B.TECH. EEC-101/EEE-201

FIRST SEMESTER EXAMINATION 2010-11

ELECTRICAL ENGINEERING

Time : 3 Hours *Total Marks : 100*

Note: All sections are compulsory.

SECTION—A

Q.1. Attempt parts are compulsory. All parts carry equal marks. (10×2=20)

Q.1. (a) A 100 ohm resistor is needed in an electric circuit to carry a current of 0.3 A. Which resistor would you specify?

(i) 100 ohm 5 W (ii) 100 ohm 7.5 W

(iii) 100 ohm 10 W

(iv) None of these

Ans. (iii) 100 ohm 10 W

Q.1. (b) An inductor at $t = 0^*$ with zero initial conditioin act as:

(i) Voltage soure (ii) Current source

(iii) Open circuit (iv) None of these

Ans. (iii) Open circuit

Q.1. (c) In star connection of resistance is R then in equivalent delta connection this value will be:

(i) R/2 (ii) 3R/2

(iii) 3R (iv) R/3

Ans. (iii) 3R

Q.1. (d) In Dynamometer type wattmeter is used for measuring:

(i) AC only

(ii) DC only

(iii) Both AC and DC

(iv) None of these

Ans. (iii) Both AC and DC

Q.1. (e) In two wattmeter method, if the reading are equal with opposite sign then the power factor of the load is ______.

Ans. 0 (zero)

Q.1. (f) The short circuit test of transformer is done to determine:

(i) iron loss

(ii) eddy current loss

(iii) copper loss at full load

(iv) copper loss at desired load

Ans. (iii) copper loss at full load

Q.1. (g) The back emf of DC motor is given by E_b = ______.

Ans. $E_b = V_t - I_a r_a$

Q.1. (h) The wound rotor induction motor is mainly used due to:

(i) High starting torque

(ii) Speed Control

(iii) High rotor resistance

(iv) None of these

Ans. (i) High starting torque

Q.1. (i) The color codes of line wires for three-phase four wire AC system are ______.

Ans. Red, Yellow, Blue, Black

Q.1. (j) The efficiency is only ______ when maximum power transfer is achieved.

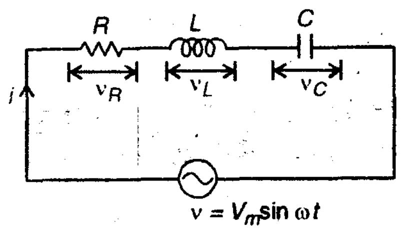
Ans. 50%

SECTION—B

Q.2. Attempt any three parts of the following. All parts carry equal marks. (10×3=30)

(a) Derive the response of RLC series circuit to sinusoidal input. Also derive the condition of resonance.

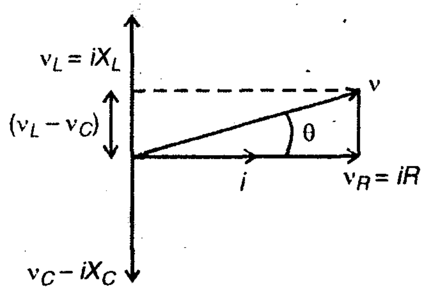
Ans. Resonance of RLC series circuit:
Let the current in the circuit is i.



Impedance $z = R + j\omega L - j\dfrac{1}{\omega C}$

$$= R + j\left(\omega L - \frac{1}{\omega C}\right)$$

Phasor diagram of the circuit is:



Suppose $v_L > v_C$

then $(v_L - v_C)$ will lead i

From phasor diagram supply voltage is

$$v = \sqrt{v_R^2 + (v_L - v_C)^2}$$

or $\quad iz = \sqrt{(iR)^2 + (iX_L + iX_C)^2}$

Z = impedance of series RLC circuit

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

Current i in the circuit

$$= \frac{v}{Z} = \frac{v}{\sqrt{R^2 + (X_L - X_C)^2}}$$

From phasor diagram θ (angle of lag of current i from voltage v)

$$= \tan^{-1}\frac{(v_L - v_C)}{v_R}$$

$$= \tan^{-1}\frac{iX_L - iX_C}{iR}$$

$$= \tan^{-1}\frac{(X_L - X_C)}{R}$$

So $i = I_m \sin(\omega t - \theta)$

where I_m = maximum current $= \dfrac{V_m}{Z}$

At resonance $X_L = X_C$

or $\omega_r L = \dfrac{1}{\omega_r C}$ so $\omega_r = \dfrac{1}{\sqrt{LC}}$

ω_r = resonance frequency

At resonance θ = 0, so v and i will be in phase at resonance.

(b) Discuss the various methods of speed control of DC shunt motor.

The armature of a four-pole DC machine has 100 turns and runs at 600 RPM. The EMF generated in open circuit is 220 V. Find the useful flux per pole when armature is:

(*i*) lap connected

(*ii*) wave connected

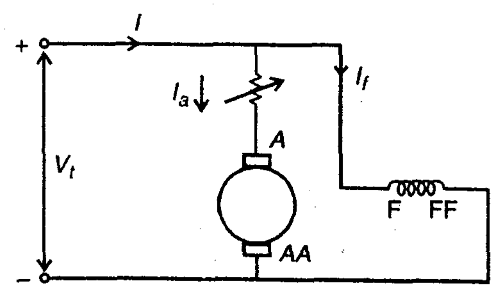
Ans. Speed control of DC shunt motor: Various methods are:

(*i*) Armature control

(*ii*) Field control

(*iii*) Voltage control

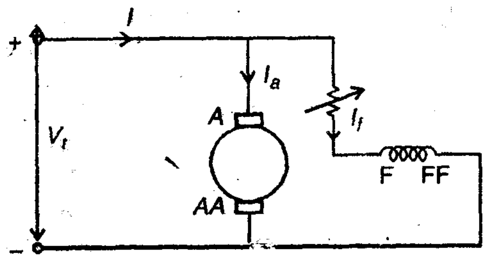
Armature Control:



$$N(\text{speed}) = \frac{V_t - I_a r_a}{K_a \phi}$$

By connecting external variable resistance in series with armature the voltage drop in armature can be controlled and hence the speed of the motor can be controlled. Speed control is from zero speed to base (rated) speed.

Field Control: By connecting external variable resistance in series with field, the field flux can be controlled and hence the speed of the motor can be controlled. Speed control is above base speed.



Voltage control: By varying the dc supply voltage input to the motor (V_t), the speed of the motor can be controlled.

Numerical: Given $P = 4$, no. of turns = 100, $N = 600$ RPM

No. of armature conductors $Z = 100 \times 2 = 200$

EMF generated $E = 220$ V.

$$E = \frac{PN\phi Z}{60A}$$

(*i*) cap connected armature $A = P = 4$

$$\text{So } 220 = \frac{4 \times 600 \times \phi \times 200}{60 \times 4} \qquad \phi = \frac{220}{10 \times 200}$$

$$\phi = \frac{11}{100} = 0.11 \text{ Wb}$$

So useful flux/pole = 0.11 Wb

(*ii*) Wave connected armature $A = 2$

$$\text{So } 220 = \frac{4 \times 600 \times \phi \times 200}{60 \times 2} \qquad \phi = \frac{220}{20 \times 200}$$

$$\phi = \frac{11}{200} = 0.055 \text{ Wb}$$

So useful flux/pole = 0.055 Wb.

(*c*) **Draw the general layout of an electrical power system and explain briefly.**

What is the significance of turn ratio in transformer? The maximum efficiency of a 100 kVA transformer is 98.40% and operates at 90% full load unity power factor. Calculate the efficiency of a transformer at unity power factor at full load.

Ans. Turn ratio in transformer

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

In transformer HV side has more number of turns.

LV side has less number of turns.

Maximum efficiency of 100 KVA transformer = 98.4%. When transformer operates at 90% full load unity power factor.

For maximum efficiency Cu loss = core loss

So

$$0.9840 = \frac{0.9 \times 100 \times 10^3 \times 1}{0.9 \times 100 \times 10^3 \times 1 + P_{core} + P_{core}}$$

$$\text{or } 2P_{core} = \frac{0.9 \times 100 \times 10^3}{0.9840} - 0.9 \times 100 \times 10^3$$

$$2P_{core} = 0.9 \times 100 \times 10^3(1.01626 - 1) = 1463.4$$

So $P_{core} = 731.7$ W.

Now $0.9 \times 0.9 \; I_{fl}^2 r = P_{core} = 731.7$

$$I_{fl}^2 r = \frac{731.7}{0.81} = 903.33 \text{ W}$$

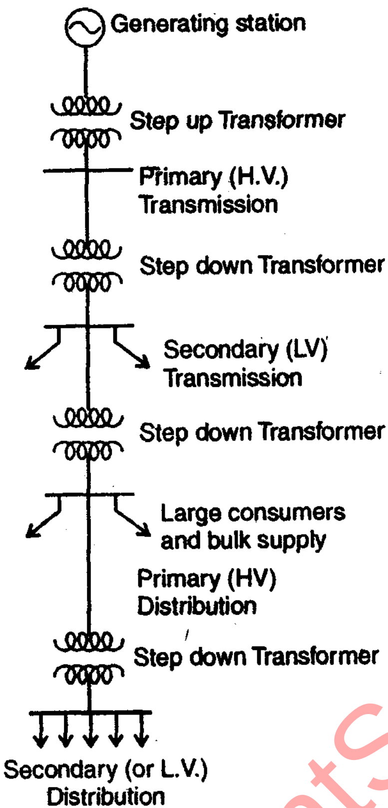
So $I_{fl}^2 r$ = full load Cu loss

So full load efficiency at unity power factor.

$$\eta_{fl} = \frac{1 \times 100 \times 10^3 \times 1}{1 \times 100 \times 10^3 \times 1 + 903.33 + 731.7}$$

$$= \frac{100000}{101635.03} = 0.9839 \text{ or } 98.39\%$$

Layout of electrical power system:



Remotely generated power is brought to load centers through transmission lines and then distributed. The transmission network is mostly at EHV level. Overhead line conductors are mostly utilised for bulk power transmission. Distribution network consists of feeders and distributors. They distribute power to service mains in consumer premises.

(*d*) What are the different torques required in an indicating type instruments? Draw and epxlain the working of attration type moving iron instrument.

Ans. Different torques required in an indicating type instrument are:

(*i*) Operating or deflecting torque (T_d)

(*ii*) Controlling torque (T_C) or restoring torque

(*iii*) damping torque

Attractioin type moving iron instruments: The attraction type moving iron instrument operates on the principle of attraction of a single piece of soft iron in a magnetic field. The atraction type moving iron instrument uses a solenoid and a moving oval shaped soft iron pivoted eccentrically.

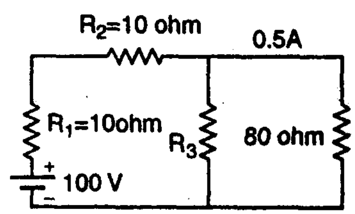
Working: When the instrument is connected in the circuit then the operating current which is to be measured by ammeter (or proportional current to measure voltage if used as a voltmeter) flows through the fixed coil. A magnetic field is set up and the soft iron piece is magnetised which is attracted towards the center of coil. A pointer attached to the spindle is deflected over the calibrated scale. If the current in the coil is reversed then the direction of magnetic field produced by the coil reverses and the magnetism produced in the soft iron piece also gets reversed. Hence the direction of deflecting torque remains unchanged. So these instruments can be used on ac as well as dc systems.

SECTION—C

Note: All questions are compulsory. All questions carry equal marks. (10×5=50)

Q.3. Attempt any two parts of the following: All parts carry equal marks.

(a) Find the voltage drop across R_1 and R_2 (see Figure). The resistance R_3 is not specified.



Ans. Drop across 80 ohms resistor = 80 × 0.5 = 40 V = drop across R_3

Now applying KVL to loop 1

$$100 - 10I_1 - 10I_1 - 40 = 0$$

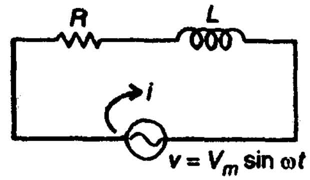
$$60 = 20I_1,\ I_1 = 3\text{ A}$$

i.e drop across R_1 and R_2 = 30V and 30V respectively.

(b) What is meant by the time constant of a first-order linear circuit? Also derive the sinusoidal response of series RL circuit.

Ans. Sinusoidal response of series RL circuit: Let v is the supply voltage to RL circuit.

KVL equation:



$$V = V_m \sin \omega t = Ri + L\frac{d}{dt}i$$

By taking laplace of this equation, assuming zero initial condition

$$V_m \frac{\omega}{S^2+\omega^2} = RI(S) + LSI(S)$$

$$\text{So} \quad I(S) = \frac{V_m\,\omega}{(R+LS)(S^2+W^2)} = \frac{\omega V_m}{L\left(S+\frac{R}{L}\right)(S^2-\omega^2)}$$

$$= \frac{\omega V_m}{L}\left[\frac{L^2}{(R^2+\omega^2L^2)\left(S+\frac{R}{L}\right)} - \frac{L^2SRL}{(R^2+\omega^2L^2)(S^2+\omega^2)}\right]$$

$$= \frac{\omega L V_m}{R^2+\omega^2L^2}\,\frac{1}{S+\frac{R}{L}} - \frac{\omega V_m LS}{(R^2+\omega^2L^2)(S^2+\omega^2)} + \frac{\omega V_m R}{(R^2+\omega^2L^2)(S^2+\omega^2)}$$

$$= \frac{\omega L V_m}{R^2+\omega^2L^2}\left[\frac{1}{S+\frac{R}{L}} - \frac{S}{S^2+\omega^2} + \frac{R}{L(S^2+\omega^2)}\right]$$

$$i(t) = L^{-1}[I(s)] = \frac{\omega L V_m}{R^2+\omega^2L^2}\left[e^{-\frac{R}{L}t} - \cos\omega t + \frac{R}{\omega L}\sin\omega t\right]$$

$$i(t) = \frac{\omega L V_m}{R^2+\omega^2L^2}e^{-\frac{R}{L}t} + V_m \sin(\omega t - \phi)$$

$$\phi = \tan^{-1}\frac{\omega L}{R},$$

$i(t)$ represents the sinusoidal response of series RL circuit.

RL circuit represents first order linear circuit. $\frac{L}{R} = \tau$, represents the time constant of RL circuit. Time constant is the time in which the transient current decays to 36.8% of the initial current at $t = 0$.

(c) Derive the relation between line voltage and phase voltage in three-phase star circuit. Also derive the expression for power.

Ans. Relations for Star Connected Load: Consider the balanced star connected load as shown in figure.

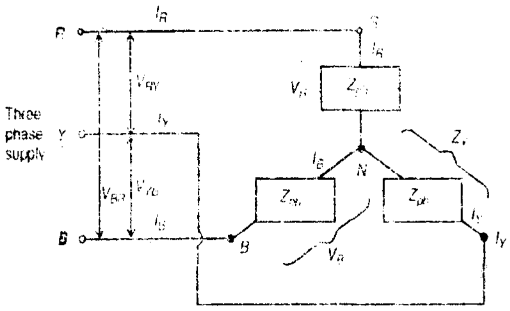


Fig. Star Connected Load

Line voltages $V_L = V_{RY} = V_{YB} = V_{BR}$

Line currents $I_L = I_R = I_Y = I_B$

Phase voltages $V_{ph} = V_R = V_Y = V_B$

Phase currents $I_{ph} = I_R = I_Y = I_B$

As seen earlier, $I_L = I_{ph}$ for star connected load. To derive relation between V_L and V_{ph}, consider line voltage V_{RY}. From the figure we can write,

$$\bar{V}_{RY} = \bar{V}_{RN} + \bar{V}_{NY}$$

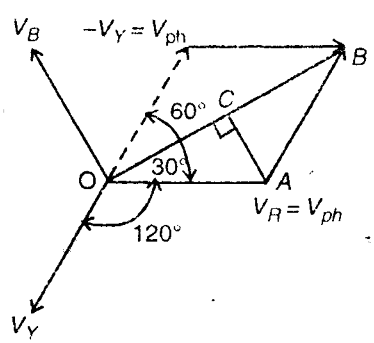
but $\quad \bar{V}_{NY} = -\bar{V}_{YN}$

Hence, $\quad \bar{V}_{RY} = \bar{V}_R - \bar{V}_Y \quad ...(1)$

Similarly, $\quad \bar{V}_{YB} = \bar{V}_{YN} + \bar{V}_{NB}$

$\quad = \bar{V}_{YN} - \bar{V}_{BN} = \bar{V}_Y - \bar{V}_B \quad ...(2)$

and $\quad \bar{V}_{BR} = \bar{V}_B - \bar{V}_R \quad ...(3)$



The three phase voltages are displaced by 120° from each other. The phasor diagram to get V_{RY} is shown in the figure. The V_Y is reversed to get $-V_Y$ and then it is added to V_R to get V_{RY}.

The perpendicular is drawn from point A on vector OB representing V_L. In triangle OAB, the sides OA and AB are same as phase voltages. Hence OB bisects angle between V_R and $-V_Y$.

$$\therefore \quad \angle BOA = 30°$$

and perpendicular AC bisects the vector OA.

$$\therefore \quad OC = CB = \frac{V_L}{2}$$

From triangle OAB,

$$\cos 30° = \frac{OC}{OA} = \frac{(V_{RY}/2)}{V_R}$$

$$\therefore \quad \frac{\sqrt{3}}{2} = \frac{(V_L/2)}{V_{ph}}$$

$$\therefore \quad V_L = \sqrt{3}\, V_{ph} \text{ for star connection.}$$

Thus line voltage is $\sqrt{3}$ times the phase voltage in star connection.

3-Phase Power $= 3\, V_{ph} I_{ph} \cos\phi$

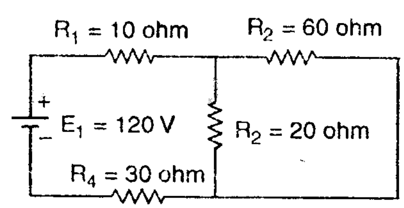
$\cos\phi$ = phase power factor

$= 3[V_L/(3)^{0.5}]\, I_L \cos\phi$

$= (3)^{0.5}\, V_L I_L \cos\phi$

Q.4. Attempt any two parts of the following. All parts carry equal marks.

(a) By means of superposition theorem find the current which flows through R_2 in the circuit of figure.



Ans. As superposition is not applicable here, solving through current division

$R_{eq} = \{(60 * 20) / 80\} + 10 + 30 = 55\,\Omega$

$I_{main} = 120 / 55$

Current through

$R_2 = (120/55) * (60/80) = 90 / 55 = 1.64\text{ A}$

(b) What is B-H curve? Also explain the hysteresis and eddy current loss.

Ans.

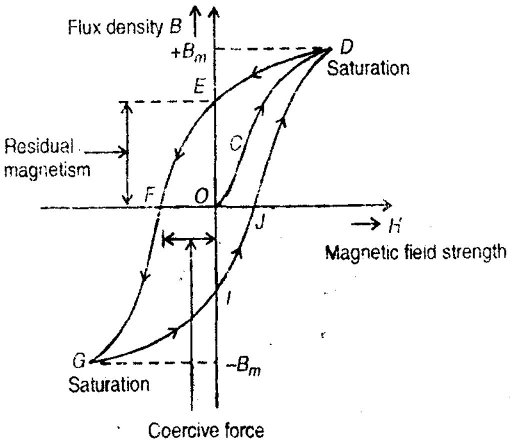


Fig. Hysteresis loop.

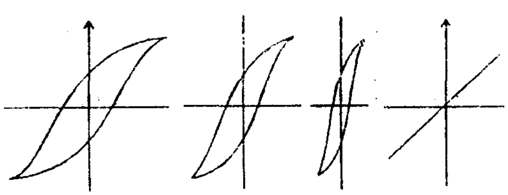
As we have seen that hysteresis loss is undesirable as it produces heat which increases temperature and also reduces the efficiency.

In machines where the frequency of the magnetization and demagnetization cycle is more, such hysteresis loss is bound to be more.

So selection of the magnetic material in such machines is based on the hysteresis loss. Less is the hysteresis loop area for the material, less will be the hysteresis loss.

Key point: So generally material with less hysteresis loop area are preferred for different machines like transformer cores, alternating current machines, telephones.

Shapes of hysteresis loops for different materials are shown in the figure.



Hysteresis loss occurring in the magnetic frame of the transformer depends upon the following:

(*i*) Area of the hysteresis loop of magnetic material used for magnetic frame, which again depends upon the flux density at which the material is being worked.

(*ii*) Volume of the core.

(*iii*) Frequency of magnetic flux reversal.

Dr. Charles Steinmetz suggested an empirical formula based on a series of tests for calculating the hysteresis loss and is given by

Hysteresis loss $= \eta V f (B_{max})^n$ watt

where n varies from 1.6 to 2.1 depending upon the material of magnetic frame and η is a constant for a particular material and is commonly known as Steinmetz's coefficient.

Eddy current loss is due to the flow of eddy current in the magnetic core and yoke of the transformer, caused by small emf induced in the magnetic frame. Eddy current loss depends upon the following factors:

(*i*) Thickness of lamination of magnetic core and yoke, t.

(*ii*) Frequency of flux reversal, f.

(*iii*) Maximum value of flux density in core and yoke, B_{max}.

(*iv*) Volume of core and yoke, V.

(*v*) Quality of magnetic material used for the magnetic frame.

Hence, eddy current losses in core and yoke of a transformer are given by,

Eddy current loss $= k V B_{max}^2 f^2 t^2$ watts

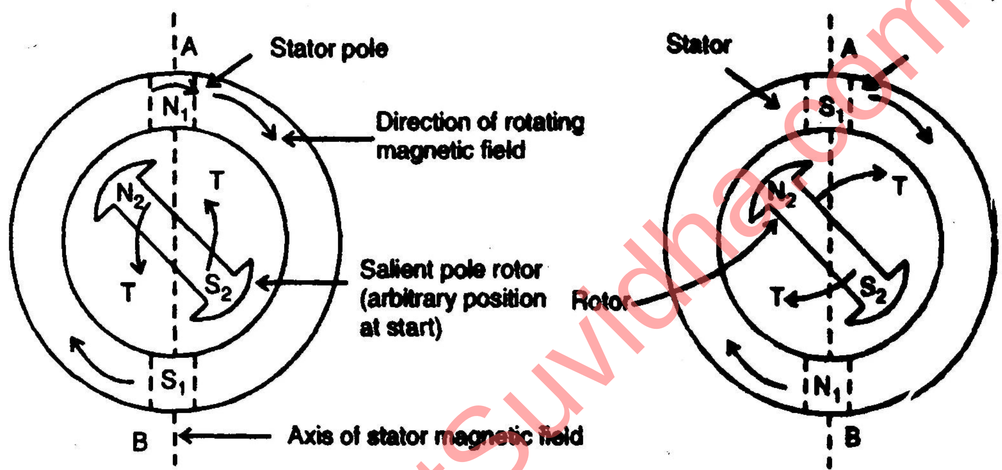
Thus, eddy current losses are directly proportional to the square of maximum value of flux density, frequency of flux reversal and thickness of lamination of magnetic frame. Eddy current losses are reduced by decreasing the thickness of lamination and also by adding a certain percentage (3 to 4 per cent) of silicon to steel. Addition of silicon to steel increases the electrical resistivity thereby decreasing the eddy current loss.

(c) Write down the principle of operation of 3-phase synchronous motor. Also write its applications.

Ans. Principle of operation of synchronous motor: Consider the rotating magnetic field as equivalent to physical rotation of two stator poles N_1 and S_1.

Consider an instant when two poles are at such a position where stator magnetic axis is vertical, along $A - B$ as shown in the figure (*a*).

At this instant, rotor poles are arbitrarily positioned as shown in the figure.



(*a*) Action of synchronous motor **(*b*) Action of synchronous motor**

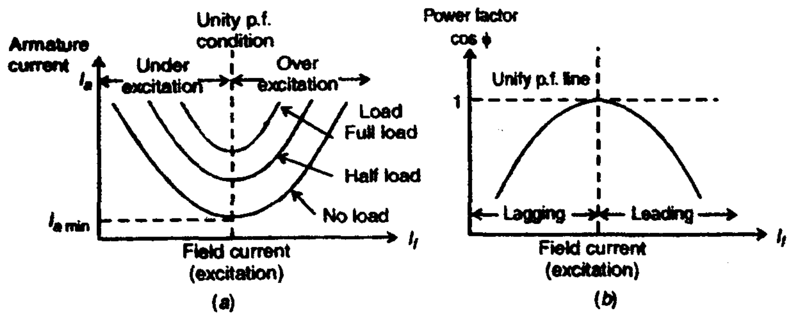
At this instant, rotor is stationary and unlike poles will try to attract each other. Due to this rotor will be subjected to an instantaneous torque in anticlockwise direction as shown in the fig. (*a*).

Now stator poles are rotating very fast i.e. at a speed N_s r.p.m. Due to inertia, before rotor hardly rotates in the direction of anticlockwise torque, to which it is subjected, the stator poles change their positions. Consider an instant half a period latter where stator poles are exactly reversed but due to inertia rotor is unable to rotate from its initial position. This is shown in the figure. (*b*)

At this instant, due to the unlike poles trying to attract each other, the rotor will be subjected to a torque in clockwise direction. This will tend to rotate rotor in the direction of rotating magnetic field.

But before this happens, stator poles again change their positions reversing the direction of the torque exerted on the rotor.

As a result, the average torque exerted on the rotor is zero. And hence the synchronous motor is not self starting.



V-curves and inverted V-curves

Synchronous motor works on the principle of the magnetic locking. When two unlike poles are brought near each other, if the magnets are strong, there exists a tremendous force of attraction between those two poles. In such condition the two magnets are said to be magnetically locked.

If now one of the two magnets is rotated, the other also rotatesin the same direction, with the same speed due to the force of attraction i.e. due to magnetic locking condition. The principle is shown schematically in the figure.

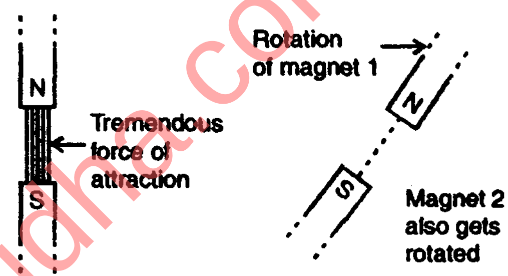


Fig. Principle of magnetic locking.

So to have the magnetic locking condition, there must exist two unlike poles and magnetic axes of two must be brought very close to each other.

Applications of synchronous motor:

1. As a constant speed motor.

2. Used as synchronous condenser, for power factor improvement of load, when working in overexcited(leading power factor) region.

Q.5. Attempt any two parts of the following. All parts carry equal marks.

(a) State the Thevenin's theorem and Norton's theorem.

Ans. Norton's Theorem:

Statement: Any combination of linear bilateral circuit elements and active sources, regardless of the connection or complexity, connected to a given load R_L, can be replaced by a simple two terminal network, consisting of a single current source of I_N amperes and a single impedance R_{eq} in parallel with it, across the two terminals of the load R_L. The I_N is the short circuit current flowing through the short circuited path, replaced instead of R_L. It is also called Norton's current. The R_{eq} is the equivalent impedance of the given network as viewed through the load terminals, with R_L removed and all the active sources are replaced by their internal impedances. If the internal impedances are unknown then the independent voltage sources must be replaced by short circuit while the independent current sources must be replaced by open circuit, while calculating R_{eq}.

Thevenin's Theorem: Statement: Any combination of linear bilateral circuit elements and active sources, connected to a given load R_L, can be replaced by a simple two terminal network, consisting of a voltage source V_{TH} and an impedance R_{eq} in series with it, across the two terminals of the load R_L. V_{TH} is the open circuit voltage at the terminals from where R_L is removed. It is known as Thevenin Voltage. R_{eq} is the equivalent impedance of the given network as viewed through load terminals with R_L removed and all the active sources are replaced by their internal impedances if any.

(b) **Explain the following terms:**

(i) Phase representation of sinusoids

(ii) Bandwidth and Quality factor.

Ans. (i) Phase representation of sinusoids:

For the given sinusoidal voltage $v = V_m \sin(\omega t + \phi)$

the phasor representation is $\bar{V} = V\angle\phi$ where V = rms value of $v = \frac{V_m}{\sqrt{2}}$

Similarly the other phasors can be represented.

(ii) Bandwidth and Quality factor: Selectivity is also defined as the ratio of resonant frequency to the bandwidth of resonant circuit.

$$\therefore \text{ Selectivity} = \frac{\text{Resonant frequency}}{\text{Bandwidth}} = \frac{f_0}{(f_2 - f_1)}$$

$$\text{Bandwidth} = f_2 - f_1 = \frac{R}{2\pi L}$$

Substituting value of bandwidth in above equation,

$$\therefore \text{ Selectivity} = \frac{f_0}{\left(\frac{R}{2\pi L}\right)} = \frac{(2\pi f_0)L}{R} = \frac{\omega_0 L}{R} = Q_0$$

Thus, selectivity of series resonant circuit is directly proportional to the quality factor of circuit at resonant frequency.

So selectivity of the resonant circuit depends on Q_0. If Q_0 is very high, amplitude response curve becomes sharper effectively decreasing bandwidth.

If Q_0 is very small, bandwidth increases making amplitude response curve flater.

We can express selectivity as

$$\therefore \text{ Selectivity} = Q_0 = \frac{f_0}{\text{Bandwidth}} = \frac{f_0}{(f_2 - f_1)}$$

$$\therefore \text{ Bandwidth} = (f_2 - f_1) = \frac{f_0}{Q_0}.$$

(c) What is accuracy and resolution of an instrument? Briefly explain the induction type energy meter.

Ans. Accuracy: It is the degree of closeness with which the instrument reading approaches the true value of the quantity to be measured. It denotes the extent to which we approach the actual value of the quantity. It indicates the ability of an instrument to indicate the true value of the quantity. The accuracy can be expressed in the following ways:

1. Accuracy as 'Percentage of Full Scale Reading': In case of instruments having uniform scale, the accuracy can be expressed as percentage of full scale reading. For example, the accuracy of an instrument having full scale reading of 50 units may be expressed as ± 0.1% of full scale reading. From this accuracy indication, practically accuracy is expressed in terms of limits of error. So for the accuracy limits specified above, there will be ± 0.05 units error in any measurement. So for a reading of 50 units, there will be error of ± 0.05 units i.e. ± 0.1% while for reading of 25 units, there will be error of ± 0.05 units in the reading i.e. ± 0.2%. Thus as reading decreases, error in measurement is ± 0.05 units but net percentage error is more. Hence, specification of accuracy in this manner is highly misleading.

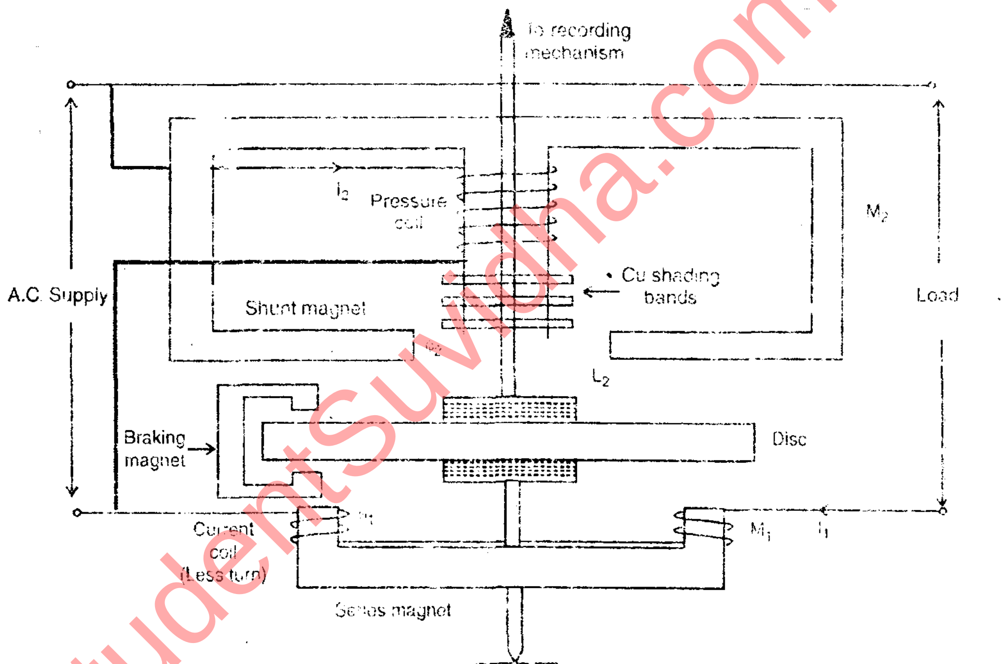
Resolution: It is the smallest increment of quantity being measured which can be detected with certainity by an instrument.

Key point: Thus, the resolution means the smallest measurable input change.

So if a non zero input quantity is slowly increased, output reading will not increase until some minimum change in the input takes place. This minimum change which causes the change in the output is called resolution. The resolution of an instrument is also referred as discrimination of the instrumnet. The resolution can affect the accuracy of the measurement.

Induction type energy meter: Induction type instruments are most commonly used as energy meters. Energy meter is an integrating instrument which measures quantity of electricity. Induction type of energy meters are universally used for domestic and industrial applications. These meters record the energy in kilo-watt-hours (kWh).

The figure shows the induction type single phase energy meter.



It works on the principle of induction i.e. on the production of eddy currents in the moving system by the alternating fluxes. These eddy currents induced in the moving system interact with each other to produce a driving torque due to which disc rotates to record the energy.

In the energy meter there is no controlling torque and thus due to driving torque only, a continuous rotation of the disc is produced. To have constant speed of rotation braking magnet is provided.

There are four main parts of operating mechanism:

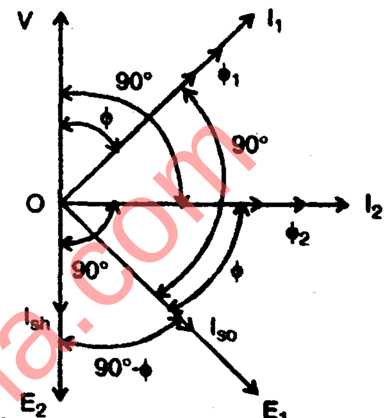
(1) Driving system, (2) Moving system, (3) Braking system, (4) Registering system.

1. Driving system: It consists of two electromagnets whose core is made up of silicon steel laminations. The coil of one of the electromagnets, called current coil, is excited by load current which produces flux further. The coil of another electromagnet is connected across the supply and it carries current proportional to supply voltage. This coil is caleld pressure coil. These two electromagnets are called series and shunt magnets respectively.

The flux produced by shunt magnet is brought in exact quadrature with supply voltage with the help of copper shading bands whose position is adjustable.

2. Moving system: Light aluminium disc mounted in a light alloy shaft is the main part of moving system. This disc is positioned in between series and shunt magnets. It is supported between jewel bearings. The moving system runs on hardened steel pivot. A pinion engages the shaft with the counting mechanism. There are no springs and no controlling torques.

3. Braking system: A permanent magnet is placed near the aluminium disc for braking mechanism. This magnet reproduced its own field. The disc moves in the field of this magnet and braking torque is obtained. The position of this magnet is adjustable and hence braking torque is adjusted by shifting this magnet to different radial positions. This magnet is called Braking magnet.



Now I_2 lags V by 90° as pressure coil is highly inductive and copper shading bands. And ϕ_2 and I_2 are in phase. While I_1 lags V by ϕ where ϕ is decided by the load connected. The flux ϕ_1 and I_1 are in phase.

The phasor diagram is shown in the figure.

E_1 = induced emf in disc due to ϕ_1

E_2 = induced emf in disc due to ϕ_2

I_{sh} = eddy current due to E_1

I_{se} = eddy current due to E_2

The induced e.m.f. lags the respective flux producing it by 90°. The eddy curmets are in phase with the induced emf producing them.

Now there is interaction between ϕ_1 and I_{sh} which produces torque T_1 and the interaction between ϕ_2 and I_{se} which produces torque T_2. T_2 is in opposite direction to T_1. Hence net deflecting torque is

$$T_d \propto T_2 - T_1$$

$$\propto \phi_2 I_{se} \cos(\phi_2 \wedge I_{se}) - \phi_1 I_{sh} \cos(\phi_2 \wedge I_{sh})$$

Now $\phi_2 \wedge I_{se} = \phi$ and $\phi_1 \wedge I_{sh} = \phi$ from fig.

$\therefore$ $$T_d \propto \phi_2 I_{se} \cos\phi - \phi_1 I_{sh} \cos(180 - \phi)$$

$$T_d \propto \phi_2 I_{se} \cos\phi + \phi_1 I_{sh} \cos\phi$$

as $\cos(180 - \phi_1) = -\cos\phi$

but $\phi_2 \propto I_2 \propto V,\ I_{se} \propto E_1 \propto I_1,\ \phi_1 \propto I_1,\ I_{sh} \propto E_2 \propto I_2 \propto V$

Now braking torque is proportial to speed N with which disc rotates.

$\therefore$ $T_d \propto N$

For constant speed, $T_b = T_d$

$\therefore$ $N \propto VI_1 \cos\phi$

Multiplying both side by t, $Nt \propto VI_1 t \cos\phi \propto Pt$

Number of revolutions in time $t \propto$ energy supplied.

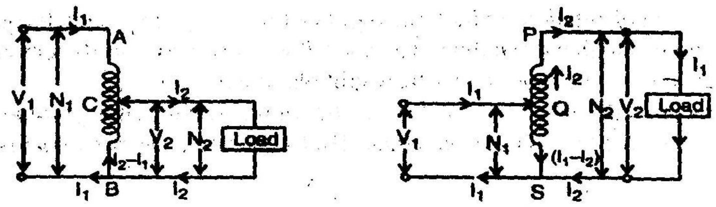
Q.6. Attempt any two parts of the following. All parts carry equal marks.

(a) Describe the working of an auto transformer.

Ans. An autotransformer is a special type of transformer such that a part of the winding is common to both primary as well as secondary. It has only winding wound on a laminated magnetic core. With the help of autotransformer the voltage can be stepped down or can be stepped up also, to any desird value.

Fig. (*a*) shows the step down autotransformer. *AB* acts as a primary winding while part of the primary winding *BC* acts as a secondary winding. The position of *C* called as % tapping tapping point, can be selected as per the requirement of the secondary voltage.

Fig. (*b*) shows the step up autotransformer where *QS* acts as a primary winding while *PS* acts as a secondary winding.



(a) Step down (b) Step up

(b) Explain the PMMC instrument. Also derive the expression for deflecting torque.

Ans. The various advantages or function of PMMC instruments are:

1. It has uniform scale.
2. With a powerful magnet, its torque to weight ratio is very high. So operating current is small.
3. The sensitivity is high.
4. The eddy currents induced in the metallic form over which coil is wound, provide effective damping.
5. It consumes low power, of the order of 25 W to 200 μW.
6. It has high accuracy.
7. Instrument is free from hysteresis error.
8. Extension of instrument range is possible.
9. Not affected by external magnetic fields called stray magnetic fields.

PMMC (Permanent magnet moving coil) instruments are used for measuring d.c. quantities.

It has been mentioned that the interaction between the induced field and the field produced by the permanent magnet causes a deflecting torque, which results in rotation of the coil. The deflecting torque produced is described below in mathematical form:

Deflecting Torque: If the coil is carrying a current of i amp, the force on a coil side =Bil N (newton, N).

Torque due to both coil sides=2r (Bil N) Nm =Gi Nm

Where G = Galvanometer Constant = 2rBlN Nm/amp. = NBANm/amp

A = 2rl = area of the coil

N = No. of turns on the coil

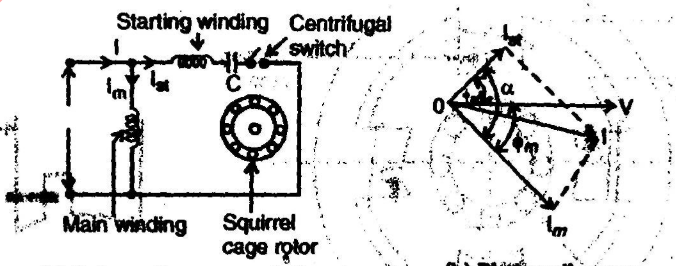
B = flux density

l = length of vertical side of coil

2r = breadth of the coil

(c) Explain the starting methods of single phase induction motor.

Ans.



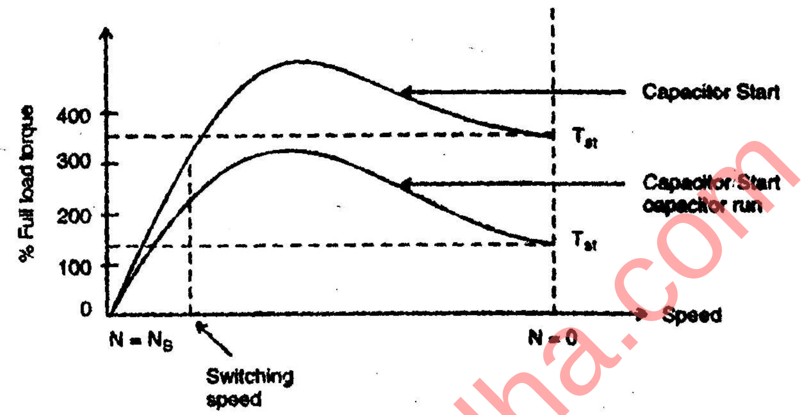
(a) Schematic representation (b) Phasor diagram

The starting torque is proportional to 'α' and hence such motors produce very high starting torque.

When speed approaches to 75 to 80% of the synchronous speed, the starting winding gets disconnected due to operation of the centrifugal switch. The capacitor remains in the circuit only at start hence it is called capacitor start motors.

The direction of rotation, in both the types can be changed by interchanging the connections of main winding or auxiliary winding. The capacitor permanently in the circuit improves the power factor. These motors are more costly than split phase type motors.

The capacitor value can be selected as per the requirement of starting torque, the starting torque can be as high as 350 to 400% of full load torque. The torque-speed characteristics is as shown in the figure.

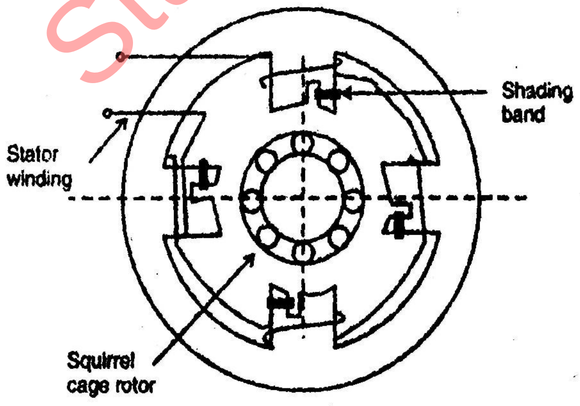


Torque-speed characteristics of capacitor split phase motor: These motors have high starting torque and hence are used for hard starting loads. These are used for compressors, conveyors, grinders, fans, blowers, refrigerators, air conditioners etc. These are most commonly used motors. The capacitor start capacitor run motors are used in ceiling fans, blowers and air-circulators. These motors are available upto 6 kW.

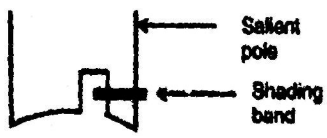
Shaded pole type induction motor: This type of motor consists of a squirrel cage rotor and stator consisting of salient poles i.e. projected poles. The poles are shaded i.e. each pole carries a copper band on one of its unequally divided part called shading band. Fig. (*a*) shows 4 pole shaded pole construction while fig. (*b*) shows a single pole consisting of copper shading band.

The production of rotating magnetic field can be explained as below:

The current carried by the stator winding is alternating and produces alternating flux. The waveform of the flux is shown in the fig. (*a*). The distribution of this flux in the pole area is greatly influenced by the role of copper shading band. Consider the three instants say t_1, t_2 and t_3 during first half cycle of the flux as shown in the figure.

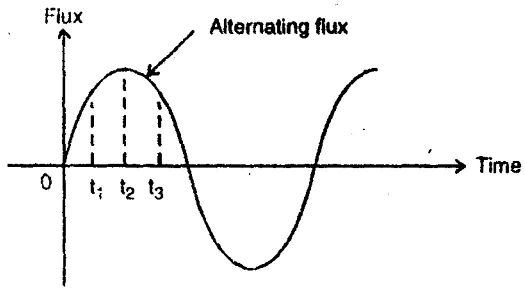


(a) 4-pole shaded pole construction

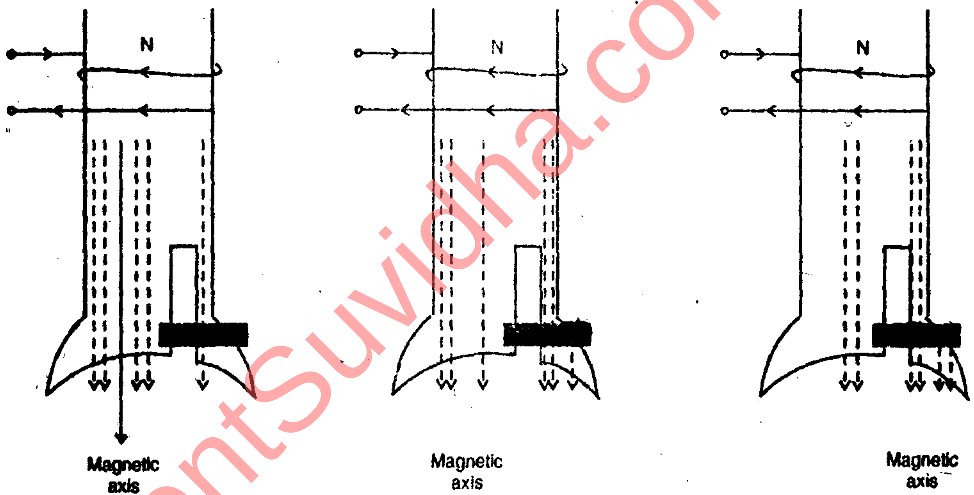


(b) Salient pole with shading band

At instant $t = t_1$, rate of rise of current and hence the flux is very high. Due to the transformer action, large emf gets induced in the copper shading band. This circulates current through shading band as it is short circuited, producing its own flux. According to Lenz's law, the direction of this current is so as to oppose the cause i.e. rise in current. Hence shading ring flux is opposing to the main flux. Hence there is crowding of flux in nonshaded part while weakening of flux in shaded part. Overall magnetic axis shifts in nonshaded part as shown in the figure.

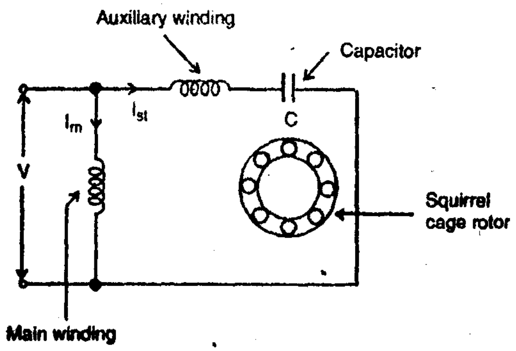


Waveform of stator flux



(b) At $t = t_1$ (c) At $t = t_2$ (d) At $t = t_3$

Capacitor start capacitor run: In case of capacitor start capacitor run motor, there is no centrifugal switch and capacitor remains parmanently in the circuit. This improves the power factor. The schematic representation of such motor is shown in the figure.



Capacitor start capacitor run motor

The phasor diagram remains same as shown in the figure (*b*). The performance not only at start but in running condition also depends on the capacitor *C* hence its value is to be designed so as to compromise between best starting and best running condition.

Q.7. Attempt any two parts of the following. All parts carry equal marks.

(a) Derive the sinusoidal response of parallel RC circuit.

Ans. Sinusoidal Resonse of parallel RC Circuit: The parallel RC circuit is generally of less interest than the series circuit. This is largely because the output voltage V_{out} is equal to the input voltage V_{in} – as a result, this circuit does not act as a filter on the input signal unless fed by a current source.

With complex impedances:

$$I_R = V_{in}/R \quad \text{and} \quad I_c = jwC\, V_{in}$$

this shows that the capacitor current is 90° leading from the resistor current.

Soruce current $I = \sqrt{I_R^2 + I_c^2}$ I will lead from I_R (or V_{in}) by angle $\phi = \tan^{-1}\frac{I_c}{I_R}$

(b) Explain the following:

(*i*) Efficiency of transformer

(*ii*) Operation of alternator

Ans. (*i*) **Efficiency of transformer:** As is the case with other types of electrical machines, the efficiency of a transformer at a particular load and power factor is defined as the output divided by the input the two being measured in the same units (either watts or kilowatts).

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

But a transformer being a highly efficient piece of equipment, has very small loss, hence it is impractical to try to measure transformer, efficiency by measuring input and output. These quantities are nearly of the same size. A better method is to determine the losses and then to calculate the efficiency from;

$$\text{Efficiency} = \frac{\text{Output}}{\text{Output + losses}} = \frac{\text{Output}}{\text{Output + Cu loss + iron loss}}$$

or $$\eta = \frac{\text{Input} - \text{Losses}}{\text{Input}} = 1 - \frac{\text{Losses}}{\text{Input}}$$

It may be noted here that efficiency is based on power output in watts and not in volt-amperes, although losses are proportional to VA. Hence, at any volt-ampere load, the efficiency depends on power factor, being maximum at a power factor of unity.

(*ii*) Operation of alternator: AC generators or alternators (as they are usually called) operate on the same fundamental principles of electromagnetic induction as dc generators. They also consist of an armature winding and a magnetic field. But there is one important difference between the two. Whereas in dc generators, the armature rotates and the field system is stationary, the arrangement in alternators is just the reverse of it. In their case, standard construction consists of armature winding mounted on a stationary element called stator and field windings on a rotating element called rotor.

When the rotor rotates, the stator conductors (being stationary) are cut by the magnetic flux, hence they have induced emf produced in them. Because the magnetic poles are alternately *N* and *S*, they induce an emf and hence current in armature conductors, which first flows in one direction and then in the other. Hence, an alternating emf is produced in the stator conductors (*i*) whose frequency depends on the number of N and S poles moving past a conductor in one second and (ii) whose direction is given by Fleming's Right hand rule.

(c) A three-phase 4 pole induction motor is running with 4% slip. The supply frequency is 50 Hz. Find out the speed of induction motor.

Ans. Synchronous speed = 120 × 50/4 = 1500 RPM

$$N_r = N_s(1-s) = 1500(1 - 0.04) = 1440 \text{ RPM.}$$