Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.

2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.

3) The language errors such as grammatical, spelling errors should not be given importance (Not applicable for subject English and Communication Skills).

4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure/figures drawn.

5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer (as long as the assumptions are not incorrect).

6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate's understanding.

7) For programming language papers, credit may be given to any other program based on equivalent concept

1 A) Attempt any six of the following: **12**

1 A) a) State potential difference and its unit.

Ans:

Potential Difference:

The difference between the electrical potentials at any two given points in the electrical circuit is known as potential difference between those points.

Unit:- volt (V)

1mark for definition

1 mark for unit

1 A) b) If the two resistances of 24Ω in series are connected in parallel with two resistances of 24Ω, find the equivalent resistance.

Ans:

Equivalent resistance of series combination $R_1 = 24 + 24 = \mathbf{48\Omega}$ 1 mark

Equivalent resistance of parallel combination

$$\frac{1}{R_{AB}} = \frac{1}{48} + \frac{1}{24} + \frac{1}{24} = 0.02083 + 0.04167 + 0.04167 = 0.1042$$

1 mark

$$\therefore \boldsymbol{R_{AB} = 9.6\,\Omega}$$

1 A) c) State reluctance. What is its unit?

Ans:

Reluctance:

The opposition offered by material to the magnetic flux to set up through it, is called ‘Reluctance’ of material to the flux.

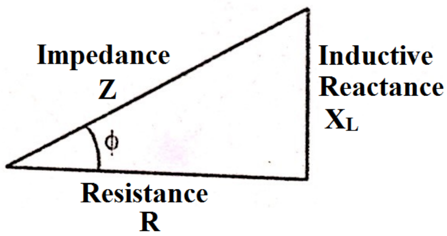
Unit: ampere-turns/weber or AT/wb or A/wb

1 mark for valid definition

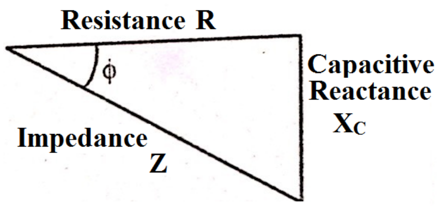
1 mark for unit

1 A) d) Draw impedance triangle and label it.

Ans:



Impedance triangle for R-L series circuit



Impedance triangle for R-C series circuit

Any one labeled triangle 2 marks

1 A) e) State any four applications of 3-phase circuit.

Ans:

Application of 3 phase circuit:

1] Power and distribution system
2] Large generators
3] 3 phase motors like induction and synchronous motors
4] Low power industrial applications like cranes, conveyors, furnaces.
5] For large building loads.
6] For transmission of bulk amount of power over the lines.

½ mark for each of any four application s

1 A) f) State the concept of balanced load.

Ans:

Balanced load: If all the 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.

1 mark

e.g Balanced load: (3+j4), (3+j4), (3+j4) all impedances = 5∠53.13°Ω
Unbalanced load: (3+j4), (3-j4), (4+j3) all impedance magnitudes are 5Ω but angles are different. — 1 mark

1 A) g) Define the voltage regulation of single phase transformer.

Ans:

Voltage Regulation: — 1 mark for definition

The change in secondary terminal voltage from no load to full load expressed as fraction of no load voltage or full load voltage, with primary voltage kept constant, is called voltage regulation.

Let V_{NL} = No load secondary voltage
V_{FL} = Full load secondary voltage

So % Voltage Regulation-up $= \frac{V_{NL}-V_{FL}}{V_{FL}} \times 100$ — 1 mark for equation

% Voltage Regulation-down $= \frac{V_{NL}-V_{FL}}{V_{NL}} \times 100$

1 A) h) State the basic difference between fues and MCB.

Ans:

Basic difference between fuse and MCB:

FUSE: — 1 mark for each of any two differences

- Performs both functions: detection and interruption
- Fuse melts/fuses in case of excessive load (due to increase in temperature)
- Needs replacement after it is blown away once.

MCB:

- Performs Interruption only. Detection is made by relay system.
- MCB trips off in case of excessive load (works on bimetal expansion or induced magnetism)
- Can be reused after successful operation.

1 A) i) State the need of earthing in electrical systems.

Ans:- — 1 mark each for any two

1. Earthing is needed for safety of working personnel, safety of animals and property so that any live part touching the body of the equipment must be grounded (connected to zero volts);
2. For protection as under such circumstances the low resistance path results in heavy current drawn from supply which is sensed to trip the circuit or blow fuses.
3. Earthing is also needed in electrical installations of substations to hold the neutral voltage to very low values so that fault on one phase does not affect the other (neutral earthing)

1 B) Attempt any two of the following: **8**

1 B) a) State the following terms and write the formula.
i) Inductive reactance ii) Capacitive reactance
State the relation of frequency for both the terms.

Ans:

1. **Inductive Reactance**:-
Inductive reactance is defined as the opposition offered by inductance to the — ½ mark for

flow of an alternating current.
Inductive Reactance is expressed as $X_L = 2\pi f L \; ohm$

2. **Capacitive Reactance**:
Capacitive reactance is defined as the opposition offered by capacitance to the flow of an alternating current.
Capacitive Reactance is expressed as $X_C = \frac{1}{2\pi f C} \; ohm$
where, L is the inductance in henry,
C is the capacitance in farad,
f is the frequency in Hz

definition of each = 1mark

1 mark for each equation of X =2 marks

3. **Relation of frequency:**
The inductive reactance (X_L) is directly proportional to frequency (f).
$$X_L \propto f$$
The capacitive reactance (X_C) is inversely proportional to frequency (f).
$$X_C \propto \frac{1}{f}$$

½mark for each relation = 1 mark

1 B) b) For the given circuit as shown in the figure 1B(b) find the current flowing and the magnitude of p.f.

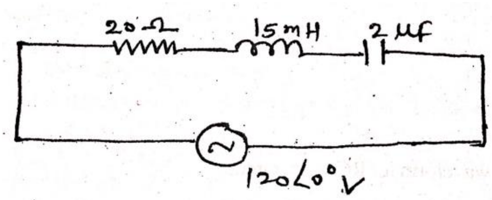


Fig. 1B (b)

Ans:
Data Given: Resistance R = 20Ω, Inductance L = 15 mH, Capacitance C = 2μF
Supply Voltage V = 120∠0°
Assuming supply frequency f = 50Hz,

(i) Inductive reactance $X_L = 2\pi f L = 2\pi(50)(15 \times 10^{-3})$ =4.71Ω
(ii) Capacitive reactance $X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(50)(2\times 10^{-6})} = 1591.55\Omega$

½ mark for each X = 1 mark

(iii) Impedance of series circuit
$$Z = R + jX_L - jX_C = 20 + j4.71 - 1591.55 = 1586.97\angle -89.28°\Omega$$

1 mark

(iv) **Current** $I = \frac{V}{Z} = \frac{120\angle 0°}{1586.97\angle -89.28°} = \mathbf{0.0756\angle 89.28°}$ **A**

1 mark

(v) **Power factor** cosϕ = cos(89.28°) = **0.01257 leading**

1 mark

1 B) c) Explain the working principle of shaded pole single-phase induction motor.

Ans:

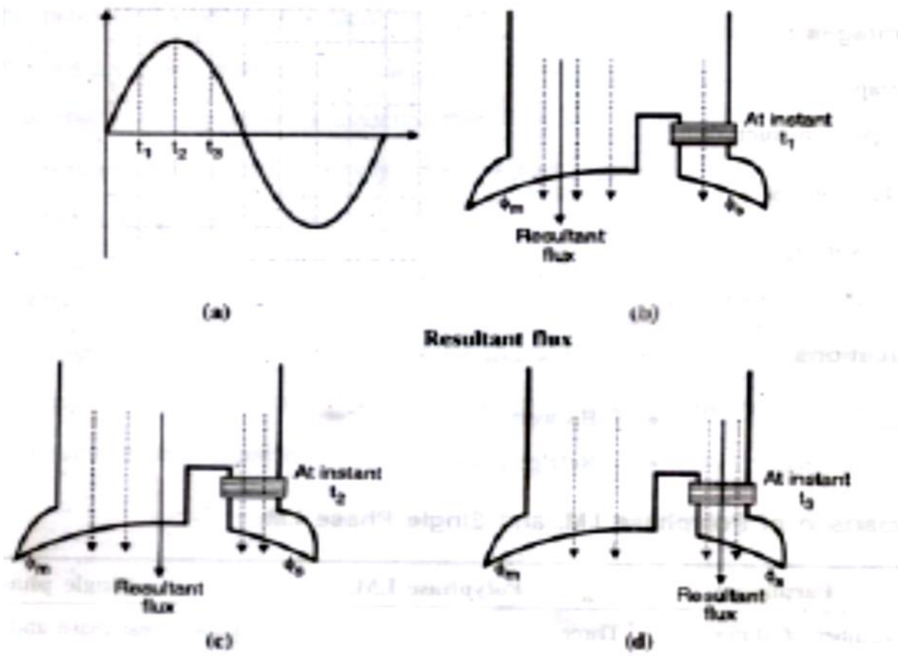
Shaded pole single-phase induction motor:

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 produce the magnetic flux the shaded part of core 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 of the flux wave to examine the effect of shading band as shown in the fig below. The magnetic neutral

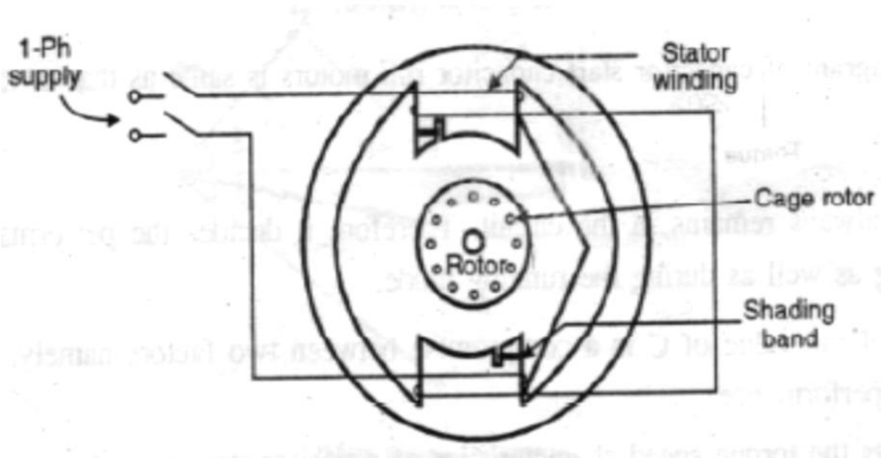
2 Marks for

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 may be sufficient to provide starting torque to squirrel cage rotor and rotor rotates.

working principle



2 Marks for diagram



2 **Attempt any four of the following:** **16**

2 a) Applying mesh loop current method, find current flowing through 12 Ω connected between terminals A and B (Refer fig. 2(a)).

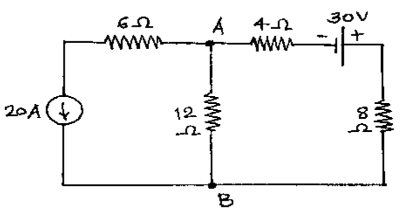
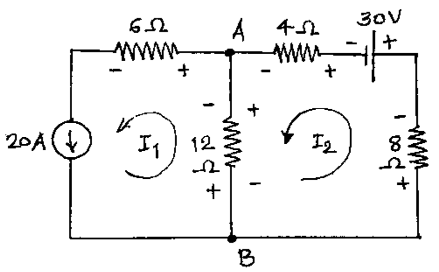


Fig. 2(a)



Ans:
Mesh Analysis:

i) There are two meshes in the network.

ii) Mesh currents I_1 and I_2 are marked anticlockwise as shown.

iii) The polarities of voltage drops across resistors are also shown with reference to respective mesh currents.

iv) By tracing mesh 1 clockwise, we can write

$\therefore I_1 = 20\text{ A} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$

By tracing mesh 2 anticlockwise, KVL equation is,

$-8I_2 - 30 - 4I_2 - 12(I_2 - I_1) = 0$

$\therefore 12I_1 - 24I_2 = 30 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$

v) Substituting eq.(1) in to (2), we get,

$12(20) - 24I_2 = 30$

$-24I_2 = 30 - 240 = -210$

$\therefore I_2 = 8.75\text{ A} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$

vi) Current through 12Ω is $I = (I_1 - I_2)$ flowing from B to A

I = 20 – 8.75 = **11.25A from B to A**

1 mark for mesh identification and marking

1 mark for I_1

1 mark for mesh equation

1 mark for final solution

2 b) State Kirchhoff's laws, with sign convention concept. How KVL is different than mesh loop method?

Ans:

Kirchhoff's laws:

1) Kirchhoff's Current Law (KCL):

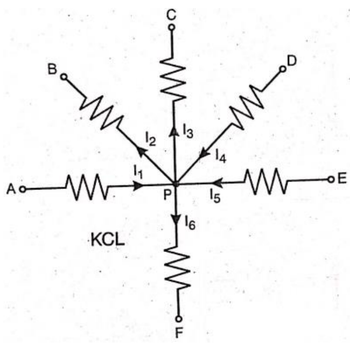
It states that in any electrical network, the algebraic sum of the currents meeting at a node (point or junction) is zero.

i.e ΣI=0

At junction point P, $I_1 - I_2 - I_3 + I_4 + I_5 - I_6 = 0$

Sign convention:

Incoming current at the node is considered to be positive and outgoing current to be negative.



1 mark for KCL

½ mark for sign convention

2) Kirchhoff's Voltage Law (KVL):

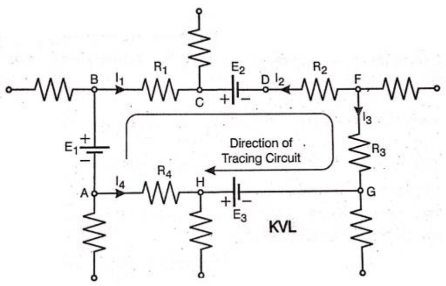
It states that, in any closed path in an electric circuit, the algebraic sum of the emfs and products of the currents and resistances is zero.

i.e ΣE - ΣIR=0 or ΣE = ΣIR

OR

It states that, in any closed path in an electrical circuit, the total voltage rise is equal to the total voltage drops.

i.e Voltage rise = Voltage drop



1 mark for KVL

½ mark for sign convention

Refering to the circuit, by KVL we can write,

$(E_1 - E_2 + E_3) = (I_1R_1 - I_2R_2 + I_3R_3 - I_4R_4)$

Sign convention:

While tracing the loop or mesh, the voltage rise is considered as positive and voltage drop is considered as negative.

Difference between Mesh Loop Method and KVL:

In mesh loop method, the mesh/loop currents are marked first and then the branch currents are expressed in terms of mesh currents to write the voltage equations. — 1 mark for difference

In KVL method, the branch currents are marked and voltage equations are written in terms of it.

2 c) An alternating voltage is represented by $v = 114.8\sin(314t)\ volt$.
Find: (i) rms value (ii) average value (iii) maximum value (iv) frequency of voltage.

Ans:

Standard equation of sinusoidal quantity is $v = V_m \sin(\omega t)\ volt$. On comparing the given voltage with standard equation, we get — 1 mark for each point

(i) Maximum Value $V_m = \mathbf{114.8}$ **volt**

(ii) RMS value $V = \frac{V_m}{\sqrt{2}} = \frac{114.8}{\sqrt{2}} = \mathbf{81.175}\ \boldsymbol{volt}$

(iii) Average value (over full cycle) = 0 volt

Average value (over half cycle) $V_{av} = 0.637V_m = 0.637 \times 114.8$
= **73.13 volt**

(iv) Angular frequency ω = 314 rad/sec = 2πf

$\therefore$ frequency f $= \frac{314}{2\pi} = 49.97 \cong$ **50Hz**

2 d) State the following terms:

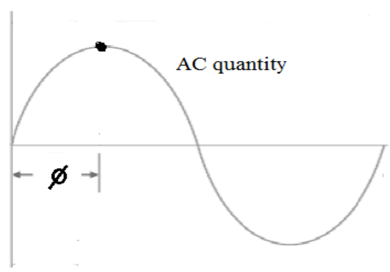
(i) Phase
(ii) Phase difference
(iii) In-phase quantity
(iv) Out-of-phase quantity

Ans:

i) Phase:-

It is the angular distance covered by an alternating quantity since it passed through its last zero value while increasing towards positive maximum value. — 1mark for each term

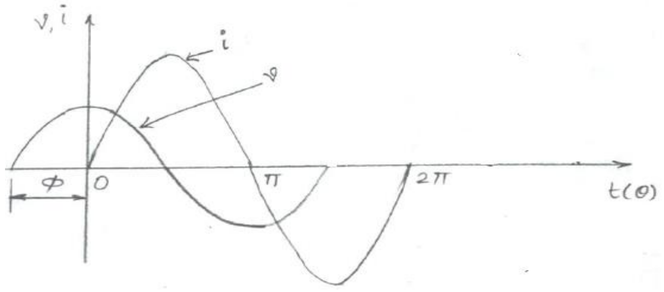
In the following figure the phase of quantity at positive maximum value is Ø = 90°.



ii) Phase difference:-

Phase difference between two alternating quantities is the angular

distance between their respective zero or maximum values.
In the following figure, it is seen that the angular distance between corresponding zero values is Ø, hence phase difference between them is Ø.

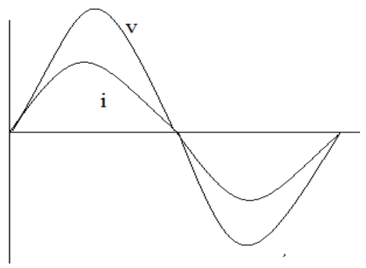


iii) In phase quantity:-

If phase difference between two alternating quantities is zero then they are called as 'In phase quantities'.

OR

If two alternating quantities attain their zero values or maximum values simultaneously, then such quantities are called "In-phase" quantities.

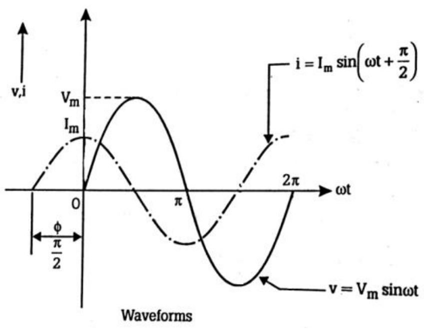


iv) Out of phase quantity:-

If phase difference between two alternating quantities is non-zero, then they are called as "Out-of- phase" quantities.

OR

If two alternating quantities do not attain their zero values or maximum values simultaneously, then such quantities are called "Out-of-phase" quantities.

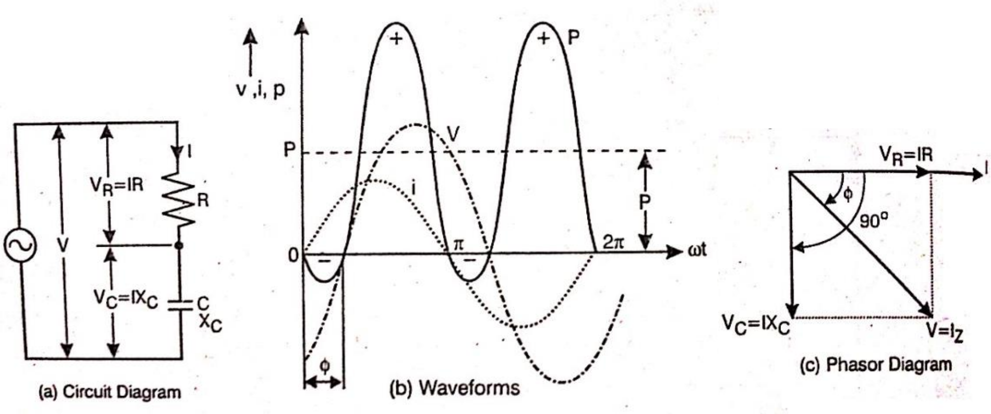


2 e) Draw a phasor diagram and waveform for RC series circuit.

Ans:

RC series circuit:

The circuit diagram, waveforms and phasor diagram for series RC circuit are shown below.



(a) Circuit Diagram (b) Waveforms (c) Phasor Diagram

2 marks for waveforms

2 marks for phasor diagram

2 f) If R = 25Ω, L = 10mH and C = 50μF, find active power, reactive power when they are connected in series across a a.c. source of 220∠0° volt.

Ans:

Data Given: Resistance R = 25Ω, Inductance L = 10 mH, Capacitance C = 50μF
Supply Voltage V = 220∠0°
Assuming supply frequency f = 50Hz,

(i) Inductive reactance $X_L = 2\pi f L = 2\pi(50)(10\times10^{-3})$ =3.14Ω — 1 mark for I

(ii) Capacitive reactance $X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(50)(50\times10^{-6})} = 63.66\Omega$

(iii) Impedance of series circuit — 1 mark for ∅
$Z = R + jX_L - jX_C = 25 + j3.14 - j63.66$
$= 25 - j60.52 = 65.48\angle-67.56°\Omega$

(iv) Current $I = \frac{V}{Z} = \frac{220\angle0°}{65.48\angle-67.56°} = 3.36\angle67.56°$ A — 1 mark for P

(v) Power factor cos∅ = cos(67.56°) = 0.38 leading

(vi) **Active power** $\boldsymbol{P} = VIcos\emptyset = (220)(3.36)(0.38) = \mathbf{282.16\ watt}$ — 1 mark for Q

(vii) **Reactive power** $\boldsymbol{Q} = VIsin\emptyset = (220)(3.36)(0.92) = \mathbf{680.064\ var}$

3 Attempt any four of the following: 16

3 a) For the circuit shown in fig. 3(a) find the resistance between terminals A and B using star delta conversion.

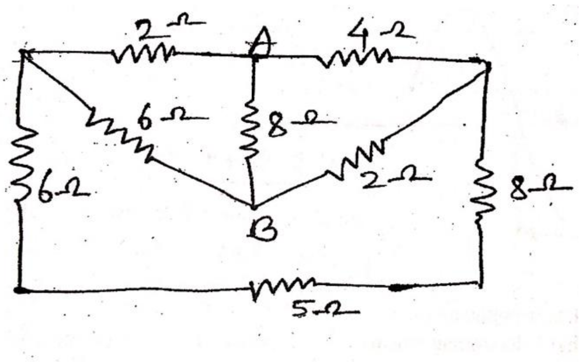
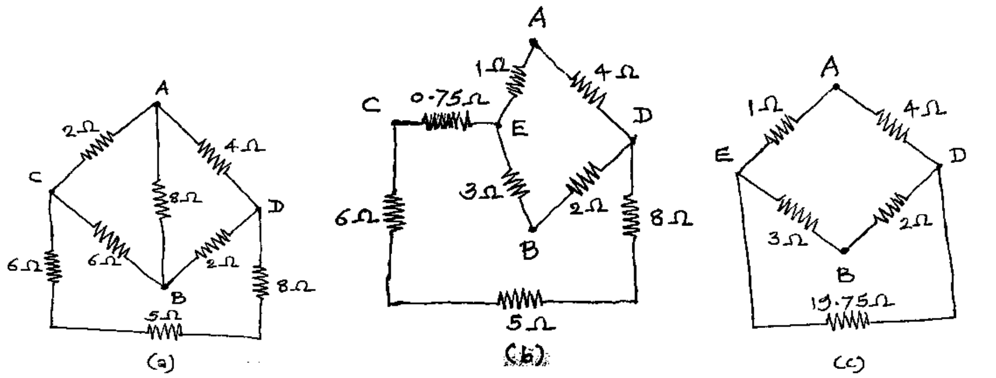


Fig. 3(a)

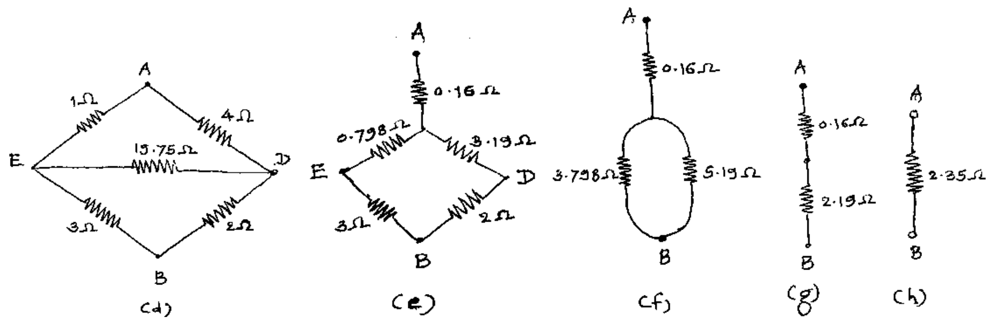
Ans:

The circuit is redrawn as shown in Fig.(a) below.

Step I: Converting delta ABC in to equivalent star.



4 marks for stepwise solution



$$R_A = \frac{2 \times 8}{2 + 8 + 6} = 1\Omega$$

$$R_B = \frac{6 \times 8}{2 + 8 + 6} = 3\Omega$$

$$R_C = \frac{6 \times 2}{2 + 8 + 6} = 0.75\Omega$$

The modified circuit diagram is shown in Fig.(b)

Step II: Equivalent resistance of series combination between E and D

$= 0.75 + 6 + 5 + 8 = 19.75\Omega$

The modified circuit diagram is shown in Fig.(c). This circuit can be redrawn as shown in Fig.(d).

Step III: Converting delta AED in to equivalent star

$$R_A = \frac{1 \times 4}{1 + 4 + 19.75} = 0.16\ \Omega$$

$$R_E = \frac{1 \times 19.75}{1 + 4 + 19.75} = 0.798\ \Omega$$

$$R_D = \frac{4 \times 19.75}{1 + 4 + 19.75} = 3.19\ \Omega$$

The modified circuit diagram is shown in Fig.(e).

Step IV: Solving series combinations

$0.798+3 = 3.798\ \Omega$

$3.19 + 2 = 5.19\ \Omega$

The modified circuit diagram is shown in Fig.(f).

Step V: Solving parallel combination

Equivalent resistance $= \frac{3.798 \times 5.19}{3.798 + 5.19} = 2.19\Omega$

The modified circuit diagram is shown in Fig.(g).

Step VI: Final solution

Referring to Fig.(g), the equivalent resistance between terminal A and B is given by,

$$\boldsymbol{R_{AB}} = 0.16 + 2.19 = \mathbf{2.35\Omega}$$

3 b) AC voltage of $v = 110\sin(314t)$ is applied across a 39mH inductor. Write the equation for current, draw phasor diagram.

Ans:

i) Equation for current:

Comparing voltage equation with standard form, we can write,

Angular frequency ω = 2πf = 314 rad/sec — 1 mark for f

∴ Frequency f = 314/(2π) = 49.97 ≅ 50 Hz.

∴ Inductive reactance $X_L = 2\pi f L = 2\pi(50)(39 \times 10^{-3}) = 12.25\,\Omega$

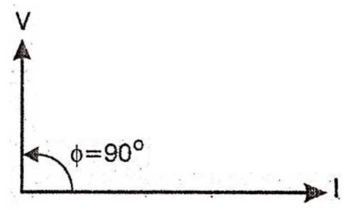
Maximum value of current $I_m = \frac{V_m}{X_L} = \frac{110}{12.25} = 8.98A$ — 1 mark for I_m

Since it is pure inductor, current lags behind the voltage by 90°.

The current is expressed as, — 1 mark for eq. of i

$$\boldsymbol{i = 8.98\sin(314t - 90°)\,A}$$

ii) Phasor diagram: — 1 mark for phasor diagram



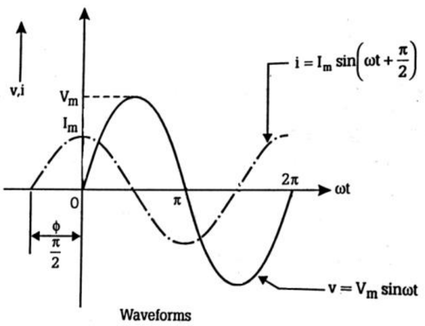
Phasor Diagram

3 c) State the concept of lagging and leading quantity. State its nature for capacitive circuit only.

Ans:

Concept of lagging and leading quantity: — 1 mark for lagging quantity

In case of two out-of-phase quantities, the quantity which attains its zero or maximum value first as compared to other quantity, is called leading quantity. The quantity which attains its zero or maximum value later as compared to other quantity, is called as lagging quantity. — 1 mark for leading quantity



Waveforms

In the waveforms shown, it is seen that the current becomes zero first and after an angle of 90° voltage becomes zero. Similarly, current reaches to its maximum value first and after an angle of 90° voltage becomes maximum. So here current is a leading quantoty and voltage is lagging quantity. — 1 mark for diagram

Nature for Capacitive circuit: — 1 mark for nature

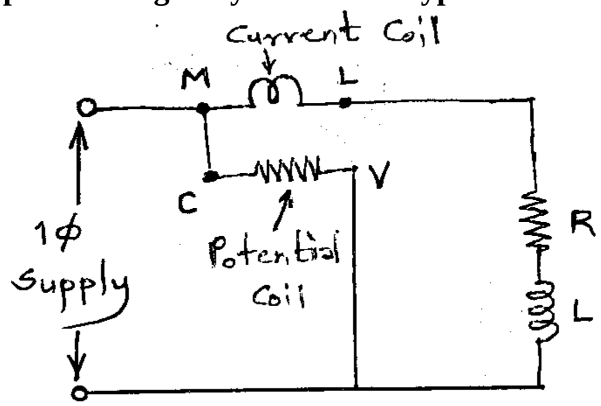
For capacitive circuit, the current leads the voltage by some angle, usually less than

90°. However, if the circuit is purely capacitive, the current leads voltage by 90°. We can also say thet the voltage lags behind current by 90°.

3 d) Draw a neat circuit for measurement of power using of dynamometer type wattmeter on R-L series circuit. Label the current coil and potential coil.

Ans:

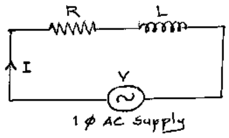
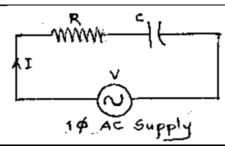
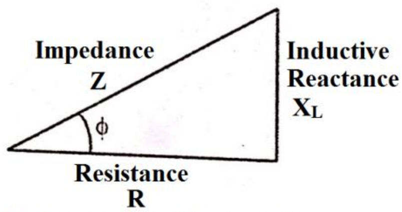
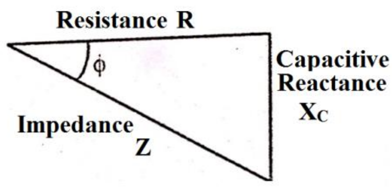
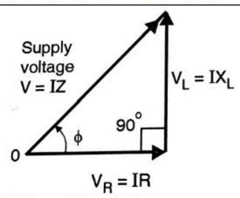
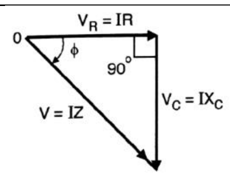
Measurement of power using of dynamometer type wattmeter: — 4 marks for Labeled diagram

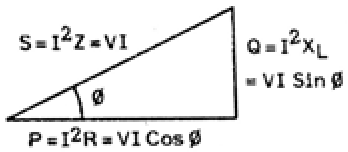
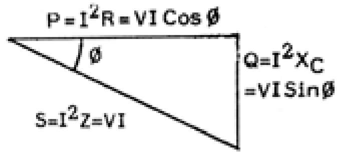


3 e) State any four comparisons between R-L series and R-C series circuit.

Ans:

Comparison between R-L series and R-C series circuit: — 1 mark for each of any four points

Particulars	R-L series circuit	R-C series circuit
Circuit diagram		
Impedance	$Z = R + jX_L = \|Z\|\angle\emptyset$	$Z = R - jX_C = \|Z\|\angle-\emptyset$
Phase angle	0 < Ø < 90° lagging	0 < Ø < 90° leading
Power factor	0 < cosØ < 1 lagging	0 < cosØ < 1 leading
Imdedance triangle	 Impedance triangle for R-L series circuit	 Impedance triangle for R-C series circuit
Voltage triangle	 Voltage Triangle for R-L Series Circuit	 Voltage Triangle for R-C Series Circuit

Power triangle		

3 f) For a balanced 440V, 50Hz, star connected system, three equal coils of resistance 12 ohm and inductance 15mH are connected per phase. Calculate line current and power absorbed by the circuit.

Ans:

Data Given: Line Voltage V_L = 440V, Frequency f = 50 Hz — 1 mark for X_L

Resistance R = 12 Ω, Inductance L = 15 mH

∴ Inductive reactance per phase $X_L = 2\pi fL = 2\pi(50)(15\times10^{-3}) = 4.71\,\Omega$

∴ Impedance per phase $Z = R + jX_L = 12 + j4.71 = 12.89\angle 21.43°\,\Omega$ — 1 mark for Z

In star-connected system, phase voltage $V_{ph} = \frac{1}{\sqrt{3}}$ Line voltage = $\frac{440}{\sqrt{3}} = 254.03\,V$

∴ Phase current $I_{ph} = \frac{V_{ph}}{Z} = \frac{254.03\angle 0°}{12.89\angle 21.43°} = 19.71\angle -21.43°$ A — 1 mark for I_L

In star-connected system, **Line current = Phase current = 19.71 A**

Power absorbed by the circuit, — 1 mark for $P_{3Ø}$

$$P_{3Ø} = \sqrt{3}V_L I_L cos Ø = 3V_{ph}I_{ph}cos Ø$$
$$= \sqrt{3}(440)(19.71)\cos(-21.43°)$$

= **13982.55 watt**

4 Attempt any four of the following: **12**

4 a) State the difference between statically and dynamically induced emf. For each type state one example.

Ans:

Statically induced emf	**Dynamically induced emf**
Emf is induced without any relative motion between conductor and magnetic field.	Emf is induced due to relative motion between conductor and magnetic field.
Emf is induced when changing magnetic field links with a conductor.	Emf is induced when conductor cuts the magnetic field due to relative motion between them.
Direction of statically induced emf is given by Lenz's law.	Direction of dynamically induced emf is given by Fleming's Right hand rule.
Two types: Self-induced emf Mutually induced emf	No such further classifcation
e.g. emf induced in transformer windings	e.g emf induced in Generator, Alternator armature windings

2 marks for difference

2 marks for 2 examples

4 b) State form factor and peak factor. State the relation between:

i) rms and max value
ii) max and average value

Ans:

Form factor:

It is the ratio of the RMS value to the average value.

Form factor $= \frac{RMS\ Value}{Average\ Value}$ 1 mark

Peak factor:

It is the ratio of Maximum or peak value to the RMS value. 1 mark

Peak factor $= \frac{Maximum\ Value\ or\ Peak\ Value}{RMS\ Value}$

Relation:

i) Relation between rms value and maximum value is given by peak factor and for sinusoidal quantity, it is $\sqrt{2}$. 1 mark

Maximum value = $\sqrt{2}$ (rms value)

ii) Relation between maximum value and average value for sinusoidal quantity is given by, 1 mark

Average value = 0.637 (Maximum value)

4 c) A circuit takes a current of 12A at a voltage of 220V and its p.f. is 0.8 leading. Draw power triangle and find active, reactive and apparent power.

Ans:

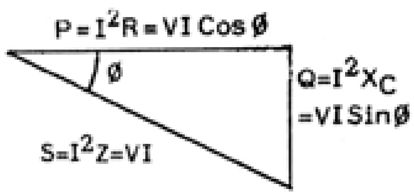
Data Given: V = 220V I = 12A cosϕ = 0.8 leading

The p.f. angle is $\phi = cos^{-1}(0.8) = 36.87°$ leading

i) Active power P = V I cosϕ = (220)(12) cos(36.87°) = 2112 watt. 1 mark

ii) Reactive power Q = V I sinϕ = (220)(12) sin(-36.87°) = -1584 var 1 mark

iii) Apparent power S = V I = (220)(12) = 2640 volt-amp 1 mark



1 mark

4 d) Draw all series resonance curves and state the relation of all elements with frequency.

Ans:

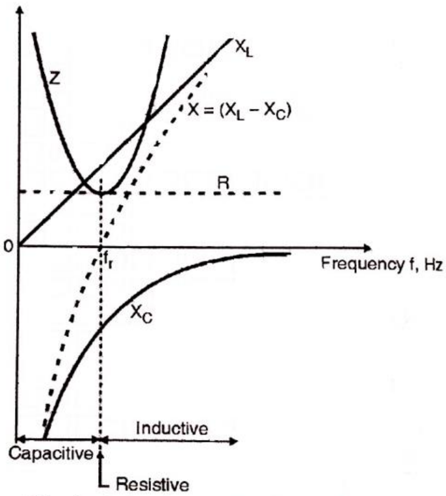
Series resonance curves:

1) Resistance is independent of frequency, i.e frequency have no effect on the value of resistance. 1 mark

2) Inductive reactance is expressed by, $X_L = 2\pi fL$. Thus the value of inductive reactance linearly changes with frequency. The inductive reactance is directly proportional to frequency. 1 mark

3) Capacitive reactance is expressed as $X_C = \frac{1}{2\pi fC}$. Thus the value of capacitive reactance is inversely proportional to the frequency. 1 mark

The relation of all elements with frequency is shown in the following figure.



Variation of reactances and impedance with frequency

1 mark

4 e) A 3-phase, 440V, 50Hz, supply is connected to a balanced 3-phase delta connected load of impedance (6 – j8) Ω/phase. Calculate:

i) Phase current
ii) Line current
iii) Power factor
iv) Total reactive power

Ans:

Data Given: Line voltage V_L = 440V, Frequency f = 50 Hz,

Delta connected load impedance per phase Z = (6 – j8) = 10∠-53.13°Ω

For delta connection, Phase voltage = Line voltage = 440V

i) Phase current = $\frac{Phase\ Voltage}{Impedance\ per\ phase} = \frac{440\angle 0°}{10\angle -53.13°} = 44\angle 53.13°\ A$ 1 Mark

ii) Line current $= \sqrt{3}(Phase\ current) = \sqrt{3}(44) = 76.21\ A$ 1 Mark

iii) Power factor cosϕ = cos(-53.13°) = 0.6 leading 1 Mark

iv) Total reactive power $Q_{3\emptyset} = \sqrt{3}V_L I_L sin\emptyset$

$= \sqrt{3}(440)(76.21)\sin(-53.13°)$ 1 Mark

$= -46463.79 var$

4 f) How single-phase I. M. is made self-starting?

Ans:

When single-phase ac supply is given to single-phase stator winding of motor, a magnetic field is produced in the air gap between stator and rotor. However, this magnetic field is not rotating in nature, rather it is pulsating or oscillating in nature. So torque is not developed and motor can not start itself. Thus single-phase induction motor is not self-starting. 4 Marks

To make the motor self-starting, it is essential that rotating magnetic field must be produced in the air gap between stator and rotor. For that, the single phase winding is split into two parts (windings) and such two windings are placed in stator core with 90° displacement. To obtain large phase difference (close to 90° in time phase) between their currents, a capacitor is inserted in series with one winding. This winding is referred as Starting or Auxiliary winding. Other winding is the main or running winding. These two windings when connected in parallel across single-phase supply, two currents of large phase difference flow through these windings and rotating magnetic field is produced. The rotating magnetic field is cut by short circuited rotor conductors, which then carry current. Due to interaction between rotor current and stator magnetic field, force is exerted on rotor ans rotor rotates.

5 Attempt any four of the following: **16**

5 a) Refer figure 5(a) and find (i) max value of current (ii) form factor (iii) peak factor and (iv) frequency.

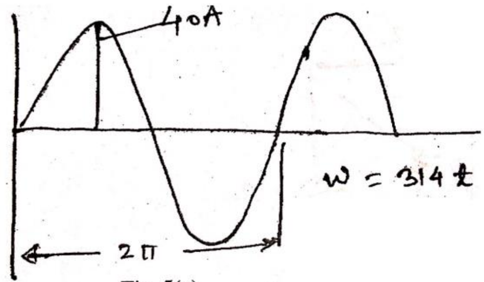


Fig. 5(a)

Ans:

Data Given: Angular frequency ω = 314 rad/sec — 1 mark for each bit

(i) Maximum value of current I_m = 40A

(ii) Form factor :

Average value of current = $0.637I_m$ = 0.637(40) = 25.48 A

RMS value of current = $0.707I_m$ = 0.707(40) = 28.28 A

∴Form factor = (RMS value)/(Average value)

$$= \frac{0.707I_m}{0.637I_m} = 1.11$$

(iii) Peak Factor:

∴Peak factor = (Peak or maximum value)/(RMS value)

$$= \frac{I_m}{0.707I_m} = 1.41$$

(iv) Frequency $f = \frac{\omega}{2\pi} = \frac{314}{2\pi} = 49.97 \cong 50\ Hz$

5 b) State following laws with their applications.

i) Faraday's Laws (both) of electromagnetism

ii) Lenz's Law

Ans:

i) Faraday's Laws of Electromagnetic Induction:

First Law:

Whenever a changing magnetic flux links with a conductor, an emf is induced in that conductor. — 1 mark

OR

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

Second Law:

The magnitude of induced emf is directly proportional to the rate of change of flux linking with the conductor or the rate of flux cut by the

conductor.
Applications: emfs induced in transformers, motors, generators, alternators etc. 1 mark

ii) Lenz's Law:
The direction of statically induced emf is such that it always opposes the cause of its production. 1 mark
Application: Finding direction of emfs in transformer windings. 1 mark

5 c) Refer figure 5(c) and find the current flowing through ~~(1)~~ 10Ω branch using node-voltage method.

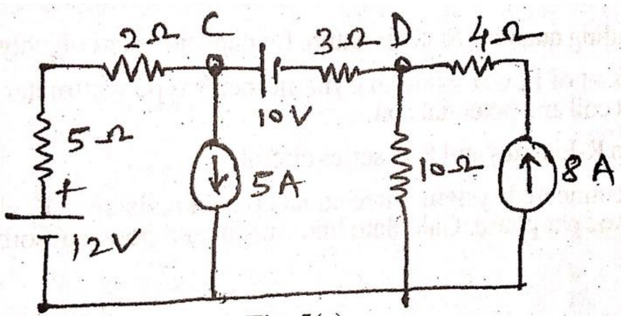


Fig. 5(c)

Ans:
Node Voltage Analysis:
Step I: Mark the nodes.
Here nodes are already marked as C and D.
Step II: Write KCL equations
By KCL at node C, we can write,

$$\frac{V_C-12}{2+5}+5+\frac{V_C-10-V_D}{3}=0$$

$$V_C\left(\frac{1}{7}+\frac{1}{3}\right)+V_D\left(\frac{-1}{3}\right)-\frac{12}{7}-\frac{10}{3}=0$$

$$V_C(0.476)+V_D(-0.333)-5.048=0$$

$$V_C(0.476)+V_D(-0.333)=5.048\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

1 mark for eq. (1)

By KCL at node D, we can write,

$$\frac{V_D}{10}-8+\frac{V_D+10-V_C}{3}=0$$

$$V_C\left(-\frac{1}{3}\right)+V_D\left(\frac{1}{3}+\frac{1}{10}\right)-8+\frac{10}{3}=0$$

$$V_C(-0.333)+V_D(0.433)-4.67=0$$

$$V_C(-0.333)+V_D(0.433)=4.67\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

1 mark for eq. (2)

Step III: Solving Simultaneous equations
Expressing eq. (1) and (2) in matrix form,

$$\begin{bmatrix}0.476 & -0.333\\ -0.333 & 0.433\end{bmatrix}\begin{bmatrix}V_C\\ V_D\end{bmatrix}=\begin{bmatrix}5.048\\ 4.67\end{bmatrix}$$

$$\therefore \Delta=\begin{vmatrix}0.476 & -0.333\\ -0.333 & 0.433\end{vmatrix}=0.206-(0.11)=0.096$$

By Cramer's rule,

$$V_C=\frac{\begin{vmatrix}5.048 & -0.333\\ 4.67 & 0.433\end{vmatrix}}{\Delta}=\frac{(2.186)-(-1.555)}{0.096}=\frac{3.741}{0.096}$$

$$\boldsymbol{V_C=38.97\ \text{volt}}$$

1 mark for node voltages

$$V_D = \frac{\begin{vmatrix} 0.476 & 5.048 \\ -0.333 & 4.67 \end{vmatrix}}{\Delta} = \frac{(2.223)-(-1.68)}{0.096} = \frac{3.904}{0.096}$$

$$\boldsymbol{V_D = 40.67\ \text{volt}}$$

Step IV: Solving for currents

Current in 10Ω resistor is given by,

$$I_{10} = \frac{V_D}{10} = \frac{40.67}{10} = \boldsymbol{4.067\ A}$$

1 mark for final ans

5 d) For a delta connected balanced system prove $I_L = \sqrt{3}\ I_{Ph}$ where I_L = line current and I_{Ph} = phase current.

Ans:

Relationship Between Line Current and Phase Current in Delta Connected System:

Let I_1, I_2 and I_3 be the phase currents.

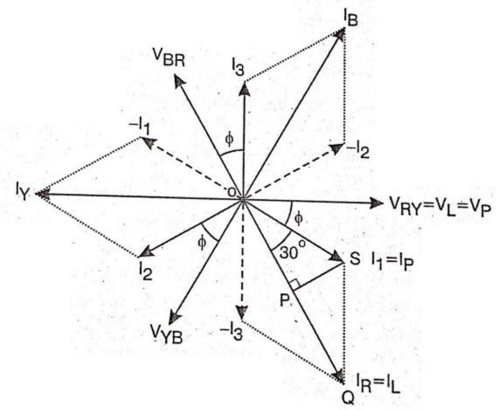
I_R, I_Y and I_B be the line currents.

The line currents are expressed as:

$I_R = I_1 – I_3$

$I_Y = I_2 – I_1$

$I_B = I_3 – I_2$



1 mark for phasor diagram

In phasor diagram, the phase currents are drawn first with equal amplitude and displaced from each other by 120°. Then line currents are drawn as per the above equations. It is seen that the line current I_R is the phasor sum of phase currents I_1 and $–I_3$. We know that in parallelogram, the diagonals bisect each other with an angle of 90°.

3 marks for stepwise derivation

Therefore in ΔOPS, ∠P = 90° and ∠O = 30°.

$$[OP] = [OS] \cos 30°$$

$$\text{Since } [OP] = I_L/2 \text{ and } [OS] = I_{ph}$$

$$\therefore \frac{I_L}{2} = I_{ph} \cos 30°$$

$$I_L = 2 I_{ph} \frac{\sqrt{3}}{2}$$

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

Thus Line current = $\sqrt{3}$ (Phase Current)

5 e) Compare single-phase two winding transformer with single-phase autotransformer.

Ans:

Comparison between Two winding transformer and Autotransformer:

	Two winding Transformer	Autotransformer
1	There are two separate windings for primary and secondary.	Only one winding, part of the winding is common for primary and secondary.
2	No movable contact between primary and secondary	Movable contact exist

1 mark for each of any four points

3	Electrical isolation between primary and secondary windings.	Electrical connection between primary and secondary.
4	Comparatively more losses	Comparatively lower losses.
5	Efficiency is less as compared to autotransformer.	Efficiency is more as compared to two winding transformer.
6	Copper required is more.	Copper required is less, thus copper is saved.
7	Core type or shell type construction	Spiral core construction
8	Most of the general purpose transformers where fixed voltage is required.	Special applications where variable voltage is required.

5 f) Explain construction of single phase transformer. State the losses occurred in transformer.

Ans:

Construction of single phase transformer:

Single-phase transformer essentially consists of following components:

i) Windings: Two windings of aluminium or copper are placed round the core and are insulated from each other and also from the core.

ii) Core: Magnetic core is made up of thin silicon steel laminations of thickness 0.35 to 0.5 mm.

3 marks for construction

For big size transformers, tank is used to accommodate the core-winding assembly. In fact, the core-winding assembly is kept immersed in oil in the tank. The oil acts as a cooling medium and also the insulating medium. The terminals are taken out of the tank using bushings.

There are two types of core constructions:

i) Core type construction

ii) Shell type construction

In core type construction, the winding surrounds the core, whereas in shell type construction, the core surrounds the winding. The vertical portion of core is called ‘Limb’ or ‘leg’. The horizontal portion of the core is called ‘yoke’. The core is made from the E and I or L type laminations stacked together.

The low-voltage winding has few turns, hence it is usually helical winding. The high voltage winding has large no. of turns, hence it is usually disc type winding.

Losses in Transformer:

i) Core or Iron loss: It takes place in the magnetic core and depends upon the magnetic flux. It is treated as constant loss since flux remains constant. Core loss is further divided into two types: (1 mark for losses)

a) Hysteresis loss

b) Eddy current loss

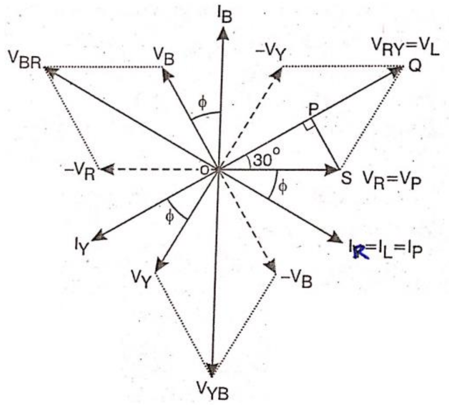
ii) Copper or I^2R loss: It takes place in the windings of transformer due to current and resistance of the winding.

6 Attempt any four from the following: 16

6 a) Draw phasor diagram for both star and delta connected balanced load.

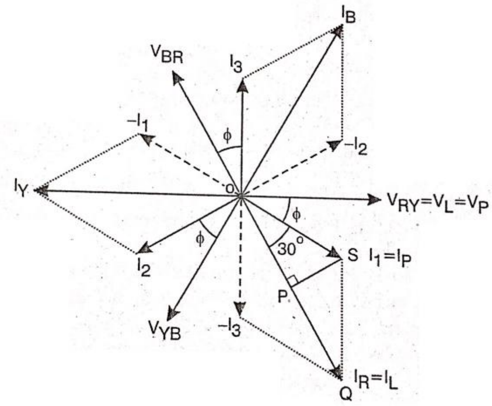
Ans:

Phasor Diagram for Balanced Star Connected Load:



2 marks

Phasor Diagram for Balanced Delta Connected Load:



2 marks

6 b) State the term: i) voltage ratio ii) current ratio iii) transformation ratio vi) EMF ratio related to single phase transformer.

Ans:

i) **Voltage Ratio:**
The ratio of secondary load voltage V_2 to the primary supply voltage V_1 is known as the voltage ratio.

Voltage Ratio $= \frac{V_2}{V_1}$

ii) Current Ratio:
The ratio of secondary current I_2 to the primary current I_1 is known as the current ratio.

Current Ratio $= \frac{I_2}{I_1}$

1 mark for each definition

iii) Transformation Ratio:
In general, the turns ratio or emf ratio is called as transformation ratio. The ratio of secondary emf E_2 to the primary emf E_1 is known as the transformation ratio. Also the ratio of secondary turns N_2 to the primary turns N_1 is known as the transformation ratio.

Transformation Ratio $= \frac{E_2}{E_1} = \frac{N_2}{N_1}$

iv) EMF Ratio:

The ratio of secondary emf E_2 to the primary emf E_1 is known as the transformation ratio.

EMF Ratio $= \frac{E_2}{E_1}$

6 c) Justify the name "Universal motor". State its applications.

Ans:

Universal motor:

A series motor which can operate on both AC supply or DC supply is termed as Universal motor. It has high starting torque and variable speed characteristics. Due to its design features, its performance is not affected much when supply type changes i.e it gives out approximately same speed and output for equivalent voltage conditions in AC and DC supply. Since the motor exhibits almost same performance on both AC and DC supply conditions, we can operate it universally on available supply, hence it is termed as "Universal Motor". 2 marks

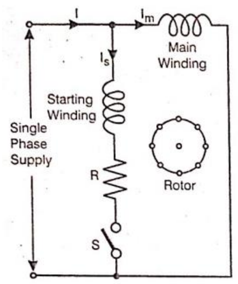
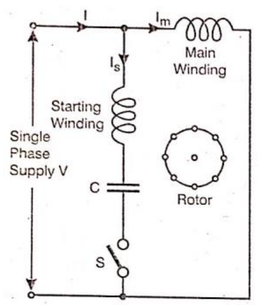
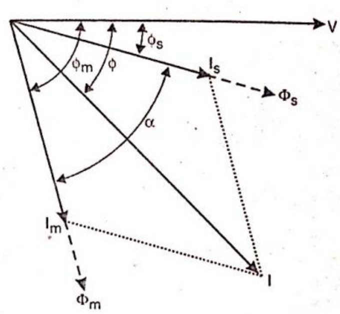
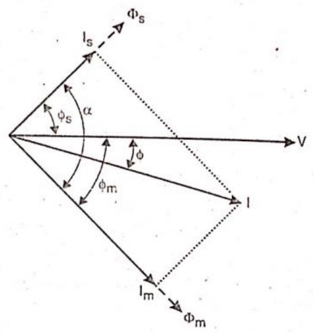
Applications:

Domestic appliances such as vacuum cleaners, food processers, mixers, grinders, sewing machines, portable drilling machines, coffee grinders, electric shavers etc. 2 marks

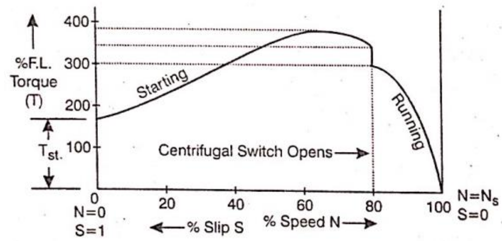
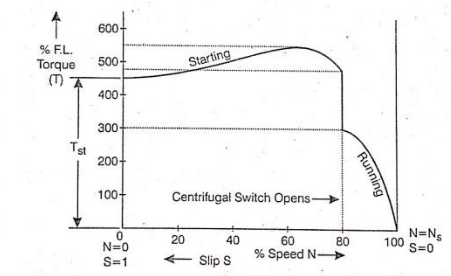
6 d) State the comparison between resistance split phase and capacitor start single phase I. M.

Ans:

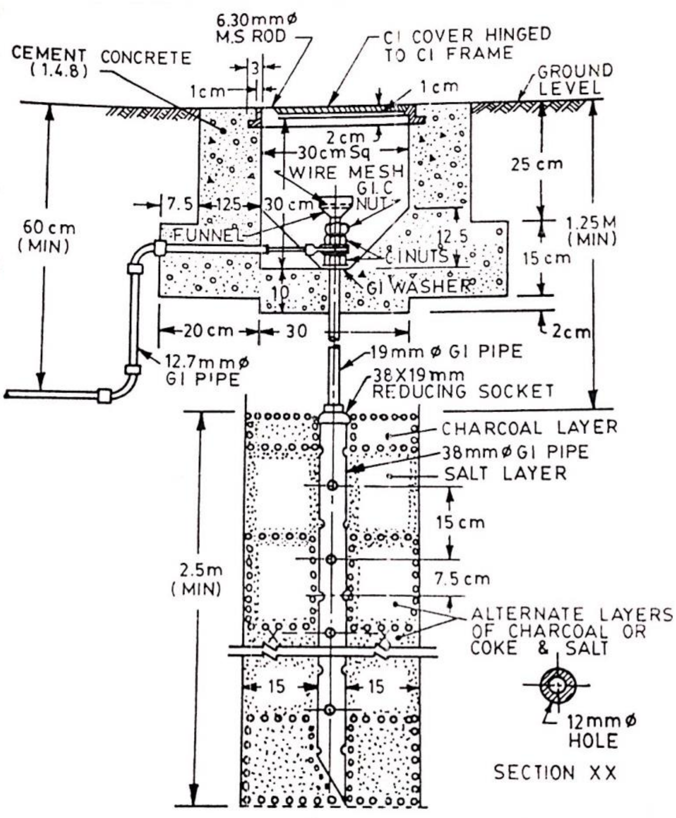
Comparison between resistance split phase and capacitor start induction motor:

<table>
<tr><th></th><th>Resistance Split phase induction motor</th><th>Capacitor start induction motor</th></tr>
<tr><td>1</td><td>
</td><td>
</td></tr>
<tr><td>2</td><td>
</td><td>
</td></tr>
</table>

1 mark for each of any four

3		
4	The main winding has very low resistance and high inductive reactance.	The main winding has very low resistance and high inductive reactance.
5	The auxiliary winding has high resistance and in addition to that external resistance is inserted in series with it to increase the phase angle between two fluxes.	The auxiliary winding has low resistance and a capacitor is inserted in series with it to increase the phase angle between two fluxes
6	Due to losses in resistance, the efficiency is poor	Efficiency is high as resistance is absent
7	Poor or moderate starting torque (125 to 200% of full load torque) with high starting current.	High starting torque (350 to 450% of full load torque)
8	Low power factor	Better power factor
9	Cheaper that capacitor motors	Costly due to capacitor
10	Constant speed operation	Constant speed operation
11	Main applications in domestic refrigerators, fans, blowers, centrifugal pumps and separators, washing machines, wood working machines, small lathes and machine tools, duplicating machines, portable drills and grinders	Compressors, Mixers, pumps

6 e) Draw a neat sketch of pipe earthing with label. State any two drawbacks of it.
Ans:
Pipe earthing:
The figure of Pipe earthing is shown below.
Drawbacks of Pipe Earthing:
1) Less reliable than plate earthing. 2 marks for drawbacks
2) Only applicable for small installations.
3) Earth resistance obtained is more than plate earthing.



A typical illustration of pipe earthing.

2 marks for diagram

6 f) State minimum 4 precautions against electric shock.

Ans:

Precautions against electric shock:

1) While using any electrical device, put on rubber sole footwear and keep your hands dry.
2) Always switch off main switch before replacing a blown fuse.
3) Ensure that the electrical equipment is properly earthed.
4) Keep earth connection in good condition.
5) Replace broken or damaged switchs, plugs etc.
6) A plug point should never be disconnected by pulling the flexible cable.
7) Make plug point connection by plug tops and not by bare wires.
8) Check for proper working of safety devices.
9) Keep electrical hand tools in proper condition.
10) Don’t wear loose clothes while working on installation.

1 mark for each of any four.