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S.Y. Diploma : Sem. IV [ME/MH/MI/PG/PT]

Electrical Engineering

Prelim Question Paper Solution

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1. (a) **(i) Generator :** A machine which convert mechanical energy of rotation into electrical energy is defined as 'generator' for AC supply − AC generator (Alternator).
Similarly D.C. Supply − D.C. generator.

(ii) Invertor : An electronic circuit which converts D.C. voltage into A.C. voltage is defined as invertor.

1. (b) **Digital Instruments**

Because of the introduction of electronics most of the analog instruments are being replaced by digital instruments. In this case a lighted display in the form of L.E.D. or LCD is used on which the magnitudes is directly displayed.

1. (c) **Classification of Indicating instruments**

Indicating Instruments
- Moving coil Instruments
  - (a) Permanent Magnet Moving Coil (PMMC)
  - (b) Dynamometer Type
- Moving iron Instruments
  - (a) Attraction Type
  - (b) Repulsion type

1. (d) Let T = Torque in n−m
ϕ = Magnetic flux in webers
I_C = Armature current in amp.

Then it can be shown that

$$T_a \propto \phi I_a$$

Hence as shown above torque produced in Dc motor is directly proportional to the product of magnetic flux ϕ in webers and armature current (I_a) in amp.

1. (e) **Core or Iron Losses :** These losses consist of hysteresis and eddy current losses called by the alternating flux in the transformer core.

(i) Hysteresis Loss : This loss takes place in the transformer core because it is continuously subjected to rapid reversals of magnetization by the alternating flux.
Thus, the hysteresis loss is frequently dependent. As we increase frequency of operation, the hysteresis loss will increase proportionally.

(ii) Eddy Current Loss : Due to time varying flux, there is some induced emf in the transformer core. This induced emf causes some currents to flow through the core body known as eddy current. Hence due to the flow of eddy currents, heat will be produced. The power loss due to the eddy current is given by

$$\text{Eddy Current Loss} = (\text{Eddy Current})^2 \times r$$

where r – resistance of core.

1. (f) Disadvantages of AC motor

(i) Efficiency varies with speed
(ii) Low starting torque

1. (g) Types of Stepper Motors

Stepper motors are classified in two categories according to type of rotor used.

(i) Permanent Magnet type
(ii) Variable reluctance type

1. (h) (i) 5A socket outlet

(ii) SPDT

1. (i) Type of Tariff

(i) Simple tariff
(ii) Flat rate tariff
(iii) Block rate tariff
(iv) Two part tariff
(v) Maximum demand tariff
(vi) Power factor tariff
(vii) Three part tariff

1. (j) Advantages of Static Capacitors

(i) As there are no moving parts and no winding, the losses in capacitors are very less.
(ii) Weight of capacitor bank is very low hence they can be installed at any location. Also they doesn't require any foundation.
(iii) They require very little maintenance due to absence of moving parts.
(iv) They have low cost below 500 kVA rating.

1. (k) Use of test lamp to check phase voltage

- A test lamp can be used for checking the phase voltage.
- To do so, one wire is connected to the neutral point of the ac supply and the other wire is inserted into the phase point.
- If the phase voltage is present then the test lamp will glow.
- Similarly the test lamp can be used for continuity of wiring.

1. (l) Three part tariff

When the fixed charges, semi-fixed charges and running charges are taken into account it is known as three part tariff.

$$\text{Total charges} = \text{Rs. } (a + b \times \text{kW} + e \times \text{kWh})$$

where, a = fixed charge (includes interest and depreciation capital cost etc.)
b = semi-fixed cost i.e. charge per kW of maximum demand.
c = Running cost i.e. charge per kWh of energy consumed.

2. (a) (i) VIR (Vulcanised Indian Rubber) wires

- A VIR wire mainly consists of a tinned conductor having rubber coating.
- Tinning of conductor prevents the sticking of rubber to the conductor.
- Thickness of rubber mainly depends on the operating voltage to which wire is designed.
- A cotton bradding is done over the rubber insulations to protect the conductor against the moisture.
- Finally the wire is finished with wax for cleanliness.
- Now a days these wires are not used since a better quality wires are available at a cheaper rate.

(ii) CTS (Cab Type Sheathed) or TRS (Tough Rubber Sheathed) wires

- This type of wire is a modification of V.I.R. wire. It consist of the ordinary rubber coated conductors with an additional sheath of tough rubber.
- This layer provides better protection against moisture and wear and tear. Also it provides an extra insulation.
- These wires are generally available in single conductor, two conductors or three conductors.

(iii) PVS (Poly Vinyl Chloride) wires

- This is the most commonly used wire for wiring purpose.
- Conductor is insulated by poly vinyl chloride (insulating material).
- P.V.S. has following properties :
  - Moisture proof
  - Tough
  - Durable
  - Chemically inert
- But it softens at high temperatures therefore not suitable for connection to heating appliances.

(iv) MCCB (Moulded Case Circuit Breaker)

- MCCB is a operating switch which is use manually under normal operating condition for making ON and OFF the circuit.
- Under fault condition it automatically trips the circuit.
- The tripping mechanism is actuated by magnetic and thermal sensing devices.
- The tripping mechanism and the terminal contacts are assembled in a moulded case therefore the name of this type of circuit breaker is moulded case circuit breaker.
- When the contacts of MCCB are opened under normal as well as under abnormal circuit condition, it produces arc between two contacts.
- To extinguish the arc, arc chute is provided which has a special construction which increases the length of the arc by the magnetic field created by the arc itself.
- The arc chute is so placed that the hot gases may not come in contact with any of the important part of the breakers.
- Following are certain ratings of MCCB.

Voltage rating	–	240 V/415 V (AC)
		50 V /110 V (DC)
Current rating	–	5, 10 ...upto 60 Amps.
Breaking capacity	–	3 kA

(v) ELCB (Earth Leakage Circuit Breaker)

- A_1 earth leakage circuit breaker (ELCB) is a device with two earth terminals used to directly detect currents leaking to earth from an installation and cut the power.
- They were mainly used on TT earthing system before RCDs (Residual Current Device) became common. They have been almost totally replaced by RCDs (except in very old installations) due to a number of problems such as –
  (1) They cannot detect earth faults that do not go through the earthing system.
  (2) They do not allow a system to be easily split into multiple sections with independent fault protection, due to the fact that earthing systems are usually bonded to things like pipework.
  (3) They may be tripped by external voltages on something connected to the earthing system such as metal pipes, a TN-S earth or a TN-C-S combined neutral and earth.
  (4) They introduce additional resistance and an additional point of failure into the earthing system.

2. (b) UNIVERSAL MOTOR

If a D.C. series motor is connected to an A.C. supply, it will rotate and produce unidirectional torque. This is because currents in both armature and field windings reverses at the same time. This is the principle of operation of Universal Motor.

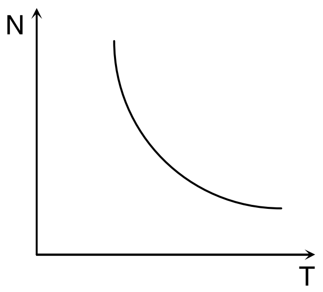
Universal motor is one which can be operated either on D.C. or A.C. 1-ϕ supply, at approximately the same speed and output. Therefore, they are called as Universal Motors.

In fact it is smaller version of 1-ϕ A.C. series motors, having rating from $\frac{1}{200}$HP to $\frac{1}{3}$ HP. Following modifications have to be done to improve the performance.

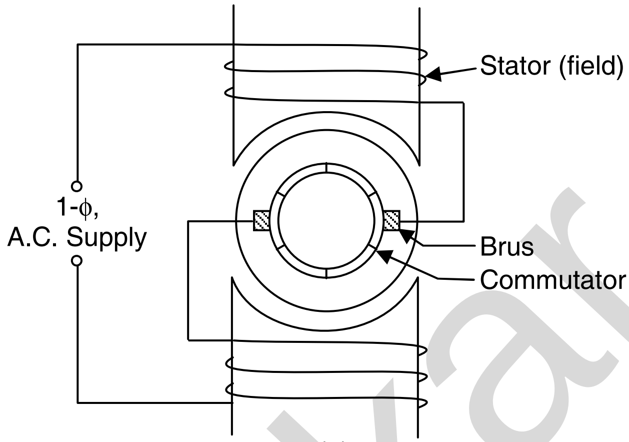
(i) The A.C. flux will produce eddy current loss, which will heat the motor. To reduce this laminated iron sheets are used for rotor and stator.
(ii) Because of high inductance of field and armature circuits, p.f. will be low. This can be improved by providing compensating winding (CW) in pole shoe. For smaller ratings of universal motors, CW is not used.
(iii) Commutation is improved by using high resistance brushes (instead of commutating poles called as compoles).

Also voltage induced by transformer action (in which field winding acts as primary and short circuited armature coil as secondary) in armature coil during its commutation period is not sufficient to cause any serious commutation troubles, as universal motors are usually of low ratings.

Basically universal motor is a series motor having series N-T characteristics, as shown in figure (a).
Figure (b) shows a salient pole construction for field (stator).



(a)



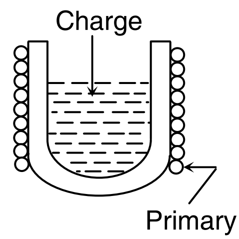
(b)

Reversal of Rotation : Direction of rotation can be changed by interchanging leads for armature only (i.e. by interchanging leads at brushes) or by interchanging leads for field only.

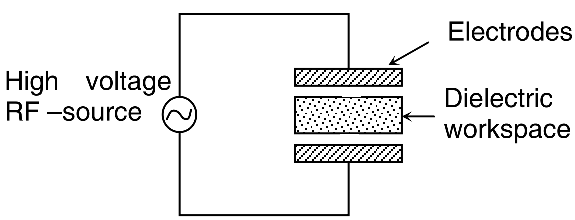
Applications : It runs at dangerously high speed on No Load. Hence these motors are built into the device they drive, so that the load is always connected to it.
They are used for vacuum cleaners, drink and food mixers, domestic drill and sewing machine, hair driers, air blowers, etc.

2. (c) (i) Coreless Furnance

- Figure shows a coreless type furnace.
- Primary winding is wound on a crucible and magnetic flux produced by primary set up eddy currents in the charge.
- These currents heat the metal upto melting point.
- Due to absence of core, flux linking is poor.
- Hence current density (ratio of current to cross sectional area of conductor) is high.
- Primary conductors become hot due to this and they need some cooling arrangement.
- This furnace has low p.f. and capacitor has to be installed across supply to improve it.
- With lower frequency supply its performance is better.



(ii) Dielectric Heating

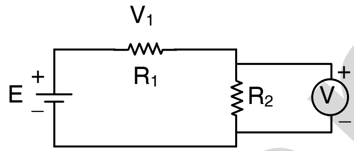
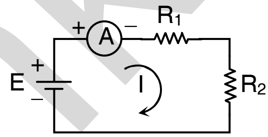


In dielectric heating, a high frequency, high voltage ac voltage is applied across a dielectric material.

The dielectric work piece is held between two metal electrodes. The dielectric material can be plastic, wode etc. Due to the high voltage RF excitation, some current flows through the dielectric material and due to this current flow. Some loss tables place in the dielectric which is called as dielectric loss.

This power loss takes place in the form of heat and the dielectric material gets heated up due to it. This is the principle of dielectric heating.

2. (d) Comparison between Voltmeter and Ammeter

Paramter		Voltmeter	Ammeter
1)	Definition	Instrument which is used for measuring AC or DC voltage	Instrument which is used for measuring AC current or DC current
2)	Connection diagram	 Thus voltmeter is always connected in parallel to the resistor across which voltage is to be measured.	 Ammeter is always connected in series with the resistor through which the current flowing is to be measured.
3)	Internal resistance	For ideal voltmeter $r = \infty$ and for practical voltmeter value of (r) must be as high as possible.	Ideal ammeter $r = 0$ and practically (r) should be as low as possible.
4)	Conversion of galvanometer	By connecting high value resistor in series with galvanometer it can be converted into voltmeter.	By connecting a low value (shunt) resistor in parallel with galvanometer it can be converted into ammeter.

2. (e) The instantaneous value of alternating voltage is given by

$v = V_m \sin(\omega t + \theta)$

where,

V_m = Maximum value of voltage

ω = frequency of supply in radian

θ = phase difference angle

Comparing the given equation with above equation, we get

(i) Maximum value (V_m)

$V_m = 141.42$ volt

(ii) RMS value of voltage (V_{rms})

$$V_{rms} = \frac{V_m}{\sqrt{2}} \text{ volt}$$

$$V_{rms} = \frac{141.42}{\sqrt{2}}$$
$$V_{rms} = 100 \text{ volt}$$

(iii) Frequency (f)
The relation between ω and f is given by

$$\omega = 2\pi f$$
$$f = \frac{\omega}{2\pi}$$
$$f = \frac{157.08}{2\pi}$$
$$f = 25 \text{ Hz}$$

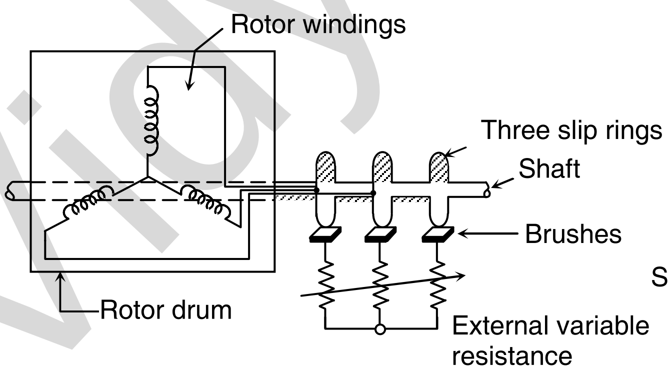
(iv) Periodic time (T)

$$T = \frac{1}{f}$$
$$= \frac{1}{25} = 0.04$$
$$T = 0.04 \text{ second}$$

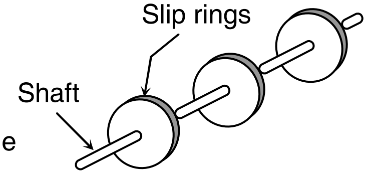
2. (f) Types of Induction Motor
Depending on the type of rotor used, the induction motors are classified as :

3 Phase induction motor
- Squirrel Cage type
- Wound rotor or Slip ring induction motor

Wound rotor or Slip Ring type rotor



(a) Construction of slip ring rotor or a wound rotor



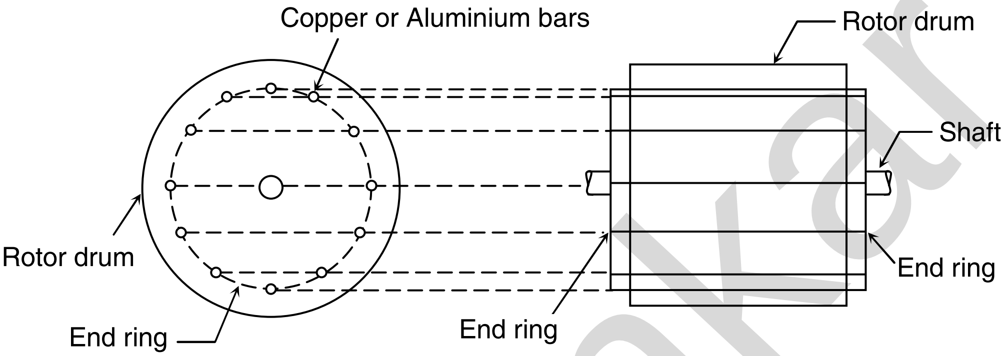
(b) Slip rings

(i) Rotor is in the form of three phase winding.
(ii) Slip rings and brushes are used. So the construction is complicated.
(iii) It is possible to connect the external resistance to the rotor. So that we can adjust the torque by varying external resistance.

(iv) Starting high starting torque can be obtained.
(v) As there is a use of resistance. There will be high rotor copper loss.
(vi) Applications : Cranes, elevators, compressors, lifts etc.

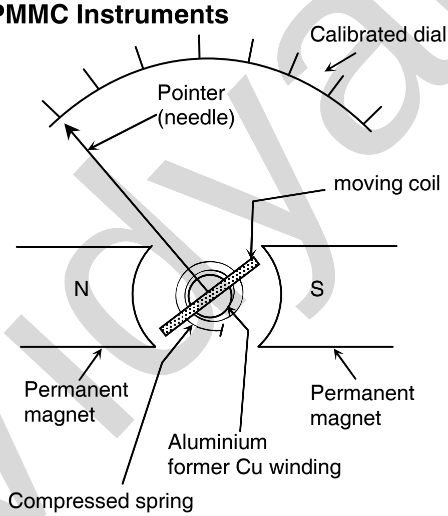
Squirrel Cage Rotor

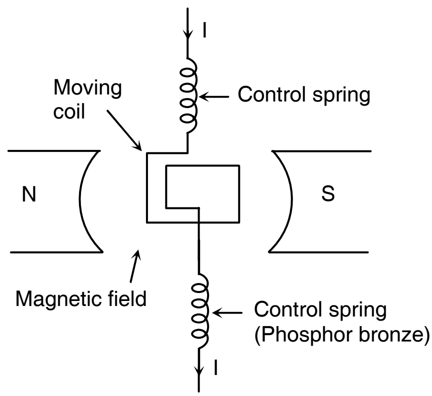
The diagrammatical representation for squirrel cage rotor is as shown below.



(i) Rotor is in the form of bars which are shorted at the ends with the help of end rings.
(ii) There is not any use of slip rings or brushes therefore construction will be simple.
(iii) As external resistance is not being used, starting torque cannot be adjusted.
(iv) There will be less rotor copper loss.
(v) Applications : Latches, fans, water pumps, blowers etc.

3. (a) PMMC Instruments





Three torques are produced as follows :

(i) Deflecting torques : It is produced by the electromagnetic effect of the current passing though copper wire which is wound on aluminium former and placed in a magnetic field.

(ii) Control torque : It is produced by using compressed spring whose one end is attached to a fixed part of the instrument. Its other end is connected to the moving system. When the moving system rotates due to deflecting torque the spring gets compressed. Potential energy stored in the compressed spring produces the required control torque which acts in a direction which is opposite to the direction of deflecting torque.

(iii) Damping torque : It is produced by using eddy current effect. When the moving system starts rotating magnetic flux linking with iron cylinder placed in the aluminium former changes w.r.t. time. An e.m.f. is induced in it due to which eddy current start flowing due to which damping torque is produced which acts in the direction which is opposite to the direction of deflecting torque but this torque is produced only if moving system is rotating and not stationary.

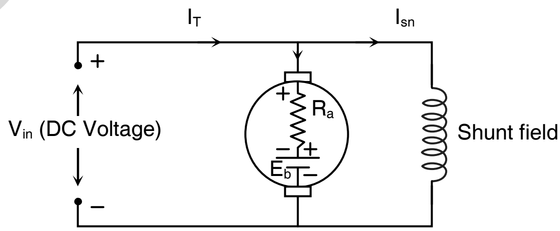
3. (b) Advantages of polyphase supply systems over single phase system:

(i) Polyphase transmission line requires less conductor material for same power transfer at same voltage.
(ii) For same frame size, polyphase machine gives more output.
(iii) For same rating, polyphase machines have small size.
(iv) Polyphase motors produce uniform torque.
(v) Polyphase induction motors are self-starting.
(vi) For same rating, polyphase motors have better power factor.
(vii) Polyphase transformers are more economical. Power capacity to weight ratio is more.
(viii) Polyphase machines have higher efficiencies.
(ix) Polyphase system is more economical with regards to generation, transmission and distribution of power.
(x) Polyphase system requires less maintenance and it increases the life of the system.
(xi) In polyphase system, stationary three-phase armature winding produces rotating magnetic field, which is not possible by single-phase winding.

3. (c)

$I_T = I_a + I_{Sh}$

$I_{Sh} = \dfrac{V_{in}}{R_{Sh}}$



When DC voltage of V_{in} volts is applied to DC motor total current of I_T amp starts flowing as shown above. It is divided into two currents.

(i) I_{Sh} ⇒ This is DC current flowing in the shunt field winding of DC shunt motor. This produces required DC magnetic field.
(ii) I_a ⇒ This is a current taken by the armature winding of DC motor. Since current carrying armature conductor is placed in DC magnetic field it starts rotating. Due to which a back e.m.f. of E_b volts is produced in the armature which is shown in the diagram.

Applying KVL to the input side we get

$\sum$ All voltages $= 0$

$$-I_aR_a - E_b + V_{in} = 0$$
$$V_{in} = E_b + I_aR_a \quad \ldots(i)$$

Above equation is known as voltage equation of DC motor now multiplying each term by current I_a we get

$$V_{in}\,I_a = E_bI_a + I_a^2\,R_a$$

Electrical input = Electrical output + Heat losses

Thus in the above equation E_bI_a represents electrical output of the motor which actually gets converted into mechanical energy of rotation.

Hence in the absence of E_b electrical energy will not get converted into mechanical energy hence motor will not rotate.

Also from equation

$$V_{in} = E_a + I_aR_a$$
$$V_{in} - E_b = I_aR_a$$
$$\frac{V_{in} - E_b}{R_a} = I_a$$

Hence due to the opposition of back e.m.f. e_b value of armature current I_a reduces and motor take safe armature current.

Hence in the absence of back e.m.f. e_b very large armature current I_a will flow in the motor which will damage the motor.

3. (d) Derivation for EMF equation of a Transformer

An alternating current produces an alternating flux (ϕ).

Let N_1 and N_2 are numbers of turns on the primary and secondary winding.

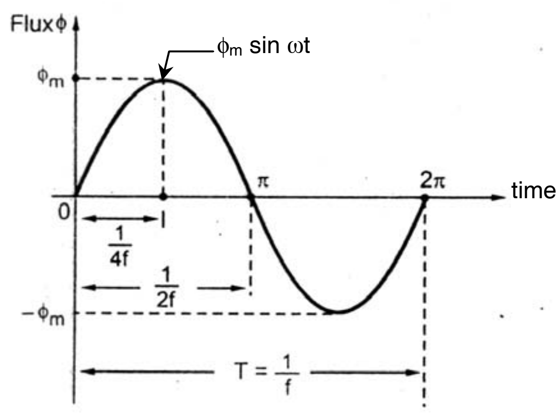
ϕ_m – maximum value of alternating flux.

f – frequency of supply

On cycle of sinusoidal flux is as follows :

Now, it is seen from above waveform that flux will get its maximum value in one quarter of cycle.

i.e., $T = \frac{1}{4f}$ sec.



$\therefore$ Average rate of change of flux $= \frac{\phi_m}{t}$

$$= \frac{\phi_m}{(1/4)\,f}$$

$$= 4\,\phi_m f \;\; \text{web/sec}$$

According to Faraday's law of electromagnetic induction.

Average emf induced in each turn = Average rate of change of flux

$= 4\,\phi_m f$ volt

Now, Form factor $= \dfrac{\text{RMS value}}{\text{Average value}} = 1.11$

$\therefore$ RMS value of emf induced in each turn $= 1.11 \times$ Average value

$= 1.11 \times 4\,\phi_m f$

$= 4.44\,\phi_m f$ volt

$\therefore$ RMS value of induced emf in primary winding,

E_1 = (induced emf/turn) $\times$ no. of primary turns

$= 4.44\,\phi_m f \times N_1$ volts

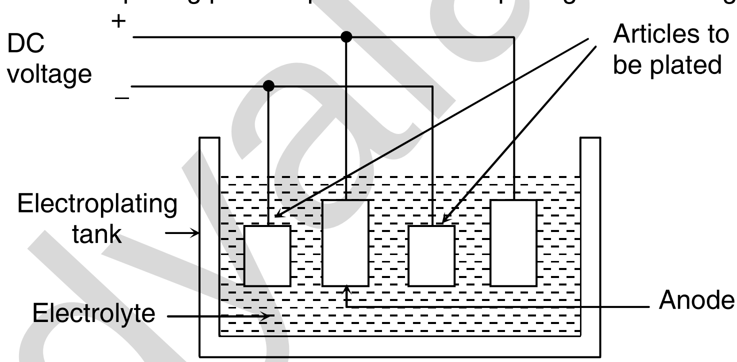
$E_1 = 4.44\,\phi_m\, f\, N_1$ volts

$\therefore \quad E_2 = 4.44\,\phi_m\, f\, N_2$ volts

3. (e) Electroplating

Electroplating is a process of depositing a layer of some material for protective purposes on the articles of other base metals.

- The electroplating plant required for electroplating is show in figure.



- The electroplating tank is made up of a container which is of chemically resistant material to avoid the effect of electrolyte on the container.
- The materials used for the tanks is RCC, wood, fibre glass or stainless steel.
- The tank is filled with suitable electrolyte in which the anodes and the articles to be plated are dipped.

The anodes are connected to the positive end of the de supply while the articles to be plated act as cathodes and they are connected to the negative terminal of the dc supply.

The articles to be electroplated should be thoroughly cleaned. They should be free from dust, dirt, scales, rust etc.

As soon as the external dc supply (3 to 24 V) is turned on the process of electrolysis will take place.

The anode is made of the metal to be deposited. So it loses the metal and a layer of that metal gets deposited on the cathode i.e. the articles to be electroplated.

For ensuring even deposition, the anodes are rotated slowly. Sometimes the metal to be deposited is supplied by the electrolyte.
After platting, the electrolyte is washed, cleaned and dried.

Applications of Electroplating :
(i) Gold or silver plating on the ornaments.
(ii) Zink, nickel or chromium plating on the cast iron and steel iron parts to prevent corrosion.
(iii) While surface are plated with Nickel or chromium for giving extra shining.

3. (f) Energy Audit
An energy audit is a preliminary activity towards instituting energy efficiency programs in an establishment. It consists of activities that seek to identify conservation opportunities preliminary to the development of an energy savings program.

The role of an energy audit :
To institute the correct energy efficiency programs, you have to know first which areas in your establishment unnecessarily consume too much energy, e.g. which is the most cost-effective to improve. An energy audit identifies where energy is being consumed and assesses energy saving opportunities, so you get to save money where it counts the most.

In the factory, doing an energy audit increases awareness of energy issues among plant personnel, making them more knowledgeable about proper practices that will make them more productive. An energy audit in effect gauges the energy efficiency of you plant against "best practices". When used as a "baseline" for tracking yearly progress against targets, an energy audit becomes the best first step towards saving money in the production plant.

Contents of an audit :
An energy audit seeks to document things that are sometimes ignored in the plant, such as the energy being used on site per, which processes use the energy, and the opportunities for savings. In so doing, it assesses the effectiveness of management structure for controlling energy use and implementing changes. The energy audit report establishes the needs for plant metering and monitoring, enabling the plant manager to institutionalize the practice and hence, save money for the years to come. The energy audit action plan lists the steps and sets the preliminary budget for the energy management program.

4. (a) Advantages of Dynomometer :
(i) It can be used for measuring both AC and DC voltage and current.
(ii) It is the best instrument when used as wattmeter for measuring power.
(iii) Scale of the dial is linear only if it is used as wattmeter.

(iv) Accuracy is good.
(v) Reading is not affected by magnetic hysteresis hence no error is produced by hysterisis.

Disadvantages of Dynomometer :
(i) One of the costliest instruments.
(ii) Scale of the dial is not uniform when used as voltmeter and ammeter.
(iii) Magnetic field is produced by coils hence comparatively it is small due to this reading is affected by external magnetic field. Due to which errors can be produced in the readings.
(iv) Sensitivity of this instrument is comparatively low w.r.t. PMMC instrument.

4. (b) Given data
(i) Resistance (R) = 10 ohm
(ii) Inductance (L) = 0.2 H
(iii) Voltage (V) = 100 volt
(iv) Frequency (f) = 50 Hz

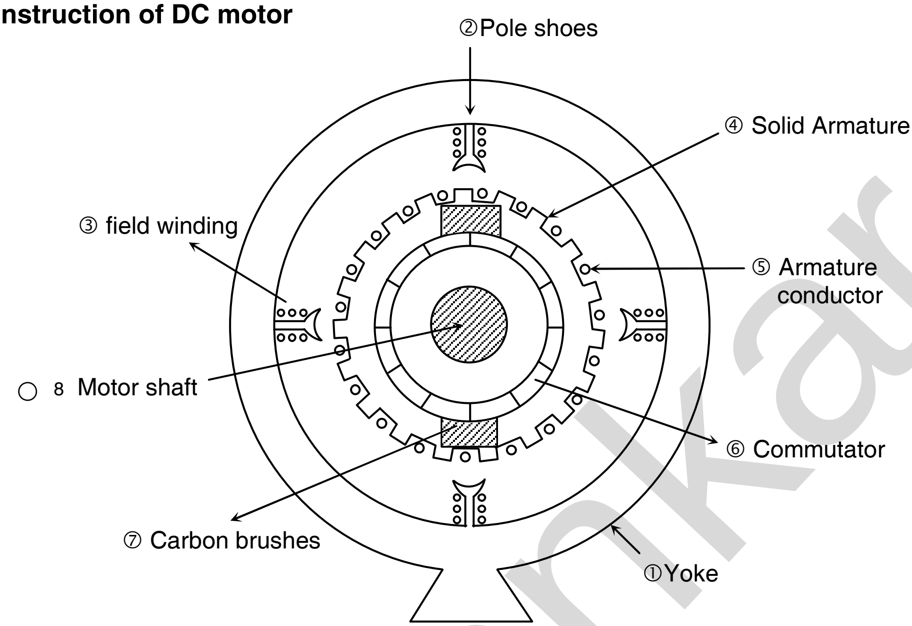
(i) Reactance (X_L)
$X_L = 2\pi fL$
$X_L = 2\pi * 50 * 0.2$
$X_L = 62.832$ ohm

(ii) Impedance (Z)
$Z = \sqrt{R^2 + X^2}$
$Z = \sqrt{10^2 + 62.832^2}$
$Z = \sqrt{100 + 3947.86}$
$Z = 63.623$ ohm

(iii) Current (I)
$I = \frac{V}{Z}$
$I = \frac{100}{63.623}$
$I = 1.5718$ Ampere

(iv) Power consumed (P)
$P = i^2 * R$
$P = (1.5718)^2 * 10$
$P = 24.705$ watt

4. (c) **Construction of DC motor**



Note : Do not touch the outer circle.

	Name of part	Material used	Function
(1)	Yoke	Cast iron	To provide mechanical support It provides a path for magnetic flux to flow
(2)	Pole shoes	Iron	It produces and spread the magnetic flux produced
(3)	Field winding	Copper	When DC convert flows through it DC magnetic flux is produced.
(4)	Slotted Armature	Silicon steel	In the slots of the armature conductor are placed to which mechanical support is given.
(5)	Armature winding	Copper	When DC current flows through armature winding a torque is produced due to which armature of motor starts rotating.
(6)	Commutator	Wedge-shaped copper and insulated mica	It converts bi-directional AC into unidirectional DC.
(7)	Carbon brushes	Carbon	These make contact with the moving armature and hence sends DC current to the armature from external DC supply.
(8)	Motor shaft	Iron	Used for connecting mechanical load to the motor by using belt or gear.

4. (d) Given : f = 50 Hz, P = 4, frequency of rotor current, f = 2 Hz.

(i) Synchronous speed :

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

$$N_S = 1500 \text{ rpm}$$

(ii) Percent slip :

$$\% S = \frac{N_S - N}{N_S} = \frac{f}{f} \times 100 = \frac{2}{50} \times 100$$

$$\% S = 4\%$$

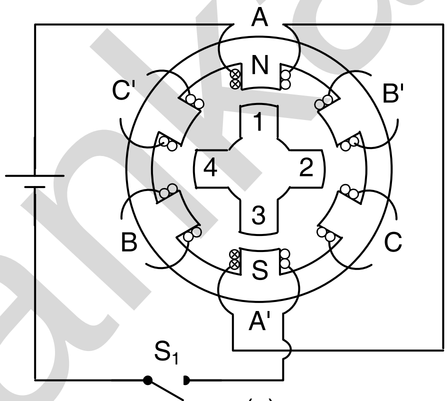
4. (e) Reluctance Stepper Motors

The stator has number of salient (projected) poles. It is wound for 3 phases located 120° apart. Only one phase of stator is excited at a time by D.C. supply in a particular sequence.

The rotor is also made of magnetic material but it is not a permanent magnet. The rotor has also number of salient poles.

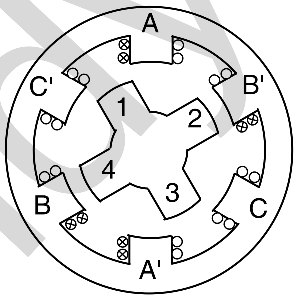
Figure (a) shows a stator having six poles and rotor having four poles.

When phase A is excited by closing switch S_1 (as shown in figure (a)), it forms N pole at coil A and S pole at coil A'. Thus rotor is subjected to electromagnetic torque. Therefore, rotor rotates till the rotor poles are aligned opposite to the stator poles of phase A. This is shown in figure (a). This is the position of minimum reluctance and the motor is in stable equilibrium.

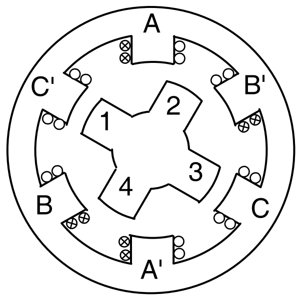


(a)

If not phase A is de-energized and phase B is energized, the rotor will move by 30° in anticlockwise direction as shown in figure (b). [Actually the rotor poles which are nearest to excited phase B, will align with it. In this case, rotor poles, 2 and 4 will align with poles of phase B].



(b)
Rotor has rotated by 30° in anticlockwise direction.



(c)
Rotor has further rotated by 30° in anticlockwise direction.

Step angle = pole pitch of rotor − pole pitch of stator

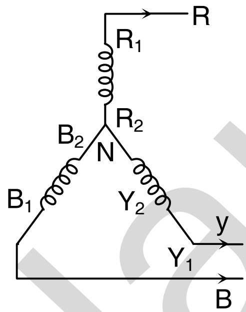
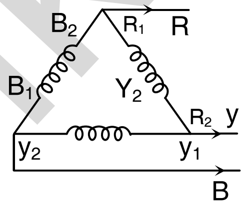
$$= \frac{360}{4} - \frac{360}{6} = 90 - 60 = 30^\circ$$

Next if phase C is energized while disconnecting the supply to phase B, the rotor will move by another 30° in anticlockwise direction as shown in figure (c).

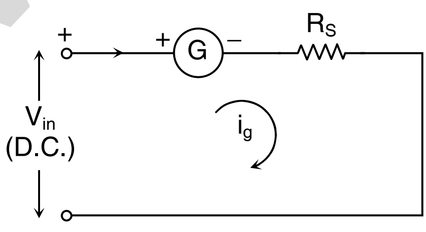
Thus if 3 phases are successively excited by pulses in particular sequence (A–B–C), the motor will take one step of 30° with each voltage pulse. If the sequence is reversed to A–C–B, then the motor will move in clockwise direction.

Step angle can be reduced by increasing number of stator phases or rotor poles. This can also be done by adopting different type of construction such as multi-stack or cascade type of construction. Typical step angles of stepper motors are 15°, 75°, 2° and 0.72°.

4. (f) Comparison between Star Connection and Delta Connection

	Parameter	Star Connection	Delta Connection
(i)	Circuit		
(ii)	Relation between V_L (Line voltage) and V_{ph} (phase voltage)	$V_L = \sqrt{3}\, V_{ph}$	$V_L = V_{ph}$
(iii)	Relation between I_L(line current) and I_{ph} (Phase current)	$I_L = I_{ph}$	$I_L = \sqrt{3}\, I_{ph}$
(iv)	Total power consumed (P_t)	(i) $P_T = 3\, V_{ph}\, I_{ph} \cos \phi$ OR (ii) $P_T = \sqrt{3}\, V_L\, I_L \cos \phi$	(i) $P_T = 3$ ph $I_{ph} \cos \phi$ OR (ii) $P_T = \sqrt{3}\, V_L\, I_L \cos \phi$
(v)	Total power consumed (P_t)	More	Less
(vi)	No. of wires used	3 (Balanced Load) **or** 4 (Unbalanced Load)	Three wires

5. (a) How to convert galvanometer into voltmeter?



Let G = Resistance of galvanometer (known)
R_S = High value series resistor to be selected properly
V_{in} = Highest d.c. voltage to be measured. (Given)
f_g = f.s.d.(full scale deflection) galvanometer (known)

As shown above a galvanometer is converted into voltmeter by connecting suitable high value resistor R_S in series with galvanometer.

Value of R_S is selected as follows. In the above circuit current I_G flowing in the circuit is given by Ohm's law.

$$I_g = \frac{V_{in}}{R_t} \quad \text{where } R_t = \text{ total resistance in the circuit}$$

Since two resistor R_S and G are connected in series total resistance is given by

$$R_t = G + R_s$$

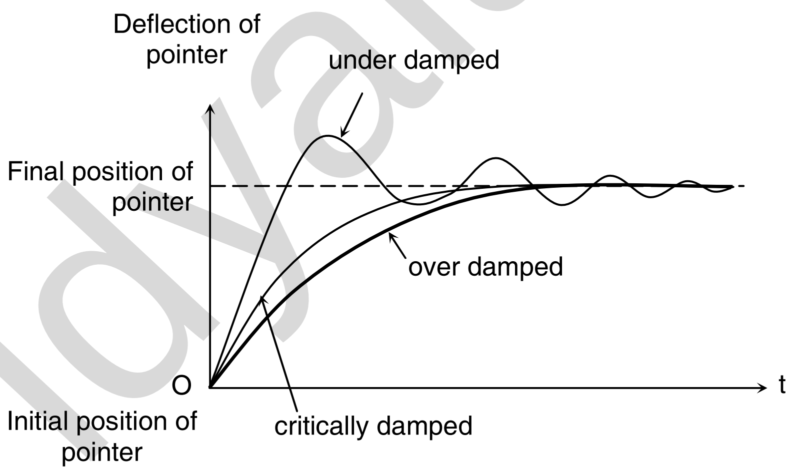
$$I_s = \frac{V_{in}}{(G+R_s)}$$

$$G + R_s = \frac{V_{in}}{I_s}$$

$$R_s = \frac{V_{in}}{I_g} - G$$

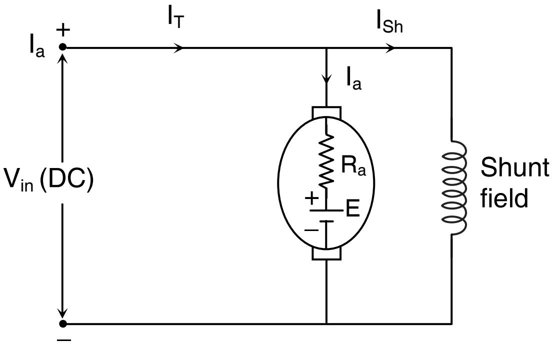
In the above equation all the values in R.H.S. are known hence suitable value of R_s can be selected by using above equation.

5. (b)



As shown above when critical damping is used pointer takes least time to settle down to the final position and hence critical damping is preferred in all the indicating instruments.

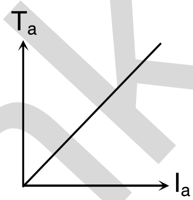
5. (c) (i) Three characteristics of DC shunt motor



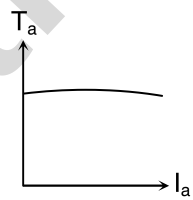
(This diagram need not be drawn)

(a) T_a v/s I_a
Since $T_a \propto \phi I_a$ and
ϕ is constant for DC shunt motor

$T_a \propto I_a$
(Hence it is a straight line)
passing through origin

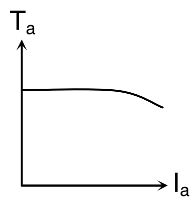


(b) N v/s I_a
Speed of D.C. shunt motor is always constant. Hence it is horizontal straight line.



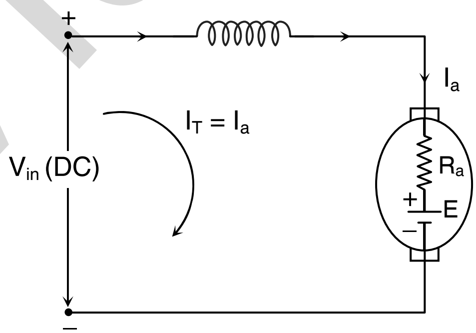
$N \propto \frac{E_b}{\phi}$

(c) N v/s T_a



$N \propto \frac{E_b}{\phi}$

(ii) D.C. series motor



Two equation used for plotting the three characteristics are :

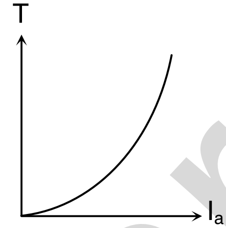
A. $T_a \propto \phi I_a$

$N_a \propto \dfrac{E_b}{\phi}$

(i) T_a v/s $I_a \rightarrow$

Since $T_a \propto i_a$ and $\phi \propto I_a$

$T_a \propto i_a^2$ [Hence it is a parabola]

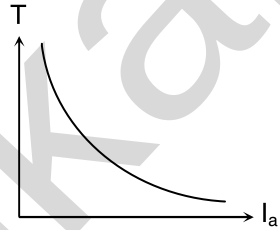


(ii) N v/s I_a

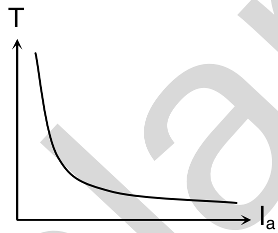
$N \propto \dfrac{E_b}{\phi}$

$\therefore \quad N \propto \dfrac{1}{I_a}$

[$\therefore E_b$ is constant and $\phi \propto I_a$ hence hyperbola]



(iii) N v/s T_a



5. (d) Comparison of squirrel cage and slip ring motors.

	Particular	Squirrel cage induction motor	Slip Ring Induction Motor
1)	Construction	Simple, Robust	Loss robust
2)	Cost	Cheap	Costly
3)	Efficiency and pf	Higher	Less than squirrel cage
4)	Fire proof	It is fire proof	Because of slip rings sparking occurs and therefore it is not fire proof
5)	Starting torque	Low	High (by adding external rotor resistance)
6)	Speed control	Difficult	Easier (by adding external rotor resistance)
7)	Starting current	High	Low
8)	Maintenance required	Less	More (due to slip rings)

5. (e) Symmetrical 3 phase AC supply

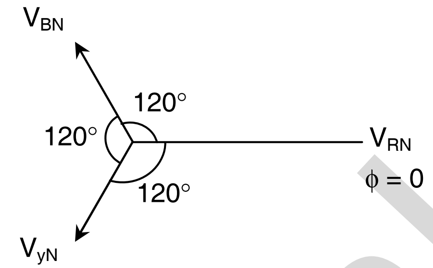
(i) 3 Phase supply is said to be symmetrical if the magnitudes of all the 3 phase voltages are same and they are displaced from each other by 120° $\left(120^\circ = \dfrac{360}{3}\right)$.

For convenience 3 difference colours Red, Yellow, Blue are used to distinguish 3 phase voltage hence the 3 phase voltage are denoted by

V_{RN} = Red phase voltage
V_{YN} = Yellow phase voltage
V_{BN} = Blue phase voltage

where N = Neutral wire

(ii) Phasor diagram



Equation of 3 phase voltage

Note : $120° = \frac{2\pi}{3}$

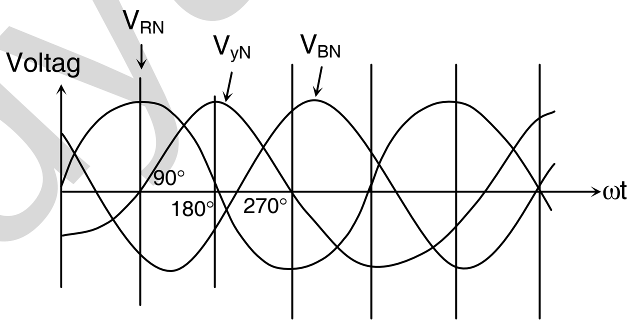
and $240° = \frac{4\pi}{3}$

$V_{RN} = V_m \sin\omega t$ (Reference $\phi = 0$)

$V_{YN} = V_m \sin\left(\omega t - \frac{2\pi}{3}\right)$ $\left(\phi = -120^\circ = \frac{-2\pi}{3} \text{ lagging}\right)$

$V_{BN} = V_m \sin\left(\omega t - \frac{4\pi}{3}\right)$ $\left[\phi = -40^\circ = -\frac{4\pi}{3} \text{ lagging}\right]$

(iii) Waveform



5. (f) Tariff

- Tariff is the rate at which electrical energy is supplied to the consumer.
- Tariff should recover the cost of producing electrical energy in power station. Capital investment in transmission and distribution system.
- It should also recover the cost of operation and maintenance.
- It should have some suitable profit on the capital investment.

Types of Tariff :

(a) Simple tariff : In the type of tariff, the rate per unit consumption of electrical energy is constant. It does not change with increase or decrease in number of units consumed.

(b) Flat rate tariff : In the type of tariff, consumers are grouped into different classes and each class is charged at different rate. For example : say residential load is charged at 0.8 Rs. / unit and industrial / power load is charge of 0.75 Rs. / unit.

(c) Block rate tariff :
- In this type of tariff, the energy consumption is divided into certain blocks and each block is charged at different rate.
- For example : For first 100 units charge is 0.8 Rs. / unit, for 101 to 300 units charge is 0.7 Rs. / unit and so on.
- Thus 0 to 100 units is the first block of unit, 101 to 300 units is second block of unit.

(d) Two part tariff :
- In this type of tariff charge made for consumer is split into two parts i.e. fixed charge and running charge.
- Fixed charges are dependent on maximum demand and running charges are dependent upon the number of units consumed by consumer.

Total changes = Rs. $(b \times kW + c \times kWh)$

b = Charge per kW of maximum demand.
c = Charge per kWh of energy consumption.

(e) Maximum demand tariff : It is similar to two part tariff only difference is that, maximum demand is actually measured by maximum demand indicator which is installed in consumers premises.

(f) Power factor tariff : The tariff which power factor of the consumers load is considered is called as power factor tariff.

(g) Three part tariff : When the fixed charges, semi-fixed charges and running charges are taken into account it is known as three part tariff.

Total charges = Rs. $(a + b \times kW + e \times kWh)$

where, a = fixed charge (includes interest and depreciation capital cost etc.)
b = semi-fixed cost i.e. charge per kW of maximum demand.
c = Running cost i.e. charge per kWh of energy consumed.

6. (a) (i) RMS (Root Mean Square) also known as "effective" values

$$H_1 = I_{rms}^2 Rt$$

RMS values of a.c. is defined as that steady state D.C. current which produces same amount of heat in same circuit as equal to heat produced by an A.C. current flowing through the same circuit for same time, if I_1, I_2, ……… I_n are instantaneous values of A.C. current then

$$I_{RMS} = \sqrt{\frac{I_1^2 + I_2^2 + \dots\dots\dots + I_n^2}{n}} \quad \textbf{OR} \quad I_{RMS} = \frac{I_m}{\sqrt{2}} = 0.707\, I_m \quad \text{(By formula)}$$

(ii) D.C. or average values :

$$I = \frac{Q}{t}$$

It is defined as that steady state D.C. current which transfers same amount of charge across same circuit, in same time as charge transferred by A.C. current across same circuit, in same time.

$$I_{DC} = I_{avg.} = \frac{I_1 + I_2 + ... + I_n}{n}$$

It is defined as average of all instant values of the quantity taken over **half cycle**.

By formula $I_{DC} = \frac{2I_m}{\pi} = 0.636\ I_m$

(iii) Form factor (K_f) :

$$K_f = \frac{I_{RMS}}{I_{DC}} \quad \text{or} \quad K_f = \frac{V_{RMS}}{V_{DC}}$$

It is defined as the ratio of rms value of alternating quantity to the D.C. (or) average value of same quantity. For sinusoidal waveform value of form factor as given below :

$$K_f = \frac{I_{rms}}{I_{dc}} = \frac{0.707 I_m}{0.636 I_m}$$

$K_f = 1.11$ (No unit of measurement)

(iv) Crest or Peak factor or amplitude factor :

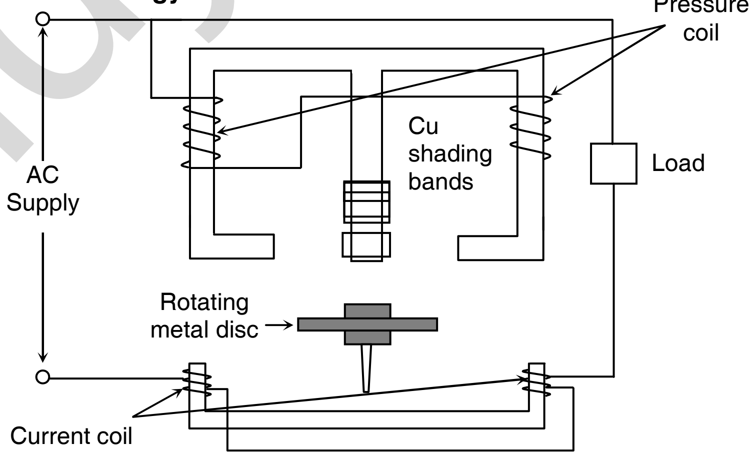
$$\frac{I_{max}}{I_{rms}} = K_a$$

It is the ratio of maximum value of alternating quantity to rms value of same quantity.

K_a is constant and has no unit of measurement its value is fixed for sine wave as shown below :

$$K_a = \frac{I_{max}}{I_{rms}} = \frac{I_m}{I_m / \sqrt{2}} = \sqrt{2} = 1.414$$

6. (b) Construction of Energy Meter



Application : Energy meter is basically used for measuring electrical energy consumed by individual flat owner or by Industry. E.E. energy consumed is measured in kilo–watt–hour–which is equal to 1 unit.

Depending upon the number of units consumed by customers electric belt is prepared. Hence more the units consumed more will be the amount of electric bill.

6. (c) Comparison between Core and Shell type

	Core Type	Shell Type
1)	The core has only one window.	The core has two windows.
2)	Windings encircle the core.	Core encircles the windings.
3)	Cylindrical windings are used.	Sandwich type windings are used.
4)	Transformer is easy to repair.	Not so easy to repair.
5)	Better cooling since more surface is exposed to the atmosphere.	Cooling is not very effective.
6)	Less mechanical protection to the coils.	Better mechanical protection to the coils.

6. (d) Given :

V_1 = 230 V, V_2 = 150 V, V_A = 1000 volt-amp, frequency f = 50 Hz

(i) Full load primary current

$$I_{1FL} = \frac{V_A}{V_1} = \frac{1000}{230} = 4.347 \text{ A}$$

(ii) Full load secondary current

$$I_{2FL} = \frac{V_A}{V_2} = \frac{1000}{150} = 6.66 \text{ A}$$

6. (e) Earthing

Definition : Connecting the metallic frame of electrical machines conducts pipes etc. to ground is known as earthing.

- Any electrical equipment is mainly made up of minimum two parts – conducting material and insulating material.
- Conducting part (winding) is the inner part which is covered by insulating material.
- This entire assembly is kept into metallic body.
- If due to certain reason, insulation between the conducting part and metallic body fails, then metallic body also carries certain current and becomes conducting.
- In such situation suppose any person comes into contact with the

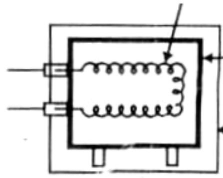


Fig. 1

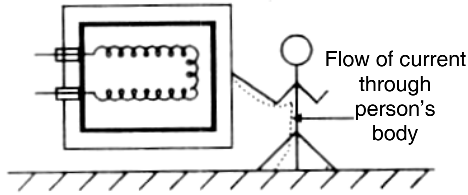


Fig. 2

instrument then the circuit gets completed through his body i.e. current flows from metallic part, through his body to earth as shown in Figure 2, if the system is not earthed the person gets the shock.

- If the system is effectively grounded, then leakage current will flow through the earth connection to ground as shown in Figure 3.

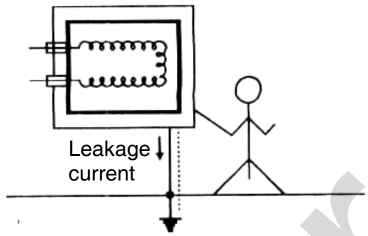


Fig. 3

- And thus the person get protected against the electric stock.
- Basically there are two types of earthing, viz –
  (a) Equipment earthing (b) Neutral earthing

6. (f) Various safety precautions to be taken while handling an electric equipment:

(1) Only qualified person should be allowed to handle the equipment, untrained person should not be allowed.
(2) Place yourself at safe distance from working equipment.
(3) Wear appropriate clothing.
(4) Use shoes with rubber sole to avoid electric shock.
(5) Use proper instrument to test the circuit.
(6) Always obey the safety instructions given by the person in charge.
(7) Use approved discharge earth rod for earthing before working.
(8) Do not touch or operate switches when your hands are wet.
(9) The earth connection should be perfectly sound are proper.
(10) Avoid overloading of circuits or circuits.
(11) Do not expose your eyes, face to an electric arc.
(12) Never speak to any person while working on live installation.
(13) Don't make safety devices inoperative.
(14) Follow strictly the maintenance schedule.
(15) Avoid working on live parts.
(16) Switch off the supply before starting of work.
(17) Never touch the wire till you are sure that it is not live.
(18) Make habit to observe for danger notices, cautions boards, flags and tags.

❑ ❑ ❑ ❑ ❑