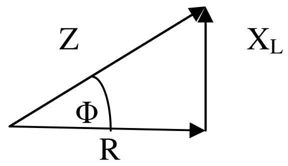
1 a) Definition :- opposition to the flow of electric current — 1 mark
Unit:- Ohm or Ω — 1 mark

1 b) Definition: no. of cycles / oscillations of alternating qty. completed in 1 sec. — 1 mark
Unit: hertz or cycles / second. — 1 mark

1 c) Active Network:- network that consists one or more energy sources. — 1 mark
Example: circuit containing voltage and current source/s. — 1 mark

1 d) Power factor: cosine of angle between voltage and current or ratios R/Z, (active power)/(apparent power) or kW/kVA of a circuit. — 2 marks

1 e)



½ mark each R, X_L, Z & Φ

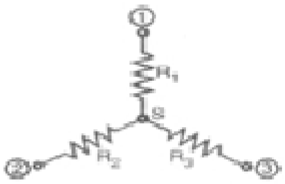
1 f) Admittance:-Reciprocal of Impedance Y= 1/Z — 1 mark
Unit:- mho or Siemens or ℧ — 1 mark

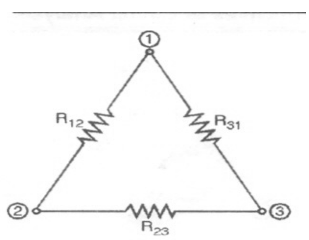
1 g) For 3 phase delta connection Line voltage = Phase voltage or $V_L = V_{ph}$ — 2 marks

1 h) Balanced load – The impedances in each of the 3 phases are equal in magnitude and same in nature (phase angle) — 1 mark
Unbalanced load – all the three phase impedances are not identical in magnitude and in nature (phase angle) — 1 mark

1 i) Mesh analysis steps 1) mark loop currents 2) Mark polarity for voltage drops 3) write loop equations 4) solve them by any one method (simultaneous or matrix) — ½ mark for each point

1 j)





½ Mark

$R_{12} = R_1 + R_2 + (R_1R_2)/R_3$
$R_{23} = R_2 + R_3 + (R_2R_3)/R_1$
$R_{31} = R_3 + R_1 + (R_3R_1)/R_2$

½ mark each

1 k) Thevenin's theorem:- States that current flowing through any load resistance (R_L) of an active, bilateral circuit can be calculated by Thevenin's theorem as — *2 marks for correct statement*

$$I_L = V_{th}/ (R_{th} + R_L)$$

where,
V_{th} = the open circuit voltage measured across load terminals by removing the load resistance
R_{th} (called as the Thevenin's equivalent source resistance) = resistance measured across load terminals after removing the load resistance and replacing all sources by their internal resistances.

1 l) For maximum power transfer $R_L = R_S$, — *1 mark*
where R_L = Load resistance connected across the terminals of the source whose internal resistance is R_S. — *1 mark*

1 m) Types of energy sources 1) Current source 2) Voltage source — *1 mark each*

1 n) Q factor for series resonant circuit – it is the voltage magnification in series circuit or ratio: V_C/V or V_L/V — *2 marks*

2 a) In case of purely inductive circuit $v = V_m \sin\omega t$ and $i = I_m(\sin\omega t - \pi/2)$ — *1 mark*

$p = v \times i = V_m \sin\omega t .\ I_m(\sin\omega t - \pi/2)$ — *1 mark*

$= V_m I_m \sin\omega t(-\cos\omega t)$

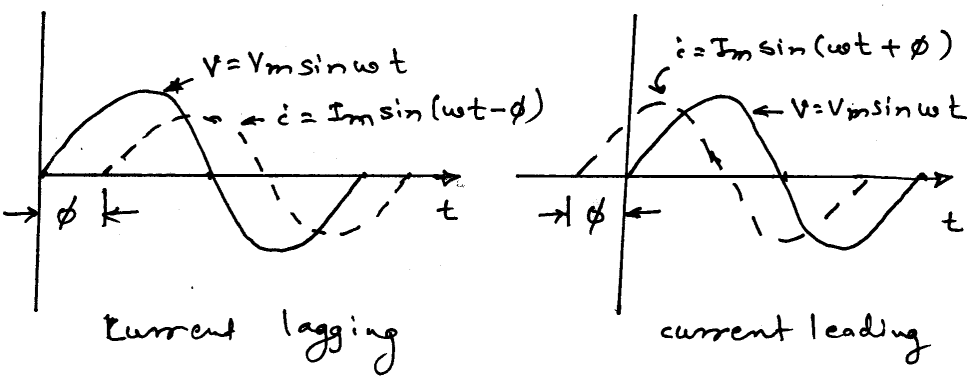
$= -V_m I_m .\ (\sin 2\omega t)/2$

$= -(V_m I_m)/2 \times (\sin 2\omega t)$ — *1 mark*

Average value over a cycle of the term $\sin 2\omega t = 0$

$\therefore$ Average power consumed by purely inductive circuit, $P = 0$ — *1 mark*

2 b) — *1 mark each for waveform*



Lag :- one waveform(current in this case) reaches its maximum or zero value after other waveform (voltage in this case) by an angle Φ (time phase) — *1 mark each for definition*
Lead :- one wave form(current in this case) reaches its maximum or zero value before other waveform (voltage in this case) by an angle Φ(time phase)

2 c) Definition 1) phase angle(Φ) :- time related angle between voltage and current in degrees or radians. — *1 mark each*
2) Active power P:- It the power which is responsible for work done in circuit $P = VI \cos Φ$.

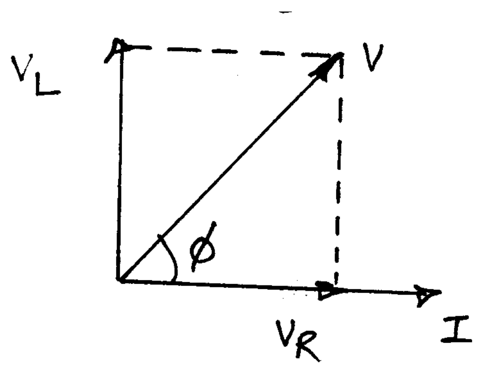
3) Reactive power :- It the power which is developed in the reactance of the circuit but does no work over a cycle .OR It is the power stored and released by L and C. given by $Q = V I \sin \Phi$ or I^2X

4) Apparent power :- it is the product of r.m.s. values of applied voltage and circuit current or the power that seems to be drawn in terms of V & I.
$S = VI$ or I^2Z.

2 d) Phasor diagram of R-L- series circuit

Neat diagram – 2 Marks

Correct labeling – 2 Marks

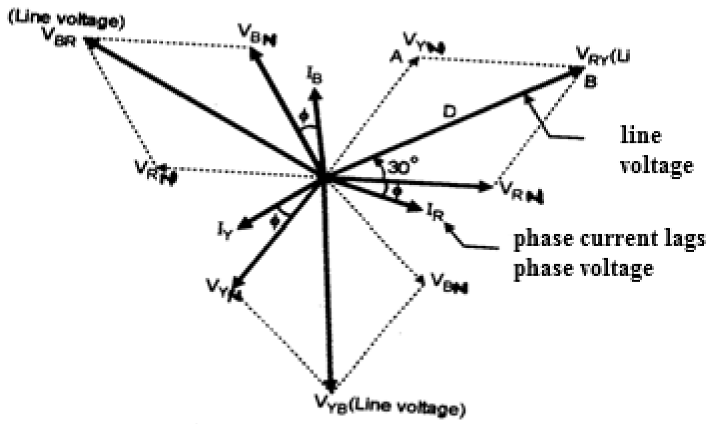


2 e For balaced star connection the phasor diagram is as shown below:

Phasor diagram:

unlabeled or partially labeled 1 mark,

fully labeled 2 Marks



$V_{RY} = 2 \times V_{RN} \times \cos \theta$

V_{RY} = line voltage = V_L

V_{RN} = Phase Voltage = V_{ph}

$V_L = 2 \times V_{ph} \times \cos\theta,\ \theta = 30^0$ 1 mark

$\because V_L = 2 \times Vph \times \cos 30^0$

$\therefore V_L = 2\ V_{ph} \times \sqrt{3}/2$

$\therefore V_L = \sqrt{3}\ V_{ph}$ 1 mark

2 f) $Z_{ph} = 8 + j8\ \Omega$
ii) $V_{ph} = V_L = 400$ V — 1 mark
i) $I_{ph} = Vph/Z_{ph} = 400/(8+j8) = 400 \angle 0^0 / 11.31 \angle 45^0 = 35.37 \angle -45^0$ A
$I_L = \sqrt{3} I_{ph} = 61.26$ A — 1 mark
iii) $PF = \cos(-45^0) = 0.707$ lag. — 1 mark
iv) $P = \sqrt{3} V_L I_L \cos\Phi = 30006.6$ W = 30 kW — 1 mark

3 a) $R = 5\ \Omega$
$X_L = 2\Pi f L = 62.83\ \Omega$ — ½ mark
$X_C = 1/(2\Pi f C) = 63.66\ \Omega$ — ½ mark
i) $Z = \sqrt{R^2 + (X_L - X_C)^2} = 5.068\ \Omega$ — ½ mark
ii) $I = V/Z = 230/5.068 = 45.38$ A — 1 mark
iii) $PF = R/Z = 0.986$ lead as $X_C > X_L$ — ½ mark
iv) $P = VI \cos\Phi = 230 \times 45.38 \times 0.986 = 10291.27$ W = 10.29 kW — 1 mark

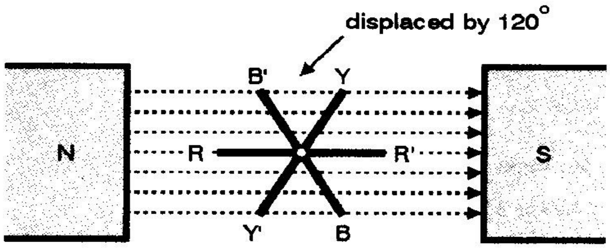
3 b) The Condition for series resonance is $X_L = X_C$
X_L = inductive reactance and X_C = capacitive reactance — 1 mark
$\therefore 2\Pi f_0 L = 1/2\Pi f_0 C$, f_0 = resonant frequency — 1 mark
$\therefore f_o^2 = 1/\{(2\Pi)^2 LC\}$ — 1 mark
$\therefore f_0 = 1/(2\Pi\sqrt{LC})$ Hz — 1 mark

3 c) $Z = 8 + j6\ \Omega = R + jX$
$R = 8$, $X = 6$
g = conductance and b = susceptance
$g = R/(R^2 + X^2)$ and $b = X/(R^2 + X^2)$ — 1 mark each for g and b
g = 0.08 mho b = 0.06 mho or ℧
$Y = g - jb = 0.08 - j0.06$ mho (rectangular form) — 1 mark
$Y = 0.1 \angle -36.87$ (polar form) — 1 mark

3 d) Advantages of polyphase circuit
1) for same amount of power size of 3 ph machine is smaller
2) for same amount of power transmission size of conductor is smaller
3) Maintenance is easier & cheaper
4) 3 ph motors are self starting
5) More power can be transmitted
6) Better Power Factor

1 mark for each point (Any Four)

3 e)



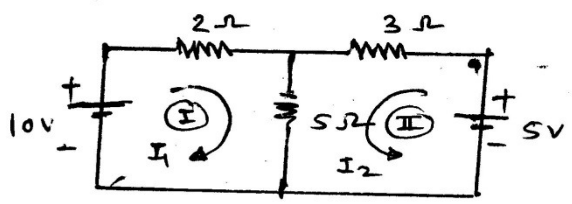
Generation of a 3-phase voltage

2 marks for figure or equiv. Fig.

Points expected:

1) 3coils/ winding(conductor) displaced by 120 degree in space.
2) Placed in uniform magnetic field. 2 mark for explanation
3) Winding system rotated
4) Emf generated in each conductor by faradays laws and lenz's law
5) Induced emfs in the windings are sinusiodal, equal in magnitude & displaced by 120 degrees in time phase.

3 f)



For loop I –

$2I_1 + 5(I_1 + I_2) - 10 = 0$

$\therefore\ 7I_1 + 5I_2 = 10$ —— (1) 1 mark

For loop II –

$3I_2 + 5(I_2 + I_1) - 5 = 0$

$\therefore\ 5I_1 + 8I_2 = 5$ —— (2) 1 mark

solving simultaneously or by matrix method on calculator

$$\begin{bmatrix} 7 & 5 \\ 5 & 8 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 10 \\ 5 \end{bmatrix}$$

1 mark

$I_1 = 1.774$ A & $I_2 = -0.48$ A

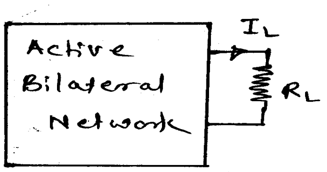
Meaning of negative I_2 is its direction is reverse

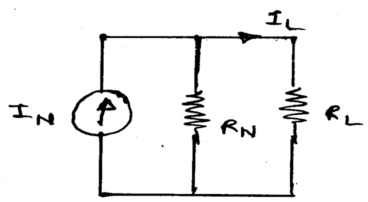
current flowing through 5 Ω resistor is I_2

$= \underline{0.48}$ A 1 mark

4 a) Norton's theorem statement :- current flowing through a load resistor R_L of an active bilateral circuit can be found with the help of Norton's theorem as 2 mark

$I_L = I_N \times (R_N) / (R_N + R_L)$



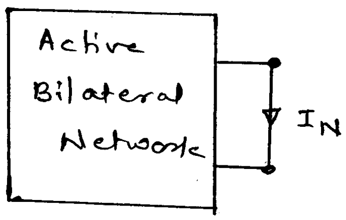


Equivalent circuit

Where -

i) I_N is the short circuit Norton's current flowing through the shorted load terminals

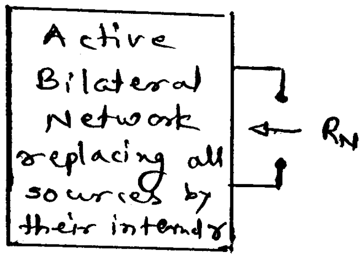
To Find I_N 1 mark



and

ii) R_N is the Norton's equivalent resistance measured across load terminals by removing load resistance and replacing all sources by their internal resistances

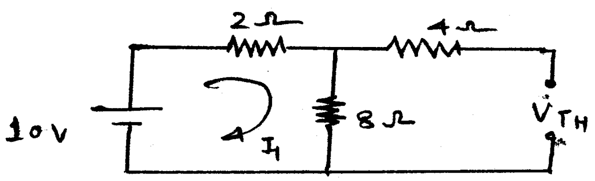
To Find R_N



1 mark

4 b) Current through 8 ohm resistor using Thevenin's theorem is

1) step 1 : find V_{TH}



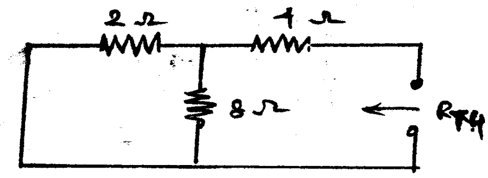
V_{TH} = voltage across 8 Ω resistor

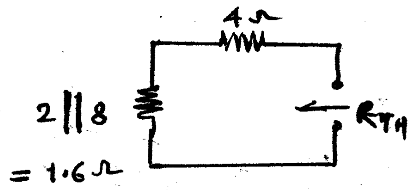
For this calculate I_1

$I_1 = \frac{10}{2+8} = 1\ A$ 1 Mark

$V_{TH} = 8\ I_1 = 8 \times 1 = 8\ V$ 1 Mark

ii) step 2 – To find R_{TH}

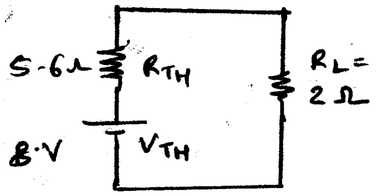




1 mark

$R_{TH} = 4 + 1.6 = 5.6\,\Omega$

iii) Equivalent circuit



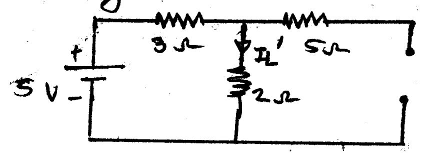
1 mark

$$\therefore I_L = \frac{V_{TH}}{R_{TH}+R_L} = \frac{8}{5.6+2} = 1.052\,A$$

4 c)

Superposition theorem –

i) using 5 V source

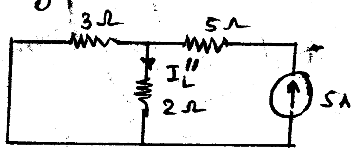


½ mark fig

$$I_L' = \frac{5}{3+2} = 1\,A$$

1 mark

ii) using 5 A source



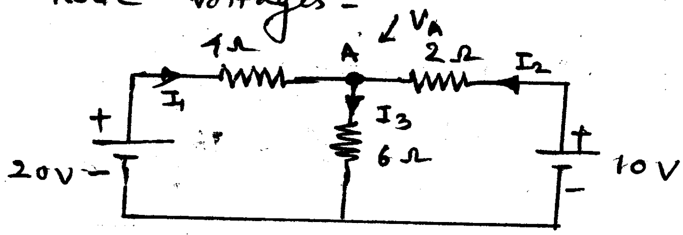
½ mark fig

$$I_L'' = I \times \frac{3}{3+2} = 5 \times \frac{3}{5} = 3A$$ 1 mark

$$I_L = I_L' + I_L'' = 1 + 3 \quad \boxed{I_L = 4A}$$ 1 mark

4 d)

Node voltages -



By KCL

$$-I_1 + I_2 = I_3$$

$$\frac{20 - V_A}{4} + \frac{10 - V_A}{2} = \frac{V_A - 0}{6}$$ 1 mark

$$60 - 3V_A + 60 - 6V_A = 2V_A$$

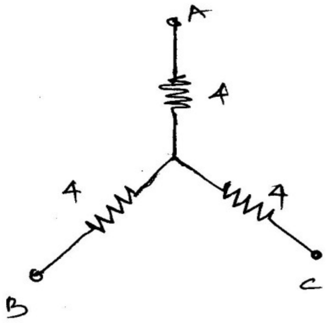
$$120 = 11\,V_A$$

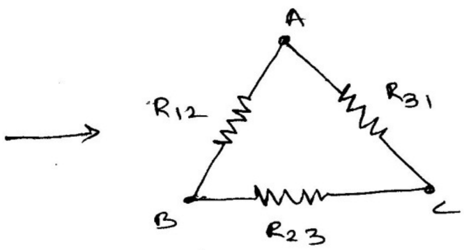
$$\therefore V_A = 10.91\ V$$ 1 mark

Current thro' 6 Ω resistor is I_3

$$I_3 = \frac{V_A}{6} = \frac{10.91}{6} = 1.82\ A$$ 2 mark

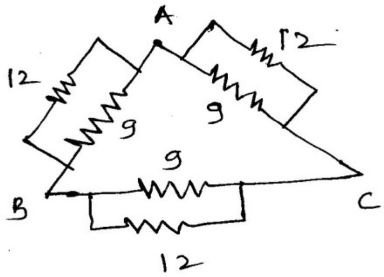
4 e)



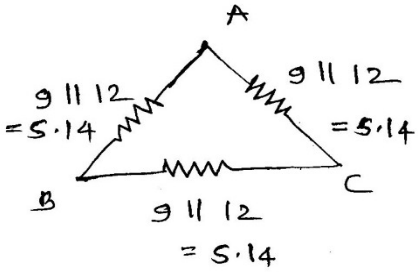


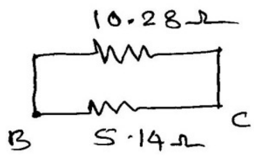
$$R_{12} = R_{23} = R_{31} = 4 + 4 + \frac{4 \times 4}{4}$$

$$= 12\ \Omega$$ 1 mark

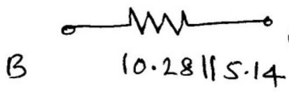


1 mark





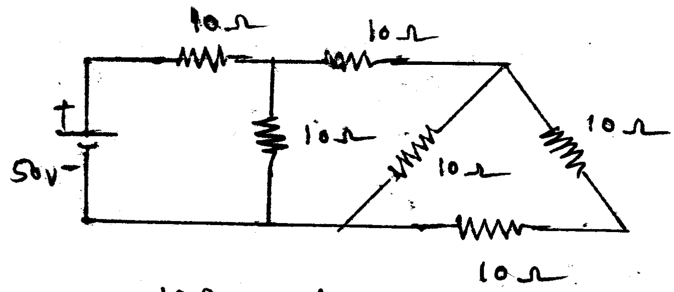
1mark

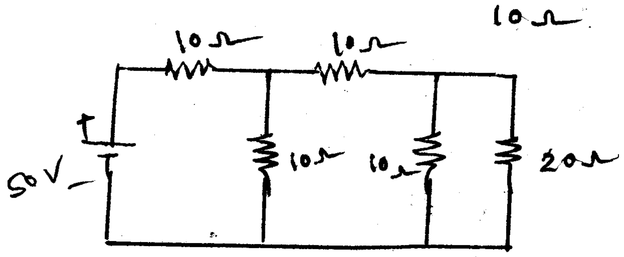


$10.28 \parallel 5.14$

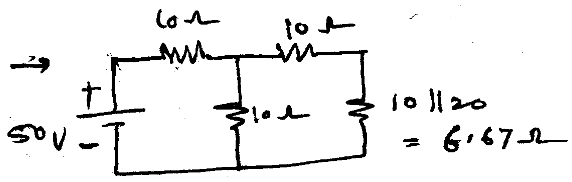
$= 3.42\ \Omega$ 1 mark

4 f)

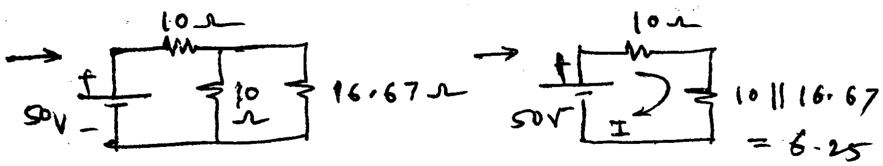




1 mark



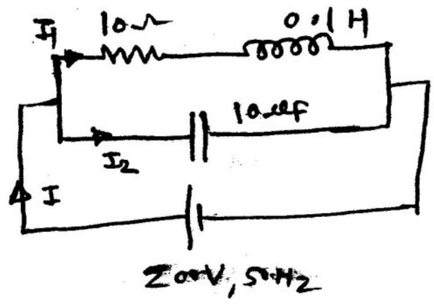
1 mark



1 mark

$$I = \frac{50}{10 + 6.25} = 3.077 \text{ A}$$ 1 mark

5 a)



$X_L = 2\pi fL = 2\pi \times 50 \times 0.1 = 31.41\ \Omega$

$X_C = 1/2\pi fC = 1/(2\pi \times 50 \times 10\times 10^{-6}) = 318.3\ \Omega$

$Z_1 = 10 + j31.41\ \Omega$ $Z_2 = 0 - j318.3\ \Omega$ ½ mark

$Y_1 = 1/Z_1$ or $g1 - jb_1$ $Y_2 = 1/Z_2$ or $g_2 + jb_2$

$g_1 = R / (R^2 + X^2) = 10/(10^2 + 31.41^2) = 9.2 \times 10^{-3}$ mho

$b_1 = X/(R^2 + X^2) = 31.41/(10^2 + 31.41^2) = 0.029$ mho ½ mark

$g_2 = 0$ mho, $b_2 = 318.3/318.3^2 = 0.00314$ mho ½ mark

$Y_1 = 0.0092 - j0.029$ mho $= 0.03\angle{-72.4^0}$ mho 1 mark

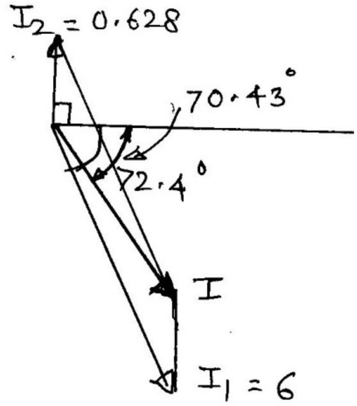
1 mark

$Y_2 = 0 + j0.00314$ mho $= 0.0031 \angle 90^0$

$I_1 = V x Y_1 = 200 \angle 0^0 \text{ x } 0.03 \angle -72.4^0 = 6 \angle -72.4^0 = 1.81 - j\,5.72$ Amp — 1 mark

$I_2 = V \text{ x } Y_2 = 200 \angle 0^0 \text{ x } 0.0031 \angle 90^0 = 0.628 \angle 90^0 = 0 + j0.628$ Amp — 1 mark

$I = I_1 + I_2 = 1.81 - j\,5.72 + 0 + j0.628 = 1.81 - j\,5.092 = 5.4 \angle -70.43^0$ Amp — 1 mark



1 ½ mark

5 b) $R = 20\ \Omega$, $X_L = 2\pi fL = 2\pi \text{ x } 50 \text{ x } 0.3 = 94.25\ \Omega$ — 1 mark

$Z_{ph} = \sqrt{(R^2 + X_L^2)} = 96.35\ \Omega$ — 1 mark

$V_{ph} = V_L = 400$ V, delta connection — 1 mark

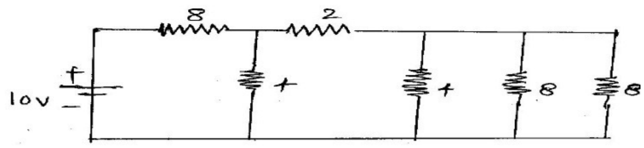
$I_{ph} = V_{ph}/Z_{ph} = 400/96.35 = 4.15$ A — 1 mark

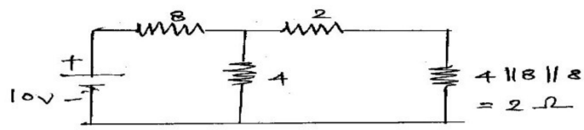
$I_L = \sqrt{3}\, I_{ph} = \sqrt{3} \text{ x } 4.15 = 7.19$ A — 1 mark

$\cos \phi = R/Z = 20/96.35 = 0.207$ lag — 1 mark

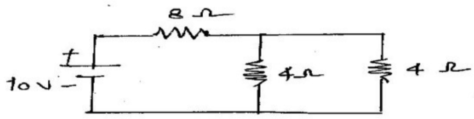
$P = \sqrt{3}\, V_L\, I_L \cos\phi = \sqrt{3} \text{ x } 400 \text{ x } 7.19 \text{ x } 0.207 = 1031.14 \text{ W} = 1.031 \text{ kW}$ — 2 marks

5 c)

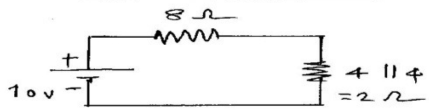


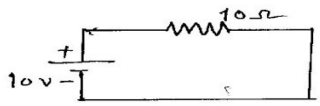


2 Marks

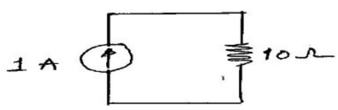


2 Marks



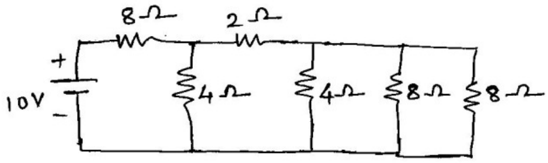


2 Marks

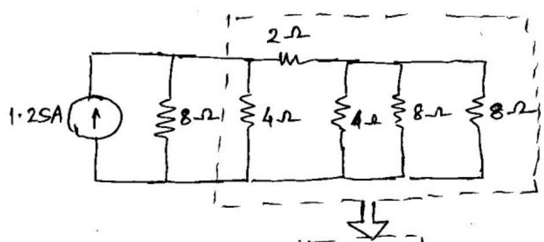


2 Marks

OR

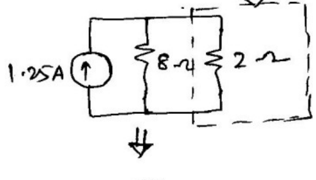


Converting 10 V source and 8 Ω resistance into current source

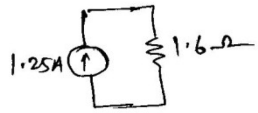


3 Marks

3 Marks



2 Marks



6 a) $R = 5\Omega$

i) $X_L = 2\pi fL = 62.83\ \Omega$ — 1 Mark

ii) $X_C = 1/(2\pi fC) = 31.83\ \Omega$ — 1 Mark

iii) $Z = \sqrt{\{R^2 + (X_L - X_C)\}^2} = 31.4\ \Omega$ — 1 Mark

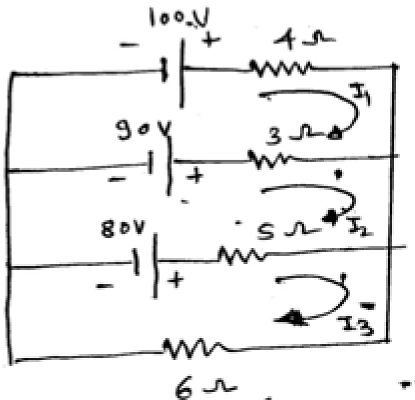
iv) $I = V/Z = 230/31.4 = 7.32$ A — 1 Mark

v) $Pf = R/Z = 0.16$ — 1 ½ Mark

vi) $V_L = I\,X_L = 459.9$ V — 1 ½ Mark

1 Mark

6 b)



1 Mark

write equation for three loops

$4I_1 + 3(I_1 - I_2) + 90 - 100 = 0$

$7I_1 - 3I_2 = 10$ —— (1) — 1 mark

$3(I_2 - I_1) + 5(I_2 - I_3) + 80 - 90 = 0$

$-3I_1 + 8I_2 - 5I_3 = 10$ —— (2) — 1 mark

$5(I_3 - I_2) + 6I_3 - 80 = 0$

$-5I_2 + 11I_3 = 80$ —— (3) — 1 mark

The matrix is

$$\begin{bmatrix} 7 & -3 & 0 \\ -3 & 8 & -5 \\ 0 & -5 & 11 \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 10 \\ 10 \\ 80 \end{bmatrix}$$

2 Marks

$$I_3 = \begin{vmatrix} 7 & -3 & 10 \\ 3 & 8 & 10 \\ 0 & 5 & 80 \end{vmatrix} \Big/ \begin{vmatrix} 7 & -3 & 0 \\ 3 & 8 & -5 \\ 0 & 5 & 11 \end{vmatrix}$$

Solving above equations, $I_3 = 12.465$ A — 2 marks

c) $Z_{ph} = 15 + j20 = 25 \angle 53.13^0 \ \Omega$ 1 Mark

$V_{ph} = V_L/\sqrt{3}$ (Star connection) = $400/\sqrt{3} = 231$ V

$I_{ph} = V_{ph}/Z_{ph} = 9.24 \angle -53.13^0$ A

$I_L = I_{ph} = 9.24$A

i) PF = $\cos\phi = \cos(53.13^0) = 0.6$ or R/Z = 0.6 1 Mark

ii) Active power = P = $\sqrt{3} V_L I_L \cos\phi$ = 3841 W = 3.81 kW 1 Mark

iii) Reactive power = Q = $\sqrt{3} V_L I_L \sin\phi$ (Where $\sin\phi = 0.8$) = 5121 VAR = 5.12 kVAR 1 Mark

iv) Apparent power = S = $\sqrt{3} V_L I_L$ = 6401 VA = 6.4 kVA 1 Mark

v) $V_{ph} = V_L/\sqrt{3}$ (Star connection) = $400/\sqrt{3} = 231$ V 1 Mark

vi) $I_L = I_{ph} = 9.24$A 1 Mark

vii) $I_{ph} = 9.24$A 1 Mark