Model Question Paper-I/II with effect from 2021 (CBCS Scheme)

USN | | | | | | | | | | |

First Semester __BE__ Degree Examination
Subject Title: Basic Electrical Engineering

TIME: 03 Hours **Max. Marks: 100**

Note: 01. Answer any **FIVE** full questions, choosing at least **ONE** question from each **MODULE**.
02.
03.

		Module -1	**Marks**
Q.01	a	With respect to DC circuit, state and explain Kirchhoff's law.	6
	b	A sinusoidally varying alternating voltage is given by, $v(t) = V_m sin\omega t$, obtain its RMS value of voltage in terms of maximum value.	8
	c	A resistance R is connected in series with a parallel circuit comprising two resistances of 12 Ω and 8Ω respectively. The total power dissipated in the circuit is 70 W when the applied voltage is 20V. Calculate R.	6
		OR	
Q.02	8	A load resistance $R_L \Omega$ is connected across the source V_S with internal resistance R_{int} in series with source; obtain the condition that the power transferred to load from source is maximum.	6
	6	A pure inductor excited by sinusoidally varying AC voltage, show that the average power consumed by inductor is zero.	8
	c	Two resistors are connected in parallel and a voltage of 200V is applied to the terminals. The total current taken is 2.5 A, and the power dissipated in one of the resistor is 1500 W. What is the resistance of each element?	6
		Module-2	
Q. 03	a	With the help of phasor diagram, show that the current drawn by the R-L series circuit, lags the applied voltage by an angle ∅ with respect to voltage.	8
	b	A voltage of 125 V at 60 Hz is applied across a non-inductive resistor connected in series with a capacitor. The current is 2.2 A. The power loss in the resistor is 96.8 W, and that in the capacitor is negligible. Calculate the resistance and the capacitance.	6
	c	A three single phase balanced load connected in three phase three wires star form, with the help of phasor diagram, obtain the relationship between line and phase quantities of voltage and current.	6
		OR	
Q.04	a	With the help of phasor diagram, show that the current drawn by the R-C series circuit, leads the applied voltage by an angle ∅ with respect to voltage.	**8**
	b	Two circuits, the impedances of which are given by $Z_1 = 10 + j15\ \Omega$ and $Z_2 = 6 - j8\ \Omega$, are connected in parallel. If the total current supplied is 15 A, what is the power taken by each branch.	**6**
	c	Three phase power consumed by the balanced load is given by $P = \sqrt{3} V_L I_L \cos(\emptyset)$ watts, then show that two wattmeter sufficient to measure three phase power P.	**6**
		Module-3	
Q. 05	a	With a neat diagram, explain the constructional details of DC generator.	8
	b	A shunt generator delivers 50 KW at 250 V and 400 rpm. The armature and shunt field resistances are 0.02 Ω and 50 Ω respectively. Calculate the speed of the machine running as a shunt motor and taking 50 KW input at 250 V. Allow 1 V brush for contact drop.	6
	c	For the single phase transformer, obtain an expression for EMF induced in either primary side or secondary side.	6
		OR	

Q. 06	a	A dc motor running with a speed of N rpm, obtain an expression for EMF induced in the armature winding.	8
	b	A 4-pole, 500V, shunt motor has 720 wave-connected conductors on its armature. The full-load armature current is 60 A, and the flux per pole 0.03 Webers. The armature resistance is 0.2 Ω, and the contact drop is 1 V per brush. Calculate the full load speed of the motor.	6
	c	To operate the transformer in maximum efficiency always, derive at what condition, this can be achieved.	6
		Module-4	
Q. 07	a	With the help of neat diagram, explain the constructional details of three phase induction motor.	6
	b	A three phase 400 V, 50 Hz supply is given to three induction motor with 4 pole running and runs at 1440 rpm. Determine the speed of the rotor and frequency of the rotor current.	6
	c	With the help of diagram, explain the construction details of salient and non-salient generator.	8
		OR	
Q. 08	a	An alternator running at N rpm, induces an emf in the armature conductors of the machine and obtain an expression of induced emf.	6
	b	A 3-phase 16-pole alternator has a star connected winding with 144 slots and 10 conductors per slot. The flux per pole is 0.03 webers, sine-distributed, and the speed is 375 rpm. Find the frequency, and the phase and line voltages.	6
	c	When a three phase supply given is given to the three phase induction motor, explain how a rotating magnetic field produces in the airgap of the machine.	8
		Module-5	
Q. 09	a	With the help of block diagram, discuss low voltage distribution system (400 V and 230 V) for domestic, commercial, and small-scale industry.	6
	b	List out the power rating of household appliances including air conditioners, PCs, laptops, printers, etc. Find the total power consumed.	6
	c	Why earthing is need in a building service. With neat diagram explain the pipe earthing.	8
		OR	
Q. 10	a	In a domestic consumers end, discuss how two-part electricity tariff imposed to calculate electricity bills.	6
	b	Discuss how electricity bill is calculated based on "unit" which is consumption of electrical energy for domestic consumers.	6
	c	With a neat circuit diagram, explain the operation of MCB and RCCB	8

Table showing the Bloom's Taxonomy Level, Course Outcome and Program Outcome

Question		Bloom's Taxonomy Level attached	Course Outcome	Program Outcome
Q.1	(a)	L2	CO1	PO1
	(b)	L2	CO1	PO2
	(c)	L1 L2	CO1	PO2
Q.2	(a)	L2	CO1	PO1
	(b)	L2	CO1	PO2
	(c)	L1 L2	CO1	PO2
Q.3	(a)	L2	CO1	PO2
	(b)	L1 L2	CO1	PO2
	(c)	L2	CO1	PO2
Q.4	(a)	L2	CO1	PO2
	(b)	L1	CO1	PO2

		L2	CO1	
	(c)	L2	CO1	PO2
Q.5	(a)	L2	CO2	PO2
	(b)	L1 L2	CO2	PO2
	(c)	L2	CO2	PO2
Q.6	(a)	L2	CO2	PO2
	(b)	L1 L2	CO2	PO2
	(c)	L2	CO2	PO2
Q.7	(a)	L2	CO2	PO2
	(b)	L1 L2	CO2	PO2
	(c)	L2	CO2	PO2
Q.8	(a)	L2	CO2	PO2
	(b)	L1 L2	CO2	PO2
	(c)	L2	CO2	PO2
Q.9	(a)	L2	CO3	PO1
	(b)	L2	CO4	PO2
	(c)	L2	CO4	PO1
Q.10	(a)	L2	CO3	PO2
	(b)	L2	CO4	PO2
	(c)	L2	CO4	PO2

Bloom's Taxonomy Levels	**Lower order thinking skills**		
	Remembering (knowledge): L_1	Understanding Comprehension): L_2	Applying (Application): L_3
	Higher order thinking skills		
	Analyzing (Analysis): L_4	Valuating (Evaluation): L_5	Creating (Synthesis): L_6

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Department of Electrical & Electronics Engineering

Sem - I.
Subject - Basic Electrical Engineering
Code - 21ELE13

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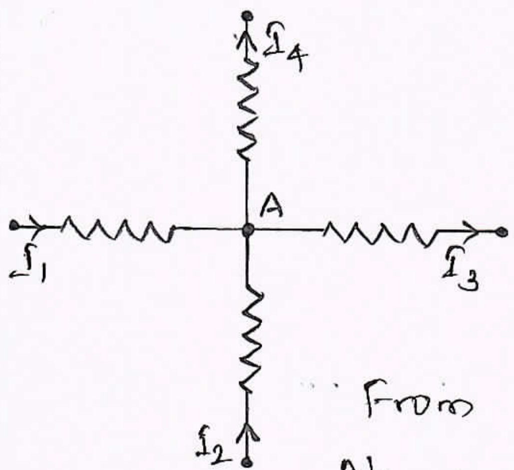
Module - 01

Q 1 a) With respect to DC circuit, state & explain Kirchhoff's law. [06 Marks]

i) Kirchhoff's Current Law [KCL]

The algebraic sum of all the currents meeting at any junction of an electrical circuit is zero.

i.e $\Sigma I = 0$



- Incoming currents are taken +ve.
- Outgoing currents are taken -ve.

Then, $I_1 + I_2 - I_3 - I_4 = 0$

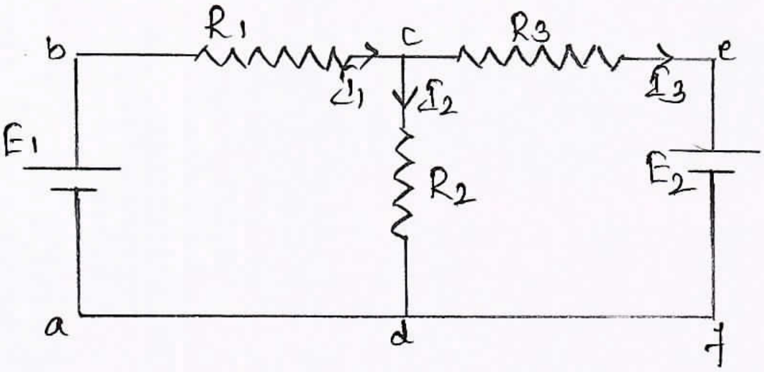
or $I_1 + I_2 = I_3 + I_4$ —— (1)

From eqn. (1) KCL can also be defined as, At any junction of an electrical circuit, the sum of all the currents entering the junction is equal to the sum of all the currents leaving the junction.

ii) Kirchhoff's Voltage Law [KVL]

In any closed electrical circuit, the algebraic sum of all the emf's & the resistive drops is equal to zero.

ie $\Sigma E + \Sigma IR = 0$.



For loop abcda:

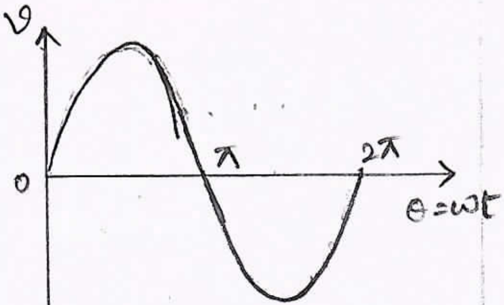
$E_1 - I_1 R_1 - I_2 R_2 = 0$.

For loop dcefd:

$I_2 R_2 - I_3 R_3 - E_2 = 0$.

Q 1 b) A sinusoidally varying alternating voltage is given by, $v(t) = V_m \sin \omega t$, obtain its RMS value of voltage in terms of maximum value. [08 Marks]

The equation for the alternating voltage representing the sinusoidal waveform shown in Fig. is



$$v(t) = V_m \sin \omega t = V_m \sin \theta$$

The effective value of this voltage is given by,

$$V^2 = \frac{1}{2\pi} \int_0^{2\pi} v^2 \, d\theta = \frac{1}{2\pi} \int_0^{2\pi} V_m^2 \sin^2\theta \cdot d\theta$$

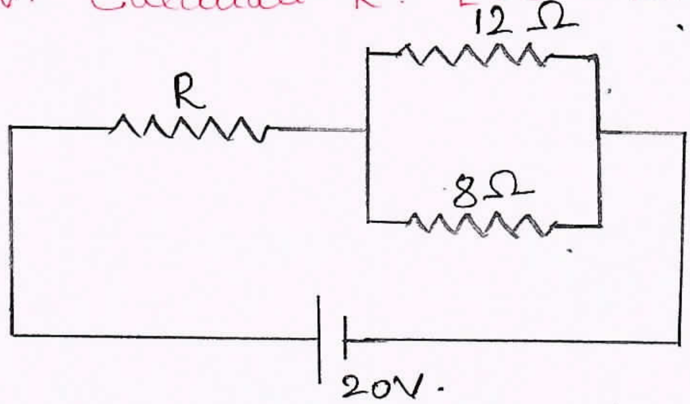
$$= \frac{V_m^2}{2\pi} \int_0^{2\pi} \frac{1 - \cos 2\theta}{2} \, d\theta$$

$$= \frac{V_m^2}{4\pi} \left[\theta - \frac{\sin 2\theta}{2} \right]_0^{2\pi} = \frac{V_m^2}{4\pi} \left[2\pi - 0 - (0 - 0) \right]$$

$$V^2 = \frac{V_m^2}{2} \Rightarrow \boxed{V = \frac{V_m}{\sqrt{2}} = 0.707\, V_m}$$

The RMS value of current is 0.707 times its maximum value.

Q1 c) A resistance R is connected in series with a parallel circuit comprising two resistances of 12 Ω & 8 Ω respectively. The total power dissipated in the circuit is 70W when the applied voltage is 20V. Calculate R. [06 Marks]



$P = 70\,W$.

We have, $P = V^2/R_{Total}$

$\therefore R_{Total} = \frac{V^2}{P} = \frac{20^2}{70}$

$R_{Total} = 5.71\,\Omega$.

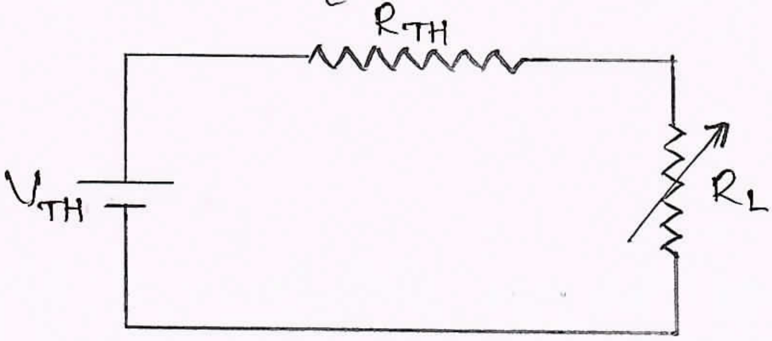
Also, $R_{Total} = R + \left[\frac{12 \times 8}{12 + 8}\right]$

ie $5.71 = R + 4.8$

$\therefore$ $\boxed{R = 0.91\,\Omega.}$

Q2 a) A load resistance R_L Ω is connected across the source V_s with internal resistance R_{int} in series with source. Obtain the condition that the power transfe-rred to the load from source is maximum. [06 Marks]

Maximum power transfer theorem states that, the DC voltage source will deliver maximum power to the variable load resistor only when the load resistance is equal to the source resistance.



The amount of power dissipated across the load resistor is,

$$P_L = I^2 R_L$$

Substitute, $I = \dfrac{V_s}{R_{int} + R_L}$ in the above equation,

$$P_L = \left[\frac{V_s}{R_{int} + R_L}\right]^2 \cdot R_L$$

$$P_L = V_s^2 \left[\frac{R_L}{(R_{int} + R_L)^2}\right] \quad \text{—— (1)}$$

Maximum power transfer is obtained when,

$$\frac{dP_L}{dR_L} = 0.$$

ie $$\frac{dP_L}{dR_L} = V_s^2 \left[\frac{(R_{int} + R_L)^2 \times 1 - R_L \times 2(R_{int} + R_L)}{(R_{int} + R_L)^4}\right] = 0$$

$$\Rightarrow (R_{int} + R_L)^2 - 2R_L(R_{int} + R_L) = 0.$$

$$\Rightarrow (R_{int} + R_L)(R_{int} + R_L - 2R_L) = 0$$

$$\Rightarrow R_{int} - R_L = 0$$

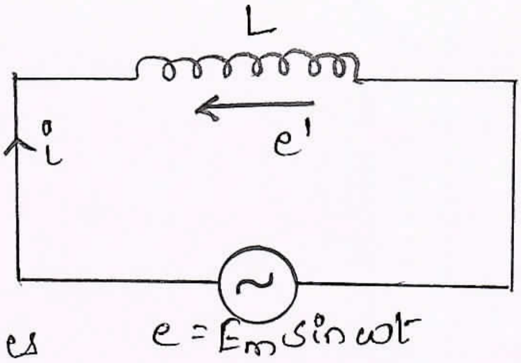
or $$\boxed{R_L = R_{int}}$$

Thus, maximum power transfer is obtained when $R_L = R_{int}$.

Q 2b) A pure inductor excited by sinusoidally varying AC voltage, show that the average power consumed by inductor is zero. [08 Marks]

Consider a coil of pure inductance L henrys, across which an alternating voltage $e = E_m \sin \omega t$ is applied as shown.

Because of which an alternating current i flows through it.



This current produces an alternating flux, which links the coil & hence an emf e' is induced in it, which opposes the applied voltage & is given by,

$$e = E_m \sin \omega t$$

$$e' = -L \cdot \frac{di}{dt} = -e$$

$$\therefore \quad e = L \cdot \frac{di}{dt}$$

$$di = \frac{e}{L} \cdot dt = \frac{1}{L} \cdot E_m \sin\omega t \cdot dt$$

$$i = \frac{E_m}{L} \int \sin\omega t \cdot dt$$

$$= \frac{E_m}{\omega L} \left[-\cos\omega t \right]$$

$$= \frac{E_m}{\omega L} \sin(\omega t - \pi/2)$$

$$i = I_m \sin(\omega t - \pi/2)$$

where $X_L = \omega L = 2\pi f L$ = inductive reactance in Ohm's.

The instantaneous power is given by

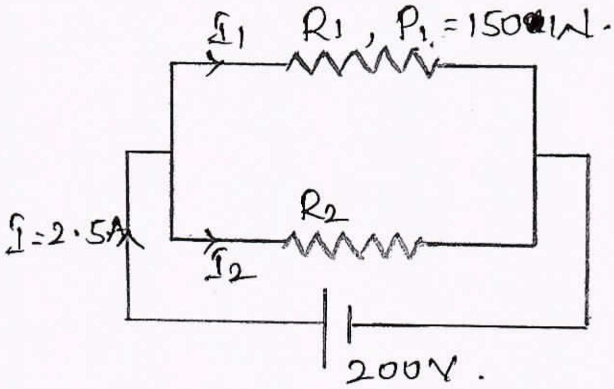
$$P = e \times i = E_m \sin\omega t \cdot I_m \sin(\omega t - \pi/2)$$

$$P = E_m I_m \sin \omega t \cdot (-\cos\omega t)$$

$$P = -\frac{1}{2} E_m I_m \sin 2\omega t$$

The eqn. for 'P' consist of a quantity which is periodically varying & having a frequency two times the frequency of applied voltage & whose average value is zero. Hence power consumed by a pure inductor is zero.

Q 2c) Two resistors are connected in parallel & a voltage of 200V is applied to the terminals. The total current taken is 2.5A, & power dissipa-ted in one of the resistor is 150W. What is the resistances of each element. [06 Marks]



We have, $P_1 = V I_1$

$$I_1 = \frac{P_1}{V} = \frac{150}{200}$$

$$I_1 = 0.75 \text{ A}.$$

$$\therefore \quad R_1 = \frac{V}{I_1} = \frac{200}{0.75} = 266.66\,\Omega.$$

$$I_2 = I - I_1 = 2.5 - 0.75 = 1.75 \text{ A}.$$

$$\therefore \quad R_2 = \frac{V}{I_2} = \frac{200}{1.75} = 114.2\,\Omega.$$

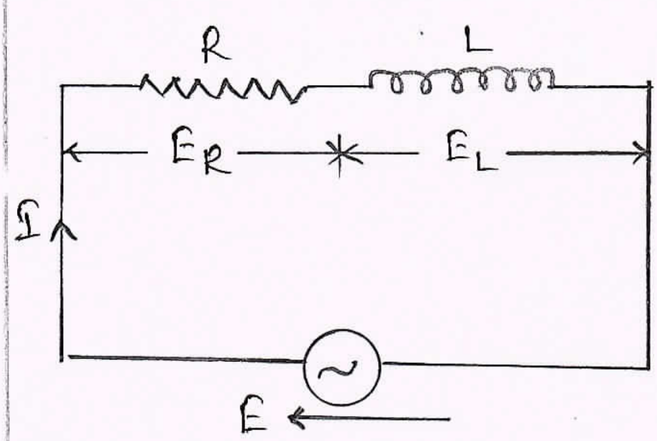
$R_1 = 266.66\,\Omega$	$R_2 = 114.2\,\Omega$

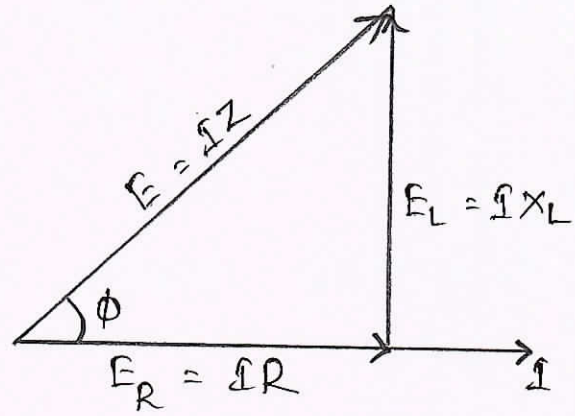
Module - 2

Q 3a) With the help of phasor diagram, show that the current drawn by the R-L series circuit lags the applied voltage by an angle ϕ with respect to voltage. [08 Marks]

Consider an R-L series circuit to which an alternating voltage of rms value E is applied due to which an rms value of current I flows through the circuit.

The vector diagram taking I as a reference vector is also shown.

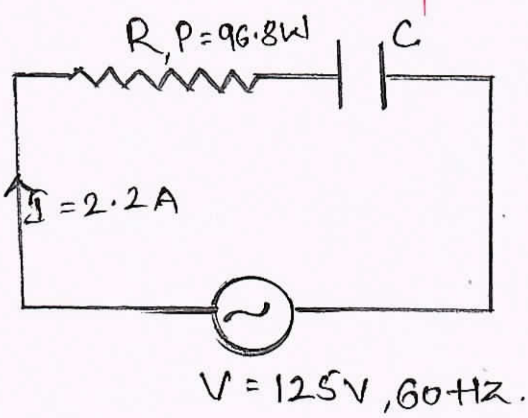




The vector diagram consist of three voltages, $E_R = IR$ which is inphase with current, $E_L = IX_L$ which leads current by 90°. The vector sum of these two voltages is the applied voltage $E = IZ$, where Z is impedance of the circuit.

From the vector diagram, we observed that the current lags the voltage by an angle ϕ.
If $e = E_m \sin \omega t$ then $i = I_m \sin(\omega t - \phi)$.

Q3 b) A voltage of 125V at 60Hz is applied across a non-inductive resistor connected in series with a capacitor. The current is 2.2A. The power loss in the resistor is 96.8W & that in the capacitor is negligible. Calculate the resistance & capacitance [6 Marks]



$P = I^2 R$

$R = I^2/P = 2.2^2/96.8$

$R = 0.05\ \Omega$

$Z = \frac{V}{I} = \frac{125}{2.2} = 56.81\ \Omega$

We have, $Z = \sqrt{R^2 + X_c^2}$

$$\therefore X_c = \sqrt{Z^2 - R^2} = \sqrt{(56.81)^2 - (0.05)^2}$$

$$X_c = 56.80\ \Omega.$$

We know that, $X_c = \frac{1}{2\pi f C}$.

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

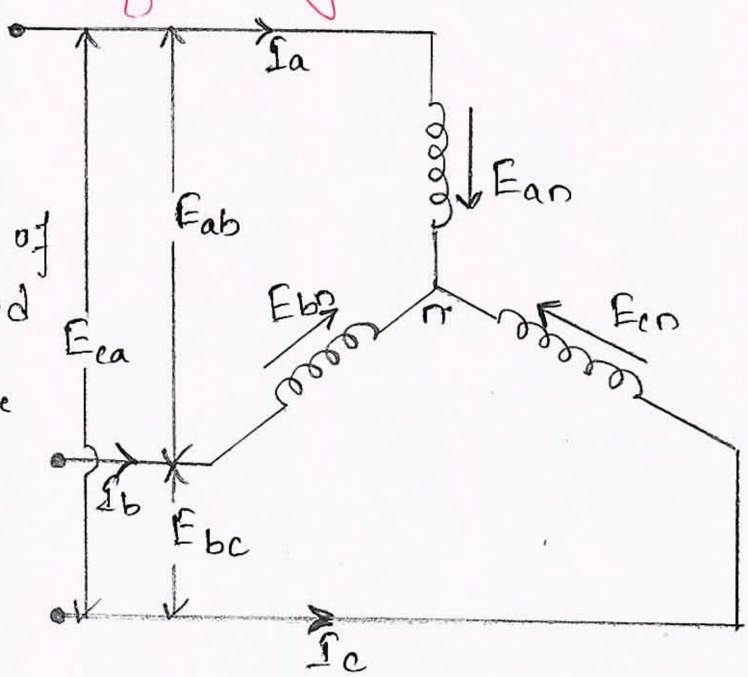
$$= \frac{1}{2\pi \times 60 \times 56.80}$$

$$\boxed{C = 46.7\ \mu F.}$$

Q3c) A three single-phase balanced load connected in 3-φ three wire star form, with the help of phasor diagram obtain the relationship between Line & phase quantities of voltage & current.

[06 Marks]

A star connection is formed, when the ends of the three coils are joined together at point n, the other three ends being free as shown in fig.



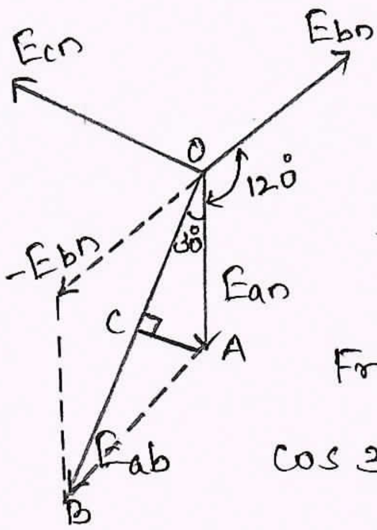
Let E_{an}, E_{bn} & E_{cn} are phase voltages & E_{ab}, E_{bc} & E_{ca} are line voltages.

From circuit diagram, the currents flowing through the lines are the same as the currents flowing through the phases.

Hence

Line Current = Phase Current.
$I_{line} = I_{phase}$

The vector diagram of line voltages & phase voltages for the star connection is shown in Fig.



The line voltage Eab is given by,

$$E_{ab} = E_{an} + E_{nb} = E_{ab} - E_{bn}$$

Draw a perpendicular AC on OB,

$$\angle AOC = 30^\circ.$$

From ΔAOC,

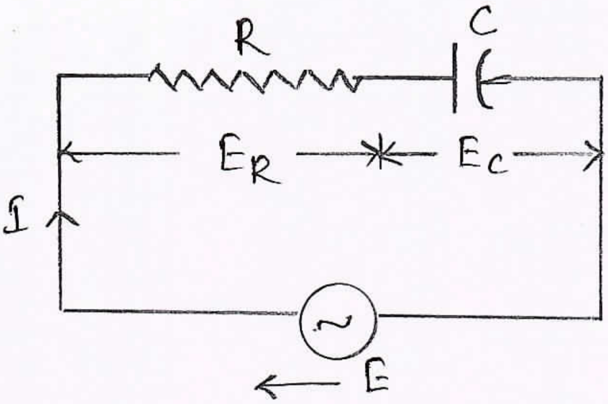
$$\cos 30^\circ = \frac{OC}{OA} = \frac{OB/2}{OA} = \frac{E_{ab}/2}{E_{an}}$$

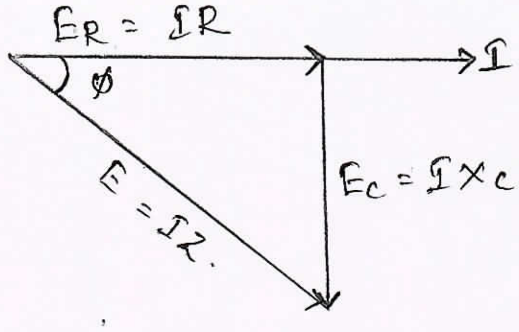
$$\therefore E_{ab} = 2 E_{an} \cos 30^\circ = 2 E_{an} \times \frac{\sqrt{3}}{2} = \sqrt{3} E_{an}$$

$\therefore \quad E_l = \sqrt{3}\, E_{ph}$
Line Voltage = $\sqrt{3}$ × phase Voltage.

Q4a) With the help of phasor diagram, show that the current drawn by the R-C series circuit leads the applied voltage by an angle ϕ with respect to voltage. [08 Marks]

Consider R-C series circuit to which an alternating voltage of rms value E is applied, due to which an rms value of current I flows through the circuit.





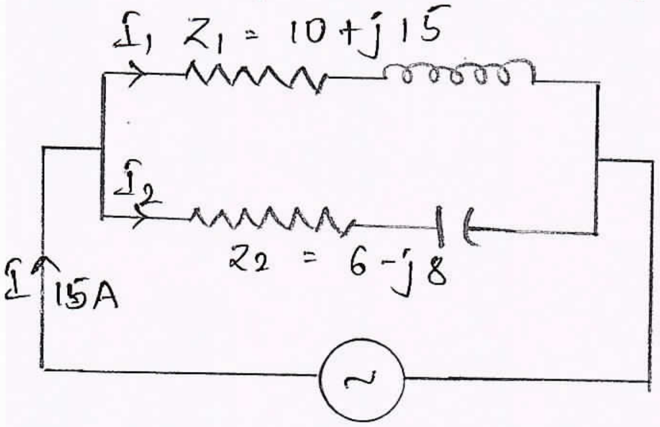
From the vector diagram, we observe that the current leads the voltage by an angle ϕ.

If $e = E_m \sin \omega t$

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

From the above eqns. we conclude that, in R-C series circuit the current leads the voltage by an angle ϕ.

Q 4 b) Two circuits the impedances of which are given by $Z_1 = (10 + j15)\,\Omega$ & $Z_2 = (6 - j8)\,\Omega$ are connected in parallel. If the total current supplied is 15A, what is the power taken by each branch? [06 Marks]



$Z_1 = 10 + j15 = 18.02 \angle 56.3^\circ$

$Z_2 = 6 - j8 = 10 \angle -53.13^\circ$

$$I_1 = I \left[\frac{Z_2}{Z_1 + Z_2} \right]$$

$$= 15 \left[\frac{10 \angle -53.13^\circ}{17.46 \angle 23.62} \right]$$

$$= 15 \left[0.572 \angle -76.75 \right]$$

$$I_1 = 8.58 \angle -76.75$$

$$I_2 = I\left[\frac{Z_1}{Z_1+Z_2}\right]$$

$$= 15\left[\frac{18.02\angle 56.3}{17.46\angle 23.62}\right]$$

$$= 15\left[1.03\angle 32.68\right]$$

$$I_2 = 15.45\angle 32.68^\circ$$

$$Z_{Total} = \frac{Z_1 Z_2}{Z_1+Z_2} = \frac{180.2\angle 3.17}{17.46\angle 23.62} = 10.32\angle -20.45^\circ.$$

Applied Voltage $V = I Z_{Total} = 15 \times 10.32\angle -20.45^\circ$

$$V = 154.8\angle -20.45^\circ$$

$P_1 = V I_1 \cos\phi$ = ~~154.8 ∠-20.45°~~ ×

$$= 154.8 \times 8.58 \times \cos\left[-20.45 + 76.75\right]$$

$$\boxed{P_1 = 736.93 \text{ Watts.}}$$

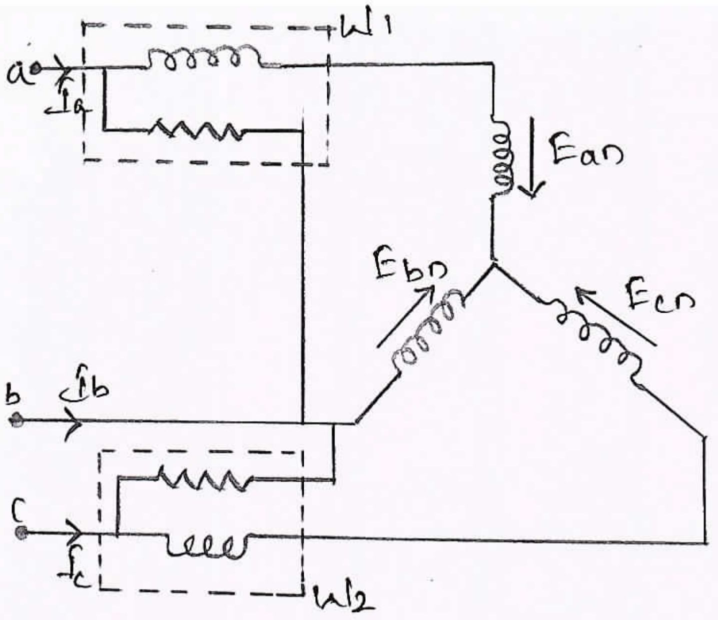
$$P_2 = V I_2 \cos\phi$$

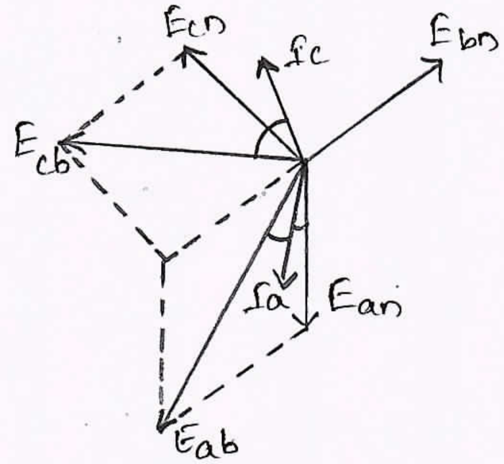
$$= 154.8 \times 15.45 \times \cos\left[-20.45 - 32.68\right]$$

$$\boxed{P_2 = 1434.99 \text{ Watts}}$$

Q4c) Three phase power consumed by the balanced load is given by $P = \sqrt{3} V_L I_L \cos\phi$ watts, then show that two wattmeter sufficient to measure three-phase power [06 Marks]

Consider a star connected balanced load as shown in fig. and also phasor diagram.





The wattmeter reading W_1 is given by,

$$W_1 = E_{ab} I_a \cos \angle E_{ab} \,\&\, I_a$$

Similarly, $W_2 = E_{bc} I_c \cos \angle E_{bc} \,\&\, I_c$

The angle between E_{ab} & I_a and E_{bc} & I_c is found as shown in vector diagram.

Assuming the load to be inductive, I_a lags E_{an} by angle ϕ. Hence, the angle between E_{ab} & I_a is $(30 - \phi)$.

$$\therefore \quad W_1 = E_{ab} I_a \cos(30 - \phi) = E_L I_L \cos(30 - \phi) \quad \text{---(1)}$$

Again, assuming load to be inductive, I_c lags E_{cn} by angle ϕ. Hence the angle between E_{bc} & I_c is $(30 + \phi)$

$$\therefore W_2 = E_{cb} I_c \cos(30 + \phi) = E_L I_L \cos(30 + \phi) \quad \text{---(2)}$$

Adding eqns. (1) & (2),

$$W_1 + W_2 = E_L I_L \left[\cos(30 - \phi) + \cos(30 + \phi)\right]$$

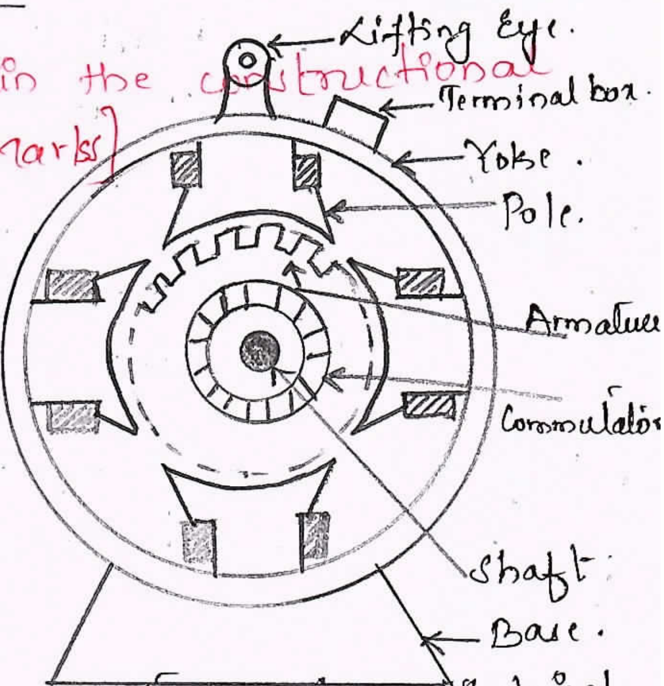
$$= E_L I_L \cdot 2 \cos 30 \cdot \cos \phi$$

$$= E_L I_L \cdot 2 \times \frac{\sqrt{3}}{2} \cdot \cos \phi$$

$$\boxed{W_1 + W_2 = \sqrt{3}\, E_L I_L \cos\phi = 3\text{-}\phi \text{ power}}$$

Module - 03

Q5 a) With a neat diagram explain the constructional details of DC generator [08 Marks]



The DC generator consist of
i) Yoke
ii) Pole
iii) Armature
iv) Commutator
v) Shaft

Yoke:
It is the outer cover for DC generator & is cylindrical in shape. For small generator it is madeup of cast iron & for larger generators it is made up of cast steel.

Pole: These are madeup of alloy steel.
It consist of pole core and pole shoe. The pole is laminated to reduce eddy current losses. The shape of pole shoe is cylindrical at the bottom, so that flux produced is spreadout uniformly in the air gap.
When a direct current is passed through the field coils pole core becomes an electromagnet & produces the main flux required for generation of emf.

Armature: It consist of armature core & armature winding. The armature core is made up of high permiability & low loss silicon steel laminations which are usually 0.4 to 0.5mm thick & are insulated from one another by varnish.
The armature conductors are placed in the slots of the armature & are connected together either as lap winding or wave winding.

Commutator: The commutator is cylindrical in shape & madeup of hard drawn copper which are insulated from one another & from the shaft by mica strips. The segments are connected to the armature Conductors through risers. The commutator converts alternating emf generated in the armature winding into direct current voltage in the external circuit.

Shaft: The shaft of the DC generator is rotated by prime mover due to which armature fixed to it also rotates.

Q5b) A shunt generator delivers 50kW at 250V & 400rpm. The armature & shunt field resistances are 0.02Ω & 50Ω respectively. Calculate the speed of the machine running as a shunt motor & taking 50kW input at 250V. Allow 1V brush for contact drop. [06 Marks]

As a generator, $I_{sh} = \frac{250}{50} = 5\ A$.

$I_{L1} = \frac{P}{V} = \frac{50\,000}{250} = 200\ A$.

$I_{a1} = I_{L1} + I_{sh} = 200 + 5 = 205\ A$.

$E_g = V + I_{a1} R_a + BCD$

$= 250 + (205 \times 0.02) + (2 \times 1)$

$E_g = 256.1\ V$

As a Motor, $I_{L2} = \frac{P}{V} = \frac{50000}{250} = 200\ A$.

$I_{a2} = I_{L2} - I_{sh} = 200 - 5 = 195\ A$.

$\therefore E_b = V - I_{a2}R_a - BCD$

$= 250 - (195 \times 0.02) - (2 \times 1)$

$E_b = 244.1\ V$

We know that, $\frac{E_g}{E_b} = \frac{N_1}{N_2}$

$\therefore \frac{256.1}{244.1} = \frac{400}{N_2}$

$N_2 = 381$ rpm

Q5c) For the single-phase transformer, obtain an expression for EMF induced in either primary side or secondary side. [06 Marks]

When the alternating voltage $v_1 = V_m \sin \omega t$ of rms value $V_1 = V_m/\sqrt{2}$ is applied to the primary winding of the transformer, the alternating current flowing through the primary winding produces an alternating flux ϕ which links both primary winding & secondary winding. Hence an emf e_1 is induced in the primary winding & an emf e_2 is induced in the secondary winding. The equation for e_1 is,

$$e_1 = -N_1 \cdot \frac{d\phi}{dt} \quad \text{--- (1)}$$

The eqn. for the flux is given by,

$$\phi = \phi_m \sin \omega t$$

Substituting this value of ϕ in eqn. (1)

$$e_1 = -N_1 \cdot \frac{d\phi}{dt} = -N_1 \cdot \frac{d}{dt}(\phi_m \sin \omega t)$$

$$= -\omega N_1 \phi_m \cos \omega t$$

$$e_1 = 2\pi f N_1 \phi_m \sin(\omega t - 90) \quad \text{--- (2)}$$

The magnitude of the maximum value of the emf induced in the primary winding is given by,

$$E_{m1} = 2\pi f N_1 \phi_m$$

The rms value of the emf induced in the primary winding is given by,

$$E_1 = \frac{E_{m1}}{\sqrt{2}} = \frac{2\pi f N_1 \phi_m}{\sqrt{2}}$$

$$E_1 = 4.44 f \phi_m N_1 \text{ volts.}$$

lll^{ly}

$$E_2 = 4.44 f \phi_m N_2 \text{ Volts.}$$

Q6 a) A DC motor running ~~at~~ with a speed of N rpm. Obtain an expression for EMF induced in the armature winding. [08 Marks]

Let
Z = Total no. of armature conductors.
ϕ = Useful flux per pole in Webers.
N = Speed of armature in rpm.
P = No. of poles.
A = No. of parallel paths.

The flux cut by a conductor in one revolution

$$= \phi P = d\phi$$

The time taken by conductor to make one revolution

$$= 60/N \text{ sec} = dt$$

Hence EMF induced in one conductor $= \frac{d\phi}{dt} = \frac{\phi P}{60/N}$

$$= \frac{\phi P N}{60} \text{ volts.}$$

The emf induced per parallel path

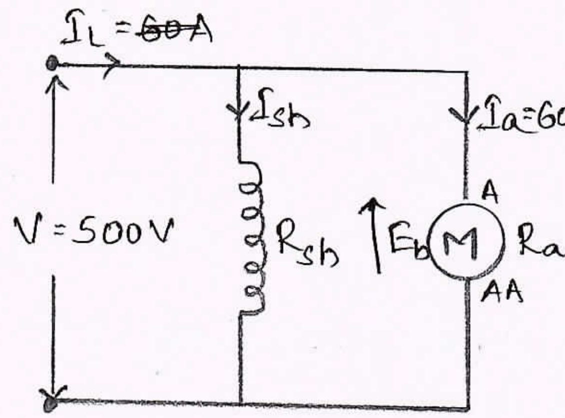
= EMF induced per conductor x No. of conductors per parallel paths

$$E = \frac{\phi P N}{60} \times \frac{Z}{A} = \frac{\phi Z N P}{60\,A} \text{ volts.}$$

For lap winding, $A = P \Rightarrow$ $\boxed{E = \frac{\phi Z N}{60} \text{ volts.}}$

For wave winding, $A = 2 \Rightarrow$ $\boxed{E = \frac{\phi Z N P}{120} \text{ volts}}$

Q6b) A 4-pole, 500V shunt motor has 720 wave connected conductors on its armature. The full load armature current is 60A & the flux per pole is 0.03 webers. The armature resistance is 0.2Ω & the contact drop is 1V per brush. Calculate the full load speed of the motor. [06 marks]



We have,

$$E_b = V - I_a R_a - BCD$$

$$= 500 - (60 \times 0.2) - (2 \times 1)$$

$$E_b = 486 \text{ V}$$

But $E_b = \frac{\phi Z N P}{60\,A}$

$$486 = \frac{0.03 \times 720 \times N \times 4}{60 \times 2}$$

$$\boxed{N = 675 \text{ rpm}}$$

Q6 c) To operate the transformer in maximum efficiency always, derive at what condition, this can be achieved. [06 Marks]

The efficiency of a transformer at any load & p.f. is defined as the ratio of the output at the secondary winding to the power input to the primary winding

$$\text{Efficiency } \eta = \frac{\text{Power Output}}{\text{Power Input}}$$

$$\text{Power input} = V_1 I_1 \cos\phi_1$$

$$\eta = \frac{\text{Input} - \text{Losses}}{\text{Input}}$$

$$= \frac{\text{Input} - \text{Copper Loss} - \text{Iron Loss}}{\text{Input}}$$

$$= \frac{V_1 I_1 \cos\phi_1 - I_1^2 R_{01} - W_i}{V_1 I_1 \cos\phi_1}$$

$$= 1 - \frac{I_1 R_{01}}{V_1 \cos\phi_1} - \frac{W_i}{V_1 I_1 \cos\phi_1}$$

The efficiency is maximum, when $\frac{d\eta}{dI_1} = 0$.

ie, $$\frac{d\eta}{dI_1} = 0 - \frac{R_{01}}{V_1 \cos\phi_1} + \frac{W_i}{V_1 I_1^2 \cos\phi_1} = 0$$

$$\frac{R_{01}}{V_1 \cos\phi_1} = \frac{W_i}{V_1 I_1^2 \cos\phi_1}$$

$$W_i = I_1^2 R_{01}$$

Iron losses = Copper Losses

Module - 04

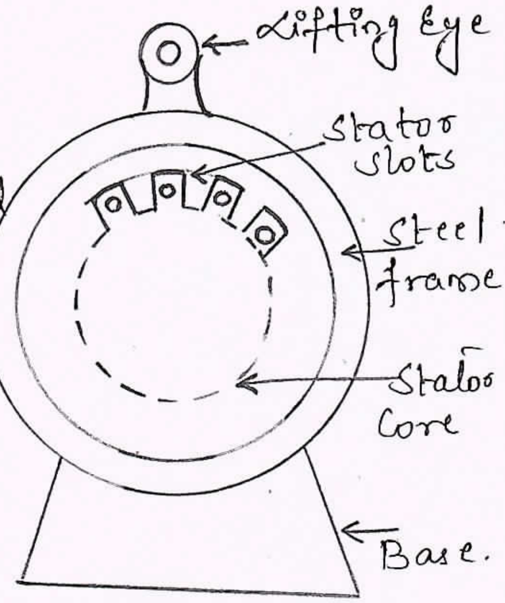
Q7 a) With the help of neat diagram explain the constructional details of 3-φ Induction motor. [06 Marks]

A 3-φ Induction motor mainly consist of two parts. i) Stator & ii) Rotor.

***Stator:**

It consist of steel frame, which encloses a hollow, cylindrical core, made up of thin laminations of Silicon steel to reduce eddy current loss & hysteresis loss.

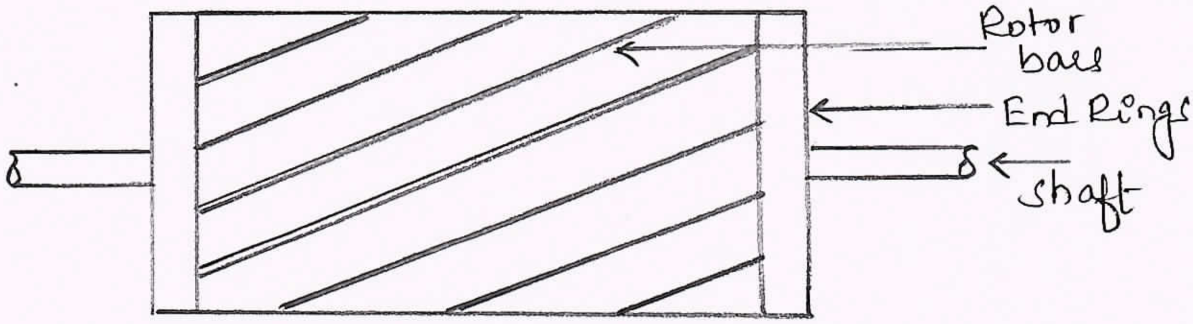
A large no. of uniform slots are cut on the inner periphery of the core in which stator conductors are placed which are star/delta winding.



***Rotor:** i) Squirrel Cage Rotor & ii) Phase wound Rotor.

Squirrel Cage Rotor.

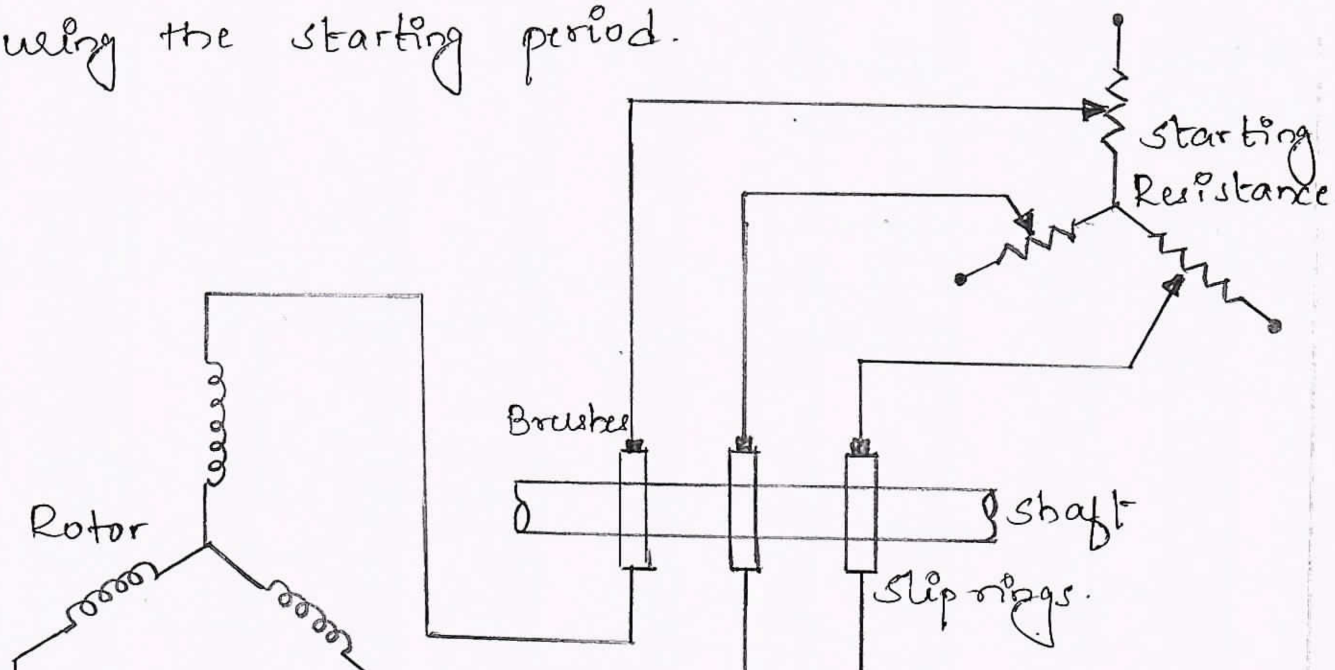
90% of the induction motors are of squirrel cage because of simple & rugged construction.



It consist of cylindrical laminated core with parallel slots for carrying heavy bars of copper or aluminium rotor conductors. The slots are slightly skewed, which helps in two ways. i) it reduces noise due to magnetic hum & makes the rotor to run quietly. ii) it reduces the locking tendency between rotor & stator.

*Phase Wound Rotor:

This rotor is laminated, cylindrical core having uniform slots on its outer periphery. A three phase winding which is star connected is placed in these slots. The open ends of the star winding are brought out & connected to three insulated slip rings mounted on the shaft of the motor with carbon brushes resting on them. The three brushes are externally connected to a 3-ϕ star connected rheostat, which is used as a starter during the starting period.



Q 7 b) A 3-Φ 400V, 50 Hz supply is given to 3-Φ IM with 4 pole runs at 1440 rpm. Determine the speed of the rotor & frequency of rotor current [06 Marks]

$$N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500 \text{ rpm}$$

$$\therefore \text{Slip } s = \frac{N_s - N}{N_s} = \frac{1500 - 1440}{1500} = 0.04$$

$$\boxed{\text{Slip} = 0.04 = 4\%}$$

Frequency of Rotor Current $f' = sf = 0.04 \times 50$

$$\boxed{f' = 2 \text{ Hz}}$$

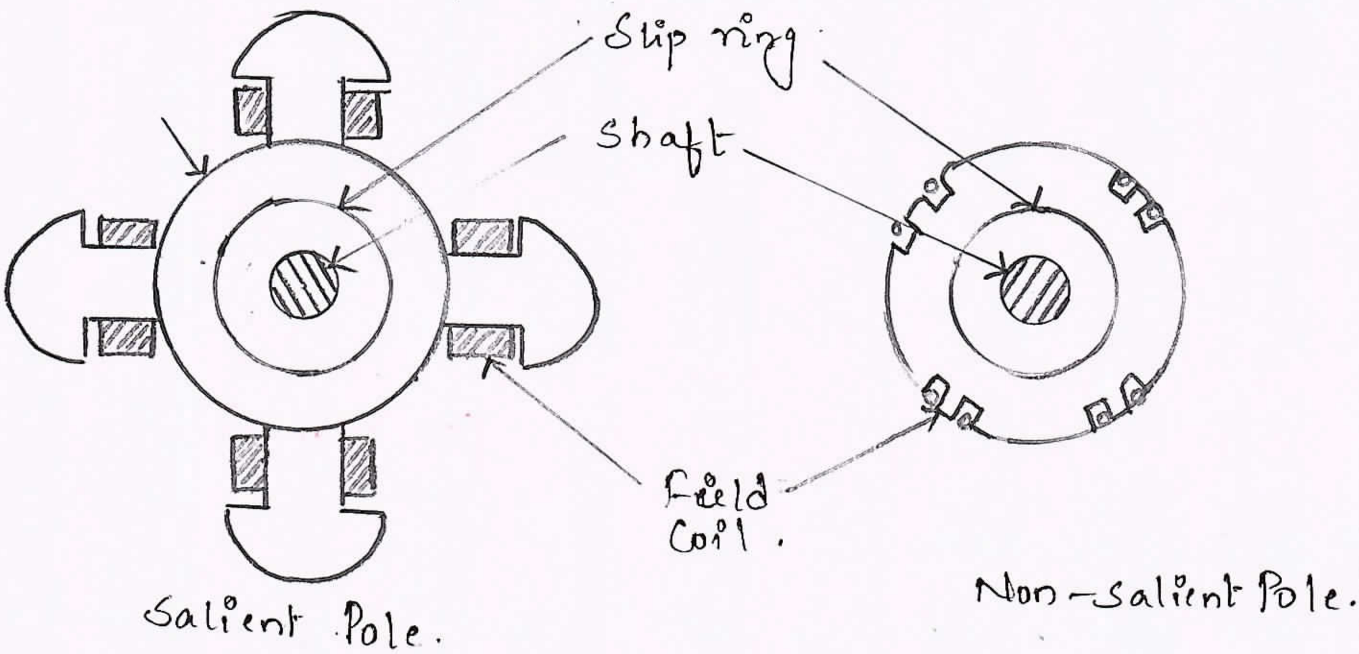
Q 7 c) With the help of diagram explain construction details of Salient & non-salient generator [08 Marks]

* Salient generator

This type of rotor is used in low & medium speed alternator (300 to 600 rpm). It has large no. of projecting poles having their cores bolted to a heavy magnetic wheel of cast iron or steel. These have large diameter & short axial length. The poles are laminated to reduce eddy current losses & coils are wound on these poles. The DC voltage required to excite pole coils is obtained from pilot exciter which is fixed on the shaft of the alternator itself. The DC voltage is fed to the field coils through two carbon brushes, which slide on two slip rings fixed to the shaft.

* Non - Salient / Smooth cylindrical.

This type of rotor is usually driven by turbine & rotates at very high speed (1500 to 3000 rpm). The rotor consist of steel laminations which are insulated from each other & pressed together to form a cylindrical core having no. of slots on its outer periphery for accommodating field winding. It has small diameter & large axial length. Two or four regions corresponding to the central polar areas are left unslotted & these areas are surrounded by the field windings placed in the slots.



Q8 a) An alternator running at N rpm, induces an emf in the armature conductors of the machine & obtain an expression of induced emf. [06 Marks]

Let, Z = No. of stator conductors per phase

P = No. of poles

f = frequency of induced emf in Hz.

ϕ = flux per pole in Wb.

The flux cut by the conductor in one revolution

$= P\phi = d\phi$

The time taken for one revolution $= 60/N$ sec $= dt$

∴ The average emf induced in one conductor

$$= \frac{d\phi}{dt} = \frac{P\phi N}{60} \text{ volts.}$$

Average emf induced per phase $= \frac{\phi N P}{60} \times Z$

$$= \frac{\phi P Z}{60} \times \frac{120 f}{P}$$

$$= 2 f \phi Z \text{ volts.}$$

For a sinusoidal wave, $\frac{E_{rms}}{E_{av}} = 1.11$

∴ rms value of emf induced per phase

$$= 1.11 \times 2 f \phi Z = 2.22 f \phi Z$$

∴ EMF equation of an alternator is,

$$E_{ph} = 2.22 f \phi Z \text{ volts.}$$

$$= 4.44 f \phi T \text{ volts}$$

where T = no. of turns $= Z/2$

Q 8b) A 3-ϕ 16 pole alternator has a star connected winding with 144 slots & 10 conductors per slot. The flux per pole is 0.03 Wb, sine distributed & the speed is 375 rpm. Find the frequency & phase & line voltages.
[06 Marks]

$$f = \frac{PN}{120} = \frac{16 \times 375}{120} = 50\ Hz$$

$$n = \frac{144}{3 \times 16} = 3, \quad Z = \frac{144 \times 10}{3} = 480$$

$$\alpha = \frac{180}{3n} = \frac{180}{3 \times 3} = 20^\circ$$

$$K_d = \frac{\sin \frac{n\alpha}{2}}{n \cdot \sin \frac{\alpha}{2}} = \frac{\sin \frac{3 \times 20}{2}}{3 \cdot \sin 20/2} = 0.96$$

The winding is assumed to be full pitched

$$E_{ph} = 2.22\ K_p K_d f \phi Z$$

$$= 2.22 \times 0.96 \times 1 \times 50 \times 30 \times 10^{-3} \times 480$$

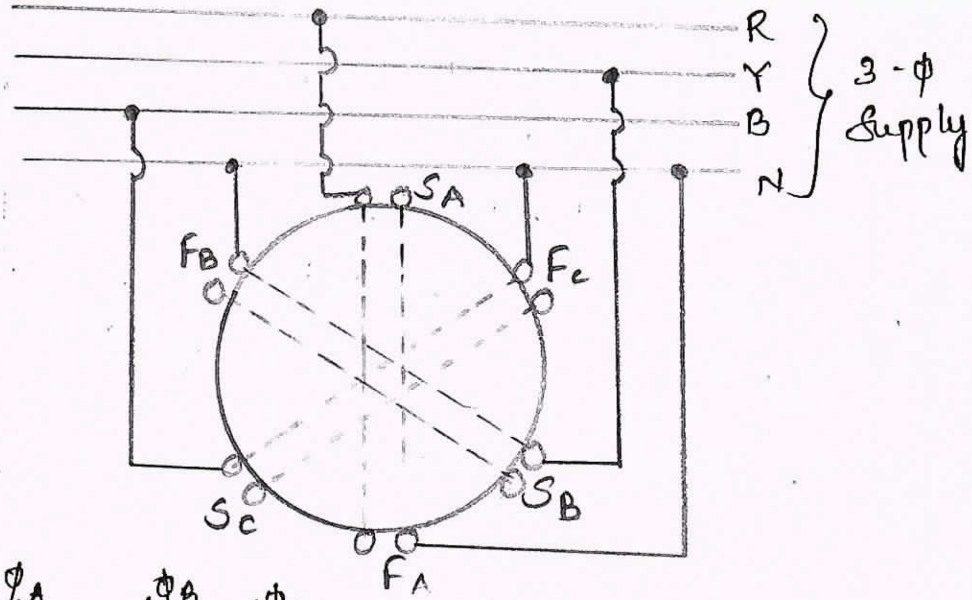
$$E_{ph} = 1534.46 \text{ volts}$$

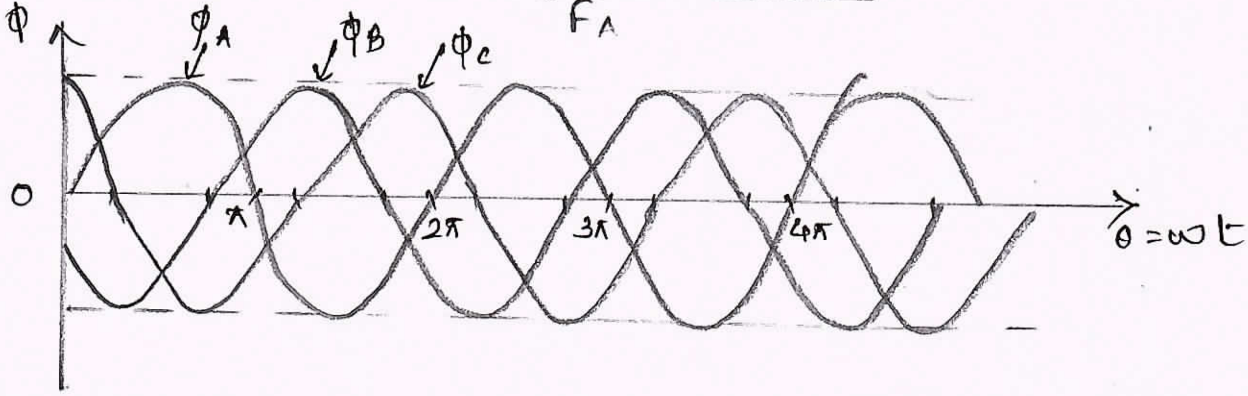
$$E_L = \sqrt{3}\ E_{ph} = \sqrt{3} \times 1534.46 = 2657.77 \text{ volts.}$$

$$E_L = 2657.77 \text{ volts}$$

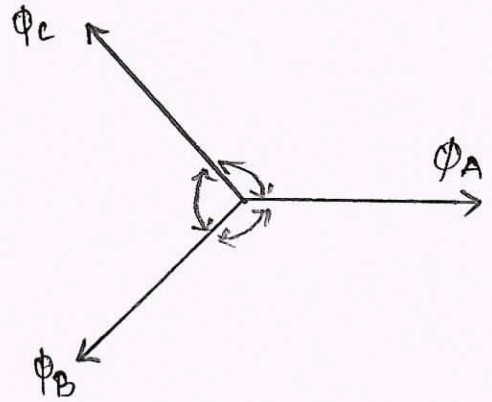
Q8c) When a 3-φ supply is given to 3-φ Induction Motor, explain how a rotating magnetic field produces in the air gap of the machine. [08 Marks]

When a 3-φ supply is given to 3-φ winding of stator, a rotating magnetic field of constant magnitude & rotating with synchronous speed is produced. Let us consider 3-φ winding connected to 3-φ supply & fluxes produced in the three winding are shown in Fig.





The assumed +ve directions of fluxes are shown below



The equations for the 3 fluxes are,

$$\phi_A = \phi_m \sin \omega t$$

$$\phi_B = \phi_m \sin(\omega t - 120^\circ)$$

$$\phi_C = \phi_m \sin(\omega t - 240^\circ)$$

The resultant flux of these 3 fluxes at any instant is given by the vector sum of individual fluxes ϕ_A, ϕ_B & ϕ_C.

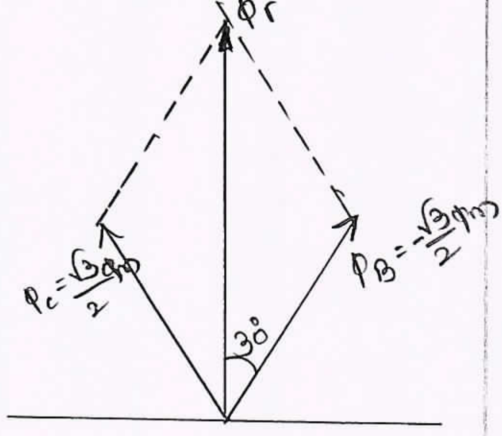
i) When $\theta = 0^\circ$,

$$\phi_A = 0$$

$$\phi_B = \phi_m \sin(-120) = -\frac{\sqrt{3}}{2}\phi_m$$

$$\phi_C = \phi_m \sin(-240) = \frac{\sqrt{3}}{2}\phi_m$$

These values of fluxes at this instant & their resultant are shown. The resultant flux ϕ_r lies along Y-axis & its magnitude is given by,



$$\phi_r = 2 \times \frac{\sqrt{3}}{2} \phi_m \cos 30^\circ = \frac{3}{2} \phi_m$$

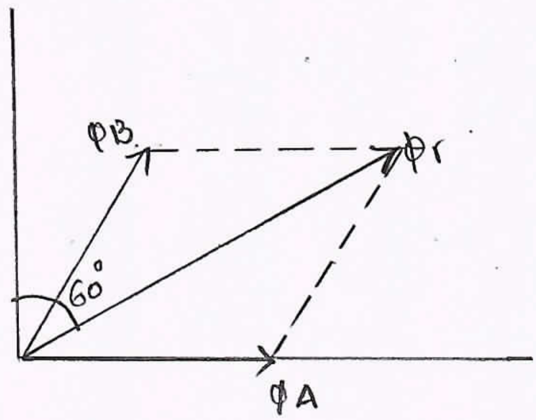
$$\phi_r = 1.5 \phi_m$$

ii) When $\theta = 60^\circ$.

$$\phi_A = \frac{\sqrt{3}}{2} \phi_m$$

$$\phi_B = -\frac{\sqrt{3}}{2} \phi_m$$

$$\phi_C = 0$$



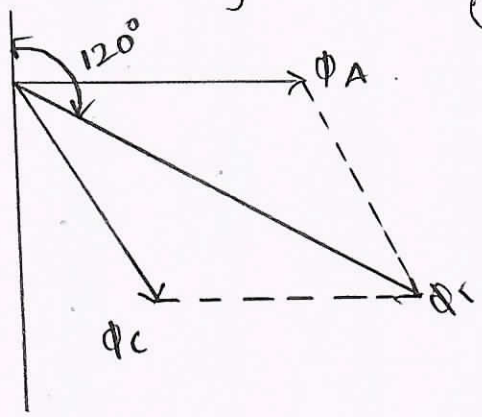
It is observed that resultant flux has rotated by 60° in the clockwise direction & its magnitude is $\phi_r = 1.5 \phi_m$

iii) When $\theta = 120^\circ$,

$$\phi_A = \frac{\sqrt{3}}{2} \phi_m$$

$$\phi_B = 0$$

$$\phi_C = -\frac{\sqrt{3}}{2} \phi_m$$



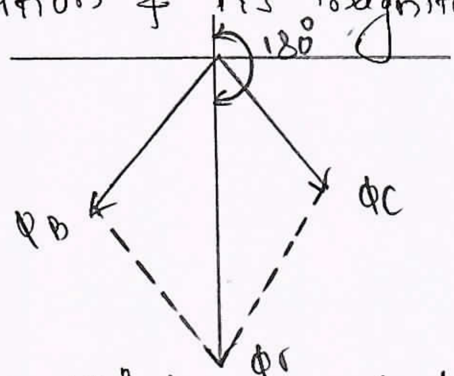
The resultant flux has rotated by another 60° ie through 120° from its original position & its magnitude is $1.5\phi_m$

iv) When $\theta = 180^\circ$.

$$\phi_A = 0$$

$$\phi_B = \frac{\sqrt{3}}{2} \phi_m$$

$$\phi_C = -\frac{\sqrt{3}}{2} \phi_m$$



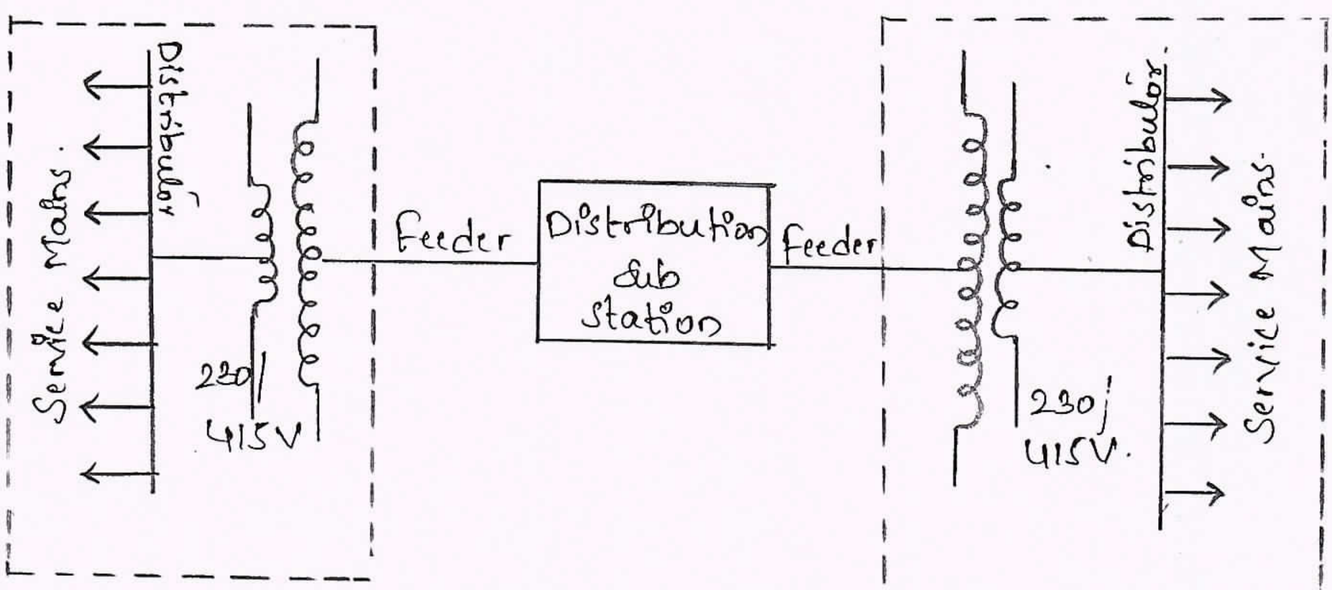
The resultant flux rotated by 180° from original position & its magnitude is $1.5 \phi_m$.

Thus we can conclude that as $\theta = \omega t$ varies from $\theta = 0$ to $\theta = 2\pi$, the resultant flux also rotates with same angular velocity ω & having constant magnitude of $1.5\phi_m$.

Module - 05

Q9a) With the help of block diagram, discuss low voltage distribution system (400V & 230V) for domestic, commercial & small-scale industry. [06 Marks]

The distribution system which operates on the voltage levels that are directly utilized without any further reduction is known as low voltage distribution system. It is part of electrical power distribution network which carries electrical power from distribution transformer to energy meter of consumer.
The voltage level of LV distribution system is equal to the mains voltage of electrical appliances. The LV distribution system is a 3-ϕ 4 wire distribution network.



Most modern low voltage distribution systems are operated at AC rated voltage of 230/415V at 50Hz in India.

Components of LV Distribution system:

1) Distribution Transformer: It is a step-down transformer which has delta connected primary & star connected secondary winding & sends electrical power to the distributors.

2) Distributor: It is a conductor from which tapings are taken for supply to the consumers. The current throughout the distributor is not constant since tapings are taken at various places along its length.

3) Service Mains: It is a small cable which connects the distributor to the electricity meter of the consumer.

Q9b) List out the power ratings of household appliances including air conditioners, PCs, laptops, printers etc., find the total power consumed. [06 Marks]

Sl No.	Household Appliances.	Rating(W)	No. of units.	Power Consumed (W)
01.	LED Bulbs	9	06	54
02.	Fan	60	04	240
03.	TV	100	01	100
04.	Refrigerator	200	01	200
05.	Washing Machine	500	01	500
06.	Mixer.	500	01	500
07.	Air conditioner.	1000	01.	1000
08.	PC	300	01	300
09.	Laptop	100	02	200
10.	Printers	100	01	100
11.	Iron	1000	01	1000
	Total load Connected		⇒	4194 W.

Q9c) Why earthing is need in a building service. With neat diagram explain the pipe earthing. [08 Marks]

Earthing | Grounding is to connect the body of an electrical equipment to the general mass of the earth by a wire of negligible resistance. Earthing brings the body of the equipment to zero potential & thus avoids shocks to the personnel, incase the body of the equipment comes in contact with live wire.

Pipe Earthing :

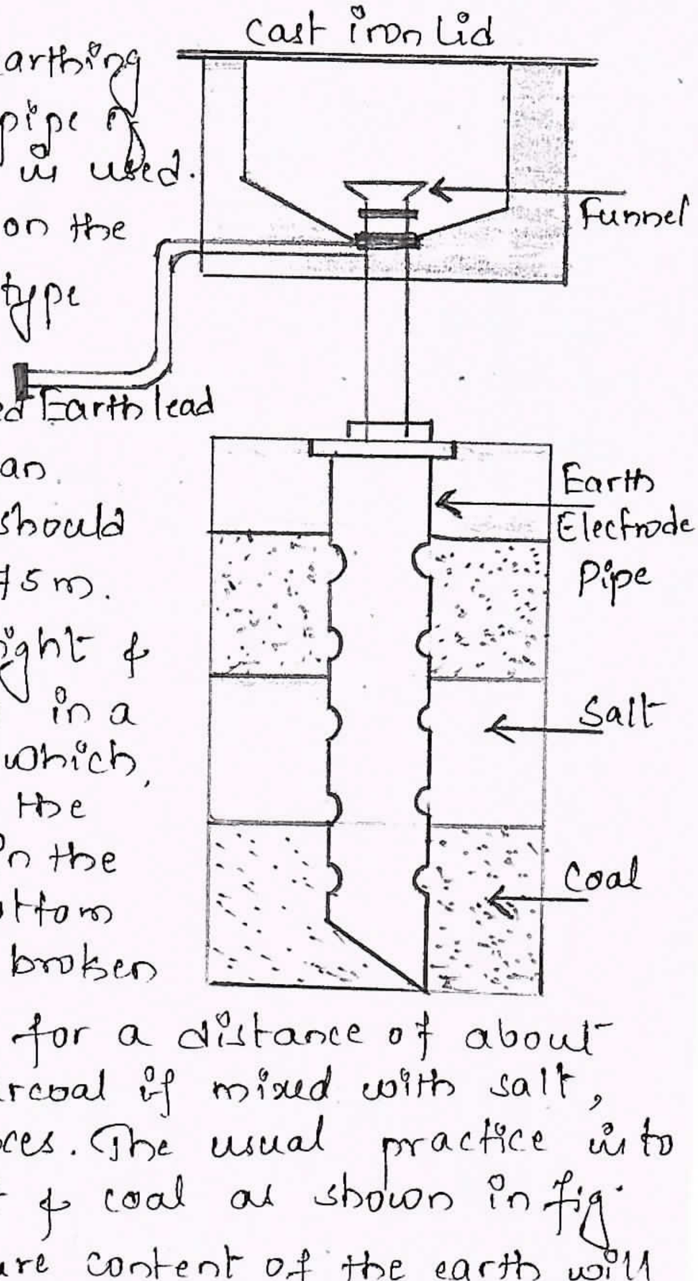


Fig. shows method of pipe earthing in which a galvanised iron pipe of approved length & diameter is used. The size of the pipe depends on the current to be carried & the type of soil. According to ISI, the diameter of the galvanised pipe should not be less than 38.1 mm & length 2 m. It should be placed to a depth of 4.75 m. The pipe must be placed upright & must be placed permanently in a wet - ground. The depth at which the pipe must be depends on the condition of the moisture in the ground. The pipe at the bottom should be surrounded by broken pieces of coke or charcoal for a distance of about 15 cm around the pipe. Charcoal if mixed with salt, further reduces the resistances. The usual practice is to put alternate layers of salt & coal as shown in fig. During summer, the moisture content of the earth will be very less & hence, in order to have effective earthing, the funnel should be filled with 3 to 4 buckets of water.

Q 10 a) In a domestic consumers end, discuss how two-part electricity tariff imposed to calculate electricity bills. [06 Marks]

The rate at which electrical energy is supplied to a consumer is known as Tariff.
When the rate of electrical energy is charged on the basis of maximum demand of consumer & the units consumed, it is called Two-part Tariff.
In two part tariff, the total charge to be made from the consumer is splitt into two components, fixed charges & running charges.
The fixed charges depend upon the maximum demand of the consumer while the running charges depend upon the no. of units consumed by the consumer.
Thus, the consumer is charged at a certain amount per kW of maximum demand plus a certain amount per kWhr of energy consumed.
ie Total Charges = Rs.[b×kW + c×kWhr]
where,
b = Charge per kW of maximum demand.
c = Charge per kWhr of energy consumed.

Q 10 b) Discuss how electricity bill is calculated based on unit which is consumption of electrical energy for domestic consumers. [06 Marks]

The electrical energy consumed is expressed as Units. 1 unit = 1 kWhr.

Example to calculate ~~energy~~ electricity bill.

- To calculate the power consumption of the current month, we need to subtract the current meter reading from the reading of last month.

• Once we know the exact energy consumption, we can calculate the energy charge by multiplying the units by per-unit charges.

• For example slabwise energy charges are,
Rs. 4.22 for 1-100 units.
Rs. 5.02 for 101-200 units
Rs. 5.87 for 201-300 units.

• If we have used 250 units in a month, then energy charges will be,

$$[(100 \times 4.22) + (100 \times 5.02) + (50 \times 5.87)] = Rs. 1218$$

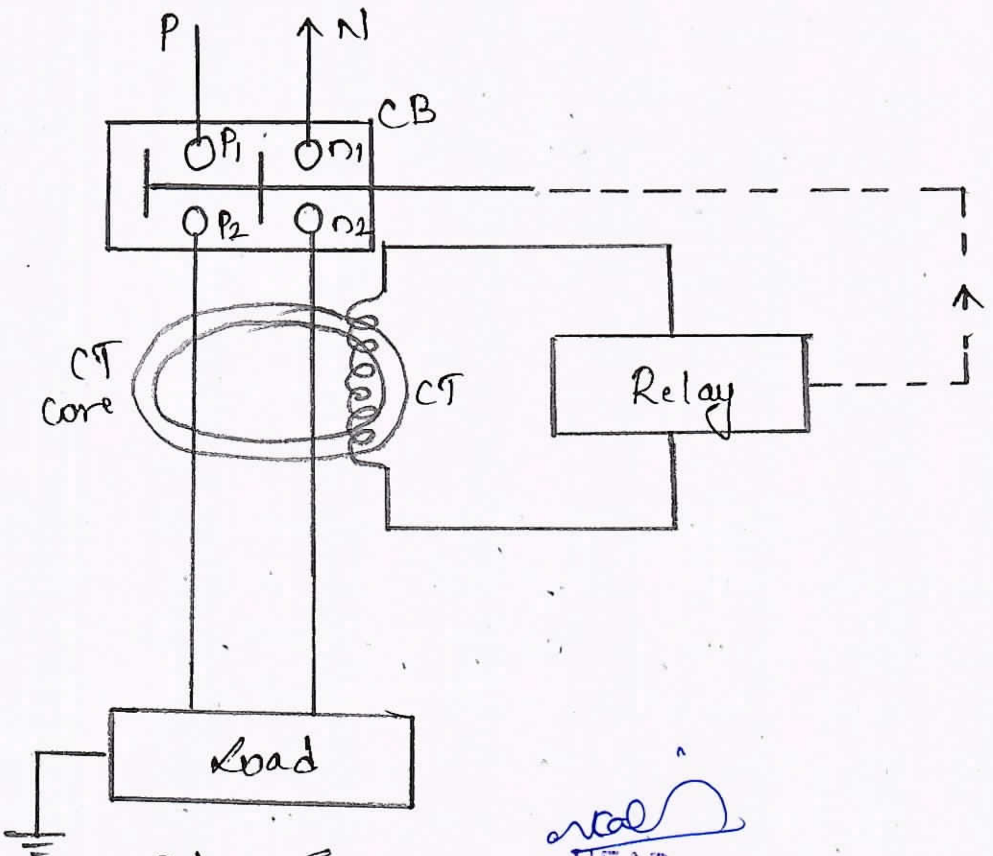
• The total energy bill can be calculated by adding the fixed charge of Rs. 40. & ~~the~~ Thus making the total bill amount to be Rs. 1218 + Rs. 40 = Rs. 1258

Q 10 c) With a neat circuit diagram, explain the operation of MCB & RCCB. [08 Marks]

Miniature Circuit Breaker [MCB]
CB are electrical switching devices which are used to protect the electrical equipments & circuits under overload & short circuit conditions. When normal current is flowing through the circuit, the CB is in closed position. When over current flows, it opens so that the fault current does not flows through the circuit & protects it.
CB's used in residential & light commercial installations at low voltages are reffered as MCB's. These may also be used for tripping during ground-faults which includes an extra ground fault detection with an operating mechanism to open the contacts in the event of a line to ground fault or neutral to ground fault

Residual Current Circuit Breaker [RCCB].

The construction is shown in fig. One CT core is energized by both plate wire & neutral wire.
Under normal condition, the ~~mmf~~ mmf of a one winding opposes the mmf of the other. Then there is no leakage. Resultant mmf of phase & neutral current is zero & contacts $p_1 n_1$ & $P_2 n_2$ are still connected. The relay coil is connected to the third winding wound on the CT core as secondary.
Under normal condition, no current circulates in the third winding. When earth leakage occurs in the equipment, part of the phase current flows to the earth. Then neutral current is not equal to the phase current. When this difference between phase & neutral current exceeds a preset value, the current in the third winding, the relay is energized. This activates the CB, & it trips. Contacts A & B move away from the terminals n_1, n_2 & P_1, P_2. Thus circuit is broken. Equipment is disconnected & is saved.



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