Winter – 2017 Examinations

Model Answer **Subject Code: 17323 (ECN)**

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 <u>TEN</u> of the following: **20**

1 a) Define cycle and time period related to a. c. waveform.
Ans:

i) 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. 1 Mark

ii) Time Period:
Time period of an alternating quantity is defined as the time required for an alternating quantity to complete one cycle. 1 Mark

1 b) Define active power and reactive power for R-L-C series circuit.
Ans:
Active power and reactive power for R-L-C series circuit:

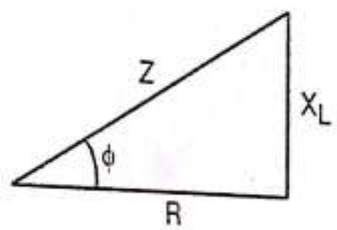
(i) Active Power (P):
Active power (P) is given by the product of voltage, current and the cosine of the phase angle between voltage and current. 1 Mark
Unit: watt (W) or kilo-watt (kW) or Mega-watt (MW)

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

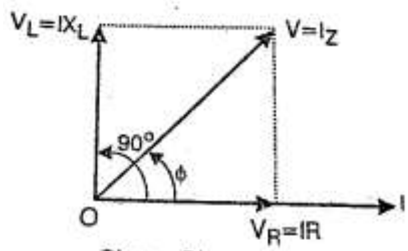
(ii) Reactive Power (Q):
Reactive power (Q) is given by the product of voltage, current and the sine of the phase angle between voltage and current.
Unit: volt-ampere-reactive (VAr), or kilo-volt-ampere-reactive (kVAr) or Mega-volt-ampere-reactive (MVAr) 1 Mark

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

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



Impedance Triangle



Phasor Diagram

1 Mark For each = 2 Marks

1 d) Define susceptance and admittances for a parallel circuit.
Ans:
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. 1 Mark

Admittance (Y):
Admittance is defined as the ability of the circuit to carry (admit) alternating 1 Mark

current through it. It is the reciprocal of impedance Z. i.e Y = 1/Z.
If impedance is expressed as $Z = R \pm jX$, then the admittance is obtained as, (Equations are optional)

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

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

1 e) State superposition theorem applied to D.C. circuits.

Ans:

Superposition Theorem applied to D.C. circuits:

Superposition theorem states that in any linear, bilateral, multisource network, the response (voltage across any element or current through any element) of any branch is equal to the algebraic sum of the responses produced in it with each source acting alone, while the other sources are replaced by their internal resistances. 2 Marks

OR

Any other valid statement

1 f) State maximum power transfer theorem for DC circuit.

Ans:

Maximum power transfertheorem for DC circuit:

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

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 g) Write down the units of R, L, C and G

Ans:

Units of R, L, C and G: ½ mark each =2 Marks

R - ohm L – henry C – farads G - siemens or mho

1 h) Define Quality factor of series AC circuit.

Ans:

Quality Factor of Series AC circuit:

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: $Q = 2\pi\left[\frac{Maximum\ energy\ stored}{Energy\ dissipated\ per\ cycle}\right]$ 2 Marks

OR

In series circuit it is defined as voltage magnification in the circuit at resonance

OR

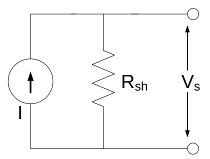
It is also defined as the ratio of the reactive power of either the inductor or the capacitor to the average power of the resistor.

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

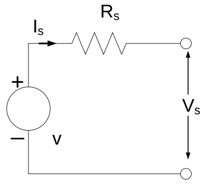
1 i) How current source can be converted into equivalent voltage source?

Ans:

Conversion of current source into equivalent voltage source:



current source

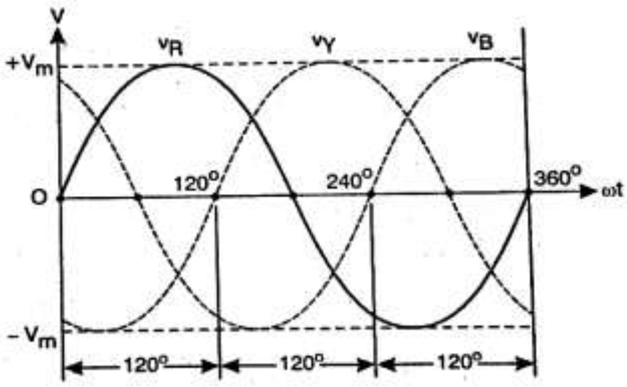


equivalent voltage source

- Find magnitude of equivalent voltage source, $V = I \times R_{sh}$ 1 Mark
- Find magnitude of internal resistance of equivalent voltage source
  $R_s = R_{sh}$ 1 Mark

1 j) Draw the sinusoidal waveform of 3 phase emf and also indicate the phase sequence.

Ans:



1½ Marks

Phase sequence is R-Y-B ½ Mark

1 k) Find frequency and RMS value of following voltage waveform refer Fig. No.1

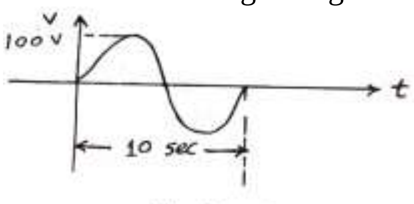


Fig. No. 1

Ans:

Frequency (f) $= \frac{1}{T} = \frac{1}{10} = 0.1\text{Hz}$ 1 Mark

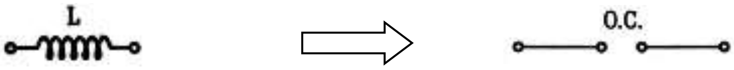
RMS Value $V = \frac{V_{peak}}{\sqrt{2}} = 0.707 \times V_{peak} = 0.707 \times 100 = 70.7\ V$ 1 Mark

1 l) State the behavior of following elements at the time of switching i.e. transient period. - i) Pure L ii) Pure C

Ans:

Behavior of pure L at the time of switching i.e. transient period:

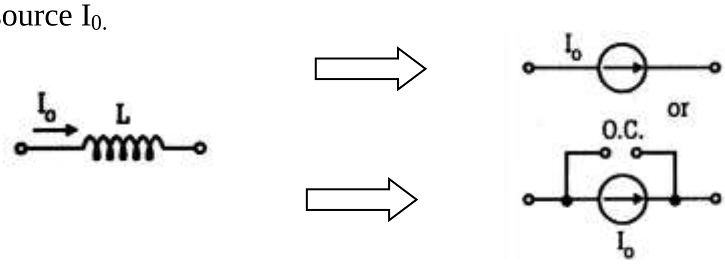
i) The pure inductor, carrying zero current prior to switching, acts as OPEN CIRCUIT.



1 Mark

OR

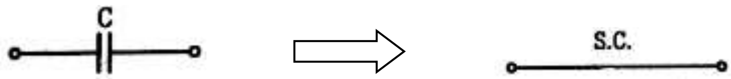
ii) The pure inductor, carrying some current, say I_0, prior to switching, acts as a current source I_0 or an Open Circuit in parallel with current source I_0.



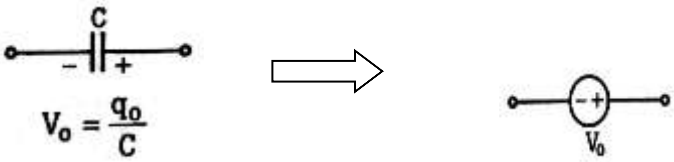
Behavior of pure C at the time of switching i.e.transient period:

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

1 Mark



ii) The pure capacitor, having some voltage, say V0, prior to switching, acts as a voltage source V0 or Short Circuit in series with voltage source V0.



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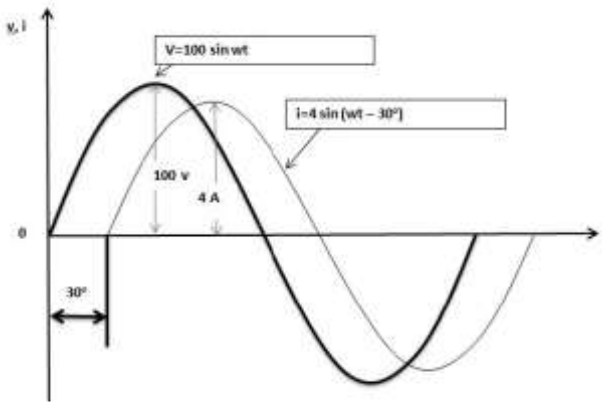
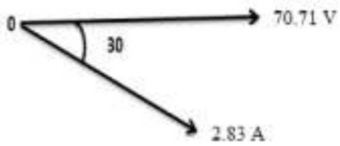
2 **Attempt any <u>FOUR</u> of the following:** 16

2 a) Draw waveform and vector diagram to show following voltage and current.

$V = 100 \sin wt$, and $I = 4 \sin (wt - 30°)$

Ans:





2 Marks for waveform

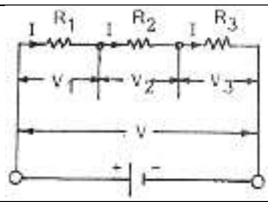
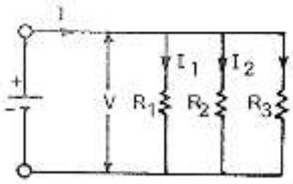
2 Marks for vector diagram

In vector diagram, RMS values have been shown.

2 b) Compare series and parallel circuits on any six points.

Ans:

Comparison between Series and Parallel Circuits:

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 individual resistances 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 individual 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, $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

4 Marks for any 6 points

($\frac{2}{3}$ Marks for each point)

12	Series RLC resonant circuit is Accepter circuit.	Parallel RLC resonant circuit is Rejecter circuit.

2c) An alternating voltage of 250 V, 50 Hz is applied to a coil which takes 5A of current, the power absorbed by the circuit is 1 kW. Find the resistance and inductance of the coil.

Ans:

Given: V = 250V, f = 50Hz, I = 5A, P = 1 kW

$$Z = \frac{V}{I} = \frac{250}{5} = 50\ \Omega$$

$$P = VI\ cos\emptyset$$ 1 Mark for Z

$$\therefore cos\emptyset = \frac{P}{VI} = \frac{1\times10^3}{250\times5} = 0.8$$

$$\therefore sin\emptyset = 0.6$$ 1 Mark for R

$$R = Z\cos\emptyset = 50\times0.8 = 40\Omega$$

$$X_L = Z\sin\emptyset = 50\times0.6 = 30\Omega$$ 1 Mark for X_L

$$\therefore L = \frac{X_L}{2\pi f} = \frac{30}{2\pi\times50} = 0.09549\text{henry} = 95.49\text{mH}$$ 1 Mark for L

2d) Derive the expression for resonance frequency for R-L-C series circuit.

Ans:

The frequency at which the net reactance of the series circuit becomes zero, is called the resonant frequency f_r. 1 Mark

Its value can be found as under:

At resonance $X_L - X_C = 0$ or $X_L = X_C$ $\omega_r L = 1/\omega_r C$ 1 Mark

$\omega_r^2 = 1/LC$

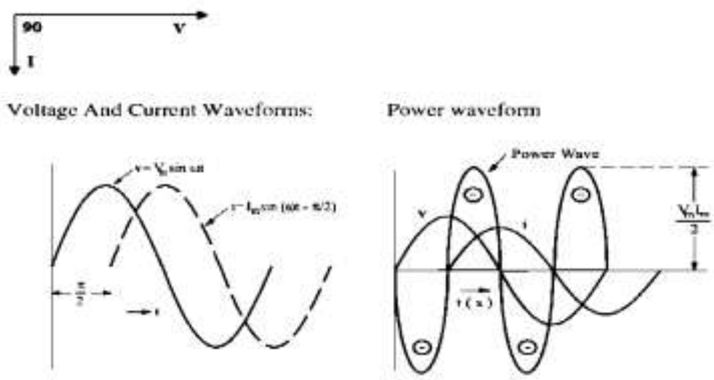
$\therefore (2\pi f_r)^2 = LC$ 1 Mark

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$ 1 Mark

2e) Draw the phasor diagram and waveforms of voltage, current and power in a pure inductance circuit supplied by a 1-phase a.c. source.

Ans:

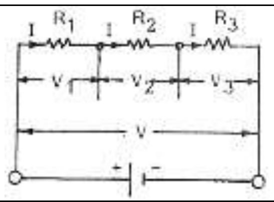
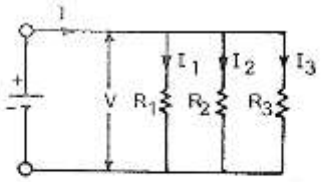
Phasor diagram and waveforms of purely inductive circuit:



1 Mark for Phasor diagram

1Mark for each Waveform of V, I, P

2 f) Compare series and parallel circuit.
Ans:

Sr. No.	Series Circuit	Parallel Circuit
1		
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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	The Q-factor for parallel resonant circuit is,

1 Mark for each of any 4 points = 4 Marks

	$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$	$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$
12	Series RLC resonant circuit is Accepter circuit.	Parallel RLC resonant circuit is Rejecter circuit.

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

3 a) A choke coil has a resistance of 2 Ω and an inductance of 0.035H is connected in parallel with a 350μF capacitor which is in series with a resistance of 20 Ω. When combination is connected across a 200V, 50Hz supply.
Calculate:
i) The total current taken and
ii) Power factor of whole circuit

Ans:

Given: $R_1 = 2\ \Omega$ $L = 0.035H$ $R_2 = 20\ \Omega$ $C = 350\mu F$

$$X_L = 2\pi f L = 2\pi \times 50 \times 0.035 = 11\Omega$$ ½ Mark for X_L

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 50 \times 350 \times 10^{-6}} = 9.09\Omega$$ ½ Mark for X_C

$Z_1 = R_1 + j\,X_L = (2 + j11) = 11.18\angle 79.89°\ \Omega$ ½ Mark for Z_1

$Z_2 = R_2 - j\,X_C = (20 - j9.09) = 21.96\angle -24.44°\ \Omega$ ½ Mark for Z_2

Branch 1 current is given by,

$$I_1 = \frac{V}{Z_1} = \frac{200\angle 0°}{11.18\angle 79.89°} = 17.88\angle -79.89° A = (3.138 - j17.60)\ A$$ ½ Mark for I_1

½ Mark for I_2

Branch 2 current is given by,

$$I_2 = \frac{V}{Z_2} = \frac{200\angle 0°}{21.96\angle -24.44°} = 9.107\angle 24.44° A = (8.29 + j3.76)\ A$$

Total current is,

$I = I_1 + I_2 = (3.138 - j17.60) + (8.29 + j3.76)$

i) $I = (11.428 - j13.84)A = \mathbf{17.94\angle -50.45°\ A}$ ½ Mark for I

(I can be calculated by considering equivalent impedance also)

ii) $\cos\emptyset = \cos(-50.45°) = \mathbf{0.6368}$ **lagging** ½ Mark for pf

3 b) A coil having resistance of 5Ω and inductance of 0.2H is arranged in parallel with another coil having resistance of 1Ω and inductance of 0.08H. Calculate the current through the combination and power absorbed when voltage of 100V, 50Hz is applied. Use impedance method.

Ans:

Given: $R_1 = 5\ \Omega$ $L_1 = 0.2H$ $R_2 = 1\ \Omega$ $L_2 = 0.08H$

Branch 1

$$X_{L1} = 2\pi f L_1 = 2\pi \times 50 \times 0.2 = 62.84\Omega$$

$$Z_1 = R_1 + jX_{L1} = 5 + j62.84 = 63.03\angle 85.45°\Omega$$ ½ Mark

Branch 2

$$X_{L2} = 2\pi f L_2 = 2\pi \times 50 \times 0.08 = 25.136\Omega$$

$$Z_2 = R_2 + jX_{L2} = 1 + j25.136 = 25.155\angle 87.72°\Omega$$ ½ Mark

$$Z_{eq} = \frac{Z_1 \times Z_2}{Z_1 + Z_2} = \frac{(63.03\angle 85.45°)\times(25.155\angle 87.72°)}{(5+j62.84)+(1+j25.136)} = \frac{1585.52\angle 173.17°}{6+j87.976}$$

1 Mark

$$= \frac{1585.52\angle 173.17°}{88.18\angle 86.098°} = 17.98\angle 87.072°\Omega$$

1 Mark

i) Current through the combination

$$I = \frac{V}{Z_{eq}} = \frac{100\angle 0°}{17.98\angle 87.072°} = 5.56\angle -87.072° \text{ amp}$$

1 Mark

ii) Power absorbed

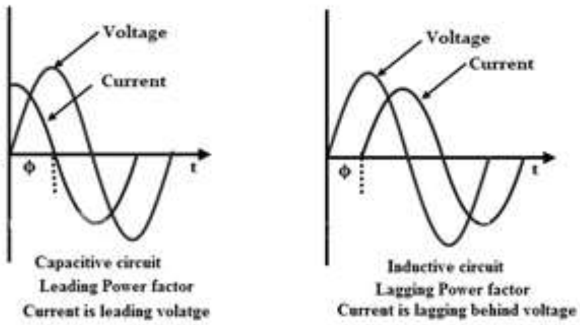
$$P = VI\cos\emptyset = 100 \times 5.56 \times \cos(-87.072°) = 28.40W$$

3 c) Define the following terms:

(i) Leading quantity

(ii) Lagging quantity

Ans:



2 marks for diagram

When two alternating quantities attain their respective zero or peak values simultaneously, the quantities are said to be in-phase quantities.

When the quantities do not attain their respective zero or peak values simultaneously, then the quantities are said to be out-of-phase quantities.

Leading Quantity:

The quantity which attains the respective zero or peak value first, is called 'Leading Quantity'. 1 Mark

Lagging Quantity:

The quantity which attains the respective zero or peak value later, is called 'Lagging Quantity'. 1 Mark

In above diagram, it is seen that for inductive circuit, the current is lagging behind the voltage or the voltage is said to be leading the current.

Similarly, for capacitive circuit, the current is leading the voltage or the voltage is said to be lagging behind the current.

3d) A RC series circuit consisting of R = 10 Ω, C = 100 μF is connected across 200V, 50Hz AC supply. Find the value of current and power factor. What will be the value of current and power factor if the value of resistance is doubled?

Ans:

Given: R = 10Ω, C = 100μF, V = 200V, f = 50 Hz

Capacitive reactance

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi \times 50 \times 100 \times 10^{-6}} = 31.83\Omega$$ 1 Mark for X_C

Circuit Impedance

$$Z = R - jX_C = 10 - j31.83 = 33.36\angle -72.55°\Omega$$

Current

$$I = \frac{V}{Z} = \frac{200\angle 0°}{33.36\angle -72.55°} = 5.99\angle 72.55° \text{ amp}$$ 1 Mark for current

Power factor

$$\cos\emptyset = \cos(72.55°) = 0.299 \quad \text{leading}$$ ½ Mark for cosϕ

If the resistance is doubled, then R = 20 Ω

Circuit Impedance

$$Z = R - jX_C = 20 - j31.83 = 37.59\angle -57.86°\Omega$$

Current

$$I = \frac{V}{Z} = \frac{200\angle 0°}{37.59\angle -57.86°} = 5.32\angle 57.86° \text{ amp}$$ 1 Mark for current

Power factor

$$\cos\emptyset = \cos(57.86°) = 0.532 \quad \text{leading}$$ ½ Mark for cosϕ

3e) A 200W, 100V lamp is connected in series with a capacitor to a 120V, 50Hz AC supply. Calculate:

i) The capacitance required
ii) The phase angle between voltage and current

Ans:

Given: Power rating of lamp P = 200W
Rated voltage of lamp V_R = 100V
Supply voltage V = 120V, Frequency f = 50Hz

1) Capacitance required:

The value of capacitance should be such that rated voltage of 100V appears across the lamp and lamp consumes rated power of 200W.

$$P = \frac{V_R^2}{R} \qquad \therefore \textit{Resistance of lamp } R = \frac{V_R^2}{P} = \frac{100^2}{200} = 50\Omega$$ 1 Mark for R

For rated power consumption in lamp, the required current be,

$$I = \frac{V_R}{R} = \frac{100}{50} = 2\ amp$$

Impedance required to draw this current from 120V supply, 1 Mark for Z

$$Z = \frac{V}{I} = \frac{120}{2} = 60\Omega$$

Capacitive reactance $X_C = \sqrt{(Z^2 - R^2)} = \sqrt{(60^2 - 50^2)} = 33.16\Omega$ 1 Mark for C

$$Capacitance\ C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi \times 50 \times 33.16} = \mathbf{100.54\mu F}$$

Power loss in the circuit $P = VIcos\emptyset$

$$\therefore power\ factor\ cos\emptyset = \frac{P}{VI} = \frac{200}{120 \times 2} = 0.833$$

Phase angle between voltage and current, 1 Mark for ϕ

$$\emptyset = cos^{-1}(0.833) = \mathbf{33.59}°$$

3 f) State the relation between line and phase values of current and voltage for star and delta connection.

Ans:

Star Connection:

$$\text{Line Voltage } = \sqrt{3}\text{ (Phase Voltage)}$$ 1 Mark

$$\text{i.e } V_L = \sqrt{3}V_{ph}$$

$$\text{Line Current } = \text{Phase Current}$$ 1 Mark

$$\text{i.e } I_L = I_{ph}$$

Delta Connection:

$$\text{Line Voltage } = \text{Phase Voltage}$$ 1 Mark

$$\text{i.e } V_L = V_{ph}$$

$$\text{Line Current } = \sqrt{3}\text{ (Phase Current)}$$ 1 Mark

$$\text{i.e } I_L = \sqrt{3}I_{ph}$$

4 Attempt any FOUR of the following: 16

4 a) Three coils each with resistance of 10Ω and inductance of 0.35mH are connected in star to a 3-phase, 440V, 50Hz supply. Calculate the line current and total power taken per phase.

Ans:

Data Given:

Line voltage V_L = 440V, f = 50Hz
Resistance per phase R = 10Ω
Inductance per phase L = 0.35mH
Inductive reactance per phase

$X_L = 2\pi fL = 2\pi \times 50 \times 0.35 \times 10^{-3} = 0.11\Omega$ 1 Mark

Z_{ph} = (10+j0.11) Ω = 10.0006∠0.63° Ω

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

$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{440}{\sqrt{3}}$ = 254.03V

(i) Line Current $I_L = I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{254.03\angle 0°}{10\angle 0.63°}$ 1 Mark

$= 25.40\angle -0.63\ °A$

(ii) Power factor cosϕ = $\frac{Rph}{Zph} = \frac{10}{10}$ = 0.999 1 Mark

(iii) Power taken per phase P = $V_{Ph}\ I_{Ph}$ cosϕ
= (254.03)(25.4)(0.999) 1 Mark
= 6445.909 W

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

Ans:

Advantages of Polyphase circuit over Single phase circuit:

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

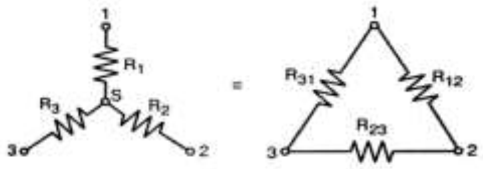
ii) Parallel operation of 3-phase alternators is easier than that of single-phase alternators.
iii) Single-phase loads can be connected along with 3-ph loads in a 3-ph system.
iv) Instead of pulsating power of single-phase supply, constant power is obtained in 3-phase system.
v) Three-phase induction 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) Three-phase supply produces a rotating magnetic field in 3-phase rotating machines which gives uniform torque and less noise.

1 Mark for each of any 4 advantages = 4 Marks

4 c) Derive the formulae for delta and star transformation.

Ans:

i) Star to Delta Transformation:



(a) Star Circuit (b) Delta Circuit

If the star circuit and delta circuit are equivalent, then the resistance between any two terminals of the circuit must be same.

For star circuit, resistance between terminals 1 & 2, say $R_{1\text{-}2} = R_1 + R_2$

For delta circuit, resistance between terminals 1 & 2, $R_{1\text{-}2} = R_{12}||(R_{31} + R_{23})$

2 Marks for star to delta conversion

$$\therefore R_1 + R_2 = R_{12}||(R_{31}+R_{23}) = \frac{R_{12}(R_{31}+R_{23})}{R_{12} + (R_{31}+R_{23})} = \frac{R_{12}(R_{31}+R_{23})}{R_{12}+R_{23} + R_{31}}$$

$$\therefore R_1 + R_2 = \frac{R_{12}R_{31}+R_{12}R_{23}}{R_{12}+R_{23} + R_{31}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Similarly, the resistance between terminals 2 & 3 can be equated as,

$$\therefore R_2 + R_3 = \frac{R_{12}R_{23} + R_{23}R_{31}}{R_{12}+R_{23} + R_{31}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

And the resistance between terminals 3 & 1 can be equated as,

$$\therefore R_3 + R_1 = \frac{R_{23}R_{31} + R_{12}R_{31}}{R_{12}+R_{23} + R_{31}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Subtracting eq. (2) from eq.(1),

$$\therefore R_1 - R_3 = \frac{R_{12}R_{31} - R_{23}R_{31}}{R_{12}+R_{23} + R_{31}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Adding eq.(3) and eq.(4) and dividing both sides by 2,

$$\therefore R_1 = \left[\frac{R_{12}R_{31}}{R_{12}+R_{23} + R_{31}}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Similarly, we can obtain,

$$\therefore R_2 = \left[\frac{R_{12}R_{23}}{R_{12}+R_{23} + R_{31}}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$\therefore R_3 = \left[\frac{R_{31}R_{23}}{R_{12}+R_{23}+R_{31}}\right] \ldots\ldots\ldots\ldots\ldots (7)$$

Multiplying each two of eq.(5), (6) and (7),

$$\therefore R_1R_2 = \left[\frac{(R_{12})^2R_{31}\,R_{23}}{(R_{12}+R_{23}+R_{31})^2}\right] \ldots\ldots\ldots\ldots (8)$$

$$\therefore R_2R_3 = \left[\frac{(R_{23})^2R_{31}\,R_{12}}{(R_{12}+R_{23}+R_{31})^2}\right] \ldots\ldots\ldots\ldots (9)$$

$$\therefore R_3R_1 = \left[\frac{(R_{31})^2R_{12}\,R_{23}}{(R_{12}+R_{23}+R_{31})^2}\right] \ldots\ldots\ldots\ldots (10)$$

Adding the three equations (8), (9) and (10),

$$\therefore R_1R_2 + R_2R_3 + R_3R_1 = \frac{(R_{12})^2R_{31}\,R_{23}+(R_{23})^2R_{31}\,R_{12}+(R_{31})^2R_{12}\,R_{23}}{(R_{12}+R_{23}+R_{31})^2}$$

$$= \frac{R_{12}R_{31}\,R_{23}(R_{12}+R_{23}+R_{31})}{(R_{12}+R_{23}+R_{31})^2}$$

$$\therefore R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_{12}R_{31}\,R_{23}}{R_{12}+R_{23}+R_{31}} \ldots\ldots\ldots\ldots (11)$$

Dividing eq.(11) by eq.(6), (dividing by respective sides)

$$\therefore R_1 + R_3 + \frac{R_3R_1}{R_2} = R_{31}$$

$$\therefore R_{31} = R_3 + R_1 + \frac{R_3R_1}{R_2} \ldots\ldots\ldots\ldots (12)$$

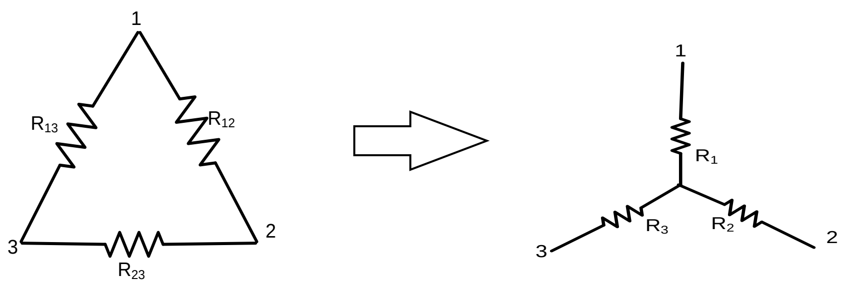
Similarly, we can obtain,

$$\therefore R_{12} = R_1 + R_2 + \frac{R_1R_2}{R_3} \ldots\ldots\ldots\ldots (13)$$

$$\therefore R_{23} = R_2 + R_3 + \frac{R_2R_3}{R_1} \ldots\ldots\ldots\ldots (14)$$

Thus using known star connected resistors R_1, R_2 and R_3, the unknown resistors R_{12}, R_{23} and R_{31} of equivalent delta connection can be determined.

ii) Delta to Star transformation:



Delta connection Equivalent star connection

R_{12}, R_{23} and R_{32} connected in delta fashion between terminals 1, 2 and 3. It is possible to replace delta by its equivalent star circuit.

Considering terminals 1 and 2, Resistance R_{12} appears in parallel with ($R_{23}+R_{31}$)

Hence resistance between terminals 1 and 2

$$\frac{R_{12}(R_{23}+R_{31})}{R_{12}+R_{23}+R_{31}} \ldots\ldots\ldots\ldots (1)$$

In Case of Star network, resistance between terminals 1 and 2 is

$$= R_1 + R_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

For equivalence between two networks, equating Equation (1) & (2) — 2 Marks for delta to star conversion

$$R_1 + R_2 = \frac{R_{12}(R_{23}+R_{31})}{R_{12}+R_{23}+R_{31}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Similarly, we can write:

$$R_2 + R_3 = \frac{R_{23}(R_{31}+R_{12})}{R_{12}+R_{23}+R_{31}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

$$R_3 + R_1 = \frac{R_{31}(R_{12}+R_{23})}{R_{12}+R_{23}+R_{31}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

By subtracting equation (4) from (3)

$$R_1 - R_3 = \frac{R_{12}R_{23} + R_{12}R_{31} - R_{23}R_{31} - R_{23}R_{12}}{R_{12} + R_{23} + R_{31}}$$

$$R_1 - R_3 = \frac{R_{12}R_{31} - R_{23}R_{31}}{R_{12}+R_{23}+R_{31}} \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

By adding equation (5) & (6)

$$2R_1 = \frac{R_{31}R_{12} + R_{31}R_{23} + R_{12}R_{31} - R_{23}R_{31}}{R_{12} + R_{23} + R_{31}}$$

Equivalent star resistances for delta connection are then given by,

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

$$R_2 = \frac{R_{12}R_{23}}{R_{12} + R_{23} + R_{31}}$$

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

4 d) A delta connected induction motor is supplied by 3-phase, 400V, 50Hz supply the line current is 43.3A and the total power taken from the supply is 24kW. Find the resistance and reactance per phase of motor winding.

Ans:

Data Given:

Line voltage $V_L = V_{ph}$ = 400V, f = 50Hz

Line current I_L = 43.3A

Total power P = 24kW

$$P = \sqrt{3}V_L I_L \cos\emptyset$$

$$\therefore \ \cos\emptyset = \frac{P}{\sqrt{3}V_L I_L} = \frac{(24 \times 10^3)}{\sqrt{3} \times 400 \times 43.3} = 0.8 \text{ lag}$$

1 Mark

Thus, $\sin\emptyset = 0.6$

$$I_{ph} = \frac{I_L}{\sqrt{3}} = \frac{43.3}{\sqrt{3}} = 25amp$$

$$Z_{ph} = \frac{V_{ph}}{I_{ph}} = \frac{400}{25} = 16\Omega$$ 1 Mark

Resistance per phase

$R = Z\cos\emptyset = 16 \times 0.8 = 12.8\Omega$ 1 Mark

Reactance per phase

$X = Z\sin\emptyset = 16 \times 0.6 = 9.6\Omega$ 1Mark

4 e) Using mesh analysis find values of R_1 and R_2 shown in Figure No. 2

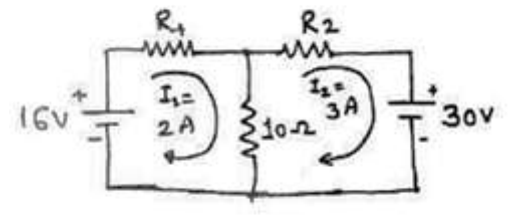
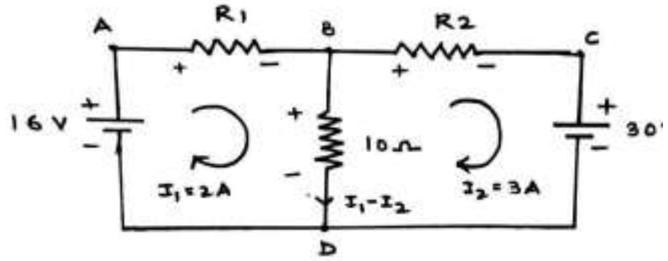


Fig. No. 2

Ans:



By applying KVL to loop ABDA

$$-I_1R_1 - 10(I_1 - I_2) + 16 = 0$$ 1 Mark

$$-2R_1 - 10(2-3) + 16 = 0$$

$$-2R_1 + 10 + 16 = 0$$

$$-2R_1 = -26$$

$$\boldsymbol{R_1 = 13\Omega}$$ 1 Mark

By applying KVL to loop BCDB

$$-I_2R_2 + 10(I_1 - I_2) - 30 = 0$$ 1 Mark

$$-3R_2 - 10 - 30 = 0$$

$$3R_2 = -40$$

$$\boldsymbol{R_2 = -13.33\Omega}$$ 1 Mark

(NOTE: Negative resistance is only hypothetical, does not exist)

4 f) Derive the condition for maximum power transfer theorem.

Ans:

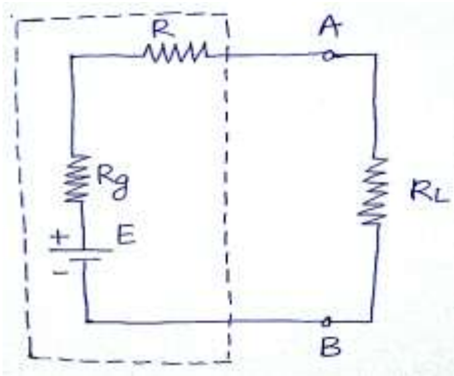
Condition for maximum power transfer theorem:

Maximum power transfer theorem states that, resistive load will absorb maximum power from a network when the load resistance is equal to the resistance of the network as viewed from the output terminals, with all energy sources removed leaving behind their internal resistances**.**

In Fig, a load resistance of R_L is connected across the terminals A and B of a network which consists of a generator of e.m.f. E and internal resistance Rg and a series resistance R which represents the lumped resistance of the connecting wires.

Let Ri = Rg + R = internal resistance of the network as viewed from A and B.

According to this theorem, R_L will absorb maximum power from the network when $R_L = R_i$. 1 Mark



1 Mark

Current in the above circuit is I = $\frac{E}{R_L+R_i}$

Power consumed by the load is

$P_L = I^2 R_L = \frac{R_L\ E^2}{(R_L+R_i)^2}$ ………………………………………..…..(1)

For P_L to be maximum, $\frac{d\,P_L}{d\,R_L} = 0$ 1 Mark

Differentiating equation (1), we get

$$\frac{d\,P_L}{d\,R_L} = \frac{(R_L+R_i)^2E^2 - R_LE^2 2(R_L+R_i)}{(R_L+R_i)^4} = 0$$

$$= E^2\left[\frac{1}{(R_L+R_i)^2} + \frac{(-2\,R_L)}{(R_L+R_i)^3}\right] = 0$$

$$= E^2\left[\frac{1}{(R_L+R_i)^2} - \frac{2\,R_L}{(R_L+R_i)^3}\right] = 0$$

$$\frac{1}{(R_L+R_i)^2} = \frac{2\,R_L}{(R_L+R_i)^3}$$

i.e. R_L + Ri = $2R_L$ OR R_L= Ri 1 Mark

5 **Attempt any TWO of the following** 16

5 a) A coil of resistance 50Ω and inductance of 0.1 H is connected in series with 100µF capacitor. The combination is supplied with 230V, 50 Hz AC supply. Calculate voltage across each, current through the circuit, power factor and draw complete vector diagram.

Ans:

RMS supply voltage V = 230 volt

Supply frequency f = 50 Hz

L = 0.1H, $X_L = 2\pi fL = 2 \times \pi \times 50 \times 0.1 = 31.42\ \Omega$ 1 Mark for X_L and X_C

C= 100 µF, $X_c = \frac{1}{2\pi fC} = \frac{1}{2\times\pi\times50\times100\times10^{-6}} = 31.83\ \Omega$

$Z = R + j(X_L - X_C) = 50 + j(31.42 - 31.83) = 50 - j0.41$ 1 Mark for Z

$= 50\angle -0.48°\Omega$

A) Current through the circuit:

$I = \frac{V}{Z} = \frac{230\angle 0°\Omega}{50\angle -0.48°\Omega} = 4.6\angle -0.48°A$ 1 Mark for I

B) Voltage across each element:

Voltage across resistor,

$$V_R = IR = 4.6 \times 50 = 230V$$ 1 Mark

Voltage across inductor,

$$V_L = IX_L = 4.6 \times 31.42 = 144.48V$$ 1 Mark

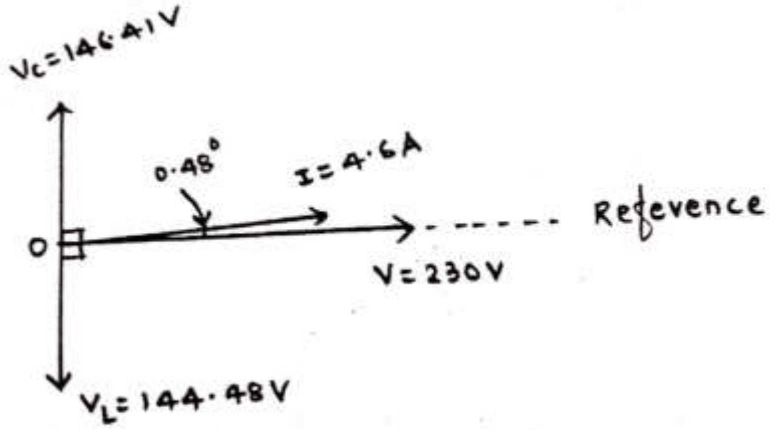
Voltage across capacitor,

$$V_C = IX_C = 4.6 \times 31.83 = 146.41V$$ 1 Mark

C) Power factor of the circuit:

$\cos\varphi = \frac{R}{Z} = \frac{50}{50} = 1$ OR $\cos\varphi = \cos(-0.48°) = 0.9999 \cong 1$ 1 Mark

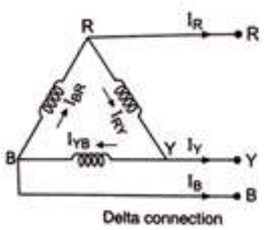
D) Vector diagram:

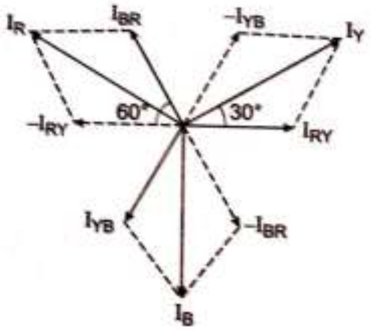


1 Mark

5b) With the help of necessary phasor diagram, derive the relationship between line and phase current in balanced delta connected load connected to 3 phase A.C. supply.

Ans:





2 Mark for circuit diagram

3 Mark for Phasor diagram

From above diagram current in each lines are vector difference of the two phase currents flowing through that line.

For example:

Current in line R is $I_R = I_{BR} - I_{RY}$

Current in line Y is $I_Y = I_{RY} - I_{YB}$ 1 Mark

Current in line B is $I_B = I_{YB} - I_{BR}$

Current in line R is found by compounding I_{BR} and I_{RY} and value given by parallelogram in phasor diagram.

Angle between I_{BR} and $-I_{RY}$ is $60°$, 1 Mark

where $|I_{BR}| = |I_{RY}|$ = Phase current I_{ph}

$$I_R = I_{BR} - I_{RY} = 2I_{ph}\cos\left(\frac{60}{2}\right) = 2I_{ph}\frac{\sqrt{3}}{2} = \sqrt{3}I_{ph}$$
$$I_Y = I_{RY} - I_{YB} = 2I_{ph}\cos\left(\frac{60}{2}\right) = 2I_{ph}\frac{\sqrt{3}}{2} = \sqrt{3}I_{ph}$$
$$I_B = I_{YB} - I_{BR} = 2I_{ph}\cos\left(\frac{60}{2}\right) = 2I_{ph}\frac{\sqrt{3}}{2} = \sqrt{3}I_{ph}$$
As $I_R = I_Y = I_B = I_L$
$$\mathbf{I_L = \sqrt{3}I_{ph}}$$ 1 Mark

5c) i) State Thevenin's theorem and write its procedural steps to find current in a branch. (Assume simple circuit)

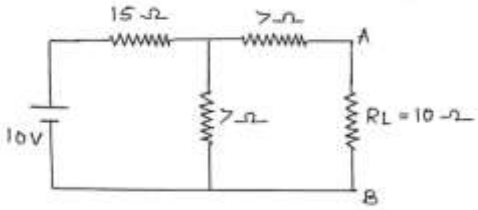
Ans:

Thevenin'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 voltage source V_{Th} in series with an impedance Z_{Th}, where the source voltage V_{Th} is equal to the open circuit voltage appearing across the two terminals due to internal sources of circuit and the series impedance Z_{Th} 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

Procedural steps to find current in a branch using Thevenin's theorem:

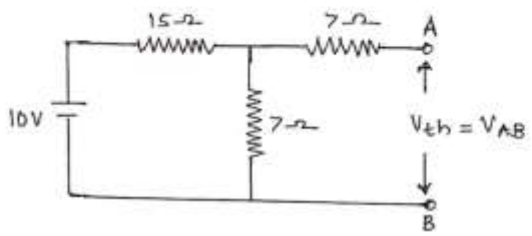
Consider a simple circuit shown below in which we need to find the current flowing through 10Ω resistor.



½ Mark

Step I: Identify the load branch: It is the branch whose current is to be determined.

Step II: Calculation of V_{Th}: Remove R_L and find open circuit voltage across the load terminals A and B.

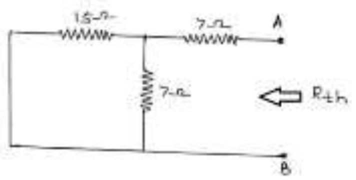


½ Mark

Current through circuit will be =10/(15+7)=0.45 Amp

$V_{OC} = V_{Th} = V_{AB} = 0.45 \times 7 = 3.18$ V ½ Mark

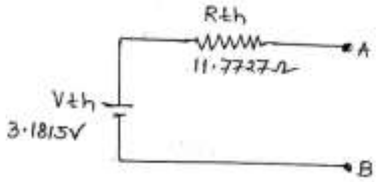
Step III: Calculation of R_{Th}:

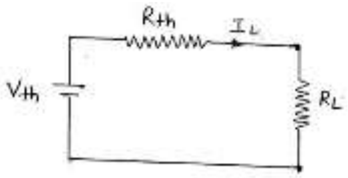


½ Mark

Resistances 15 & 7 are in parallel =15 x 7/(15+7)=4.77 Ω
R_{Th}= 7+4.77=11.77 Ω

Step IV: Thevenin's equivalent circuit:





½ Mark

Step V: Determination of Load current:

$I_L= V_{Th}/(R_{Th}+R_L)$=3.18/(11.77+10)=0.146 Amp ½ Mark

5c) ii) Develop Thevenin's equivalent across A and B in network shown below in Figure No. 3

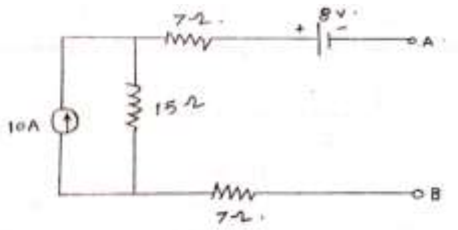
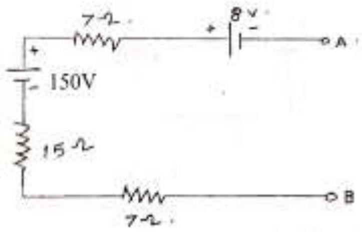


Fig. No. 3

Ans:

1) Converting current source of 10A with 15Ω as internal resistance into voltage source V = 10X15 = 150V



1 Mark

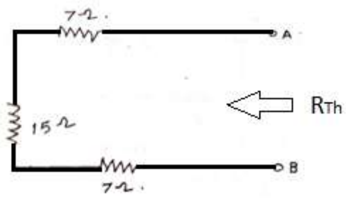
2) **Determination of Thevenin's equivalent voltage V_{Th}:**

Due to open circuit between A & B, the current is zero and voltage drop across all resistors is zero. The open circuit voltage between A & B can be obtained by KVL as,

V_{AB} = 7(0) + 15(0) + 150 + 7(0) – 8 = 142

$\therefore$ $V_{Th} = V_{AB}$ = 142V 1 Mark

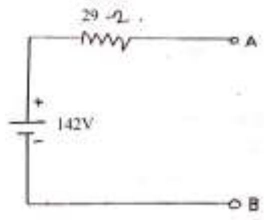
3) **Determination of Thevenin's equivalent resistance R_{Th}:**



1 Mark

R_{Th} = 7 + 15 + 7 = 29Ω

4) **Thevenin's Equivalent Circuit:**



1 Mark

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

6 a) Calculate current through 10Ω resistance in the network shown in Figure No. 4 using superposition theorem.

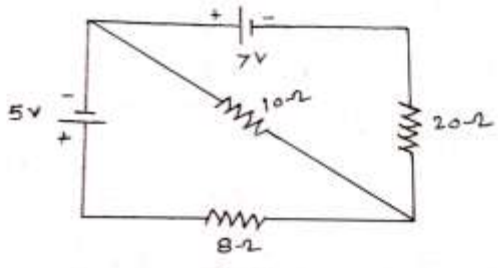
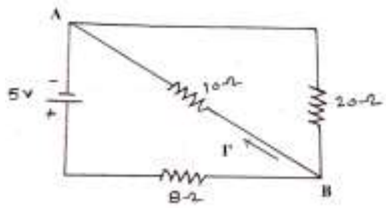


Fig. No. 4

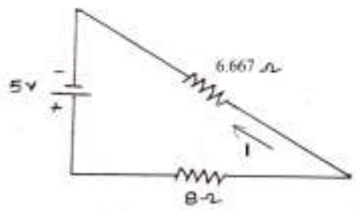
Ans:

A) Consider 5 V source only:



Resistances of 10 & 20 are in parallel = 10 x20/(10+20) = 6.667Ω

1 Mark

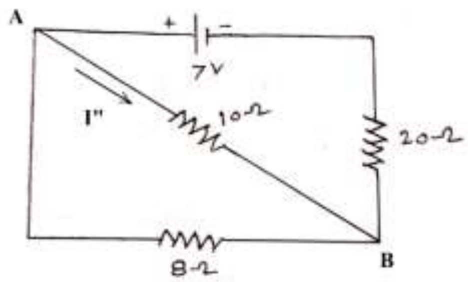


Total current I= 5/(8+6.667)=5/14.667 =0.341 amp

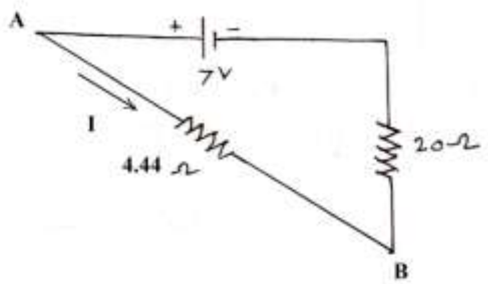
Therefore I'=0.341 × 20/(10+20) = 0.227 amp

I' = 0.227 amp from B to A

B) Now consider 7 V source only:



Resistances of 10 & 8 are in parallel=10 × 8/(10+8) = 4.44Ω 1 Mark



Therefore current I =7/(20+4.44) = 0.286 amp

I" = 0.286 × 8/(10+8) = 0.127 amp from A to B

C) Final Current:

I = I' - I" from B to A OR I = I" - I' from A to B 1 Mark

= 0.227 - 0.127 = 0.099 amp from B to A 1 Mark

6b) Using Norton's theorem, find current through 4Ω resistance in Figure No. 5

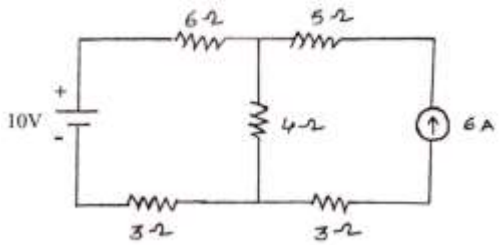


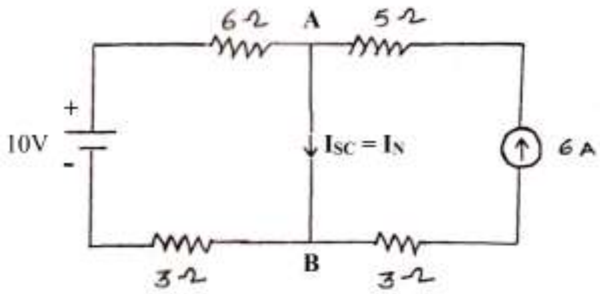
Fig. No. 5

Ans:

Here load branch is 4Ω, hence R_L = 4Ω

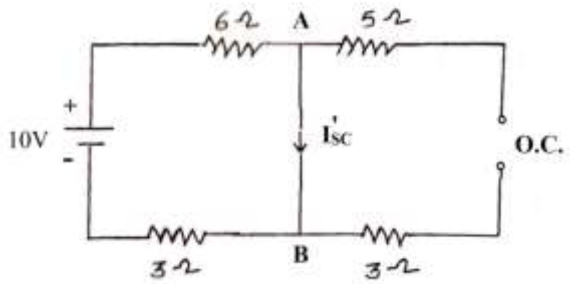
A) **Determination of Norton's Equivalent Current Source I_N:**

Remove R_L and short the path, now circuit becomes as shown below



Apply Superposition theorem to find out the $I_{SC} = I_N$

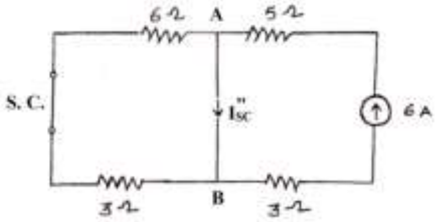
(i) Consider 10 V source only



1Mark

I_{SC}' = 10/(6+3) =10/9 = 1.11 amp from A to B

(ii) Consider 6 A source only



1 Mark

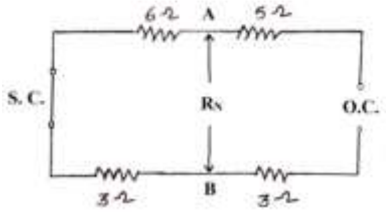
I_{SC}'' = 6 amp from A to B

$I_{SC} = I_N = I_{SC}' + I_{SC}'' = 1.11 + 6$

$I_N = I_{SC}$ = 7.11 amp from A to B

B) **Determination of Norton's Equivalent Resistance R_N:**

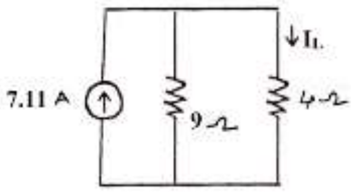
Now calculate $R_N = R_{Th}$



$R_N = R_{AB} = 6+3 = 9\ \Omega$

1Mark

Norton's equivalent circuit becomes



Therefore current through R_L is I_L= 7.11 x 9/(9+4)

I_L = 4.922 amp

1Mark

6c) Find current through 8Ω resistance using nodal analysis in Figure No. 6.

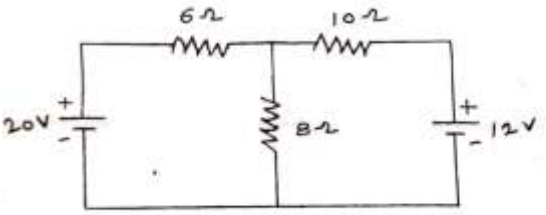
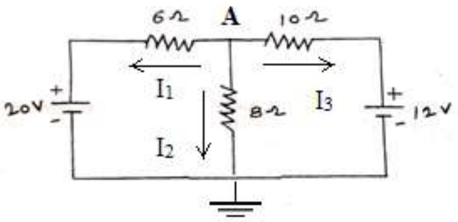


Fig. No. 6

Ans:



1 Mark

By applying KCL to Node A

$$I_1+I_2+I_3=0$$

$$\frac{V_A-20}{6}+\frac{V_A}{8}+\frac{V_A-12}{10}=0$$ 1 Mark

$$\frac{8(V_A-20)+6V_A}{6\times 8}+\frac{V_A-12}{10}=0$$

$$\frac{14V_A-160}{6\times 8}+\frac{V_A-12}{10}=0$$

$$140V_A-1600+48V_A-576=0$$

$$188V_A=2176$$

$$V_A=11.57\text{ volts}$$ 1 Mark

Current flowing through resistance 8 Ω = $\frac{V_A}{8}=1.446$ Amp 1 Mark

6 d) Find the value of R_L to transfer maximum power in the network shown in Figure No. 7

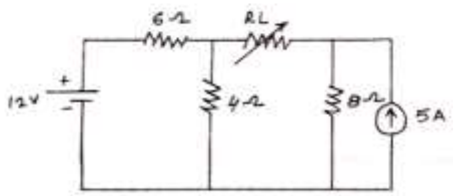
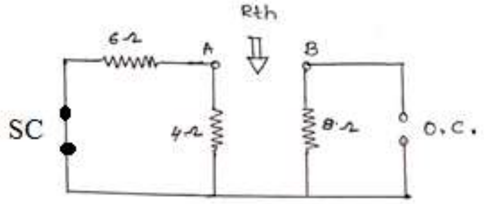


Fig. No. 7

Ans:

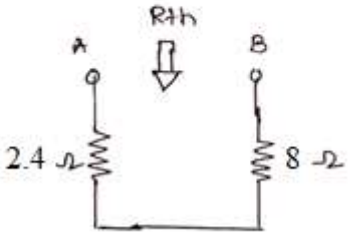
Maximum power will be transferred when load resistance is equal to internal resistance i.e. $R_L= R_{TH}$

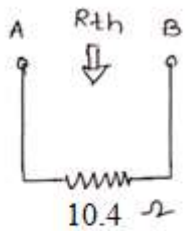


1 Mark

Resistances of 6 & 4 are in parallel = 6×4/(6+4)= 2.4 Ω and circuit is simplified as

1 Mark





1 Mark

R_{TH}=2.4+8= 10.4 Ω

Hence in the given circuit maximum power will be transferred when

$R_L= R_{th}$=10.4Ω 1 Mark

6 e) Explain concept of initial and final conditions in switching circuits. 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. 1 Mark

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. 1 Mark

iii) Capacitor:

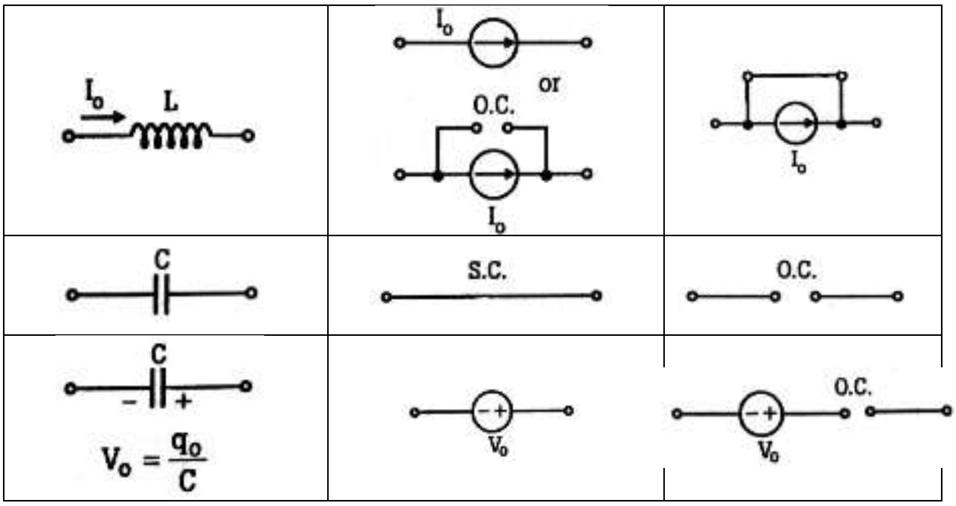
The voltage across capacitor cannot change instantly. If the capacitor voltage is zero initially just before switching, then whatever may be the current flowing, just after switching the capacitor voltage will remain zero. i.e the capacitor must be acting as short-circuit at instant t = 0. If capacitor 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

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:

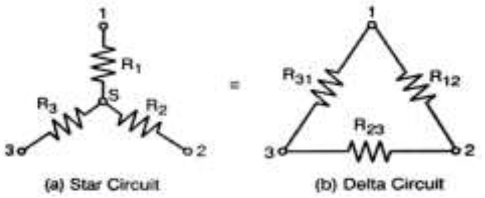
Element and condition at $t = 0^-$	Initial Condition at $t = 0^+$	Final Condition at $t = \infty$
R	R	R
L	O.C.	S.C.

1 Mark For table



6 f) Give the expression for star to delta and delta to star transformation.

Ans:



(a) Star Circuit (b) Delta Circuit

1 Mark

Star to Delta Transformation:

$$\therefore R_{12} = R_1 + R_2 + \frac{R_1R_2}{R_3}$$

$$\therefore R_{23} = R_2 + R_3 + \frac{R_2R_3}{R_1}$$

$$\therefore R_{31} = R_3 + R_1 + \frac{R_3R_1}{R_2}$$

½ Mark for each equation = 1½ Marks

Delta to Star Transformation:

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

$$R_2 = \frac{R_{12}R_{23}}{R_{12} + R_{23} + R_{31}}$$

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

½ Mark for each equation = 1½ Marks