INTRODUCTION TO ELECTRICAL ENGINEERING "BESCK104B-204B"

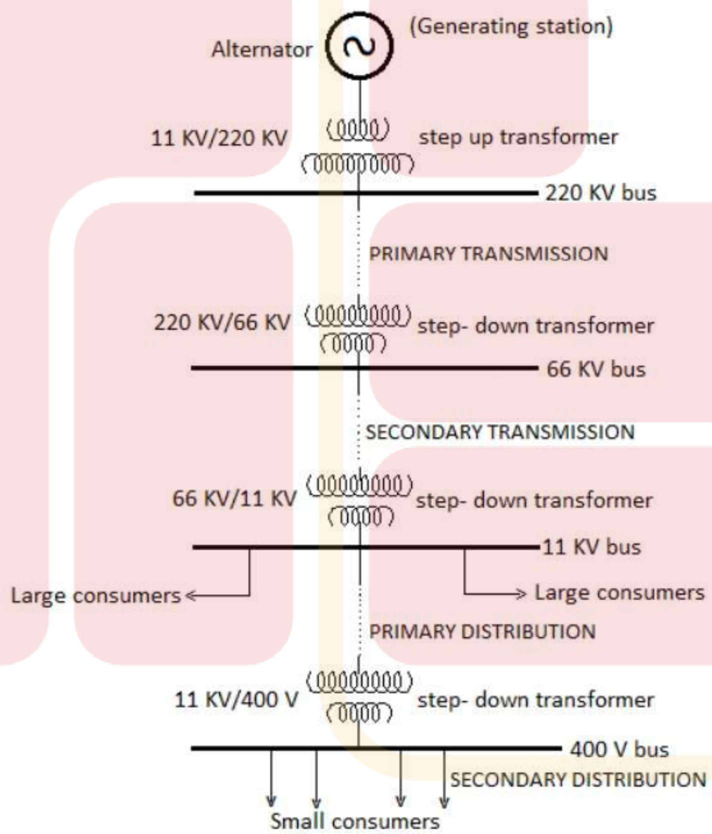
SOLUTIONS FOR MODEL QUESTION PAPER

1. a) With neat single line diagram explain the various steps of electrical power transmission and distribution system. (6 Marks)

The flow of electrical power from the generating station to the consumer is called an ***Electrical Power System*** or ***Electrical Supply System***. It is highly complex electrical network. It is basically divided in to three stages:

I. Generation stage
II. Transmission stage
III. Distribution stage

The electrical energy generated at a remote place has to be transmitted over a long distance to the load centres through transmission lines, feeders and distribution lines. A typical transmission and distribution power system scheme is shown in figure.



Generating Station:

The electrical energy is generated at 11 kV by alternators at ***Generating Station*** which is typically far away from cities/towns. It is required to increase this level for transmission purpose, since 11 kV is too small for the purpose of transmission of bulk power over long distances. Hence, this voltage is stepped up to higher voltages of 220 kV or 400 kV by means of step-up transformers at generating station itself.

Primary Transmission:

The electrical energy at these high levels (220 kV or 400 kV) is transmitted to a receiving station which is far away from the generating station. This forms the ***Primary Transmission***.

Secondary Transmission:

At receiving station, the high voltage is stepped down to 66 kV and is again transmitted to substations which are located very near to the load centres. This is known as ***Secondary Transmission.***

Primary Distribution:

At the substations, 66 kV is stepped down to 11 kV and is distributed to local distribution centres with the help of distributors. These 11 kV lines run along the important road sides of the city. Sometimes for the large consumers with bulk loads, the distributors transfer power directly. Transmission of energy from substation to distribution transformers forms the ***Primary Distribution***.

Secondary Distribution:

To supply energy for domestic consumption, there are distribution centres consisting of distribution transformers which step down the voltage level from 11 kV to 400V (Three phase) and 230V (Single phase) supply. The transfer of electrical energy from distribution transformers to domestic consumers is known as ***Secondary Distribution***.

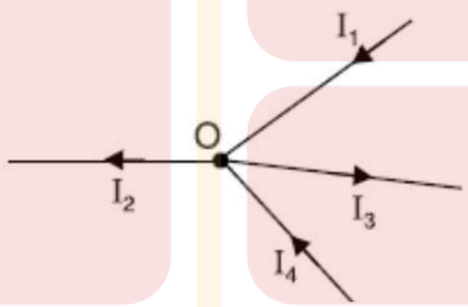
1. b) State and explain Kirchhoff's current and voltage law. (6 Marks)

1. KIRCHHOFF'S CURRENT LAW (KCL):

This law relates to the currents at the junctions of an electric circuit and may be stated as under:

The algebraic sum of the currents meeting at a junction in an electrical circuit is zero.

An algebraic sum is one in which the sign of the quantity is taken into account. For example, consider four conductors carrying currents I_1, I_2, I_3 and I_4 and meeting at point O as shown in Fig.



If we take the signs of currents flowing towards point O as positive, then currents flowing away from point O will be assigned negative sign. Thus, applying Kirchhoff's current law to the junction O in Fig, we have,

$(I_1) + (I_4) + (-I_2) + (-I_3) = 0$

or $I_1 + I_4 = I_2 + I_3$

i.e., Sum of incoming currents = Sum of outgoing currents.

Hence, Kirchhoff's current law may also be stated as under:

The sum of currents flowing towards any junction in an electrical circuit is equal to the sum of currents flowing away from that junction.

Kirchhoff's current law is also called junction rule.

Kirchhoff's current law is based on the law of conservation of charge.

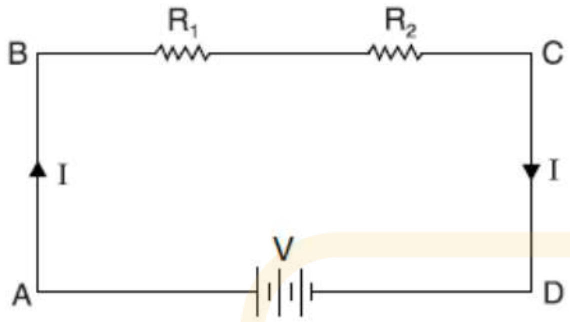
2. KIRCHHOFF'S VOLTAGE LAW (KVL):

This law relates to e.m.fs and voltage drops in a closed circuit or loop and may be stated as under :

In any closed electrical circuit or mesh, the algebraic sum of all the electromotive forces (e.m.fs) and voltage drops in resistors is equal to zero, i.e.,

In any closed circuit or mesh,

Algebraic sum of e.m.fs + Algebraic sum of voltage drops = 0



For the above circuit, applying KVL in clockwise direction we get: $V - IR_1 - IR_2 = 0$

Consider the closed loop ABCDA as shown in Figure. If we start from any point (say point A) in this closed circuit and go back to this point (i.e., point A) after going around the circuit, then there is no increase or decrease in potential. This means that algebraic sum of the e.m.fs of all the sources (here only one e.m.f. source is considered) met on the way plus the algebraic sum of the voltage drops in the resistances must be zero.

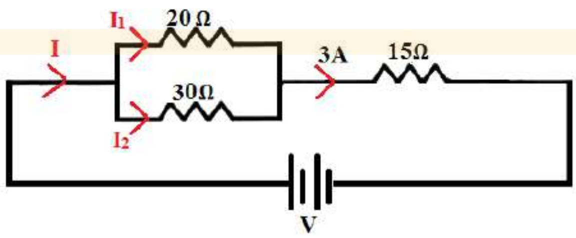
Kirchhoff's voltage law is also called loop rule.

Kirchhoff's voltage law is based on the law of conservation of energy.

1. c) A circuit of two parallel resistors having resistances of 20Ω and 30Ω connected in series with 15Ω. If the current through 15Ω resistor is 3A. Find i) current in 20Ω and 30Ω resistors ii) voltage across the whole circuit iii) the total power and power consumed in all resistors. (6 Marks)

<u>Sol</u>: i) Current in 20Ω and 30Ω resistors:

Using Branch current formula:



Current through 20Ω, $I_1 = I\frac{R_2}{R_1+R_2} = 3 \times \frac{30}{20+30} = \mathbf{1.8A}$

Current through 30Ω, $I_2 = I\frac{R_1}{R_1+R_2} = 3 \times \frac{20}{20+30} = \mathbf{1.2A}$

ii) Voltage across whole circuit:

$R_{eq} = \left(\frac{R_1 \times R_2}{R_1+R_2}\right) + R_3$

$R_{eq} = \left(\frac{20\times30}{20+30}\right) + 15 = \mathbf{27\Omega}$

Voltage across whole circuit: $V = I \times R_{eq} = 3\times27 = \mathbf{81V}$

iii) The total power and power consumed in all resistors:

Power consumed in 20Ω resistor, $P_1 = I_1^2R_1 = (1.8)^2 \times 20 =$ **64.8W**

Power consumed in 30Ω resistor, $P_2 = I_2^2R_2 = (1.2)^2 \times 30 =$ **43.2W**

Power consumed in 15Ω resistor, $P_3 = I^2R_3 = (3)^2 \times 15 =$ **135W**

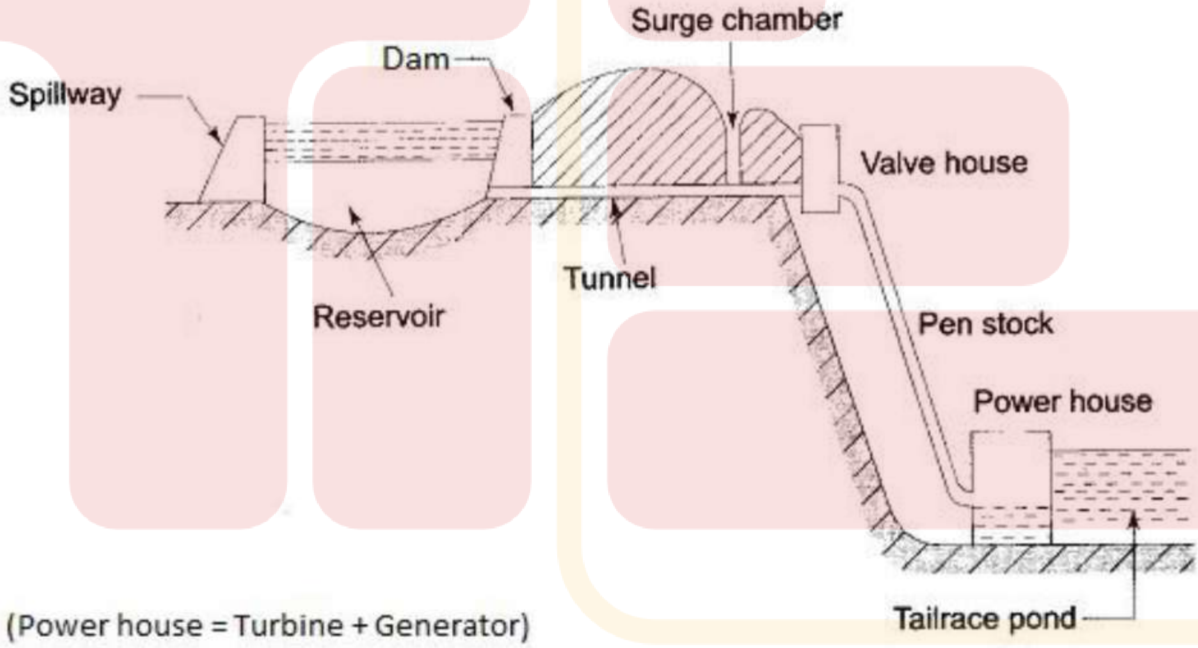
∴ Total power consumed in all resistors, $P_T = P_1+P_2+P_3 =$ **243W**

Or

Total power consumed in all resistors, $P_T = VI = 81 \times 3 =$ **243W**

2. a) With block diagram explain hydel power generation. (6 Marks)

The oldest and cheapest method of power generation is that of utilizing the potential energy of water. The term 'hydropower' refers to shaft power generated by converting potential and kinetic energy of water. The energy is obtained almost free of running cost and is completely pollution free. Of course, it involves high capital cost because of the heavy civil engineering construction works involved. Hydroelectric stations are designed, mostly, as multipurpose projects such as river flood control, storage of irrigation and drinking water, and navigation. A simple block diagram of a hydro plant is given in Fig. The vertical difference between the upper reservoir and tail race is called the head.



(Power house = Turbine + Generator)

The dam is constructed across a river or lake and water from the catchment area collects at the back of the dam to form a reservoir. A pressure tunnel is taken off from the reservoir and water brought to the valve house at the start of the penstock. From the valve house, water is taken to water turbine through a huge steel pipe known as penstock. The water turbine converts hydraulic energy into mechanical energy. The turbine drives the alternator (A.C. generator) which converts mechanical energy into electrical energy.

A surge tank (open from top) is built just before the valve house and protects the penstock from bursting in case the turbine gates suddenly close due to electrical load being thrown off. When the gates close, there is a sudden stopping of water at the lower end of the penstock and consequently the penstock can burst like a paper log. The surge tank absorbs this pressure swing by increase in its level of water.

FUNCTIONS OF DIFFERENT COMPONENTS IN PLANT:

(i) Reservoir: It is the basic requirement of hydro-electric plant. Its purpose is to store the water which is utilised to run the prime mover (turbine) to produce electrical power. This stores the water during rainy season and supply the same during dry season.

(ii) Dam: A dam is a barrier which stores water and creates water head. Dams are built of concrete or stone masonry, earth or rock fill. The type and arrangement depends upon the topography of the site. The type of dam also depends upon the foundation conditions, local materials and transportation available, occurrence of earthquakes and other hazards. Dam increases the reservoir capacity.

(iii) Surge tank: Open conduits (pipes) leading water to the turbine require no protection. However, when closed conduits are used, protection becomes necessary to limit the abnormal pressure in the conduit. For this reason, closed conduits are always provided with a surge tank. A surge tank is a small reservoir or tank (open at the top) in which water level rises or falls to reduce the pressure swings in the conduit.

A surge tank is located near the beginning of the conduit. When the turbine is running at a steady load, there are no surges in the flow of water through the conduit i.e., the quantity of water flowing in the conduit is just sufficient to meet the turbine requirements. However, when the load on the turbine decreases, the governor closes the gates of turbine, reducing water supply to the turbine. As a result of sudden change in the rate of flow of water there will be sudden change of pressure in the penstock pipes. This sudden change of pressure above normal is known as ***Water Hammer***. If we install surge tank, then the excess water at the lower end of the conduit rushes back to the surge tank and increases its water level. Thus the conduit is prevented from bursting. On the other hand, when load on the turbine increases, additional water is drawn from the surge tank to meet the increased load requirement. Hence, a surge tank overcomes the abnormal pressure in the conduit when load on the turbine falls and acts as a reservoir during increase of load on the turbine.

(iv) Spillways: There are times when the river flow exceeds the storage capacity of the reservoir. Such a situation arises during heavy rainfall in the catchment area. In order to discharge the surplus water from the storage reservoir into the river on the down-stream side of the dam, spillways are used. Spillways are constructed of concrete piers on the top of the dam. Gates are provided between these piers and surplus water is discharged over the crest of the dam by opening these gates.

(v) Penstocks: Penstocks are open or closed conduits which carry water to the turbines. They are generally made of reinforced concrete or steel. Concrete penstocks are suitable for low heads (< 30 m) as greater pressure causes rapid deterioration of concrete. The steel penstocks can be designed for any head; the thickness of the penstock increases with the head or working pressure.

(vi) Power house: This unit consists of a Turbine-Generator set. The water turbine converts hydraulic energy into mechanical energy. The turbine drives the alternator (A.C. generator) which converts mechanical energy into electrical energy.

(vii) Tail race: The tail race, containing tail water, is a channel that carries water away from a hydroelectric plant. The water in this channel has already been used to rotate turbine blades or the water wheel itself. This water has served its purpose, and leaves the power generation unit. In hydroelectric dams, the tail race is at a much lower level than the height of the reservoir behind the dam.

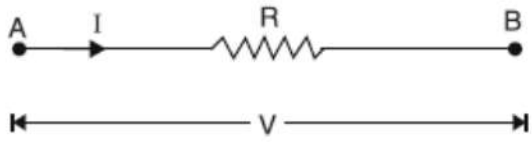
2. b) State and explain Ohm's law with its limitations. (6 Marks)

Electric current (I) flowing through a conductor is directly proportional to the potential difference (V) between its two ends, provided the physical conditions (e.g. temperature etc.) remains unchanged.

$$I \propto V$$

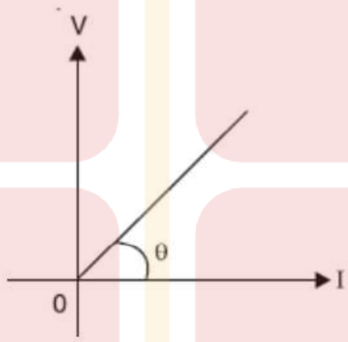
$$V/I = \text{Constant} = R$$

where R is the resistance of the conductor between the two points considered.



For example, if in above fig, the voltage between points A and B is V volts and current flowing is I amperes, then V/I will be constant and equal to R, the resistance between points A and B. If the voltage is doubled up, the current will also be doubled up so that the ratio V/I remains constant.

If we draw a graph between V and I, it will be a straight line passing through the origin as shown in below fig.



The resistance R between points A and B is given by slope of the graph i.e.

$$R = \tan \theta = V/I = \text{Constant}$$

Ohm's law can be expressed in three forms viz.

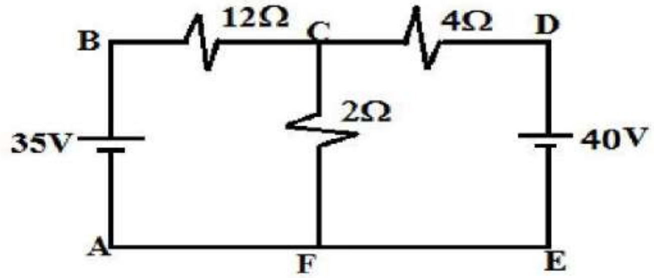
$$I = V/R \; ; \; V = IR \; ; \; R = V/I$$

These formulae can be applied to any part of a d.c. circuit or to a complete circuit. It may be noted that if voltage is measured in volts and current in amperes, then resistance will be in ohms.

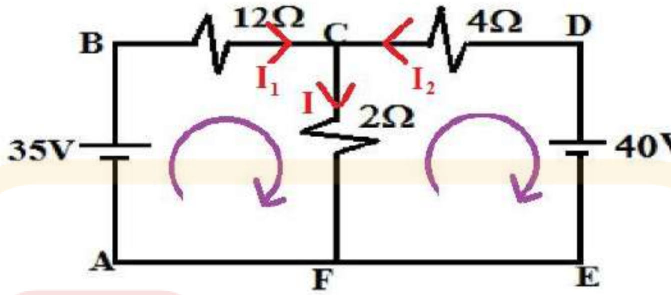
LIMITATIONS OF OHM'S LAW:

1. It is not applicable to the non-linear devices such as Semiconductors, Zener diodes, etc
2. It does not hold good for non-metallic conductors such as silicon carbide. The law for such conductors is given by $V=KI^m$ where k, m are constants.
3. It cannot be applied to arc lamps due to its non-linear characteristics.
4. Ohms law is valid as long as temperature and the other physical parameter remains constant.
5. It cannot be applied to complicated circuits having more number of branches & voltage sources.

2. c) For the circuit shown in fig (i) find the current in 2Ω resistor. (6 Marks)



Sol: Assign the currents as shown in fig below:



Apply KCL at the node B, we get

$I_1 + I_2 = I$ …………(1)

Apply KVL to loop 1 (clockwise)

$35 - 12I_1 - 2I = 0$ …………(2)

Substitute $I = I_1 + I_2$ from eqn(1) in eqn(2), we get

$35 - 12I_1 - 2(I_1 + I_2) = 0$

$14I_1 + 2I_2 = 35$ …………(3)

Apply KVL to loop 2 (clockwise)

$-40 + 2I + 4I_2 = 0$

$-40 + 2(I_1 + I_2) + 4I_2 = 0$

$2I_1 + 6I_2 = 40$ …………(4)

Consider eqns (3) & (4), we get:

$14I_1 + 2I_2 = 35$ …………(3)

$2I_1 + 6I_2 = 40$ …………(4)

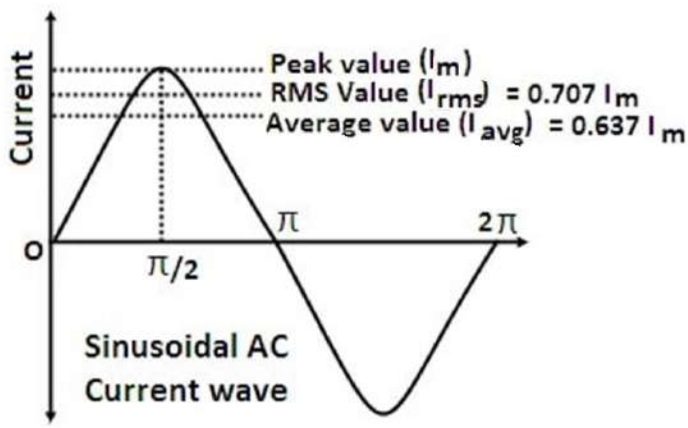
After solving the above 2 eqns, we get:

Current I_1 = **1.625A**

Current I_2 = **6.125A**

Current through 2Ω resistor, $I = I_1 + I_2 = 1.625+6.125$ = **7.75A**

3. a) Define the following by referring a sine wave i) RMS value ii) average value iii) form factor iv) peak factor v) phase and vi) phase difference. (6 Marks)



R.M.S. OR EFFECTIVE VALUE:

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

$\boldsymbol{I_{r.m.s} = 0.707 \times I_m}$

Similarly, it can be proved that for alternating voltage varying sinusoidally, $V_{r.m.s} = 0.707\ V_m$.

$$\boxed{\therefore \textit{R.M.S value} = 0.707 \times \textit{Maximum value}}$$

AVERAGE VALUE:

The arithmetical average of all the values of an alternating quantity over one cycle is called average value.

$\boldsymbol{I_{avg} = 0.637 \times I_m}$

Hence, the half-cycle average value of a.c. is 0.637 times the peak value of a.c.

For positive half-cycle, $I_{avg} = +\ 0.637\ I_m$: For negative half-cycle, $I_{avg} = -\ 0.637\ I_m$

Clearly, average value of a.c. over a complete cycle is zero. Similarly, it can be proved that for alternating voltage varying sinusoidally, $V_{avg} = 0.637\ V_m$

$$\boxed{\therefore \textit{Average value} = 0.637 \times \textit{Maximum value}}$$

FORM FACTOR:

The ratio of r.m.s. value to the average value of an alternating quantity is known as form factor *i.e.*

For a sinusoidal voltage or current,

$$\boxed{\text{Form factor} = \frac{\text{R.M.S.value}}{\text{Average value}} = \frac{0.707 \times \text{Max.value}}{0.637 \times \text{Max.value}} = 1.11}$$

PEAK FACTOR:

The ratio of maximum value to the r.m.s. value of an alternating quantity is known as peak factor *i.e.*

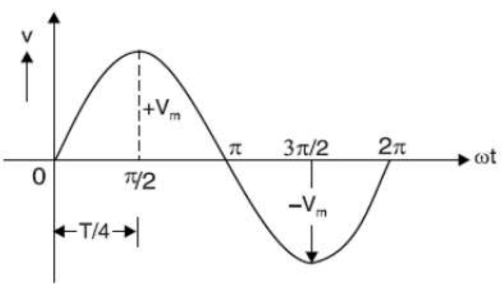
For a sinusoidal voltage or current,

$$\boxed{\text{Peak factor} = \frac{\text{Max.value}}{\text{R.M.S.value}} = \frac{\text{Max.value}}{0.707 \times \text{Max.value}} = 1.414}$$

Peak factor is also called ***crest factor or amplitude factor.***

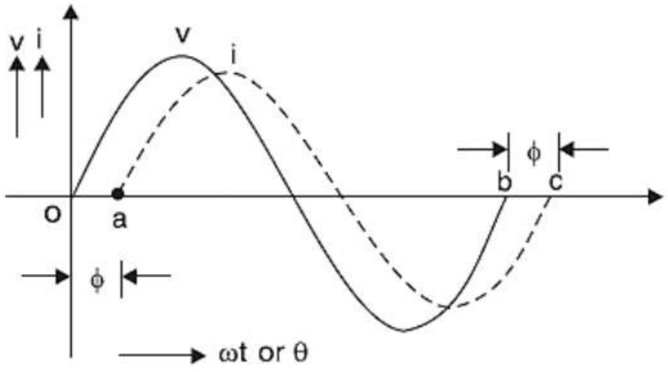
PHASE:

Phase of a particular value of an alternating quantity is the fractional part of time period or cycle through which the quantity has advanced from the selected zero position of reference.



PHASE DIFFERENCE:

When two alternating quantities of the same frequency have different zero points, they are said to have a **phase difference**.



3. b) Show that the current through purely capacitive circuit leads the applied voltage by 90º and average power consumed is zero. Draw the wave shapes of current, voltage and power. (8 Marks)

When an alternating voltage is applied across the plates of a capacitor, the capacitor is charged in one direction and then in the other as the voltage reverses. The result is that electrons move to and fro around the circuit, connecting the plates, thus constituting alternating current.

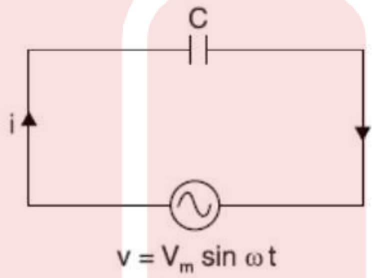


Fig.10

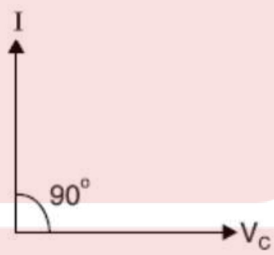


Fig. 11

Consider an alternating voltage applied to a capacitor of capacitance C farad as shown in Fig 10. Let the equation of the applied alternating voltage be:

$$\boxed{v = V_m \sin \omega t} \quad ...(i)$$

As a result of this alternating voltage, alternating current will flow through the circuit. Let at any instant i be the current and q be the charge on the plates.

Charge on capacitor, $q = C\,v = C\,V_m \sin \omega t$

$$\therefore \quad \text{Circuit current, } i = \frac{d}{dt}(q) = \frac{d}{dt}(C\,V_m \sin \omega t) = \omega\,C\,V_m \cos \omega\,t$$

$$\therefore \quad i = \omega\,C\,V_m \sin(\omega\,t + \pi/2) \quad ...(ii)$$

The value of i will be maximum (*i..e.* I_m) when $\sin(\omega\,t + \pi/2)$ is unity.

$$\therefore \quad I_m = \omega\,C\,V_m$$

Substituting the value $\omega C\,V_m = I_m$ in eq. (*ii*), we get,

$$\boxed{i = I_m \sin(\omega\,t + \pi/2)} \quad ...(iii)$$

Here Capacitive reactance $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

Note that X_C will be in Ω if C is in Farad and f in Hz.

(i) PHASE ANGLE: It is clear from eqs. (i) and (iii) that current leads the voltage by π/2 radians or 90º. Hence in a pure capacitance, current leads the voltage by 90º. This is also indicated in the phasor diagram shown in Fig 11. The wave diagram shown in Fig. 12 also reveals the same fact. There is also physical explanation for the lagging of voltage behind the current in a capacitor. Capacitance opposes the change in voltage and serves to delay the increase or decrease of voltage across the capacitor. This causes the voltage to lag behind the current.

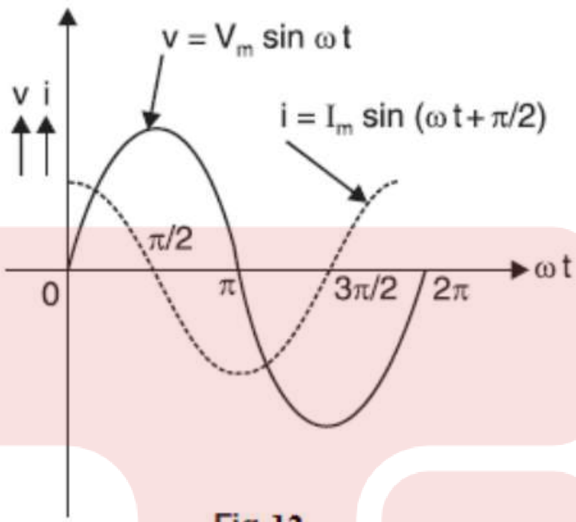


Fig.12

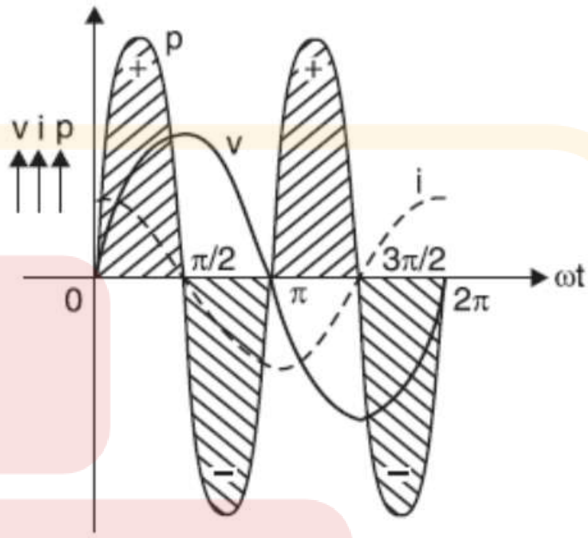


Fig.13

(ii) POWER: Instantaneous power is given by:

$$p = v\,i = V_m \sin \omega t \times I_m \sin(\omega t + \pi/2) = V_m I_m \sin \omega t \cos \omega t$$

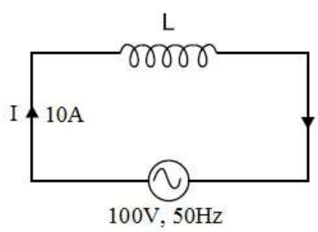
$$\therefore \quad p = \frac{V_m I_m}{2} \sin 2\omega t$$

$$\therefore \quad \text{Average power, } P = \text{Average of } p \text{ over one cycle}$$

$$= \frac{1}{2\pi} \int_0^{2\pi} \frac{V_m I_m}{2} \sin 2\omega t \, d(\omega t) = 0$$

Hence power absorbed in a pure capacitance is zero.

3. b) An inductive coil takes a current of 10A from a supply of 100V, 50Hz and lags the voltage by 30º. Calculate i) parameters of the circuit ii) power factor iii) active, reactive and apparent power. (8 Marks)



Given: I=10A, V=100V, f=50Hz, ϕ =30º

i) To find the Impedance, Z

$$Z = \frac{V}{I} = \frac{100}{10} = \mathbf{10\Omega}$$

To find the Resistance, R

$$\text{Cos}\phi = \frac{R}{Z}$$

$$R = Z\ \text{Cos}\phi = 10 \times \text{Cos}(30) = \mathbf{8.66\Omega}$$

To find the Inductance, L

$$X_L = Z\ \text{Sin}\phi = 10 \times \text{Sin}(30) = \mathbf{5\Omega}$$

Also, $X_L = 2\pi fL$

$$L = \frac{XL}{2\pi f} = \frac{5}{2\pi \times 50} = \mathbf{0.0159H}$$

ii) Power factor, $\text{Cos}\phi = \text{Cos}(30) = \mathbf{0.866}$

iii) Active Power, $P = VI\ \text{Cos}\phi = 100 \times 10 \times \text{Cos}(30) = \mathbf{866W}$

Reactive Power, $P = VI\ \text{Cos}\phi = 100 \times 10 \times \text{Sin}(30) = \mathbf{500VAr}$

Apparent Power. $S = VI = 100 \times 10 = \mathbf{1000VA}$

4. a) Develop an equation for the power consumed by an R-L series circuit. Draw the waveforms of voltage, current and power. (8 Marks)

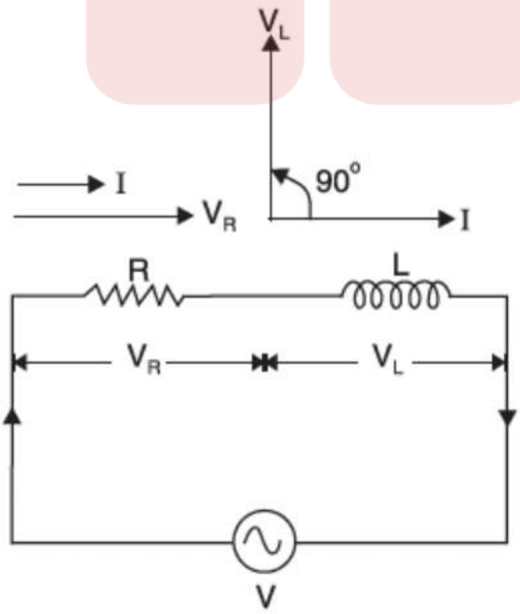
This is the most general case met in practice as nearly all a.c. circuits contain both resistance and inductance. Fig (i) shows a pure resistance of R ohms connected in series with a coil of pure inductance L henry.

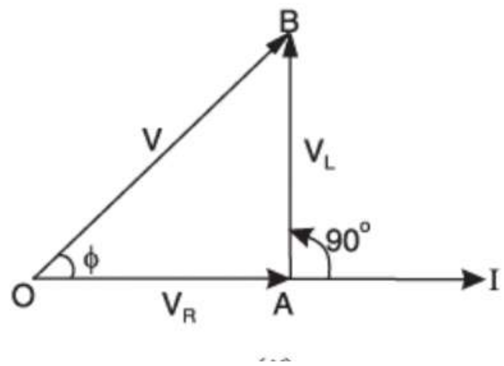
Let V = r.m.s. value of the applied voltage

I = r.m.s. value of the circuit current

$\therefore$ $V_R = IR$ .... where V_R is in phase with I

$V_L = IX_L$ .... where V_L leads I by 90°





Taking current as the reference phasor, the phasor diagram of the circuit can be drawn as shown in Fig (ii). The voltage drop V_R ($= IR$) is in phase with current and is represented in magnitude and direction by the phasor OA. The voltage drop V_L ($= I X_L$) leads the current by 90° and is represented in magnitude and direction by the phasor AB. The applied voltage V is the phasor sum of these two drops i.e.

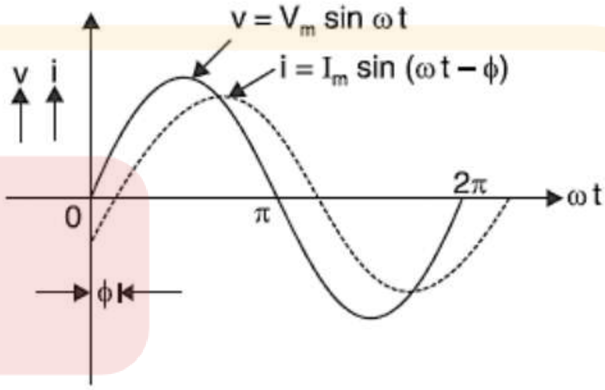
$$V = \sqrt{V_R^2 + V_L^2} = \sqrt{(IR)^2 + (IX_L)^2} = I\sqrt{R^2 + X_L^2}$$

$$\therefore \quad I = \frac{V}{\sqrt{R^2 + X_L^2}}$$

The quantity $\sqrt{R^2 + X_L^2}$ offers opposition to current flow and is called **impedance** of the circuit. It is represented by Z and is measured in ohms (Ω).

$$\therefore \quad I = \frac{V}{Z} \quad \text{where } Z = \sqrt{R^2 + X_L^2}$$

(i) PHASE ANGLE: It is clear from the phasor diagram that circuit current I lags behind the applied voltage V by ϕ°. This fact is also illustrated in the wave diagram shown in Fig. The value of phase angle ϕ can be determined from the phasor diagram.



$$\tan\phi = \frac{V_L}{V_R} = \frac{I X_L}{I R} = \frac{X_L}{R}$$

Since X_L and R are known, ϕ can be calculated.

If the applied voltage is $v = V_m \sin \omega t$, then equation for the circuit current will be :

$$i = I_m \sin(\omega t - \phi) \quad \text{where } I_m = V_m / Z$$

(iii) POWER:

Instantaneous power, $p = v\,i = V_m \sin \omega t \times I_m \sin(\omega t - \phi)$

$$= \frac{1}{2} V_m I_m \, [2 \sin \omega t \sin(\omega t - \phi)]$$

$$= \frac{1}{2} V_m I_m \, [\cos\phi - \cos(2\omega t - \phi)]$$

$$= \frac{1}{2} V_m I_m \cos\phi - \frac{1}{2} V_m I_m \cos(2\omega t - \phi)$$

Thus instantaneous power consists of two parts :

(*a*) Constant part $\frac{1}{2} V_m I_m \cos\phi$ whose average value over a cycle is the same.

(*b*) A pulsating component $\frac{1}{2} V_m I_m \cos(2\omega t - \phi)$ whose average value over one complete cycle is zero.

$$\therefore \quad \text{Average power, } P = \frac{V_m I_m}{2}\cos\phi = \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}} \times \cos\phi$$

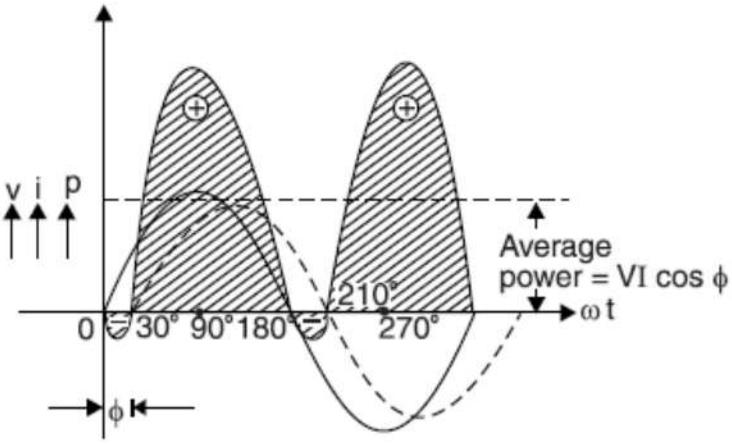
or

$$P = V I \cos\phi$$

$$\text{Power factor, } \cos\phi = \frac{IR}{IZ} = \frac{R}{Z}$$

Alternatively. $P = VI\cos\phi = (IZ)\, I\,(R/Z) = I^2 R \qquad [\because V = IZ \text{ and } \cos\phi = R/Z]$

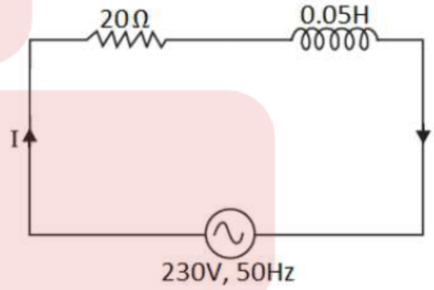
POWER CURVE:



4. b) A circuit consists of a resistance of 20Ω, an inductance of 0.05H connected in series. A supply of 230V at 50 Hz is applied across the circuit. Determine the current, power factor and power consumed by the circuit.

(6 Marks)

Given: R=20Ω, L=0.05H, V=230V, f=50Hz



i) To find the Inductive reactance, X_L

$$X_L = 2\pi fL = 2\pi \times 50 \times 0.05 = \mathbf{15.7\Omega}$$

ii) To find the impedance, Z

$$Z = \sqrt{R^2 + (X_L)^2} = \sqrt{20^2 + (15.7)^2} = \mathbf{25.42\Omega}$$

iii) To find the Current, I

$$I = \frac{V}{Z} = \frac{230}{25.42} = \mathbf{9.045A}$$

iv) To find the power factor, Cosϕ

$$\cos\phi = \frac{R}{Z} = \frac{20}{25.42} = \mathbf{0.786} \text{ lag}$$

v) To find the Power, P

$$P = VI\cos\phi = 230 \times 9.045 \times 0.786 = \mathbf{1636.78W}$$

4. c) Three coils having resistance of 10Ω and inductance of 0.02H are connected in star across 440V, 50Hz three phase supply. Calculate the line current, power factor and total power consumed. **(6 Marks)**

Given: R = 10Ω, L = 0.02H, V_l = 440V, f = 50Hz

i) FOR STAR CONNECTION:

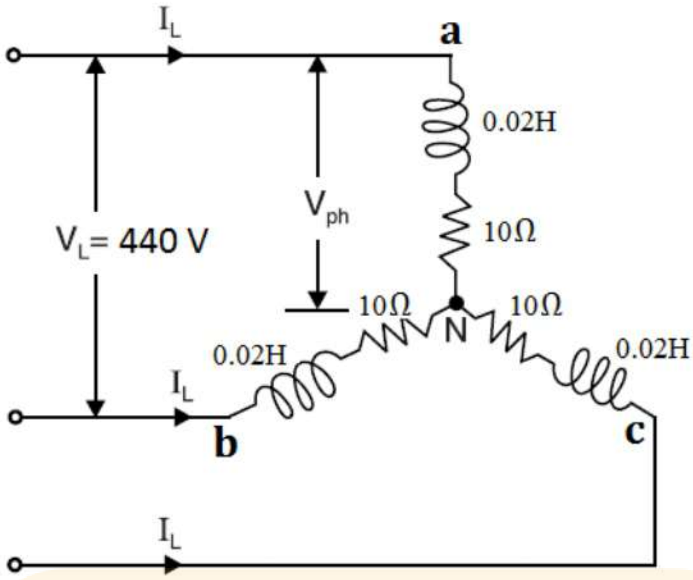
<u>1: To find the Impedance/phase (Z)</u>

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

$X_L = 2\pi f L$

$X_L = 2\pi \times 50 \times 0.02 = \mathbf{6.283\Omega}$

$Z = \sqrt{10^2 + (6.283)^2} = \mathbf{11.81\Omega}$



2: To find the Phase Voltage

$V_{ph} = V_l / \sqrt{3}$

$V_{ph} = 440 / \sqrt{3} = \mathbf{254.03V}$

3: To find the Phase Current

$I_{ph} = V_{ph} / Z$

$I_{ph} = 254.03 / 11.81 = \mathbf{21.5A}$

4: To find the Line Current

$I_l = I_{ph}$

$I_l = I_{ph} = \mathbf{21.5A}$

5: To find the Power factor

$\cos\phi = R/Z$

$\cos\phi = 10/11.81 = \mathbf{0.846}$

6: To find the Power

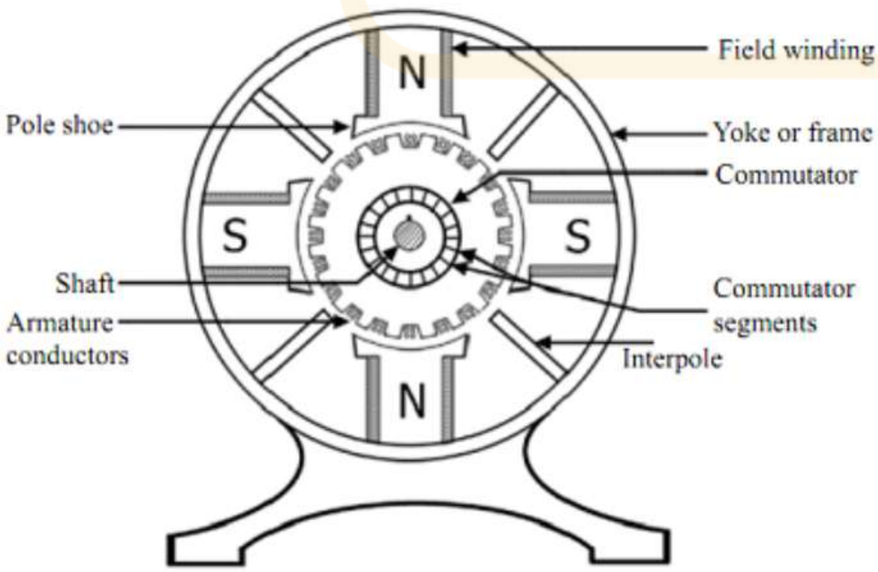
$P = 3\, V_{ph}\, I_{ph} \cos\phi$

$P = 3 \times 254.03 \times 21.5 \times 0.846 = \mathbf{13861.88W}$

or $P = \sqrt{3}\, V_l\, I_l \cos\phi$

$P = \sqrt{3} \times 440 \times 21.5 \times 0.846 = \mathbf{13861.88W}$

5. a) With a neat diagram explain the construction of D.C. generator. (8 Marks)



i) Yoke:

- It serves the purpose of outermost cover of the D.C. machine. So that the insulating materials get protected from harmful atmospheric elements like moisture, dust and various gases like SO_2, acidic fumes etc.
- It provides mechanical support to the poles.
- It forms a part of the magnetic circuit. It provides a path of low reluctance for magnetic flux.

ii) Poles:

- Each pole is divided into two parts a) pole core and b) pole shoe
- ***Pole core*** basically carries a field winding which is necessary to produce the flux.
- It directs the flux produced through air gap to armature core, to the next pole.
- ***Pole shoe*** enlarges the area of armature core to come across the flux, which is necessary to produce larger induced EMF. To achieve this, pole shoe has given a particular shape.

iii) Field winding:

- The field winding is wound on the pole core with a definite direction.
- To carry current due to which pole core on which the winding placed behave as an electromagnet, producing necessary flux. As it helps in producing the magnetic field i.e. exciting the pole as electromagnet it is called Field winding or Exciting winding.

iv) Armature:

- It is further divided into two parts namely,

I. Armature core and

II. Armature winding

- Armature core is cylindrical in shape mounted on the shaft. It consists of slots on its periphery and the air ducts to permit the air flow through armature which serves cooling purpose.
- Armature windings (conductors) are normally made up of copper and are placed within the slots provided on periphery.

v) Commutator:

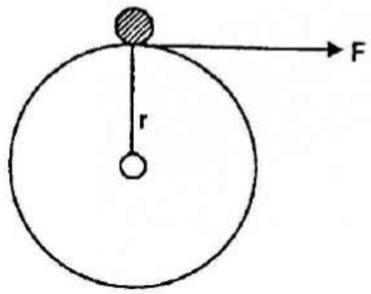
- The basic nature of EMF induced in the armature conductors is alternating.
- This needs rectifications in case of D.C. generator which is possible by device called commutator.

vi) Brushes:

- To collect current from commutator and make it available to the stationary external circuit.
- Brushes are normally made up of soft material like carbon.

5. b) Derive an expression of armature torque developed in a D. C. motor. (6 Marks)

Torque is the turning moment of a force about an axis and is measured by the product of force (F) and radius (r) at right angle to which the force acts.



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

$T_a = F \times r$

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

W = Force × distance covered in one revolution = $F \times 2\pi r$ W-S

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

$= F \times 2\pi r \times$ number of revolutions per second

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

We know that the electrical equivalent of the mechanical power developed by the armature of the DC motor is equal to $E_b I_a$. where back EMF $E_b = \Phi ZNP/60A$

$$\therefore \frac{2\pi N T_a}{60} = E_b I_a$$

$$\frac{2\pi N T_a}{60} = \frac{\Phi ZNP}{60A} I_a$$

$$\therefore T_a = \frac{1}{2\pi} \Phi Z I_a \left(\frac{P}{A}\right)$$

$$\therefore \boxed{T_a = 0.159\, \Phi\, Z\, I_a \left(\frac{P}{A}\right)} \text{ N-m}$$

5. c) An 8 pole generator has 500 armature conductors and has a useful flux per pole of 0.065wb. What will be the emf generated if it is lap connected and runs at 1000rpm? What must be the speed at which it is to be driven to produce the same emf if it is wave wound? (6 Marks)

Given: P = 8, Z = 500, ϕ = 0.065 Wb, For LAP: A = P = 8, N = 1000 RPM

(*Note*: Here armature conductors (Z) is given, so need not find the 'Z' again)

<u>1: To find the Generated EMF (For LAP)</u>

$$E = \frac{\Phi ZNP}{60A}$$

For Lap winding, A = P = 8

$$E = \frac{0.065 \times 500 \times 1000 \times 8}{60 \times 8} = \mathbf{541.66\ V}$$

2: To find the Speed (For WAVE)

$E = \frac{\Phi ZNP}{60A}$

Speed, $N = \frac{E \times 60A}{\Phi ZP}$

For Wave winding, A = 2

$N = \frac{541.66 \times 60 \times 2}{0.065 \times 500 \times 8} = \mathbf{250\ RPM}$

6. a) Explain the various methods used to control the speed of D.C. series motor. (8 Marks)

1. FIELD (FLUX) CONTROL METHOD

i) FIELD DIVERTER: A variable resistance is connected parallel to the series field as shown in fig (a). This variable resistor is called as a diverter, as the desired amount of current can be diverted through this resistor and, hence, current through field coil can be decreased. Thus, flux can be decreased to the desired amount and speed can be increased.

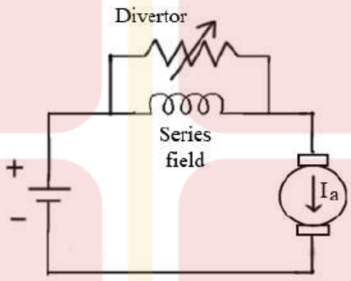


fig (a) Field Divertor

ii) ARMATURE DIVERTER: Diverter is connected across the armature as shown in fig (b). For a given constant load torque, if armature current is reduced then the flux must increase, as $T_a \propto ØI_a$. This will result in an increase in current taken from the supply and hence flux Ø will increase and subsequently speed of the motor will decrease.

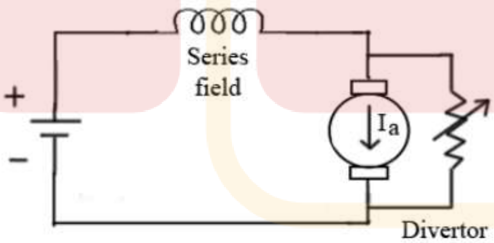


fig (b) Armature Divertor

iii) TAPPED FIELD CONTROL: As shown in fig (c) field coil is tapped dividing number of turns. Thus we can select different value of Ø by selecting different number of turns.

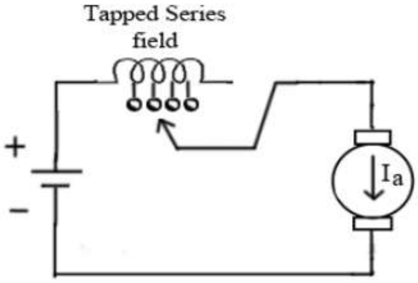


fig (c) Tapped field

iv) PARALLELING FIELD COILS: In this method, several speeds can be obtained by regrouping coils as shown in fig (d).

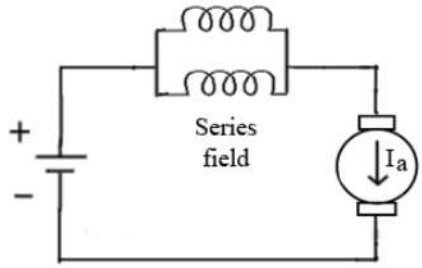
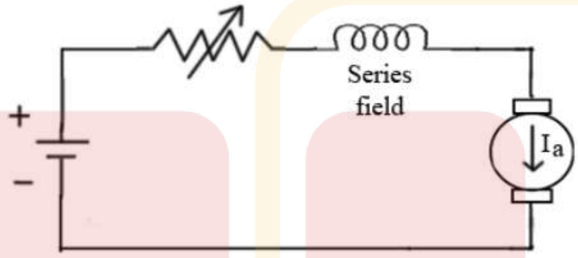


fig (d) Paralleling Field coils

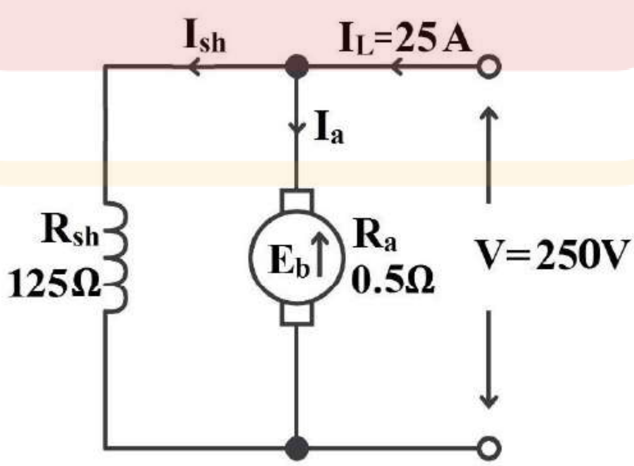
2. ARMATURE CONTROL METHOD

By introducing resistance in series with the armature, voltage across the armature can be reduced. And, hence, speed reduces in proportion with it.



6. b) A 4 pole D.C. shunt motor takes 25A from a 250V supply. The armature and field resistances are 0.5Ω and 125Ω respectively. The wave wound armature has 30 slots and each slot containing 10 conductors. If the flux per pole is 0.02wb, calculate i) speed ii) torque developed iii) power developed. (6 Marks)

Given: $P = 4$, $I_L = 25A$, $V = 250V$, $R_a = 0.5\Omega$, $R_{sh} = 125\Omega$, For wave: $A = 2$, $Z = 30\times10 = 300$, $\Phi = 0.02$ Wb



1: To find the Field Current I_{sh}

$I_{sh} = V/R_{sh}$

$I_{sh} = 250/125 = \mathbf{2A}$

2: To find the Armature Current I_a

$I_a = I_L - I_{sh}$

$I_a = 25 - 2 = \mathbf{23A}$

3: To find the Back EMF E_b

$E_b = V - I_a R_a$

$E_b = 250 - (23 \times 0.5) = \mathbf{238.5V}$

4: To find the Speed N

$$N = \frac{E_b\ 60\ A}{\Phi\ Z\ P}$$

$$N = \frac{238.5 \times 60 \times 2}{0.02 \times 300 \times 4} = \mathbf{1192\ RPM}$$

5: To find the Torque T_a

$$T_a = 0.159\ \Phi\ Z\ I_a \left(\frac{P}{A}\right)$$

$$T_a = 0.159 \times 0.02 \times 300 \times 23 \times \left(\frac{4}{2}\right) = \mathbf{43.88\ Nm}$$

6. c) With usual notations derive an emf equation of D.C. generator. (4 Marks)

Let Φ = flux/pole in Wb

Z = total number of armature conductors

P = number of poles

A = number of parallel paths = 2 ... for wave winding

= P ... for lap winding

N = speed of armature in r.p.m.

E_g = e.m.f. of the generator = e.m.f./parallel path

Flux cut by one conductor in one revolution of the armature, $d\Phi = \Phi P$ webers

Time taken to complete one revolution, $dt = 60/N$ second

E.M.F generated/conductor $= \frac{d\Phi}{dt} = \frac{\Phi P}{60/N} = \frac{\Phi PN}{60}$ volts

E.M.F. of generator,

E = e.m.f. per parallel path

= (e.m.f/conductor) × No. of conductors in series per parallel path

$$E = \frac{\Phi PN}{60} \times \frac{Z}{A} = \frac{\Phi ZNP}{60\ A}$$

$$\boxed{\therefore \mathbf{E = \frac{\Phi ZNP}{60\ A}}} \text{ volts}$$

For-wave winding, A = 2

$$\therefore E = \frac{\Phi ZNP}{120} \text{ volts}$$

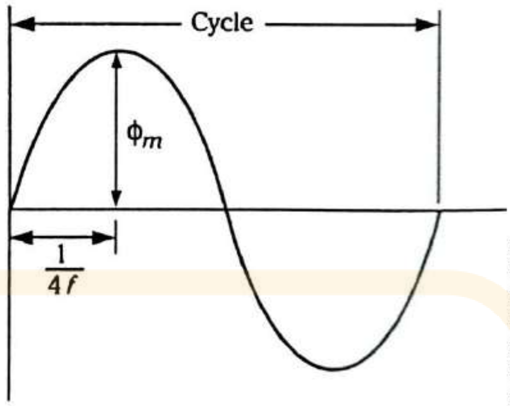
For-lap winding, A = P

$$\therefore E = \frac{\Phi ZN}{60} \text{ volts}$$

7. a) Derive the emf equation of a transformer and hence obtain the voltage and current transformation ratios. (8 Marks)

Let N_1, N_2 be the no of turns of the primary and secondary windings. E_1, E_2 be the induced emf in the primary and secondary coils. ϕ_m is maximum value of flux which is sinusoidal and f be the frequency in Hz.

The flux in the core will vary sinusoidally as shown in the fig, so that it increases from zero to maximum value ϕ_m in one quarter of the cycle i.e., $\frac{1}{4f}$ seconds



$\therefore$ Average rate of change of flux $= \frac{\phi_m}{\frac{1}{4f}} = 4\ f\ \phi_m$

Hence Average EMF induced / turn = $4\ f\ \phi_m$ volts

Since the flux is varying sinusoidally, the RMS value of induced EMF is obtained by multiplying the average value by the form factor.

$\therefore$ RMS value of EMF induced / turn = $1.11 \times 4\ f\ \phi_m$

$= 4.44\ f\ \phi_m$ volts

The RMS value of emf induced in the entire primary winding = (induced EMF/turn) × No of primary turns

$\therefore$ $\boxed{\mathbf{E_1 = 4.44\ f\ \phi_m\ N_1}}$

Similarly $\boxed{\mathbf{E_2 = 4.44\ f\ \phi_m\ N_2}}$ for secondary winding.

For an ideal transformer;

(i) $E_1 = V_1$ and $E_2 = V_2$ as there is no voltage drop in the windings.

$$\frac{E_2}{E_1} = \frac{V_2}{V_1} = \frac{N_2}{N_1} = K$$

(ii) There are no losses. Therefore, volt-amperes input to the primary are equal to the output volt-amperes i.e.

$$V_1 I_1 = V_2 I_2$$

$$\frac{V_2}{V_1} = \frac{I_1}{I_2} = K$$

or

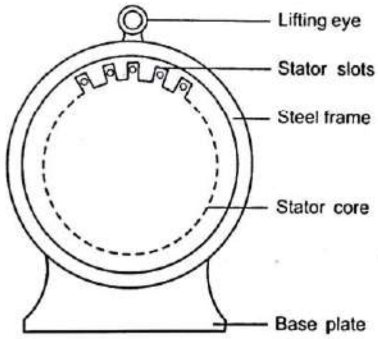
$$\boxed{\frac{E_2}{E_1} = \frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2} = K}$$

Hence, currents are in the inverse ratio of voltage transformation ratio. This simply means that if we raise the voltage, there is a corresponding decrease of current.

7. b) With neat diagram explain the types of three phase induction motor. (6 Marks)

A 3-phase induction motor has two main parts (i) *stator* and (ii) *rotor*. The rotor is separated from the stator by a small air-gap which ranges from 0.4 mm to 4 mm, depending on the power of the motor.

(i) STATOR:



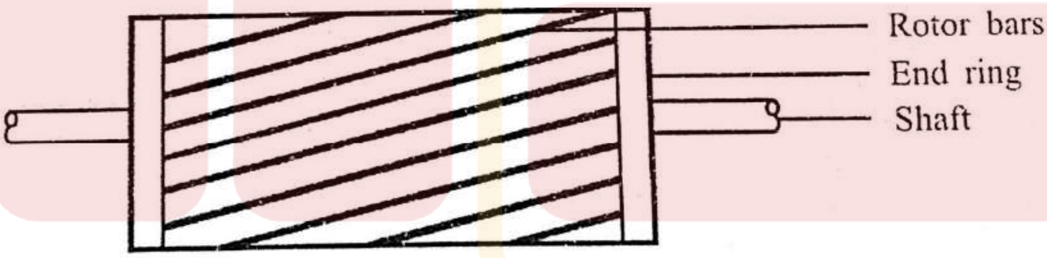
- It consists of a steel frame which encloses a hollow, cylindrical core made up of thin laminations of silicon steel to reduce hysteresis and eddy current losses.
- A number of evenly spaced slots are provided on the inner periphery of the laminations.
- The stator conductors are placed in these slots, which are insulated from one another and also from the slots are connected to form a balanced 3-phase star or delta circuit.
- The 3-phase stator winding is wound for a definite number of poles as per requirement of speed.
- Greater the number of poles, lesser is the speed of the motor and vice-versa.
- When 3-phase supply is given to the stator winding, a rotating magnetic field of constant magnitude is produced. This rotating field induces currents in the rotor by electromagnetic induction.

(ii) ROTOR:

The rotor, mounted on a shaft, is a hollow laminated core having slots on its outer periphery. The winding placed in these slots (called rotor winding) may be one of the following two types:

(i) *Squirrel cage type* (ii) *Wound type*

(a) Squirrel Cage Rotor:

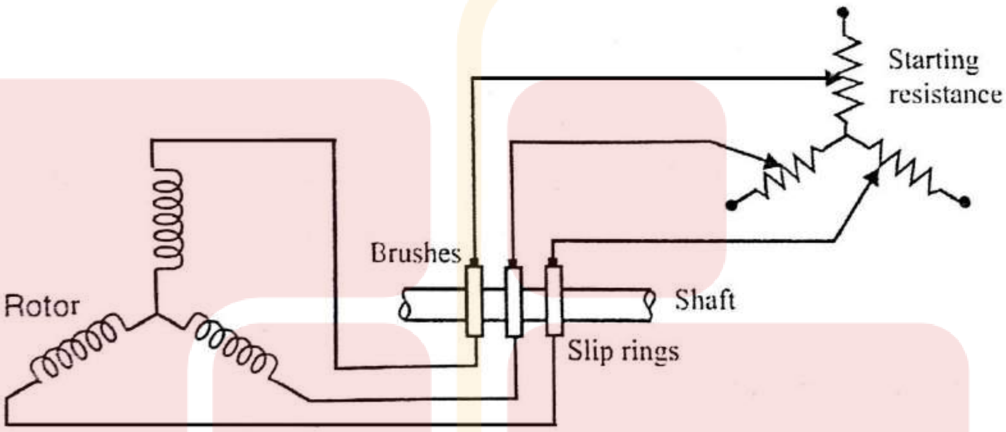


- It consists of a laminated cylindrical core having parallel slots on its outer periphery.
- One copper or aluminium bar is placed in each slot. All these bars are joined at each end by metal rings called end rings. This forms a permanently short-circuited winding which is indestructible.
- The entire construction (bars and end rings) resembles a squirrel cage and hence the name. Those induction motors which employ squirrel cage rotor are called squirrel cage induction motors.
- The rotor is not connected electrically to the supply but has current induced in it by transformer action from the stator.
- Most of 3-phase induction motors use squirrel cage rotor as it has a remarkably simple and robust construction.
- However, it suffers from the disadvantage of a low starting torque.
- It is because the rotor bars are permanently short-circuited and it is not possible to add any external resistance to the rotor circuit to have a large starting torque.

- The slots are slightly skewed, which helps in two ways: 1) It reduces the noise due to magnetic hum and makes the rotor to run quietly and 2) It reduces the locking tendency between the rotor and the stator.

(b) Wound Rotor:

- It consists of a laminated cylindrical core and carries a 3- phase winding, similar to the one on the stator.
- The rotor winding is uniformly distributed in the slots and is usually star-connected.
- The open ends of the rotor winding are brought out and joined to three insulated slip rings mounted on the rotor shaft with one brush resting on each slip ring.
- The three brushes are connected to a 3-phase star-connected rheostat as shown in Fig 3.
- At starting, the external resistances are included in the rotor circuit to give a large starting torque. These resistances are gradually reduced to zero as the motor runs up to speed.



7. c) A transformer is rated at 100 kVA. At full load its copper loss is 1200W and its iron loss is 960W. Calculate: i) the efficiency at full load, UPF ii) the efficiency at half load, 0.8 p.f. iii) the load kVA at which maximum efficiency will occur iv) maximum efficiency at 0.85 p.f. (6 Marks)

Given: Rating = 100×10^3 VA, P_i = 960W, P_c = 1200W

i) Efficiency at Full load, UPF

$$\text{Efficiency, } \eta = \frac{x \times \text{Full load VA} \times \text{p.f}}{x \times \text{Full load VA} \times \text{p.f} + P_i + x^2 P_c}$$

$$\eta_{FL,\,Upf} = \frac{1 \times 100\times10^3 \times 1}{1 \times 100\times10^3 \times 1 + 960 + [(1)^2 \times 1200]}$$

$\eta_{FL,\,Upf}$ = **0.9788** or **97.88%**

ii) Efficiency at Half Full load, 0.8 PF

$$\text{Efficiency, } \eta = \frac{x \times \text{Full load VA} \times \text{p.f}}{x \times \text{Full load VA} \times \text{p.f} + P_i + x^2 P_c}$$

$$\eta_{\frac{1}{2}FL,\,Upf} = \frac{\frac{1}{2}\times 100\times10^3 \times 0.8}{\frac{1}{2}\times 100\times10^3 \times 0.8 + 960 + \left[\left(\frac{1}{2}\right)^2 \times 1200\right]}$$

$\eta_{\frac{1}{2}FL,\,Upf}$ = **0.9694** or **96.94%**

iii) Load for Maximum efficiency

$$\text{Load for Maximum efficiency} = \text{Full load VA} \times \sqrt{\frac{P_i}{P_c}}$$

$$\text{Load for Maximum efficiency} = 100\times10^3 \times \sqrt{\frac{960}{1200}} = \mathbf{89.44\times10^3\ VA = 89.44kVA}$$

iv) Maximum efficiency at 0.85PF

At Maximum Efficiency, Core loss = Copper loss

At Maximum Efficiency, $P_i = x^2 P_c$

$$x = \sqrt{\frac{P_i}{P_c}} = \sqrt{\frac{960}{1200}} = 0.8944$$

$$\text{Efficiency, } \eta = \frac{x \times \text{Full load VA} \times p.f}{x \times \text{Full load VA} \times p.f + P_i + P_i}$$

$$\text{Max } \eta_{0.85\,pf} = \frac{0.8944 \times 100\times10^3 \times 0.85}{0.8944 \times 100\times10^3 \times 0.85 + 960 + 960}$$

Max $\eta_{0.85\,pf}$ = **0.9753** or **97.53%**

OR

$$\text{Max } \eta_{0.85\,pf} = \frac{89.44\times10^3 \times 0.85}{89.44\times10^3 \times 0.85 + 960 + 960} \quad \text{...(Alternative method)}$$

Max $\eta_{0.85\,pf}$ = **0.9753** or **97.53%**

8. a) Explain the various losses in a transformer and how to minimize them? (8 Marks)

The power losses in a transformer are of two types, namely;

1. Core or Iron losses 2. Copper losses

These losses appear in the form of heat and produce (i) an increase in temperature and (ii) a drop in efficiency.

1. CORE OR IRON LOSSES (P_i):

These consist of hysteresis and eddy current losses and occur in the transformer core due to the alternating flux. These can be determined by open-circuit test.

$$\text{Hysteresis loss, } = k_h\ f\ B_m^{1.6} \quad \text{watts}/m^3$$

$$\text{Eddy current loss, } = k_e\ f^2\ B_m^2 t^2 \quad \text{watts}/m^3$$

Both hysteresis and eddy current losses depend upon (i) maximum flux density B_m in the core and (ii) supply frequency f. Since transformers are connected to constant-frequency, constant voltage supply, both f and B_m are constant. Hence, core or iron losses are practically the same at all loads.

Iron or Core losses, P_i = Hysteresis loss + Eddy current loss

= Constant losses

The hysteresis loss can be minimized by using steel of high silicon content whereas eddy current loss can be reduced by using core of thin laminations.

2. COPPER LOSSES (P_C):

These losses occur in both the primary and secondary windings due to their ohmic resistance. These can be determined by short-circuit test.

$$\text{Total Cu losses, } P_C = I_1^2R_1 + I_2^2R_2$$
$$= I_1^2R_{01} \text{ or } I_2^2R_{02}$$

It is clear that copper losses vary as the square of load current Thus if copper losses are 400 W at a load current of 10 A, then they will be $(1/2)^2 \times 400 = 100$ W at a load current of 5A.

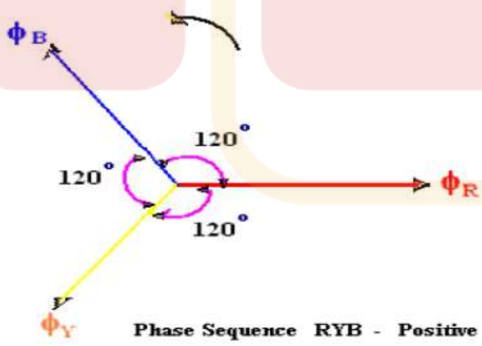
Total losses in a transformer = $P_i + P_C$

= Constant losses + Variable losses

It may be noted that in a transformer, copper losses account for about 90% of the total losses.

8. b) With diagrams explain the concept of rotating magnetic field. (6 Marks)

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 not 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 field. It can be shown that magnitude of this rotating field is constant and is equal to 1.5 ϕ_m where ϕ_m is the maximum flux due to any phase.



The corresponding phase fluxes can be represented by the following equations:

$\phi_R = \phi_m \sin \omega t = \phi_m \sin \theta$

$\phi_Y = \phi_m \sin (\omega t\text{-}120^\circ) = \phi_m \sin (\theta\text{-}120^\circ)$

$\phi_B = \phi_m \sin (\omega t\text{-}240^\circ) = \phi_m \sin (\theta\text{-}240^\circ)$

The resultant flux at any instant is given by the vector sum of the flux in each of the phases.

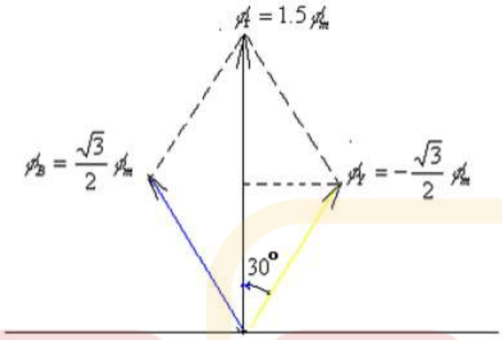
(i) When θ =0º, from the flux waveform diagram, we have

$\phi_R = \phi_m \sin 0 = 0$

$\phi_Y = \phi_m \sin (0\text{-}120^\circ) = -\frac{\sqrt{3}}{2}\phi_m$

$\phi_B = \phi_m \sin (0\text{-}240^\circ) = \frac{\sqrt{3}}{2}\phi_m$

$\phi_r = 2 \times \frac{\sqrt{3}}{2}\phi_m \cos (30^\circ) = 1.5\ \phi_m$



Resultant flux at θ = 0°

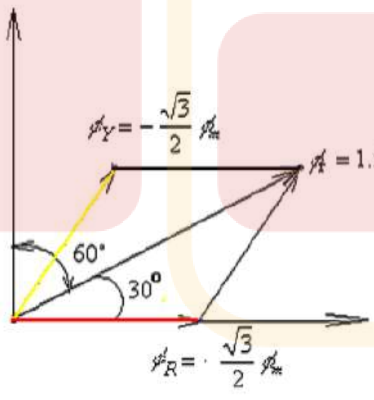
(ii) When θ =60º, from the flux waveform diagram, we have

$\phi_R = \phi_m \sin 60^\circ = \frac{\sqrt{3}}{2}\phi_m$

$\phi_Y = \phi_m \sin (60^\circ\text{-}120^\circ) = -\frac{\sqrt{3}}{2}\phi_m$

$\phi_B = \phi_m \sin (60^\circ\text{-}240^\circ) = 0$

$\phi_r = 2 \times \frac{\sqrt{3}}{2}\phi_m \cos (30^\circ) = 1.5\ \phi_m$



Resultant flux at θ = 60°

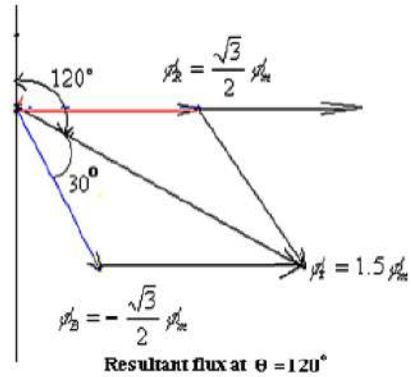
(iii) When θ =120º, from the flux waveform diagram, we have

$\phi_R = \phi_m \sin 120^\circ = \frac{\sqrt{3}}{2}\phi_m$

$\phi_Y = \phi_m \sin (120^\circ\text{-}120^\circ) = 0$

$\phi_B = \phi_m \sin (120^\circ\text{-}240^\circ) = -\frac{\sqrt{3}}{2}\phi_m$

$\phi_r = 2 \times \frac{\sqrt{3}}{2}\phi_m \cos (30^\circ) = 1.5\ \phi_m$



Resultant flux at θ = 120°

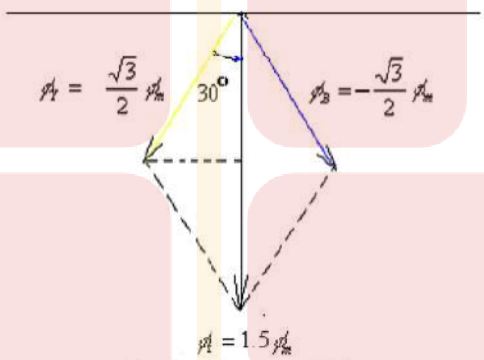
(iv) When θ =180°, from the flux waveform diagram, we have

$\phi_R = \phi_m \sin 180° = 0$

$\phi_Y = \phi_m \sin (180°\text{-}120°) = \frac{\sqrt{3}}{2}\phi_m$

$\phi_B = \phi_m \sin (180°\text{-}240°) = -\frac{\sqrt{3}}{2}\phi_m$

$\phi_r = 2 \times \frac{\sqrt{3}}{2}\phi_m \cos (30°) = 1.5\ \phi_m$



Resultant flux at θ = 180°

8. c) A three phase induction motor with 4 poles is supplied from the alternator having 6 poles running at 1000rpm. Calculate synchronous speed, rotor speed of the induction motor when slip is 0.04 and frequency of the rotor emf when the speed is 600rpm. (8 Marks)

Given: P = 4, P_a = 6, N_a = 1000 RPM, s = 0.04

1: To find the frequency (f):

$f = \frac{P_a N_a}{120}$

$f = \frac{6 \times 1000}{120} =$ **50 Hz**

2: To find the synchronous speed (N_s):

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

$N_s = \frac{120 \times 50}{4} =$ **1500 RPM**

3: To find the Rotor Speed at s = 0.04:

Slip, $s = \frac{N_S - N}{N_S}$

$0.04 = \frac{1500 - N}{1500}$

$N = 1500 - (0.04 \times 1500) =$ **1440 RPM**

4: To find the Rotor frequency (f_r) at N = 600rpm:

Slip, $s = \frac{N_S - N}{N_S} = \frac{1500 - 600}{1500} =$ **0.6**

$f_r = s \times f$

$f_r = 0.6 \times 50 =$ **30 Hz**

9. a) With neat circuit diagram and switching table explain two way and three way control of load. (8 Marks)

TWO WAY CONTROL LAMP:

The lamp circuits used for house wiring are quite simple and they are generally controlled from one point, such as room lighting, bath room lighting etc., but in stair case wiring, it is necessary to control the lamp circuit from points i, e. one at the top of the stair case and other at the bottom of the stair case. Similarly in big halls, corridors or bedrooms, it may be necessary to control the lamps from two points. In such cases, a two way control lamp circuit is used for wiring.

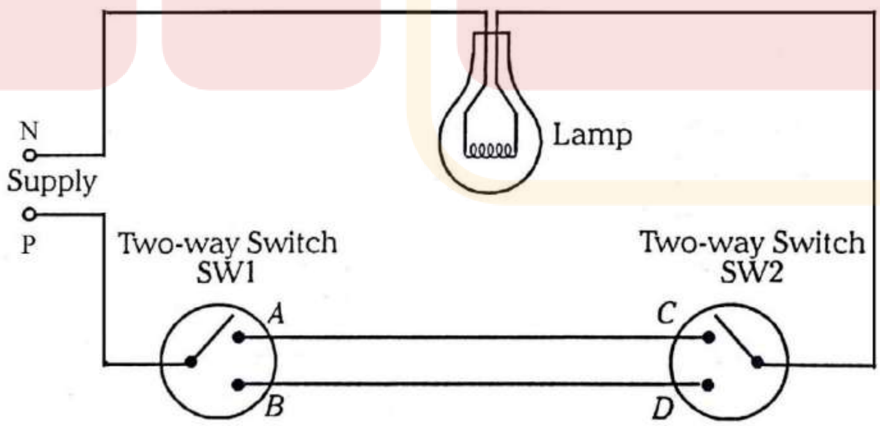


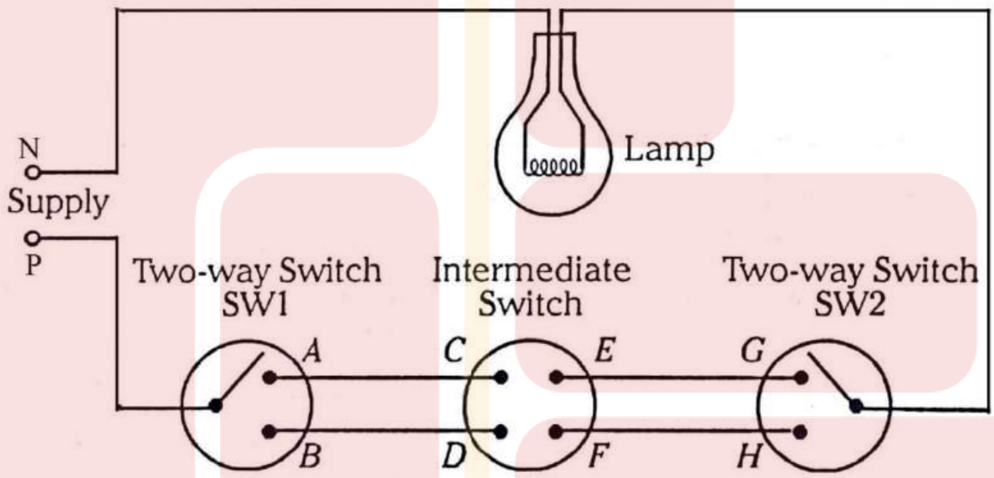
Figure shows the way in which the connections are made to control a lamp from two points. Two, two-way switches are used. The wires used between the switches are called strap wires.

For the different positions of the switches, i, e. say when switch 1 is in position A and the switch 2 is in position D, the lamp circuit is not closed and hence the lamp is dark. Let us say that the switch 1 is in the down stairs and switch 2 is in the upstairs. When switch 1 is changed to position B, the lamp circuits is closed and hence the lamp glows. Walking on to the upstairs, if the switch 2 is changed to position c, again the circuit continuity is broken and the lamps is switched off. Thus, the lamp can be controlled from two points. The same switching operations may be repeated while coming down stairs. Table below gives the positions of switches and the lamp conditions, whether it is ON or OFF.

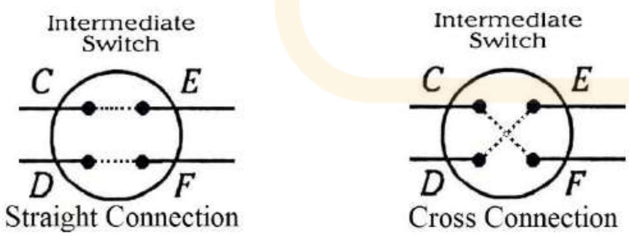
S. NO	POSITION OF SWITCH 1	POSITION OF SWITCH 2	LAMP ON / OFF
1	A	D	OFF
2	B	D	ON
3	B	C	OFF
4	A	C	ON

THREE WAY CONTROL LAMP:

Some times in very big corridors, godowns or workshops, it may be necessary to control a lamp from three points, in such cases, the circuits connection requires two, two-way switches and an intermediate switch as shown in fig below.



An intermediate switch is a connection of two, two-way switches coupled together. It has four terminals CDEF. For one position, it connects points CE and DF, which is called ***straight connection***. For another position, it connects points CF and DE, which is called ***cross connection***.



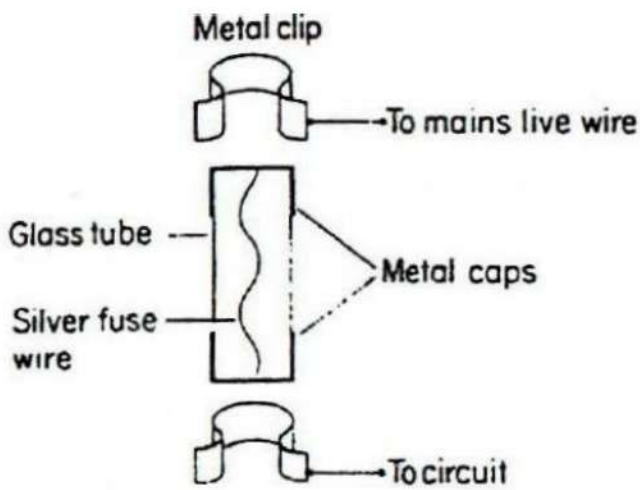
When the switches 1 and 2 are in positions A and G respectively, and the intermediate switch is in the position of straight connection, i.e., when CE and DF are connected, the lamp circuit is complete and hence the lamp glows. Now, if the intermediate switch is changed to the position of cross connection i.e., when points CF and DE are connected, the lamp circuit is open and hence the lamp is switched OFF. Now if the position of switch 2 is changed from G to H, the lamp circuit is again closed and the lamp is switched ON. Thus, the lamp can be controlled from three points. Table below gives the positions of the various switches and the conditions of lamps.

S.NO	CONNECTION	POSITION OF SWITCH 1	POSITION OF INTERMEDIATE SWITCH	POSITION OF SWITCH 2	LAMP ON / OFF
1	STRAIGHT	A	CE, DF	G	ON
2		A	CE, DF	H	OFF
3		B	CE, DF	G	OFF
4		B	CE, DF	H	ON
5	CROSS	A	CF, DE	G	OFF
6		A	CF, DE	H	ON
7		B	CF, DE	G	ON
8		B	CF, DE	H	OFF

9. b) With diagram explain the working of fuse. (6 Marks)

The fuses was first invented by Thomas Alva Edison in 1980 and is the weakest link in an electrical circuit. A fuse is essentially a small piece of metal connected between two terminals mounted on an insulating base in series with the circuit. The function of the fuse wire is to carry the normal working current safely without heating, but when the normal working current is exceeded, it should heat up rapidly to the melting point and break the circuit. ***Hence fuse is the simplest protective device used in an electrical circuit against overloading or faults.*** The heat produced is given by $H=I^2Rt$. Hence, the material used as a fuse wire must have high resistivity and low melting point so that the wire reaches the melting point in shortest possible time. It should be free from oxidation and should be non-deteriorating. The various materials that can be used as fuse wire are tin, lead, zinc, silver, aluminium, copper and their alloys.

Silver has been found to be quite satisfactory material as fuse wire as it is not subjected to oxidation, as its oxide is unstable. It does not deteriorate in dry air and remains bright. The only drawback is that it is costly, normally an alloy of tin and lead is used as an ordinary fuse wire.



As shown in fig above, the most common type of fuse is the cartridge in which the fusible element is made of silver wire and runs between metal caps, through a tube of glass or other suitable non-inflammable insulating material. It is held in position by metal contact clips. The whole tube is replaced when necessary.

CHARACTERISTICS OF FUSE MATERIAL:

1. Low melting point
2. Low ohmic losses
3. High conductivity
4. Lower rate of deterioration

TERMS RELATED WITH FUSES:

1. ***Minimum fusing current:*** It is the minimum value of current at which it melts.
2. ***Current rating of the fusing element:*** It is the value of the current which the fuse can carry without melting.
3. ***Fusing Factor:*** The fusing factor of a fuse is defined as the ratio of the minimum fusing current to the current rating of the fuse element. The value of fusing factor is always more than 1.

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

9. c) What is earthing? With neat diagram explain the pipe earthing. (6 Marks)

Earthing or Grounding is to connect the body of an electrical apparatus to the general mass of the earth by a wire of negligible resistance.

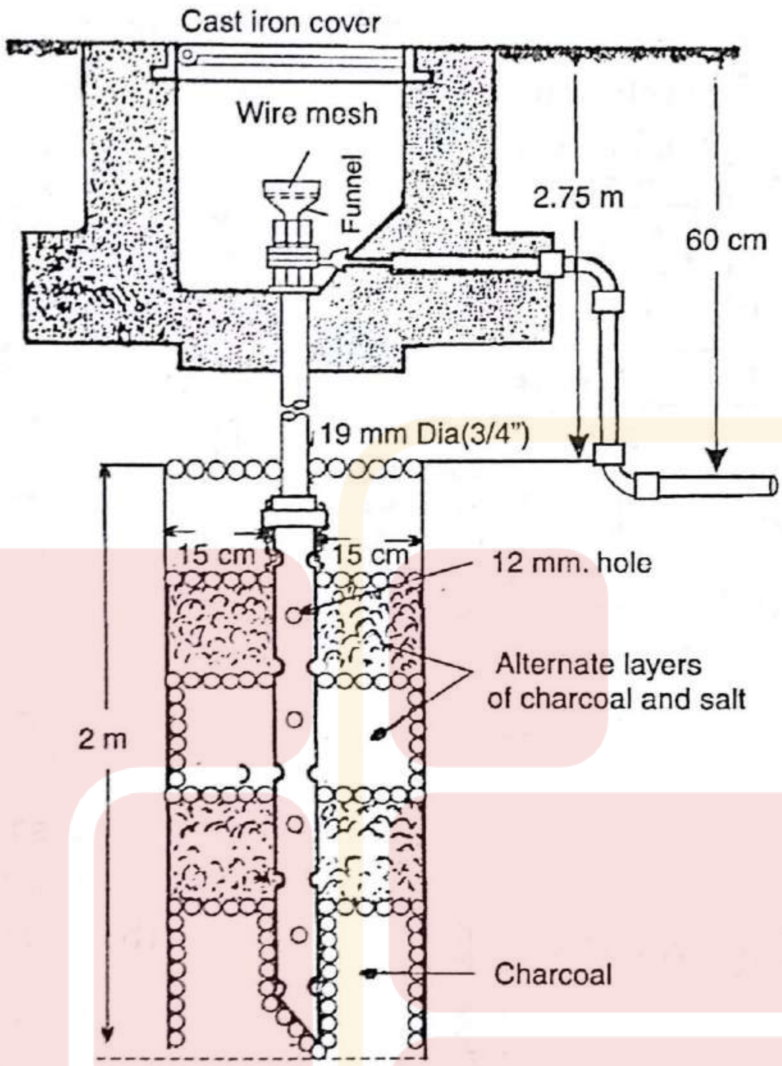
NECESSITY OF EARTHING:

1. To protect the operating personnel from danger of shock in case they come in contact with the charged frame due to defective insulation.
2. To maintain the line voltage constant under unbalanced load condition.
3. Protection of the equipments.
4. Protection of large buildings and all machines fed from overhead lines against lightning.

PIPE EARTHING:

Earth electrode made of a GI (galvanized) iron pipe of 38mm in diameter and length of 2m (depending on the current) with 12mm holes on the surface is placed upright at a depth of 4.75m in a permanently wet ground. To keep the value of the earth resistance at the desired level, the area (15 cms) surrounding the GI pipe is filled with a mixture of salt and coal. The efficiency of the earthing system is improved by pouring water through the funnel periodically. The GI earth wires of sufficient cross- sectional area are run through a 12.7mm diameter pipe (at 60cms below) from the 19mm diameter pipe and secured tightly at the top as shown in the following figure.

When compared to the plate earth system the pipe earth system can carry larger leakage currents as a much larger surface area is in contact with the soil for a given electrode size. The system also enables easy maintenance as the earth wire connection is housed at the ground level.



10. a) Define "unit" used for consumption of electrical energy and explain the two part tariff with its advantages and disadvantages. (6 Marks)

Unit of electrical energy:

If power is expressed in kilowatts and time in hours, then unit of electrical energy will be kilowatt-hour (kWh)

Energy in kWh = Power in kW × Time in hours

It may be pointed out here that in practice, electrical energy is measured in kilowatt-hours (kWh). Therefore, it is profitable to define it.

One kilowatt-hour (kWh) of electrical energy is expended in a circuit if 1 kW (1000 watts) of power is supplied for 1 hour.

The electricity bills are made on the basis of total electrical energy consumed by the consumer. The unit for charge of electricity is 1 kWh. One kWh is also called Board of Trade (B.O.T.) unit or simply unit. Thus when we say that a consumer has consumed 100 units of electricity, it means that electrical energy consumption is 100 kWh.

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 maximum demand of the consumer and the units consumed, it is called a two-part tariff.

In two-part tariff, the total charge to be made from the consumer is split into two components viz., fixed charges and running charges. The fixed charges depend upon the maximum demand of the consumer while the running charges depend upon the number 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 kWh of energy consumed

$$\boxed{\textbf{Total charges} = \textbf{Rs}\ (a \times \textbf{kW} + b \times \textbf{kWh})}$$

Where, a = charge per kW of maximum demand

b = charge per kWh of energy consumed

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

ADVANTAGES:

1. It is easily understood by the consumers.
2. It recovers the fixed charges which depend upon the maximum demand of the consumer but are independent of the units consumed.

DISADVANTAGES:

1. The consumer has to pay the fixed charges irrespective of the fact whether he has consumed or not consumed the electrical energy.
2. There is always error in assessing the maximum demand of the consumer.

10. b) What is electric shock? Give the list of preventive measures against the shock. (8 Marks)

Electric shock is a sudden stimulation of the nervous system of human body by flow of current through a part of the body.

The following precautions may be taken to prevent persons from getting shocks in the homes.

1. Care must be taken to see that ground points are provided to all the sockets to which electrical appliances are connected.
2. Proper earthing has to be provided and periodically the earthing resistance has to be checked to see that it does not exceed 3 to 5 ohms.
3. Install Ground Fault Circuit Interrupts (GFCIs) in wall outlets located in bath room, kitchen, basement, garages and outdoor boxes.
4. Cover all electrical sockets with plastic safety caps.
5. Never use an electrical appliance like a radio or an iron near water.
6. Do not touch electrical appliances and switches with wet hands.
7. Operators should use insulated tools and gloves.
8. Use footwear while operating the electrical equipment in order to avoid earthing through the body of the operator.
9. Metal parts of the electrical gadgets and equipment should be properly earthed.
10. Replace worn out electrical cords/wires and cables.

10. c) List out the power rating of household appliances including air conditioners, PCs, laptops, printers, etc. Find the total power consumed.(6 M)

Power ratings of appliances used at home are always mentioned on the product. Typical power rating (in watt) of some of the appliances are given in Table. But one should try to get the actual power rating or what is called the 'name-plate rating' of the appliances.

Name of the appliances	**Range of available power rating (in watts)**
Incandescent light (bulb)	5 to 100
Tube light	30 to 50
Compact fluorescent lamp (CFL)	3 to 30
Ceiling fan	30 to 70
Air conditioner (room)	1000 to 1500
Air conditioner (central)	2000 to 5000
CD player	15 to 30
TV	60 to 300
Laptop	50 to 75
Desktop computer	80 to 200
Printer	100 to 250
Washing machine	500 to 1000
Refrigerator	50 to 300

SAMPLE CALCULATION

Name of appliances	**Power rating (in watts)**	**Number of appliances (in numbers)**	**Total Power rating (watts)**
	a	***b***	***c = a×b***
CFL	12	3	36
Fan	50	2	100
TV	150	1	150
Laptop	75	1	75
Printer	100	1	100
Computer	200	1	200
AC	1000	1	1000
TOTAL			**1661**

Note: Remember some values. Calculation can be done as per your values.