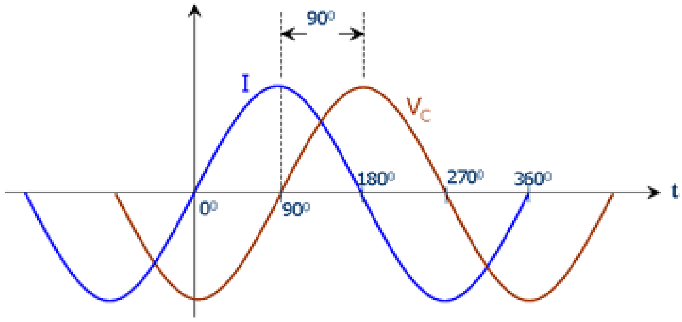
Important Instructions to examiners:

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 more 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 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.
6) In case of some questions credit may be given by judgement 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

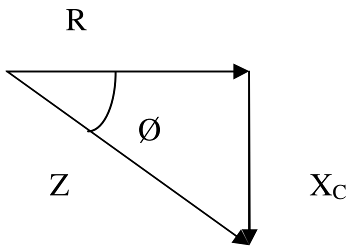
1 a)



Voltage and current in pure capacitive circuit

Voltage wave 1 mark, current wave 1 mark

1 b) Impedance triangle of RC series circuit:



Labeled 2 marks, unlabebed 1 mark

1 c) 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. 1 mark

$S = VI$ or I^2Z. (VA) 1 mark

1 d) RMS or effective value of AC is that value of constant DC that will produce identical heating effect in the same resistance. 1 mark

For sinusoidal AC, $V_{RMS} = V_{max} / \sqrt{2}$. 1 mark

1 e) 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 f) Thevenin's theorem:- States that current flowing through any load resistance (R_L) of an active, bilateral circuit can be calculated as;

$I_L = V_{th}/ (R_{th} + R_L)$ 1 mark

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 mark

1 g) Period: the time for one complete cycle or oscillation, (it is reciprocal of frequency = $T = 1/f$ (sec) if frequency is given in c/s or hertz). 1 mark

Frequency: no. of cycles / oscillations of alternating qty. completed in 1 sec. Unit: hertz or cycles / second. 1 mark

1 h) Impedance is the combined effect of resistance and reactance in alternating circuits. 1 mark

Mathematically it is given by $Z = \sqrt{\{R^2 + (X_L - X_C)^2\}}$ (ohms). 1 mark

1 i) Advantages of polyphase circuit

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

Any four points; ½ mark for each point

1 j) Q – factor of parallel resonant circuit is the current magnification obtained in the inductance or capacitance with respect to the current drawn from supply; 1 mark

Q – factor = $X_L/R = 2\pi f_O L/R$;

Where f_O = resonant frequency (Hz), L = inductance of coil (henries) and R = total resistance of the inductive branch. 1 mark

1 k) Given voltage source E (V) with internal resistance 'r' (ohms) the equivalent current source is given by a constant current source given by E/r (A); 1 mark

and its conductance given by 1/r connected across the current source (or the resistance 'r' connected across the current source). 1 mark

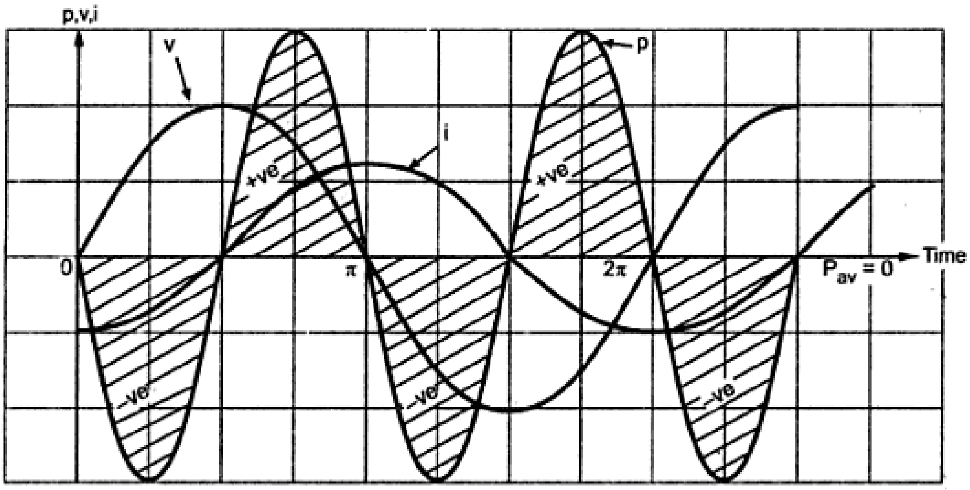
1 l) Condition for series resonance:

Inductance reactance = capacitive reactance 1 mark

$X_L = X_C$, we have $2\pi f_O L = 1/(2\pi f_O C)$ which gives us frequency of resonance

$f_O = 1/[2\pi\sqrt{(LC)}]$. (Where L = coefficient of inductance in henry, and C = Capacitance in farads). 1 mark

2 a) AC applied to pure inductance:



Waveforms of voltage, current and power

Voltage wave 1 mark
Current wave 1 mark
Power wave 1 mark

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

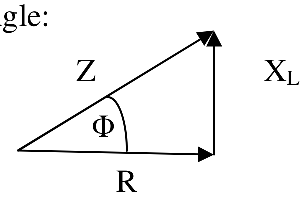
$$p = v \times i = V_m \sin\omega t . I_m(\sin\omega t - \pi/2)$$
$$= V_m I_m \sin\omega t(-\cos\omega t)$$
$$= -V_m I_m . (\sin 2\omega t)/2$$
$$= -(V_m I_m)/2 \times (\sin 2\omega t)$$

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

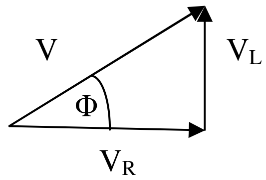
$\therefore$ Average power consumed by purely inductive circuit, P = 0 1 mark

2 b) R- L series circuit:

Impedance triangle:



Voltage triangle:



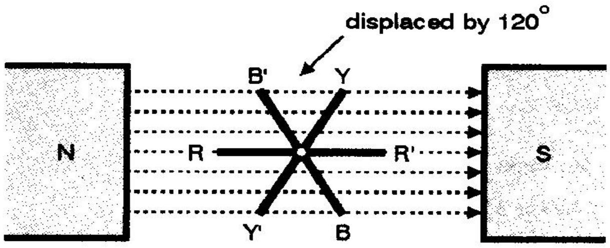
Each diagram 2 marks if labeled and 1 mark if unlabeled.

2 c)

	Parameter	Series resonance	Parallel resonance
1	Impedance	minimum = R	maximum = L/(CR)
2	Current	maximum= V/R	minimum = V/(L/CR)
3	Resonant frequency	$f_r = 1/[2\pi\sqrt{(LC)}]$	$f_r = (1/2\pi)\sqrt{\{[1/(LC)] - (R^2/L^2)\}}$
4	Power factor	unity	unity
5	Magnification	voltage	current
6	Q	$(1/R)[1/\sqrt{(LC)}]$	$(1/R)[1/\sqrt{(LC)}]$

Any 4 pts. 1 mark each.

2 d)



Generation of a 3-phase voltage

Diagram: labeled 2 marks; unlabeled 1 mark

Points expected:

1) 3coils/ winding(conductor) displaced by 120 degree in space.
2) Placed in uniform magnetic field.
3) Winding system rotated
4) Emf generated in each conductor by faradays laws

2 marks

Induced emfs in the windings are sinusiodal, equal in magnitude & displaced by 120 degrees in time phase.

2 e) $Z = (6 + j8)\ \Omega$

Therefore $Y = 1/Z = 1/(6 + j8) = (6 - j\,8)/100 = (0.06 - j\,0.08)$ mho — 2 marks

Susceptance B = - 0.08 mho — 1 mark

Conductance G = 0.06 mho. — 1 mark

2 f) Star connected: $Z_{ph} = (10 + j8)$ ohms, $V_L = 400$ V, $V_{ph} = 400/\sqrt{3} = 231$ V.

$I_{ph} = V_{ph}/Z_{ph} = (231 + j\,0)/(10 + j8) = (231\angle 0)/(12.8\angle 38.65) = 18\angle -38.65$A — 1 mark

$I_L = I_{ph} = 18\angle -38.65$A. — 1 mark

Power absorbed by load $= \sqrt{3}\ V_L\ I_L \cos \text{Ø}$ — 1 mark

$= \sqrt{3} \times 400 \times 18 \times \cos(-38.65) = 9739$ W = 9.739 kW — 1 mark

3 a) Peak value = 141.42 V — 1 mark

Effective or RMS value = peak value/$\sqrt{2}$ = $141.42/\sqrt{2}$ = 100 V. — 1 mark

Frequency = $\omega/2\pi = 942/2\pi = 150$ Hz. — 1 mark

Periodic time = 1/frequency = 1/150 = 0.00667 sec = 6.667 msec. — 1 mark

3 b) R = 40 ohms.

$X_L = 2\,\pi\, f\, L = 2\,\pi \times 50 \times 0.08 = 25.13$ ohm. — 1 mark

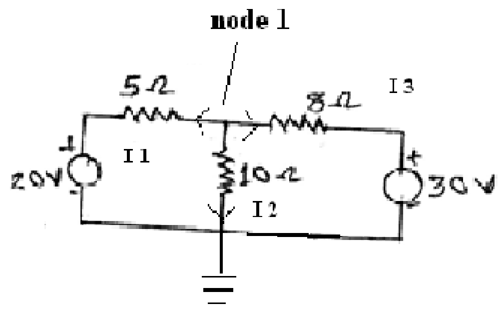
$|Z| = \sqrt{\{R^2 + X_L^2\}} = \sqrt{\{40^2 + 25.13^2\}} = 47.24$ ohm.; $\text{Ø} = \cos^{-1}(R/Z) =$

$= \cos^{-1}(40/47.24) = 32.14^o$. $Z = 47.24\angle 32.14^o$ ohms. — 1 mark

$I = V/Z = (230\angle 0)/(47.24\angle 32.14) = 4.87\angle -32.14$ A. — 1 mark

pf $= \cos \text{Ø} = \cos(-32.14) = 0.847$ lag — 1 mark

3 c)



1 mark

Voltage of node 1 = V_1, at node 1 we apply Kirchoff's current law

$I_1 + I_2 + I_3 = 0$ 1 mark

$(V_1 – 20)/5 + V_1/10 + (V_1 – 30)/8 = 0$, which gives

$17 V_1 = 310$, therefore $V_1 = 18.23$ V. 1 mark

Current in 10 ohm = $I_2 = V_1/10 = 18.23/10 = 1.823$ A. 1 mark

3 d) Balanced delta connected load; $V_L = 500$ V, $I_L = 12.5$ A, pf = 0.8 lag,

$Ø = \cos^{-1}0.8 = -36.87^o$, $I_{ph} = I_L/\sqrt{3} = 7.217 \angle -36.87^o$ A. $V_{ph} = V_L$. 2 marks

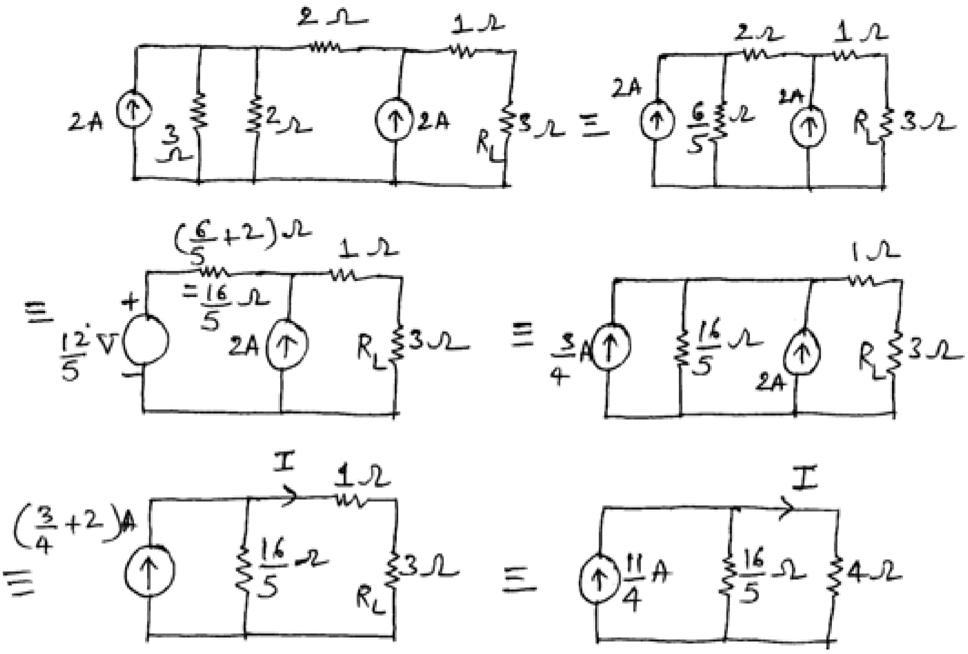
$Z_{ph} = V_{ph}/I_{ph} = (500\angle 0)/(7.217 \angle -36.87) = 69.3\angle 36.87 = (55.4+j41.57)$ohm (2 marks Or

or 1 mark &

$R_{ph} = Z_{ph} \cos Ø = 69.3 \cos(36.87) = 55.4$ ohms. 1 mark)

$X_{ph} = Z_{ph} \sin Ø = 69.3 \sin(36.87) = 41.57$ ohms.

3 e)



1 mark

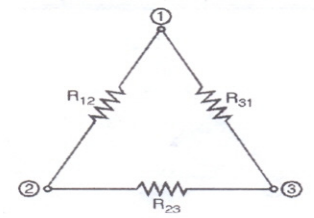
1 mark

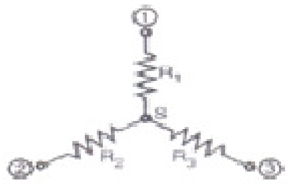
1 mark

By Division of current in parallel branches

$I = (11/4) \times (16/5)/[(16/5) + 4] = 11/9 = 1.22$ A. 1 mark

3 f)





This diagram not compulsory

$R_1 = R_{12}R_{31}/(R_{12} + R_{23} + R_{31})$ and similarly for other star resistances. 1 mark

$R_1 = R_2 = R_3 = (9 \times 9)/(9 + 9 + 9) = 3$ ohms. 1 mark

We have two star networks where each branch resistance is 3 ohms.

Resultant resistance between A – B is (3+3) in parallel to (3+3) i.e two 6 ohms in parallel = 6x6/(6+6) = 3 ohms. 1 mark

1 mark

4 a) All phasors are with respect to supply voltage unless stated specifically.

2) Reactance of coil = $X_L = 2\pi f L = 2\pi \times 50 \times 0.05 = 15.7$ ohm

$Z_{coil} = (15 + j15.7)$ ohms $= 21.7\angle 46.3$ ohm

Capacitive reactance $X_C = 1/(2\pi fC) = 1/(2\pi \times 50 \times 100 \times 10^{-6}) = 31.8$ ohm

= j 31.8 ohm.

Impedance of the series circuit = $Z = Z_{coil} - jX_C = (15 + j15.7 - j\,31.8)$

$= (15 - j\,16.1)$ ohms $= 22\angle -47^o$ ohms. 1 mark

3) pf = R/Z = 15/22 or cos(47) = 0.682 lead (as $X_C > X_L$) ½ mark

1) Current drawn from supply

$I = V/Z = 230\angle 0/22\angle -47 = 10.45\angle 47^o$ A. 1 mark

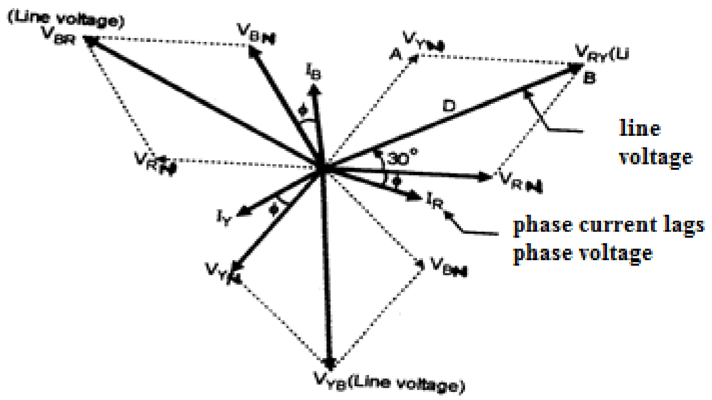
4) Voltage drop across coil = $I \times Z_{coil} = 10.45\angle 47 \times 21.7\angle 46.3 = 226.7\angle 93.3$

$= (-13 + j\,226)$ V 1 mark

Voltage drop across capacitor reactance $= I \times X_C = 10.45\angle 47 \times 31.8\angle -90$

$= 332.3\angle -43$ V. ½ mark

4 b) For balanced star connection the phasor diagram is as shown below:



Labeled Diagram 4 marks, unlabeled 2 marks.

$V_{RY} = 2 \times V_{RN} \times \cos\theta$ 1 mark

V_{RY} = line voltage = V_L 1 mark

V_{RN} = Phase Voltage = V_{ph} 1 mark

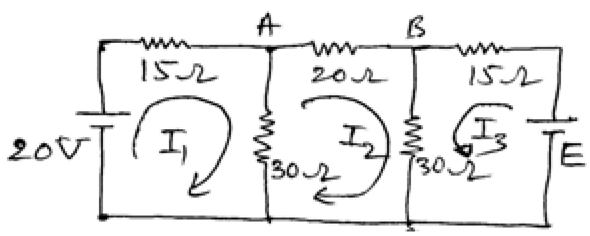
$V_L = 2 \times V_{ph} \times \cos\theta,\ \theta = 30^0$

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

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

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

4 c) Given data is insufficient to solve for numerical answer. However the students may assume suitable value by observing the symmetry of the circuit and the source connected. The value of EMF source in the right most branch (which has not been given) may be assumed to be 20 V or any value or a general value E. Solutions so obtained must only be considered for award of marks. Un-attempted question other than options stated above must not be awarded any marks.



Marking loop currents 1 ½ mark

Loop equations are

$20 = 45\,I_1 - 30\,I_2 + 0\,I_3$ Equations

$0 = -30\,I_1 + 80\,I_2 + 30\,I_3$ 1 mark

$E = 0\,I_1 + 30\,I_2 + 45\,I_3$

(some students may assume E = 20 V or other)

If E = 20 V (assumed) then solving simultaneously

$I_1 = 4/9$ A ½ mark

$I_2 = 0$ A 1 mark

$I_3 = 4/9$ A ½ mark

Branch currents:

Branch current 20 V, 15 ohm (to pt A) = $I_1 = 4/9$ A, ½ mark

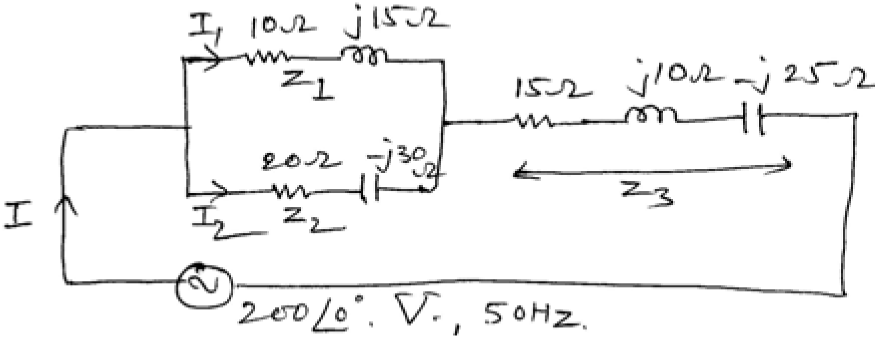
Branch current 30 ohm to pt A = $I_1 - I_2 = 4/9$ A, 1 mark

Branch current 20 ohm (A-B) = $I_2 = 0$ A, ½ mark

Branch current 30 ohm to pt B = $I_3 - I_2 = 4/9$ A, 1 mark

Branch current 20 V, 15 ohm (to pt B) = 4/9 A. ½ mark

5 a)



All phasor angles with respect to supply voltage.

$Z_1 = (10+j15) = 18\angle 56.3^o$ ohm, $Z_2 = (20-j30) = 36\angle -56.3$ohm;

$Z_3 = (15 - j15) = 21.2\angle -45^o$ ohm 1 mark

Total impedance $Z = (Z_1Z_2/(Z_1 + Z_2) + Z_3$

$= 19.32\angle 26.56 + Z_3 = 17.28 + j\,8.64 + 15 - j15 = (32.28 - j6.36)$

$= 32.9\angle -11.14^o$ ohms. 1 mark

$I = V/Z = 200\angle 0/32.9\angle -11.14 = 6\angle 11.14 = (5.89 + j1.16)$ A 2 marks

$I_1 = I\,Z_2/(Z_1 + Z_2) = (6\angle 11.14)(36\angle -56.3)/(33.54\angle -26.56) = 6.44\angle -18.6^o$

$= (6.1 - j\,2)$ A — 2 marks

$I_2 = I\,Z_1/(Z_1 + Z_2) = (6\angle 11.14)(18\angle 56.3)/(33.54\angle -26.56) = 3.22\angle 94$

$= (-0.224 + j\,3.212)$ A. — 2 marks

5 b) As star connected load $V_L = \sqrt{3}\,V_{ph}$, $I_L = I_{ph} = 10\angle -36.87$ A.

$P = \sqrt{3}\,V_L\,I_L\,\cos Ø$,

$V_L = P/(\sqrt{3}\,I_L\,\cos Ø) = 3000/(\sqrt{3} x 10 x 0.8) = 216.5$ V.

$V_{ph} = V_L/\sqrt{3} = 216.5/1.732 = 125$ V. — 1 mark

$Z_{ph} = V_{ph} / I_{ph} = 125/10 = 12.5$ ohm. — 1 mark

$R_{ph} = Z_{ph} \cos Ø = 12.5 \text{ x } 0.8 = 10$ ohm — 1 mark

$X_{ph} = Z_{ph} \sin Ø = 12.5 \text{ x } 0.6 = 7.5$ ohm. — 1 mark

If connected in delta:

$V_L = V_{ph} = 216.5$V.

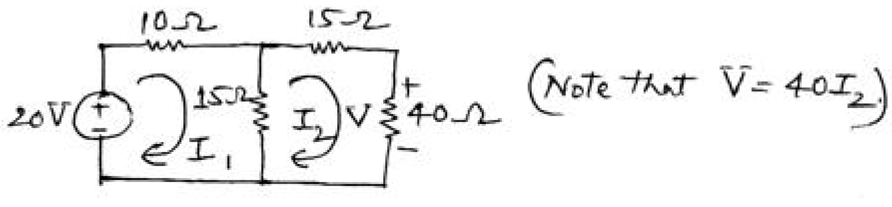
$I_{ph} = V_{ph} / Z_{ph} = 216.5/12.5 = 17.32$ A. — 1 mark

$I_L = \sqrt{3} I_{ph} = \sqrt{3} \text{ x } 17.32 = 30$ A — 1 mark

Power factor is unchanged.

$P = \sqrt{3}\,V_L\,I_L\,\cos Ø = \sqrt{3} \text{ x } 216.5 \text{ x } 30 \text{ x } 0.8 = 9000$ W = 9 kW. — 2 marks

5 c) 1)



Loop equations:

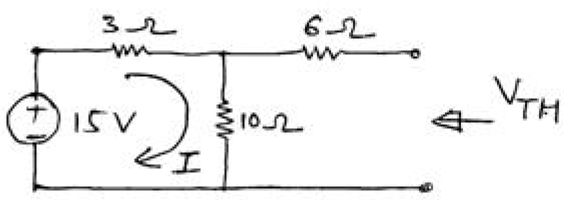
$20 = 25\,I_1 - 15\,I_2$, — 1 mark

$0 = -15\,I_1 + 70\,I_2$. — 1 mark

Solving simultaneously $I_2 = 12/61 = 0.196$ A — 1 mark

$V = 40\,I_2 = 40 \text{ x } 0.196 = 7.868$ V. — 1 mark

5 c) 2)



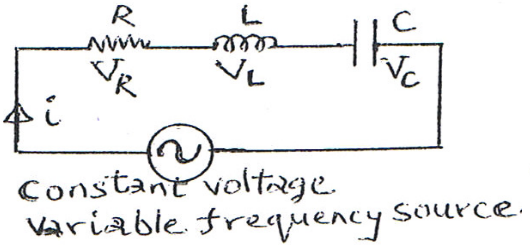
V_{TH} = 10 I = 10 x15/13 = 11.54 V. 1 mark

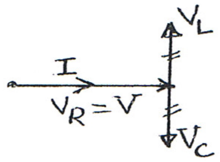
R_{TH} = 6 + (10x3)/(10+3) = 8.3 ohm. 1 mark

$I_L = V_{TH} /(R_{TH} + R_L)$ = 11.54/(8.3 + 6) 1 mark

= 0.8 A 1 mark

6 a) Resonance in series RLC circuit: 1 mark





As the frequency is increased from zero towards higher values at a certain frequency f_O, $X_L = X_C$ and the net reactance of the circuit becomes zero. This is resonance condition. At resonance the voltages across the inductive reactance and capacitive reactance (X_L and X_C) are equal and opposite in phase. 2 marks

$V_L = - V_C$ and hence $V_L + V_C = 0$, (phasor addition).

Also $Z = \sqrt{[R^2+(X_L - X_C)^2]}$ and $V = \sqrt{[V_R^2+(V_L - V_C)^2]}$ 1 mark

Gives $V = V_R$.

Hence the supply voltage applied is across the resistance R, $V = V_R$.

The impedance is minimum at resonance.

Current is max. = I_O = V/R. And is in phase with applied voltage. 1 mark

As $X_L = X_C$, we have $2\pi f_O L = 1/(2\pi f_O C)$ which gives us

$f_O = 1/[2\pi\sqrt{(LC)}]$. (Where L = coefficient of inductance in henry, and C = Capacitance in farads).

Q factor of series circuit: is the ratio of voltage across inductance or capacitance at resonance to the supply voltage applied to series RLC circuit. 1 mark

$Q = V_L/V = V_C/V$ also called as voltage magnification.

1 mark

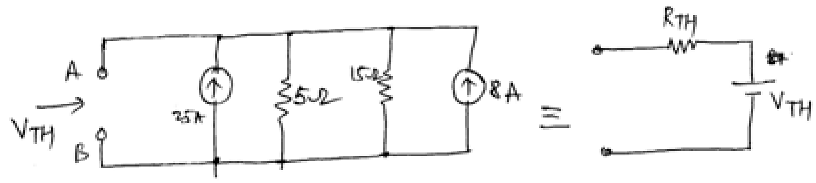
Here $Q = (1/R)\sqrt{(L/C)}$. 1 mark

6 b) Points:

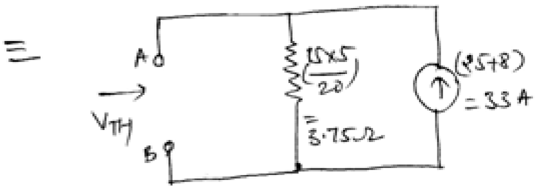
For maximum power transfer $R_L = R_S$,
where R_L = Load resistance connected across the terminals of the source whose internal resistance is R_S. the maximum power that can be transferred from source of EMF 'E' with internal resistance R_S is $E^2/(4R_S)$. 1 mark

For given circuit we are to find the equivalent source (i.e. Thevenin's equivalent between A-B) to get the value of load resistance for max. power transfer. 1 mark

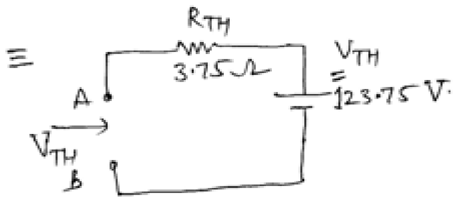
Hence remove R and convert 125V, 5 ohm to current source of 25 A, 5 ohm, across A-B. then combine 8A and 25 A along with resistances to get single source of 123.75 volts, 3.75 ohms.



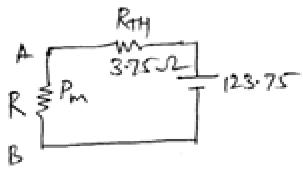
1 mark



1 mark



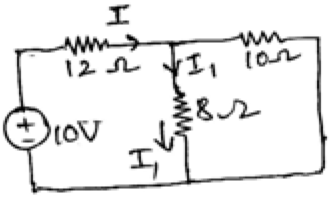
1 mark



For max. power in R, $R = R_{TH} = 3.75$ ohm. 1 mark

$P_{max} = 123.75^2/(4 \times 3.75) = 1020.93$ W = 1.02 kW. 2 marks

6 c) Keep only 10 V:



1 mark

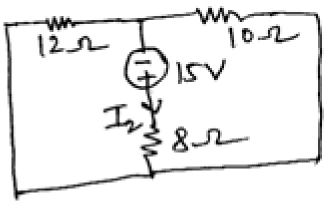
$I_1 = I(10)/(10+8) = 10I/18$

$= (10/18) \times 10/[12 + (10\times8)/(10+8)]$

$= 0.338$ A

1 mark

Keep only 15 V:



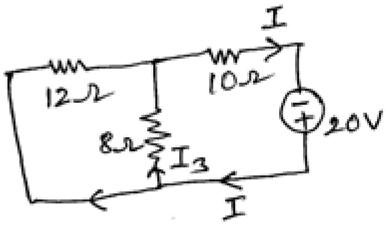
1 mark

$I_2 = (15)/[8 + (12 \times 10)/(12 + 10)]$

$= 1.114$ A

1 mark

Keep only 20 V



1 mark

$I_3 = I(12)/(12+8) = 12I/20$

$= (12/20) \times 20/[10 + (12\times8)/(12+8)]$

$= 0.81$ A

1 mark

By superposition theorem:
Current through the 8 ohm resistance is

$I_1 + I_2 + (-I_3) = 0.338 + 1.114 + (-0.81)$ 1 mark

$= 0.642$ A. 1 mark