

Electrical Circuits and Network (313332)

MSBTE K-Scheme · Model Question Paper — Set C · Model Answers

Q.1

a) RMS value and form factor.

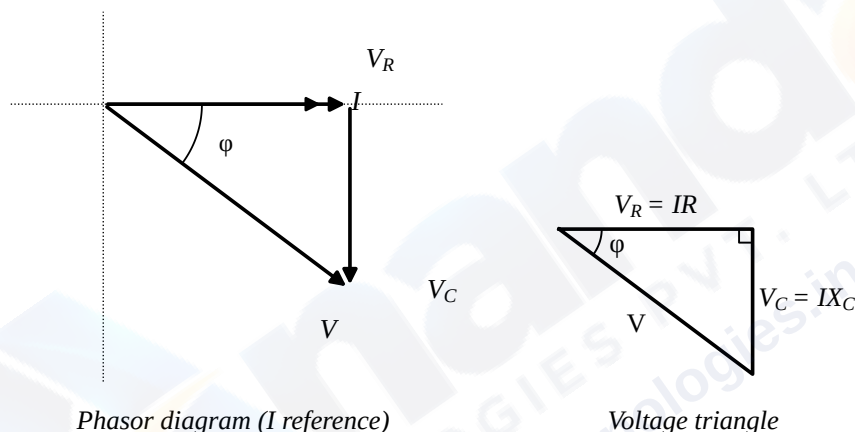
2 M

- **RMS (effective) value:** That steady (DC) current which, when flowing through a given resistance for a given time, produces the same heat as produced by the alternating current flowing through the same resistance for the same time. For a sine wave $I_{\text{rms}} = I_m/\sqrt{2} = 0.707 I_m$.
- **Form factor:** Ratio of RMS value to average value. $K_f = I_{\text{rms}}/I_{\text{av}} = 0.707 I_m/0.637 I_m = 1.11$ for a sine wave.

(Each definition 1 M)

b) R-C series — voltage triangle and phasor diagram.

2 M



Current leads the applied voltage by ϕ , $\tan \phi = V_C/V_R = X_C/R$.

(Phasor diagram 1 M, voltage triangle 1 M)

c) Conductance and susceptance.

2 M

- **Conductance (G):** the real (in-phase) component of admittance; $G = R/Z^2$. Unit: siemens (S) or mho.
- **Susceptance (B):** the reactive (quadrature) component of admittance; $B = X/Z^2$. Unit: siemens (S) or mho. $Y = G - jB_L$ (inductive) or $G + jB_C$ (capacitive).

(Each definition with unit 1 M)

d) Phase sequence.

2 M

- **Phase sequence:** the order in which the three phase voltages attain their positive maximum values.
- For sequence R-Y-B, v_R reaches maximum first, then v_Y (120° later) and then v_B (240° later).
- Reversing any two supply lines reverses the phase sequence (R-B-Y) and hence the direction of rotation of a 3-phase motor.

(Definition 1 M, importance 1 M)

e) Branch and loop.

2 M

- **Branch:** A part of the network lying between two junction points, containing one or more elements in series (e.g. E1-R1 branch, R3, R2).
- **Loop:** Any closed path in a network, which may contain other closed paths within it (e.g. outer path E1-R1-R3-R5-R4-E2).

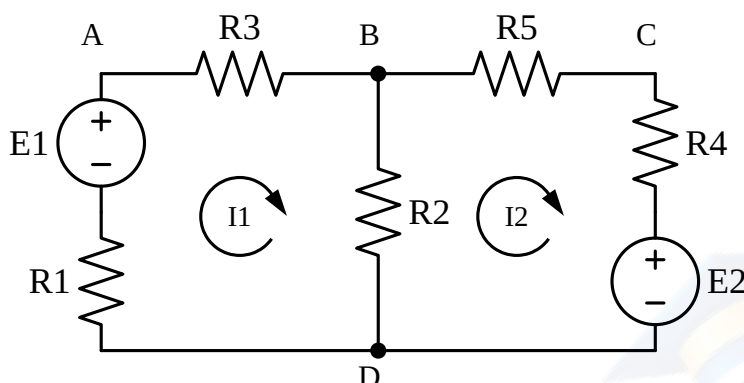


Fig.: Network showing nodes, branches, loops and meshes

(Each definition 1 M)

f) Thevenin's theorem.

2 M

Any linear, bilateral, active network having two terminals A and B can be replaced by an equivalent circuit consisting of a single voltage source V_{Th} (open-circuit voltage across A-B) in series with a single resistance R_{Th} (resistance seen from A-B with all sources replaced by their internal resistances).

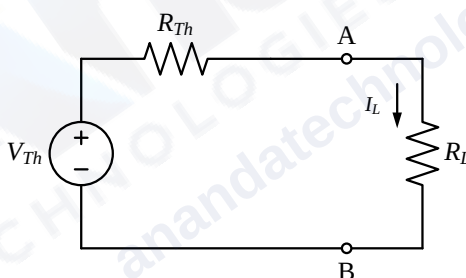


Fig.: Thevenin's equivalent circuit

(Statement 2 M)

g) Condition for maximum power transfer.

2 M

- Condition: load resistance must be equal to the Thevenin (internal) resistance of the network:
 $R_L = R_{Th}$.
- Maximum power: $P_{max} = V_{Th}^2 / (4R_L) = V_{Th}^2 / (4R_{Th})$; efficiency = 50 %.

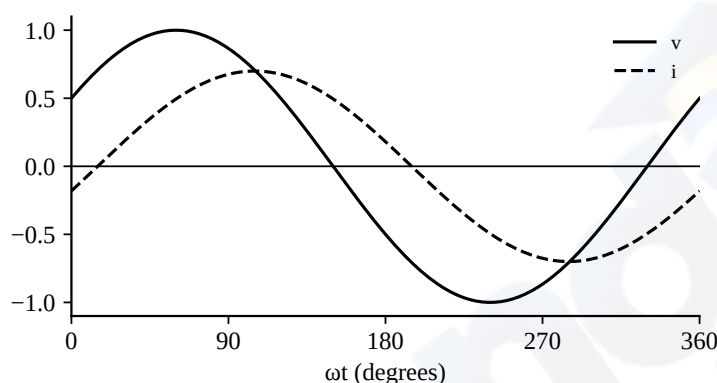
(Condition 1 M, expression 1 M)

Q.2

a) Series circuit from $v = 200 \sin(314t + 30^\circ)$, $i = 8 \sin(314t - 15^\circ)$.

4 M

1. Maximum values: $V_m = 200 \text{ V}$, $I_m = 8 \text{ A}$; $\omega = 314 \text{ rad/s} \Rightarrow f = \omega/2\pi = 49.975 \text{ Hz}$
2. Phase difference $\phi = 30^\circ - (-15^\circ) = 45^\circ \rightarrow$ current **lags** voltage, so the circuit is inductive (R-L)
3. Impedance $Z = V_m/I_m = 200/8 = 25 \Omega$
4. Resistance $R = Z \cos \phi = 25 \times \cos 45^\circ = 17.6777 \Omega$
5. Reactance $X = Z \sin \phi = 25 \times \sin 45^\circ = 17.6777 \Omega$
6. Inductance $L = X_L/\omega = 17.6777/314 = 0.0563 \text{ H}$ (56.298 mH)
7. Power factor $= \cos \phi = \cos 45^\circ = 0.7071$ **lagging**
8. Power $P = V_{\text{rms}} I_{\text{rms}} \cos \phi = (V_m I_m / 2) \cos \phi = (200 \times 8 / 2) \times 0.7071 = 565.685 \text{ W}$



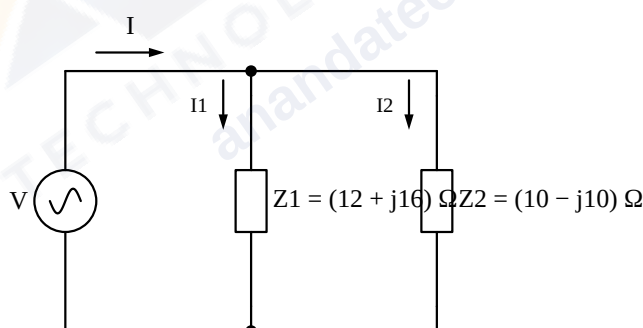
Waveforms: i lags v by 45°

(Z and ϕ 1 M, R 1 M, L 1 M, p.f. and power 1 M)

$Z = 25 \Omega$, $R = 17.678 \Omega$, $L = 56.3 \text{ mH}$, p.f. = 0.7071 lagging, $P = 565.7 \text{ W}$

b) Parallel $(12 + j16) \Omega$ and $(10 - j10) \Omega$, total current 20 A.

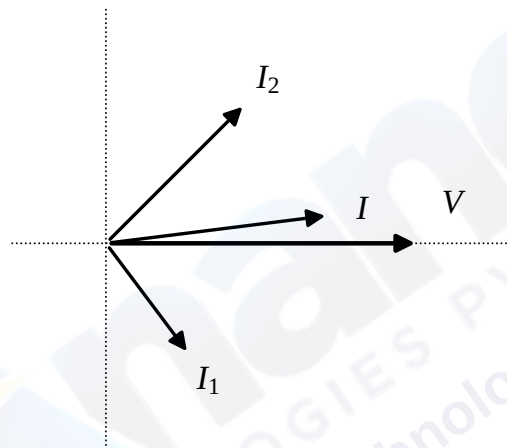
4 M



Circuit diagram

1. $Z_1 = (12 + j16) \Omega = 20 \angle 53.13^\circ \Omega$
2. $Z_2 = (10 - j10) \Omega = 14.142 \angle -45^\circ \Omega$
3. $Z_1 + Z_2 = (22 + j6) = 22.804 \angle 15.26^\circ$
4. Equivalent impedance $Z = Z_1 Z_2 / (Z_1 + Z_2) = (20 \angle 53.13^\circ)(14.142 \angle -45^\circ) / (22.804 \angle 15.26^\circ) = 12.403 \angle -7.13^\circ \Omega = (12.308 - j1.538) \Omega$

5. Supply voltage $V = I \times |Z| = 20 \times 12.403 = \mathbf{248.069 \text{ V}}$ (taking V as reference, $V = 248.069 \angle 0^\circ$ V)
6. Branch current $I_1 = V/Z_1 = 248.069 \angle 0^\circ / 20 \angle 53.13^\circ = \mathbf{12.403 \angle -53.13^\circ \text{ A}} = (7.442 - j9.923) \text{ A}$
7. Branch current $I_2 = V/Z_2 = 248.069 \angle 0^\circ / 14.142 \angle -45^\circ = \mathbf{17.541 \angle 45^\circ \text{ A}} = (12.403 + j12.403) \text{ A}$
8. Total current $I = I_1 + I_2 = (19.846 + j2.481) \text{ A} = \mathbf{20 \angle 7.13^\circ \text{ A}}$
1. p.f. of branch 1 = $\cos \phi_1 = R_1/|Z_1| = 12/20 = \mathbf{0.6 \text{ lagging}}$
2. p.f. of branch 2 = $\cos \phi_2 = R_2/|Z_2| = 10/14.1421 = \mathbf{0.7071 \text{ leading}}$
3. Overall p.f. = $\cos(\text{angle between } V \text{ and } I) = \cos 7.13^\circ = \mathbf{0.9923 \text{ leading}}$
4. Power taken by branch 1: $P_1 = I_1^2 R_1 = 12.403^2 \times 12 = \mathbf{1846.15 \text{ W}}$
5. Power taken by branch 2: $P_2 = I_2^2 R_2 = 17.541^2 \times 10 = \mathbf{3076.92 \text{ W}}$
6. Total power $P = P_1 + P_2 = 4923.08 \text{ W}$ (check: $VI \cos \phi = 248.069 \times 20 \times 0.9923 = 4923.08 \text{ W}$ ✓)



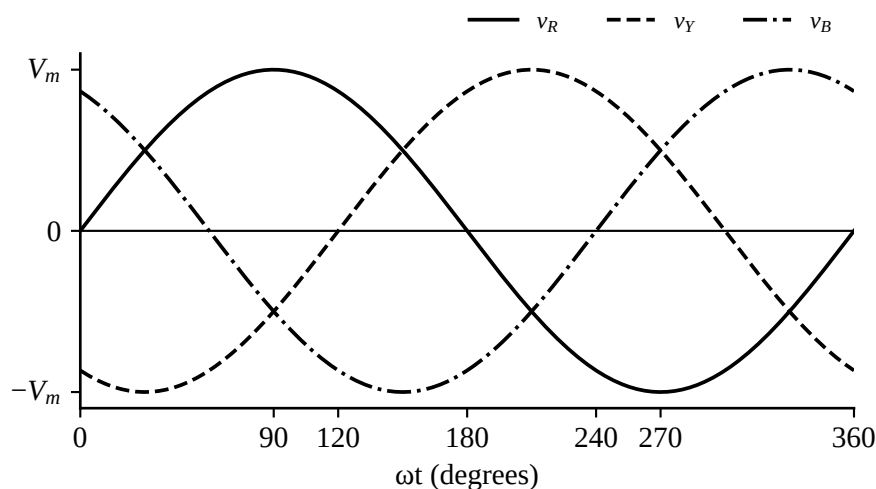
Phasor diagram (V as reference)

(Branch currents 2 M, total current/p.f. 2 M, power/phasor diagram 2 M)

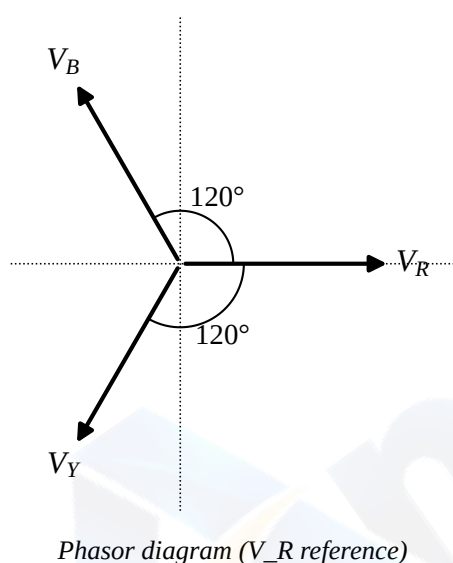
$I_1 = 12.403 \text{ A}, I_2 = 17.541 \text{ A}, P_1 = 1846.2 \text{ W}, P_2 = 3076.9 \text{ W}, \text{p.f.} = 0.9923 \text{ leading}$

c) Three-phase voltages — waveforms, phasor diagram, equations, polar form.

4 M



Waveforms of three-phase voltages (phase sequence R-Y-B)



Phasor diagram (V_R reference)

Instantaneous values:

$$v_R = V_m \sin \omega t$$

$$v_Y = V_m \sin(\omega t - 120^\circ)$$

$$v_B = V_m \sin(\omega t - 240^\circ) = V_m \sin(\omega t + 120^\circ)$$

Polar form (V = RMS phase voltage):

$$V_R = V \angle 0^\circ$$

$$V_Y = V \angle -120^\circ$$

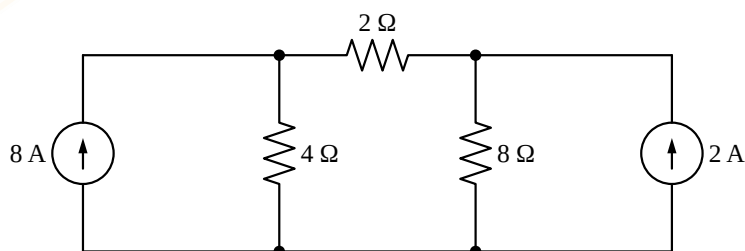
$$V_B = V \angle +120^\circ (= V \angle -240^\circ)$$

The three voltages are equal in magnitude and frequency and displaced by 120° electrical from each other; their phasor sum is zero ($V_R + V_Y + V_B = 0$).

(Waveforms 1 M, phasor diagram 1 M, equations 1 M, polar form 1 M)

d) Node analysis — current in 2Ω (Fig. No. 1).

4 M



Node voltages marked w.r.t. bottom reference node

Take the bottom line as reference node (0 V). Unknown node voltage(s): V_1 , V_2 . Applying KCL at each node (sum of currents leaving the node = 0):

At node V_1 : $-8 + V_1/4 + (V_1 - V_2)/2 = 0$

At node V_2 : $V_2/8 - 2 + (V_2 - V_1)/2 = 0$

Simplifying:

$$3 V_1 - 2 V_2 = 32 \quad \dots(1)$$

$$-4 V_1 + 5 V_2 = 16 \quad \dots(2)$$

Solving: $V_1 = 27.4286 \text{ V}$, $V_2 = 25.1429 \text{ V}$

Current in 2Ω resistor (from left node to right node) = $(V_1 - V_2)/2 = (27.4286 - (25.1429))/2 = 1.1429 \text{ A}$

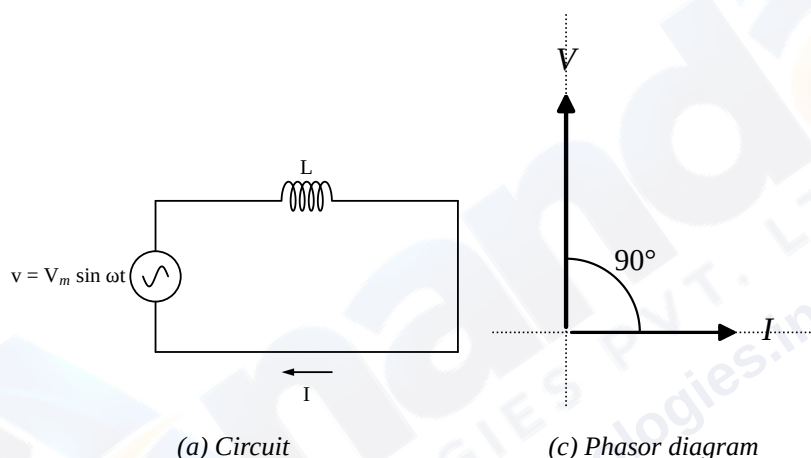
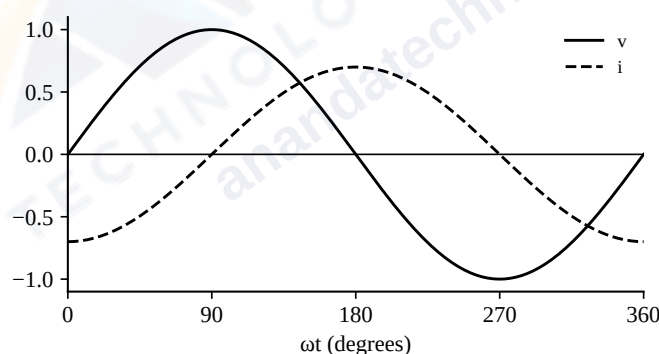
$I = 1.1429 \text{ A}$, flowing from left to right through 2Ω resistor

(KCL equations 2 M, solution 1 M, answer 1 M)

Q.3

a) Purely inductive circuit.

4 M



- Applied voltage $v = V_m \sin \omega t$. Self-induced emf opposes it: $v = L di/dt$.
- Current $i = I_m \sin(\omega t - 90^\circ) = I_m \sin(\omega t - \pi/2)$, where $I_m = V_m/X_L$.
- Inductive reactance $X_L = \omega L = 2\pi fL$ ohm; current **lags** voltage by 90° .
- Power factor = $\cos 90^\circ = 0$ (lagging); average power $P = 0$ — energy is only stored in the magnetic field and returned to the supply.

(Circuit 1 M, waveforms 1 M, phasor diagram 1 M, equations 1 M)

b) Series vs parallel resonant circuits.

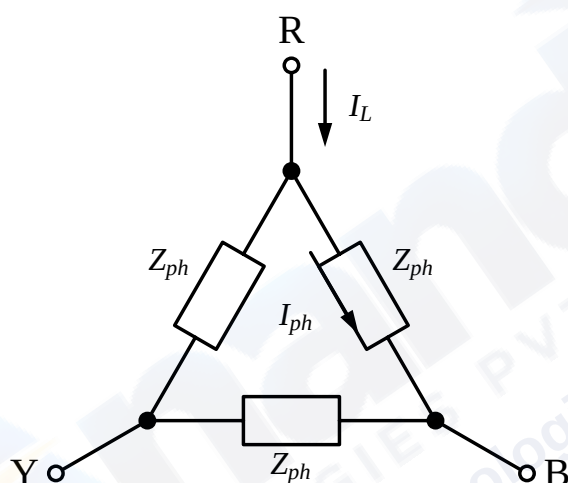
4 M

Point	Series resonance	Parallel resonance
Impedance at resonance	Minimum, $Z = R$	Maximum, $Z_D = L/CR$ (dynamic impedance)
Current at resonance	Maximum, $I = V/R$	Minimum, $I = V/Z_D = VCR/L$
Type / name of circuit	Acceptor circuit (accepts current at f_r)	Rejector circuit (rejects current at f_r)
Magnification	Voltage magnification: $V_L = V_C = QV$	Current magnification: $I_C = QI$
Application	Tuning circuits, radio receivers (selecting a station)	Tank circuit of oscillators, filters, IF amplifiers

(Any four points, 1 M each)

c) Delta load: $R = 15 \Omega$, $L = 0.05 \text{ H}$, $C = 300 \mu\text{F}$ per phase, 400 V.

4 M



Balanced delta connected load, $Z_{ph} = (15 + j5.098) \Omega$

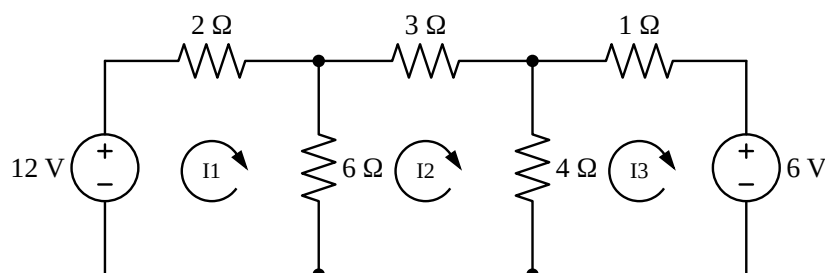
- $X_L = 2\pi fL = 2\pi \times 50 \times 0.05 = 15.708 \Omega$
- $X_C = 1/(2\pi fC) = 1/(2\pi \times 50 \times 300 \times 10^{-6}) = 10.61 \Omega$
- $Z_{ph} = R + j(X_L - X_C) = (15 + j5.098) \Omega = 15.843 \angle 18.77^\circ \Omega$
- Delta connection: $V_{ph} = V_L = 400 \text{ V}$
- Impedance per phase $Z_{ph} = (15 + j5.098) \Omega$; $|Z_{ph}| = \sqrt{(15^2 + 5.098^2)} = 15.843 \Omega$
- Phase current $I_{ph} = V_{ph}/Z_{ph} = 400/15.843 = 25.2485 \text{ A}$
- Line current $I_L = \sqrt{3} I_{ph} = \sqrt{3} \times 25.2485 = 43.7317 \text{ A}$ (delta)
- Power factor $\cos \phi = R_{ph}/Z_{ph} = 15/15.843 = 0.9468$ lagging
- Total active power $P = \sqrt{3} V_L I_L \cos \phi = \sqrt{3} \times 400 \times 43.7317 \times 0.9468 = 28686.87 \text{ W}$ (check: $3I_{ph}^2 R_{ph} = 28686.87 \text{ W}$)
- Total reactive power $Q = \sqrt{3} V_L I_L \sin \phi = 9749.01 \text{ VAR}$
- Total apparent power $S = \sqrt{3} V_L I_L = 30298.18 \text{ VA}$

(Z_{ph} 1 M, I_{ph} 1 M, I_L 1 M, p.f. 1 M)

$$Z_{ph} = 15.843 \, \Omega, I_{ph} = 25.248 \, A, I_L = 43.732 \, A, p.f. = 0.9468 \text{ lagging}$$

d) Mesh analysis — current in 4 Ω (Fig. No. 2).

4 M



Mesh currents assumed clockwise

Assume clockwise mesh currents I_1, I_2, I_3 as shown. Applying KVL to each mesh (voltage drops = emf in the mesh):

Mesh 1: $6(I_1 - I_2) + 2 I_1 = 12$

Mesh 2: $6(I_2 - I_1) + 3 I_2 + 4(I_2 - I_3) = 0$

Mesh 3: $4(I_3 - I_2) + 1 I_3 = -6$

Simplifying:

$$8 I_1 - 6 I_2 = 12 \quad \dots(1)$$

$$-6 I_1 + 13 I_2 - 4 I_3 = 0 \quad \dots(2)$$

$$-4 I_2 + 5 I_3 = -6 \quad \dots(3)$$

Solving by Cramer's rule: $\Delta = \begin{vmatrix} 8 & -6 & 0 \\ -6 & 13 & -4 \\ 0 & -4 & 5 \end{vmatrix} = 212$

$$\Delta_1 = \begin{vmatrix} 12 & -6 & 0 \\ 0 & 13 & -4 \\ -6 & -4 & 5 \end{vmatrix} = 444 \Rightarrow I_1 = \Delta_1 / \Delta = 444 / 212 = \mathbf{2.0943 \, A}$$

$$\Delta_2 = \begin{vmatrix} 8 & 12 & 0 \\ -6 & 0 & -4 \\ 0 & -6 & 5 \end{vmatrix} = 168 \Rightarrow I_2 = \Delta_2 / \Delta = 168 / 212 = \mathbf{0.7925 \, A}$$

$$\Delta_3 = \begin{vmatrix} 8 & -6 & 12 \\ -6 & 13 & 0 \\ 0 & -4 & -6 \end{vmatrix} = -120 \Rightarrow I_3 = \Delta_3 / \Delta = -120 / 212 = \mathbf{-0.566 \, A}$$

Current in 4 Ω resistor (common to mesh 2 and mesh 3) = $I_2 - I_3 = 0.7925 - (-0.566) = \mathbf{1.3585 \, A}$

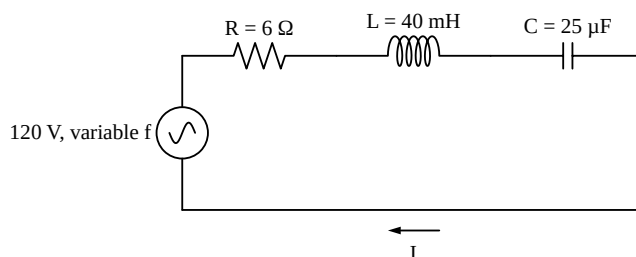
Current through 4 Ω resistor = 1.3585 A, flowing downward

(KVL equations 2 M, solution 1 M, answer 1 M)

Q.4

a) Series resonance: $R = 6 \Omega$, $L = 40 \text{ mH}$, $C = 25 \mu\text{F}$, 120 V .

4 M



Series R-L-C circuit

1. Resonant frequency $f_r = 1/(2\pi\sqrt{LC}) = 1/(2\pi\sqrt{0.04 \times 25 \times 10^{-6}}) = \mathbf{159.155 \text{ Hz}}$
2. Current at resonance $I_0 = V/R = 120/6 = \mathbf{20 \text{ A}}$
3. Quality factor $Q = X_L/R = (1/R)\sqrt{L/C} = 40/6 = \mathbf{6.6667}$
4. Bandwidth $BW = R/(2\pi L) = 6/(2\pi \times 0.04) = \mathbf{23.873 \text{ Hz}} (= f_r/Q)$

(f_r 1 M, I_0 1 M, Q 1 M, f_1 and f_2 1 M)

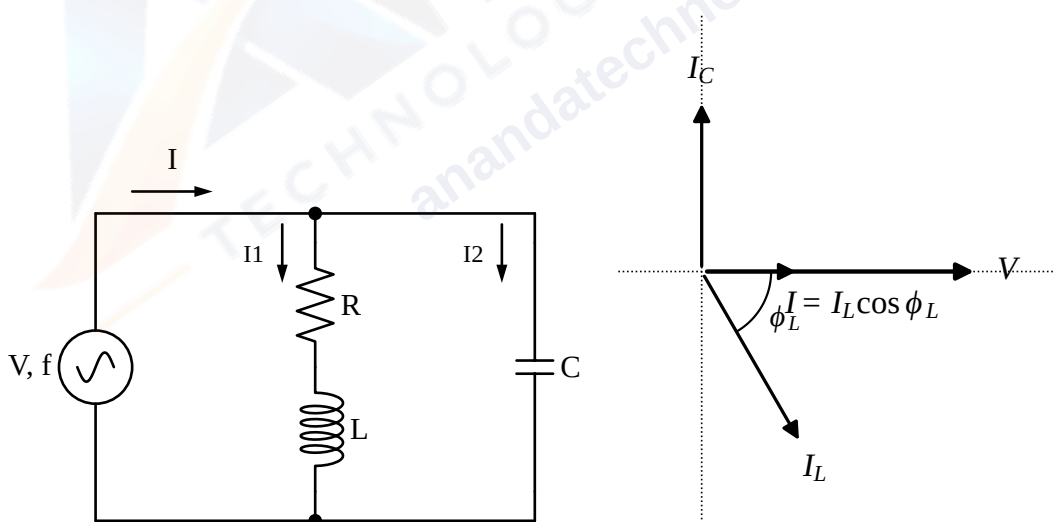
Half-power frequencies (exact): $f_{1,2} = \mp R/(4\pi L) + \sqrt{((R/4\pi L)^2 + f_r^2)}$, with $R/(4\pi L) = 11.937 \text{ Hz}$:

1. Lower half-power frequency $f_1 = -11.937 + \sqrt{(11.937^2 + 159.155^2)} = \mathbf{147.67 \text{ Hz}}$
2. Upper half-power frequency $f_2 = 11.937 + \sqrt{(11.937^2 + 159.155^2)} = \mathbf{171.54 \text{ Hz}}$
3. Check: $f_2 - f_1 = 23.873 \text{ Hz} = BW \checkmark$ and $\sqrt{f_1 f_2} = 159.155 \text{ Hz} = f_r \checkmark$

$f_r = 159.15 \text{ Hz}$, $I_0 = 20 \text{ A}$, $Q = 6.667$, $f_1 = 147.67 \text{ Hz}$, $f_2 = 171.54 \text{ Hz}$

b) Resonant frequency and dynamic impedance of parallel circuit.

4 M



Coil (R-L) in parallel with capacitor C

Phasor diagram at resonance

- Coil current $I_L = V/Z_L$, $Z_L = \sqrt{R^2 + X_L^2}$, lags V by ϕ_L ; capacitor current $I_C = V/X_C$ leads V by 90° .

- At resonance the supply current is in phase with V , so the reactive (quadrature) components cancel: $I_C = I_L \sin \phi_L$.
- $V/X_C = (V/Z_L)(X_L/Z_L) \Rightarrow Z_L^2 = X_L X_C = L/C \Rightarrow R^2 + (2\pi f_r L)^2 = L/C$
- $f_r = (1/2\pi)\sqrt{(1/LC - R^2/L^2)}$; if R is negligible, $f_r = 1/(2\pi\sqrt{LC})$.
- Supply current $I = I_L \cos \phi_L = (V/Z_L)(R/Z_L) = VR/Z_L^2 = VRC/L$.
- **Dynamic impedance $Z_D = V/I = L/(CR)$** — purely resistive and maximum; so line current is minimum.

(Diagram 1 M, f_r derivation 2 M, Z_D 1 M)

c) Single-phase vs three-phase.

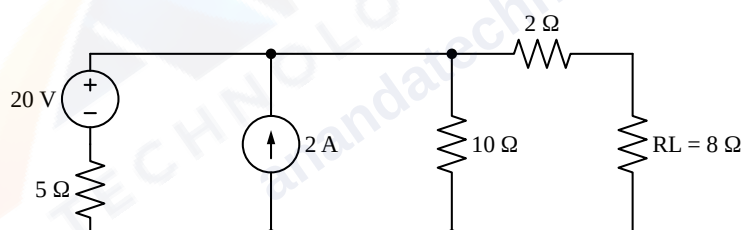
4 M

Point	Single-phase circuit	Three-phase circuit
Number of phases / wires	One phase; 2 wires (phase and neutral)	Three phases, 120° apart; 3 or 4 wires
Power delivered	Pulsating (zero twice per cycle)	Constant / uniform
Conductor material for same power	More	Less (about 75 %)
Motor starting	1-phase induction motor is not self-starting	3-phase induction motor is self-starting
Output of machine of same size	Less	About 1.5 times more
Efficiency and power factor	Lower	Higher

(Any four points, 1 M each)

d) Source transformation — current in 8Ω (Fig. No. 3).

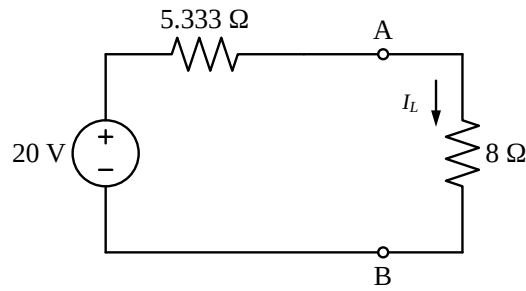
4 M



Given network

Reduce the network to the left of the load step by step using source transformation:

1. Voltage source 20 V in series with $5 \Omega \rightarrow$ current source $I = 20/5 = 4$ A in parallel with 5Ω .
2. Current source of 2 A is kept as it is (acting upwards).
3. 10Ω resistor is in parallel with the source(s).
4. Combining the parallel elements: $I_{eq} = 6$ A, $R_{eq} = 3.3333 \Omega \rightarrow$ converting back to voltage source: $V_{eq} = I_{eq} \times R_{eq} = 20$ V in series with 3.3333Ω .
5. Adding series resistance 2Ω : $V_{eq} = 20$ V in series with $R_{eq} = 5.3333 \Omega$.



Final equivalent circuit

Load current $I = 20/(5.3333 + 8) = 1.5 \text{ A}$

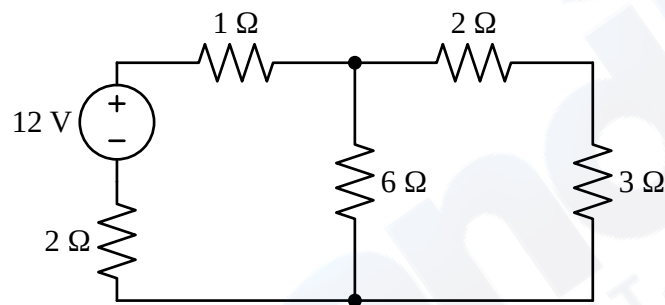
Current through $R_L = 8 \Omega = 1.5 \text{ A}$

(Each conversion step 1 M, final current 1 M)

e) Reciprocity theorem verification (Fig. No. 4).

4 M

Case 1: Source in source (2Ω) branch, current measured in 3Ω branch.

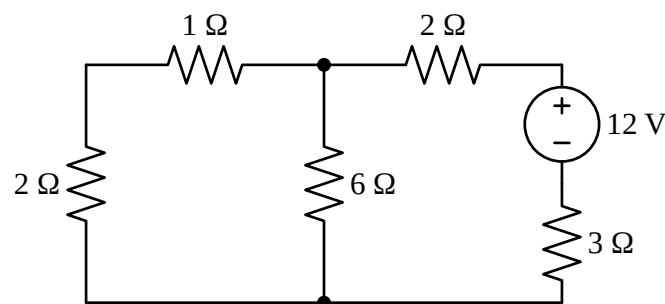


Case 1

- $2 + 3 = 5 \Omega$ (series)
- $6 \parallel 5 = (6 \times 5)/(6 + 5) = 2.727 \Omega$
- $1 + 2.727 = 3.727 \Omega$ (series)
- Current supplied by 12 V source $= 12/(2 + 3.727) = 2.0952 \text{ A}$
- Current passing on to the next section (current divider) $= 2.0952 \times 6/(6 + 5) = 1.1429 \text{ A}$

Current in 3Ω branch $I_1 = 1.1429 \text{ A}$

Case 2: Source shifted to 3Ω branch, current measured in source (2Ω) branch.



Case 2 (source and ammeter interchanged)

- $1 + 2 = 3 \Omega$ (series)
- $6 \parallel 3 = (6 \times 3)/(6 + 3) = 2 \Omega$

- $2 + 2 = 4 \Omega$ (series)
- Current supplied by 12 V source = $12/(3 + 4) = 1.7143 \text{ A}$
- Current passing on to the next section (current divider) = $1.7143 \times 6/(6 + 3) = 1.1429 \text{ A}$

Current in source (2Ω) branch $I_2 = \mathbf{1.1429 \text{ A}}$

Since $I_1 = I_2 = 1.1429 \text{ A}$, the transfer resistance $E/I = 12/1.1429 = 10.5 \Omega$ is the same in both cases.

Hence reciprocity theorem is verified.

Comment: The network is linear, bilateral and contains a single source, so interchanging the source and the response (ammeter) does not change the current.

(Case 1: 2 M, case 2: 1 M, verification 1 M)

Q.5

a) Variation of X_L , X_C , R , Z and I with frequency (series R-L-C).

6 M

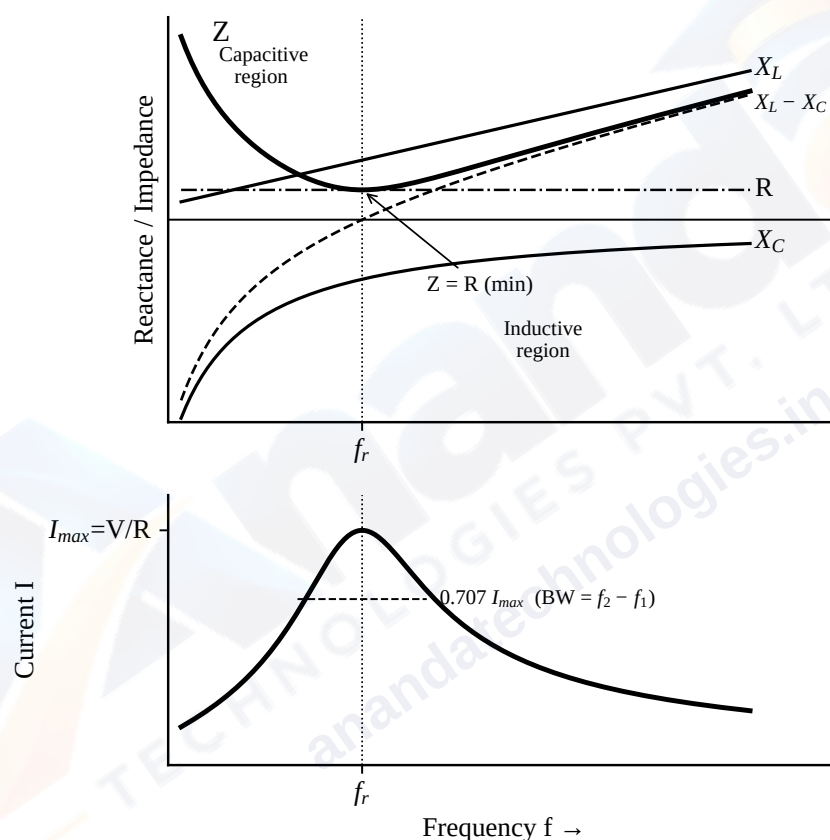


Fig.: Variation of X_L , X_C , X , R , Z (top) and current I (bottom) with frequency in series R-L-C circuit

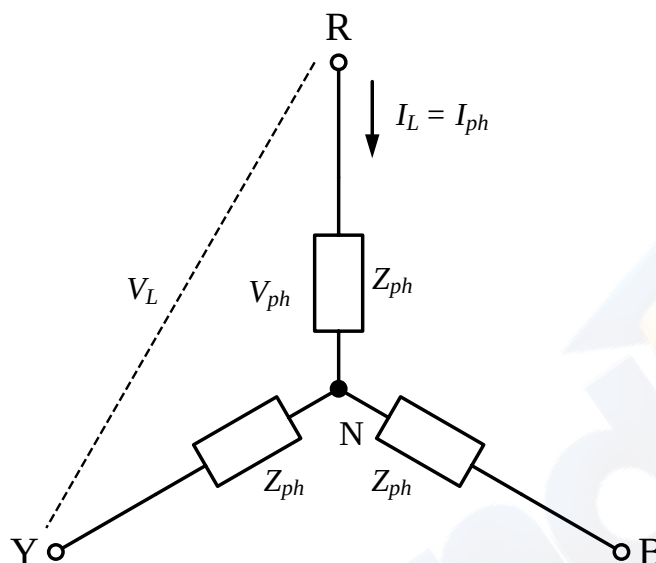
- $X_L = 2\pi fL$: increases linearly with frequency (straight line through origin).
- $X_C = 1/(2\pi fC)$: inversely proportional to frequency (rectangular hyperbola, drawn negative).
- **Net reactance $X = X_L - X_C$** : negative (capacitive) below f_r , zero at f_r , positive (inductive) above f_r .
- **R**: independent of frequency (horizontal line).
- **Impedance $Z = \sqrt{R^2 + X^2}$** : very high at low frequency, **minimum** = R at f_r , increases again above f_r .

- **Current $I = V/Z$:** maximum $I_{\max} = V/R$ at f_r and falls on both sides; the bell shaped curve is the resonance curve.
- **$f_r = 1/(2\pi\sqrt{LC})$:** resonant frequency where $X_L = X_C$; p.f. = 1.
- **Bandwidth** = $f_2 - f_1$ (half-power frequencies where $I = 0.707 I_{\max}$) = $R/(2\pi L)$.

(Graph 3 M, explanation 3 M)

b) Star load: 400 V, $I_L = 12$ A, 6 kW leading.

6 M



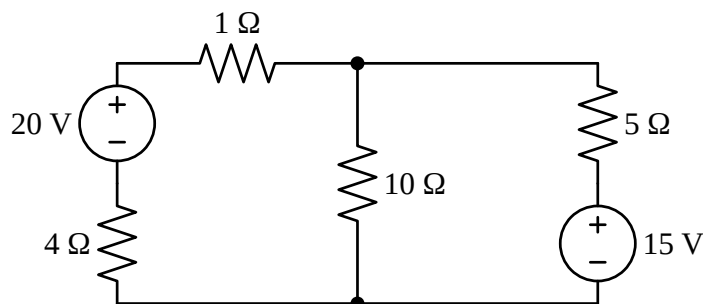
Star connected load

1. $P = \sqrt{3} V_L I_L \cos \phi \Rightarrow \cos \phi = P/(\sqrt{3} V_L I_L) = 6000/(\sqrt{3} \times 400 \times 12) = \mathbf{0.7217 \text{ leading}}$
2. $V_{ph} = V_L/\sqrt{3} = 230.94 \text{ V}$; $I_{ph} = I_L = 12 \text{ A}$ (star)
3. $Z_{ph} = V_{ph}/I_{ph} = 230.94/12 = \mathbf{19.245 \Omega}$
4. $R_{ph} = Z_{ph} \cos \phi = 19.245 \times 0.7217 = \mathbf{13.8889 \Omega}$
5. $X_{ph} = Z_{ph} \sin \phi = 19.245 \times 0.6922 = \mathbf{13.3218 \Omega}$ (capacitive)
6. Capacitance per phase $C = 1/(2\pi f X_C) = 1/(2\pi \times 50 \times 13.3218) = \mathbf{238.94 \mu F}$
7. Three-phase reactive power $Q = \sqrt{3} V_L I_L \sin \phi = \sqrt{3} \times 400 \times 12 \times 0.6922 = \mathbf{5755 \text{ VAR}}$ (5.755 kVAR)

(p.f. 1 M, Z_{ph} 1 M, R_{ph} 1 M, X_C 1 M, C 1 M, Q 1 M)

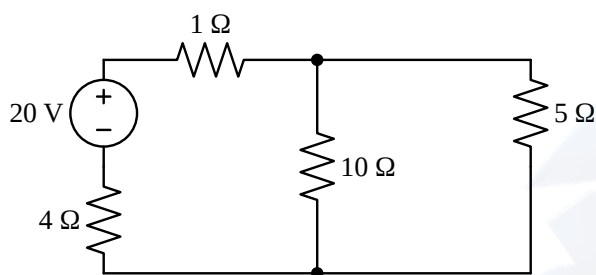
p.f. = 0.7217 lead, $R_{ph} = 13.889 \Omega$, $C = 238.94 \mu F$, $Q = 5.755 \text{ kVAR}$

c) Superposition — current in $10\ \Omega$ (Fig. No. 5).



Given network

Step 1: 20 V source acting alone (other voltage source short-circuited):

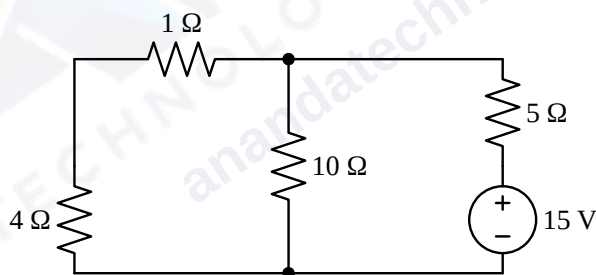


20 V source acting alone

- $10 \parallel 5 = (10 \times 5)/(10 + 5) = 3.333\ \Omega$
- $1 + 3.333 = 4.333\ \Omega$ (series)
- Current supplied by 20 V source = $20/(4 + 4.333) = 2.4\ \text{A}$
- Current in the required branch = $2.4 \times 5/(5 + 10) = 0.8\ \text{A}$

I_1' in $10\ \Omega = 0.8\ \text{A}$ downward

Step 2: 15 V source acting alone (other voltage source short-circuited):



15 V source acting alone

- $1 + 4 = 5\ \Omega$ (series)
- $10 \parallel 5 = (10 \times 5)/(10 + 5) = 3.333\ \Omega$
- Current supplied by 15 V source = $15/(5 + 3.333) = 1.8\ \text{A}$
- Current in the required branch = $1.8 \times 5/(5 + 10) = 0.6\ \text{A}$

I_2' in $10\ \Omega = 0.6\ \text{A}$ downward

Total current (algebraic sum, taking downward as positive):

Source acting	Current in 10 Ω
20 V source	0.8 A downward
15 V source	0.6 A downward
Total	1.4 A downward

Current through 10 Ω = 1.4 A (downward)

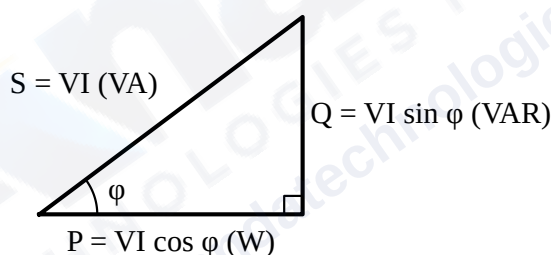
(Each source acting alone 2 M each, total 2 M)

Q.6

a) Types of power, power factor, power triangle; 10 kW at 0.8 p.f.

6 M

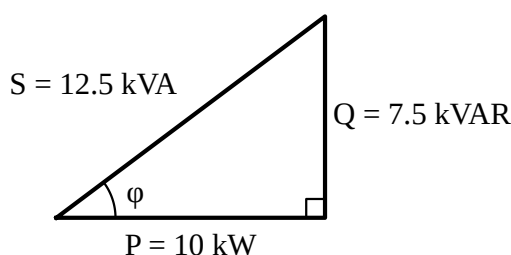
- **Active (true/real) power P:** power actually consumed (converted to heat, work) in the resistance. $P = VI \cos \phi = I^2 R$. Unit: watt (W), kW.
- **Reactive power Q:** power that flows back and forth between source and the inductance/capacitance; average value zero. $Q = VI \sin \phi = I^2 X$. Unit: volt-ampere reactive (VAR), kVAR.
- **Apparent power S:** product of RMS voltage and RMS current. $S = VI = I^2 Z = \sqrt{P^2 + Q^2}$. Unit: volt-ampere (VA), kVA.
- **Power factor:** cosine of the phase angle between voltage and current; also $= P/S = R/Z$. It is lagging for R-L (inductive) and leading for R-C (capacitive) circuits; its value lies between 0 and 1. Low p.f. means more current for the same power, so more copper loss and larger equipment rating.



Power triangle for R-L series circuit

Numerical:

1. Apparent power $S = P/\cos \phi = 10/0.8 = 12.5 \text{ kVA}$
2. $\sin \phi = \sqrt{1 - 0.8^2} = 0.6$; reactive power $Q = S \sin \phi = 12.5 \times 0.6 = 7.5 \text{ kVAR}$ (check: $\sqrt{P^2 + Q^2} = 12.5 \text{ kVA} \checkmark$)

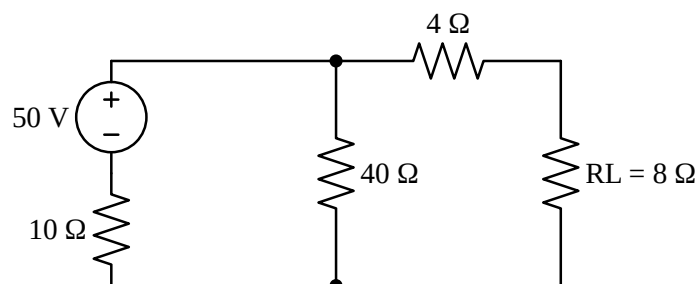


Power triangle for the given load ($\phi = 36.87^\circ$)

(Types of power 2 M, power factor 1 M, triangle 1 M, numerical 2 M)

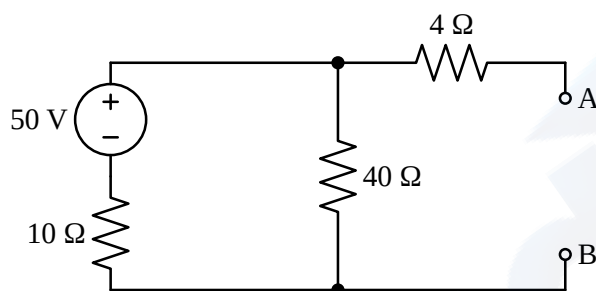
b) Thevenin's theorem and maximum power (Fig. No. 6).

6 M



Given network

Step 1: Find V_{Th} . Remove $R_L = 8\Omega$ and mark terminals A-B:



Load removed (A-B open)

Take the bottom line as reference node (0 V). Unknown node voltage(s): V_1 , V_2 . Applying KCL at each node (sum of currents leaving the node = 0):

At node V_1 : $(V_1 - 50)/10 + V_1/40 + (V_1 - V_2)/4 = 0$

At node V_2 : $(V_2 - V_1)/4 = 0$

Simplifying:

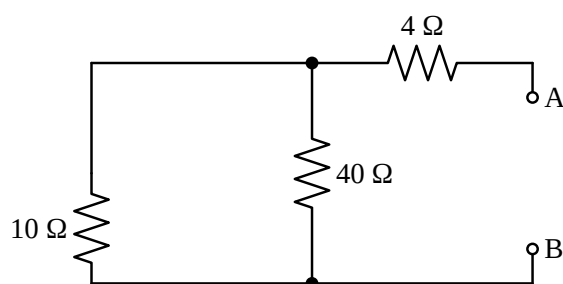
$$3V_1 - 2V_2 = 40 \quad \dots(1)$$

$$-V_1 + V_2 = 0 \quad \dots(2)$$

Solving: $V_1 = 40\text{ V}$, $V_2 = 40\text{ V}$

V_{Th} = voltage of the open-circuited terminal node = 40 V

Step 2: Find R_{Th} . Replace voltage sources by short circuits and current sources by open circuits:

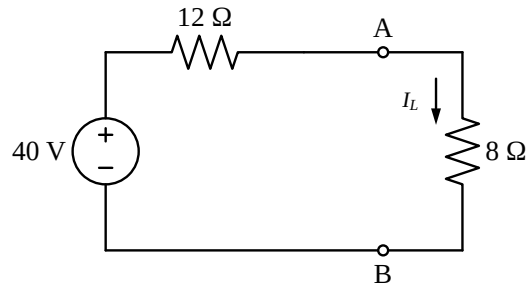


Sources replaced by internal resistances

- $40 \parallel 10 = (40 \times 10)/(40 + 10) = 8\Omega$

- $4 + 8 = 12 \Omega$ (series)
- $R_{Th} = 12 \Omega$

Step 3: Thevenin equivalent circuit and load current:



Thevenin equivalent with load

$$I_L = V_{Th} / (R_{Th} + R_L) = 40 / (12 + 8) = 2 \text{ A}$$

Current through $R_L = 8 \Omega = 2 \text{ A}$ (downward)

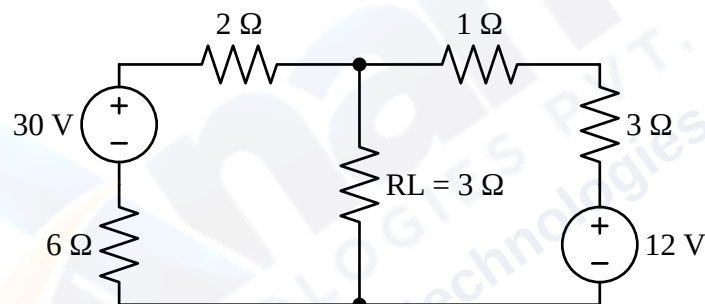
(V_{Th} 1 M, R_{Th} 1 M, I_L 2 M, R_L and P_{max} 2 M)

Maximum power: $R_L = R_{Th} = 12 \Omega$; $P_{max} = V_{Th}^2 / (4R_{Th}) = 40^2 / (4 \times 12) = 33.333 \text{ W}$

(With $R_L = 8 \Omega$ the load power is $I_L^2 R_L = 32 \text{ W}$, which is less than P_{max} .)

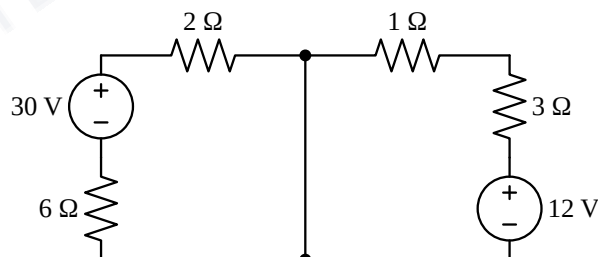
c) Norton's theorem — current in $R_L = 3 \Omega$ (Fig. No. 7).

6 M



Given network

Step 1: Find I_N . Remove $R_L = 3 \Omega$ and short-circuit its terminals:



Load terminals short-circuited

Take the bottom line as reference node (0 V). Unknown node voltage(s): V_1 , V_3 . Applying KCL at each node (sum of currents leaving the node = 0):

At node V_1 : $(V_1 - 30)/6 + V_1/2 = 0$

At node V_3 : $(V_3 - 12)/3 + V_3/1 = 0$

Simplifying:

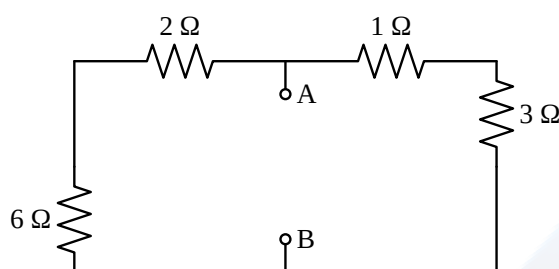
$$2 V_1 = 15 \quad \dots(1)$$

$$4 V_3 = 12 \quad \dots(2)$$

Solving: $V_1 = 7.5 \text{ V}$, $V_3 = 3 \text{ V}$

Short-circuit current (sum of currents flowing into the shorted terminals): $I_N = I_{SC} = (V_1)/2 + (V_3)/1 = (7.5)/2 + (3)/1 = \mathbf{6.75 \text{ A}}$

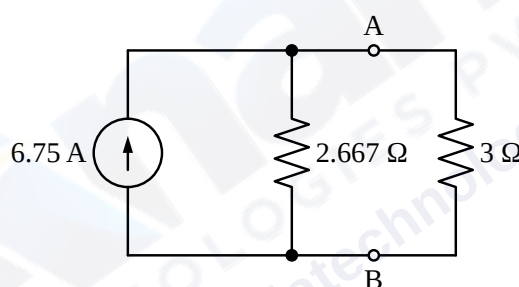
Step 2: Find R_N . Open the load terminals and replace sources by internal resistances:



Sources replaced by internal resistances

- $2 + 6 = 8 \Omega$ (series)
- $1 + 3 = 4 \Omega$ (series)
- $R_N = 8 \parallel 4 = (8 \times 4)/(8 + 4) = 2.667 \Omega$

Step 3: Norton equivalent and load current:



Norton equivalent with load

By current divider: $I_L = I_N \times R_N/(R_N + R_L) = 6.75 \times 2.6667/(2.6667 + 3) = \mathbf{3.1765 \text{ A}}$

Current through $R_L = 3 \Omega = 3.1765 \text{ A}$ (downward)

(I_N 2 M, R_N 2 M, equivalent circuit and I_L 2 M)

Note: This is a **model question paper prepared by Ananda Technologies** only for practice and exam preparation, based on the pattern of previous MSBTE question papers and the K-scheme syllabus. It is **not an official MSBTE paper**, and it does **not** mean that these questions will come in the exam. Answers follow standard textbook points; marks shown are indicative. Free for students — anandatechnologies.in