# Elements of Electrical Engineering

Prelim Question Paper Solution

**Time: 3 Hrs.]** **[Marks : 70**

**Q.1 Attempt any FIVE of the following : [10]**

**Q.1(a) Define Faraday's first law of electromagnetic induction. [2]**

**Ans.: Faraday's First Law:**

Whenever a changing magnetic flux links with a conductor, an emf is induced in that conductor.

**OR**

When a conductor cuts across magnetic field, an emf is induced in that conductor.

**Q.1(b) State working principle of transformer. [2]**

**Ans.: Working principle of transformer:**

Transformer works on the principle of mutual electromagnetic induction. When AC voltage is applied to the primary winding it causes ac current to flow through primary winding which produces alternating flux in the core. This changing flux links with the secondary winding and according to Faraday's law of electromagnetic induction, an emf is induced in the secondary winding. The current flows in the secondary circuit if load is connected.

**Q.1(c) Write two applications of D.C. series motor. [2]**

**Ans.: The applications of D.C. series motor:**

(i) Cranes
(ii) Hoists
(iii) Trolley and cars
(iv) Conveyors
(v) For traction work i.e. electric locomotives
(vi) Elevator
(vii) Air compressor

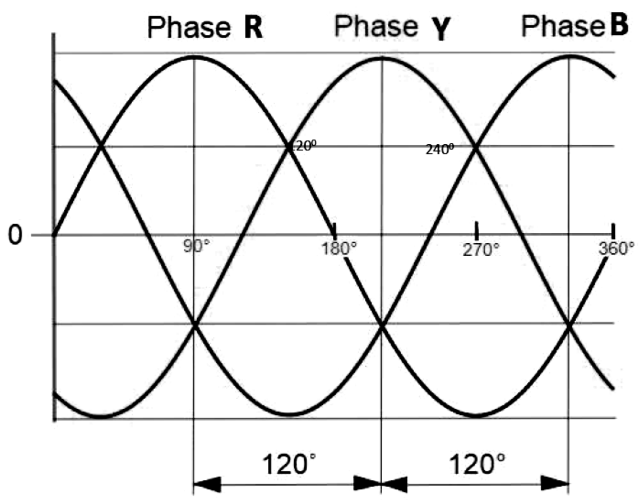
**Q.1(d) Write any two advantages of AC over DC. [2]**

**Ans.: Advantages of AC over DC:**

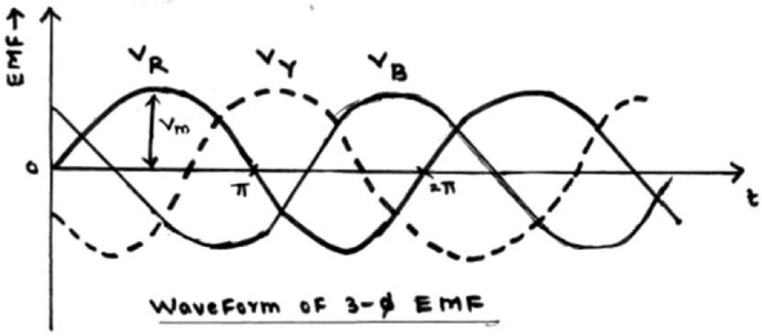
(i) We can easily step up or step down the voltage easily with the help of transformer
(ii) Generation is easy.
(iii) Design of AC machine is easy.

**Q.1(e) Draw the waveform representation of a three phase AC supply with neat labels. [2]**

**Ans.:**




OR equivalent Figure




**Q.1(f) Define the transformation ratio of a transformer.** **[2]**

**Ans.: Transformation Ratio (k):**

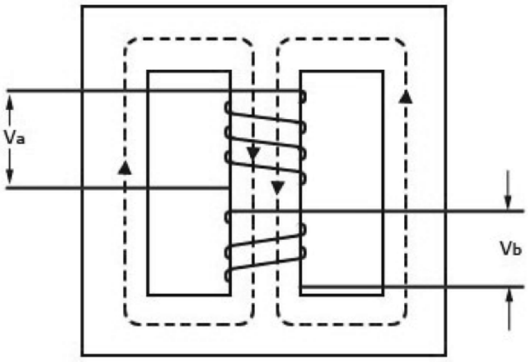
It is the ratio of secondary number of turns to primary number of turns. OR It is the ratio of secondary voltage to primary voltage. OR It is the ratio of primary current to secondary current.

***OR***

Transformation ratio (k) = $\frac{N_2}{N_1}$ or = $\frac{E_2}{E_1}$ or = $\frac{V_2}{V_1}$ or = $\frac{I_1}{I_2}$

**Q.1(g) Draw neat constructional sketch of shell type transformer.** **[2]**

**Ans.: Constructional sketch of shell type transformer:**




**Q.2 Attempt any THREE of the following :** **[12]**

**Q.2(a) Explain the concept of lagging and leading phase angle by waveform.** **[4]**

**Ans.: (i) Leading phase angle:**

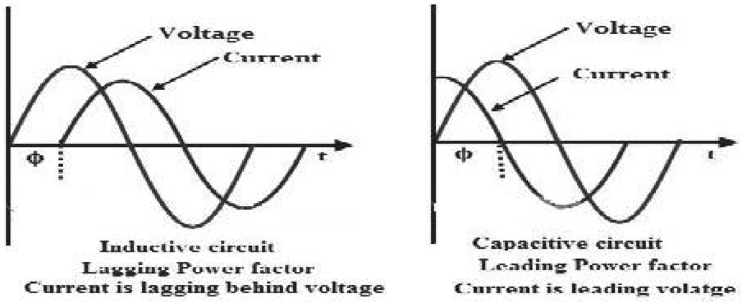
When two ac quantities of same frequency do not attain their respective zero or peak values simultaneously, then the quantities are said to be out-of-phase quantities. The quantity which attains the respective zero or peak value first, is called 'Leading Quantity'.

In the following first diagram, the voltage attains its zero or positive peak first and after an angle of $\phi$, the current attains its respective zero or positive peak value, hence voltage is said to be leading the current by an angle of $\phi$. Similarly, in the second diagram, the current is said to be leading the voltage by $\phi$.

**(ii) Lagging phase angle:**

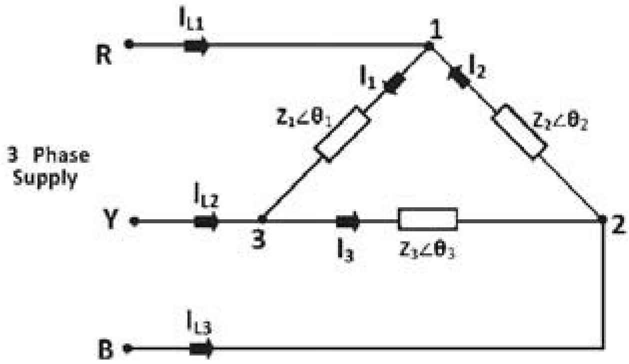
The quantity which attains the respective zero or peak value later, is called 'Lagging Quantity'.

In the following first diagram, the current attains its zero or positive peak later than the voltage after an angle of $\phi$, hence current is said to be lagging the voltage by an angle of $\phi$. Similarly, in the second diagram, the voltage is said to be lagging the current by $\phi$.




**Q.2(b) Draw delta connected load. Sate relation between:** **[4]**
**(i) Line voltage and phase voltage**
**(ii) Line current and phase current**

**Ans.:**




(i) Relation between Line voltage and phase voltage in delta connection:

Line voltage = Phase voltage

$V_L = V_{ph}$

(ii) Relation between Line current and phase current in delta connection:

Line current = $\sqrt{3}$ phase current

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

**Q.2(c) List the main parts of DC motor. Give the function of any two parts.** **[4]**

**Ans.: Main parts of D.C. motor and their functions:**

| Part | Functions |
|---|---|
| Yoke | (i) Provides mechanical support for poles.<br>(ii) Acts as protecting cover for machine.<br>(iii) Carries magnetic flux. |
| Pole Core & Pole Shoes | (i) Provides support for the field winding, which is placed around it.<br>(ii) Allows the field winding to produce magnetic flux in it.<br>(iii) Pole shoes spread out the magnetic flux over the armature periphery more uniformly. |
| Field Winding | Produces mmf and consequently magnetic flux when carries current. |
| Armature | (i) It houses the armature conductors.<br>(ii) It provides rotation of armature conductors in the magnetic field. |
| Armature Winding | Provides conductors to<br>- induce emf in it (in generator)<br>- produce force on it (in motor) |
| Commutator | (i) Works as media to collect from or to send current to the armature winding.<br>(ii) Helps to maintain unidirectional current in armature winding. |

| | |
|---|---|
| Brush | (i) To inject or collect current from rotating armature winding.<br>(ii) To facilitate electrical connection of rotating armature winding to external stationary circuit. |
| Bearings | (i) To support the rotor and reduce friction for smooth rotation of rotor.<br>(ii) Maintains rotor in a fixed physical position relative to the stator. |
| Shaft | Used to transfer mechanical power |

**Q.2(d) State four advantages of poly-phase circuit over single phase circuit.** **[4]**

**Ans.:** **Advantages of 3-phase supply over 1-phase supply:**

**(i) Constant power output:** The power delivered by a three phase supply is constant and that of single phase supply is oscillating.

**(ii) Higher power:** For the same copper size output of 3 phase supply is always higher than single phase supply.

**(iii) Smaller conductor cross section:** For given power, cross section area of copper is smaller as compared to single phase.

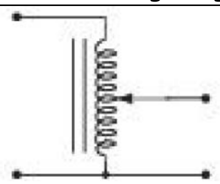
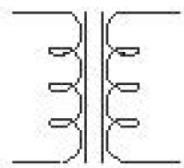
**(iv) Magnetic field:** Three phase supply has rotating magnetic field and single phase supply has pulsating magnetic field.

**(v) Power Handling Capacity:** Power handling capacity of three phase supply is three times more than single phase supply

**Q.3 Attempt any THREE of the following :** **[12]**

**Q.3(a) Compare autotransformer with two winding transformer (any four points)** **[4]**

**Ans.:** **Comparison of Autotransformer with Two winding transformer:**

| Sr. No. | Autotransformer | Two winding Transformer |
|---|---|---|
| 1 | Only one winding, part of the winding is common for primary and secondary. | There are two separate windings for primary and secondary. |
| 2 | Movable contact exist | No movable contact between primary and secondary |
| 3 | Electrical connection between primary and secondary. | Electrical isolation between primary and secondary windings. |
| 4 | Comparatively lower losses. | Comparatively more losses |
| 5 | Efficiency is more as compared to two winding transformer. | Efficiency is less as compared to autotransformer. |
| 6 | Copper required is less, thus copper is saved. | Copper required is more. |
| 7 | Spiral core construction | Core type or shell type core construction |
| 8 | Special applications where variable voltage is required. | Most of the general purpose transformers where fixed voltage is required. |
| 9 | Cost is less | Cost is more |
| 10 | Better voltage regulation | Poor voltage regulation |
| 11 | <br>Symbol of Autotransformer | <br>Symbol of Two winding transformer |

**Q.3(b) Give the working of MCCB.** **[4]**

**Ans.: Working of MCCB: (Molded Case Circuit Breaker)**

- The operating mechanism consisting of lever, spring, contacts etc. is used to open or close the MCCB electrically.
- The arc extinguisher facilitates for the quenching of arc by lengthening it which is produced when MCCB gets opened and current is interrupted.
- The trip unit is the brain of the circuit breaker. It senses the overload or shortcircuit condition and trip mechanism is operated to trip the MCCB.
- When overload occurs, the thermal relay mechanism permits overload for short duration, then bimetal strip actuates the tripping mechanism to open the MCCB contacts.
- When short-circuit occurs, large magnetic force produced by short-circuit current operates the lever to trip the MCCB immediately and open the contacts.

**Q.3(c) Write emf equation of transformer and explain each term.** **[4]**

**Ans.:** There are two emf equations of a transformer :

$E_1 = 4.44\ f\ \Phi m\ N_1$ volts

$E_2 = 4.44\ f\ \Phi m\ N_2$ volts

where,

$E_1$ = emf induced in primary winding of transformer in **volts.**

$E_2$ = emf induced in secondary winding of transformer in **volts.**

f = frequency of the applied electrical signal to the winding in **Hertz.**

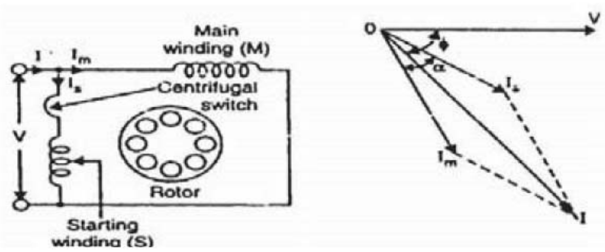
$\Phi m$ = maximum flux induced in the winding in **webers.**

$N_1$ = number of turns on primary winding.

$N_2$ = number of turns on secondary winding.

**Q.3(d) Draw and explain split phase induction motor.** **[4]**

**Ans.:**
- The stator of a split-phase induction motor is provided with an auxiliary or starting winding S in addition to the main or running winding M.
- The starting winding is located 90° electrical from the main winding and operates only during the brief period when the motor starts up. The two windings are so designed that the starting winding S has high resistance and relatively small reactance while the main winding M has relatively low resistance and large reactance as shown in the schematic connections. Consequently, the currents flowing in the two windings have reasonable phase difference ($\alpha$ = 25° to 30°) as shown in the phasor diagram.
- When the two stator windings are energized from a single-phase supply, the main winding carries current $I_m$ while the starting winding carries current $I_s$.



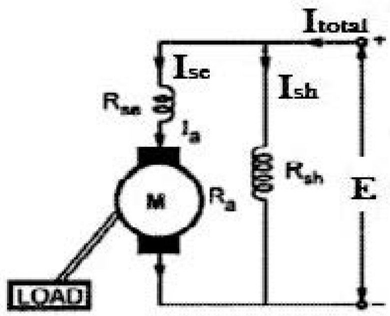

- Since main winding is highly inductive while the starting winding is highly resistive, the currents Im and Is have a reasonable phase angle ($\alpha$ = 25° to 30°) between them.
- Consequently, a revolving field approximating to that of a 2-phase machine is produced which starts the motor.
- When the motor reaches about 75% of synchronous speed, the centrifugal switch opens the circuit of the starting winding. The motor then operates as a single-phase induction motor and continues to accelerate till it reaches the normal speed. The normal speed of the motor is below the synchronous speed and depends upon the load on the motor.

**Q.4 Attempt any THREE of the following :** **[12]**

**Q.4(a) Draw schematic diagram of long shunt DC compound motor. Give one application.** **[4]**

**Ans.:** **Long shunt D.C. compound motor:**

Applications:
(i) Rolling mills
(ii) Cutting and shearing tools.
(iii) Presses
(iv) Punches
(v) Conveyors
(vi) Elevators.




**Q.4(b) With neat sketch give the working of shaded pole induction motor.** **[4]**

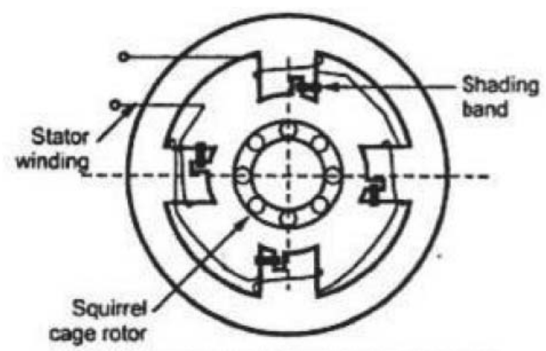
**Ans.:** **Working of Shaded Pole Induction Motor:**

When single phase supply is applied across the stator winding, an alternating field is created. The flux distribution is non uniform due to shading bands on the poles. The shading band acts as a single turn coil and when links with alternating flux, emf is induced in it. The emf circulates current as it is simply a short circuit. The current produces the magnetic flux in the shaded part of pole to oppose the cause of its production which is the change in the alternating flux produced by the winding of motor. Now consider three different instants of time $t_1$, $t_2$, $t_3$ on the flux wave to examine the effect of shading band as shown in the figure.

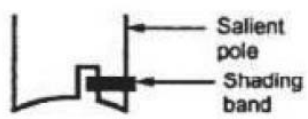
**At instant $t_1$:** The flux is positive and rising, hence the shading band current produces its own flux to oppose the rising main flux. Due to this opposition, the net flux in shaded portion of pole is lesser than that in unshaded portion. Thus the magnetic axis lies in the unshaded portion and away from shaded portion.

**At instant $t_2$:** The flux is maximum, the rate of change of flux is zero. So the shading band emf and current are zero. Thus the flux distribution among shaded and unshaded portion is equal. The magnetic axis lies in the centre of the pole.

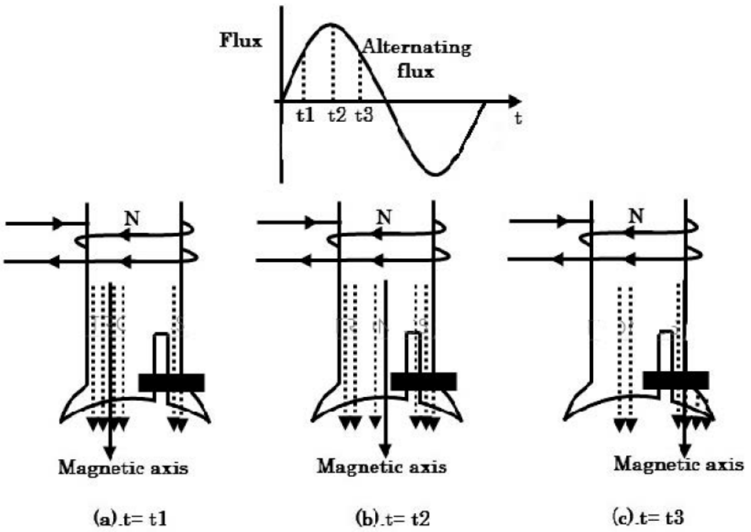
**At instant $t_3$:** The flux is positive but decreasing, hence according to Lenz's rule, the shading band emf and current try to oppose the fall in the main flux. So the shading band current produces its own flux which aids the main flux. Since shading band produces aiding flux in shaded portion, the strength of flux in shaded portion increases and the magnetic axis lies in the shaded portion. Thus it is seen that as time passes, the magnetic axis shifts from left to right in every half cycle, from non-shaded area of pole to the shaded area of the pole. This gives to some extent a rotating field effect which is sufficient to provide starting torque to squirrel cage rotor and rotor rotates.



(a) 4 - pole shaded pole construction



(b) Salient pole with shading band




**Q.4(c) Give the function of fuse and switch.** **[4]**

**Ans.: Functions of fuse:**

- To break the circuit under fault condition.
- To provide overcurrent protection to the circuit.
- To provide short circuit protection to the circuit.
- To provide safety to the users.

**Functions of Switch:**

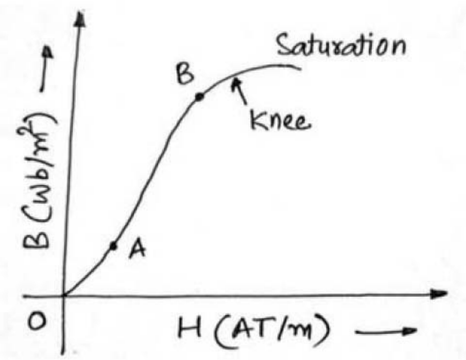
- To make the electric circuit manually.
- To break the electric circuit manually.

**Q.4(d) Explain B-H curve and draw with all parameters.** **[4]**

**Ans.: B-H curve:**

The B-H curve is the graphical representation of relation between flux density (B) and applied field strength (H), with H plotted on the x-axis and B plotted on the y-axis.

Typical B-H curve is as shown in figure below:

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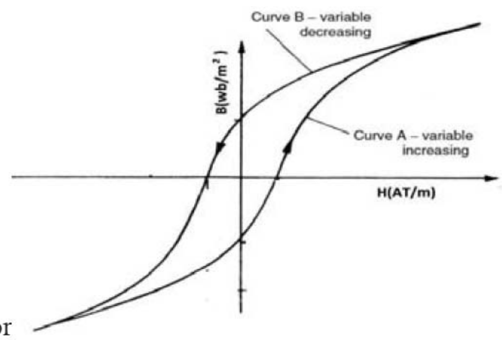



OR Equivalent Figure

**The B-H curve can be described by dividing it into 3 regions.**

- **Region OA:** For zero current, H = 0 and B is also zero. The flux density B then increases gradually as the value of H is increased. However B changes slowly in this region.
- **Region AB:** In this region, for small change in H, there is large change in B. The B-H curve is almost linear in this region.
- **Region beyond B:** After point B, the change in B is small even for a large change in H. Finally, the B-H curve will tend to be parallel to X axis. This region is called as saturation region.

**Q.4(e) Give classification of fuse and material used for fuse.** **[4]**

**Ans.:** **Classification of fuses:**

(i) Rewireable or Kit-Kat type (semi enclosed type)
(ii) HRC (high rupturing capacity) fuse
(iii) Totally enclosed type
(iv) Cartridge type.

**Name the material used for fuse wire:**

| Sr. No. | Material used for fuse wire |
|---|---|
| 1 | Tin |
| 2 | Lead |
| 3 | Zinc |
| 4 | Silver |
| 5 | Copper |
| 6 | Aluminum |

**Q.5 Attempt any TWO of the following :** **[12]**

**Q.5(a) A balanced 3– $\phi$ star connected load consist of three resistances each of four Ohm's connected to 400 V, 3 phase 50 Hz supply, find:** **[6]**

**(i) Phase voltage (ii) Phase current**
**(iii) Line current (iv) Power consumed**

**Ans.:** Given Data:

Load is star connected.
Line voltage = $V_L$ = 400 Volt
Frequency = f = 50 Hz
Resistance per phase = $R_{ph}$ = 4 $\Omega$

(i) Phase voltage: $V_{ph} = \frac{V_L}{\sqrt{3}} = 400/\sqrt{3} = 230.94$ Volt

(ii) Phase current: $I_{ph} = \frac{V_{ph}}{R_{ph}} = \frac{230.94}{4} = 57.73$ ampere

(iii) Line Current: $I_L = I_{ph} = 57.73$ ampere

(iv) Power consumed: $P = \sqrt{3} \times V_L \times I_L \times \cos\phi$
$= \sqrt{3} \times 400 \times 57.73 \times 1$
= 39996.51 watt or 39.99 KW

**OR**

Power consumed = $P = 3 \times V_{ph} \times I_{ph} \times \cos\phi$
$= 3 \times 230.94 \times 57.73 \times 1$
= 39996.49 watt or 39.99 KW

**Q.5(b) An alternating current given by equation i = 142.14 sin 628t. find –** **[6]**

**(i) Maximum value (ii) Time period (iii) RMS value**
**(iv) Average value (v) Form factor (vi) Peak factor**

**Ans.:** i = 142.14 sin 628t

Comparing with standard equation: $i = I_M \sin \omega t$

**(i) Maximum Value:** $I_M$ = 142.14 Amp

Frequency $= \frac{\omega}{2\pi}$

$= \frac{628}{2\pi}$

F = 99.94 $\cong$ 100 Hz

**(ii) Time Period (T):**

$$T = \frac{1}{F} = \frac{1}{100}$$

$$T = 0.01 \text{ sec}$$

**(iii) RMS Value $I_{rms}$** $= 0.707 \times I_m$

$= 0.707 \times 142.14$

$= 100.49$ Amp

**(iv) Average Vale $I_{avg}$** $= 0.637 \times I_m$

$= 0.637 \times 142.14$

$= 90.54$ Amp

**(v) Form Factor** $= \dfrac{\text{RMS Value}}{\text{Average Value}}$

$= \dfrac{100.49}{90.54}$

$= 1.11$

**(vi) Peak Factor** $= \dfrac{\text{Maximum Value}}{\text{RMS Value}}$

$= \dfrac{142.14}{100.49}$

$= 1.41$

**Q.5(c) Three impedance, each of 10 Ω resistance and 5 Ω inductive reactance in series, are connected in star across a 3 phase, 400V, 50 Hz AC supply. Determine –** **[6]**

**(i) Phase current (ii) Line current (iii) Phase voltage**

**(iv) Line voltage (v) Power factor (vi) Total line power**

**Ans.:** Given Data:

$Z_{ph} = 10 + j\,5\ \Omega$ $\qquad V_L = 400$ V

$R_{ph} = 105\ \Omega$ $\qquad X_{LPh} = 5\Omega$ $\qquad F = 50H_Z$

**(i) Phase voltage ($V_{ph}$):**

$$V_{ph} = \frac{V_L}{\sqrt{3}}$$

$$V_{ph} = \frac{400}{\sqrt{3}}$$

$$V_{ph} = 230.94 \text{ volts}$$

**(ii) Phase Current ($I_{ph}$):**

$$I_{ph} = \frac{V_{ph}}{Z_{ph}}$$

$$I_{ph} = \frac{230.94}{10 + j5}$$

$$I_{ph} = \frac{230.94}{11.18\angle 26.56}$$

$$I_{ph} = 20.65 \angle -26.56 \text{ Amps}$$

**(iii) Line Current ($I_L$):**

In Star connection $I_L = I_{ph}$

$I_L = 20.65$ Amps

**(iv) Line Voltage ($V_L$):** 400 Volt

**(v) Power Factor (P.F):**

$$\cos\phi = \frac{R}{Z}$$

$$\cos\phi = \frac{10}{11.18}$$

$\cos\phi = 0.8944$ lag OR P.F = $\cos\phi$ 26.56 = 0.8944 lag

**(vi) Total Line Power ($P_T$):**

$$P_{total} = \sqrt{3}\,V_L\,I_L\,\cos\phi$$

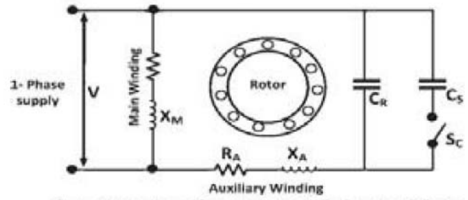
$$P_{total} = \sqrt{3}\times 400\times 20.65\times 0.89$$

$P_{total}$ = 12732.99 watt

**Q.6 Attempt any TWO of the following : [12]**

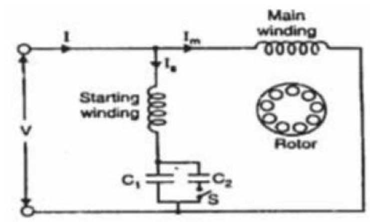
**Q.6(a) Draw schematic diagram of capacitor start capacity run induction motor. Give any two applications of the same. [6]**

**Ans.: Capacitor-start, Capacitor-run Induction Motor:**




Capacitor-start, Capacitor-run Induction Motor

OR



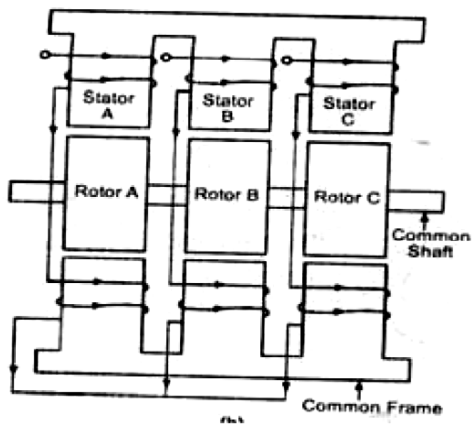

Applications of Capacitor-start, Capacitor- run Induction Motor:
Fans, Blowers, Grinder, Drilling Machine, Washing Machine, Refrigerator, Air conditioner, Domestic Water Pumps, Compressor.

**Q.6(b) Explain the working principle of stepper motor and explain any one type with neat sketch. [6]**

**Ans.: Types of Stepper Motor:**

(i) Variable Reluctance Motor
(ii) Permanent Magnet Motor

**(i) Variable Reluctance Motors:**



**Working:**

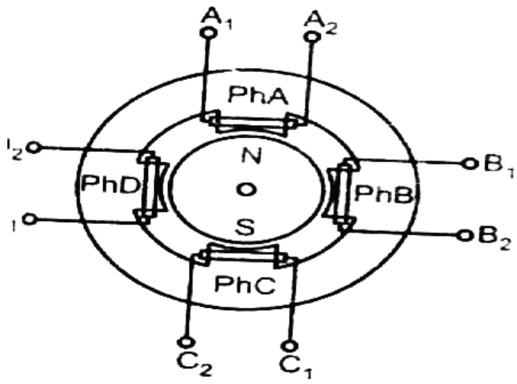
When phase A is excited rotor attempts minimum reluctance between stator and rotor and is subjected to an electromagnetic torque and there by rotor rotates until its axis coincides with the axis of phase A.

Then phase 'B' is excited disconnecting supply of phase 'A' then rotor will move 30 anticlockwise directions. The Same process is repeated for phase 'C'

In this way chain of signals can be passed to get one revolution and direction can be also changed.

**OR**

**(ii) Permanent Magnet Motor:**




**Working:**

If the phase is excited in ABCD, due to electromagnetic torque is developed by interaction between the magnetic field set up by exciting winding and permanent magnet.

Rotor will be driven in clockwise direction.

**Q.6(c) Explain the need of earthing in electrical systems. State the types of earthing and any two advantages of earthing.** **[6]**

**Ans.: Necessity of Earthing:**

1. To provide an alternative path for the leakage current to flow towards earth.
2. To save human life from danger of electrical shock due to leakage current.
3. To protect high rise buildings structure against lightening stroke.
4. To provide safe path to dissipate lightning and short circuit currents.
5. To provide stable platform for operation of sensitive electronic equipment's.

**Types of Earthing:**

1. Pipe type earthing
2. Plate earthing
3. Rod earthing or Driven Rod earthing
4. Strip earthing or Wire earthing

**Advantages of Earthing :**

1. It provides an alternative path for the leakage current to flow towards earth.
2. It saves human life from danger of electrical shock due to leakage current.
3. It protects high rise buildings structure against lightening stroke.
4. It provide safe path to dissipate lightning and short circuit currents.
5. It provide stable platform for operation of sensitive electronic equipment's.

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