1. Back emf E_b of a DC motor is nothing but the induced emf in armature conductors due to rotation of the armature in magnetic field. Thus, the magnitude of E_b can be given by EMF equation of a DC generator.

$E_b = PØNZ/60A$

(where, P = no. of poles, Ø = flux/pole, N = speed in rpm, Z = no. of armature conductors, A = parallel paths)

E_b can also be given as,

$E_b = V - I_aR_a$

thus, from the above equations

$N = E_b\,60A/PØZ$

but, for a DC motor A, P and Z are constants

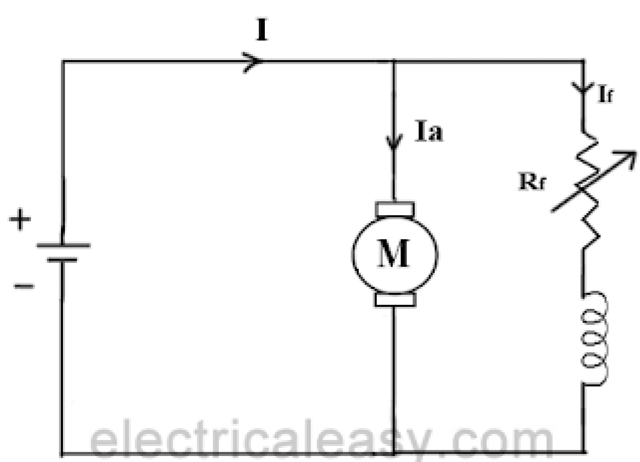
Therefore, $N \propto K\, E_b/Ø$ (where, K=constant)

This shows the **speed of a dc motor** is directly proportional to the back emf and inversely proportional to the flux per pole.

Speed Control Methods Of DC Motor

Speed Control Of Shunt Motor

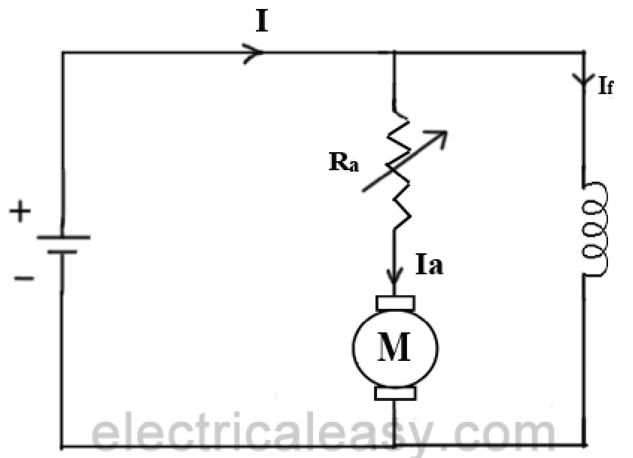
1. Flux Control Method



It is already explained above that the **speed of a dc motor** is inversely proportional to the flux per pole. Thus by decreasing the flux, speed can be increased and vice versa.

To control the flux, a rheostat is added in series with the field winding, as shown in the circuit diagram. Adding more resistance in series with the field winding will increase the speed as it decreases the flux. In shunt motors, as field current is relatively very small, I_{sh}^2R loss is small. Therefore, this method is quite efficient. Though speed can be increased above the rated value by reducing flux with this method, it puts a limit to maximum speed as weakening of field flux beyond a limit will adversely affect the commutation.

2. Armature Control Method



Speed of a dc motor is directly proportional to the back emf E_b and $E_b = V - I_aR_a$. That means, when supply voltage V and the armature resistance R_a are kept constant, then the speed is directly proportional to armature current I_a. Thus, if we add resistance in series with the armature, I_a decreases and, hence, the speed also decreases. Greater the resistance in series with the armature, greater the decrease in speed.

3. Voltage Control Method

a) **Multiple voltage control**:
In this method, the shunt field is connected to a fixed exciting voltage and armature is supplied with different voltages. Voltage across armature is changed with the help of suitable switchgear. The speed is approximately proportional to the voltage across the armature.

2.Torque and Armature Current Characteristics

It is the graph plotted between the armature torque (τ_a) and the armature current (I_a) of a DC motor. It is also known as electrical characteristics of the DC motor.

Speed and Armature Current Characteristics

It is the graph plotted between the speed (N) and the armature current (I_a) of a DC motor. This characteristic curve is mainly used for selecting a motor for a particular application.

Speed and Torque Characteristics

The graph plotted between the speed (N) and the armature torque (τ_a) for a DC motor is known as the speed-torque characteristics. It is also known as mechanical characteristics of DC motor.

Characteristics of DC Shunt Motor

The shunt motors are the constant flux machines i.e. their magnetic flux remains constant because their field winding is directly connected across the supply voltage which is assumed to be constant.

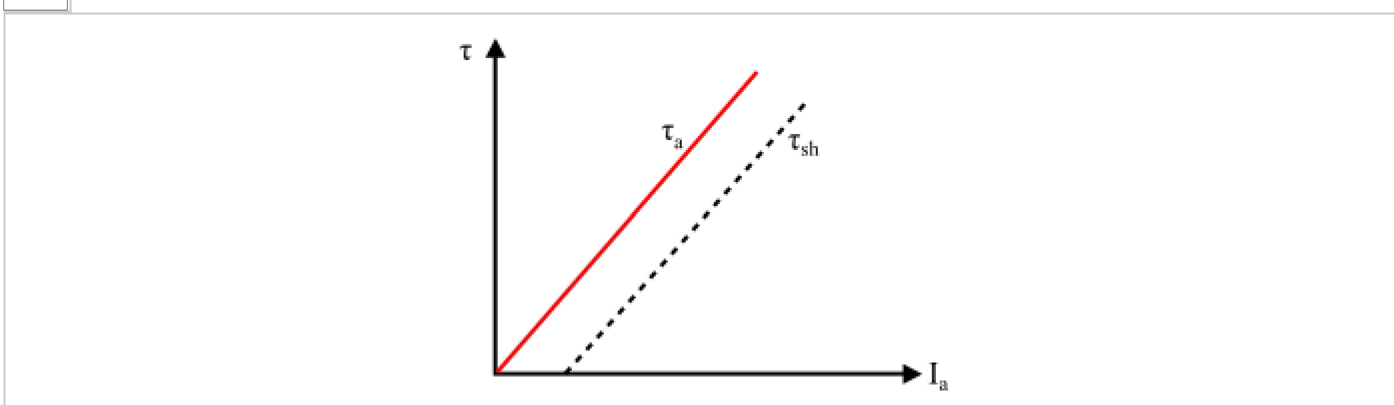
Torque and Armature Current Characteristics

The armature torque in a DC motor is directly proportional to the flux and the armature current, i.e.,

$\tau a \propto \varphi Ia$�a∝�Ia

In case of a shunt motor, the flux is also constant. Therefore,

$\tau a \propto Ia$�a∝Ia



Hence, the torque and armature current characteristics of DC shunt motor is straight line passing through the origin (see the figure). The shaft torque is less than the armature torque which is represented by the dotted line.

From the characteristics, it can be seen that a very large current is required to start a heavy load. Thus, the shunt motor should not be started on heavy loads.

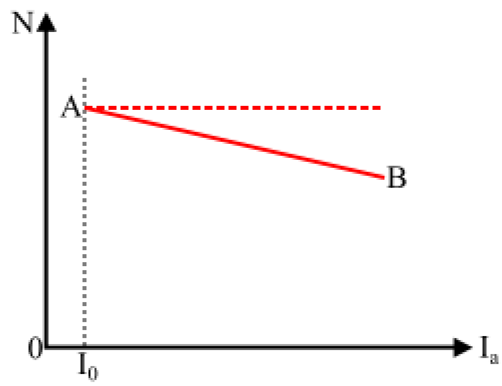
Speed and Armature Current Characteristics

The Speed of a shunt DC motor is given by,

$N \propto E_b N \propto E_b$

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

$\therefore N \propto (V - I_a R_a) \therefore N \propto (V - I_a R_a)$



For a DC shunt motor, the back EMF and flux both are constant under normal operating conditions. Therefore, the speed of a shunt motor will remain constant with respect to armature current as shown by dotted line.

However, when the load is increased, the back EMF and flux decreases due to the drop in armature resistance and armature reaction respectively. Although the back EMF decreases somewhat greater than the flux so that speed of motor decreases slight with the increase in load (as line AB).

Speed and Torque Characteristics

This is the curve plotted between the speed and the torque for various armature currents. It can be seen that the speed of the shunt motor decreases as the load torque increases.

Characteristics of DC Series Motor

In a DC series motor, the field winding is connected in series with the armature and hence carries the full armature current. When the load on shaft of the motor is increased, the armature current also increases. Hence, the flux in a series motor increases with the increase in the armature current and vice-versa.

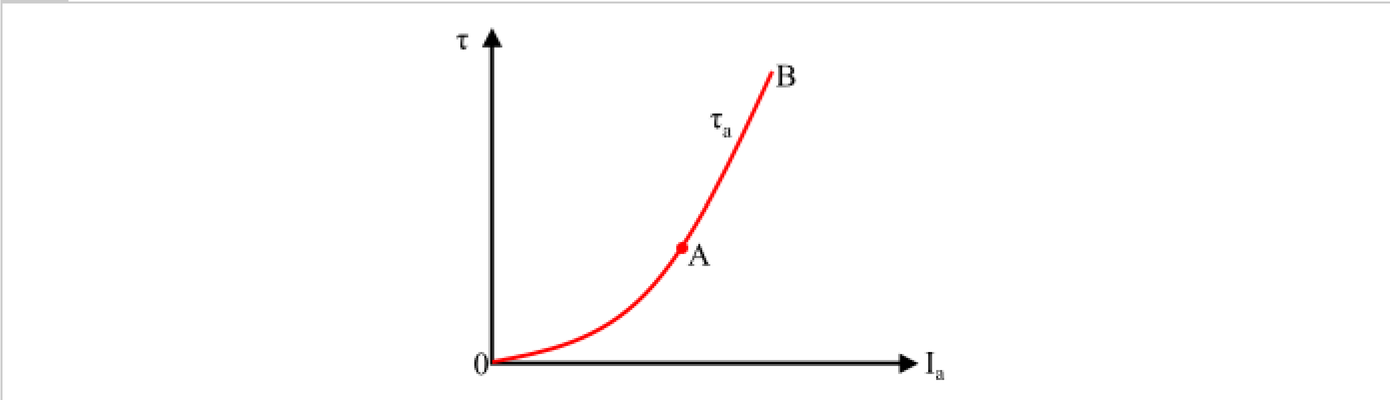
Torque and Armature Current Characteristics

In a DC motor,

$\tau_a \propto \varphi I_a$ �a∝�Ia

Up to magnetic saturation, $\varphi \propto I_a$; so that $\tau_a \propto I_a^2$ Uptomagneticsaturation,�∝Ia;sothat�a∝Ia2

After magnetic saturation, φ becomes constant so that, $\tau_a \propto I_a$ Aftermagneticsaturation,φbecomesconstantsothat,�a∝Ia



Therefore, up to magnetic saturation, the armature torque is directly proportional to the square of the armature current. Hence, the torque versus armature current curve upto magnetic saturation is a parabola (part OA of the curve).

After the magnetic saturation, the armature torque is directly proportional to the armature current. Hence, torque versus armature current curve after magnetic saturation is a straight line (Part AB of the curve).

From the torque versus armature current curve, it is clear that the starting torque of a DC series motor is very high.

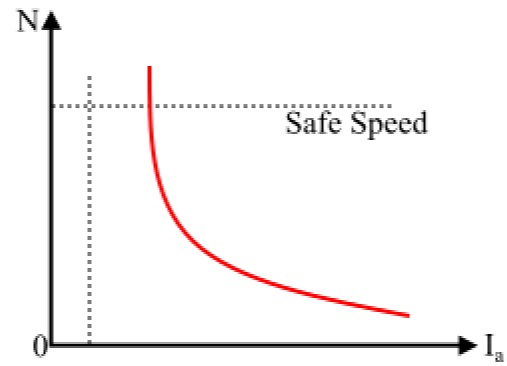
Speed and Armature Current Characteristics

The speed of a DC series motor is given by,

$$N \propto \frac{E_b}{\varphi}; \text{Where, } E_b = V - I_a(R_a + R_{se})$$

With the increase in the armature current, the back EMF is decreased due to the ohmic drop in armature and series field resistances whereas the flux is increased. Although, the resistance drop is very small under normal operating conditions and can be neglected, thus,

$$N \propto \frac{1}{\varphi} \propto \frac{1}{I_a}; \text{Upto magnetic saturation.}$$



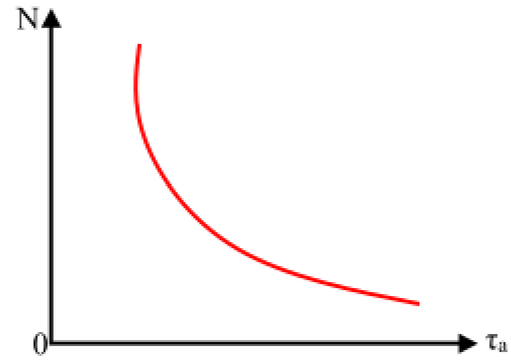
Hence, up to magnetic saturation the speed versus armature current curve is a hyperbola while after the magnetic saturation, the flux becomes constant and hence the speed

Speed and Torque Characteristics

The speed torque characteristics of a DC series motor can be obtained from its speed-armature current and torque-armature current characteristics as follows

For a given value of I_a determine τ_a from the torque-armature current curve and N from the speed-armature current curve. This will give a point (τ, N) on speed-torque curve. Repeat this procedure for different values of armature current and determine the corresponding values of speed and torque (τ_1, N_1), (τ_2, N_2) etc.

When these points are plotted on the graph, we obtain the speed and torque characteristics of a DC series motor as shown in the figure.



It is clear from the characteristics that the series motor has high torque at low speed and vice-versa. Thus, the series DC motor is used where high starting torque is required.

Important – At no-load, the armature current is very small and so is the flux. Hence, the speed increases to a dangerously high value which can damage the machine. Therefore, a series motor should never be started on no-load.

3 a

House hold appliances

		Power consumer		for 1month
i) Air Conditioner	–	1.3 KW		$= 1.3 \times 10 \times 30$ (days) $= 390$ KWh
ii) TV	–	90W	$= 0.09$ KW	$= 0.09 \times 12 \times 30 = 32.4$ KWh
iii) Ceiling fan (2)	–	80W	$= 0.08$ KW	$= 0.08 \times 10 \times 30 \times 2$ = 48 KWh
iv) Water pump	–	1.5hP	$= 1.5 \times 746 \times 10^{-3} = 1.119$ KW	$= 1.11 \times 1 \times 30 = 33.57$ KWh
v) led lamp (8)	–	9W	$= 0.009$ KW	$= 0.009 \times 24 \times 30 \times 8 = 51.84$ KWh
vi) iron box	–	1100W	$= 1.1$ KW	$= 1.1 \times 1 \times 30 = 33$ KWh
vii) Printer	–	375W	$= 0.375$ KW	$= 0.375 \times 1 \times 30 = 11.25$ KWh
viii) Refrigerator	–	380W	$= 0.38$ KW	$= 0.38 \times 24 \times 30 = 273.6$ KWh

Considering this load conditions. electricity bill is

Considering this load conditions. electricity bill is Calculated as follows.

Considering 1unit = 3rs

Total Kwh = 390 + 32.4 + 48 + 33.57 + 51.84 + 33 + 11.25 + 273.6

= 873.66 Kwh

so, 873.66 units

So, Total tariff per month = 873.66 * 3

= Rs2,620.98

3 b) Write a short note on MCB and Fuse

An electrical fuse is a safety device that operates to provide protection against the overflow of current in an electrical circuit. An important component of an electrical fuse is a metal wire or strip that melts when excess current flows through it. It helps to protect the device by stopping or interrupting the current.

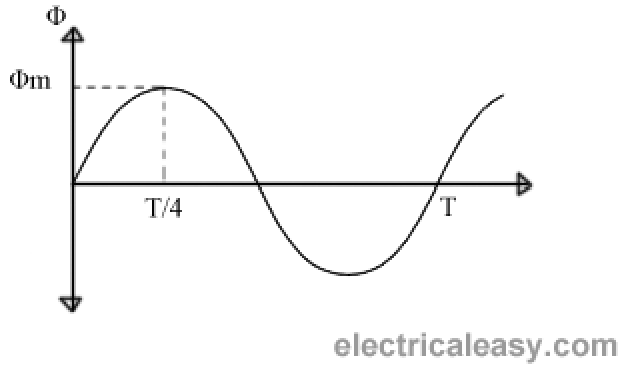
A Miniature Circuit Breaker (MCB) is an automatically operated electrical switch used to protect low voltage electrical circuits from damage caused by excess current from an overload or short circuit. MCBs are typically rated up to a current up to 125 A, do not have adjustable trip characteristics, and can be thermal or thermal-magnetic in operation

Construction : MCB • Miniature circuit breaker construction is very simple, robust and maintenance-free. Generally, an MCB is not repaired or maintained, it just replaced by a new one when required. A miniature circuit breaker has normally three main constructional parts. These are: 1. Frame of Miniature Circuit Breaker • The frame of a miniature circuit breaker is a molded case. This is a rigid, strong, insulated housing in which the other components are mounted.

2. Operating Mechanism of Miniature Circuit Breaker • The operating mechanism of a miniature circuit breaker provides the means of manual opening and closing operation of a miniature circuit breaker. It has three-positions “ON,” “OFF,” and “TRIPPED”. The external switching latch can be in the “TRIPPED” position if the MCB is tripped due to over-current. • When manually switch off the MCB, the switching latch will be in the “OFF” position. In the closed condition of an MCB, the switch is positioned at “ON”. By observing the positions of the switching latch one can determine the condition of MCB whether it is closed, tripped or manually switched off.

3. Trip Unit of Miniature Circuit Breaker The trip unit is the main part, responsible for the proper working of the miniature circuit breaker. Two main types of trip mechanisms are provided in MCB. A bimetal provides protection against overload current and an electromagnet provides protection against short-circuit current.

4. EMF Equation of transformer:
EMF Equation Of The Transformer
Let,
N1 = Number of turns in primary winding
N2 = Number of turns in secondary winding
Φm = Maximum flux in the core (in Wb) = (Bm x A)
f = frequency of the AC supply (in Hz)



As, shown in the fig., the flux rises sinusoidally to its maximum value Φm from 0. It reaches to the maximum value in one quarter of the cycle i.e in T/4 sec (where, T is time period of the sin wave of the supply = 1/f).
Therefore,
average rate of change of flux = Φm /(T/4)   = Φm /(1/4f)
Therefore,
average rate of change of flux = 4f Φm   .... (Wb/s).
Now,
Induced emf per turn = rate of change of flux per turn

Therefore, average emf per turn = 4f Φm   ....(Volts).
Now, we know, Form factor = RMS value / average value
Therefore, RMS value of emf per turn = Form factor X average emf per turn.

As, the flux Φ varies sinusoidally, form factor of a sine wave is 1.11

Therefore, RMS value of emf per turn = 1.11 x 4f Φm = 4.44f Φm.

4 b) A 250KVA single phase transformer has 98.135% efficiency at full load and 0.8 lagging power factor. The efficiency at half load and 0.8 lagging power factor is 97.75%. Calculate full load iron loss and copper loss.

4 b) 250 kVA, $\eta_1 = 0.98135$, $x = 1$, $\cos\phi = 0.8$

$\eta_2 = 0.9775$, $x = 0.5$, $\cos\phi = 0.8$

W_i and W_{cu} = ?

$$\eta = \frac{x V_2 I_2 \cos\phi}{x V_2 I_2 \cos\phi + x^2 W_{cu} + W_i}$$

i)

$$0.98135 = \frac{250 \times 10^3 \times 0.8}{(250 \times 10^3 \times 0.8) + W_{cu} + W_i}$$

$$W_{cu} + W_i = \frac{250 \times 10^3 \times 0.8}{0.98135} - 250 \times 10^3 \times 0.8$$

$$\boxed{W_{cu} + W_i = 3800.870} \quad \text{— (1)}$$

ii)

$$0.9775 = \frac{250 \times 10^3 \times 0.8 \times 0.5}{(250 \times 10^3 \times 0.8 \times 0.5) + (0.5)^2 W_{cu} + W_i}$$

$$\boxed{0.25 W_{cu} + W_i = 2301.79} \quad \text{— (2)}$$

$W_{cu} = 1998.77\ W$

$W_i = 1802.09\ W$

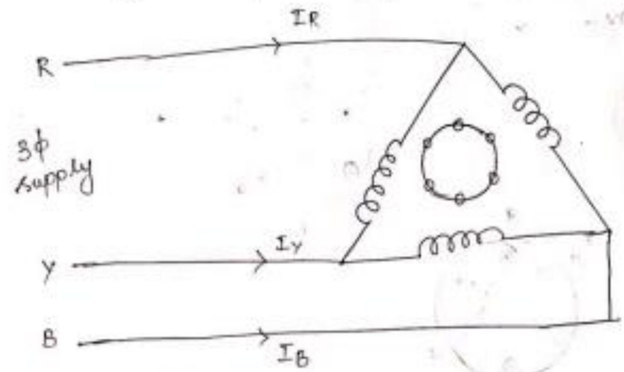
5 Explain how rotating magnetic field is developed in three phase induction motor.

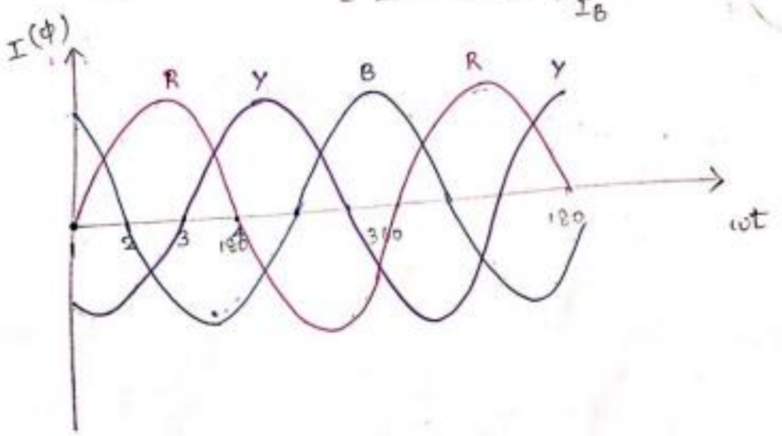
Concept of "rotating magnetic field":-

* A rotating magnetic field is produced when 3ϕ winding is energised from 3ϕ supply.
* The produced magnetic field is such that, the poles do not remain in fixed position hence the name, rotating magnetic field.

Consider a 3ϕ winding energized from 3ϕ source.

Position 1.



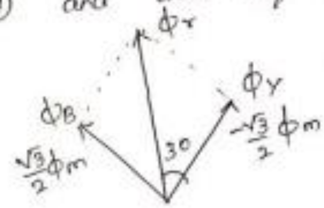


Let ϕ_m be the maximum flux due to any phase,

$$\left.\begin{aligned} \phi_R &= \phi_m \sin \omega t \\ \phi_Y &= \phi_m \sin(\omega t - 120) \\ \phi_B &= \phi_m \sin(\omega t + 120) \end{aligned}\right\} \quad (1)$$

i) at $\omega t = 0$,

Substituting the value of ωt in (1) and also refering the wave form,



$$\phi_R = 0$$

$$\phi_Y = \phi_m \sin(-120)$$

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

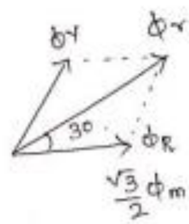
$$\phi_B = \phi_m \sin(120)$$

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

$$\therefore \phi_r = 2\ \frac{\sqrt{3}}{2}\phi_m \cos 30$$

$$\boxed{\phi_r = 1.5\phi_m}$$

ii) at $\omega t = 60$,



$$\phi_R = \phi_m \sin 60$$

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

$$\phi_Y = \phi_m \sin -60$$

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

$$\phi_B = \phi_m \sin 180$$

$$= 0.$$

$$\boxed{\phi_r = 1.5\phi_m}$$

iii) at $\omega t = 120$,

$\phi_R = \phi_m \sin 120$

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

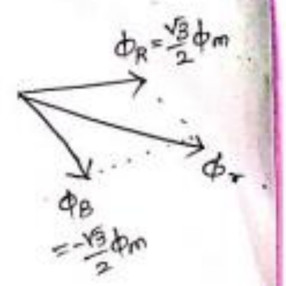
$\phi_Y = \phi_m \sin 0$

$= 0$

$\phi_B = \phi_m \sin 240$

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

$\boxed{\phi_r = 1.5\phi_m}$.



iv) at $\omega t = 180$.

$\phi_R = \phi_m \sin 180$.

$= 0$.

$\phi_Y = \phi_m \sin (180 - 120)$

$= \phi_m \sin 60$

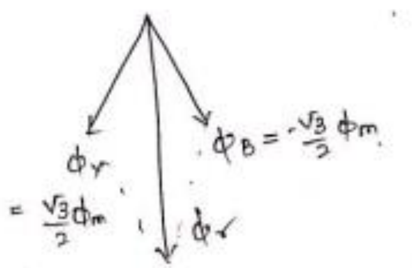
$= \frac{\sqrt{3}}{2}\phi_m$.

$\phi_B = \phi_m \sin (180 + 120)$

$= \phi_m \sin 300$

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

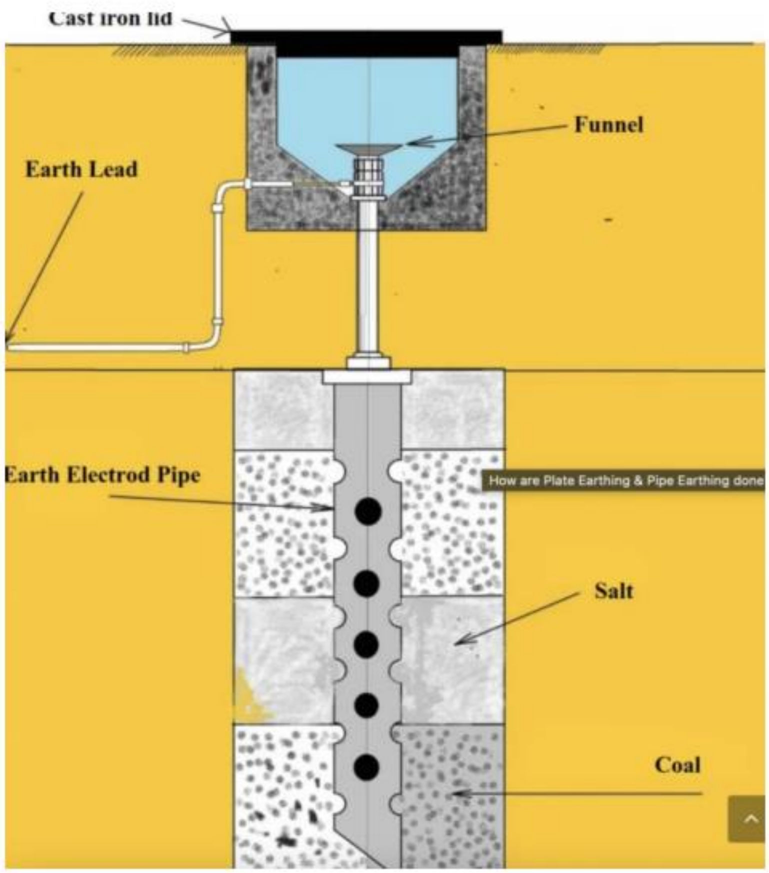
$\boxed{\phi_r = 1.5\phi_m.}$



Thus from above discussion, it is clear that a 3ϕ supply produces a rotating field of const value $1.5\phi_m$ rotating at synchronous speed $N_S = \frac{120f}{P}$ - speed of rotating magnetic field

6 Explain the term 'earthing'. Why earthing is earthing required?. With a neat diagram, explain the operation of pipe earthing.

The process of transferring the immediate discharge of the electrical energy directly to the earth by the help of the low resistance wire is known as the electrical earthing. • The earthing protects the personnel from the short circuit current. • The earthing provides the easiest path to the flow of short circuit current even after the failure of the insulation. • The earthing protects the apparatus and personnel from the high voltage surges and lightning discharge.
Pipe Earthing:
A pit is made 70cm long, 70cm wide and 3.75 meters deep in the ground for Pipe Earthing. a G.I., 38mm in diameter and 2 meters long. The Pipe is used as the earth electrode in that pit. • The entire surface of that Pipe has 12mm holes. Which are made at a spacing of 7.5 cm. This means the electrode is fitted with a reducing socket with a diameter of 19mm and two such 12.7mm diameter G.I. Pipes are connected. • A funnel is attached at the top end of the 19mm diameter Pipe. The funnel is used to water the Earthing. An open conductor for the earth lead is connected to the earth electrode through a 12.7mm diameter Pipe.



7 a) Compare squirrel cage and slip ring types of induction motor.

S.No	Phase Wound or Slip Ring IM	Squirrel Cage IM
1	Construction is complicated due to presence of slip ring and brushes	Construction is very simple
2	The rotor winding is similar to the stator winding	The rotor consists of rotor bars which are permanently shorted with the help of end rings
3	We can easily add rotor resistance by using slip ring and brushes	Since the rotor bars are permanently shorted, it is not possible to add external resistance
4	Due to presence of external resistance high starting torque can be obtained	Staring torque is low and cannot be improved

7 b) A 4 pole, 3phase, 50 Hz induction motor runs at a speed of 1470 rpm. Find the synchronous speed , the slip and frequency of the induced EMF in the rotor under this condition

7 b) $P = 4$, 3ϕ, $50Hz$

$N = 1470$ rpm.

$$N_s = \frac{120f}{P} \Rightarrow \frac{120 \times 50}{4}$$

$$= 1500 \text{ rpm}$$

$$S = \frac{N_s - N}{N_s} \Rightarrow 0.02$$

$$f' = sf = 0.02 \times 50$$

$$= 1 \text{ Hz}.$$