
Energy utilized by washing machine = 400 x 3 = 1200 Wh
Energy utilized by Water pump = 0.5 * 746 * 15/60 = 93.25 Wh
Total Energy utilized on per day basis = 3,893.25 Wh = 3.893 kWh or units per day
Total Energy utilized for the month of April = 3.893 * 30 = 116.8 kWh

The electricity bill amount for the month of April is Rs. 408.8.

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<tr><td>Nov 2020</td><td>

Que: Discuss types of cables used for residential and commercial wiring.
Answer:
In residential and commercial wiring, low tension cables are employed. These cables have voltage withstanding capacity upto 1000V. Depending on the type of insulation employed, different types of cables are enlisted as follows:
1. Vulcanized Indian Rubber (VIR) insulated cables.
2. Tough rubber sheathed (TRS) or cabtyre sheathed (CTS) cables.
3. Lead sheathed cables.
4. Polyvinyl chloride (PVC) cables.
5. Weatherproof cables.
6. Flexible cords and cables.
7. XLPE cables.
8. Multi-strand cables.

1. Vulcanized Indian Rubber (VIR) insulated cables.
VIR, cables are available in 240/415 volt as well as in 650/1,100-volt grades.
VIR cable consists of either tinned copper conductor covered with a layer of vulcanized Indian rubber insulation. Over the rubber insulation cotton tape sheathed covering is provided with moisture resistant compound bitumen wax or some other insulating material for making cables moisture proof. The thickness of rubber insulation depends upon the voltage grade for Which the cable is required.

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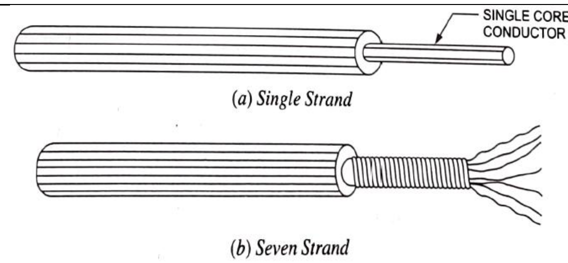
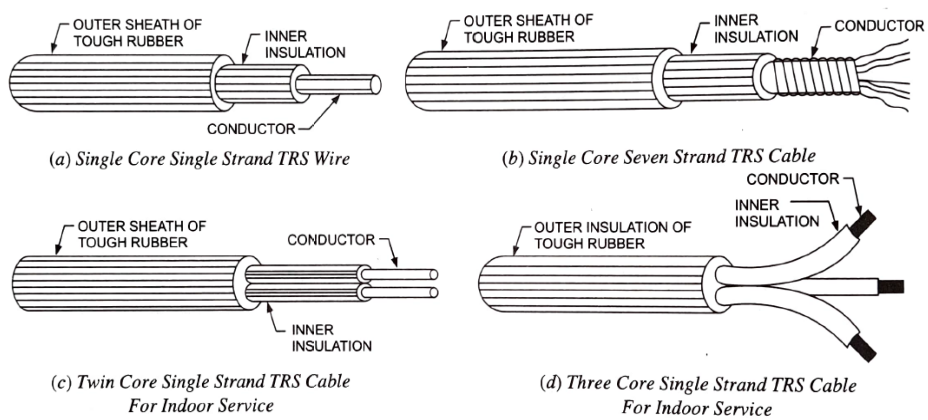


VIR cables

2. Tough rubber sheathed (TRS) or cabtyre sheathed (CTS) cables.

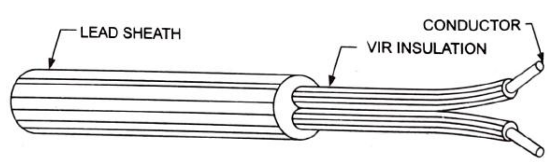
These cables are available in 250/440 volt and 650/1,100 volt grades and used in CTS (or TRS) wiring. TRS cable is nothing, but a vulcanized rubber insulated conductor with an outer protective covering of tough rubber, which provides additional insulation and protection against wear and tear. These cables are waterproof, hence can be used in wet conditions. These cables are available as single core, circular twin core, circular three core, flat three core, twin or three core with an earth continuity conductor (ECC). The cores are insulated from each other and covered with a common sheathing.



TRS cables

3. Lead sheathed cables.

These cables are available in 240/415 volt grade. The lead sheathed cable is a vulcanized rubber insulated conductor covered with a continuous sheath of lead. The lead sheath provides very good protection against the absorption of moisture and sufficient protection against mechanical injury and so can be used without casing or conduit system. It is available as a single core, flat twin core, flat three core and flat twin or three core with an earth continuity conductor.



Lead Sheath Cables

	4. Polyvinyl chloride (PVC) cables. These cables are available in 250/440 volt and 650/1,100-volt grades and are used in casing-capping, batten and conduit wiring system. In this type of cable conductor is insulated with PVC insulation. Since PVC is harder than rubber, PVC cable does not require cotton taping and braiding over it for mechanical and moisture protection. PVC cables are most widely used for internal wiring these days. Though the insulation resistance of PVC is lower than that of VIR but its effect is negligible for low and medium voltages, below 600V.	
Nov 2020	**Que: Explain the following protective devices in detail:** **(i) SFU (ii) MCB (iii) ELCB** **Answer:** In electrical distribution system of residential, commercial, or industrial buildings, as and when the fault occurs or abnormality is detected, it becomes necessary to isolate the abnormal condition from the rest of the connection. This function is fulfilled by using protective devices such as Fuses, Switch Fuse Units (SFU), MCB or ELCBs. These apparatuses are discussed below in detail. (i) SFU – Switch Fuse Unit(SFU) is a combined unit and is known as an iron clad switch, being made of iron. It may be double pole for controlling single phase two-wire circuits or triple pole for controlling three-phase, 3-wire circuits, or triple pole with neutral link for controlling 3-phase, 4-wire circuits. The respective switches are known as double pole iron clad(DPIC), triple pole iron clad (TPIC), and triple pole with neutral link iron clad (TPNIC) switches. Switch Fuse Units are classified into following: 1. For Two-wire DC Circuits or Single-Phase AC Circuits: 240V, 16A, DPIC switch fuse 2. For Three-Wire DC Circuits: 500V, 32A (63/100/150 or higher amperes), IS approved TPIC switch fuse. 3. For Three-Phase Balanced Load Circuits: 415V, 32A (63/100/150 or higher amperes), IS approved TPIC switch fuse. **(ii) Miniature Circuit Breaker (MCB):** A miniature circuit breaker is an electromechanical device which operates and disconnected the circuit when the current reaches a predetermined value. The MCB may therefore, be used in lieu of fuses and can be fitted in consumer's distribution panel. An MCB is a replacement or most modern substitute for a conventional rewirable fuse. It is more accurate and efficiency system in overload and short circuit protection. An MCB will normally operate at 1.25 times its rated current i.e. a 20A MCB operates at 25A. MCB is a device which operate on the two principles for the protection against overload and short circuit: 1. Thermal for normal overload protection 2. Magnetic for short circuit protection	07

The thermal operation is achieved by bimetallic strip, which deflected when heated by any overcurrent flowing through it. In doing so, it releases latch mechanism and causes the contact to open.
It possesses inverse time-current characteristics i.e. greater the current short the time required to operate the MCB.

(iii) Earth Leakage Circuit Breaker (ELCB):
It is a device designed to prevent death, injury and fire arising from electric shock to a human body or a loose current carrying wire accidentally touching an earthed metal part of a component. The component cuts off the supply before any hazard occurs.
It is a current operated device designed to operate when a leakage current exceeds a predetermined value. It essentially consists of an operating coil and a trip mechanism which operates contacts controlling the supply to the circuit.

Nov 2020

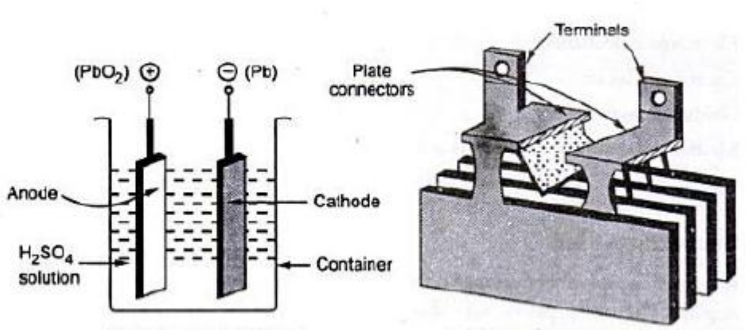
Que: Explain the construction of the lead-acid battery with neat diagram 04

Answer:

The various parts of the lead acid battery are as follows:

1. Positive Plate or Anode: It is lead peroxide (PbO_2) plate of chocolate, dark brown color.
2. Negative Plate or Cathode: It is made up of pure lead (Pb) which is grey in color.
3. Electrolyte: For necessary chemical action, aqueous solution of sulphuric acid (H_2SO_4) is used as an electrolyte.
4. Separators: The positive and negative plates are arranged in groups and are placed alternately. The separators are used to prevent them from coming in contact with each other short circuiting the cell.
5. Container: The entire assembly of plates along with the solution is placed in the plastic or ceramic container.
6. Bottom blocks: To prevent short circuiting of cell due to active material fallen from the plates, the space known as bottom blocks is provided at the bottom of the container.
7. Plate Connector: The number of negative and positive plates are assembled alternately. To connect positive plates together (or negative plates together) separate connectors are used which are called plate connectors. The upward connection of plates are nothing but the terminals of the cell.
8. Vent Plug: These are made of rubber and screwed to the cover of the cell. Its function is to allow the escape of gases and prevent escape of the electrolyte.

Figure below shows the construction of lead acid battery.



(a) Battery construction (b) Assembly of – ve and + ve plates

Nov 2020

Que: Explain different types of earthing and its importance in electrical utility system in detail. 07

Answer:

Earthing means the connection of the neutral point of the supply system or the non-current carrying parts of electrical apparatus such as metallic framework (CPU body), metallic covering of cables, earth terminals of socket outlet etc. to the general mass of the earth by wire of negligible resistance in such a manner that at all times an immediate discharge of electrical energy takes place without danger.

This brings the body of the equipment to zero potential and thus will avoid the electric shock to the operator.

There are various types of achieving the zero potential and few of the common types are as follows:

1. Strip earthing or wire earthing
2. Earthing through water mains
3. Rod Earthing
4. Pipe earthing
5. Plate earthing

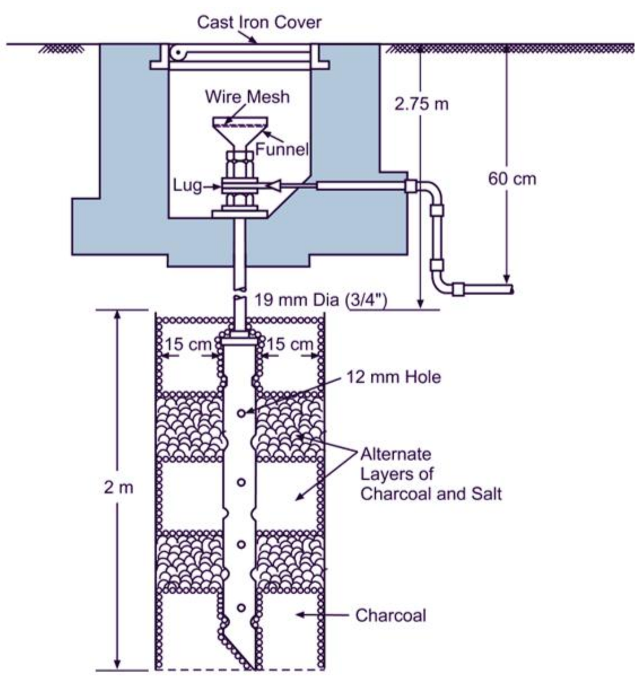


Diagram of pipe earthing

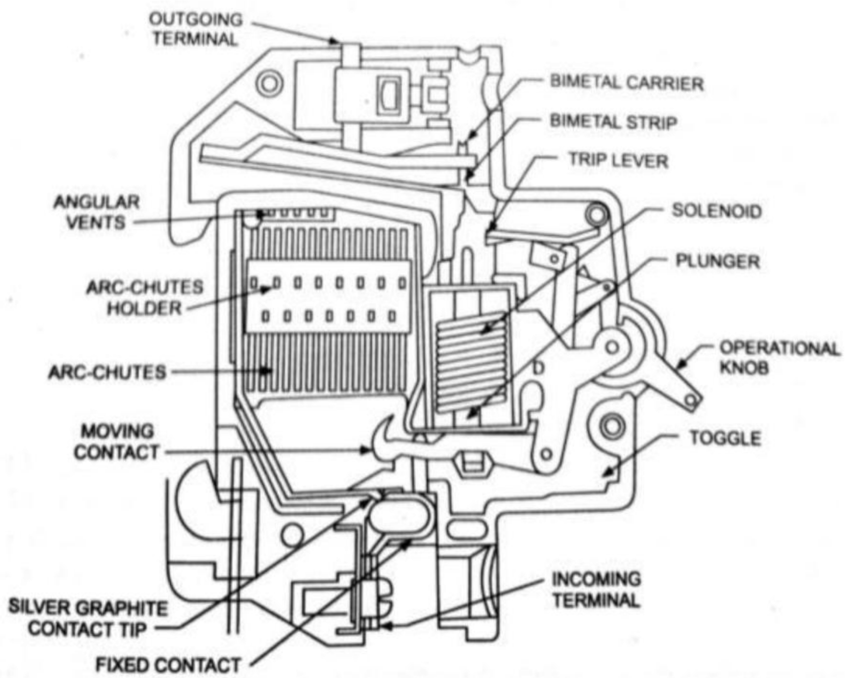
The pipe earthing is explained below.

Pipe earthing:

Taking into consideration the factors such as initial cost, inspection, resistance measurement etc. the GI pipe earthing is the best form of ground connection. Iron is the cheapest material and remains serviceable even if put in salty mass of earth. The pipe used as earth electrode is galvanized and perforated.

According to ISI standard specifications, the galvanized pipe shall not be less than 38 mm diameter and 2 meter long for ordinary soil but if the soil is dry and rocky, the length of the

	pipe should be increased to 2.75 meter. The diameter of the pipe has little effect on the resistance of the earth connection. The pipe must be placed in a permanently wet ground. The depth at which the pipe should be buried depends upon condition of the soil and moisture. According to ISI, the pipe should be placed at a depth of 4.75 meter again depending upon moisture. The pipe having tapered casting at the bottom is placed up right in that pit. The charcoal and salt are filled in that pit alternately in layers upto about 2 meters from the bottom and for a distance of about 15 cm around the pipe to increase dampness and moisture around each pipe. The pipe placed has 12 mm diameter holes drilled in it so that water poured from top is made to spread in the charcoal layers through the holes to decrease earth resistance accordingly. The pit of about 40 cm^2 is dug in the soil. At the top, a cement concrete work is made for the protection of earth pipe from mechanical damage and to facilitate water pouring arrangements for provision of dampness. A funnel with wire mesh is provided in the concrete work so that water is put through that funnel to have an effective earth. Another GI pipe is taken from the funnel towards outer side for its connection to earth wire. According to ISI specifications, GI wire of size not less than 8 SWG(standard wire gauge) should be used for earthing in case of small installations. The earth wire from the GI pipe of 19 mm diameter should be carried in a GI pipe of diameter 12.7 mm at a depth of about 60 cm below the ground. The size of continuous earth wire used with cables in domestic installation should not be less than 14 SWG in any case. It is important to note that the earth wire must be electrically continuous.	
Jan 2019	**Que: Give a list of safety devices used for home appliances.** **Answer:** Following is the list of safety devices used for home appliances: 1. Fuse 2. Miniature Circuit Breaker (MCB) 3. Earth Leakage Circuit Breaker (ELCB) 4. Residual current devices (RCDs) In addition to above, following devices can also be used for protection: 5. Ground fault circuit interrupters (GFCIs) 6. Arc fault circuit breakers (AFCBs) 7. Surge protection devices (SPDs)	03
Jan 2019	**Que: Why the consumers should improve their power factor?** **Answer:** The consumer should Improve their power factor in installation as it presents several technical and economic advantages, notably in the reduction of electricity bills. The poor power factor leads to increased current in the conductor. The increased current causes more losses in the current carrying conductor resulting into poor efficiency. Improving the PF can maximize current-carrying capacity, improve voltage to equipment, reduce power losses, and lower electric bills.	04

Jan 2019	**Que: What is MCCB? Where is it used?** **Answer:** The **Moulded Case Circuit Breaker (MCCB)** provides overload and short circuit protection to normal service apart from serving as a circuit breaker. The overload and instantaneous tripping element are adjustable over wide range. This makes it ideal for **distribution applications**.	03
Jan 2019	**Que: Compute the monthly energy charges for an air conditioner having consumption of 2 kW. Daily usage of the air conditioner is 10 hours. Energy charges are Rs 8 per unit.** **Answer:** Let us calculate the energy utilization of an air conditioner (AC) per day. Energy utilized by AC per day = Consumption of AC x duration of operation of AC Energy utilized by AC per day = 2kW x 10 hours = 20 kWh (units) Considering an average month of 30 days, Energy utilized by AC per month = 20 kWh x 30 days = 600 kWh (units) Since the energy charges per units are Rs. 8 per unit. The total electricity bill of AC for the month = 600 kWh x Rs. 8/- per unit = Rs. 4800	04
Jan 2019	**Que: Write a short note on Miniature Circuit Breaker (MCB)** **Answer:**  A miniature circuit breaker is an electromechanical device which operates and disconnected the circuit when the current reaches a predetermined value. The MCB may therefore, be used in lieu of fuses and can be fitted in consumer's distribution panel. An MCB is a replacement or most modern substitute for a conventional rewirable fuse. It is more accurate and efficiency system in overload and short circuit protection. An MCB will normally operate at 1.25 times its rated current i.e., a 20A MCB operates at 25A compared with 30A for cartridge fuse or 40A for rewireable fuse. Other advantages of MCB are that they can be quickly reset by hand after operations without any cost and they can be reclosed if the fault still exists. They can be manually reclosed after rectifying the	04

fault. Also, the MCB which has tripped due to overload or short circuit can be readily identified as the knob automatically moves to the OFF position.

MCB is a device which operate on the two principles for the protection against overload and short circuit:

1. Thermal for normal overload protection
2. Magnetic for short circuit protection

The thermal operation is achieved by bimetallic strip, which deflected when heated by any overcurrent flowing through it. In doing so, it releases latch mechanism and causes the contact to open.

It possesses inverse time-current characteristics i.e. greater the current short the time required to operate the MCB.

When the short circuit occurs, the rising current energizes the solenoid operating plunger to strike the trip lever causing immediate release of the latch mechanism. Rapidity of the magnetic solenoid operation causes instantaneous opening of contacts.

Application of MCB:

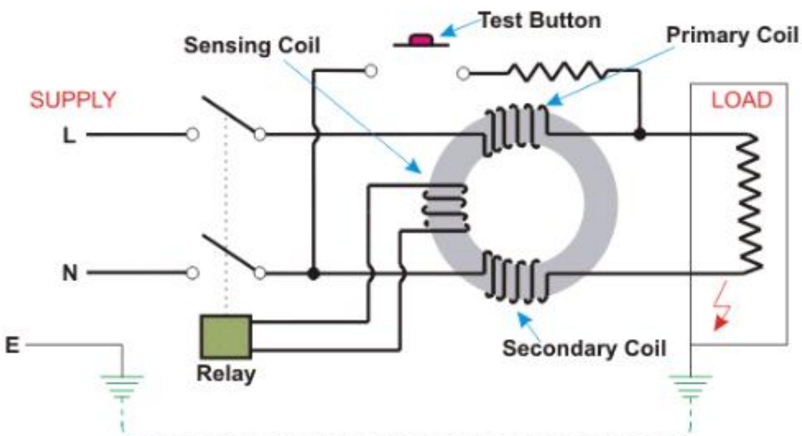
MCBS are required in homes, offices, shops, distribution boards for protection of individual circuit and complete wiring system.

MCBs are slightly expensive than fuses but this is offset by the fact that no cost is involved in resetting them.

Jan 2019 **Que: Write a short note on Earth Leakage Circuit Breaker (ELCB)** 04

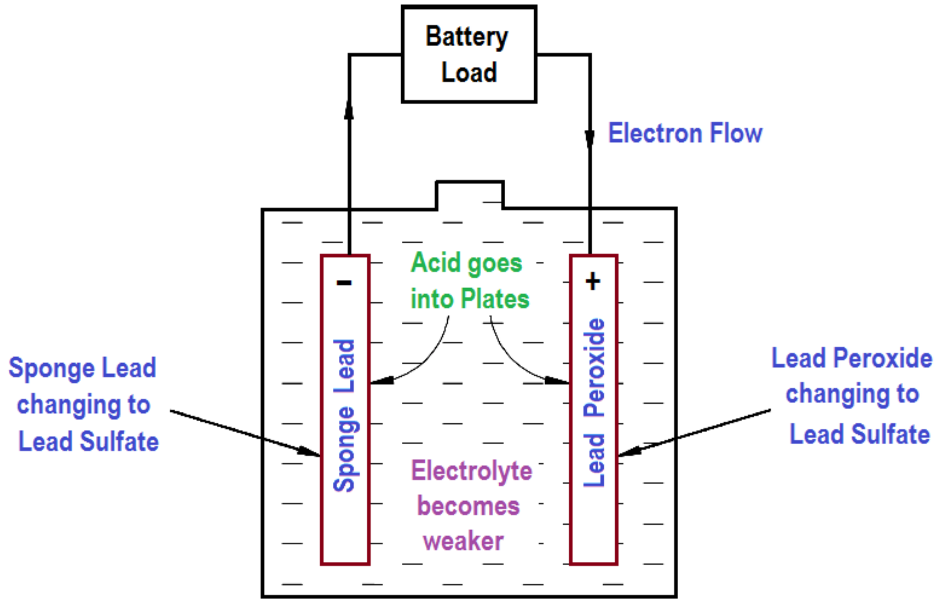
An Earth Leakage Circuit Breaker (ELCB) is current operated device designed to operate when leakage current exceeds a predetermined value. It essentially consists of an operating coil and a trip mechanism which operates contacts controlling the supply to the circuit concerned.

Consider a single-phase circuit. The two supply wires i.e. phase and neutral are fed through separate winding of current transformer as shown in the figure. Another winding controls the tripping mechanism. The current through the phase wire is equal to the current in the neutral wire i.e. $I_p = I_n$.



Circuit Diagram of Earth Leakage Circuit Breaker

	Therefore, the fluxes linking the phase and neutral conductor are equal in magnitude and opposite in direction. Thus, no flux links with the tripping winding. Hence, no induced emf is produced at the secondary or tripping winding. However, if more current flows in the phase conductor than in the neutral conductor as a result of leakage or fault between phase and earth, an out of balance flux will result in an emf being in the trip coil of secondary coil wound on the transformer. This will open the contacts of ELCB and isolate the circuit from the supply. A test button is included in the ELCB testing the trip mechanism. ELCB should be tested by pressing the "Test Switch", at least once in a month. If the ELCB does not trip even after pressing the "Test Switch", it means that the ELCB has become faulty and will not trip even if the human body comes in contact with live conductor.	
Jan 2020	**Que: Classify different types of cables with reference to voltage and insulation materials.** **Answer:** The underground cable is classified mainly as follows: 1. According to the voltage level 2. According to the insulation material used. Usually, classification according to voltage level is preferred. **1. According to voltage level, cables are classified as:** (i) Low Voltage (LT) Cables – upto 1 kV (ii) High Voltage (HT) cables – upto 11 kV (iii) Super Tension (ST) cables – upto 33 kV (iv) Extra High Tension (EHT) cables – upto 66 kV (v) Extra Super Voltage cables – upto 132 kV and above **According to the insulating material, cables are classified as:** (i) Vulcanized Rubber Sheathed (VRS) cables (ii) Tough Rubber Sheathed (TRS) cables (iii) Cab Tyre Sheathed (CTS) cables (iv) Weatherproof cables (v) Polyvinyl Chloride (PVC) cables (vi) Lead Sheathed cables	03
Jan 2020	**Que: Explain the process of charging and discharging of Lead acid cell**. **Answer:** When a lead acid cell is ready for use, its positive plate is of lead peroxide (PbO2)- chocolate brown in color and negative plate is of spongy lead (Pb)- grey in color. Both the plates are immersed in a dilute sulphuric acid of specific gravity 1.28. When the load is connected across the terminals of the cell, it starts delivering current to the load and this process is called as discharging of cell. In this process chemical energy is converted into electrical energy.	07



Operation of Lead Acid Battery

Discharging Operation of Cell:

When the load is connected, the sulphate ions move towards cathode and hydrogen ions moves toward anode. The following chemical action takes place.

At cathode, $Pb + SO_4 \rightarrow PbSO_4$

At anode, $PbO_2 + H_2SO_4 + 2H \rightarrow PbSO_4 + 2H_2O$

Thus during discharging :

Both plates are converted to lead sulphate

Specific gravity of sulphuric acid is 1.15

Terminal voltage fall from 2.0 V to 1.8 V

Chemical energy changes to electrical energy

Charging Operation of Cell:

For recharging anode is connected to positive terminal of source and cathode is connected to negative terminal. During this hydrogen ions moves towards cathode and sulphate ions towards anode.

At anode, $PbSO_4 + O + H_2O \rightarrow PbO_2 + H_2SO_4$

At cathode, $PbSO_4 + 2H \rightarrow Pb + H_2SO_4$

During recharging :

Plates regain their original composition

Specific gravity of acid become 1.28

Terminal voltage increases from 1.8 V to 2.0 V

Electrical energy converted to chemical energy which is stored in cell.

Jan 2020	**Que: Compare MCB and ELCB.**	03

MCB	***ELCB***
The MCB is only installed for one cable i.e. phase cable	The ELCB is installed for both cables i.e. phase and neutral.
MCB only functions as security when there is overcurrent or short circuit.	ELCB functions when there is electrocution or electric shock or when there is current surge.
The MCB cannot work for human safety.	The ELCB works primarily for human safety.
The MCB cannot detect leakage current.	The ELCB can detect leakage current and provide protection against it.
It is relatively cheap than ELCB	It is relative expensive that MCB.

Jan 2020 **Que: Write safety precautions for electrical Applications.** 04

Answer:

Following precautions should be taken while working with the electricity:

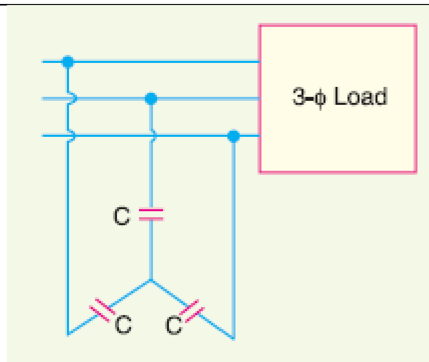
1. Never work with bare feet. It is better to wear rubber shoes while working.
2. Use safety belt before starting the work on the electric pole or tower.
3. Phase or positive wire should always be connected through the switch.
4. Before replacing the blown fuse, always switch off the main switch.
5. Do not disconnect the flexible wire of an electrical apparatus from the socket by pulling it out.
6. Do not touch electrical installation without any purpose.
7. Always keep earth connection in good condition.
8. Do not charge the battery in a dark room. The wrong connection may lead to hazard.
9. In case of fire, do not throw water on a live wire and equipment, it is dangerous. The best remedy is to disconnect the main supply immediately.

Jan 2020 **Que: Explain different methods of power factor improvement** 07

Answer:

Normally, the power factor of the whole load on a large generating station is in the region of 0·8 to 0·9. However, sometimes it is lower, and, in such cases, it is generally desirable to take special steps to improve the power factor. This can be achieved by the following equipment :

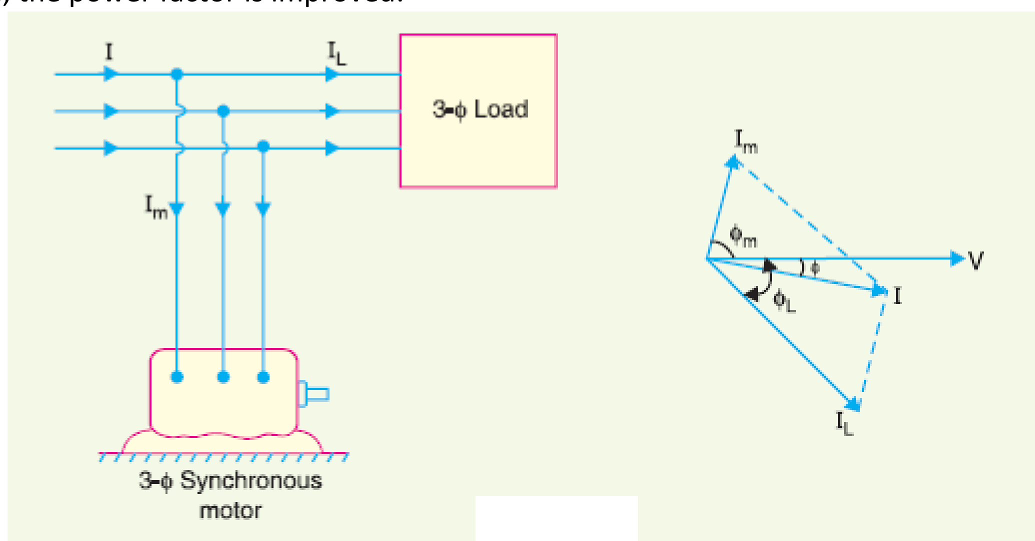
1. Static capacitors.
2. Synchronous condenser.
3. Phase advancers.



Static Capacitor for Power Factor Improvement

1. Static capacitor.
The power factor can be improved by connecting capacitors in parallel with the equipment operating at lagging power factor. The capacitor (generally known as static condenser) draws a leading current and partly or completely neutralizes the lagging reactive component of load current. This raises the power factor of the load. For three-phase loads, the capacitors can be connected in delta or star as shown in Fig. Static capacitors are invariably used for power factor improvement in factories.

2. Synchronous condenser
A synchronous motor takes a leading current when over-excited and, therefore, behaves as a capacitor. An over-excited synchronous motor running on no load is known as synchronous condenser. When such a machine is connected in parallel with the supply, it takes a leading current which partly neutralizes the lagging reactive component of the load. Thus, the power factor is improved.



Synchronous condenser for Power Factor Improvement

Fig shows the power factor improvement by synchronous condenser method. The 3ϕ load takes
current I_L at low lagging power factor cos φ_L . The synchronous condenser takes a current I_m which leads the voltage by an angle φ_m^*. The resultant current I is the phasor sum of I_m and I_L and lags the voltage by an angle φ. It is clear that φ is less than φ_L so that cos φ is

greater than $\cos\varphi_L$. Thus, the power factor is increased from $\cos\varphi_L$ to $\cos\varphi$. Synchronous condensers are generally used at major bulk supply substations for power factor improvement.

3. Phase advancers.

Phase advancers are used to improve the power factor of induction motors. The low power factor of an induction motor is due to the fact that its stator winding draws exciting current which lags behind the supply voltage by 90o. If the exciting ampere turns can be provided from some other a.c. source, then the stator winding will be relieved of exciting current, and the power factor of the motor can be improved. This job is accomplished by the phase advancer which is simply an a.c. exciter. The phase advancer is mounted on the same shaft as the main motor and is connected in the rotor circuit of the motor. It provides exciting ampere turns to the rotor circuit at slip frequency. By providing more ampere turns than required, the induction motor can be made to operate on leading power factor like an over-excited synchronous motor.