BAISC ELECTRICAL

Answer the following short answer-type questions (any seven) :

(a) Define active and passive element .

Ans. (a) There are two types of elements found in electric circuits : *passive* elements and *active* elements. An active element is capable of generating energy while a passive element is not. Examples of passive elements are resistors, capacitors and inductors. Typical active elements include generators, batteries and operational amplifiers.

The most important active elements are voltage or current sources that generally deliver power to the circuit connected to them.

(b) State and explain Norton theorem ?

Ans. Norton's theorem for a dc networks may be stated as follows :

A linear 2-terminal active dc network N consisting of independent and or/dependent voltage and current sources and resistors can be replaced at a pair of terminals $a - b$ by a simple equivalent network consisting of a single current source I_N in parallel with a single resistor R_N.

The source current, I_N, is the current through the terminals $a - b$ when they are short circuited. This current is called the *Norton equivalent current*. Since the current I_N is the current through the terminals $a - b$ when they are short-circuited, it may be also be denoted by I_{SC}. That is, $I_N = I_{SC}$.

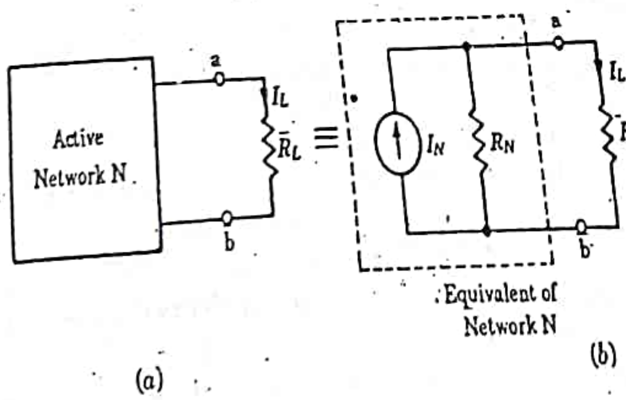


Fig. : (a) Original network,
(b) Norton equivalent network.

The equivalent Norton resistance, R_N, is the resistance between the load terminals $a - b$ of the original network N, with the load removed and all sources replaced by their internal resistances.

The linear active network N and its Norton equivalent circuit are shown in Fig.

The Norton equivalent resistance is calculated in exactly the same way as the Thevenin equivalent resistance.

$$\therefore \quad R_N = R_{Th}$$

In the Norton equivalent circuit, R_N is connected in parallel with the current source, I_N. The load current I_L is calculated by the current division rule

$$I_L = \frac{R_N}{R_N + R_L} I_N$$

(c) A half-cycle average voltage of 12 V is equal to what r.m. voltage ?

Ans. (c) $v_{av} = 12$ volt

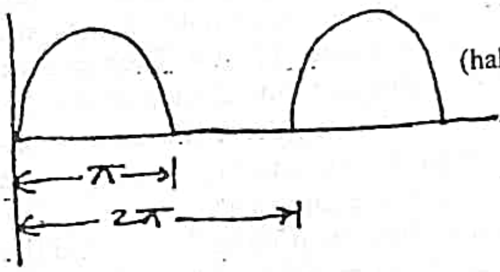


Fig.

$$v_{av} = \frac{v_{max}}{\pi}$$

$$v_{max} = v_{av} \times \pi$$

$$v_{max} = 12\pi$$

$$v_{rms} = \frac{v_{max}}{2} = \frac{12\pi}{2} = 6\pi$$

$$= 18.84 \text{ volt.}$$

(d) What are the phase voltage and phase current of three-phase delta-connected system ?

Ans. (d) In D-connected system

$$v_L = v_{ph}$$

$$I_L = \sqrt{3}\, I_{ph}$$

where, v_{ph} = Phase voltage,

v_L = line voltage

I_{ph} = Phase current,

I_L = line current

(e) Draw equivalent circuit of a DC motor .

Ans. (e)

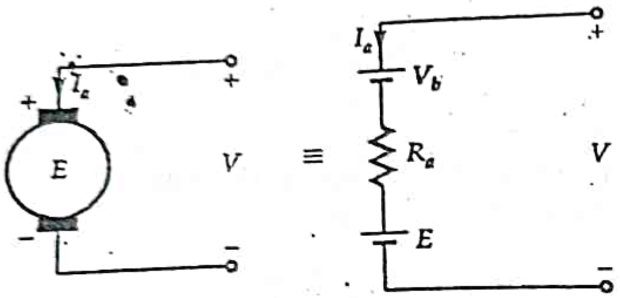


Fig. : Equivalent circuit of the armature of a d.c. motor.

(f) What is resonance ?

Ans. (f) Resonance is defined as the condition in a circuit containing at least one inductor and one capacitor when the supply voltage and the supply current are in phase. Thus, at resonance the equivalent impedance of the circuit is purely resistive. Since the supply voltage and supply current are it phase, the power factor of a resonance circuit is unity. At resonance the circuit impedance Z and the admittance Y are real quantities. Thus, if Z and Y are expressed in rectangular form their term are zero while if Z and Y are expressed in polar form their angles are zero.

For example,

(a) If $Z = R + jX$ and $Y = G + jB$

then at resonance

$Im(Z) = X = 0$ or $Im(Y) = B = 0$

(b) If $Z = Z \underline{/\phi}$ and $Y = Y \underline{/0}$

then at resonance

$f = 0$ and $q = 0$

(g) Relate flux, reluctance and permeability .

Ans. (g)

$$mm\phi = S\phi$$

$$\phi = \frac{mmf}{S}$$

$$mmf = NI$$

$$\text{reluctance} = \frac{l}{\mu_0\mu_r A},$$

$$\phi = \frac{NI}{l/\mu_0\mu_r A} \text{ webers}$$

(h) Define power factor ?

Ans. (h) Power $= V \times I \cos\phi$

or, $P = VI\cos\phi$

Where, P is known as real power

VI is known as apparent power and $\cos\phi$ is known as power factor of the circuit.

Hence, $\cos\phi = \dfrac{P}{VI}$

or, Power factor $= \dfrac{\text{Real power}}{\text{Apparent power}}$

Therefore power factor of the circuit is defined as "the ratio of the real power to the apparent power of that circuit.

Also, cosine of the angle between voltage and current, in an ac system is called as 'power factor'.

(i) Write the application of Ohm's law .

Ans. (i) Application of Ohm's Law : Ohm's law can be applied to a complete circuit or to any part of the circuit, provided that V, I and relate to the same part. When Ohm's law is applied to an entire circuit, values of V, I and R must be used for the entire circuit. When used for a certain part of a circuit, values of V, I and R must be used from only that part.

(j) Describe important characteristics of an inductor ?

Ans. An inductor is a passive element designed to store energy in the magnetic field. Inductors find numerous applications in electron and power systems. They are used in power supplies, transformers, radios, TVs, radar and electric motors.

Any conductor of electric current has inductive properties and may be regarded as an inductor. But in order to enhance the inductive effect, a practical inductor is usually formed into cylindrical coil with many turns of conducting wire, An inductor consists of a coil of conducting wire.

Q. 2. (a) Define Q-factor. What is the Q (quality factor) of a series circuit that resonates at 6 kHz, has equal reactance of 4 kilo-ohms each and a resistor value of 50 ohms ?

Ans. Given,

$$f_0 = 6\text{ KHz}$$
$$x_L = x_C = 4\ kW$$
$$R = 50W$$

Since, Quality factor,

$$Q_0 = \frac{\omega_0 L}{R}$$

$$Q = \frac{x_L}{R}$$

$$Q = \frac{4\times10^3}{50}$$

$$Q = 80$$

Quality factor : The quality factor Q of coils, capacitors and circuit is defined by

$$Q \triangleq 2p \times \frac{\text{maximum stored energy per cycle}}{\text{energy dissipated per cycle}}$$

(b) A series R-L-C circuit containing a resistance of 10Ω an inductance of 0·45 H and a capacitor of 400 μF is connected in series across a 120 V, 50 Hz supply. Calculate the total circuit impedance, the circuit current, power factor and draw the voltage phasor diagram.

Ans. Given,

$$R = 10\Omega$$
$$L = 0.45\text{ H}$$
$$C = 400\ \mu\text{F}$$
$$\upsilon = 120\ \upsilon$$
$$f = 50\text{ Hz}$$

Inductive Reactance of the circuit

$$x_L = 2pf\,L = 2p \times 50 \times 0.45$$
$$= 141.4W$$

Capacitive reactance of the circuit

$$x_C = \frac{1}{2\pi f_c} = \frac{1}{2\pi\times50\times400\times10^{-6}}$$

$$= \frac{10^6}{2\pi\times50\times400}$$

$$= 7.96W$$

Net reactance of the ckt.

$$x = x_L - x_C = (141.4 - 7.96)W$$
$$= 133.44W$$

Since $x_L > x_C$ the circuit is predominantly inductive.

Impedance of the circuit,

$$z = \sqrt{R^2 + (x_L \cdot x_C)^2}$$

$$= \sqrt{(10)^2 + (133.44)^2}$$

$$= 133.81W$$

Current in the circuit

$$I = \frac{v}{z} = \frac{120}{133.81}$$

$$= 0.89679\text{ Amp.}$$

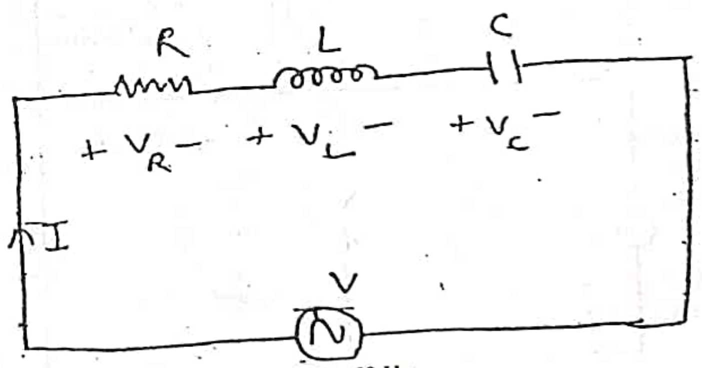
$$\approx 0.9\text{ Amp.}$$

$$\text{Power factor, } \cos\phi = \frac{R}{2}$$

$$= \frac{10}{133.81} = 0.07473$$

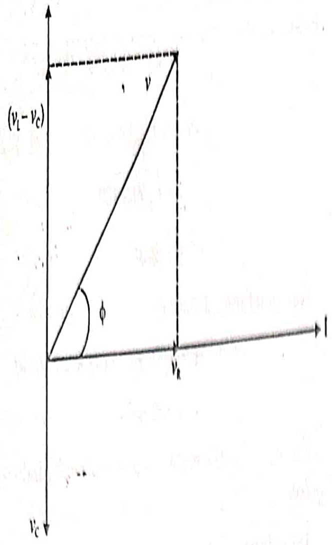
Phase angle, $\phi = \cos^{-1}(0.07473)$

$$\phi = 85.714^\circ$$



ckt diagram

Fig.



Voltage phasor diagram

Fig.

Q. 3. (a) Find the resistor value R_1 in the Fig. 1 show below :

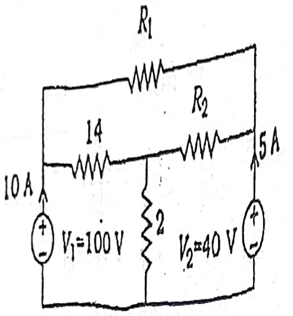


Fig. 1

Ans.

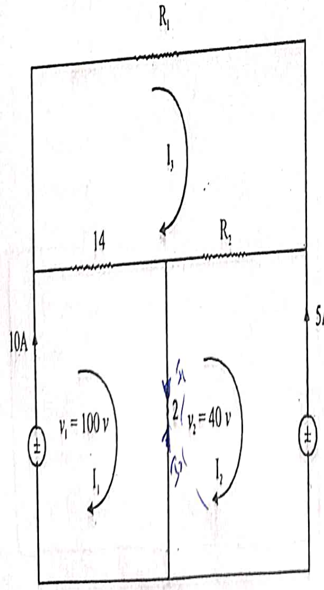


Fig.

Applying KVL in mesh I we get,

$$14\,(I_1 - I_3) + 2\,(I_1 - I_2) = 100$$

from the ckt,

$$I_1 = 10A.$$

$$I_2 = -5A$$

$$14\,(10 - I_3) + 2\,(10 + 5) = 100$$

$$140 - 14I_3 + 30 = 100$$

$$-14\,I_3 = 100 - 170$$

$$-14\,I_3 = -70$$

$$I_3 = \frac{70}{14} = 5A$$

$$I_3 = 5A$$

Applying KVL in mesh III, we get,

$$R_1 I_3 + R_2\,(I_3 - I_2) + 14\,(I_3 - I_1) = 0$$

$$R_1 \times 5 + R_2\,(5 + 5) + 14\,(5 - 10) = 0$$

$$5R_1 + 10R_2 = 70 \qquad \text{.... (1)}$$

Applying KVL in mesh II we get;

$$R_1\,(I_2 - I_3) + 40 + 2\,(I_2 - I_1) = 0$$

$$R_1\,(-5 - 5) + 40 + 2\,(-5 - 10) = 0$$

$$-10R_2 + 40 - 30 = 0$$

$$-10\,R_2 + 10 = 0$$

$$R_2 = \frac{-10}{-10} = 1$$

From equation (1) we get,

$$5R_1 + 10R_2 = 70$$

$$5R_1 + 10 \times 1 = 70$$

$$R_1 = \frac{70 - 10}{5}$$

$$R_1 = \frac{60}{5} = 12W$$

$$R_1 = 12W$$

Alternately,

$$v_1 = 100v$$

$$v_2 = 40v$$

$$I_3 = 5A$$

$$\therefore \quad R_1 = \frac{V_1 - V_2}{I_3}$$

$$= \frac{100 - 40}{5} = \frac{60}{5} = 12W$$

$$R = 12W$$

(b) In a balance 3-phase 400 V circuit, I_1 = 115·4A. When power is measured by two-wattmeter method, one meter reads 40 kW and other zero. What is the power factor of load ? If unity power factor and line current are same, what would be the reading of each wattmeter ?

Ans.

$$v_L = 400v$$
$$I_L = 115.4 \text{ A}$$
$$w_1 = 40 \text{ kw}$$
$$w_2 = 0$$

In two voltmeter method when power factor angle is 60°, one of the wattmeter shows zero deflection (i.e., $\phi = 60°$).

$\therefore$ Power factor, $\cos\phi = \cos 60° = 0.5$.

At unit p.f., i.e., $\cos\phi = 1$

when, $\phi = 0°$

$$w_1 = v_L I_L \cos(30 - \phi)$$
$$w_2 = v_L I_L \cos(30 + \phi)$$

i.e., $w_1 = w_2 = 40$ kw

Q. 4. (a) What are the general types of transformer ? Why is the low-voltage winding placed near the core ? What will be the output of transformer if it is operated on DC supply ?

Ans. The two general types of transformer are :

(a) Core type

(b) Shell type

Advantages of placing Low-voltage winding nearness to the core :

1. Insulating material required between the core and winding is less.
2. Size is less or small.
3. Cost of system is low.
4. It is easy to select desired tapping points from high voltage (HV) winding.

A transformer is never operated on DC supply. So, the output will be zero i.e. a transformer will not operate on DC. If it is done so the transformer may burn out.

(b) Describe the operation of a single-phase transformer, explaining clearly the function of different parts. Why are the cores laminated ?

Ans. **Working Principle of a Transformer :** The basic principle of transformer is electromagnetic induction.

A simple form of a transformer is shown in fig. It essentially consists of two separate winding placed over the laminated silicon steel core. The winding to which a.c. supply is connected is called *primary winding* and the winding to which load is connected is called a *secondary winding.*

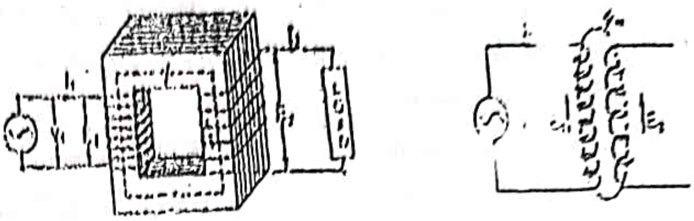


Fig.

When a.c. supply of voltage V_1 is connected to primary winding, an alternating flux is set up in the core. This alternating flux when links with the secondary winding an e.m.f. is induced in it called mutually induced e.m.f. The direction of this induced e.m.f. is opposite to the applied voltage V_1, according to Lenz's law as shown in fig.

The same alternating flux also links with the primary winding and produces self induced e.m.f. E_1. This induced e.m.f. The direction of this induced e.m.f. is opposite to the applied voltage V_1, according to Lenz's law as shown in fig.

The same alternating flux also links with the primary winding and produces self induced e.m.f. E_1. This induced e.m.f. E_1 also acts in opposite direction to the applied voltage V_1 according to Lenz's law.

The induced e.m.f. in the primary and secondary winding depends upon the rate of change of flux linkages $\left(\text{i.e.} N\frac{d\phi}{dt}\right)$. The rate of change of flux ($d\phi/dt$) is the same for both primary and secondary. Therefore, the induced e.m.f. in primary is proportional to number of turns of the primary winding ($E_1 \propto N_1$) and in secondary is proportional to number of turns of the secondary winding ($E_2 \propto N_2$).

$\therefore$ In case, $N_2 > N_1$, the transformer is step-up transformer and when $N_2 < N_1$, the transformer is step-down transformer.

Transformation ratio : The ratio of secondary voltage to primary voltage is called voltage transformation ratio of the transformer. It is represented by K.

$$K = \frac{E_2}{E_1} = \frac{N_2}{N_1} \text{ (since } E_2 \propto N_2 \text{ and } E_1 \propto N_1\text{)}$$

Q. 5. Draw and explain the B-H curves for air and a magnetic material. What are different types of magnetic losses ? How can they be minimized ?

Ans. Magnetisation Curve or B-H Curve : The graph between the flux density B and field intensity H of a magnetic material is called the *magnetisation curve or B-H curve*. In air or a non-magnetic material, the flux density B is proportional to magnetic field intensity H. Therefore the graph of B versus H is a straight line through the origin as shown in Fig.

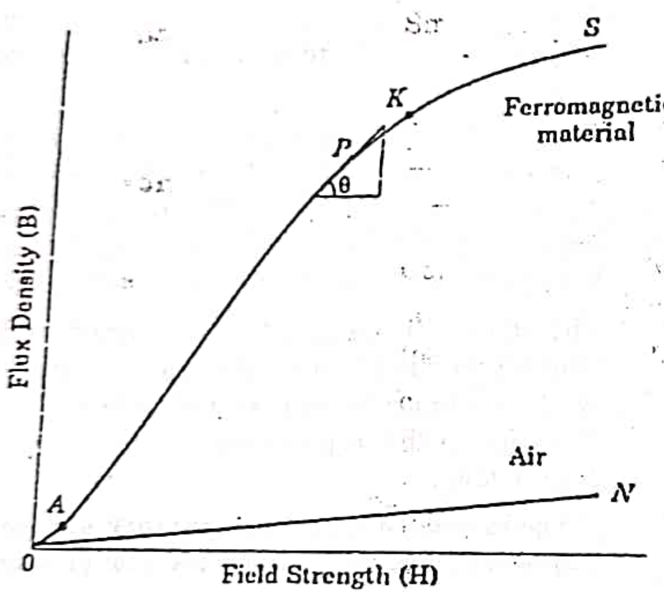


Fig. : B-H curves for air and a ferromagnetic material.

A typical B - H curve for a ferromagnetic material is also shown in Fig. Except for a small portion near the origin, the curve is linear from A to K. Over this portion the flux density B is proportional to the field intensity H and μ_r is constant. For higher values of H, there is no further increase in B with H. The curve becomes almost horizontal after the point K. The material is then said to be saturated and the point K is called the point of saturation for the material.

The slope of the B - H curve at any point P given by

$$\tan\theta = \frac{B}{H}$$

$$B = \mu_0\mu_r H;$$

$$\mu_r = \frac{1}{\mu_0}\cdot\frac{B}{H} = \frac{1}{\mu_0}\tan\theta$$

Thus, μ_r is proportional to the slope of the B – H curve at any point. Starting from a definite value at the origin, the slope increases as B increases until it becomes a maximum. It then gradually decreases as B increases further. The slope becomes almost zero in the saturation region when the curve becomes horizontal. The B – H curve shows that the permeability μ_r of a magnetic material changes with the flux density B.

Core Losses or Iron Losses :

Time-varying fluxes produce losses in ferromagnetic materials, known as core losses or iron losses. The core losses consists of hysteresis and eddy-current losses. That is $P_{core} = P_h + P_e$. These losses do not occur in ferromagnetic cores that carry flux which does not vary with time. Both hysteresis loss and eddy-current loss produce heat in a magnetic circuit. Within an electric machine hysteresis and eddy-current losses occur simultaneously.

Q. 6. What is circuit ? What is the difference between fuse and circuit breaker ? Explain the objective of earthing.

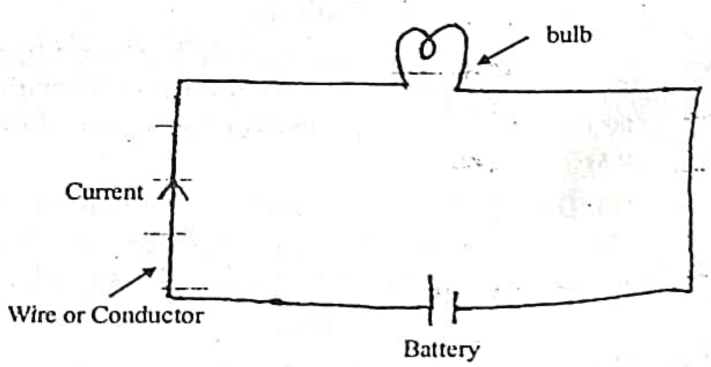
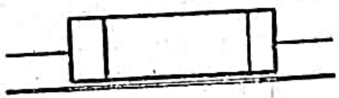


Fig. : An electric circuit.

Characteristics	Fuse	Circuit Breaker
Function	Performs detection as well as interruption function.	Performs interruption function ONLY.
Operation Mode	Inherently completely automatic operation	Needs comprehensive equipment such as relays for automatic operation
Operating time	Very small like 0.002 sec or even less	Comparatively large (ranges between 0.1 and 0.2 seconds)
Replacement	Have to replace after operation	No need to replace after every operation
Operation principle	It's operation is based on the heating property of a conducting material	It's operation is based on switching mechanism (which is electro-mechanical in nature)
Breaking Capacity	Small	Large
Representation		
Temperature	Completely independent of an ambient temperature	Depends on an ambient temperature
Characteristics curve	Because of ageing, characteristics curve shifts	Does not shift.
Cost	Low cost	Very high mainly depends upon application
Protection	Provides protection again overload	Provides protection against overload as well as short-circuit in the system
Post-Operation	It is replaced manually	It can be reset quickly after operation operation
Application	Used extensively in an electronic equipment's which draw low current	Used in power equipment's such as in motors and other heavy machines which draw a large amount of current

Objectives of Earthing : Earthing is should be done to achieve the following objectives :

- To save human life from danger or shock or death by blowing fuse of any apparatus which becomes leaky.
- To protect large building from atmospheric lightning.
- To protect all machines fed from overhead lines from lightning arrestors.
- To maintain the line voltage constant since neutral of every alternator, transformer is earthed).

Q. 7. Write Thevenin theorem statement. Determine the equivalent Thevenin's circuit between terminals *a* and *b* in the circuit shown in Fig. 2 below. Resistance are in ohms :

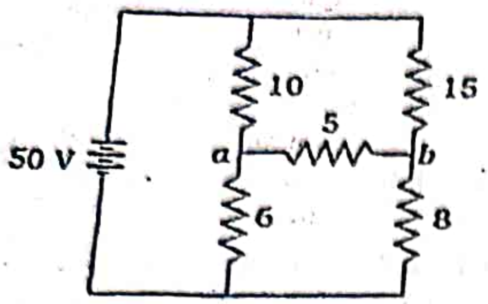
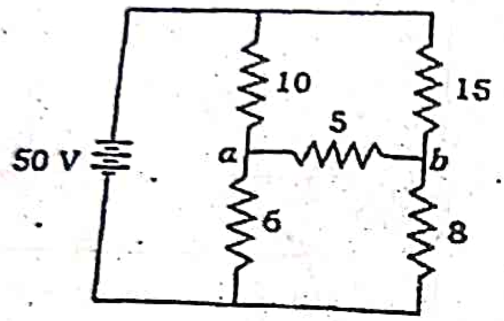


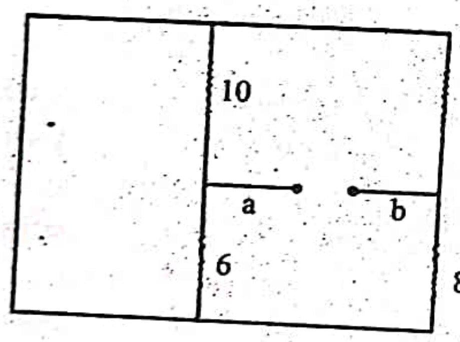
Fig.

Ans.



By thevenin's theorem

To find R_{th} or R_{ab}



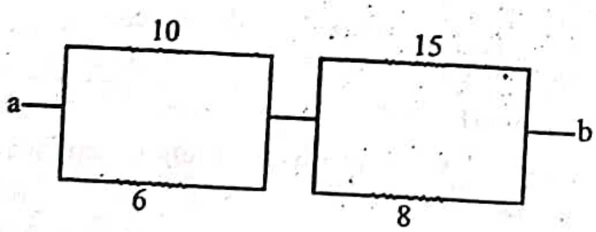


Fig.

$$R_{ab} = (10 \parallel 6) + (15 \parallel 8)$$

$$R_{ab} = 3.75 + 5.2174$$

$$R_{th} = R_{ab} = 8.967\Omega$$

To find v_{th} or v_{ab}

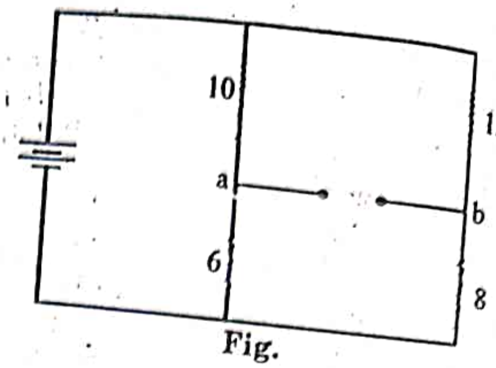


Fig.

$$v_{ab} = v_a - v_b$$

$$= \frac{10}{10+6} \times 50 - \frac{15}{15+8} \times 50$$

$$= 31.25 + 32.60$$

$$= -1.3587 \text{ volt}$$

or,

$$v_{ab} = v_a - v_b$$

$$= \frac{6}{10+6} \times 50 - \frac{8}{15+8} \times 50$$

$$= 18.75 - 17.39$$

$$v_{th} = v_{ab} = 1.3587 \text{ volt.}$$

Thevenin's equivalent clct;

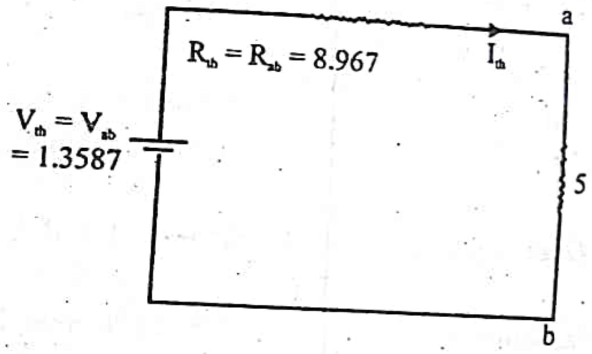


Fig.

$$I_{th} = \frac{v_{th}}{R_{th} + R_L}$$

$$= \frac{1.3587}{8.967 + 5}$$

$$I_{th} = 0.0972 \text{ Amp.}$$

Q. 8. Describe with neat sketches the construction of a 3-phase induction motor. Explain the principle of operation of a 3-phase induction motor. What is meant by slip in an induction motor ?

Ans. Construction : A three-phase induction motor essentially consists of two parts : the stator and the rotor. The stator is the stationary part and the rotor is the rotating part. The stator is built up of high-grade alloy steel laminations to reduce eddy-current losses. The laminations are slotted on the inner periphery and are insulated from each other. These laminations are supported in a stator frame of cast iron or fabricated steel plate. The insulated stator conductors are placed in these slots. The stator conductors are connected to form a three phase winding. The phase winding may be either star or delta- connected [Fig. (a)].

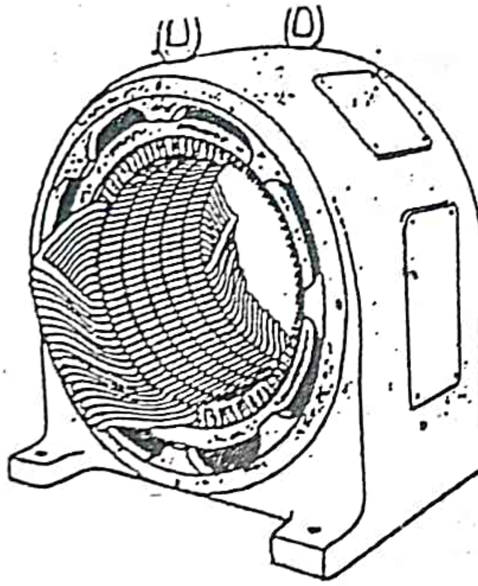


Fig. (a) Induction Motor Stator with double-layer winding partly wound.

The **rotor** is also built up of thin lamination of the same material as stator. The laminated cylindrical core is mounted directly on the shaft or a spider carried by the shaft. These laminations are slotted on their outer periphery to receive the rotor conductors. There are two types of induction motor rotors :

(a) Squirrel-cage rotor or simply cage rotor.

(b) Phase wound or wound rotor. Motors using this type of rotor are also called **slip-ring motor**

Principle of Operation of a Three-Phase Induction Motor : For the sake of simplicity, let us consider one conductor on the stationary rotor as shown in Fig. (a). Let this conductor be subject to the rotating magnetic field produced when a three-phase supply is connected to the three-phase winding of the stator. Let the rotation of the magnetic field be clockwise. A magnetic field moving clockwise has the same effect as a conductor moving anticlockwise in a stationary field. By Faraday's law of electromagnetic induction, a voltage will be induced in the conductor. Since the rotor circuit is complete, either through the end rings or an external resistance the induced voltage causes a current to flow in the rotor conductor. By right-hand rule we can determine the direction of induced current in the conductor. Since the magnetic field is rotating clockwise and the conductor is stationary we can *assume* that the conductor is in motion in the anticlockwise direction with respect to the magnetic field. By right hand rule the direction of the induced current is outwards (shown by dot) as given in Fig. (b). The current in the rotor conductor produces its own magnetic field (Fig. (c)).

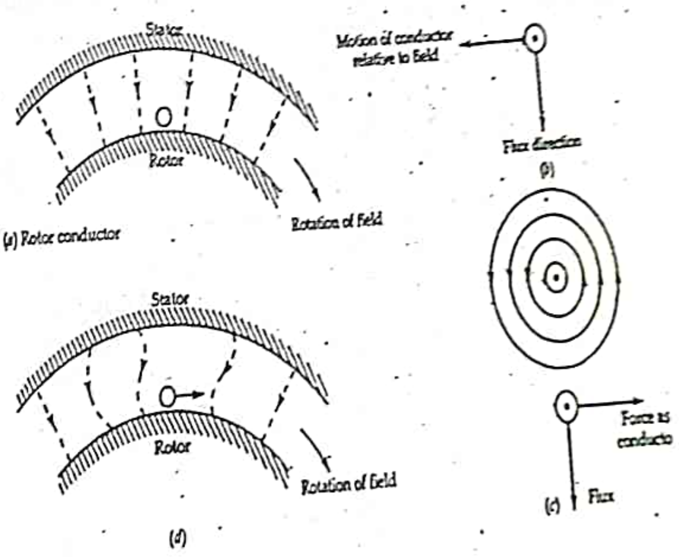


Fig. : Production of torque.

We know that when a conductor carrying current is put in a magnetic field a force is produced on it. Thus, a force is produced on the rotor conductor. The direction of this force can be found by left-hand rule (Fig. (d)). It is seen that the force acting on the conductor is in the same direction as the direction of the rotating magnetic field. Since the rotor conductor is in a slot on the circumference of the rotor, this force acts in a tangential direction to the rotor and develops a torque on the rotor. Similar torques are produced on all the rotor conductors. Since the rotor is free to move, it starts rotating in the same direction as the rotating magnetic field. Thus, a three-phase induction motor is self-starting. Since the operation of this motor depends upon the induced voltage in its rotor conductors, it is called an **induction motor.**

Speed And Slip :

An induction motor can not run at synchronous speed. Let us consider for a moment that is rotor is rotating at synchronous speed. Under this condition, there would be no cutting of flux by the rotor conductors and there would be no generated voltage, no current and no torque. The rotor speed is therefore slightly less than the syntor speed is therefore slightly less than the synchronous speed. An induction motor may also be called as '*Asynchronous motor* as it does not run at synchronous speed. The difference between the synchronous speed and the actual rotor speed is called the **slip speed.**

Thus, the 'slip speed' expresses the speed of the rotor relative to the field.

If N_s = synchronous speed in r.p.m.

N_r = actual rotor speed in r.p.m. the slip spee...

$= N_s - N_r$ r.p.m.

The slip speed expressed as a fraction of the syn... chronous speed is called the per-unit slip or fra... tional slip. The per-unit slip is usually called th... slip. It is denoted by s.

$$s \triangleq \frac{N_s - N_r}{N_s} \text{ per unit (p.u.)}$$

$$\text{Percentage slip} = \frac{N_s - N_r}{N_s} \times 100$$

Alternatively, if

n_s = synchronous speed in r.p...

n_r = actual rotor speed in r.p...

then $$s \triangleq \frac{n_s - n_r}{n_s} \text{ p.u.}$$

and percentage slip

$$= \frac{n_s - n_r}{n_s} \times 100$$

Also, $$s = \frac{\omega_s - \omega_r}{\omega_s}$$

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