WINTER – 2016 Examinations

Model Answer

Subject Code: 17323:ELECTRICAL CIRCUITS AND NETWORKS

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 toassess 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 maygive 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

WINTER – 2016 Examinations

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1 Solve any <u>TEN</u> of the following: 20

1 a) Write alternating voltage and current equations.

Ans.

Alternating Voltage: $e = E_m sin\theta$ OR $e = E_m sin\omega t$ — 1 mark

Alternating Current: $i = I_m sin\theta$ OR $i = I_m sin\omega t$ — 1 mark

1 b) Define: i) Amplitude ii) cycle.

Ans:

i) Amplitude: A maximum value or peak value attained by an alternating quantity during positive or negative half cycle is called as its amplitude. — 1 mark

ii) Cycle: - A complete set of variation in magnitude of an alternating quantity which is repeated at regular interval of time is called as cycle. — 1 mark

OR

A complete set of positive and negative values of an alternating quantity which is repeated at regular interval of time is called a cycle.

1 c) Define: i) Impedance ii) Inductive reactance.

Ans:

i) Impedance: The impedance (Z) of the circuit is defined as the total opposition of the circuit to the alternating current flowing through it. — 1 mark

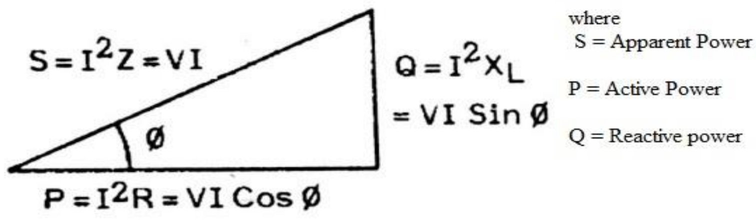
OR

It is combined effect produced by the resistance, inductive reactance and capacitive reactance in the AC circuit.

ii) Inductive reactance:- The opposition offered by the inductance of a circuit to the flow of an alternating current is called an inductive reactance. — 1 mark

1 d) Draw power triangle of for R-L series circuit.

Ans:-



2 marks for labeled diagram

1mark for Partially labeled Diagram

1 e) Define with unit Admittance.

Ans: — 1 mark

Admittance is defined as the ability of the circuit to carry (admit) alternating current through it.

OR

It is the reciprocal of impedance Z. i.e Admittance Y = 1/Z.

Unit: Its unit is siemen (S) or mho (℧). — 1 mark

1 f) Define quality factor. Give equation of it.

Ans:

Quality Factor:

The quality factor basically represents a figure of merit of a component (practical inductor or capacitor) or a complete circuit. It is a dimensionless number and defined as: $Q = 2\pi\left[\frac{Maximum\ energy\ stored}{Energy\ dissipated\ per\ cycle}\right]$

OR

In series circuit it is defined as voltage magnification in the circuit at resonance — 1mark for definition

OR

It is also defined as the ratio of the reactive power of either the inductor or the capacitor to the average power of the resistor. — 1 mark for equation

$$Q\ factor = voltage\ magnification = \frac{1}{R}\sqrt{\frac{L}{C}}$$

OR

In parallel circuit it is defined as equal to the current magnification in the circuit at resonance

OR

The quality factor or Q-factor of parallel circuit is defined as the ratio of the current circulating between two branches of the circuit to the current taken by the parallel circuit from the source.

$$Q\ factor = current\ magnification = \frac{1}{R}\sqrt{\frac{L}{C}}$$

1 g) Give emf equations for three phase a. c. circuit.

Ans:

The equation of three emfs can be represented by — 1 mark for e_a, 1 mark for e_b and e_c

$$e_a = E_m sin\omega t$$
$$e_b = E_m \sin(\omega t - 120^0)$$
$$e_c = E_m \sin(\omega t - 240^0)$$

1 h) Define line voltage and phase voltage.

Ans:

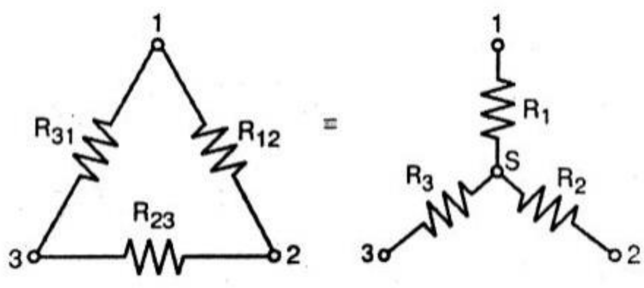
Line Voltage is defined as the potential difference or voltage between any two live lines of three phase system. Line voltages: V_{RY} or V_{YB} or V_{BR} — 1 mark

Phase Voltage is defined as the potential difference between any one live line (phase) and neutral of three phase system. Phase voltages: V_{RN} or V_{YN} or V_{BN} — 1 mark

1 i) Give equations of Delta to Star transformations.

Ans:

Equations of Delta to star transformation:



(a) Delta Circuit (b) Star Circuit

$$R_1 = \frac{R_{12}\,R_{31}}{R_{12}+R_{23}+R_{31}}$$

$$R_2 = \frac{R_{12}\,R_{23}}{R_{12}+R_{23}+R_{31}}$$ 1 mark each (any two)

$$R_3 = \frac{R_{23}\,R_{31}}{R_{12}+R_{23}+R_{31}}$$

1 j) State Maximum power transfer theorem.

Ans:

Maximum Power transfer theorem :

"It states that, the maximum amount of power is delivered to the load resistance when the load resistance is equal to the internal resistance of the source or Thevenin's equivalent resistance of the network supplying the power to load."

According to this theorem, condition for maximum power to be transferred to load is when $R_L = R_{TH}$,

where R_{TH}= Thevenin's equivalent resistance of the network across R_L

Correct statement 2 marks

1 k) State Norton's theorem.

Ans:

Norton's theorem:

It states that, any linear, active, resistive network containing one or more voltage and/or current source can be replaced by an equivalent circuit containing a single current source and equivalent conductance (resistance across the current source).

The equivalent current source (Norton's source) I_N is the current through the short circuited terminals of the load. The equivalent conductance G_N (or R_N) is the conductance (or resistance) seen between the load terminals while looking back into the network with the load removed and internal sources replaced by their internal resistances.

If R_L is load resistance then current through it is $I_L = I_N\,R_N/(R_N + R_L)$.

Correct statement 2 marks

1 l) **State the meaning of t = 0- and t = 0+**

Ans:

1) t = 0– is the instant just before the switching instant t = 0 — 1 mark each
2) t = 0+ is the instant just after the switching instant t = 0

2 Attempt any <u>FOUR</u> of the following: 16

WINTER – 2016 Examinations
Model Answer
Subject Code: 17323:ELECTRICAL CIRCUITS AND NETWORKS

2 a) Define: 1) RMS value 2) Average value

Ans:

The **RMS value** is the Root Mean Square value. It is defined as the square root of the mean value of the squares of the alternating quantity over one cycle. 2 marks

OR

For an alternating current, the RMS value is defined as that value of steady current (DC) which produces the same power or heat as is produced by the alternating current during the same time under the same conditions.

The **Average value** is defined as the arithmetical average or mean of all the values of an alternating quantity over one cycle. 2 marks

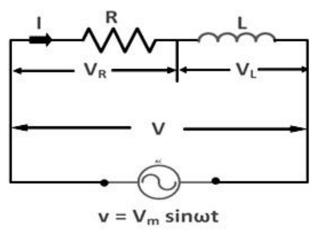
OR

For an alternating current , the average value is defined as that value of steady current (DC) which transfers the same charge as is transferred by the alternating current during the same time under the same conditions.

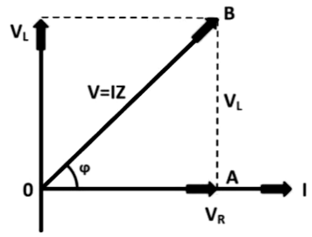
2 b) Draw circuit diagram, phasor diagram, waveform of voltage and current for R-L series circuit.

Ans:

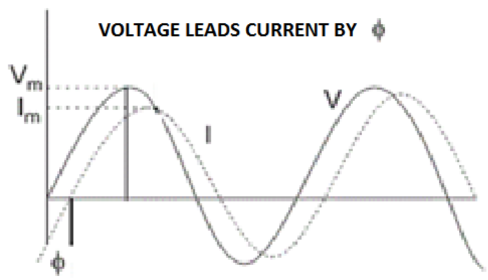
Circuit diagrm: 1 mark for circuit diagram



Phasor diagram : 1 mark for phasor diagram

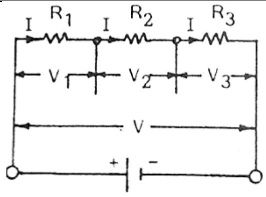
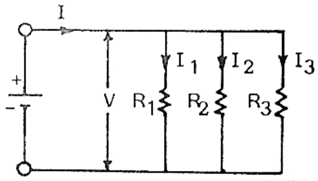


Wave form of voltage and current:- 2 marks for waveforms



2 c) **Give comparison of series and parallel circuit.**

Ans:

Sr. No.	Series Circuit	Parallel Circuit
1		

WINTER – 2016 Examinations
Model Answer
Subject Code: 17323:ELECTRICAL CIRCUITS AND NETWORKS

2	A series circuit is that circuit in which the current flowing through each circuit element is same.	A parallel circuit is that circuit in which the voltage across each circuit element is same.	
3	The sum of the voltage drops in series resistances is equal to the applied voltage V. $\therefore V = V_1+V_2+V_3$	The sum of the currents in parallel resistances is equal to the total circuit current I. $\therefore I = I_1+I_2+I_3$	
4	The effective resistance R of the series circuit is the sum of the resistance connected in series. $R = R_1 + R_2 + R_3 + \cdots$	The reciprocal of effective resistance R of the parallel circuit is the sum of the reciprocals of the resistances connected in parallel. $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$	
5	For series R-L-C circuit, the resonance frequency is, $f_r = \frac{1}{2\pi\sqrt{LC}}$	For parallel R-L-C circuit, the resonance frequency is, $f_r = \frac{1}{2\pi\sqrt{LC}}$	1 mark each (any four)
6	At resonance, the series RLC circuit behaves as purely resistive circuit.	At resonance, the parallel RLC circuit behaves as purely resistive circuit.	
7	At resonance, the series RLC circuit power factor is unity.	At resonance, the Parallel RLC circuit power factor is unity.	
8	At resonance, the series RLC circuit offers minimum total impedance Z = R	At resonance, the parallel RLC circuit offers maximum total impedance Z =L/CR	
9	At resonance, series RLC circuit draws maximum current from source, I = (V/R)	At resonance, parallel RLC circuit draws minimum current from source, $I = \frac{V}{[L/_{CR}]}$	
10	At resonance, in series RLC circuit, voltage magnification takes place.	At resonance, in parallel RLC circuit, current magnification takes place.	
11	The Q-factor for series resonant circuit is $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$	The Q-factor for parallel resonant circuit is, $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$	
12	Series RLC resonant circuit is Accepter circuit.	Parallel RLC resonant circuit is Rejecter circuit.	

2 d) Define: 1) Balanced load 2) Unbalanced load.

Ans:

Balanced Load: Balanced three phase load is defined as star or delta connection of three equal impedances having equal real parts and equal imaginary parts. 2 marks

e.g Three impedances each having resistance of 5ohm and inductive reactance of 15 ohm connected in star or delta.

Unbalanced Load: Unbalanced three phase load is defined as star or delta connection of three unequal impedances having unequal real parts or unequal imaginary parts. 2 marks

OR

If impedances of one or more legs of a three phase load are different from other legs in respect of magnitude and their nature, it is said to be an unbalanced three phase load. i.e. magnitude of voltages and resulting currents are different either in phase or magnitude or both phase & magnitude.

2 e) State why source transformation is needed. Give three steps to convert voltage source into current source.

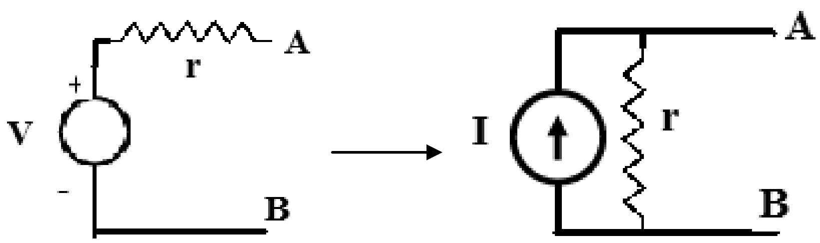
Ans:

Need:

Source transformation is needed to simplify a circuit solution and find key when circuit with mixed sources exist. 1 mark

Steps to convert voltage source into current source:-

1) Calculate equivalent current source as the short circuit current through the voltage source terminals: (I = V / r) 1 mark
2) The Shunt Resistance of current source: (Rsh = r) 1 mark
3) Draw the equivalent source.



1 mark

2 f) Explain the concept of initial conditions in switching circuits for element R, L & C.

Ans:-

Concept of initial conditions:

Initial condition means the state of the circuit or its elements just after the switching. For the three basic circuit elements the initial conditions are derived in following way:

i) Resistor: 1 mark

According to ohm's law; the relationship between voltage and current, is given by

$v = i.R$

This equation is time independent equation as R is a constant. Thus the current changes instantaneously as soon as the voltage changes or vice versa. That means initial condition at time t = 0 is same as that exists then. Hence if at t = 0, voltage v is applied the initial current will be v/R at t = 0+.

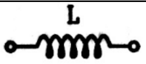
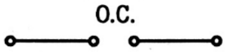
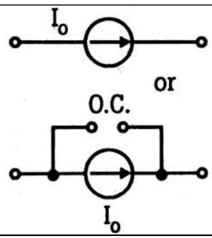
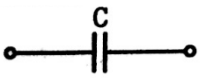
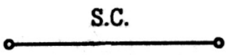
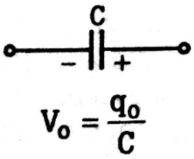
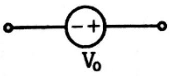
Thus at any time it acts like resistor only, with no change in condition.

ii) Inductor:

The current through an inductor cannot change instantly. If the inductor current is zero just before switching, then whatever may be the applied voltage, just after switching the inductor current will remain zero. i.e the inductor must be acting as open-circuit at instant t = 0. If the inductor current is I_0 before switching, then just after switching the inductor current will remain same as I_0, and having stored energy 1 mark hence it is represented by a current source of value I_0 in parallel with open circuit.

iii) Capacitor:

The voltage across capacitor cannot change instantly. If the capacitor voltage is zero initially just before switching, then whatever may be the current flowing, just after switching the capacitor voltage will remain zero. i.e the capacitor must be acting as short-circuit at instant t = 0. If capacitor is previously charged to some voltage V_0, then also after switching at t = 0, the voltage across capacitor remains same V_0. Since the energy is stored in the capacitor, it is represented by a voltage source V_0 in series with short-circuit. 1 mark

Element and condition at $t = 0^-$	Initial Condition at $t = 0^+$
	
	
	
	
	

1 mark

3 Attempt any FOUR of the following: **16**

3 a) An a.c series circuit has a resistance of 10 ohm, an inductance of 0.2 H and a capacitance of 60 µF. Calculate: a) resonant frequency b) curent c) power at resonance. Applied voltage is 200V.

Ans:

a) **Resonant Frequency:**

$$Resonant\ frequency\ f_0 = \frac{1}{(2\pi\sqrt{LC})}$$

$$\therefore f_0 = \frac{1}{2\pi\sqrt{(0.2 \times 60 \times 10^{-6})}} = 45.944 \text{ Hz} = 46 \text{ Hz}$$

2 marks

b) **Current:**

At resonance R = Z

$$\therefore \text{Current } I = \frac{V}{Z} = \frac{200}{10} = 20\ amp$$

1 mark

c) **Power at resonance:**

$$At\ Resonance\ p.f = 1$$

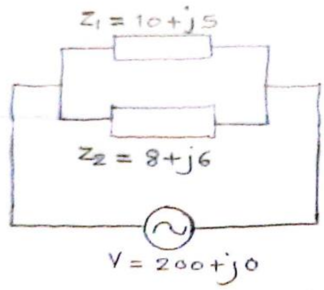
$$\therefore P = V \times I = 200 \times 20 = 4000\ watts$$ or 4 kW

1 mark

WINTER – 2016 Examinations
Model Answer
Subject Code: 17323:ELECTRICAL CIRCUITS AND NETWORKS

3 b) Two impedances given by Z_1 = (10 + j5) and Z_2 = (8 + j6) are joined in parallel and connected across a voltage of V = 200 + j0. Calculate the circuit current, its phase and branch currents. Draw the vector diagram.

Ans:



$V = 200 + j0 = 200\ \angle 0°$ volt

$Z_1\ = 10 + j5 = 11.18\ \angle 26.56°$

$Z_2\ = 8 + j6 = 10\ \angle 36.87$

Branch 1 current is given by

$Y_1 = \frac{1}{Z_1} = \frac{1}{11.18\ \angle 26.56°} = 0.08945\angle -26.56° = 0.08 - j\ 0.04\ mho$

$I_1 = V\ \times\ Y_1 = 200\ (\ 0.08 -\ j0.04) = 16 - j\ 8 = 17.88\angle - 26.56°$ — 1 mark

OR $I_1\ =\ \frac{V}{Z_1} = \ \frac{200\ \angle 0}{11.18\ \angle 26.56} = \ 17.88\ \angle - 26.56°$ amp

Branch 2 current is given by

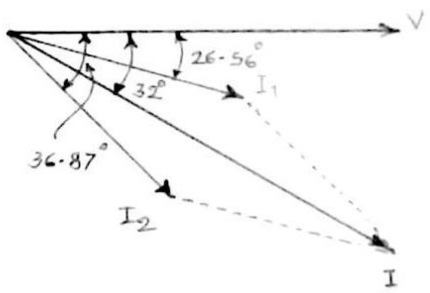
$$Y_2 = \frac{1}{Z_2} = \frac{1}{10\ \angle 36.87°} = 0.1\angle - 36.87° = 0.08 - j\ 0.06\ mho$$

$I_2 = V\ \times\ Y_2 = 200\ (\ 0.08 -\ j0.06) = 16 - j12 = 20\angle - 36.87°$ — 1 mark

OR $I_2\ =\ \frac{V}{Z_2} = \ \frac{200\ \angle 0}{10\ \angle 36.86} = \ 20\angle - 36.86°$ amp

$I = I_1 + I_2 = 16 - j8 + 16 - j12 = 32 - j20 = 37.74\angle - 32°$ amp — 1 mark

Vector Diagram :



V

1 mark

3 c) Explain advantages of polyphase circuit over single phase circuit.

Ans:

Advantages of polyphase circuit over single phase circuit:

i) The power generated by 3-phase machine is higher than that of 1-phase machine of the same size.

ii) The size of 3-phase machine is smaller than that of 1-phase machine of the same power rating. — 1 mark for each of any four

iii) Three-phase transmission is more economical than single-phase transmission. It requires less copper material.

iv) Three-phase induction motors are self-starting.

v) They have high efficiency, better power factor and uniform torque.

vi) Parallel operation of 3-phase alternators is easier than that of single-phase alternators.

WINTER – 2016 Examinations
Model Answer
Subject Code: 17323:ELECTRICAL CIRCUITS AND NETWORKS

3 d) Find the ammeter current in fig.(1) by using mesh analysis.

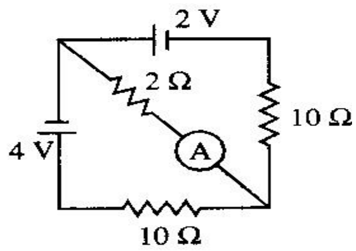
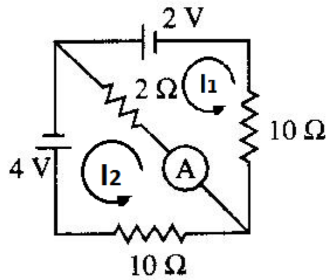


Figure (1)

Ans:
Mesh Analysis:



i) There are two meshes in the network.
ii) Mesh currents I_1 and I_2 are marked anti-clockwise as shown.
iii) By tracing mesh 1 clockwise, KVL equation is,

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

$\therefore 2 - 12I_1 + 2I_2 = 0$

$\therefore 12I_1 - 2I_2 = 2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$ 1 mark for Eq. (1)

By tracing mesh 2 clockwise, KVL equation is,

$4 - 10I_2 - 2(I_2 - I_1) = 0$

$4 - 12I_2 + 2I_1 = 0$

$\therefore 2I_1 - 12I_2 = -4 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$

iv) Expressing eq.(1) and (2) in matrix form, 1 mark for Eq. (2)

$$\begin{bmatrix} 12 & -2 \\ 2 & -12 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 2 \\ -4 \end{bmatrix}$$

$$\therefore \Delta = \begin{vmatrix} 12 & -2 \\ 2 & -12 \end{vmatrix} = -144 - (-4) = -140$$

By Cramer's rule,

$$I_1 = \frac{\begin{vmatrix} 2 & -2 \\ -4 & -12 \end{vmatrix}}{\Delta} = \frac{(2 \times -12) - (-4 \times -2)}{-140} = \frac{-24 - 8}{-140} = \mathbf{0.2286A}$$

1 mark for finding loop currents

$$I_2 = \frac{\begin{vmatrix} 12 & 2 \\ 2 & -4 \end{vmatrix}}{\Delta} = \frac{(12 \times -4) - (2 \times 2)}{-140} = \frac{-48 - 4}{-140} = \mathbf{0.3714\ A}$$

1 mark for ammeter current

v) The current flowing through ammeter is,

$I = I_2 - I_1 = 0.3714 - 0.2286 = \mathbf{0.1428\ A\ in\ the\ direction\ of\ I_2}$

3 e) Find the Norton equivalent impedance for the active linear network shown in fig.(2).

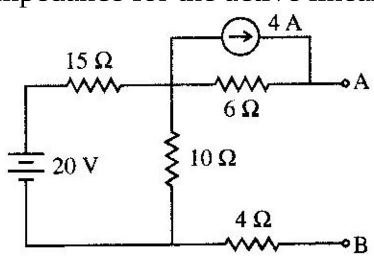


Figure (2)

Ans:
Norton equivalent impedance:

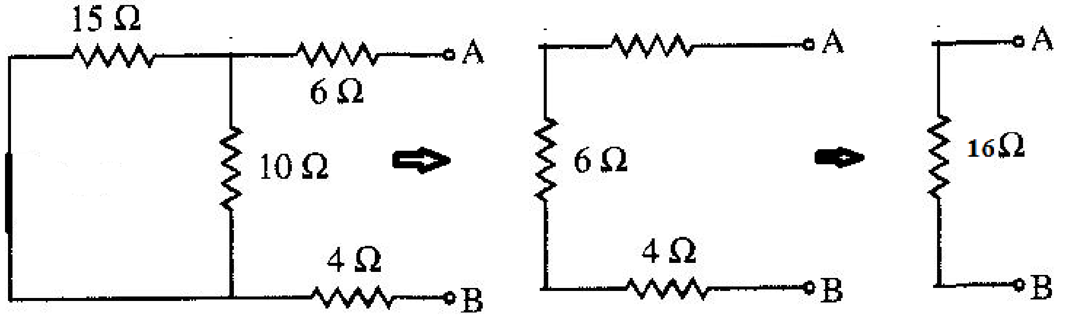
Norton's equivalent impedance is the impedance seen between the terminals A-B while looking back into the network with all sources are replaced by their internal impedances i.e voltage source by short circuit and current source by open circuit. — 1 mark for diagram

It is seen that resistances15 Ω and 10Ω are in parallel. Their resultant resistance is, — 1 mark for source replacement

$15 \parallel 10 = \frac{(15)(10)}{(15+10)} = 6\ \Omega$

Now three resistances 6Ω, 6Ω and 4Ω appears in series. Their equivalent resistance is given by: 6+6+4 = 16Ω — 1 mark for 15||10

Thus, Norton's equivalent resistance R_N = 16Ω — 1 mark for final answer



3 f) Explain concept of final condition in switching circuits for R, L and C elements.

Ans:

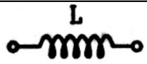
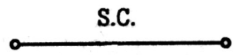
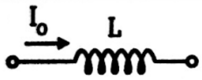
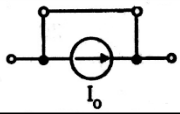
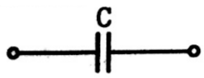
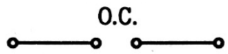
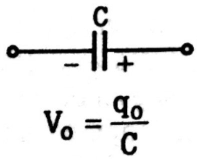
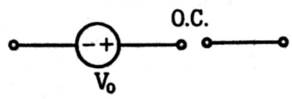
Concept of final condition:

After switching, the circuit condition is disturbed, however once transient period is over, the circuit attains steady-state condition. This steady-state condition is called "Final condition".

Resistance: As ratio of voltage to current is a constant (= R) at any time instant t, there is no change in the value of resistor. At any time it acts like resistor only, with no change in condition. — 1 mark

Inductor: After switching, as time passes the inductor current slowly changes and finally it becomes constant. Therefore the voltage across the inductor falls to zero$\left[v_L = L\frac{di_L}{dt} = 0\right]$. The presence of current with zero voltage exhibits short circuit condition. Therefore, under steady-state constant current condition, the inductor is represented by a short circuit. If the initial inductor current is non-zero I_0, making it as energy source, then finally inductor is represented by current source I_0 in parallel with a short circuit. — 1 mark

Capacitor: After switching, as time passes the capacitor voltage slowly changes and finally it becomes constant. Therefore the current through the capacitor falls to zero$\left[i_C = C\frac{dv_C}{dt} = 0\right]$. The presence of voltage with zero current exhibits open circuit condition. Therefore, under steady-state constant voltage condition, the capacitor is represented by a open circuit. If the initial capacitor voltage is non-zero V_0, making it as energy source, then finally capacitor is represented by voltage source V_0 in series with a open-circuit. — 1 mark

Element and condition at $t = 0^-$	Final Condition at $t = \infty$
	
	
	
	
	

1 mark

4 Attempt any <u>FOUR</u> of the following: 16

4 a) An alternating voltage given by e = 150 sin100 πt is applied to a circuit which offers a resistance of 50 ohms. Find r.m.s and average value of current and supply frequency.

Ans:-

The circuit current is given by,

$$i = \frac{e}{R} = \frac{150 \sin 100\,\pi t}{50} = 3 \sin 100\,\pi t$$ 1 mark

Comparing given equation with standard equation $i = I_m sin2\pi ft$

$$I_m = \frac{V_m}{R} = \frac{150}{50} = \mathbf{3\ A}$$

$$\therefore\ I_{rms} = \frac{Im}{\sqrt{2}} = \frac{3}{\sqrt{2}} = \mathbf{2.12\ A}$$ 1 mark

$$\therefore\ I_{av} = \frac{2I_m}{\pi} = \frac{3}{\pi} = \mathbf{1.909\ A}$$ 1 mark

$$\therefore\ 2\pi ft = 100\pi t \qquad \therefore\ 2f = 100$$

$$\therefore\ f = \frac{100}{2} = \mathbf{50Hz}$$ 1 mark

4 b) A 50 Hz voltage of 230 V effective value is impressed on an inductance of 0.265H.

i) Write the time equation for the voltage and resulting current. Let the zero axis of the voltage wave be at t = 0.
ii) Show the voltage and current on a phasor diagram.

Ans:-

$Vm = 230\ x\ \sqrt{2} = 325.27\ V$

$\omega = 2\pi f = 2\pi x\ 50 = 314.2\ rad/sec$

$XL = 2\pi fL = 2\pi x\ 50\ x\ 0.265 = 83.25\ \Omega$

1 mark for preliminary terms

$$Im = \frac{Vm}{XL} = \frac{325.27}{83.25} = 3.9\ A$$

$$v = 325.27\sin(314.2t)\ V$$ 1 mark

$$i = 3.9\sin(314.2t - 90^0)A$$ 1 mark

$$Irms = 0.707\ x\ 3.9 = 2.75\ A$$

1 mark

4 c) A circuit consisting of a coil of resistance 12 Ω and inductance 0.15 H in series with a capacitor of 12 μF is connected to a variable frequency supply which has a constant voltage 240 V. Calculate (a) resonant frequency (b) current in the circuit at resonance.

Ans:

a) Resonant frequency $f_r = \frac{1}{(2\pi\sqrt{LC})}$

$$\therefore\ f_r = \frac{1}{2\pi\sqrt{(0.15 \text{ x } 12 \text{ x } 10^{-6})}} = 118.63 \cong 119 \text{ Hz}$$ 2 marks

b) $At\ resonance\ R = Z = 12\ \Omega$

$$\therefore\ I = \frac{V}{Z} = \frac{240}{12} = 20\ amp$$ 2 marks

4 d) A voltage of $200\angle 53^0$ is applied across two impedances in parallel. The values of impedances are (12 + j16) and (10 – j20). Determine the kVA, kVAR and kW in each branch and power factor of the whole circuit.

Ans:

$V = 200\angle 53^0\ V$

$$Z_1 = 12 + j16 = 20\ \angle 53.13°$$

$$Z_2 = 10 - j20 = 22.36\angle -63.43°$$

$$I_1 = \frac{V}{Z_1} = \frac{200\ \angle 53°}{20\ \angle 53.13°} = 10\ \angle -0.13° = 10 - \text{j}0.022 \text{ A}$$

Angle between V and I_1 is {53 – (– 0.13) }= 53.13°

$$I_2 = \frac{V}{Z_2} = \frac{200\ \angle 53°}{22.36\angle -63.43°} = 8.94\ \angle 116.43° = -3.98 + \text{j}8 \text{ A}$$

Angle between V and I_2 is (53 – 116.43) = – 63.43°

1 mark for branch currents

Powers in first branch

$Active\ power$: $P_1 = VI_1 cos\emptyset_1 = 200 \times 10 \times \cos(53.13°)$
= 1200 watt = 1.2 kW

$Reactive\ power$: $Q_1 = VI_1 sin\emptyset_1 = 200 \times 10 \times sin(53.13°)$
= 1600 VAR = 1.6 kVAR (lagging)

$Apparent\ power$: $S_1 = VI_1 = 200 \times 10 = 2000\ VA = 2\ kVA$

1 mark for power in branch 1

Powers in second branch:

$Active\ power$: $P_2 = VI_2cos\emptyset_2 = 200 \times 8.94 \times \cos(-63.43°)$
= 799.76 watt = 0.79976 kW

$Reactive\ power$: $Q_2 = VI_2sin\emptyset_2 = 200 \times 8.94 \times \sin(-63.43°)$
= –1599.17 VAR = – 1.59917 kVAR (leading)

$Apparent\ power$: $S_2 = VI_2 = 200 \times 8.94 = 1788\ VA = 1.788\ kVA$

1 mark for power in branch 2

Circuit total current is,

$\therefore \mathrm{I} = \mathrm{I}_1 + \mathrm{I}_2 = 6.02 + \mathrm{j}\ 7.978 = 10\ \angle 52.96^0 \mathrm{A}$

Angle between V and I is (53 – 52.96) = 0.04°

P.F. $of\ whole\ circuit\ is\ \cos(0.04) = 0.999999 \cong 1$

1 mark for circuit pf

4 e) Each phase of a delta-connected load comprises a resistor of 50 ohm and capacitor of 50µF in series. Calculate the line and phase currents when the load is connected to a 440 V, 3 phase 50Hz supply.

Ans:

$$\mathrm{X_C} = \frac{1}{2\pi fC} = \frac{1}{2 \times \pi \times 50 \times 50 \times 10^{-6}} = 63.66\ \Omega$$ 1 mark

$$\therefore\ \mathrm{Z_{ph}} = (50 - \mathrm{j}63.66)\Omega = 80.94\angle -51.85°\ \Omega$$ 1 mark

For delta-connected load, phase voltage = line voltage = 440∠0°

Phase current is given by,

$$\therefore I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{440\ \angle 0°}{80.94\ \angle -51.85°} = \mathbf{5.44}\angle 51.85°\ \mathrm{A}$$ 1 mark

Line current is given by,

$$\therefore \mathrm{I_L} = \sqrt{3}.\mathrm{I_{ph}} = \sqrt{3}\ \mathrm{x}\ 5.44 = \mathbf{9.41}\ \mathrm{amp}$$ 1 mark

4 f) Use Nodal analysis to determine the value of current i in the network of fig. (3).

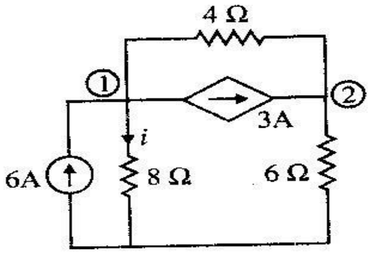


Figure (3)

Ans:-

Nodal Analysis:

i) At node 1, by KCL,

$$-6 + \frac{V_1}{8} + \frac{V_1 - V_2}{4} + 3 = 0$$

$$\therefore V_1\left[\frac{1}{8} + \frac{1}{4}\right] - V_2\left[\frac{1}{4}\right] = 3$$

$$0.375V_1 - 0.25V_2 = 3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$ 1 mark

ii) At node 2, by KCL,

$$-3+\frac{V_2}{6}+\frac{V_2-V_1}{4}=0$$

$$\therefore V_2\left[\frac{1}{6}+\frac{1}{4}\right]-V_1\left[\frac{1}{4}\right]-3=0$$ 1 mark

$$-0.25V_1+0.42V_2=3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

iii) Expressing eq.(1) and (2) in matrix form,

$$\begin{bmatrix}0.375 & -0.25\\ -0.25 & 0.42\end{bmatrix}\begin{bmatrix}V_1\\ V_2\end{bmatrix}=\begin{bmatrix}3\\ 3\end{bmatrix}$$

$$\therefore \Delta=\begin{vmatrix}0.375 & -0.25\\ -0.25 & 0.42\end{vmatrix}=0.1575-(0.0625)=0.095$$

By Cramer's rule,

$$V_1=\frac{\begin{vmatrix}3 & -0.25\\ 3 & 0.42\end{vmatrix}}{\Delta}=\frac{(1.26)-(-0.75)}{0.095}=\frac{2.01}{0.095}=\mathbf{21.16\ volt}$$ 1 mark

Current flowing through 8Ω is given by,

$$i=\frac{V_1}{8}=\frac{21.16}{8}=\mathbf{2.645\ amp}$$ 1 mark

$$V_2=\frac{\begin{vmatrix}0.375 & 3\\ -0.25 & 3\end{vmatrix}}{\Delta}=\frac{(-0.75)-(1.125)}{0.095}=\frac{-1.875}{0.095}=-19.74\text{ volt}$$ **(Optional)**

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

5 a) A pure inductance allows a current of 10 A to flow from a 230 V, 50 Hz supply. Find (i) Inductive reactance, ii) Inductance, iii) Power absorbed. Write down the equation for voltage and current.

Ans:

(i) Inductive reactance:

$$I=\frac{V}{X_L}\quad \therefore X_L=\frac{V}{I}$$

$$\therefore X_L=\frac{230}{10}=23\Omega$$ 1 mark

(ii) Inductance:

$$L=\frac{X_L}{2\pi f}=\frac{23}{(2\pi\times 50)}=0.0732\ H$$ 1 mark

(iii) In case of pure inductance , phase angle between voltage and current is 90° 1 mark

$$\therefore\ P=VI\cos\emptyset=230\times 10\times\cos 90°=0$$

(iv) Equation for voltage and current:

$$v=230\sqrt{2}\sin(2\pi ft)=325.27\sin(2\pi\times 50\times t)$$ ½ mark

$$=325.27\sin(314.2t)$$

$$i=10\sqrt{2}\sin(\omega t-90^0)=14.14\sin(314.2t-90°)$$ ½ mark

5 b) A two element series circuit is connected across an ac source.
$e=200\sqrt{2}\sin(\omega t+20^0)$ V. The current in the circuit then found to be
$i=10\sqrt{2}\cos(314t-25^0)$ A. Determine the parameters of the circuit.

Ans:

Current equation can be written as

$$i=10\sqrt{2}\sin(314t-25+90)=10\sqrt{2}\sin(314t+65°)\ A$$ 1 mark

Voltage equation is,

$$e=200\sqrt{2}\sin(314t+20^0)\ V$$

∴ Angle between v and i is 20 – 65 = - 45^0

$\therefore\ p.f\ =\ \cos(-45°)\ =\ 0.707\ (leading)$ 1 mark

Since current leads voltage, the circuit is R-C series circuit

$\therefore V_m = 200\sqrt{2}\ \ I_m = 10\sqrt{2}\ \ \therefore Z = \frac{V_m}{I_m}$

$\therefore Z = \frac{200\sqrt{2}}{10\sqrt{2}} = 20\ \Omega$

∴ Resistance $R = Z\cos\emptyset = 20 \text{ x } 0.707 = 14.1\ \Omega$ 1 mark

∴ Capacitive reactance $X_C = Z\sin\emptyset = 20 sin 45 = 14.1\ \Omega$

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

Since $X_c = \frac{1}{2\pi fc}$ $\therefore C = \frac{1}{2\pi f X_c} = \frac{1}{2\pi x 50 x 14.1} = 225.75\ \mu F$ 1 mark

5 c) Draw the vector dia. For the circuit shown in fig.(4) indicating the resistance and reactance drops, the terminal voltages V_1 and V_2 and current.

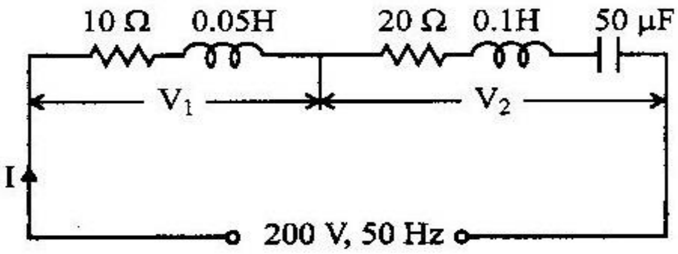


Figure (4)

Ans :-

$X_{L1} = 2\pi f L_1 = 2 \times \pi \times f \times 0.05 = 15.71\,\Omega$

$X_C = \frac{1}{2\pi fc} = \frac{1}{2\pi \times 50 \times 50 \times 10^{-6}} = 63.66\,\Omega$ 1 mark for reactances

$X_{L2} = 2\pi f L_2 = 2 \times \pi \times f \times 0.1 = 31.42\,\Omega$

$Z_T = 10 + j15.71 + 20 + j\,31.42 - j\,63.66$

$\therefore Z_T = 30 - j16.53 = 34.25\angle -28.85^0\ \Omega$

$I = \frac{V}{Z_T} = \frac{200}{34.25} = 5.84\ amp$

$V_{R1} = IR_1 = 58.4\ V$ 1 mark for all voltages

$V_{L1} = IX_{L1} = 91.74V$

$V_{R2} = IR_2 = 116.8\ V$

$V_{L2} = IX_{L2} = 183.5\ V$

$V_C = IX_C = 371.77\ V$

Power factor of complete circuit:

$cos\emptyset = \frac{R}{Z_T} = \frac{30}{34.25} = 0.876\ \ lead.$

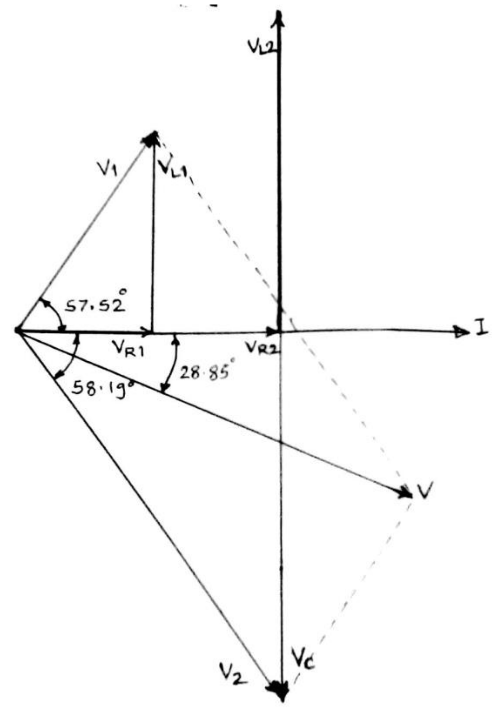
$\emptyset = 28.85°$

Voltage $V_1 = V_{R1} + jV_{L1} = 58.4 + j91.74 = 108.75\angle 57.52°$ volt

Voltage $V_2 = V_{R2} + j(V_{L2} - V_c) = 116.8 + j(183.5 - 371.77)$ 1 mark for V_1 and V_2

$= 116.8 - j188.27 = 221.56\angle -58.19°$ volt

Vector diagram :-



1 mark for phasor diagram

5 d) State relationship between line voltage and phase voltage, line current and phase current in a balanced delta connection. Draw complete phasor diagram of voltages and current.

Ans:

Relationship in 3-phase balanced delta connection:

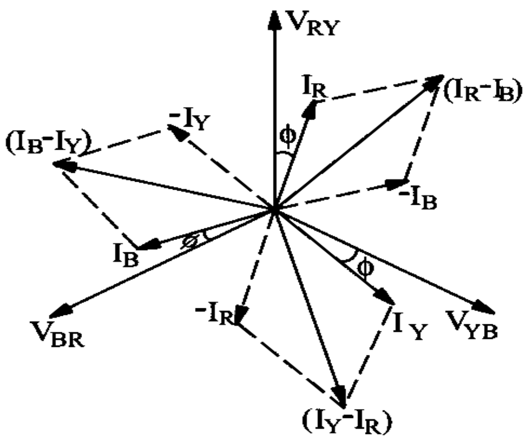
Line voltage = Phase voltage

$V_L = V_{ph}$ — 1 mark

Line current = $\sqrt{3}$ phase current

$I_L = \sqrt{3}\ I_{ph}$ — 1 mark

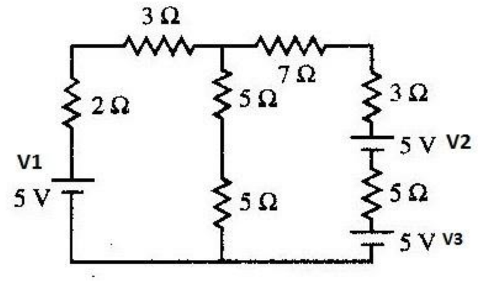
Phasor diagram:-



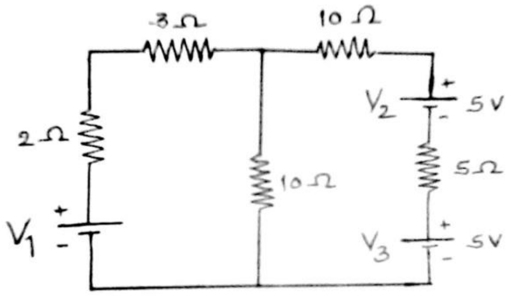
Line & Phase Current and Line & Phase Voltage in Delta (Δ) Connection

2 mark

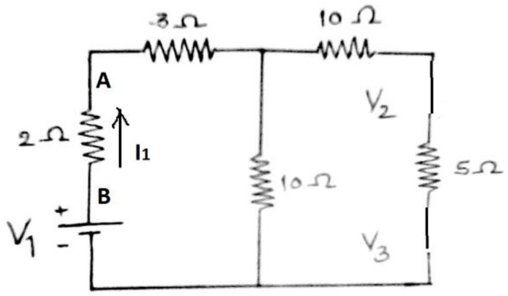
5 e) Calculate current flowing through 2 Ω resistor in fig.(5) by using super position theorem.



Ans:
Circuit is simplified as shown below:

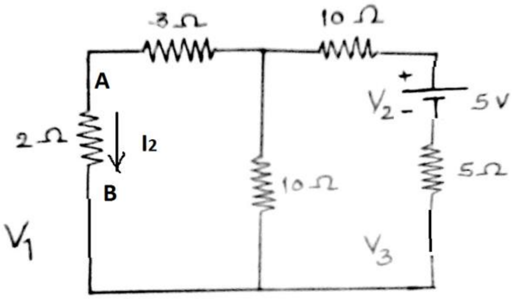


A) Voltage source V_1 acting alone:(Other voltage sources replaced by SC)



Total equivalent resistance across V_1 is given by:
$R_1 = 2 + 3 + (10||15) = 11\Omega$
Current through 2 Ω due to V_1 alone is: 1 mark
$I_1 = V_1/R_1 = 5/11 =$ **0.4545 amp (from B to A) = - 0.4545 amp (from A to B)**

B) Voltage source V_2 acting alone:(Other voltage sources replaced by SC)

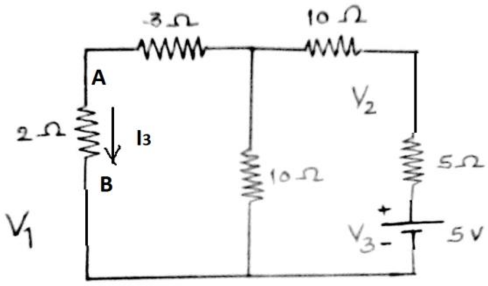


Total equivalent resistance across V_2 is given by:
$R_1 = 10 + (10||5) + 5 = 18.33\Omega$
Current supplied by V_2 is: $V_2/R_2 = 5/18.33 = 0.273$ amp

Current through 2 Ω due to V_2 alone is: (by current division formula) 1 mark

I_2 = 0.273(10/15) = **0.182 amp (from A to B)**

C) Voltage source V_3 acting alone:(Other voltage sources replaced by SC)



Since V_2 and V_3 are equal and in series, their currents will be same.

Total equivalent resistance across V_3 is given by:

R_1 = 15 + (10||5) = 18.33Ω

Current supplied by V_3 is: V_3/R_3 = 5/18.33 = 0.273 amp

Current through 2 Ω due to V_3 alone is: (by current division formula) 1 mark

I_3 = 0.273(10/15) = **0.182 amp (from A to B)**

By Superposition theorem, the current through 2 Ω is given by:

$I = I_1 + I_2 + I_3$ = - 0.4545+0.182+0.182 (from A to B)

= - 0.0905 amp (from A to B) 1 mark

= 0.0905 amp (from B to A)

5 f) Obtain the thevenin equivalent circuits for the circuit shown in fig. (6).

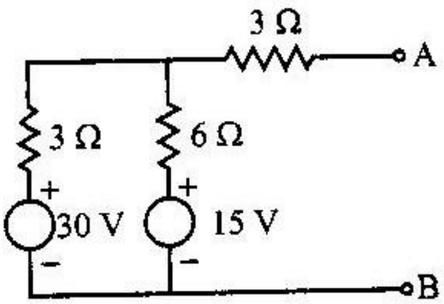


Figure (6)

Ans:

Calculation of V_{th}

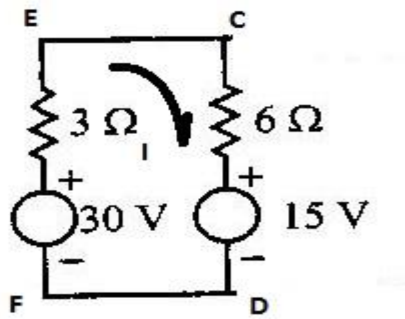
V_{th} = 30 – 3I or = 15 + 6 I

I = (30-15)/(3 +6) = 15/9 = 1.66 A

∴ V_{th} = 30 – 3(1.66) = 25 V

OR

= 15 + 6(1.66) = 25 V

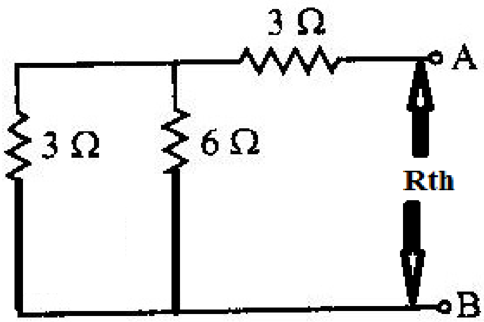


1 mark for diagram

1 mark for calculation of V_{th}

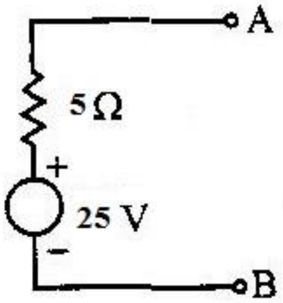
Calculation of R_{th}:

Rth = 3 + (3 || 6) = 3+2
Rth = 5Ω



1 mark

Thevenin Equivalent circuit:



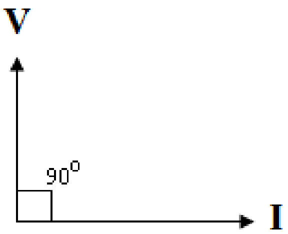
1 mark

6	**Attempt any FOUR of the following:**	**16**

6 a) Draw the phasor diagram and waveform of pure inductance and pure capacitance. Write voltage and current equation of it.

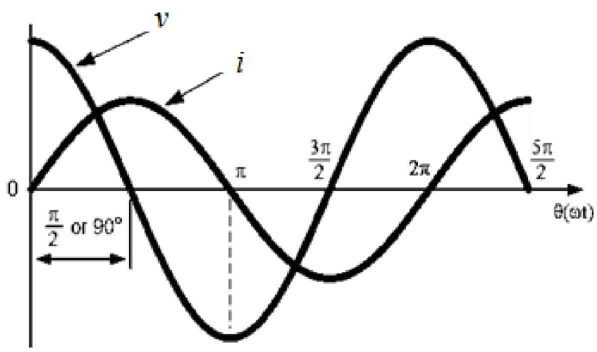
Ans:

Phasor diagram of pure inductive circuit:-



1 mark

Waveform of pure inductive circuit:

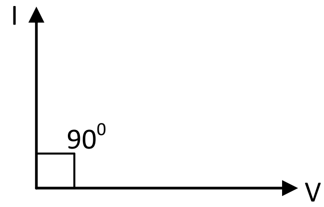


1 mark For waveform and equation

Equations:-

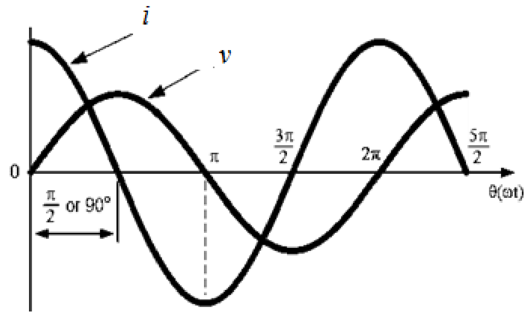
$$v = V_m \sin(\omega t + 90°) \quad and\ i = I_m \sin \omega t$$

Phasor diagram of pure capacitive circuit:



1 mark

Waveform of pure capacitive circuit:



1 mark For waveform and equation

Equations:

$$v = V_m \sin \omega t \quad and\ i = I_m \sin(\omega t + 90)$$

6 b) An ohmic resistance is connected in series with a coil across 230 V, 50 Hz supply. The current is 1.8 A and p.d. across the resistance and coil are 80 V and 170 V respectively. Calculate resistance and inductance of the circuit.

Ans:-

$${V_R}^2 = 80^2$$

$$\therefore {V_r}^2 + {V_L}^2 = 170^2 ------(1)$$

$$(V_R + V_r)^2 + {V_L}^2 = V^2$$

$$(80 + V_r)^2 + {V_L}^2 = 230^2$$

$$80^2 + 160V_r + {V_r}^2 + {V_L}^2 = 230^2$$

$$160V_r = 230^2 - 170^2 - 80^2$$

$$\therefore V_r = 110V$$

1 mark

$$\therefore r = \frac{110}{1.8} = 61.11\ \Omega$$

1 mark

$$\therefore V_L = \sqrt{(170^2 - 110^2)} = 129.61\ V$$

1 mark

$$\therefore X_L = \frac{129.61}{1.8} = 72\ \Omega$$

$$\therefore L = \frac{X_L}{2\pi f} = 0.23H$$

1 mark

6 c) State the advantages of polyphase circuit over single phase circuit.

Ans:

1 mark each (any four)

i) The power generated by 3-phase machine is higher than that of 1-phase machine of the same size.

ii) The size of 3-phase machine is smaller than that of 1-phase machine of the same power rating.

iii) Three-phase transmission is more economical than single-phase transmission. It requires less copper material.

iv) Three-phase induction motors are self-starting.

v) Polyphase machines have high efficiency, better power factor and uniform torque.

vi) Parallel operation of 3-phase alternators is easier than that of single-phase alternators.

6 d) Apply Norton's theorem to calculate current flowing through 5 ohm resistor of fig.(7)

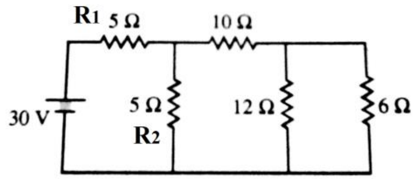


Figure (7)

Ans:

There are two 5Ω resistors, students can consider any one and solve. So examiner is requested to consider the solution considering any one of given 5Ω resistors.

A) Considering R_1 = 5Ω resistor:

a) Determination of Norton's Equivalent Current Source (I_N):

Norton's equivalent current source I_N is the current flowing through a short-circuit across the load terminals due to internal sources, as shown in fig.(a).

Total resistance across 30V source is,

$$R = \{5||[10 + (12||6)]\}$$
$$= 3.68\ \Omega$$

Therefore, current supplied by source,

$$I = \frac{V}{R} = \frac{30}{3.68} = 8.14\text{ A}$$

$$\therefore \mathbf{I_N = 8.14\ A}$$

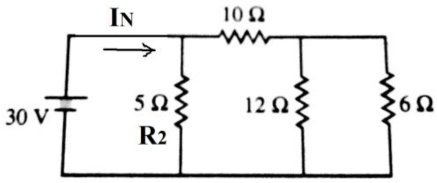


Figure (a)

2 marks

b) Determination of Norton's Equivalent Resistance (R_N):

Norton's equivalent resistance is the resistance seen between the load terminals while looking back into the network, with internal independent voltage sources replaced by short-circuit and independent current sources replaced by open-circuit. Referring to fig.(b),

$$\mathbf{R_N} = 5||[10 + (12||6)] = 3.68\ \mathbf{\Omega}$$

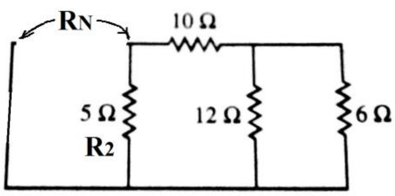


Figure (b)

1 mark

Determination of Load Current (I_L):

Referring to fig.(c), the load current is

$$\mathbf{I_L} = I_N \frac{R_N}{R_N + R_L} = 8.14 \frac{3.68}{3.68 + 5} = \mathbf{3.45\ A}$$

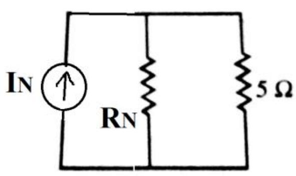


Figure (c)

1 mark

B) Considering $R_2 = 5\Omega$ resistor:

a) Determination of Norton's Equivalent Current Source (I_N):

Norton's equivalent current source I_N is the current flowing through a short-circuit across the load terminals due to internal sources, as shown in fig.(a).

Total resistance across 30V source is,

$$R = \{5 + 0||[10 + (12||6)]\}$$
$$= 5\,\Omega$$

Therefore, current supplied by source,

$$I = \frac{V}{R} = \frac{30}{5} = 6\text{ A}$$

$$\therefore \mathbf{I_N = 6\ A}$$

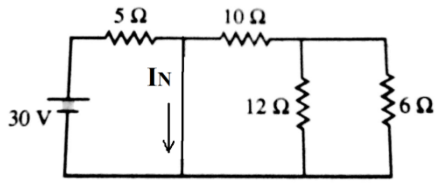


Figure (a)

2 marks

(b) Determination of Norton's Equivalent Resistance (R_N):

Norton's equivalent resistance is the resistance seen between the load terminals while looking back into the network, with internal independent voltage sources replaced by short-circuit and independent current sources replaced by open-circuit. Referring to fig.(b),

$$\mathbf{R_N} = 5||[10 + (12||6)] = 3.68\,\mathbf{\Omega}$$

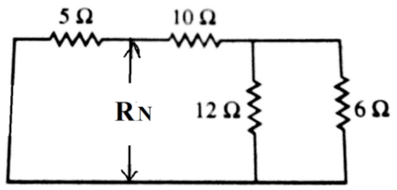


Figure (b)

1 mark

Determination of Load Current (I_L):

Referring to fig.(c), the load current is

$$\mathbf{I_L} = I_N \frac{R_N}{R_N + R_L} = 6\frac{3.68}{3.68 + 5} = \mathbf{2.54\ A}$$

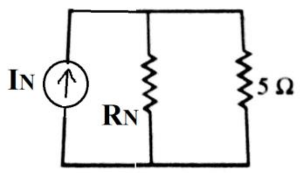


Figure (c)

1 mark

6 e) Calculate the value of R which will absorb maximum power from the circuit of fig.(8).

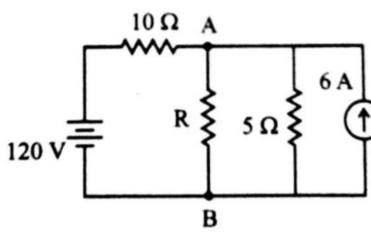
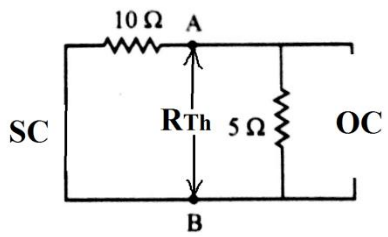


Figure (8)

Ans:

According to maximum power transfer theorem, the maximum power will be transferred to load R only when R is equal to Thevenin's equivalent resistance (R_{Th}) of the network, while looking back into the network between the load terminals, when the internal independent voltage sources are replaced by short-circuit and independent current sources are



2 marks for diagram

2 marks for calculations

replaced by open-circuit.

$$\mathbf{R_{Th}} = 5||10 = 3.333\Omega$$

Therefore, for maximum power transfer, required load resistance will be,

$$\mathbf{R_L} = \mathrm{R_{Th}} = \mathbf{3.333\ \Omega}$$

6 f) Use super position theorem to find the voltage V in the network shown in fig. (9).

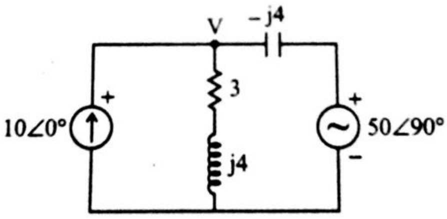


Figure (9)

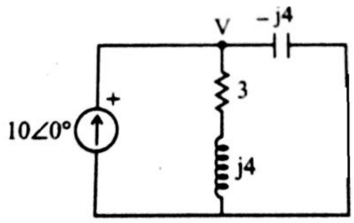
Ans:

A) Current source 10∠0° acting alone:
(Voltage source 50∠90° is replaced by short-circuit)

The current through (3+j4) is given by,

$$I = 10\angle 0° \times \frac{-j4}{3 + j4 - j4} = 10\angle 0° \times \frac{4\angle -90°}{3\angle 0°}$$

$$I = 13.33\angle -90°$$



1 mark

∴Voltage due to current source:

V_1 = I(3+j4) = $13.33\angle -90° \times 5\angle 53.13°$

$$\therefore \boldsymbol{V_1 = 66.67\angle -36.87° = 53.34 - j40}$$

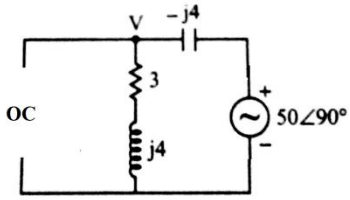
B) Voltage source 50∠90° acting alone:
(Current source 10∠0° is replaced by open-circuit)

Voltage across (3+j4) is given by,

$$V_2 = 50\angle 90° \frac{(3 + j4)}{3 + j4 - j4}$$

$$= 50\angle 90° \frac{5\angle 53.13°}{3}$$

$$\therefore \boldsymbol{V_2 = 83.33\angle 143.13° = -66.66 + j50}$$



1 mark

By Superposition theorem,

$$V = V_1 + V_2 = 53.34 - j40 - 66.66 + j50$$

$$= \boldsymbol{-13.33 + j10 = 16.66\angle 143.12°}$$

2 marks