F.Y. Diploma : Sem. II

[DE/EJ/IE/IS/CO/IF/CM/CW/ET/EN/EX]

# Elements of Electrical Engineering

Time: 3 Hrs.] Prelim Question Paper Solution [Marks : 100

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

**Q.1(a) Define Magnetic flux and Permeability. [2]**

**Ans.: Magnetic flux** [1 mark]

Total number of line of force in any particular magnetic field is called magnetic flux.
It is denoted by "$\phi$". Unit of magnetic flux is Weber (Wb).

**Magnetic Permeability** [1 mark]

It is the degree of magnetization that a material obtains in response to an applied magnetic field. It is denoted by "$\mu$". In SI units, permeability is measured in henries per meter (H/m or $H \cdot m^{-1}$)

**Q.1(b) Define form factor and peak factor. [2]**

**Ans.: Form Factor** [1 mark]

The ratio of r.m.s value to average value is called the form factor.
For a sinusoidally varying and alternating quantity, form factor = 1.11

**Peak Factor** [1 mark]

It is the ratio of maximum value to RMS value.
For a sinusoidally varying A.C. quantity,
Peak factor = 1.414

**Q.1(c) Define 3-phase balanced and unbalanced load. [2]**

**Ans.: Balanced load** [1 mark]

If all phase impedances of the three phase load are exactly identical in respect of magnitude and their nature, then it is called a balanced three phase load.

**Unbalanced load** [1 mark]

If all phase impedances of the three phase load are not identical in respect of magnitude and their nature, then it is called an unbalanced three phase load.

**Q.1(d) State the difference between step up and step down Transformer. [2]**

**Ans.:** [$\frac{1}{2}$ mark each]

| | Basis for Comparison | Step-Up Transformer | Step-Down Transformer |
|---|---|---|---|
| (i) | Definition | Step-up transformer increase the output voltage. | Step-down transformer reduces the output voltage. |
| (ii) | Voltage | Input voltage is low while the output voltage is high. | Input voltage is high while the output voltage is low. |
| (iii) | Winding | High voltage winding is the secondary winding. | High voltage winding is the primary winding. |
| (iv) | Size of the conductor | Primary winding is made up of thick insulated copper wire. | Secondary winding is made up of thick insulated copper wire. |

**Q.1(e) Write EMF equation of transformer. State the meaning of each notation in it. [2]**

**Ans.:** There are two emf equations of a transformer : [2 marks]

$E_1 = 4.44\ f\ \Phi m\ N_1$ 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.1(f) Define FHP Motor.** **[2]**

**Ans.: FHP Motor** [2 marks]

A fractional-horsepower motor (FHP) is an electric motor with a rated output power of 746 Watts or less. There is no defined minimum output, however, it is generally accepted that a motor with a frame size of less than 35mm square can be referred to as a 'micro-motor'.

**Q.1(g) State various types of Fuses.** **[2]**

**Ans.: Types of fuses :** [2 marks]

(i) Dropout fuse (ii) Kit-kat type
(iii) Expulsion fuse (iv) H.R.C. fuse (High rupturing capacity)
(v) Striker fuse (vi) Switch fuse
(vii) Semienclosed or rewirable type

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

**Q.2(a) A 30 ohm resistance is connected in series with 0.1 H inductance and the combination is connected across a 230v, 50 Hz, 1-phase supply.** **[4]**
**Calculate :**
**(i) Current** **(ii) Power factor**
**(iii) active power consumed and** **(iv) reactive power.**

**Ans.:** Given : R = 30Ω, L = 0.1H, V = 230V, f = 50 Hz

Now, $X_L = 2\pi fL = 2 \times 3.14 \times 50 \times 0.1 = 31.4\ \Omega$

$\therefore \quad Z = \sqrt{R^2 + X_L^2} = \sqrt{(30^2 + 31.4^2)} = 43.427\Omega$

(i) $I = \dfrac{V}{Z} = \dfrac{230}{43.427} = 5.296$ Amp [1 mark]

(ii) $pF = \cos\phi = \dfrac{R}{Z} = \dfrac{30}{43.427} = 0.6908$ [1 mark]

(iii) Active power, $P = I^2R = (5.296)^2 \times 30 = 841.43$ W [1 mark]

(iv) Reactive power, $Q = I^2X_L = (5.296)^2 \times 31.4 = 880.70$ VAR [1 mark]

**Q.2(b) Write standard formula for each of the following and state its unit.** **[4]**
**(i) Active Power (ii) Reactive Power (iii) Apparent Power and (iv) Copper Loss.**

**Ans.: There are three types of powers :**

**(i) Active (Real or True) Power (P)** [1 mark]

The active power is defined as the average power taken by or consumed by the given circuit.

OR

It is the product of V, I and cosine of the angle $\phi$ between V and I.

OR

It is the power developed in the resistance of the circuit. It is given by

$P = V.I. \cos\Phi$ (Unit: W OR kW)
$= I^2R$

Where $\Phi$ = Phase angle between V and I

**(ii) Reactive Power (Q)** [1 mark]

The reactive power is defined as the product of V, I and sine of the angle $\phi$ between V and I.

OR

It is the power developed in the reactance of the circuit. The reactive power is also called as imaginary power. It is given by

$Q = V.I. \sin \Phi = I^2 X_L$ (Unit: VAR OR kVAR)

**(iii) Apparent Power (S)** [1 mark]

Apparent power is defined as the product of rms values of voltage (v) and current (I). It is given by

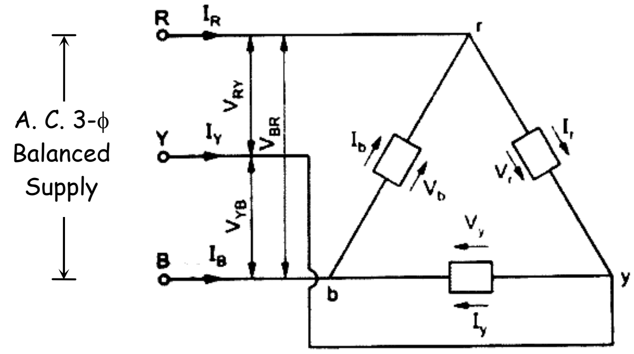
$S = V.I. = I^2 Z$ (Unit: VA OR kVA)

**(iv) Copper Loss** [1 mark]

$W_{CU} = I_1^2 R_1 + I_2^2 R_2$

**Q.2(c) Draw a balanced 3-phase delta connected load. Show various line and phase quantities on it. Also write relationship between line and phase values of voltages and currents** **[4]**

**Ans.: Three phase balanced delta connected load.** [1 mark]




**(i) Connection :** [1 mark]

It is as shown in Fig.1(a).

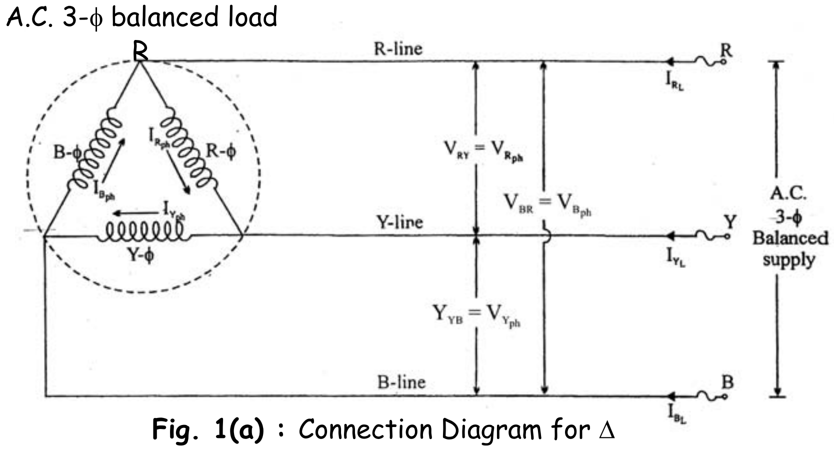



**Fig. 1(a) :** Connection Diagram for $\Delta$

**(ii) Relationship between line and phase voltages :** [1 mark]

From the connection diagram, it is seen that phase of the load is connected in parallel with respective two lines.

Thus, $V_L = V_{ph}$

**(iii) Relationship between line and phase currents :** [1 mark]

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

**Q.2(d) Draw constructional diagram of DC motor. Show different parts on it and write function of each part.** **[4]**

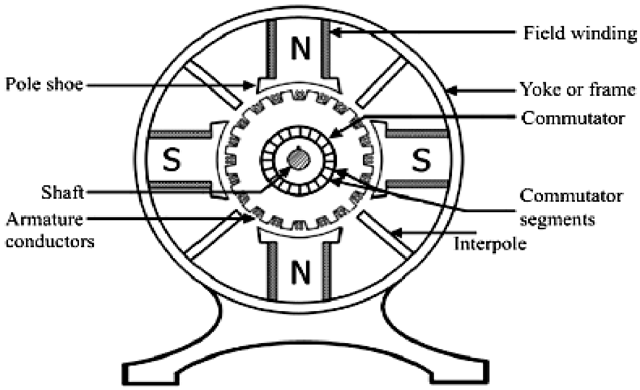
**Ans.:** A DC motor like we all know is a device that deals in the conversion of electrical energy to mechanical energy and this is essentially brought about by two major parts required for the construction of DC motor, namely. [2 marks]

**(i) Stator :** The static part that houses the field windings and receives the supply and,

**(ii) Rotor :** The rotating part that brings about the mechanical rotations.

Other than that there are several subsidiary parts namely the [2 marks]

(i) Yoke of DC motor.
(ii) Poles of DC motor.
(iii) Field winding of DC motor.
(iv) Armature winding of DC motor.
(v) Commutator of DC motor.
(vi) Brushes of DC motor.




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

**Q.3(a) Explain with neat diagram Static and Dynamic Induced EMF.** **[4]**

**Ans.:** **Statically induced emf** [2 marks]

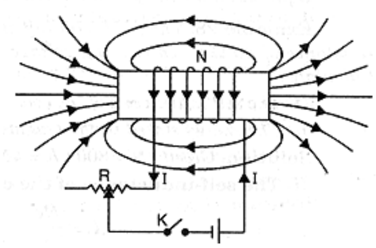
It is the e.m.f. produced in conductors when the magnetic field around them changes with the conductors being stationary.

For coils 'e' = $-N\, d\phi/dt$ (V)

where N is number of turns in coil
$\phi$ is the changing flux w.r.t time 't'.

**Application :** Transformer

**Diagram**




**Dynamically induced emf** [2 marks]

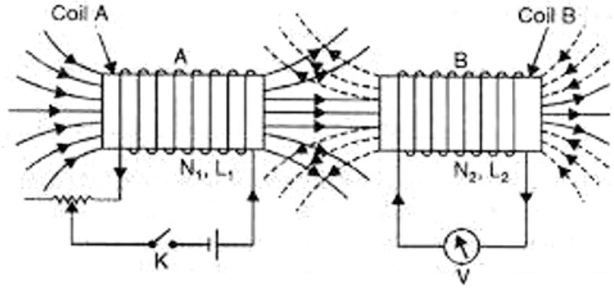
Emf Produced in conductors due to relative motion of conductors with respect to magnetic fields. It can be expressed as

$$e = B \ell V \sin\theta \text{ (volts)}$$

where B = flux density
$\ell$ = Effective length of conductor lying the magnetic field,
$V \sin\theta$ = relative velocity of conductor wrt the magnetic field.
$\theta$ = angle between velocity and the magnetic flux.

**Application :** Motor

**Diagram**




**Q.3(b) Compare Two winding Transformer with autotransformer.** **[4]**

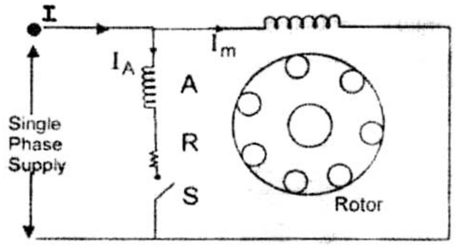
**Ans.:** [any 4, 1 mark each]

| | Two winding transformer | Auto transformer |
|---|---|---|
| 1) | Different primary & secondary winding. | Primary & secondary on common winding. |
| 2) | No electrical connection between primary and secondary. | Electrical connection between primary and secondary. |
| 3) | Amount of copper required and weight is more. | Amount of copper required and weight is less. |
| 4) | Size is larger as compared to auto transformer for similar capacity | Size is small as compared to two winding transformer for similar capacity. |
| 5) | Cost is more. | Cost is less |
| 6) | More losses hence lower efficiency as compared to auto. | Less losses hence higher efficiency. |

**Q.3(c) Write principle of operation of Split Phase Induction Motor.** **[4]**

**Ans.:** **Resistance Split phase Motors** [Diagram & Explanation - 2 marks each]

Below Figure shows the schematic representation of this motor. It consists of two windings main winding or running winding (M) and Auxiliary or starting winding (A). They are 90° electrical degrees a part. The main winding (M) and auxiliary winding (A) are connected across the supply as shown in fig. Auxiliary winding has high resistance (R) in series. When the supply is given, current flows through the windings as $I_m$ & $I_A$ which are approximately 90° phase difference.




Hence the flux produced due to these currents is displaced in space & produces rotating magnetic field there by producing rotation in rotor. Once the motor is started the auxiliary winding is disconnected with the help of centrifugal switch (S) at about 75 to 80% of synchronous speed.

**Q.3(d) Explain importance of Earthing and also list the types of earthing.** **[4]**

**Ans.:** **Importance of Earthing** [2 marks]

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 equipments.

**Types of earthing :** [2 marks]

**(i) Pipe earthing :** in this method, the galvanized iron pipe embedded vertically in the ground to work as earth electrode. The pit area around the pipe is filled with alternate layers of salt and broken pieces of coke or charcoal.

**(ii) Plate earthing :** for plate earthing a pit of a 4 meter is dug into the ground and earth electrode (plate) is placed vertical in that pit. The space around the plate is filled with layers of charcoal and salt for a minimum thickness of 15 cm.

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

**Q.4(a) A non-magnetic ring has a mean diameter of 44.5 cm and a cross-sectional area of 12 cm2 . It is uniformly wound with 500 turns. Calculate the field strength and total flux produced in the ring by a current of 1Amp. [4]**

**Ans.:** d = 44.5 cm  r = 22.25 cm  I = 1A

(i) $H = \frac{I}{2\pi r}$ [2 marks]

$H = 0.715$ A/m

(ii) $B = \mu H$ [2 marks]

$B = 0.898 \times 10^{-6}$

**Q.4(b) Write any two applications of each of the following. i) DC Shunt Motor ii) DC Series Motor. [4]**

**Ans.:** **(i) DC shunt motor** [2 marks]

The various applications of DC shunt motor are in

| | | |
|---|---|---|
| (1) Lathe Machines | (2) Centrifugal Pumps | (3) Fans |
| (4) Blowers | (5) Conveyors | (6) Lifts |
| (7) Weaving Machine | (8) Spinning machines, etc. | |

**(ii) DC series motor application** [2 marks]

Its high starting torque makes it particularly suitable for a wide range of traction applications.

Industrial uses are hoists, cranes, trolly cars, conveyors, elevators, air compressors, vacuum cleaners, sewing machines etc.

**Q.4(c) Explain principle of operation of Universal motor with neat diagram. [4]**

**Ans.:** **Principle of operation:** [Diagram & Explanation - 2 marks each]

These motors can run both on a.c. as well as d.c. Universal motor works on the principle that when a current carrying conductor is kept in magnetic field, it experiences a mechanical force and the direction of force is given by Fleming's left hand rule.

In this motor, supply is given to filed winding as well as armature winding. Field winding is connected I series with armature winding. As current flows through field winding, magnetic field is produced. Since current is flowing through armature winding also, so armature winding becomes current carrying conductor kept in magnetic field. Hence armature winding experiences force and makes armature to rotate.)

**(i) Construction**

Generally universal motors are of 2 types :

(a) Concentrated – Pole, non-compensated type (low power rating)

(b) Distributed – field, compensated type (high power rating)

Type (i) above has 2 salient i.e. projected poles and is just like a 2-pole d.c. series motor. The laminated stator is used to reduce the eddy current losses (which take place on an a.c. supply). The armature is similar to that of a d.c. motor i.e. it has a commutator and brush arrangement. It is laminated.

The type (ii) above has a stator core similar to that of a split-phase motor and a wound armature as above.

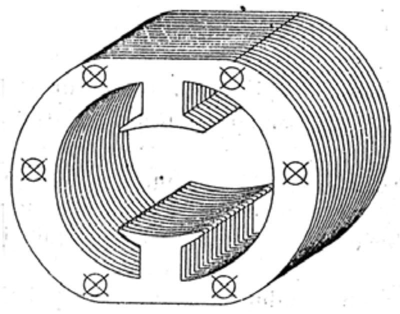


Fig. 1

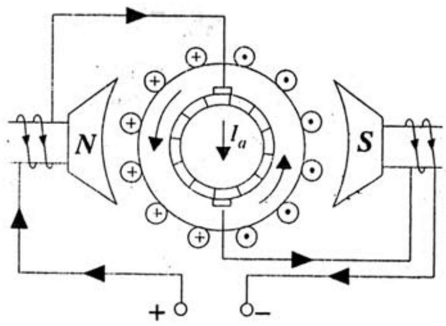



Fig. 2

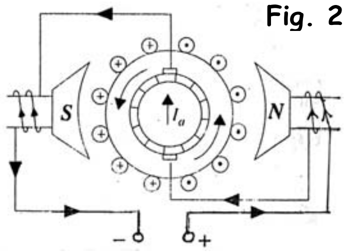



Fig. 3

**(ii) Operation**

Such motors develop a unidirectional torque regardless of the d.c. or a.c. supply. The motor works on the same basis as that of d.c. motor i.e. the force between the main pole flux and the current carrying armature conductors. This is true for a.c. or d.c. supply, as shown in figure 2 and 3.

**(iii) N v/s T characteristics**

These are as shown in figure 4.

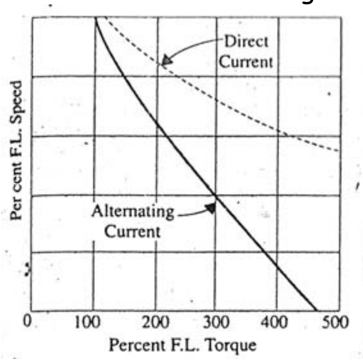



Fig. 4

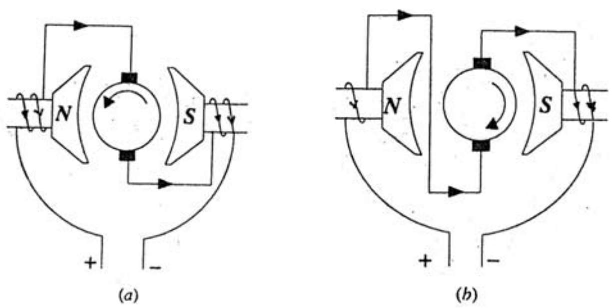



Fig. 5

**Reversal of Rotation**

The concentrated type universal motors may be reversed by interchanging the terminals of either the armature or of the field winding usually armature winding terminals are changed as shown in figure 5 above.

Same procedure applies for distributed field compensated type of universal motor.

**Ratings** : 5 W to 500 W and 1000 RPM to 20000 RPM.

**(iv) Applications**

Home food mixers, vaccum cleaners, domestic sewing machines etc.

**Q.4(d) State the types of stepper motor. Explain working of any one type of Stepper Motor.** **[4]**

Ans.: **Types of stepper motor** [Diagram & Explanation - 2 marks each]

A stepper motor is an electromechanical device which converts electrical pulses into discrete mechanical movements. The shaft or spindle of a stepper motor rotates in discrete step increments when electrical command pulses are applied to it in the proper sequence. The motors rotation has several direct relationships to these applied input pulses. The sequence of the applied pulses is directly related to the direction of motor shafts rotation. The speed of the motor shafts rotation is directly related to the frequency of the input pulses and the length of rotation is directly related to the number of input pulses applied

**Advantages**

(i) The rotation angle of the motor is proportional to the input pulse.
(ii) The motor has full torque at standstill (if the windings are energized)
(iii) Precise positioning and repeatability of movement since good stepper motors have an accuracy of 3 – 5% of a step and this error is non cumulative from one step to the next.
(iv) Excellent response to starting/ stopping/reversing.
(v) Very reliable since there are no contact brushes in the motor. Therefore the life of the motor is simply dependant on the life of the bearing.

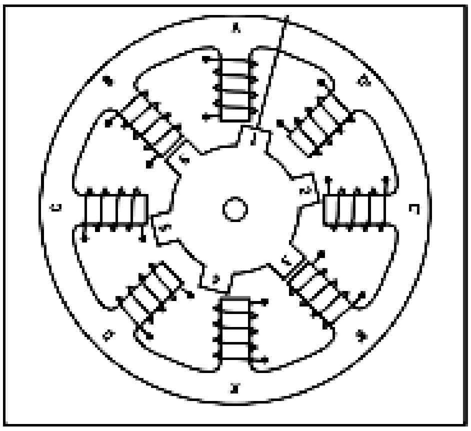


**Fig. 1:** Cross-section of a variable-reluctance (VR) motor.

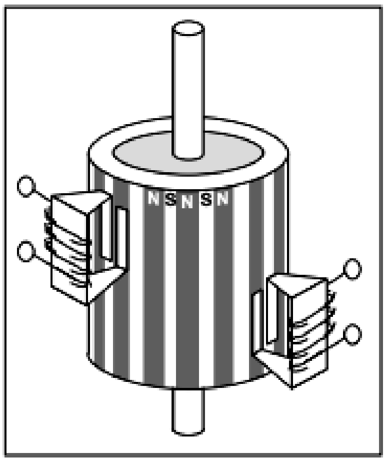
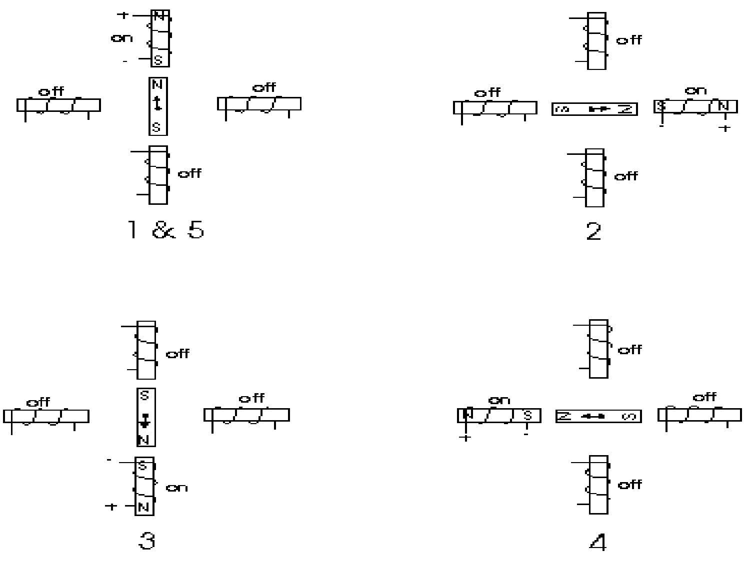



**Fig.2 :** Principle of a PM or tin-can stepper motor.

**Working of Stepper motor**

Stepper motors consist of a permanent magnetic rotating shaft, called the rotor, and electromagnets on the stationary portion that surrounds the motor, called the stator. Figure below illustrates one complete rotation of a stepper motor. At position 1, we can see that the rotor is beginning at the upper electromagnet, which is currently active (has voltage applied to it). To move the rotor clockwise (CW), the upper electromagnet is deactivated and the right electromagnet is activated, causing the rotor to move 90 degrees CW, aligning itself with the active magnet. This process is repeated in the same manner at the south and west electromagnets until we once again reach the starting position.



**Q.4(e) Explain with neat diagram operation of MCB.** **[4]**

**Ans.: MCB (Miniature Circuit Breaker)** [Diagram & Explanation - 2 marks each]

MCB is commonly used in low voltage electrical network, such as homes, for overcurrent protection. MCB automatically disconnects the network in abnormal conditions such as overload or faults. MCBs are generally used for operating currents below 63 Amps. In some cases, MCBs can be used up to 100 Amps also.

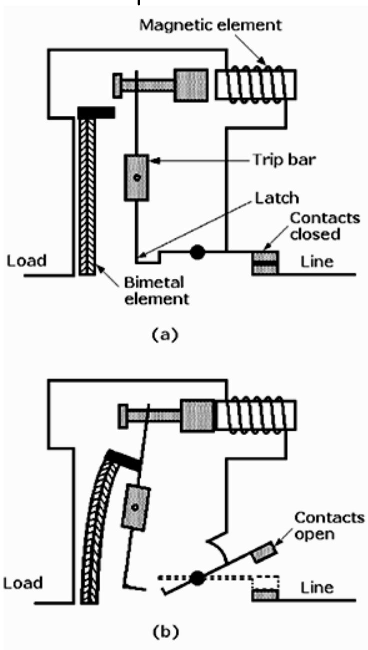



**Fig.**

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

**Q.5(a) A sinusoidal voltage with equation v=173 sin (314 t − 300 ) Volt is applied to a load. Calculate: (i) Maximum Voltage (ii) RMS Voltage (iii) Frequency (iv) Time Period (v) Phase and (vi) Angular Frequency.** **[6]**

**Ans.:** $v = 173 \sin(314t = 30°)$   $v = V_m \sin(\omega t - \phi)$

$V_m = 173$   $\omega = 314$   $\phi = -30$

**(i) Maximum Voltage** [1 mark]

$V_m = 173$ V

**(ii) RMS Voltage** [1 mark]

$$V = \frac{V_m}{\sqrt{2}} = 122.32 \text{ V}$$

**(iii) Frequency** [1 mark]

$$f = \frac{\omega}{2\pi} = \frac{314}{2\pi} = 50 \text{ Hz}$$

**(iv) Time Period** [1 mark]

$$T = \frac{1}{f} = \frac{1}{50} = 0.02 \text{ sec}$$

**(v) Phase** [1 mark]

Phase is - 30

**(vi) Angular Frequency** [1 mark]

$\omega = 314$ rad/sec

**Q.5(b) Three similar coils each of resistance of 20 Ω and an inductance of 0.5 H areconnected in star to a 3-phase, 440 V, 50Hz supply system. Calculate the phase current, line current, phase voltage, line voltage, total phase power and total line power.** **[6]**

**Ans.:** $R = 20\ \Omega$ $L = 0.5$ H $X_L = 2\pi fL = 157.07$

$Z_{ph} = \sqrt{R^2 + X_L^2} = 158.34\ \Omega$ [2 marks]

$V_L = 440$ V $f = 50$ Hz

$V_{ph} = \dfrac{V_L}{\sqrt{3}} = 254.03$ V [2 marks]

$I_{ph} = \dfrac{V_{ph}}{Z_{ph}} = \dfrac{254.03}{158.34} = 1.60$ A

$I_L = \sqrt{3} I_{ph} = 2.77$ A [2 marks]

**Q.5(c) A 1-Phase, 1 kVA, 230/115 V transformer used in a laboratory. Calculate: (i) Primary winding current (ii) Secondary winding current (iii) Turns Ratio and (iv) Current Ratio.** **[6]**

**Ans.:** $E_1 = 230$, $E_2 = 115$, KVA rating = 1000 VA

(i) $I_1 = \dfrac{\text{KVA rating}}{E_1} = \dfrac{1000}{230} = 4.34$ A [$1\frac{1}{2}$ mark]

(ii) $I_2 = \dfrac{\text{KVA rating}}{E_2} = \dfrac{1000}{115} = 8.69$ A [$1\frac{1}{2}$ mark]

(iii) $K = \dfrac{E_2}{E_1} = 0.5$ [$1\frac{1}{2}$ mark]

(iv) Current ratio = $\dfrac{I_1}{I_2} = 2$ [$1\frac{1}{2}$ mark]

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

**Q.6(a) Write any two applications of each of the following motor:** **[6]**

**(i) Universal Motor**
**(ii) Stepper Motor**
**(iii) Capacitor Start Induction Run Motor**

**Ans.:** **(i) Application of Universal Motor** [2 marks]

Universal motors are commonly used in portable power tools and equipment, as well as many household appliances. They're also relatively easy to control, electromagnetically using tapped coils, or electronically.

**(ii) Application of Stepper Motor** [2 marks]

**(1) Industrial Machines :** Stepper motors are used in automotive gauges and machine tooling automated production equipments.

**(2) Security :** New surveillance products for the security industry.

**(3) Medical** : Stepper motors are used inside medical scanners, samplers, and also found inside digital dental photography, fluid pumps, respirators and blood analysis machinery.

**(4) Consumer Electronics :** Stepper motors in cameras for automatic digital camera focus and zoom functions.

**(iii) Application of Capacitor Start Induction Run Motor** [2 marks]

A capacitor run motor has more torque, is quieter and more efficient than a capacitor start motor. With that in mind capacitor run motors are of use in high duty applications and applications requiring higher torque such as compressors. A capacitor start, capacitor run motor is not to be confused with a permanent split capacitor motor. PSC motors have lower starting torque than CSCR motors.

**Q.6(b) Write any four IE rules relevant to earthing. [6]**

**Ans.:** [Each point 1 mark]

1. (a) The neutral conductor of 3$\phi$, 4 wire system shall be earthed by not less than 2 separate and distinct connections with earth :
   (b) In case of underground cables, the external conductor of such cables shall be earthed by 2 separate and distinct connections with earth.
   (c) The connection with earth may include a link by means of which the connection may temporarily be interrupted for the purpose of testing or for locating a fault.
   (d) In case of AC system, no impedance should be inserted in between the earth connection.
   (e) No person shall make connection with earth by the aid of any water main not belonging to him except with the consent of the owner and inspector.
2. The frame of every generator, motor and the metallic parts of transformers and any other apparatus used for regulating or controlling energy and all medium voltage energy consuming apparatus shall be earthed by the owner by 2 separate and distinct connections with earth.
3. All earthing systems shall, before electric supply lines or apparatus are energized, be tested for electrical resistance to ensure efficient earthing.
4. All earthing systems belonging to supplies shall be rested for resistance on dry day during the dry season, not less than once in every 2 years.
5. Each stay wire shall be similarly earthed unless an insulator has been placed in at a height not less than 3.0 m from ground.

**Q.6(c) Write any two applications of each of the following: [6]**
**(i) ELCB (ii) MCCB (iii) MCBand (iv) Fuse.**

**Ans.:** **(i) Application of ELCB** [$1\frac{1}{2}$ marks]

An Earth-leakage circuit breaker (ELCB) is a safety device used in electrical installations with high Earth impedance to prevent shock. It detects small stray voltages on the metal enclosures of electrical equipment, and interrupts the circuit if a dangerous voltage is detected. Once widely used, more recent installations instead use residual current circuit breakers which instead detect leakage current directly.

**(ii) Application of MCCB** [$1\frac{1}{2}$ marks]

Molded case circuit breakers are a type of electrical protection device that is commonly used when load currents exceed the capabilities of miniature circuit breakers. They are also used in applications of any current rating that require adjustable trip settings, which are not available in plug-in circuit breakers and MCBs.

**(iii) Application of MCB** [$1\frac{1}{2}$ marks]

A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overcurrent, typically resulting from an overload or short circuit. Its basic function is to interrupt current flow after a fault is detected. Unlike a fuse, which operates once and then must be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation.

Circuit breakers are made in varying sizes, from small devices that protect low-current circuits or individual household appliance, up to large switchgear designed to protect high voltage circuits feeding an entire city. The generic function of a circuit breaker, RCD or a fuse, as an automatic means of removing power from a faulty system is often abbreviated as OCPD (Over Current Protection Device)

**(iv) Application of Fuse** [$1\frac{1}{2}$ marks]

Fuses are used in many industrial electronic and electrical applications, including:

- Hard Disk Drives
- LCD Monitors
- Battery Packs
- General Appliances and Devices
- Printers/ Scanners
- Laptops
- Automotive Systems
- Gaming Systems & Portable Electronics
- Cell Phones

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