CBCS SCHEME

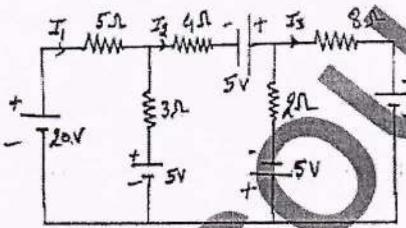
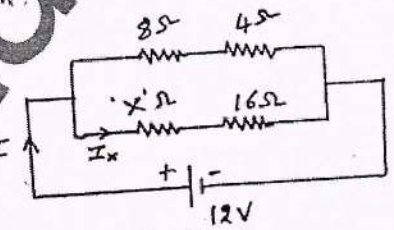
USN

BESCK104B/ BESCKB104

First Semester B.E./B.Tech. Degree Examination, June/July 2024
Introduction to Electrical Engineering

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. M : Marks , L: Bloom's level , C: Course outcomes.
3. VTU databook is permitted.

		Module – 1	M	L	C
Q.1	a.	Write the general structure of electrical power system using single line diagram approach and explain briefly.	6	L2	CO1
	b.	State ohm's law and mention its limitations.	6	L2	CO1
	c.	Find the currents I_1, I_2, I_3 for the circuit Fig Q1(c), shown below using Kirchoff's laws.  Fig Q1(c)	8	L3	CO1
		OR			
Q.2	a.	With a neat block diagram approach, explain Hydro-electric power plant.	6	L2	CO1
	b.	State Kirchoff's current and voltage law and write their the general mathematical expression.	6	L2	CO1
	c.	If the total power dissipated in the circuit Fig Q2(c), show below is 18W. Calculate the value of unknown resistance 'X' in ohms and the current flowing through it 'I_x'.  Fig Q2(c)	8	L2	CO2

			Marks	Level	CO
		Module – 2			
Q.3	a.	Define the following parameters with respect to ac sinusoidal waveform. i) RMS value ii) Average value iii) Form factor iv) Peak factor.	4	L2	CO1
	b.	Explain the concept of generation of 3ϕ A.C voltages with neat waveforms.	6	L2	CO2
	c.	Write a neat diagram of pure inductive circuit supplies by A.C sinusoidal voltage and derive the relation between instantaneous voltage and current. Draw the relevant vector diagram.	6	L3	CO2
	d.	A balanced Y – connected load is supplied from a balanced 3ϕ, 400V, 50Hz system. The current in each phase is 30A and lags 30° behind the phase voltage. Find the phase voltage and total power.	4	L3	CO2
		OR			
Q.4	a.	Define the following parameters with respect to a.c sinusoidal waveform. i) Amplitude ii) Frequency iii) Peak to Peak value iv) Instantaneous value.	4	L2	CO1
	b.	Write a neat circuit of resistance in series with capacitance supplied by A.C. sinusoidal voltage. Derive the expression for power consumed and write and relevant power wave forms.	6	L3	CO2
	c.	A series circuit with R = 10Ω, L = 50mH, C = 100μF is supplied with 200V, 50Hz, a.c supply. Calculate the i) Impedance ii) Supply current iii) Power iv) Power factor of the circuit.	6	L3	CO2
	d.	Define power factor of an a.c circuit. Mention its significance in electrical systems.	4	L2	CO2
		Module – 3			
Q.5	a.	With neat relevant diagram, explain the principle of operation of D.C motor. Briefly mention the significance of back.	8	L2	CO3
	b.	Derive an expression for induced emf of a D.C generator.	6	L2	CO3
	c.	A 4 pole D.C shunt motor takes 25A from 250V supply. The armature and field resistance are 0.5Ω and 125Ω respectively. The wave wound armature has 30 slots with 10conductors in each slot. If the flux per pole is 0.02wb Calculate speed, torque developed and power developed in armature.	6	L3	CO3
		OR			
Q.6	a.	With a neat sketch explain the construction and main parts of D.C generator. Mention the function of each part and material used to manufacture them	8	L2	CO3
	b.	Derive an expression for torque developed by a D.C motor	6	L3	CO3
	c.	A 30kW, 300V, D.C shunt generator has armature and field resistance of 0.05Ω and 100Ω respectively. Calculate power developed by the armature when it delivers full output power.	6	L3	CO3

		Module – 4			
Q.7	a.	List the various losses in a transformer. Explain how they vary with the load. Give their equations and mention how they are minimized.	8	L2	CO3
	b.	Explain the construction of slip ring and squirrel cage type induction motor.	6	L2	CO4
	c.	An 8-pole alternator runs at 750rpm and it supplies power to 4 pole induction motor. The frequency of rotor is 1.5Hz. Calculate the speed of the motor and also slip of motor.	6	L3	CO4
		OR			
Q.8	a.	A 600KVA transformer has an efficiency of 92% at full load, upf and at half load, 0.9p.f. Determine its efficiency at 75% of full load, 0.9p.f.	8	L3	CO4
	b.	A 250KVA, 11000/415V, 50Hz 1-φ transformer has 80 turns on secondary. Calculate : i) The rated primary and secondary currents ii) The number of primary turns iii) The maximum value of flux iv) Voltage induced per turn.	6	L3	CO4
	c.	Define slip of an induction motor. Derive an expression for effect of slip on the rotor frequency.	6	L2	CO4
		Module – 5			
Q.9	a.	With neat sketch, explain the working principle of a fuse. Mention its merits and demerits.	8	L2	CO5
	b.	What is electric shock? Mention few safety precautions to avoid electric shocks.	6	L2	CO5
	c.	What is electricity tariff? Explain two part electricity tariff.	6	L2	CO5
		OR			
Q.10	a.	With a neat circuit and switching table. Explain 3-ways control of load. Mention where it is applicable.	8	L3	CO5
	b.	What is earthing? With a neat diagram explain pipe earthing.	6	L2	CO5
	c.	Mention the power rating of the following electrical appliances i) Air conditioners ii) Laptops iii) LED tubelights iv) Washing machines Calculate the total power consumed by these four appliances.	6	L4	CO5

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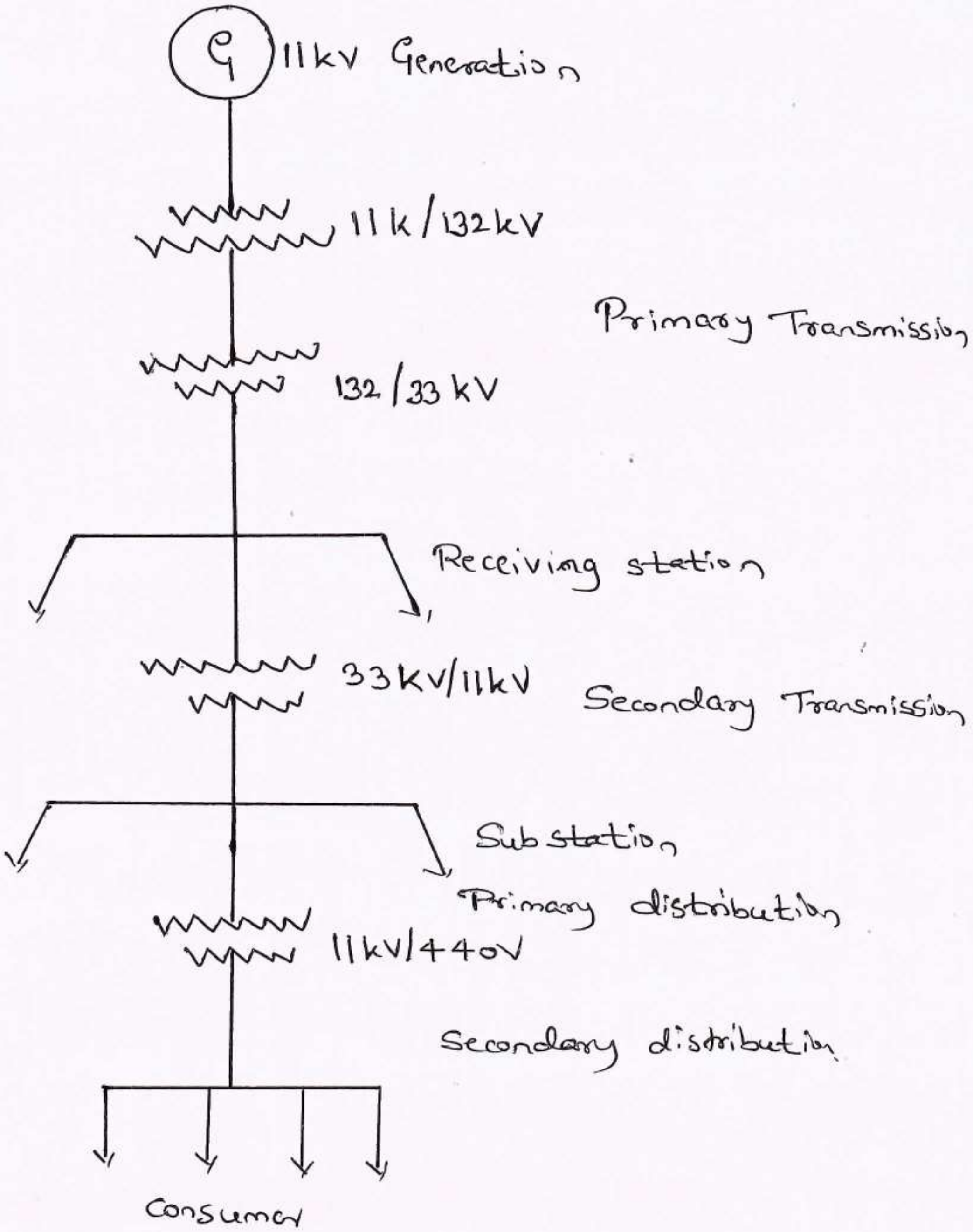
Module 1

Q1 a) Write the general structure of electrical power system using single line diagram approach and explain briefly. 6M

Ans:



Generation → Generator generates the electricity with the voltage magnetude of 11kV, 6.6kV, 3.3kV. Major equipments in generating stations are generator, turbine, protective equipment.

Primary Transmission → Generated voltage is steped up to 132kV & transmitted over a distance. further its reduced to 33kV.

Secondary Transmission → After the receiving station till sub-station secondary transmission stage is concidered. 33kV is step down to 11kV using power transformer.

Primary distribution → From the substation till primary side of the distribution transformer is primary distribution stage. Feeder distributors are the main component.

Secondary distribution → Distribution transformer step downs the voltage from 11kV to 440V, then its connected to consumers through service mains.

b) State Ohms law and its limitations

6M

Ans:- "Consider all physical condition constant, current flowing through the conductor is directly proportional to potential difference between the two ends of the conductor."

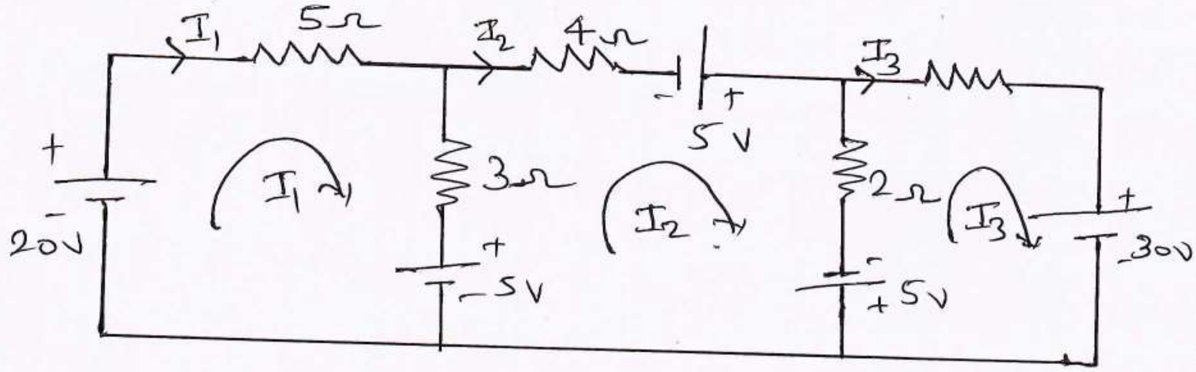
$$V = IR \quad , \quad I = \frac{V}{R} \quad , \quad R = \frac{V}{I} \quad , \quad I \propto V$$

Limitations:-

* Ohms law doesnot holds good for silicon material.
* Ohms law doesn't hold good for non-linear device like Zenor diode, voltage regulator etc...
* Ohms law doesn't hold good for arc lamps.

c) Find the current I_1, I_2 & I_3 for the fig Q1(c) shown below using Kirchoff's law.

8M



Ans :- Apply KVL to loop 1

$$20 - 5I_1 - 3I_1 + 3I_2 - 5 = 0$$

$$-8I_1 + 3I_2 = -15 \quad \text{— I}$$

Apply KVL to loop 2

$$5 - 3I_2 + 3I_1 - 4I_2 + 5 - 2I_2 + 2I_3 + 5 = 0$$

$$3I_1 - 9I_2 + 2I_3 = -15 \quad \text{— II}$$

Apply KVL to loop 3

$$-5 - 2I_3 + 2I_2 - 8I_3 - 30 = 0$$

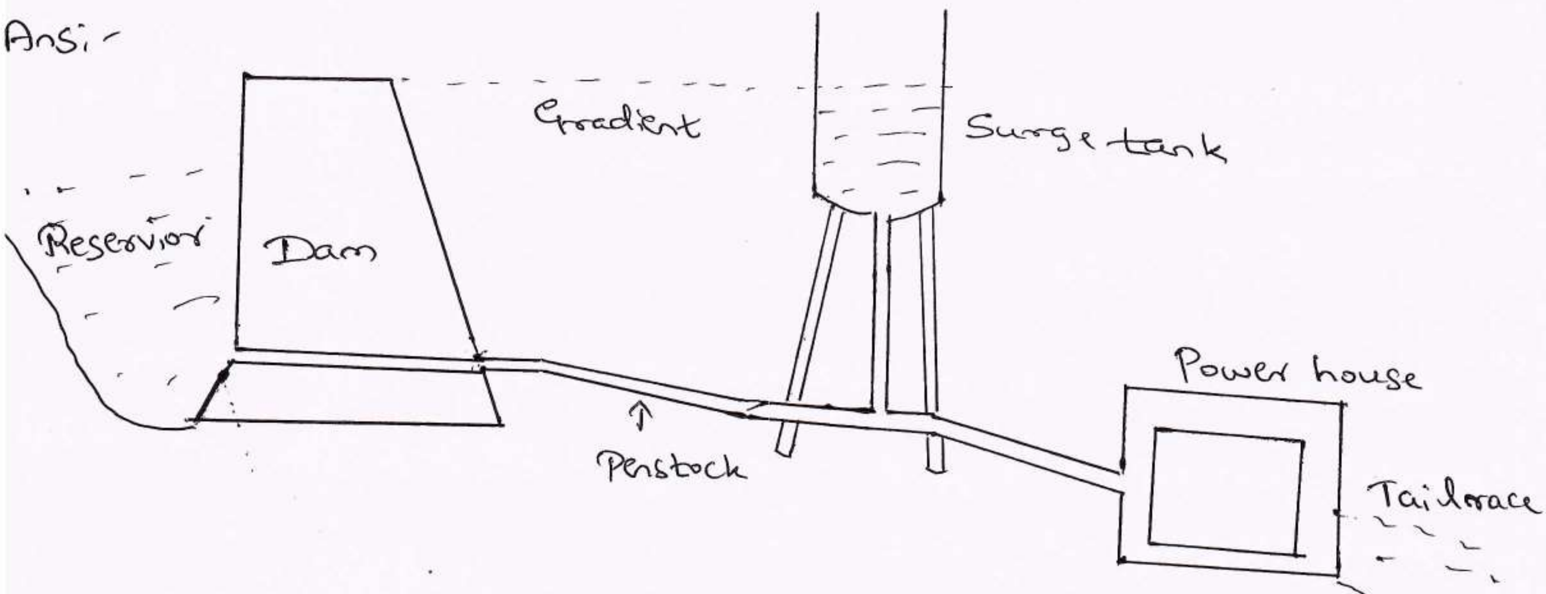
$$2I_2 - 11I_3 = 35 \quad \text{— III}$$

Solving equation I, II & III

$I_1 = 2.586\,A \quad I_2 = 1.89\,A \quad I_3 = -2.836\,A$

Q2 a) With a neat block diagram approach, explain Hydro - electric plant. 6M

Ans:-



Hydal power plant converts potential energy to kinetic energy to mechanical further electrical energy.

Dam → Using stones, cement dam is constructed. It stores the water, acts as reservior. It generates large amount of potential energy.

Penstock → Large concrete pipes helps to supply the water from dam to power house. Different diameter pipes used to veriy water force.

Surge tank → To protect the penstokk from water hammering effect an open tank is used that is called as surge tank.

Power house → Power hous converts kinetic energy to mechanical then eleelectrical energy. Generator, turbine, transformer are the major equipments.

b) State Kircoff's Current law and voltage law and write the general mathematical expression. 6M

Ans:- Kircoff's Current law

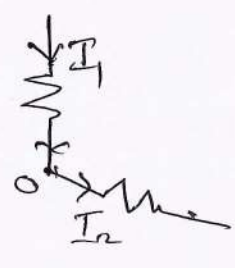
"The algebraic sum of all the currents metting at any junction of an electric circuit is zero."

$$\sum I = 0$$

" At any junction of an electric circuit, the sum of all the currents entering the junction is equal to the sum of all the currents leaving the junction".

$$I_1 - I_2 = 0$$

$$I_1 = I_2$$

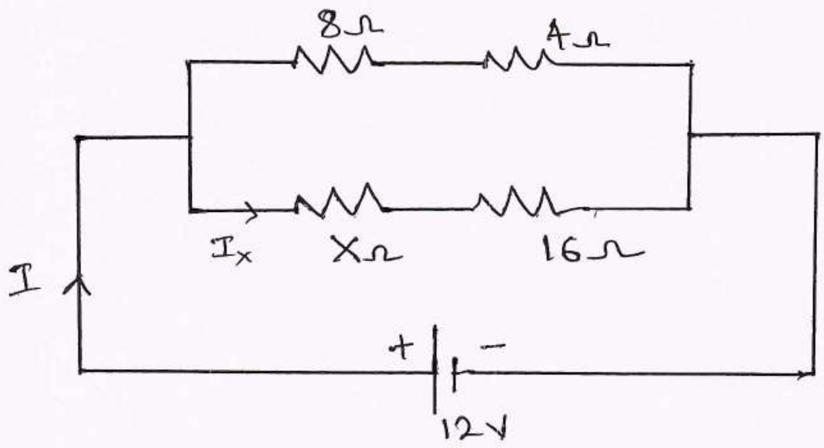


Kirchoff's Voltage Law

" In any closed electrical circuit, the algebraic sum of all the emfs & the resistive drops is equal to zero".

$$\sum E + \sum IR = 0$$

c) If the total power dissipated in the circuit Fig Q2 (c), show below is 18W. Calculate the value of unknown resistance 'X' in ohms and the current flowing through it 'I_x' 6M



P = 18 W   V = 12 V

Total resistance $R_t = \frac{V^2}{P} = \frac{12^2}{18} = 8\Omega$

$R_t = (8+4) \parallel (x+16) = 12 \parallel (x+16)$

$$8 = \frac{12 \times (x+16)}{12 + x + 16}$$

$x = 8\Omega$

$I = \frac{P}{V} = \frac{18}{12} =$ ~~0.66A~~ 1.5 A

$I_x =$ ~~$\frac{x+16}{}$~~ $\frac{12}{x+16} = \frac{12}{24} = 0.5A$

Module - 02

3a) Define the following parameters with respect to ac sinusoidal waveform.
i) RMS value ii) Average value iii) Form factor
iv) Peak factor. (04 marks)

i) RMS Value: It is equal to that steady current, which produces the same amount of heat as produced by the alternating current, when passed through the same resistance for the same time.

$$I_{rms} = \frac{I_m}{\sqrt{2}} = 0.707 I_m.$$

ii) Average Value: It is equal to that steady current, which transfers the same amount of charge, as transferred by the alternating current across the same circuit & in the same time.

$$I_{av} = \frac{2 I_m}{\pi} = 0.637 I_m.$$

iii) Form Factor (K_f): Ratio of rms value to its average value.

$$K_f = \frac{\text{rms value}}{\text{average value}} = \frac{0.707 I_m}{0.637 I_m} = 1.11$$

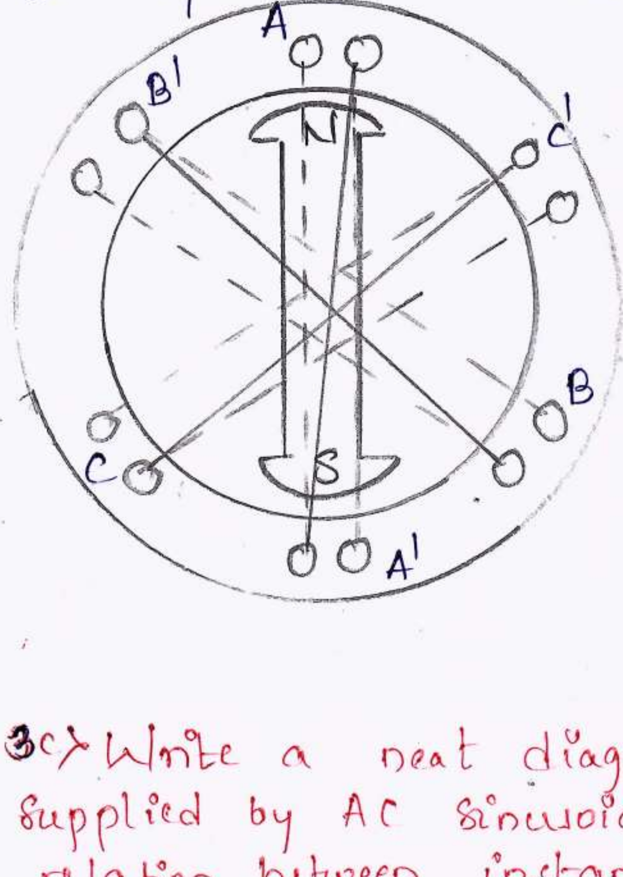
iv) Peak Factor (K_p): Ratio of maximum value to its rms value.

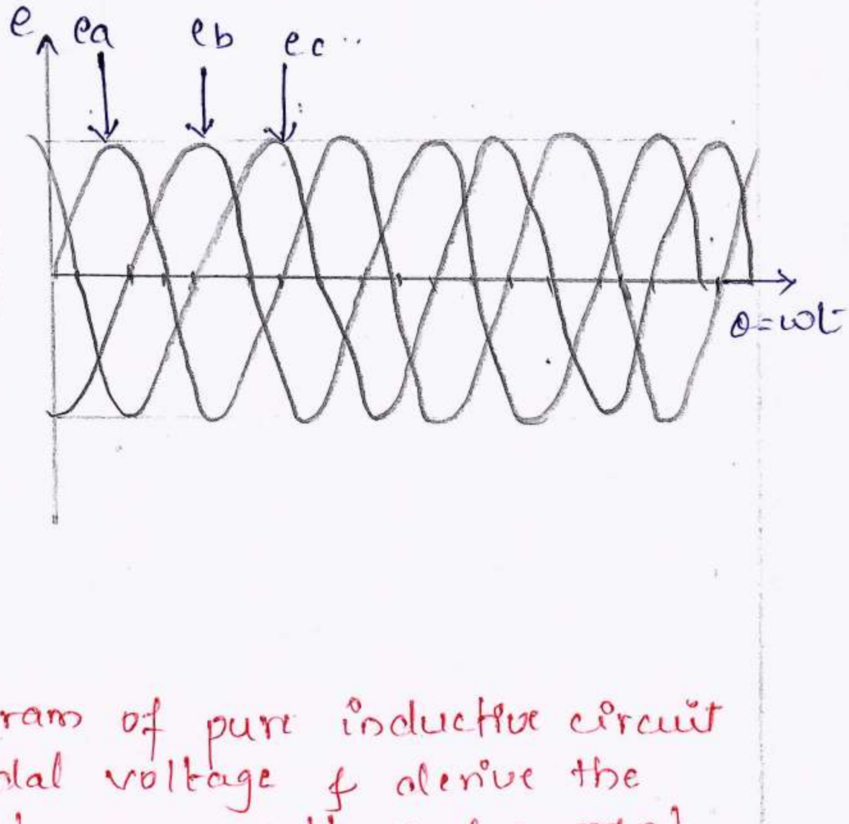
$$K_p = \frac{\text{maximum value}}{\text{rms Value}} = \frac{I_m}{0.707 I_m} = 1.414$$

3b) Explain the concept of generation of 3-ϕ AC voltage with neat waveforms (06 marks)

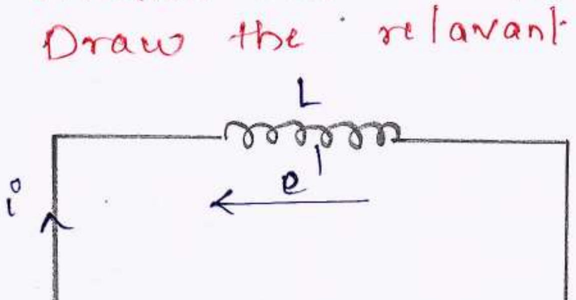
The electrical machine which generates 3-ϕ voltage is called alternator. The rotor which is the rotating part of the alternator is represented by a magnet of two poles N & S.

AA^{1}, BB^{1} & CC^{1} are 3 independent coils which are electrically displaced by 120° with respect to one another. When the rotor rotates in the clockwise direction with a perticular speed Ns, the flux produced by it sweeps across the stator conductors & hence emfs are induced in all the 3-phases, which have a phase displacement of 120° with respect to one another. The waveforms of the voltages generated are sinusoidal in nature & can be represented as shown.





3c) Write a neat diagram of pure inductive circuit supplied by AC sinusoidal voltage & derive the relation between instantaneous voltage & current. Draw the relavant vector diagram.



Consider a coil of pure inductance L henry, across which an alternating voltage $e = E_m \sin\omega t$ applied, due to which an alternating current i flows through it. This alternating 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

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

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

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

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

$$= \frac{1}{L} E_m \sin\omega t \, dt$$

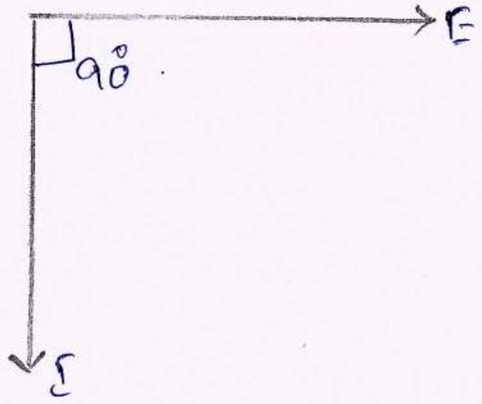
$$i = \frac{E_m}{L} \int \sin\omega t \cdot dt$$

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

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

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

Vector diagram.



3 d) A balanced Y-connected load is supplied from a balanced 3-Φ, 400V, 50 Hz system. The current in each phase is 30 A & lags 30° behind the phase voltage. Find the phase voltage & total power. [04 marks]

For Y-connection, $I_L = I_{ph} = 30 A$.

$$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 230.94 \text{ V.}$$

$$\text{Total power} = \sqrt{3} E_L I_L \cos\phi$$

$$= \sqrt{3} \times 400 \times 30 \times \cos 30°$$

$$= 18000 \text{ Watts}$$

$$= 18 \text{ KW.}$$

4a) Define the following parameters with respect to ac sinusoidal waveforms.
i) Amplitude ii) Frequency iii) Peak-to-peak value iv) Instantaneous value. [04 Marks]

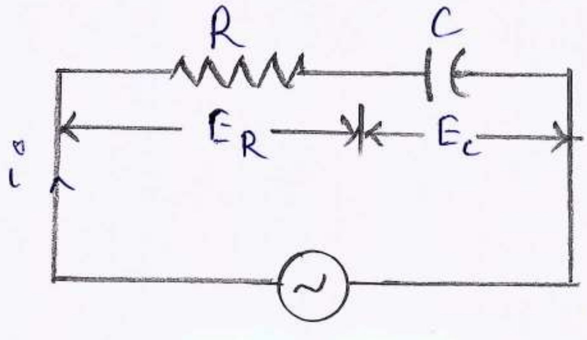
i) Amplitude : The maximum value of the emf induced in the conductor is called amplitude (E_m)

ii) Frequency : It is the number of cycles of emf induced in the conductor per second.

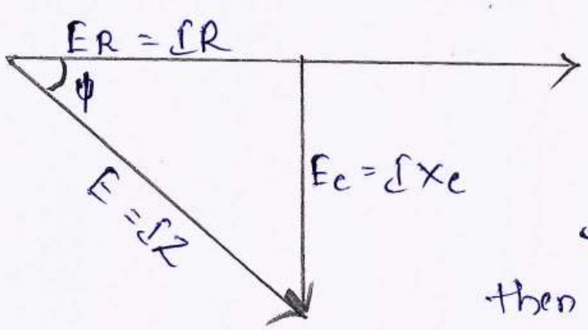
iii) Peak-to-peak value : It is the difference between the highest & the lowest values in a waveform.

iv) Instantaneous value : This is the value of the emf induced in the conductor at any instant.

4b) Write a neat circuit of resistance in series with capacitance supplied by AC sinusoidal voltage. Derive the expression for power consumed & draw relevant power waveforms.



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. The vector diagram is shown below.



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

If $e = E_m \sin \omega t$

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

The current in the circuit is given by, $I = \frac{E}{Z}$

where, Z = impedance $= \sqrt{R^2 + X_c^2}$

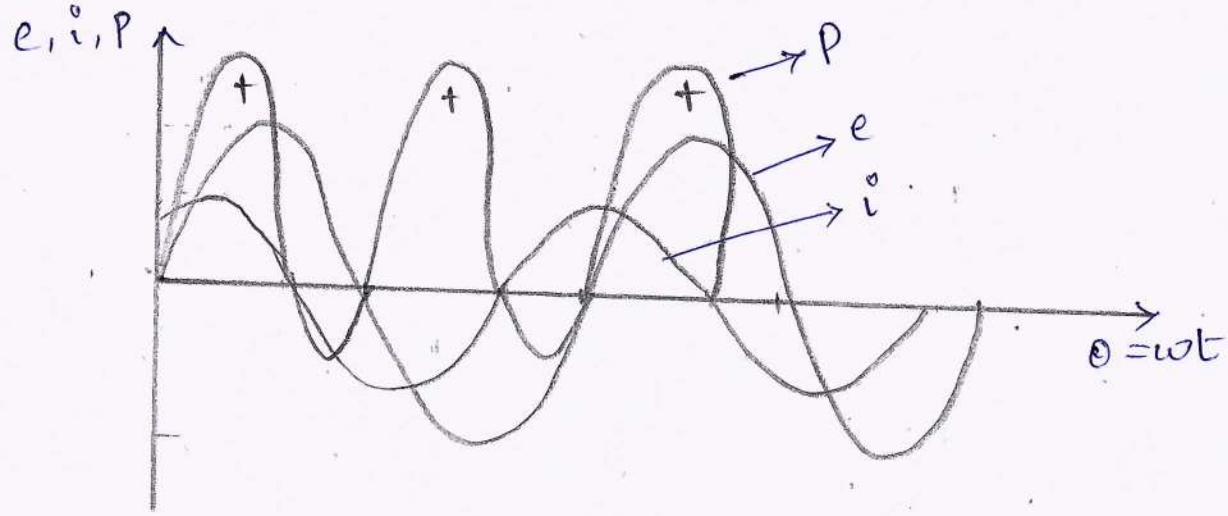
and $\phi = \tan^{-1} \frac{X_c}{R}$

The instantaneous power is given by,

$$p = ei = E_m \sin\omega t \cdot I_m \sin(\omega t + \phi)$$
$$= E_m I_m \frac{1}{2}\left[\cos(-\phi) - \cos(2\omega t + \phi)\right]$$
$$= \frac{1}{2} E_m I_m \cos\phi - \frac{1}{2} E_m I_m \cos(2\omega t + \phi)$$

The second term is periodically varying quantity & it does not contribute to the average value of power consumed by the circuit. The average power consumed by the circuit is only due to the first term.

$$\therefore P = \frac{1}{2} E_m I_m \cos\phi = \frac{E_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}} \cdot \cos\phi = EI\cos\phi.$$



4c) A series circuit with $R = 10\Omega$, $L = 50\,mH$, $C = 100\,\mu F$ is supplied with 200V, 50 Hz ac supply. Calculate,
i) Impedance ii) Supply current iii) Power
iv) power factor of the circuit.

$X_L = 2\pi f L = 15.70\,\Omega$.

$X_c = \frac{1}{2\pi f C} = 31.83\,\Omega$

i) $Z = \sqrt{R^2 + (X_c - X_L)^2} = \sqrt{100 + (260.17)} = 18.97\,\Omega$

ii) $I = \frac{E}{Z} = \frac{200}{18.97} = 10.54\,A$.

iii) $p.f. = \frac{R}{Z} = \frac{10}{18.97} = 0.52$ leading.

iv) Power $P = EI\cos\phi = 200 \times 10.54 \times 0.52$

$P = 1096.16 = 1.1$ kW.

4d) Define power factor of an ac circuit. Mention its significance in electrical systems. [04 marks]

i) Power factor is cosine of angle between voltage & Current ie $p.f. = \cos\phi$

ii) Power factor is ratio of resistance to impedance of the circuit. $p.f. = R/Z$.

* Significance in electrical system.

1) The active power consumed by the load is given by $P = EI\cos\phi$. If p.f. of load is small, the active power generated by an alternator & active power transmitted & received by consumer decreases. To generate same power from generator at poor p.f. as at good p.f., the capacity of the generator has to be increased which involves additional investment on generation.

2) If p.f. is small, for transmitting a particular power, the current in the transmission line increases & hence, Copper losses will increase & efficiency of transmission decreases.

3) Due to low p.f., the current carrying capacity of the conductors has to be increased. Hence, large sized conductors have to be used for transmission of electrical power which involves larger investment.

Module 03

5) a) With neat relavant diagram, explain the principle of operation of DC motor. Briefly mention the significance of back emf. —08 Marks

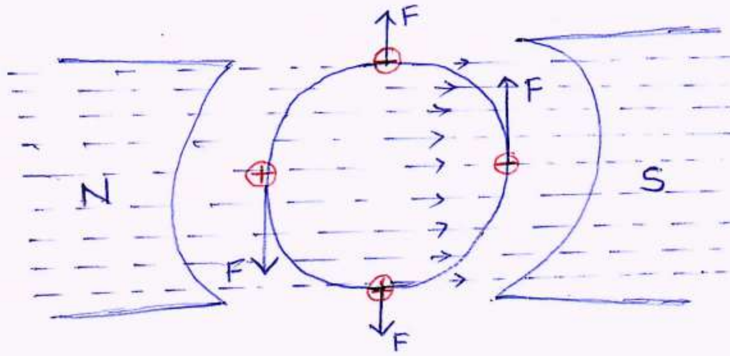
A DC motor works on the principle that "whenever a current carrying conductor is placed in a magnetic field, it experiences a force". The magnitude of the force experienced by the conductor is given by,

$$F = BIl$$

where, F = Force experienced in Newtons
B = Flux density of the magnetic field in Wb/m^2
I = Current flowing through the conductor in amperes
l = Length of the conductor in meters.

The direction of the force is given by Fleming's left hand rule.

Fleming's Left hand rule states that "when the thumb, fore finger and the middle finger of the left hand are held mutually perpendicular to each other, the fore finger in the direction of the magnetic field, the middle finger in the direction of the current, then the direction of the thumb indicates the direction of the force experienced by the conductor."



Consider a DC motor having two poles north and south represented by N & S as shown in fig. beside. These will be conductors placed uniformly in the slots of the armature.

For the sake of explaining the principle of working of DC motor, only two conductors a & b, which are placed under the influence of N-pole and S-pole resp^ly. In conductor a, the '+'ve sign marked indicates that the current is flowing inwards and '-'ve sign indicates in conductor b, the current is flowing outwards. The direction of magnetic field is represented by the lines of magnetic force, which emanate from the north pole 'N' & go into the south pole 'S' as shown in fig. above.

According to Fleming's left hand rule, the conductor 'a' experiences a force 'F' in the downward direction and the conductor 'b', experiences an equal force 'F' in the upward direction, together a & b tending to rotate the armature in anticlockwise direction. Due to this armature rotate by 90° in the anticlockwise direction and the conductors 'a' & 'b' occupy positions a' & b' respectively.

In this position, they experience a force F in opposite directions along the same line & hence the torque experienced by them is zero. But the armature consists of several other conductors which are uniformly distributed in the slots of the armature, which are connected together & experiencing a torque in the anti-clockwise direction. Thus the armature continues to rotate in the anticlockwise direction.

Significance of back emf (E_b):

W.K.T the armature current I_a is given by (for DC motor)

$$I_a = \frac{V - E_b}{R_a}$$

$$\therefore I_a R_a = V - E_b$$

$$V = E_b + I_a R_a$$

multiplying both sides by I_a we get

$$V I_a = E_b I_a + I_a^2 R_a$$

where, $V I_a$ = Electrical power input to the armature

$I_a^2 R_a$ = Copper loss in the armature

& $E_b I_a$ = Electrical equivalent of the mechanical power developed by the armature, which includes iron losses & mech losses

$\therefore$ The efficiency of the DC motor is given by

$$\eta = \frac{\text{Mechanical power developed by the armature}}{\text{Electrical power input to the motor}} = \frac{E_b I_a}{V I_a} = \frac{E_b}{V}$$

$\therefore$ Higher the value of back emf E_b, higher will be the motor efficien

5) b) Derive an expression for induced emf of a DC generator – 06 Marks

Let Z = Total no. of armature conductors

ϕ = Useful flux per pole in webers

N = Speed of armature in r.p.m

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 the conductor to make one revolution $= \frac{60}{N}$ sec $= dt$

Hence, the emf induced in one conductor $= \frac{d\phi}{dt} = \frac{\phi P}{60/N} = \frac{\phi P N}{60}$ volts

The EMF induced per parallel path = EMF induced per conductor × No. of conductors per parallel path

$$E = \frac{\phi P N}{60} \times \frac{Z}{A}$$

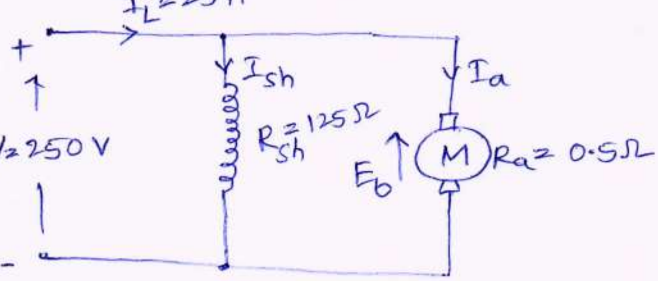
$$\therefore \quad E = \frac{\phi Z N P}{60A} \text{ ..... volts}$$

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

For wave winding $A = 2$, $\therefore E = \frac{\phi Z N P}{120}$ --- volts

5) c) A 4 pole DC shunt motor takes 25 A from 250 V supply. The armature & field resistance are 0.5 Ω & 125 Ω respectively. The wave wound armature has 30 slots with 10 conductors in each slot. If the flux per pole is 0.02 Wb, calculate speed, torque developed & power developed in armature. – 06 Marks

Given:



$P = 4$

$A = 2$

$Z = 30 \times 10 = 300$ conductors

$\phi = 0.02$ Wb

$$I_{sh} = \frac{V}{R_{sh}} = \frac{250}{125} = 2\,A$$

$$\therefore I_a = I_L - I_{sh} = 25 - 2 = 23\,A$$

$$E_b = V - I_a R_a$$
$$= 250 - 23 \times 0.5$$
$$E_b = 238.5\,V$$

W.K.T $E_b = \dfrac{\phi Z N P}{60 A}$

1) $\therefore N = \dfrac{E_b \times 60 \times A}{\phi \times Z \times P} = \dfrac{238.5 \times 60 \times 2}{0.02 \times 300 \times 4} = 1192.5$ rpm $\simeq 1193$ rpm

2) Torque developed, $T = 0.159\, \phi Z I_a \left(\frac{P}{A}\right)$

$$T = 0.159 \times 0.02 \times 300 \times 23 \times \frac{4}{2}$$
$$T = 43.88\ N\text{-}m$$

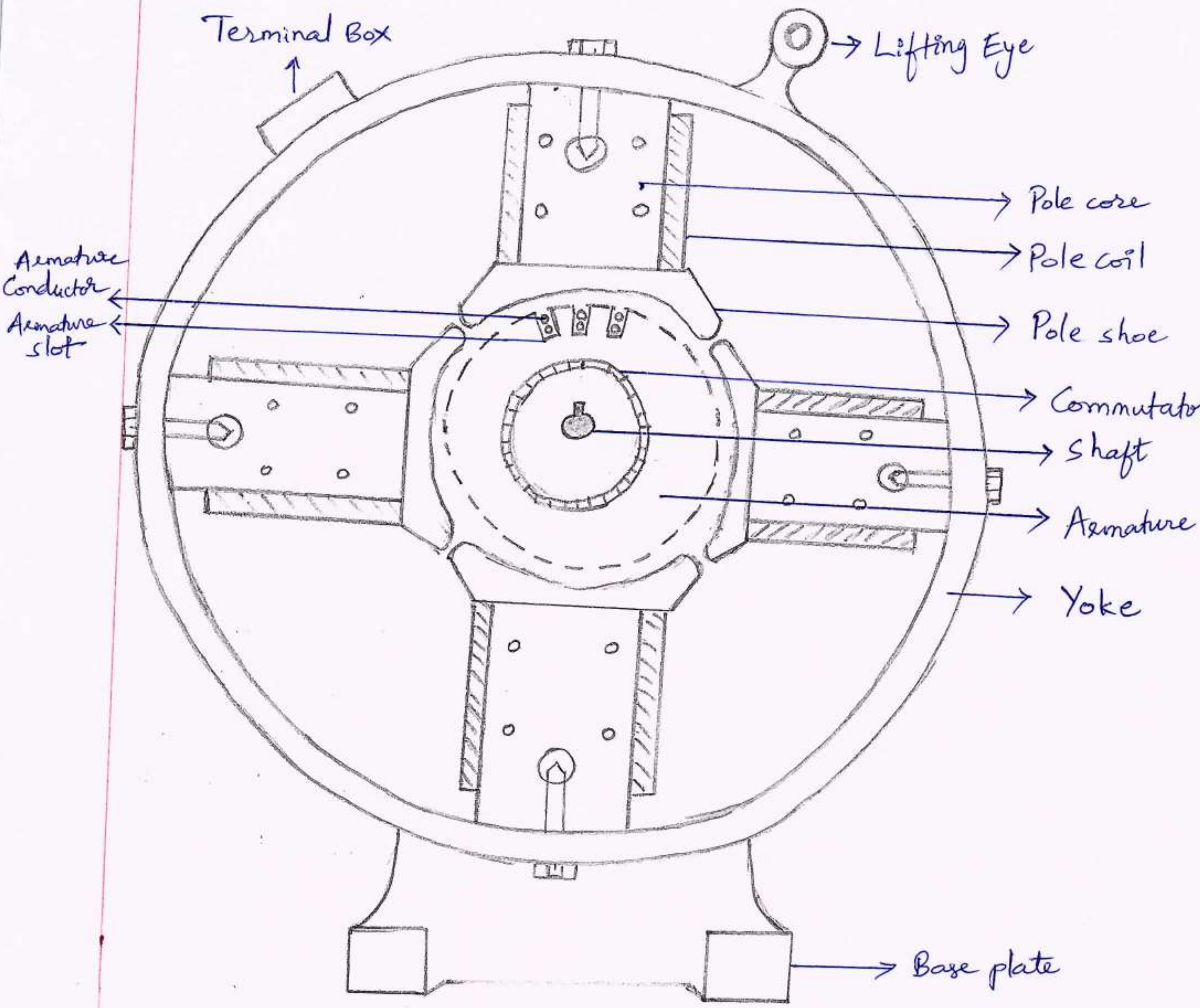
3) Power developed, $P_a = E_b I_a = 238.5 \times 23 = 5.49\ kW$

6) a) With a neat sketch explain the construction and main parts of a DC generator. Mention the function of each part & material used to manufacture them -- 08 Marks

A DC generator mainly consists of two parts i) Stationary part & ii) Rotating part

The stationary part consists of i) Yoke or magnetic frame ii) Main poles along with pole shoes and pole coils iii) Base plate iv) Lifting eye v) Brush box vi) Terminal box

The rotating part consists of the i) Armature ii) Armature windings iii) Commutator & iv) Shaft



* Yoke or Magnetic frame:

Yoke forms the outer cover for the DC generator & is cylindrical in shape. For small generators, yoke is made of cast iron, where as for large generators, it is made of cast steel.

The yoke supports the field system and also forms the part of the magnetic circuit. The lifting eye, base plate & terminal box are cast integral with the yoke.

* Main Poles, Pole shoes & Pole coils :

Main poles are made of an alloy steel of high relative permeability. The pole core is laminated to reduce eddy current losses. Thin sheets of alloy steel are insulated from one another and pressed together to form the core. The laminations are held tightly with the help of end plates, which are rivetted together.

The pole shoes are fixed to the pole core by means of counter sunk screws. The shape of the pole shoe is cylindrical at the bottom, so that, the flux produced is spread out uniformly in the air gap and also it reduces the reluctance of the magnetic path, because of the larger area of cross section.

The pole shoes support the field coils which are former wound & fixed on the pole cores. When a DC current is passed through the field coils, the pole core becomes an electromagnet and produces the main flux required for the generation of emf.

* Armature :

The armature consists of armature core and armature winding.
The armature core is made of high permeability & low loss silicon steel laminations, which are usually 0.4 to 0.5 mm thick & are insulated from one another by Varnish. There are slots cut uniformly on the outer periphery of the armature core & armature conductors are placed in these slots.

* Armature Windings :

The armature windings can be either lap winding or a wave winding.
The conductors are not only insulated from one another but also from the armature slots.

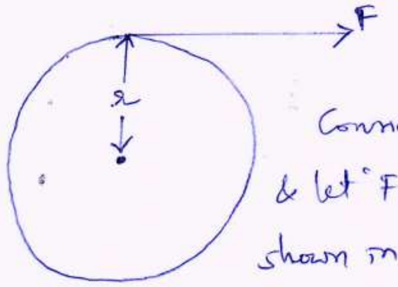
* Commutator :

The commutator converts the alternating EMF generated in the armature winding into direct current voltage in the external circuit.
The commutator is cylindrical in shape & is built of wedge shaped segments made of hard drawn copper.

* Shafts & Bearings :

The shaft of the DC generator is rotated by a prime mover due to which the armature fixed to it also rotates. For small generators roller bearings are used & for large generators roller bearings and ball bearings are used.

6) b) Derive an expression for torque developed by a DC-motor — 06 Marks



Torque is turning moment about an axis. It is equal to the product of the force & the radius at which it acts.

Consider the armature of the DC motor to have a radius 'r' & let 'F' be the force acting tangential to its surface as shown in fig.. The torque exerted by the force 'F' on the armature is given by,

$$T = F \times r \; \ldots \; N\text{-}m$$

The work done by this force F in one revolution is given by

$$W = \text{Force} \times \text{distance covered in one revolution}$$

$$W = F \times 2\pi r \; \ldots \; W\text{-}S$$

The power developed by the armature = Work done in one second

$$= F \times 2\pi r \times \text{no. of revolutions per second}$$

$$= F \times 2\pi r \times \frac{N}{60}$$

$$= \frac{2\pi N}{60}(F \times r) = \frac{2\pi N T_a}{60} \; \text{Watts}$$

We know that the electrical equivalent of the mechanical power developed by the armature of the DC motor is equal to $E_b \cdot I_a$

$$\therefore \frac{2\pi N T_a}{60} = E_b I_a = \frac{\phi Z N P}{60 A} \cdot I_a$$

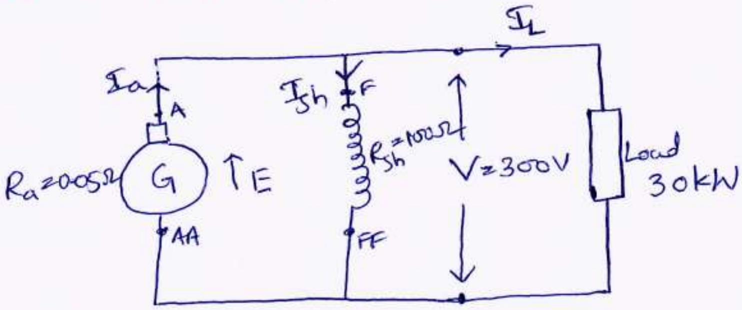
$$\therefore T_a = \frac{1}{2\pi} \phi Z I_a \left(\frac{P}{A}\right) \ldots \; N\text{-}m$$

$$T_a = 0.159 \, \phi Z I_a \left(\frac{P}{A}\right) \ldots \; N\text{-}m$$

$$T_a = 0.0163 \, \phi Z I_a \left[\frac{P}{A}\right] \ldots \; Kg\text{-}m$$

The above equation in N-m gives the gross torque developed by armature, which includes iron losses & mechanical losses of the motor.

6) c) A 30kW, 300V, DC shunt generator has armature & field resistance of 0.05 Ω & 100 Ω respectively. Calculate power developed by armature when it delivers full output power. — 06 Marks



Given: $V = 300\,V$

$P_{out} = 30\,kW$

$R_{sh} = 100\,\Omega$ & $R_a = 0.05\,\Omega$

$$\therefore I_L = \frac{P_{out}}{V} = \frac{30\times10^3}{300} = 100\,A$$

$$I_{sh} = \frac{V}{R_{sh}} = \frac{300}{100} = 3\,A$$

$$\therefore I_a = I_L + I_{sh} = 100 + 3 = 103\,A$$

$$\therefore E = V + I_aR_a + A.R.D + B.C.D$$

$$E = 300 + (103\times0.05) + 0 + 0$$

$$E = 305.15\,V$$

$\therefore$ Power developed by armature when it delivers full output power $= E\,I_a$

$= 305.15 \times 103$

$= 31.43\,kW$

Module – 4

Q. 7

a → List the various losses in Transformers. Explain how they vary with the load. Give their equations and mention how they are minimized. – 8m

Ans: List of Various Losses in Transformer

1) Copper losses 2) Eddy Current Losses

3) Core or Iron losses 4) Hysteresis Losses

5) Stray losses 6) Dielectric losses

7) Magnetostriction losses 8) Mechanical losses.

Losses variation with load

1) D.C resistance Copper loss → 90% of load losses

2) Eddy Current losses → 10% of load losses

3) I^2R losses increase with Temperature

4) No load losses caused by losses in core steel. Wo depends upon magnetic circuit, silicon steel quality.

5) I^2R losses $\propto$ load

6) $P_{cu} = I_2^2 r_{eq2}$

7) Eddy current loss $P_e = P_c - P_h$

P_c = Core loss or Constant loss

$P_h = K_h f B_m^x$

x = steinmetz constant (1.5 to 2.5) depends upon magnetic circuit

$P_e = K_e f^2 B_m^2$

8) stray load losses are due to leakage field

9) Dielectric losses are due to transformer oil or insulation.

$$\eta = \left[\frac{n \times (KVA) \cos\phi}{n(KVA) \cos\phi + P_c + n^2 P_{cu}}\right] \times 100$$

n = fraction of full load

for maximum efficiency

$\eta_{max} \Rightarrow P_c = P_{cu}$

core loss = copper loss

$$I_2 = I_2 (\text{rated}) \sqrt{\frac{P_c}{P_{cu}}}$$

Reduction of losses

1) Eddy current losses by Laminating core and insulation between each Lamination
2) Iron loss - reduced by using CRGOS steel
3) Hysteresis losses by using soft magnetic materials
4) stray load losses by splitting of conductors in to strips.

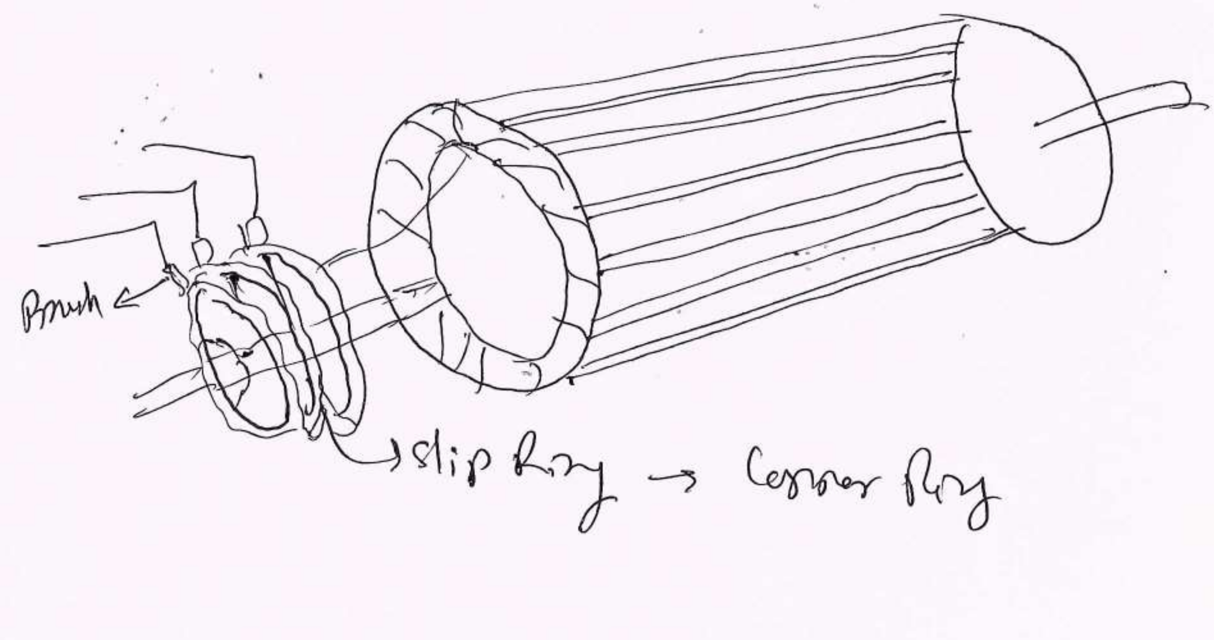
Q. 7 b → Explain construction of Slip Ring and Squirrel Cage Induction motor.

— Gonade

Solution: Slip Ring I.M is called as wound rotor motor type. Rotor comprises of cylindrical laminated steel core and semi-closed groove at outer boundary to 3 phase insulated winding. Rotor is wound to match no of poles on stator.

Stator of motor is having slots and 3φ winding is arranged.

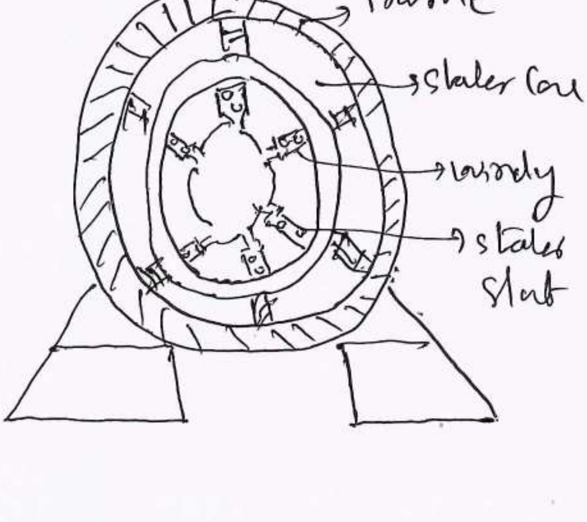
When supply is provided stator winding produces magnetic flux. So rotor winding gets induction and because of induced EMF, rotor gets torque and rotates.

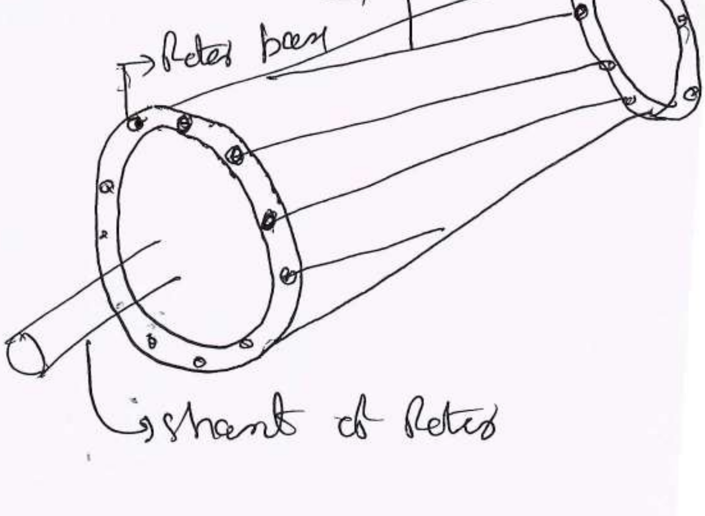


Construction of Squirrel Cage Induction Motor

Stator → It is having 3Φ winding with a core and metal housing. Windings are placed 120° apart by Electrically and mechanically. Winding is mounted on laminated core to provide Low reluctance path.
No of Poles depends upon speed required.
Stator uses semiclosed slots

Rotor → Consist of rugged construction. Rotor is having Cylindrical Laminated Core with parallel slots for carrying rotor conductor. [Heavy bars of copper, or aluminium]
Rotor bars are permanently short circuited.
Rotor slot is not parallel but having skew.





Q. No 7

C → An 8-pole alternator runs at 750 r.p.m and it supplies power to 4 pole induction motor. Frequency of Rotor is 1.5 Hz. Calculate speed of motor and also slip of motor. — 6 mark

Solution:

$$N_s = \frac{120 \times f}{P}$$

$$750 = \frac{120 \times f}{8} \quad So (f) = \frac{6000}{120}$$

$f = 50$ Hz for motor $N_s = \frac{120 \times 50}{4} = 1500$ rpm

$$\%\ slip\ s = \left(\frac{N_s - N}{N}\right) \times 100$$

$$f' = sf$$

$$\boxed{s = \frac{f'}{f} = \frac{1.5}{50} = 0.03 \times 100 = 3\%}$$

So $0.03 = \left(\frac{1500 - N}{N}\right) \times 100$

$$\frac{0.03 N}{100} = (1500 - N)$$

$$0.0003N = 1500 - N$$

$$0.0003 N + N = 1500$$

$$1.0003 N = 750$$

$$N = \frac{1500}{1.0003} = 749.77$$

Speed of Motor = 749.77 rpm

Speed of motor ⇒ 1495.51 rpm

⇒ 45 r.p.m less than $N_s = 1500$ rpm

Module - 4

Q. No 8

a → A 600 KVA transformer has an efficiency of 92% at full load upf and at half load 0.9 pf. Determine it's efficiency at 75% of full load, 0.9 p.f.

— 08 marks

Solution:

Case 1 → At full load $x = 1$

$$\eta = \frac{x(KVA) \times 1000 \times p.f}{x(KVA) \times 1000 \times p.f + P_i + x^2 P_{cu}}$$

$$0.92 = \frac{1 \times 600 \times 1000 \times 1}{1 \times 600 \times 1000 \times 1 + P_i + P_{cu}}$$

$$600 \times 10^3 + P_i + P_{cu} = \frac{600 \times 10^3}{0.92}$$

$$P_i + P_{cu} = 600 \times 10^3 \left[\frac{1}{0.92} - 1\right]$$

$$P_i + P_{cu} = 52173.39$$

Case 2 →

$$\eta = \frac{1/2 \times 600 \times 10^3 \times 0.9}{(1/2 \times 600 \times 10^3 \times 0.9) + P_i + \frac{1}{4} P_{cu}}$$

$$\eta = \frac{300 \times 10^3 \times 0.9}{300 \times 10^3 \times 0.9 + P_i + \frac{P_{cu}}{4}}$$

$$P_i + \frac{P_{cu}}{4} = 23478.6$$

$P_i + P_{cu} = 52173.39$

$P_i + \frac{1}{4} P_{cu} = 23478.36$

$0.75 P_{cu} = 28695.64$

$P_{cu} = 38260.82$ watts

$P_i = 13913$ watts

Case 3

To find Efficiency at $x = (3/4)^{th}$ load

$$\eta = \frac{(3/4) \times 600 \times 10^3 \times 0.9}{3/4 \times 600 \times 10^3 \times 0.9 + 13913 + (3/4)^2 \times 38260.8}$$

$$\eta = \frac{(3/2) \times 300 \times 10^3 \times 0.9}{(3/2) \times 300 \times 10^3 \times 0.9 + 13913 + 21521.2}$$

$$\eta = \frac{405 \times 10^3}{405 \times 10^3 + 35434.2}$$

$$\eta = \frac{405000}{440434.2}$$

$$\eta = 0.9195$$

Answer $\boxed{\eta \simeq 92\%}$

Summary

$x = 1$	$\eta = 92\%$	p.f = 1
$x = 1/2$	$\eta = 92\%$	p.f = 0.9
$x = 3/4$	$\eta = 92\%$	p.f = 0.9

Q 8 b →

A 250 KVA, 11000/415 V, 50Hz, 1φ Transformer has 80 turns on secondary — 6 marks

Calculate

i) I rated primary and secondary

ii) No of Primary Turns = Np

iii) Maximum value of Flux = ϕ_{max}

iv) Voltage induced per turn = Et

Solution: $E_2 = 4.44 f \phi_{max} N_2$

$415 = 4.44 \times 50 \times \phi_{max} \times 80$

$$\phi_{max} = \frac{415}{4.44 \times 50 \times 80}$$

$$\phi_{max} = \frac{415}{4.44 \times 4000} = 0.02337$$

$$\boxed{\phi_m = 23.37 \text{ mWb}}$$

$E_1 = 4.44 \times 50 \times 23.37 \times 10^{-3} \times N_p$

$$N_p = \frac{11000}{4.44 \times 50 \times 23.37 \times 10^{-3}}$$

$$\boxed{N_p = 11000/5.18 = 2123}$$

$I_s I_p = N_p N_s$

P.T.O

$I_s I_p = N_p N_s$

$I_s I_p = 2123 \times 80$

$E_t = \frac{E_s}{N_s} = \frac{E_2}{N_2} = \frac{415}{80}$

$E_t = 5.18$ volt/turn

$I_p = \frac{250 \times 1000}{11000}$

$I_p = I_1 = 22.72$ A

$I_s = I_2 = \frac{2123 \times 80}{22.72}$

$I_s = \frac{250 \times 1000}{415}$

$I_s = I_2 = 602$ A

Summary

i) $I_p = 22.72$ A $I_s = 602$ A

ii) $N_p = 2123$

iii) $\phi_{max} = 23.37$ mwb

$= 23.37 \times 10^{-3}$ weber

iv) $E_t = 5.18$ volt/turn

Q. No 8

C → Define slip of Induction Motor
Derive an expression for effect
of slip on the rotor frequency?
— 06 marks

Solution:

Definition of slip of Induction motor
— "As the speed of rotor drops
below the stator speed, or Ns,
the rotation rate of magnetic
field in the rotor increases,
inducing more current in the
rotor's winding and creating
more torque.

let $f' = sf$

s = slip f' = rotor frequency

f = stator frequency

$$S = \left(\frac{Ns - N}{N}\right) \times 100$$

$$f' = \text{Rotor frequency} = \left[\left(\frac{Ns - N}{N}\right) \times 100\right] \times f$$

$f' = sf$

When rotor is stationary, the frequency of rotor current is same as the supply frequency. When the induction motor is rotating, the frequency of current induced in the rotor conductor is proportional to the relative speed or slip speed.

$f' = sf$

indicates frequency of rotor current is slip times the frequency of the supply.

Module - 5

9a. With neat sketch explain working principle of fuse. Mention its merits & demerits. — 8M

→ A fuse is essentially a small piece of metal connected b/w two terminals mounted on an insulating base in series with circuit.

* The function of fuse wire is to carry the normal working current safely without heating, but when the normal current is exceeded it would heat up rapidly to the melting point & break the circuit.
* The heat produced is given by $H = I^2Rt$ hence, material used as fuse wire must have high resistivity & low melting point. So that wire reaches melting point in shortest possible time.

→ The various materials like tin, lead, zinc copper & ~~the~~ their alloys can be used as fuse wire.

* The fusing factor is defined as ratio of minimum fusing current to the current rating of the fusing element.

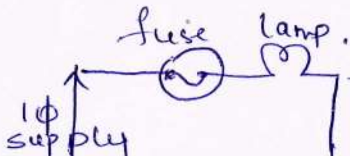
$$\text{Fusing factor} = \frac{\text{Minimum fusing Current}}{\text{Current rating of fusing element}}$$

Merits :- less Cost, Reliable, Protecting device

Demerits: Replaced when blown off

limited protection

single protection function.



9b. What is Electric shock? Mention few safety precautions to avoid electrical shock — 6M.

→ When a person touches the live part of electrical equipment he/she will receive an electrical shock.

* The severity of electric shock depends on vltg of wire & human body resistance.
* Max. current human body can withstand for a short time 25 msec is 30mA.

* The body resistance is 1kΩ when the body is wet, if a body is neither wet nor dry its 3kΩ to 5kΩ & when body is totally dry is 100000Ω.

* Precautions against electric shock:-
1) Don't touch the victim with bare hands when he is still in contact with electricity.
2) Immediately switch off the supply.
3) If supply is unable to turn off then separate the person from live part of elect. equipment.
4) Once a victim is free, check his breathing pulse. if not normal then provide artificial respiration.

1c) What is electricity tariff? Explain two part electricity tariff — 6M.

→ The rate at which electrical energy is supplied to a consumer is known as Tariff.

Two-part Tariff:-

When the rate of electrical energy is charged on the basis of max. demand of consumer & the units consumed is called. Two-part tariff.

In two part tariff, the total charge to be made from the consumer is split into two components fixed charges & running charges.

The fixed charges depends upon the maximum demand of consumer & running charges depends upon the no of unit consumed by the consumer.

ie, Total Charge = Rs [b*kW + c*kWh]

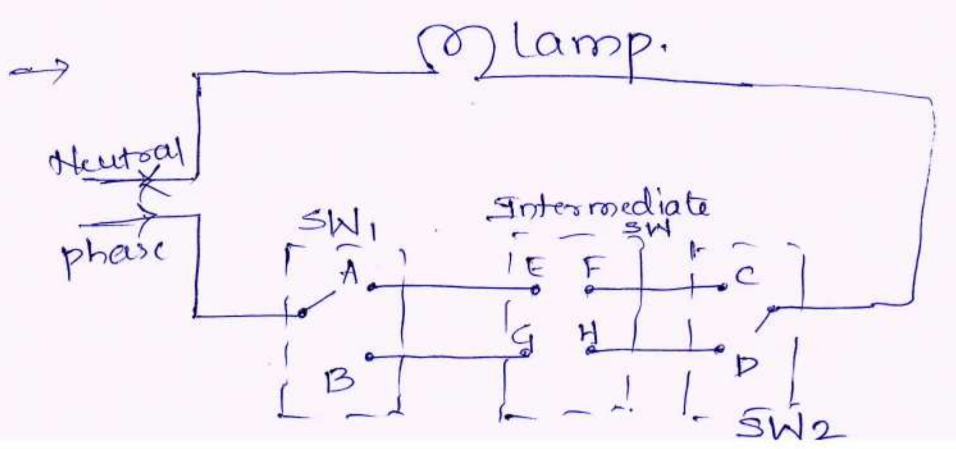
where b = Charge per kW of max. demand

c = charge per kWh of energy consumed

This type of tariff is applicable to industrial consumers who have appreciable maximum demand.

OR

10 a) With a neat circuit & switching table. Explain 3-ways control of load. Mention where its applicable → 8M



* This type of arrangement is used in godowns, high corridors, workshops.
* One lamp is controlled from 3 switches, which are located at different places.
* SW1 & SW2 are 2-way switch.
* Intermediate switch consist of 4 terminals. Two types of connections are possible in Intermediate switch namely straight connectⁿ & Cross Connection.
* Straight connection truth table (EF, GH)

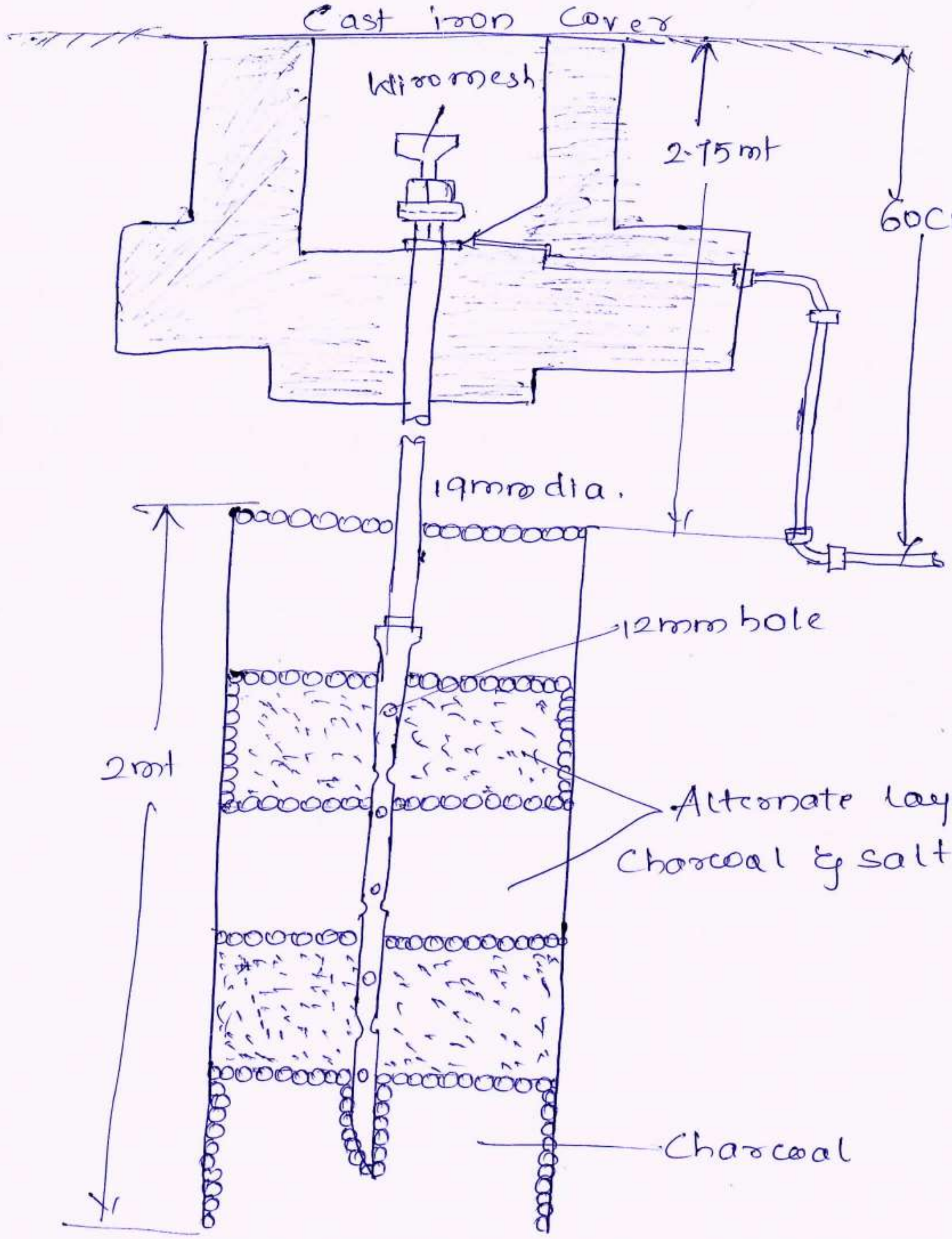
Sl. No	Position of SW1	Posⁿ of Intermed. switch	Posⁿ of SW2	lamp ON/OFF
1	A	EF, GH	C	ON
2	A	EF, GH	D	OFF
3	B	EF, GH	C	OFF
4	B	EF, GH	D	ON

* Cross connection truth table (EH, FG)

Sl. No	Posⁿ of SW1	Posⁿ of Intermedi switch	Posⁿ of SW2	Lamp ON/OFF
1	A	EH, FG	C	OFF
2	A	EH, FG	D	ON
3	B	EH, FG	C	ON
4	B	EH, FG	D.	OFF

10b) What is Earthing? With neat diagram explain pipe earthing - 6M

→ Connect the body of electrical equipment to the general mass of the earth by a least resistance wire is called earthing.



* Galvanised Iron (GI) pipe is used in this type of earthing.
* The size of the pipe depends on the current to be carried & type of the soil.
* According to ISI Standard, diameter of pipe must not be less than 38.1mm & 2mt

length & is buried at a depth of 4.75mt.
* It is placed upright in wet ground.
* The pipe at the bottom should be surrounded by charcoal, coke & sand to hold the moisture content for longer duration. This will increase the efficiency of earthing.
* A GI wire is connected b/w body of equipment & earthing pipe.
* The alternate layers of salt, charcoal & coke is used in earth pit.

10 c) Mention the power rating of the following electrical appliance & calculate the total power consumed by these 4 appliances — 6M.

→ 1) Air conditioners — ~~1200kW~~

Window AC (10,000 BTU) — ~~3250W~~ 1200W } 1.5kW to 2kW.
Window AC (12,000 BTU). — ~~3250W~~.

2) laptop — 50W - 100W

3) washing Machine — 500 - 2000W.

4) led tube lights — 18 - 25W.

Calculation of total power consumed

2000 + 75 + 1000 + 20
= 3095 W or 3.095 kW.

HEAD
Dept. of Electrical & Electronics Engg
KLS's V. D. Institute of Technology
HALIYAL-581 329

Dean, Academics
KLS VDIT, HALIYAL