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 should 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 should give credit for any equivalent figure/figures drawn.
5) Credits to 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 Attempt any ten of the following: 20

1 a) State the terms instantaneous value and maximum value of an alternating quantity.

Ans:

Instantaneous value:

The value of an alternating quantity at a particular instant is called the instantaneous value of the quantity at that instant. (1 mark each)

Maximum Value:

The maximum or peak value attained by an alternating quantity during a cycle is called the maximum value or amplitude of the quantity.

1 b) State the average power taken by a pure inductor and a pure capacitor when connected across a.c.supply.

Ans: (1 mark for equations)

The average power taken by a pure inductor is given by

$$VIcos(-90°) = 0$$

The average power taken by a pure capacitor is given by (1 mark for final ans)

$$VIcos(90°) = 0$$

1 c) Define power factor and state its value for pure resistive circuits.

Ans:

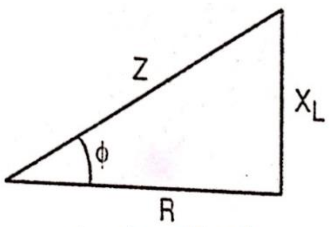
Power Factor:

- It is the cosine of the angle between the applied voltage and the resulting current. (1 mark for any one valid definition)
  Power factor = $\cos\phi$
  where, ϕ is the phase angle between applied voltage and current.
- It is the ratio of true or effective or real power to the apparent power.
  $$\text{Power factor} = \frac{\text{True Or Effective Or Real Power}}{\text{Apparent Power}} = \frac{\text{VIcos}\emptyset}{\text{VI}} = \cos\emptyset$$
- It is the ratio of circuit resistance to the circuit impedance.
  $$\text{Power factor} = \frac{\text{Circuit Resistance}}{\text{Circuit Impedance}} = \frac{R}{Z} = \cos\emptyset$$

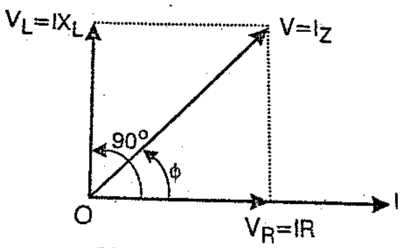
Value of power factor for purely resistive circuit = UNITY i.e one (1 mark for value)

1 d) Draw impedance triangle and voltage phasor diagram for R-L series circuits.

Ans: (1 mark for each)



Impedance Triangle



Phasor Diagram

1 e) Define the terms admittance and susceptance. State their units.

Ans:

Admittance (Y): (½ mark for each definition)

Admittance is defined as the ability of the circuit to carry (admit) alternating current through it. It is the reciprocal of impedance Z. i.e Y = 1/Z.

It's unit is siemen (S) or mho (℧). ½ mark for each unit

If impedance is expressed as $Z = R \pm jX$, then the admittance is obtained as,

$$Y = \frac{1}{Z} = \frac{1}{R \pm jX} = \frac{R \mp jX}{(R + jX)(R - jX)} = \frac{R \mp jX}{R^2 + X^2}$$

$$\therefore Y = \frac{R}{R^2 + X^2} \mp j\frac{X}{R^2 + X^2} = G \mp jB$$

Susceptance (B):

Susceptance is defined as the imaginary part of the admittance.

It is expressed as, $B = \frac{X}{R^2+X^2}$

In DC circuit, the reactance is absent, hence X=0 and susceptance becomes equal to zero.

It's unit is siemen (S) or mho (℧).

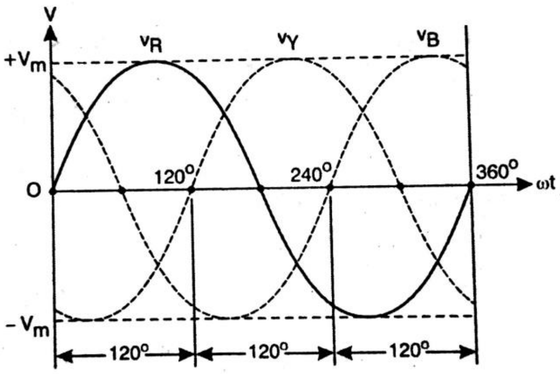
1 f) Define phase sequence w. r. t. 3ϕ A.C.

Ans:

Phase Sequence:

Phase sequence is defined as the order in which the voltages (or any other alternating quantity) of the three phases attain their positive maximum values. 1 mark for definition

In the waveforms, it is seen that the R-phase voltage attains the positive maximum value first, and after angular distance of 120°, Y-phase voltage attains its positive maximum and further after 120°, B-phase voltage attains its positive maximum value. So the phase sequence is R-Y-B.



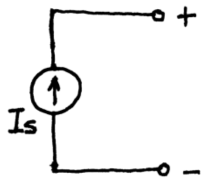
1 mark for diagram

1 g) Represent the following by symbols:

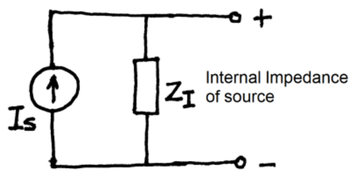
(i) Ideal current source

(ii) Practical current source

Ans:



Ideal Current Source



Practical Current Source

1 mark for each symbol

1 h) State the conditions under which superposition theorem can be applied.

Ans:

Conditions under which superposition theorem can be applied:

1) The circuit should be linear.

2) The circuit should be bilateral.

3) There should be two or more energy sources in the circuit.

1 mark for linearity
1 mark for any other valid condition

1 i) State the maximum power transfer theorem for DC circuits.

Ans:

Maximum power transfer theorem for DC circuits:

The maximum power transfer theorem states that the source or a network transfers maximum power to load only when the load resistance is equal to the internal resistance of the source or the network. *(2 marks for valid statement)*

The internal resistance of the network is the Thevenin equivalent resistance of the network seen between the terminals at which the load is connected when:

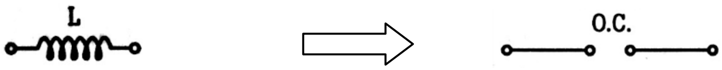
i) The load is removed (disconnected)
ii) All internal independent sources are replaced by their internal resistances.

1 j) State the behaviour of following elements at the time of switching i.e. transient period: (i) Pure L (ii) Pure C

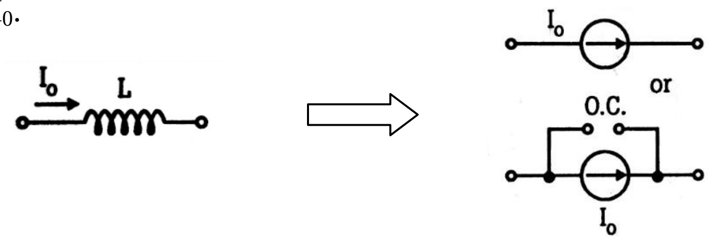
Ans:

At the time of switching: *(½ mark each)*

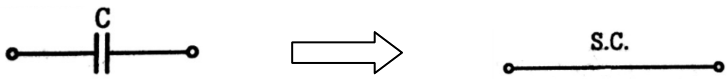
i) The pure inductor, carrying zero current prior to switching, acts as OPEN CIRCUIT.



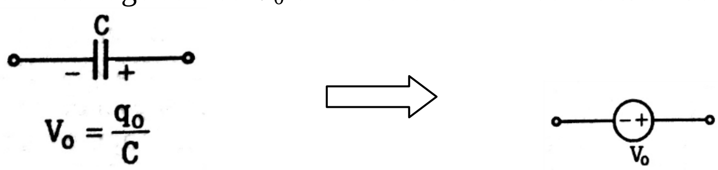
ii) The pure inductor, carrying some current, say I_0, prior to switching, acts as a current source I_0 or an Open Circuit in parallel with current source I_0.



iii) The pure capacitor, having zero voltage prior to switching, acts as SHORT CIRCUIT.



iv) The pure capacitor, having some voltage, say V_0, prior to switching, acts as a voltage source V_0 or Short Circuit in series with voltage source V_0.



1 k) Define quality factor for parallel resonance and write its mathematical expression.

Ans:

Quality Factor of Parallel Resonance:

The quality factor or Q-factor of parallel resonance 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. *(1 mark)*

It is the current magnification in parallel circuit.

Mathematical Expression:

Quality factor (Q-factor) = Current magnification = $\frac{1}{R}\sqrt{\frac{L}{C}}$ — 1 mark

Where, R is the resistance of an inductor in Ω,
L is the inductance of an inductor in henry,
C is capacitance of capacitor in farad,

1 l) State the numerical relationship for delta connected load between:
i) Line current and phase current
ii) Line voltage and phase voltage

Ans:

Numerical relationship for delta connected load:

i) Line current = $\sqrt{3}$ Phase current — 1 mark
ii) Line voltage = Phase voltage — 1 mark

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

2 a) Define the following terms with reference to alternating quantity.
i) Waveform ii) Cycle iii) Frequency iv) Time period

Ans:

i) Waveform:
The graphical plot of all the instantaneous values of an alternating quantity with respect to time is called 'Waveform' of the quantity. — 1 mark for each definition

OR

The graph showing variations in the magnitude and direction of an alternating quantity with respect to time is called 'Waveform' of the quantity.

ii) Cycle:
A complete set of variation of an alternating quantity which is repeated at regular interval of time is called as a cycle.

OR

Each repetition of an alternating quantity recurring at equal intervals is known as a cycle.

iii) Frequency:
Number of cycles completed by an alternating quantity in one second is called 'Frequency'.

iv) Time Period:
Time period of an alternating quantity is defined as the time required for an alternating quantity to complete one cycle.

2 b) A 318μF capacitor is connected across a 230V, 50Hz system.
Determine: (i) Capacitive reactance (ii) RMS value of current
(iii) Equation for voltage (iv) Equation for current

Ans:

Data Given: C = 318μF = 318×10^{-6} F
RMS Supply voltage V_{rms} = V = 230V — 1 mark for each bit
Frequency f = 50 Hz

(i) Capacitive Reactance (X_C):

$$X_c = \frac{1}{2\pi f C} = \frac{1}{2\pi(50)(318\times10^{-6})} = 10\ \Omega$$

(ii) RMS value of current (I):

$$I = \frac{V}{X_c} = \frac{230}{10} = 23\ A$$

(iii) Equation for voltage (v):

Maximum value of voltage is given by, $V_m = \sqrt{2}V_{rms}$

$$\therefore V_m = \sqrt{2}(230) = 325.27 \text{ volt}$$

Equation for sinusoidal voltage is given by,

$v = V_m \sin(\omega t) = V_m \sin(2\pi f t) = 325.27 \sin(2 \times \pi \times 50t)$

$\therefore \boldsymbol{v = 325.27 \sin(314.2t)}$ **volt**

(iv) Equation for current (i):

Maximum value of current is given by, $I_m = \sqrt{2}I_{rms}$

$$\therefore I_m = \sqrt{2}(23) = 32.53 \text{ A}$$

Equation for sinusoidal current is given by,

$i = I_m \sin\left(\omega t + \frac{\pi}{2}\right) = I_m \sin\left(2\pi f t + \frac{\pi}{2}\right)$

$\therefore \boldsymbol{i = 32.53 \sin(314.2t + \frac{\pi}{2})}$ **amp**

2 c) Write down different powers in AC circuits, also write their equations and units. Draw power triangle.

Ans:

Powers in AC circuits:

(i) Apparent Power (S):

This is simply the product of RMS voltage and RMS current. 1 mark

Unit: volt-ampere (VA) or kilo-volt-ampere (kVA)
or Mega-vol-ampere (MVA)

$$\text{S} = \text{VI} = \text{I}^2\text{Z volt-amp}$$

(ii) Active Power or Real Power or True Power (P):

Active power (P) is given by the product of voltage, current and the cosine of the phase angle between voltage and current. 1 mark

Unit: watt (W) or kilo-watt (kW) or Mega-watt (MW)

$$\text{P} = \text{VIcos}\emptyset = \text{I}^2\text{R watt}$$

(iii) Reactive Power or Imaginary Power (Q):

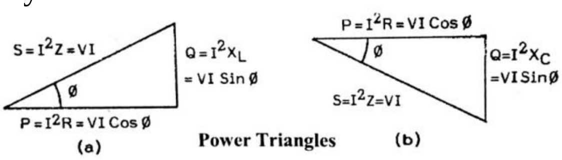
Reactive power (Q) is given by the product of voltage, current and the sine of the phase angle between voltage and current. 1 mark

Unit: volt-ampere-reactive (VAr), or kilo-volt-ampere-reactive (kVAr) or Mega-volt-ampere-reactive (MVAr)

$$\text{Q} = \text{VIsin}\emptyset = \text{I}^2\text{X volt-amp-reactive}$$

Power Triangle:

The power triangles for inductive circuit and capacitive circuit are shown in the fig. (a) and (b) respectively. 1 mark (any one)



Power Triangles

2 d) A capacitor having capacitance of 20 μF is connected in series with a non-inductive resistance of 120 Ω, across 100V, 50 Hz supply. Calculate:

(i)Current, (ii) The phase difference between voltage and current,
(ii) The power. Also draw the vector diagram.

Ans:

Data Given: C = 20 μF R = 120 Ω V = 100V f = 50 Hz

(i) Current:

The capacitive reactance is given by, 1 mark

$$X_c = \frac{1}{2\pi fC} = \frac{1}{2\pi(50)(20\times10^{-6})} = 159.15\,\Omega$$

Total impedance of series circuit is,

$$Z = R - jX_c = 120 - j159.15 = 199.32\angle -53^\circ\,\Omega$$

Current in series circuit is obtained as,

$$I = \frac{V}{Z} = \frac{100\angle 0^\circ}{199.32\angle -53^\circ} = 0.502\angle 53^\circ \text{ amp}$$

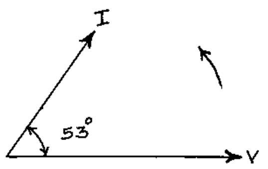
(ii) The phase difference between voltage and current:

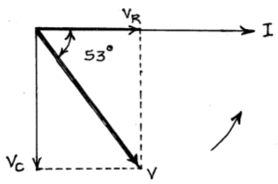
$$\emptyset = 53^\circ \;\; leading$$ 1 mark

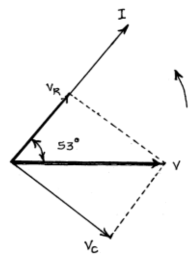
(iii) Power:

$$P = VIcos\emptyset = (100)(0.502)\cos(53^\circ) = 30.21\,watt$$ 1 mark

Vector diagram:



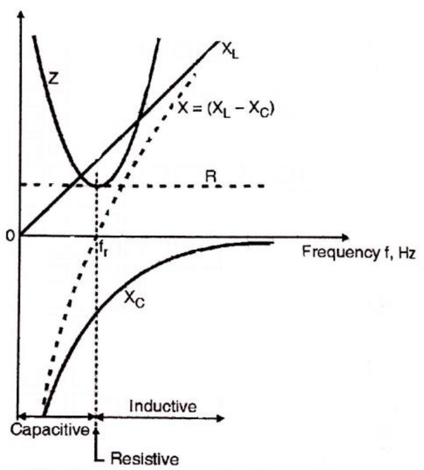




1 mark for any one

2 e) Draw graphical representation of resistance, inductive reactance, capacitive reactance and impedance related to frequency for series resonance circuit.

Ans:



Variation of reactances and impedance with frequency

1 mark each for R, X_L, X_C and Z representation

2 f) Compare series and parallel circuits on any four points.

Ans:

Comparison between Series and Parallel Circuits:

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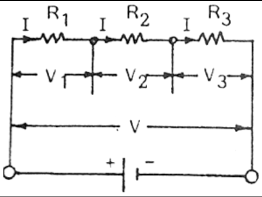
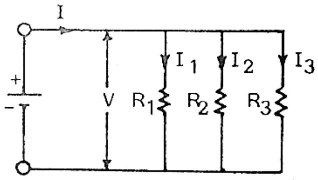
Sr. No.	Series Circuit	Parallel Circuit
1		
2	A series circuit is that circuit in which the current flowing through each circuit element is same.	A parallel circuit is that circuit in which the voltage across each circuit element is same.
3	The sum of the voltage drops in series resistances is equal 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, $f_r = \frac{1}{2\pi\sqrt{LC}}$
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.

1 mark for each of any four points

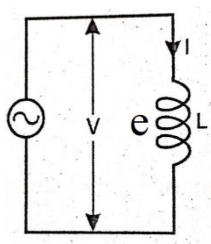
3 Attempt any four of the following: **16**

3 a) Explain the response of AC supply to pure inductance, draw waveform for the same.

Ans:

Response of AC supply to Pure Inductance:

The purely inductive coil with inductance "L" and almost negligible resistance connected across a.c. supply is shown in figure. The alternating voltage causes alternating current through the coil.



Let an alternating current flowing through coil be

$\boldsymbol{i = I_m \sin(\omega t)}$ ……………………………… $(\boldsymbol{i})$ 1 mark for eq. of current

The resulting alternating current will setup the alternating magnetic field. The change in flux linking the coil will induce emf in the coil, called as self-induced emf. This induced emf is always in opposition with the applied voltage is given by,

$$e = -L\frac{di}{dt}$$

As the resistance of coil is negligible, the applied voltage will have to overcome the self induced emf. Therfore, the applied voltage will be equal and opposite to the self induced emf at every instant 1 mark for derivation

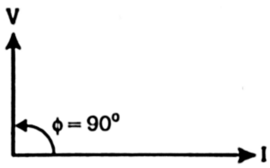
$v = -e = L\frac{di}{dt}$

$v = L\frac{di}{dt} = L\frac{d}{dt}(I_m\, sin\omega t)$

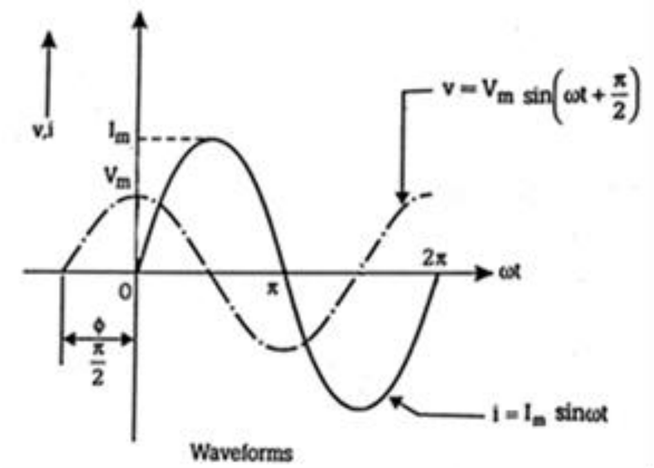
$= \omega L I_m cos\omega t = (\omega L I_m)\sin(\omega t + \frac{\pi}{2})$

$\therefore \boldsymbol{v = V_m \sin\left(\omega t + \frac{\pi}{2}\right)}$ ……………….$(\boldsymbol{ii})$ 1 mark for eq. of voltage

Referring to eq. (i) and (ii), it is clear that in case of pure inductor, the current lags behind the voltage by 90° or (π/2) rad or the voltage leads the current by 90° or (π/2) rad.



Phasor Diagram

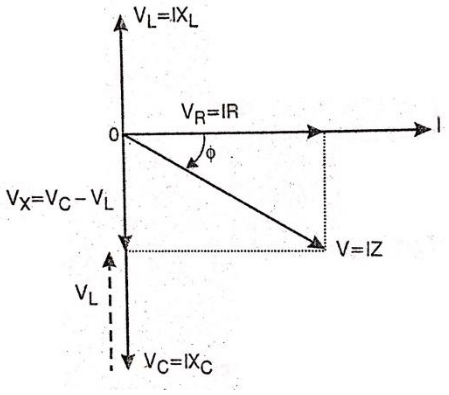


1 mark for phasor diagram or waveforms

3 b) Draw vector diagram, impedance triangle and power triangle for series R-L-C circuit when connected to single phase a. c. supply for the condition $X_L < X_C$.

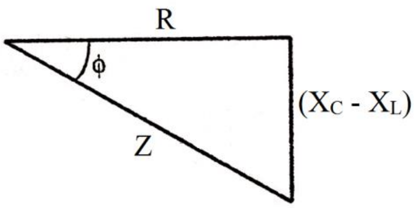
Ans:

Vector diagram of RLC series circuit for condition $X_L < X_C$:



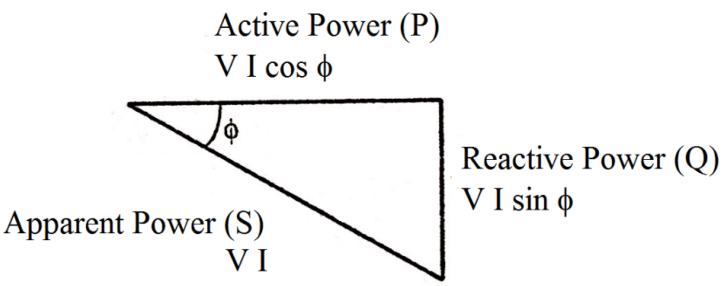
2 marks for phasor diagram

Impedance Triangle:



1 mark

Power Triangle:



1 mark

3 c) A 200W, 100V lamp is connected in series with a capacitor of 20μF to a 120V, 50Hz ac supply. Calculate (i) Impedance of circuit, (ii) the current flowing through circuit, (iii) The phase angle between voltage and current.

Ans:

Data Given:

Power rating of lamp P = 200W, Voltage rating V_R = 100V

Supply voltage V_S = 120V frequency = 50Hz Capacitor C = 20μF

The resistance (R) of lamp is obtained from its power and voltage rating.

Power consumed P = V_R x I = V_R^2 / R

Resistance of lamp, $R = \frac{V_R^2}{P} = \frac{100^2}{200} = 50\Omega.$ ½ mark for resistance of lamp

The Capacitive reactance is given by, $Xc = \frac{1}{2\pi fC} = \frac{1}{2\pi(50)(20\times10^{-6})} = 159.15\Omega.$ ½ mark for X_C

(i) Impedance of circuit (Z):

$$Z = \sqrt{(R^2 - Xc^2)} = \sqrt{(50)^2 - (159.15)^2} = \mathbf{166.82}\ \Omega.$$

(ii) Current flowing through the circuit (I): — 1 mark for Z

$$I = \frac{V_S}{Z} = \frac{120}{166.82} = \mathbf{0.719A}$$

(iii) Phase angle between voltage and current (ϕ) — 1 mark for I

$$\Phi = \tan^{-1}\frac{(-Xc)}{R} = \tan^{-1}\frac{(-159.15)}{50} = -72.56° = \mathbf{72.56\ leading}$$ — 1 mark for ϕ

3 d) A circuit having resistance of 5 Ω, L = 0.4H and capacitance in series is connected across 100V, 50Hz supply. Calculate (i) Value of capacitance to give resonance, (ii) Circuit current at resonance, (iii) Voltage across resistor, (iv) Q-factor of resonance.

Ans:

Data Given: R = 5 Ω, L = 0.4H, V=100V, f = 50Hz

(i) Value of Capacitance to give resonance (C):

Condition of series resonance is $X_L = X_C$ — 1 mark for each bit for step-wise solution = 1x4= 4

$X_L = 2\pi fL = 2\pi(50)(0.4) = 125.66\ \Omega$

Therefore $X_C = 125.66\ \Omega$

Since $X_c = \frac{1}{2\pi fC}$ the capacitance is given by,

$$C = \frac{1}{2\pi fXc} = \frac{1}{2\pi(50)(125.66)} = \mathbf{25.33\mu F}$$

(ii) Current at Resonance (I):

$$I = \frac{V}{Z_r} = \frac{V}{R} = \frac{100}{5} = \mathbf{20A}$$

(iii) Voltage across Resistor (V_R):

$$V_R = I \times R = \mathbf{100V}$$

(iv) Q-factor of resonance (Q):

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{5}\sqrt{\frac{0.4}{25.33 \times 10^{-6}}} = 25.13$$

3 e) State the various methods of solving parallel AC circuits. Explain any one method for a simple parallel circuit.

Ans:

Methods for solving parallel ac circuits: — 1 mark for methods

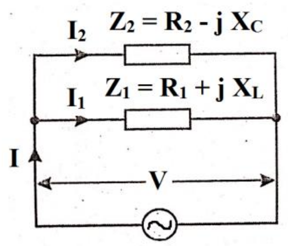
(i) By Phasor diagram.
(ii) Equivalent impedance method.
(iii) Admittance method

Explanation of methods:

(i) By Phasor Diagram :

In this method, the unknown current is determined from known currents using the phasor diagram, which is drawn taking voltage as a reference phasor. For example, if we know each branch currents, then the circuit or total current is obtained by the phasor sum of branch currents. It can be determined either (i) by parallelogram method, (ii) by method of components. — 1 mark

Consider parallel circuit consisting of two branches and connected across alternating voltage of V volts as shown in fig.



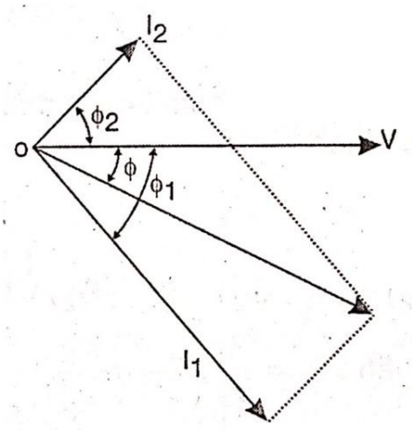
Branch 1 $Z_1 = \sqrt{(R_1{}^2 + X_L{}^2)}$;

$I_1 = \frac{V}{Z_1}$; $\emptyset_1 = \tan^{-1}\frac{X_L}{R_1}$

Branch 2 $Z_2 = \sqrt{(R_2{}^2 + X_C{}^2)}$;

$I_2 = \frac{V}{Z_2}$; $\emptyset_2 = \tan^{-1}\frac{X_C}{R_2}$

By Parallelogram Method:
The Current I_1 lags V by ϕ_1 and I_2 leads V by ϕ_2 as shown in phasor diagram. The total circuit current I is obtained by taking phasor sum of I_1 and I_2 by constructing parallelogram, as shown in the figure.



By components method:
Total current I can be expressed as

$I = \sqrt{(I\cos\emptyset)^2 + (I\ \sin\emptyset)^2}$

$I\cos\phi = I_1\cos\phi_1 + I_2\cos\phi_2$

$I\sin\phi = I_1\sin\phi_1 - I_2\sin\phi_2$

$\tan\emptyset = \dfrac{I\sin\emptyset}{I\cos\emptyset}$

(ii)Equivalent Impedance Method:

In this method, we find the equivalent impedance of parallel circuit.

Consider the same circuit with two impedances Z_1 and Z_2 in parallel such that 1 mark

$Z_1 = R_1 + jX_L = |Z_1|\angle\phi_1$ and $Z_2 = R_1 - jX_c = |Z_2|\angle{-\phi_2}$

Therefore $Zeq = \frac{Z1*Z2}{Z1+Z2}$ (Z is represented in complex form)

Current through branch 1 is $I_1 = \frac{V}{Z_1}$ and

Current through branch 2 is $I_2 = \frac{V}{Z_2}$

The total current equal to $I = \frac{V}{Zeq}$.

(iii)Admittance method:

Admittance is defined as reciprocal of impedance. It is represented by symbol Y. Its unit is mho or siemens (S). 1 mark

$Y = \frac{1}{Z} = \frac{1}{Z_1} + \frac{1}{Z_2} = Y_1 + Y_2 = \frac{I}{V}$

$\frac{1}{Zeq} = \frac{1}{z1} + \frac{1}{z2}$ and $Y_{eq} = Y_1 + Y_2$

Therefore branch current $I_1 = V\ Y_1$ and $I_2 = V\ Y_2$

Total current $I = V\ Y_{eq}$

The admittance is represented in rectangular form as $Y = G \mp jB$.

Where G – conductance and B – susceptance.
Can be found using relation
$G = \frac{R}{Z^2}$ and $B = \frac{X}{Z^2}$. The sign of susceptance is –ve for inductive circuit and +ve for capacitive circuit.

3 f) Two impedances of (3+j4)Ω and (12-j4) Ω are connected in parallel across 230V, 1-ϕ, 50Hz ac supply. Determine current drawn by each path and total current in the circuit.

Ans:

Data Given: $Z_1 = 3+j4 = 5\angle 53.13°\,\Omega$ and $Z_2 = 12 - j4 = 12.65\angle{-18.44°}\,\Omega$ — 1 mark for R to P conversion

$V = 230V$ $f = 50\ Hz$

$I_1 = \frac{V}{Z_1} = \frac{230\angle 0°}{5\angle 53.13°}$ = **46∠-53.13° = (27.6 – j36.8) A** — 1 mark

$I_2 = \frac{V}{Z_2} = \frac{230\angle 0°}{12.65\angle -18.44°}$ = **18.18∠18.44° = (17.25+j5.75) A** — 1 mark

Total current

$I = I_1 + I_2$ = **44.84 – j31.05 = 54.54∠-34.70 A** — 1 mark

4 Attempt any four of the followings **16**

4 a) A choke coil has resistance of 4 Ω and inductance of 0.07H is connected in parallel with another coil of resistance of 10 Ω and inductance of 0.12H. The combination is connected across 230V, 50Hz supply. Determine total current and current through each branch.

Ans:

Data Given: $R_1 = 4\ \Omega$ $L_1 = 0.07H$ $R_2 = 10\ \Omega$ $L_2 = 0.12H$

$X_{L1} = 2\pi f L_1 = 2\pi(50)(0.07) = 21.99 \cong 22\ \Omega$

$X_{L2} = 2\pi f L_2 = 2\pi(50)(0.12) = 37.7\ \Omega$

$Z_1 = R_1 + j\,X_{L1} = (4+j22) = 22.35\angle 79.7°\ \Omega$ — 1 mark for impedances

$Z_2 = R_2 + j\,X_{L2} = (10+j37.7) = 39\angle 75.144°\ \Omega$

Branch 1 current is given by,

$I_1 = \frac{V}{Z_1} = \frac{230\angle 0°}{22.35\angle 79.7°}$ = **10.3∠-79.7°A = (1.84 – j10.13) A** — 1 mark

Branch 2 current is given by,

$I_2 = \frac{V}{Z_2} = \frac{230\angle 0°}{39\angle 75.144°}$ = **5.89∠-75.144°A = (1.51 - j5.7) A** — 1 mark

Total current is,

$I = I_1 + I_2 = (1.84 – j10.13) + (1.51 - j5.7)$

I = (3.35 - j15.825)A = 16.17∠-78.04 A — 1 mark

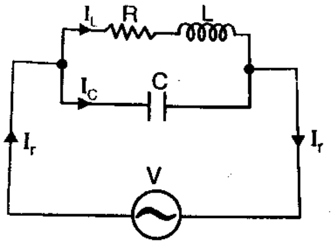
4 b) Derive the condition for parallel resonance.

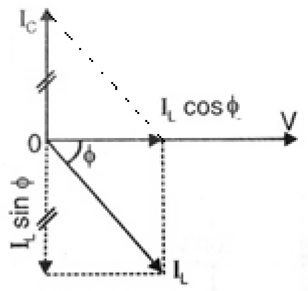
Ans:

Parallel Resonance:

A parallel circuit containing reactive elements (L&C) is said to be in resonance when the circuit power factor is unity. The frequency at which it occurs called as resonant frequency.

Consider the circuit consisting of a coil of very small resistance R and inductance L, is connected in parallel with a capacitor C as shown in the figure. If the supply frequency is adjusted such that the resultant current I is in phase with voltage V, then the circuit is said to be resonating. The corresponding frequency is — 1 mark for circuit diagram known as resonant frequency (f_r).





1 mark for phasor diagram

The capacitive current $I_C = V/X_C$ which is leading the voltage V by 90°. The phasor sum of I_L and I_C is the total circuit resonant current I_r, which is in phase with V.
The circuit will be in resonance when reactive component of circuit current I_r is zero

i.e. $I_C - I_L \sin\phi = 0$

$\therefore \mathbf{I_C = I_L \sin\phi}$ ………. Condition for parallel resonance.

Also, $\mathbf{I_r = I_L \cos\phi}$

2 marks for derivation

4 c) Explain in brief the process of generation of 3-phase e.m.f.

Ans:

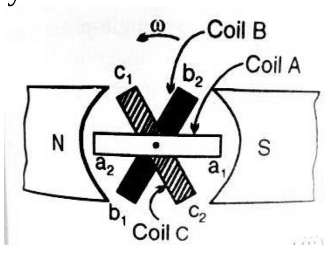
Generation of 3-phase e.m.f.:

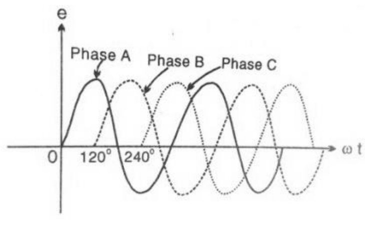
Three identical coils A, B and C displaced by 120^0 (electrical) from each other and rotating in anticlockwise direction with angular velocity ω rad/sec in the gap between two magnetic poles, cut the magnetic field. According to Faraday's law of electromagnetic induction, the emf will be induced in each coil. The magnitude of emf depends upon the rate of flux cut by the coil. Since the rate of flux cut changes with position of coil in the magnetic field, an alternating emf is induced in each coil. The nature of emf is same but since the coils are displaced from each other by 120°, the emfs induced in them will also get displaced in time phase from each other by 120°.

1 mark for diagram of basic alternator

1 mark for waveforms

2 marks for explanation





The equation of three emf can be represented by

$e_a = E_m \sin\omega t$

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

$e_c = E_m \sin(\omega t - 240^0)$.

4 d) State any four advantages of polyphase circuit over single phase circuit.

Ans:

Advantages and of polyphaser (3-phase) circuits over 1-phase circuits:

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

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

1 mark for each of any

alternators. four

iii) Single-phase loads can be connected along with 3-ph loads in a 3-ph system.
iv) Instead of pulsating power of single-phase supply, constant power is obtained in 3-phase system.
v) Three-phase induction motors are self-starting. They have high efficiency, better power factor and uniform torque.
vi) The power rating of 3-phase machine is higher than that of 1-phase machine of the same size.
vii) The size of 3-phase machine is smaller than that of 1-phase machine of the same power rating.
viii) For same power rating, three-phase motors are cheaper than the single-phase motors.

4 e) A balanced delta connected load having impedance of 3+j4 Ω connected to 400V, 3-phase ac supply. Determine (i) Line current, (ii) Power factor, (iii) Active power (iv) Apparent power.

Ans:

Data Given: $Z_{ph} = 3+j4\ \Omega = 5\angle 53.13\ \Omega$ — 1 mark for stepwise solution of each bit

For delta connection $V_L = V_{ph} = 400V$.

Therefore $I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{400\angle 0°}{5\angle 53.13°} = 80\angle -53.13°$ A

(i) Line current $I_L = \sqrt{3}\, Iph = \sqrt{3}\,(80) = \mathbf{138.56\ A}$

(ii) Power factor = $\cos\phi = \frac{Rph}{Zph} = \frac{3}{5}$ = **0.6 (lag)**

(iii) Active power P = $\sqrt{3}\, V_L I_L \cos\phi$ = **57598.31 watts = 57.59 kW**

(iv) Apparent power = S= $\sqrt{3}\, V_L I_L$ = **95997.184 VA = 95.99 kVA**

4 f) A balanced star connected load of (8+j6) Ω per phase is connected to a balanced 3-phase, 400V supply. Find the line current, power factor, power and total volt amperes.

Ans:

Data Given: $Z_{ph} = (8+j6)\ \Omega = 10\angle 36.87°\ \Omega$ $V_L = 400V$ — 1 marks for stepwise solution of each bit

In star connected load $V_L = \sqrt{3}\, Vph$ and $I_L = Iph$.

$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 230.94V$

(i) Line Current $I_L = I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{230.94\angle 0°}{10\angle 36.87°} = 23.094\angle -36.87°A$

(ii) Power factor $\cos\phi = \frac{Rph}{Zph} = \frac{8}{10}$ = 0.8 (lag).

(iii) Active power P = $\sqrt{3}\, V_L I_L \cos\phi = \sqrt{3}$ (400)(23.094)(0.8)
=12800 Watts or 12.8 kW.

(iv) Apparent power S = $\sqrt{3}\, V_L I_L = \sqrt{3}$ (400)(23.094) =16000 VA or 16 kVA.

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

5 a) Determine the current through 1.5Ω in the network using Thevenin's theorem.

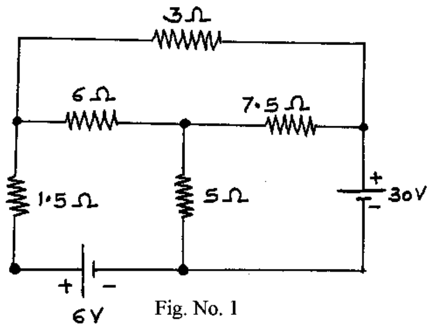


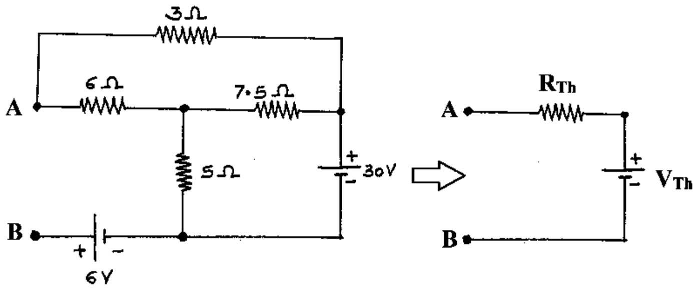
Fig. No. 1

Ans:

Using Thevenin's Theorem:

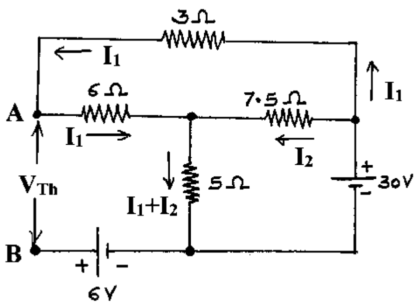
Here resistance of our interest is 1.5Ω, so this is the load resistance.

According to Thevenin's theorem, the circuit between load terminals A-B excluding load resistance can be represented by simple circuit consisting of a voltage source V_{Th} in series with a resistance R_{Th}, as shown in the following figure. 1 mark



Determination of Thevenin's Equivalent Voltage Source (V_{Th}):

Thevenin's equivalent voltage source V_{Th} is the open circuit voltage across the load terminals A-B due to internal sources, as shown in the following figure.



1 mark for circuit

Since terminal B is open (floating), the current through source 6V is zero. Therefore, circuit currents are due to source 30V only and are as shown in the figure.

2 marks for computing V_{Th} by any method

Total resistance across 30V source is,

$R = [(3+6)||7.5] + 5 = \frac{9\times7.5}{9+7.5} + 5 = 9.091\ \Omega$

Therefore, current supplied by 30V source,

$$\mathrm{I} = I_1 + I_2 = \frac{\mathrm{V}}{\mathrm{R}} = \frac{30}{9.091} = 3.3\ \mathrm{A}$$

The resistances (3+6)Ω and 7.5Ω are in parallel. By current division, the current flowing through (3+6)Ω is

$$\mathrm{I_1} = \mathrm{I}\frac{7.5}{(3+6)+7.5} = (3.3)\frac{7.5}{16.5} = 1.5\ \mathrm{A}$$

By KVL, the open circuit voltage between terminals A-B is given by,

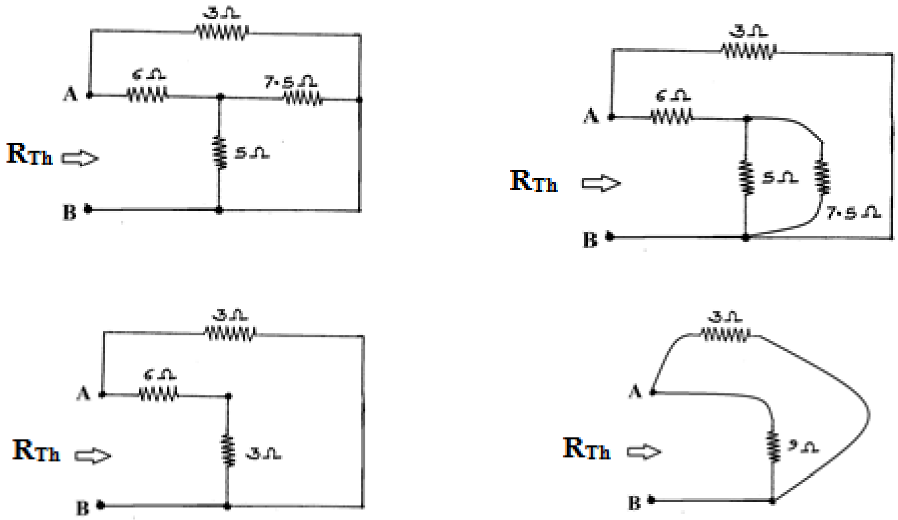
$\mathrm{V_{Th}} = \mathrm{V_{OC}} = 6\mathrm{I_1} + 5\mathrm{I} - 6 = 6(1.5) + 5(3.3) - 6 = 19.5\ \mathrm{volt}$

$\therefore \mathbf{V_{Th} = 19.5\ volt}$

Determination of Thevenin's Equivalent Resistance (R_{Th}):

Thevenin'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, 2 marks for as shown in the following figure.

stepwise solution of R_{Th}



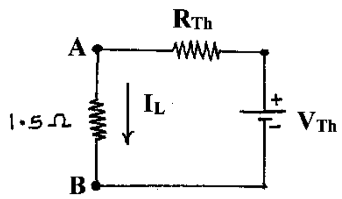
1 mark for Thevenin's equivalent circuit

$$\mathbf{R_{Th}} = (3||9) = \frac{3\times 9}{3+9} = \mathbf{2.25\,\Omega}$$

Determination of Load Current (I_L):

Referring to figure, the load current is

$$\mathbf{I_L} = \frac{V_{Th}}{R_{Th} + R_L} = \frac{19.5}{2.25 + 1.5} = \mathbf{5.2A}$$



1 mark for final answer

5 b) Find the current in 40Ω and 10Ω in Fig. No. 2 by node voltage analysis method.

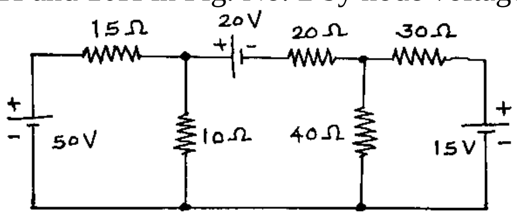
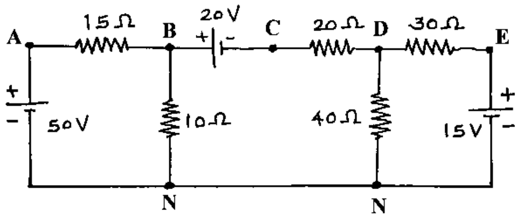


Fig. No. 2

Ans:

Node Voltage Analysis Method:

Step I: Mark the nodes and reference node.



1 mark for node identification

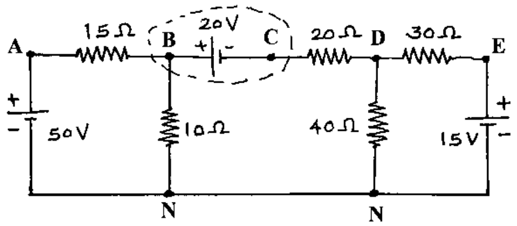
Let the nodes be A, B, C, D, E and reference node is N.

From the above circuit diagram we can write,

$$V_A = 50$$
$$V_E = 15$$
$$V_B - V_C = 20$$
$$\therefore V_C = V_B - 20$$

Only two unknown voltages are V_B and V_D.

Step II: Apply KCL at nodes with unknown voltages



1 mark for each proper application of KCL for node voltage equations

Since there is a voltage source of 20V between nodes B and C, for writing KCL equations, let us treat nodes B and C with source as "Supernode", encircled by dotted line.

By KCL at this supernode, we can write

$$\frac{V_B - V_A}{15} + \frac{V_B}{10} + \frac{V_C - V_D}{20} = 0$$

$$\frac{V_B - 50}{15} + \frac{V_B}{10} + \frac{(V_B - 20) - V_D}{20} = 0$$

$$V_B\left[\frac{1}{15} + \frac{1}{10} + \frac{1}{20}\right] - \frac{50}{15} - \frac{20}{20} - V_D\left[\frac{1}{20}\right] = 0$$

$$\boldsymbol{(0.217)V_B - (0.05)V_D = 4.33} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(\boldsymbol{i})$$

1 mark for eq. (i)

By KCL at node D, we write

$$\frac{V_D - V_C}{20} + \frac{V_D}{40} + \frac{V_D - V_E}{30} = 0$$

$$\frac{V_D - (V_B - 20)}{20} + \frac{V_D}{40} + \frac{V_D - 15}{30} = 0$$

$$V_B\left[-\frac{1}{20}\right] + \frac{20}{20} - \frac{15}{30} + V_D\left[\frac{1}{20} + \frac{1}{40} + \frac{1}{30}\right] = 0$$

$$(-0.05)V_B + (0.1083)V_D = -0.5$$

$$\boldsymbol{(0.05)V_B - (0.1083)V_D = 0.5} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(\boldsymbol{ii})$$

1 mark for eq. (ii)

Step III: Solving Simultaneous equations

Expressing eq. (i) and (ii) in matrix form,

$$\begin{bmatrix} 0.217 & -0.05 \\ 0.05 & -0.1083 \end{bmatrix}\begin{bmatrix} V_B \\ V_D \end{bmatrix} = \begin{bmatrix} 4.33 \\ 0.5 \end{bmatrix}$$

$$\therefore \Delta = \begin{vmatrix} 0.217 & -0.05 \\ 0.05 & -0.1083 \end{vmatrix} = -0.0235 - (-0.0025) = -0.021$$

By Cramer's rule,

$$V_B = \frac{\begin{vmatrix} 4.33 & -0.05 \\ 0.5 & -0.1083 \end{vmatrix}}{\Delta} = \frac{(-0.469) - (-0.025)}{-0.021} = \frac{-0.444}{-0.021}$$

$$\boldsymbol{V_B = 21.143\ \text{volt}}$$

1 mark for stepwise solution for V_B and V_D

$$V_D = \frac{\begin{vmatrix} 0.217 & 4.33 \\ 0.05 & 0.5 \end{vmatrix}}{\Delta} = \frac{(0.1085) - (0.2165)}{-0.021} = \frac{-0.108}{-0.021}$$

$$\boldsymbol{V_D = 5.143\ \text{volt}}$$

Step IV: Solving for currents

Current in 40Ω resistor is given by,

$$I_{40} = \frac{V_D}{40} = \frac{5.143}{40} = \boldsymbol{0.1286\ A}$$

1 mark

Current in 10Ω resistor is given by,

$$I_{10} = \frac{V_B}{10} = \frac{21.143}{10} = \mathbf{2.1143\ A}$$ 1 mark

5 c) Calculate current in 10Ω resistance using mesh analysis in the circuit shown in Fig. No. 3.

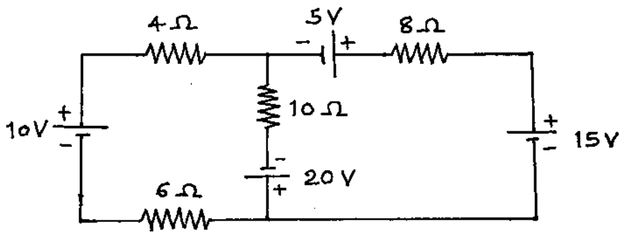
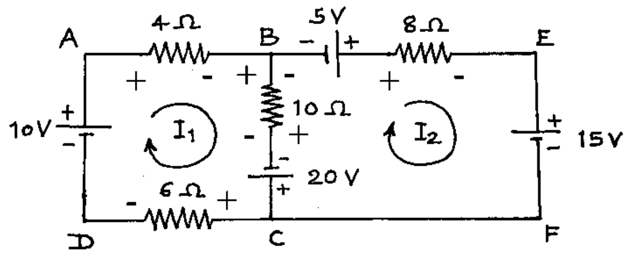


Fig. No. 3

Ans:

Mesh Analysis:



1 mark for mesh identification and current marking

i) There are two meshes in the network.
Mesh 1: ABCDA
Mesh 2: CBEFC

1 mark for correct application of KVL

ii) Mesh currents I_1 and I_2 are marked clockwise 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 from node D, KVL equation is,

$$10 - 4I_1 - 10(I_1 - I_2) + 20 - 6I_1 = 0$$

$$\therefore 20I_1 - 10I_2 = 30 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$ 1 mark for eq. (1)

By tracing mesh 2 clockwise from node B, KVL equation is,

$$5 - 8I_2 - 15 - 20 - 10(I_2 - I_1) = 0$$

$$\therefore 10I_1 - 18I_2 = 30 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$ 1 mark for eq. (2)

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

$$\begin{bmatrix} 20 & -10 \\ 10 & -18 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 30 \\ 30 \end{bmatrix}$$ 1 mark for matrix equation

$$\therefore \Delta = \begin{vmatrix} 20 & -10 \\ 10 & -18 \end{vmatrix} = -360 - (-100) = -260$$

By Cramer's rule,

$$I_1 = \frac{\begin{vmatrix} 30 & -10 \\ 30 & -18 \end{vmatrix}}{\Delta} = \frac{(30 \times -18) - (30 \times -10)}{-260} = \frac{-540 + 300}{-260} = \mathbf{0.923\ A}$$ 1 mark for I_1

$$I_2 = \frac{\begin{vmatrix} 20 & 30 \\ 10 & 30 \end{vmatrix}}{\Delta} = \frac{(20 \times 30) - (10 \times 30)}{-260} = \frac{600 - 300}{-260} = \mathbf{-1.154\ A}$$ 1 mark for I_2

vi) The current flowing through 10Ω resistor from node B to C is, — 1 mark for I

$$I = I_1 - I_2 = 0.923 - (-1.154) = \mathbf{2.077\ A}$$

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

6 a) Explain the concept of initial and final conditions in switching for the elements R, L and C.

Ans:

Concept of initial and final conditions:

For the three basic circuit elements the initial and final conditions are used in following way:

i) Resistor:

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 hence it is represented by a current source of value I_0 in parallel with open circuit.

As time passes the inductor current slowly rises 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.

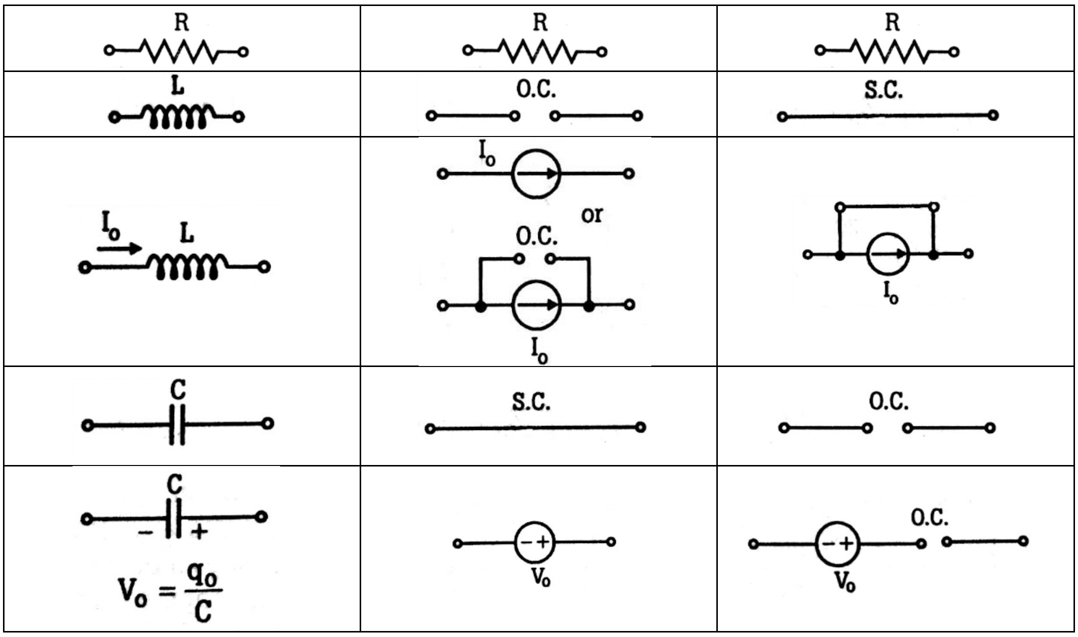
iii) Capacitor:

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.

As time passes the capacitor voltage slowly rises 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 an open-circuit.

The initial and final conditions are summarized in following table:

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



6 b) Find the current through 4Ω resistance shown in Fig. No. 4 using superposition theorem.

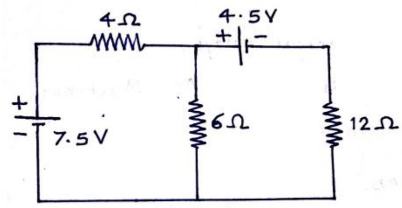


Fig. No. 4

Ans:

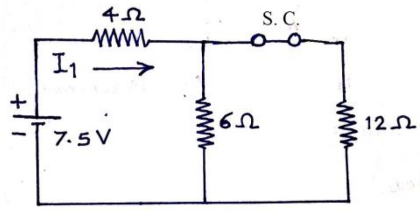
Solution by Superposition Theorm:

According to Superposition theorem, the current in any branch is given by the algebraic sum of the currents caused by the independent sources acting alone while the other voltage sources replaced by short circuit and current sources replaced by open circuit.

1 mark for circuit (a) and (b)

i) The 7.5V source acting alone:(4.5V source replaced by short-circuit)

Referring to fig.(a), total circuit resistance appearing across 7.5V source is,



(a)

$$R_{T1} = 4 + (6||12) = 4 + \frac{6 \times 12}{6 + 12} = 8\,\Omega$$

Current supplied by 7.5V source is,

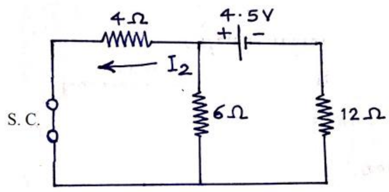
$$I_{S1} = \frac{V_1}{R_{T1}} = \frac{7.5}{8} = 0.9375\text{ A}$$

1 mark for computation of I_1 stepwise

The current flowing through 4Ω resistor due to 7.5V source alone is

$$\mathbf{I_1 = I_{S1} = 0.9375\text{ A}}$$

The 4.5 V source acting alone:(7.5V source replaced by short-circuit)



(b)

Referring to fig.(b), total circuit resistance

1 mark for computatio

appearing across 4.5V source is, n of I_2 stepwise

$$R_{T2} = (4||6) + 12 = \frac{4 \times 6}{4+6} + 12 = 14.4\,\Omega$$

Current supplied by 4.5V source is,

$$I_{S2} = \frac{V_2}{R_{T2}} = \frac{4.5}{14.4} = 0.3125\text{ A}$$

By current division formula, the current flowing through 4Ω due to 4.5V source alone is,

$$\mathbf{I_2} = I_{S2}\frac{6}{4+6} = 0.3125(0.6) = \mathbf{0.1875\ A}$$ 1 mark for computation of I_L stepwise

ii) Current through 4Ω load resistor (I_L):

Since direction of current I_2 is opposite to that of I_1, sign of I_2 must be taken as negative. By superposition theorem, load current is given by,

$$\mathbf{I_L} = I_1 - I_2 = 0.9375 - 0.1875 = \mathbf{0.75\ A}$$ **(Direction is same as I_1)**

6 c) Use Norton's theorem, find the current through 3Ω resistance, for the circuit shown in Fig. No.5

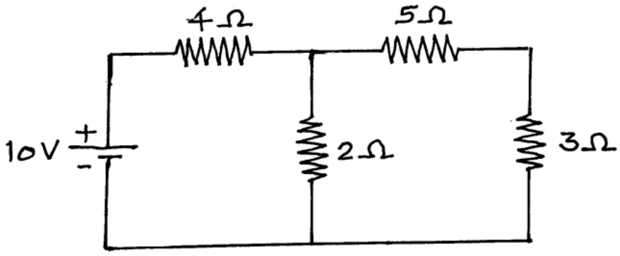
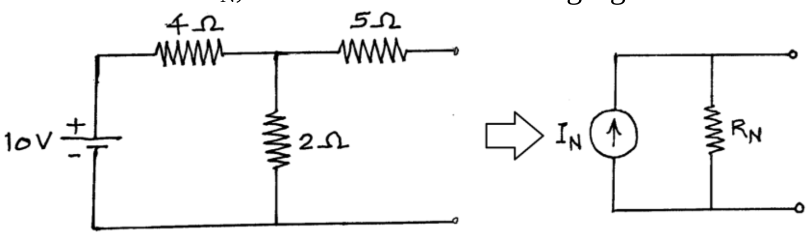


Fig. No. 5

Ans:

Solution by Norton's Theorem:

According to Norton's theorem, the circuit between load terminals excluding load resistance can be represented by simple circuit consisting of a current source I_N in parallel with a resistance R_N, as shown in the following figure. 1 mark



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). 1 mark for stepwise solution of I_N

Total resistance across 10V source is,

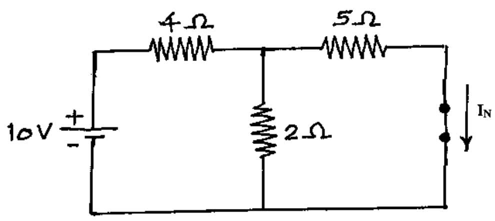
$$R = 4 + (5||2) = 4 + \frac{5\times2}{5+2} = 5.43\,\Omega$$

Therefore, current supplied by source,

$$I = \frac{V}{R} = \frac{10}{5.43} = 1.84\text{ A}$$

The resistances 2Ω and 5Ω are in parallel.

By current division, the current flowing



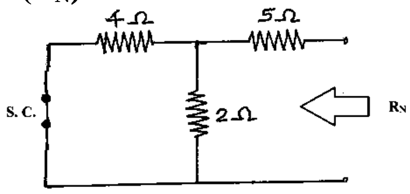
(a)

through 5Ω is same as I_N.

$$\mathbf{I_N} = I\frac{2}{2+5} = (1.84)\frac{2}{7} = \mathbf{0.526\ A}$$

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),



(b)

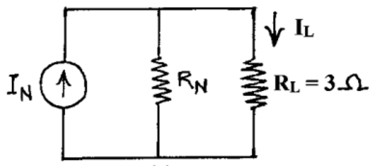
1 mark for stepwise solution of R_N

$$\mathbf{R_N} = 5 + (2||4) = 5 + \frac{2\times 4}{2+4} = \mathbf{6.33\ \Omega}$$

Determination of Load Current (I_L):

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

$$\mathbf{I_L} = I_N\frac{R_N}{R_N + R_L} = 0.526\frac{6.33}{6.33+3} = \mathbf{0.357\ A}$$



(c)

1 mark for I_L

6 d) State Norton's theorem and write its procedural steps to find current in a branch (Assume a simple circuit).

Ans:

Norton's Theorem:

Any two terminal circuit having number of linear impedances and sources (voltage, current, dependent, independent) can be represented by a simple equivalent circuit consisting of a single current source I_N in parallel with an impedance Z_N across the two terminals, where the source current I_N is equal to the short circuit current caused by internal sources when the two terminals are short circuited and the value of the parallel impedance Z_N is equal to the impedance of the circuit while looking back into the circuit across the two terminals, when the internal independent voltage sources are replaced by short-circuits and independent current sources by open circuits. 1 mark

Procedure to find branch current using Norton's Theorem:

Consider a simple circuit of Q. 6 (c), in which we need to find current through 3Ω by using Norton's theorem.

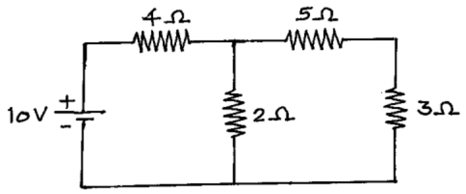
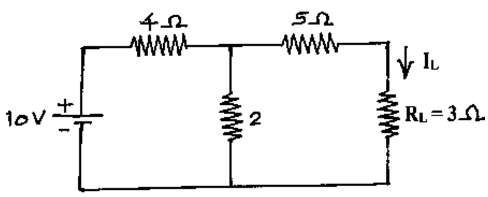


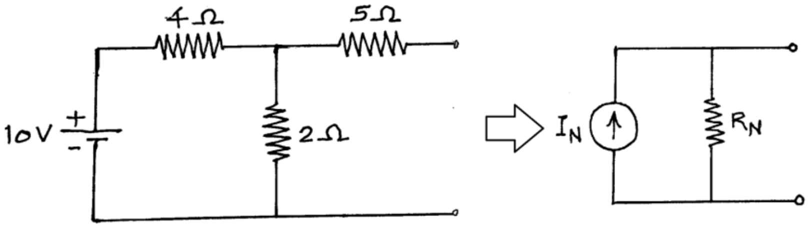
Fig. No. 5

3 marks for stepwise procedure

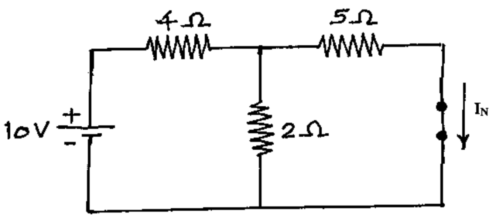
Step I: Identify the load branch and load current: Here 3Ω is the load branch and I_L be the load current as shown in the figure.



Step II: According to Norton's theorem, the circuit between load terminals excluding load resistance can be represented by simple circuit consisting of a current source I_N in parallel with a resistance R_N, as shown in the following figure.

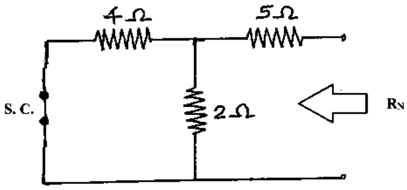


Step III: Determine of Norton's Equivalent Current Source (I_N):
Norton's equivalent current source I_N is the current flowing through a short-circuit across the load terminals due to internal sources, as shown in the fig.(a).



(a)

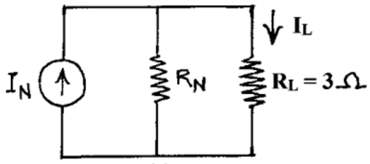
Step IV: Determination of Norton's Equivalent Resistance (R_N):
Norton's equivalent resistance is the resistance seen between the load terminals while looking back into the network, with internal independent voltage sources replaced by short-circuit and independent current sources replaced by open-circuit, as shown in fig.(b).



(b)

Step V: Determination of Load Current (I_L):
Replace the original circuit by Norton's equivalent circuit and connect load resistance to it, as shown in fig,(c). The load current is given by,

$$I_L = I_N \frac{R_N}{R_N + R_L}$$



(c)

6 e) Find the value of resistance to be connected across AB so as to consume maximum power in Fig. No. 6. Also find the maximum power consumed by it.

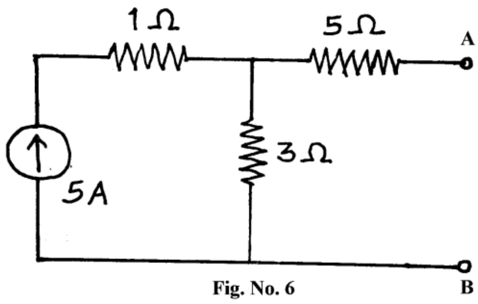
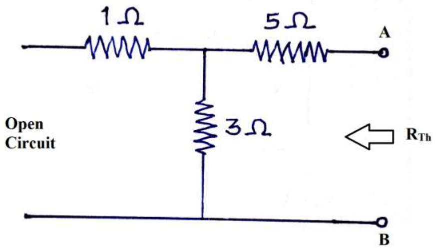


Fig. No. 6

Ans:
According to maximum power transfer theorem, the maximum power will be transferred to load R_L only when R_L 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 replaced by open-circuit. Here, only current source is present, hence it is replaced by open circuit as shown.

1 mark for



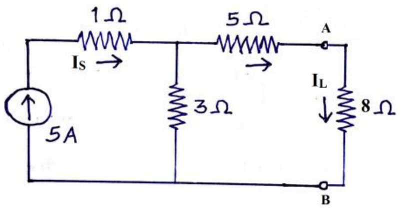
$$\mathbf{R_{Th}} = 5 + 3 = 8\,\Omega$$

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

$$\mathbf{R_L} = \mathrm{R_{Th}} = \mathbf{8\,\Omega}$$

circuit 1 mark for R_L

Maximum Power Consumed by 8Ω resistor:



Referring to the figure, the current through 8Ω resistor i.e load current I_L can be obtained from source current I_S using current division formula.

$$I_L = I_N \frac{3}{3 + (5 + 8)} = 5\left(\frac{3}{16}\right) = 0.9375\ A$$

1 mark for I_L by any method

Maximum power consumed in 8Ω resistor,

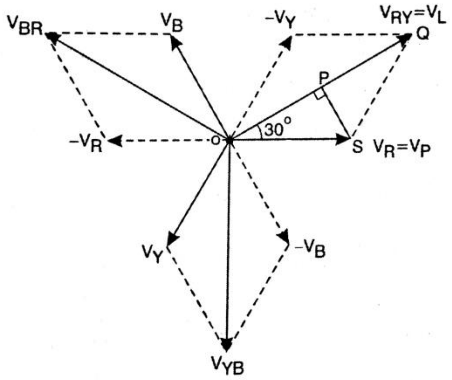
$$P_{max} = I_L^2(8) = (0.9375)^2(8) = \mathbf{7.03125\ watt}$$

1 mark for P_{max}

6 f) Prove that in a 3 phase star connected balanced load system, line voltage is $\sqrt{3}$ times phase voltage.

Ans:

Relationship Between Line voltage and Phase Voltage in Star Connected System:



1 mark for phasor diagram

Let V_R, V_Y and V_B be the phase voltages.

V_{RY}, V_{YB} and V_{BR} be the line voltages.

The line voltages are expressed as:

$V_{RY} = V_R – V_Y$

$V_{YB} = V_Y – V_B$

$V_{BR} = V_B – V_R$

In phasor diagram, the phase voltages are drawn first with equal amplitude and displaced from each other by 120°. Then line voltages are drawn as per the above equations. It is seen that the line voltage V_{RY} is the phasor sum of phase voltages V_R and $–V_Y$. We know that in parallelogram, the diagonals bisect each other with an angle of 90°.

2 marks for stepwise explanation

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

$$[OP] = [OS] \cos 30°$$

Since $[OP] = V_L/2$ and $[OS] = V_{ph}$

$$\therefore \frac{V_L}{2} = V_{ph}\cos 30°$$

$$V_L = 2V_{ph}\frac{\sqrt{3}}{2}$$

$$\mathbf{V_L = \sqrt{3}\ V_{ph}}$$

1 mark for final ans

Thus Line voltage = $\sqrt{3}$ (Phase Voltage)