Summer – 2019 Examinations

Model Answer

Subject & Code: ELECTRICAL CIRCUITS (22324)

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.

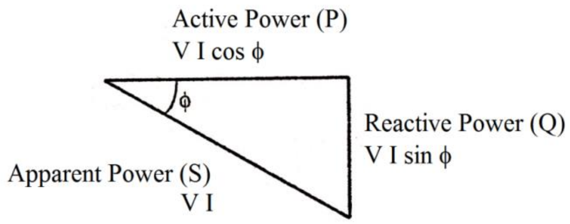
7) For programming language papers, credit may be given to any other program based on equivalent concept

Summer – 2019 Examinations
Model Answer
Subject & Code: ELECTRICAL CIRCUITS (22324)

1 Attempt any FIVE of the following: **10**

1 a) Draw power triangle for R-C series circuit. State the nature of power factor of this circuit.

Ans:



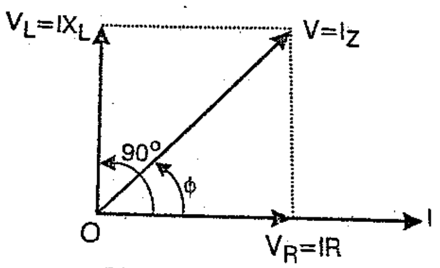
1 Mark for figure

Nature of Power-factor: **Leading**

1 Mark

1 b) Draw a phasor diagram for series R-L circuit showing supply voltage V, supply current I, voltage across resistor V_R and voltage across inductor V_L.

Ans –



Phasor Diagram

2 Marks for correct phasor diagram

1 c) What is current magnification in parallel R-L-C circuit?

Ans:

Current Magnification in Parallel R-L-C Circuit:

It is the ratio of current circulating between its branches to the line current drawn from the supply.

$$\text{Current magnification} = \frac{Current\ through\ individual\ L\ or\ C\ branch}{Total\ Current}$$

$$= \frac{I_L}{I} \text{ or } \frac{I_C}{I}$$

1 Mark for definition

OR

Current magnification in parallel resonant circuit is also known as Quality factor**.**

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

1 Mark for equation

1 d) Define: Phase sequence and write equations for instantaneous value of 3-ph voltages.

Ans:

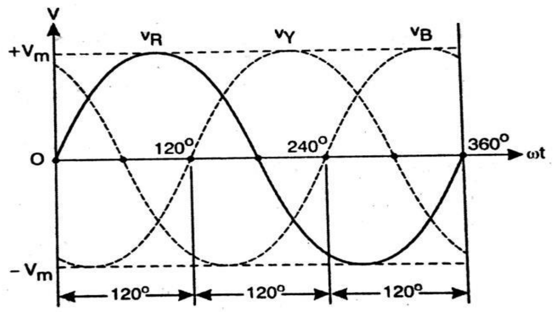
Phase sequence:

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.

In the following 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

1 Mark for definition

attains its positive maximum value. So the phase sequence is R-Y-B.



Equations for instantaneous value of 3-ph voltages:

$v_R = V_m \text{Sin}(\omega t)$ volt
$v_Y = V_m \text{Sin}(\omega t - 120^o)$ volt
$v_B = V_m \text{Sin}(\omega t - 240^o)$ volt
$= V_m \text{Sin}(\omega t + 120^o)$ volt

1 Mark for equations

1 e) Distinguish clearly between loop and mesh.

Ans:

Distinction between Loop & Mesh:

Sr. No.	Loop	Mesh
1	A loop is any closed path in a circuit, in which no node is encountered more than once	A mesh is a loop that has no other loops inside of it
2	Every loop is not a mesh	Every mesh is a loop
3	Loops are used in a more general way for circuit analysis	Meshes are used to analyze planar circuits

1 Mark for each of any two points = 2 Marks

1 f) State Thevenin's theorem.

Ans:

Thevenin's Theorem:

Any two terminal circuit having number of linear resistances 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 resistance R_{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 resistance R_{Th} is equal to the resistance 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.

2 Marks for correct statement

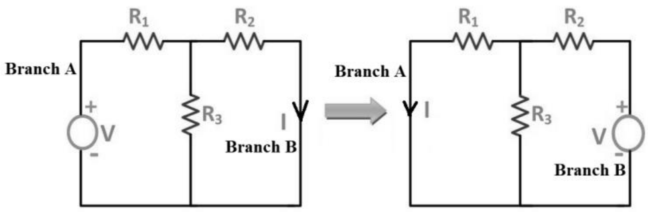
1 g) State Reciprocity theorem.

Ans:

Reciprocity theorem :

Reciprocity Theorem states that in any bilateral network if an **emf E or voltage source V** in one branch, say branch 'A' produces a **current I** in another branch, say branch 'B', then if the **emf E or voltage source**

V is moved from the branch A to the branch B, it will cause the same current I in the first branch 'A', where the emf has been replaced by a short circuit. — 1 Mark for statement



1 Mark for circuit

2 Attempt any THREE of the following: 12

2 a) An AC series circuit consisting of R = 15 Ω, L = 0.1 H and C = 80 μF is supplied from 230V, 50Hz power supply. Determine:
(i) Impedance of circuit
(ii) Current drawn by the circuit
(iii) Circuit power factor
(iv) Reactive power drawn by circuit

Ans:

Data Given: R = 15 Ω, L = 0.1 H, C = 80 μF = 80×10^{-6}F,
V = 230V, f = 50Hz

1 Mark for each bit = 4 Marks

(i) Impedance of circuit (Z):

$X_L = 2\pi fL$
$= 2 \times \pi \times 50 \times 0.1$
$\mathbf{X_L = 31.42\ \Omega}$
$X_C = 1 / (2\pi fC)$
$= 1 / (2 \times \pi \times 50 \times 80 \times 10^{-6})$
$\mathbf{X_C = 39.79\ \Omega}$
$Z = R + j(X_L - X_C) = 15+j(31.4 - 39.79)$
$\mathbf{= 15-j8.4 = 17.19\angle{-29.24°}\ \Omega}$

(ii) Current drawn by circuit:

$$I = \frac{V}{Z} = \frac{230\angle 0°}{17.19\angle -29.24°} = \mathbf{13.37\angle 29.24°A}$$

(iii) Circuit Power factor:

$$\cos\phi = \frac{R}{Z} = \frac{15}{17.19} = \mathbf{0.87\ (lead)} \quad \textbf{OR}$$
$$= \cos(29.24) = \mathbf{0.87\ (lead)}$$

(iv)Reactive power drawn by circuit:

$$P = VI\sin\phi = 230 \times 13.37 \times (0.48)$$
$$= \mathbf{1476.04\ watt}$$

2 b) An AC circuit consist of two branches in parallel.
Branch I: R = 10 Ω and L = 0.1 H in series
Branch II: C = 50μF.
If the circuit is supplied from 200V, 50Hz supply, determine:
(i) Branch impedances.
(ii) Branch currents
(iii) Circuit power factor
(iv) Power consumed by the circuit.

Ans:

Data Given: Branch I: R = 10 Ω and L = 0.1 H
Branch II: C = 50μF = 50 x 10^{-6} F
V = 200V, F = 50Hz

(i) Branch impedances (Z_1 and Z_2):

Inductive reactance $X_L = 2\pi fL$
$= 2 \times \pi \times 50 \times 0.1$
$\mathbf{X_L = 31.416\ \Omega}$

Capacitive reactance $X_C = 1 / (2\pi fC)$
$X_C = 1 / (2\pi \times 50 \times 50 \times 10^{-6})$
$\mathbf{X_C = 63.66\ \Omega}$

Impedance $Z_1 = (10 + j31.416)\ \Omega =$ **32.96 ∠72.34°Ω**
Impedance $Z_2 = 0 - j63.67\ \Omega =$ **63.67 ∠-90° Ω**

1 Mark for each bit = 4 Marks

(ii) Branch currents (I_1 and I_2) :

Branch 1 current (I_1): $I_1 = V / Z_1 = 200\angle 0^o / 32.96\ \angle 72.34^o$
$\mathbf{I_1 = 6.06\angle{-72.34°}\ A = (1.84 - j5.77)\ A}$

Branch 2 current (I_2): $I_2 = V / Z_2 = 200\angle 0^o / 63.67\ \angle{-90}^o$
$\mathbf{I_2 = 3.14\angle 90°\ A = (0 + j3.14)\ A}$

Total Current (I): $I = I_1 + I_2 = (\mathbf{1.84 - j5.77}) + (\mathbf{0\ + j3.14})$
$= \ 1.84 - j\ 2.63 = \ 3.21\angle{-55.02^0}A$

Angle between V and I is {0-(-55.02)} = 55.02°

(iii) Circuit power factor (cosϕ) :

cosϕ = cos(55.02°) = **0.573 lagging**

(iv) Power consumed by the circuit:

$P = V \times I \times \cos\phi = 200 \times 3.21 \times 0.573$
P = 367.86 watt

2 c) A star connected 3-ph load is supplied from 3-ph, 415V, 50Hz supply. If the line current is 20 A and total power taken from supply is 10 kW, then determine:
(i) Load resistance and reactance per phase.
(ii) Load power factor
(iii) Total 3-phase reactive power

Ans:

Data Given: $V_L = 415V$, f = 50Hz, $I_L = 20A$, P = 10 kW = 10000 W

In Star connection,
$V_L = \sqrt{3} \times V_{Ph}$ and $I_L = I_{Ph}$
Therefore, $V_{Ph} = V_L / \sqrt{3} = 415 / \sqrt{3}$ **= 239.6 Volt.**
And $I_L = I_{Ph}$ **= 20Amp.**
∴ Impedance per phase, $Z_{Ph} = V_{Ph} / I_{Ph} = 239.6 / 20$
$\mathbf{Z_{Ph} = 11.98\ \Omega}$

Total three-phase power is given by,
$P = 3V_{Ph}\, I_{Ph} \cos\phi$ **Or** $P = \sqrt{3}V_L\, I_L \cos\phi$
$10 \times 10^3 = 3 \times 239.6 \times 20 \times \cos\phi$
Therefore,
$\cos\phi = 10 \times 10^3 / (3 \times 239.6 \times 20)$

$\therefore \cos\phi = 0.695$

$\phi = \cos^{-1}(0.695) = \mathbf{45.97^o}$

(i) Load Resistance and Reactance per phase:

Resistance per phase (R_{ph}) = Z_{ph} x $\cos\phi$ = 11.98 x 0.695

$\mathbf{R_{ph} = 8.326\ \Omega}$

Reactance per phase (X_{ph}) = Z_{ph} x $\sin\phi$ = 11.98 x 0.718

$\mathbf{X_{ph} = 8.601\ \Omega}$

1 Mark for R_{Ph}
1 Mark for X_{Ph}
1 Mark for pf

(ii) Load Power Factor:

$\cos\phi = 0.695$ (lagging)

(iii) Total 3-phase reactive power:

$P_{reactive} = \sqrt{3} \times V_L \times I_L \times \sin\phi = 3\, V_{Ph}\, I_{Ph} \sin\phi$

$= \sqrt{3} \times 415 \times 20 \times \sin(45.97°)$

$= 10336.01$ VAR

$\mathbf{P_{reactive} = 10.336\ kVAR}$

1 Mark for Reactive power

2 d) Using Node analysis, find current I in the circuit shown in Fig. No. 1

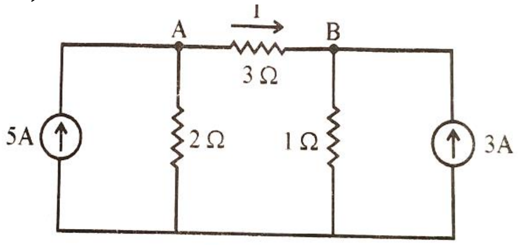


Fig. No. 1

Ans:

Apply KCL at node A

$$-5 + \frac{V_A}{2} + \frac{V_A - V_B}{3} = 0$$

$$V_A\left[\frac{1}{2} + \frac{1}{3}\right] - V_B\left[\frac{1}{3}\right] = 5$$

$$V_A[0.833] - V_B[0.33] = 5 \quad \text{.........................(1)}$$

1 Mark for Eq. (1)

Apply KCL at node B

$$\frac{V_B - V_A}{3} + \frac{V_B}{1} - 3 = 0$$

$$V_B\left[\frac{1}{3} + 1\right] - V_A\left[\frac{1}{3}\right] = 3$$

$$V_A[-0.33] + V_B[1.333] = 3 \text{........................(2)}$$

1 Mark for Eq. (2)

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

$$\begin{bmatrix} 0.833 & -0.33 \\ -0.33 & 1.333 \end{bmatrix} \begin{bmatrix} V_A \\ V_B \end{bmatrix} = \begin{bmatrix} 5 \\ 3 \end{bmatrix}$$

$$\therefore \Delta = \begin{vmatrix} 0.833 & -0.33 \\ -0.33 & 1.333 \end{vmatrix} = 1.1079 - 0.1089 = 0.999$$

By Cramer's rule,

$$V_A = \frac{\begin{vmatrix} 5 & -0.33 \\ 3 & 1.333 \end{vmatrix}}{\Delta} = \frac{(5\times1.333)-(3\times-0.33)}{0.999} = \frac{6.665+0.99}{0.999} = \mathbf{7.662\ volt}$$

$$V_B = \frac{\begin{vmatrix} 0.833 & 5 \\ -0.33 & 3 \end{vmatrix}}{\Delta} = \frac{(0.833\times3)-(-0.33\times5)}{0.999} = \frac{2.499+1.65}{0.999} = \mathbf{4.153\ volt}$$

1 Mark for V_A & V_B

Current through branch AB (3Ω) = $(V_A - V_B)/3$ = (7.662 – 4.153)/3
= 1.169 A from A to B

1 Mark for I

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

3 a) A series R-L-C circuit consists of R = 15 Ω, L = 0.5 H and C = 25μF. If the circuit is supplied from 230V, 50 Hz AC supply, determine:

(i) Circuit power factor
(ii) Active power
(iii) Reactive power
(iv) Apparent power

Ans:

Data Given: R = 15 Ω, L = 0.5 H, C = 25μF = 25×10^{-6}F
V = 230V, f = 50 Hz

(i) Circuit power factor:

1 Mark for each bit = 4 Marks

$X_L = 2\pi fL = 2\times\pi\times50\times0.5 = 157.08\ \Omega$

$X_c = \frac{1}{2\pi fC} = \frac{1}{2\times\pi\times50\times25\times10^{-6}} = 127.32\ \Omega$

$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{15^2 + (157.08 - 127.32)^2}$
$= 33.326\ \Omega$

Circuit power factor $\cos\phi = \frac{R}{Z} = \frac{15}{33.326}$ = **0.45 (lagging)**

Power factor angle $\phi = \cos^{-1}(0.45) = 63.25°$

(ii) Active Power (P):

Circuit current $I = \frac{V}{Z} = \frac{230}{33.326}$ = 6.901 A

P = VI cos ϕ = 230 × 6.901 × 0.45
= **714.25 W**

(iii) Reactive Power (Q):

Q = VI sin ϕ = 230 × 6.901 × sin(63.25°)
= **1417.36 VAR**

(iv) Apparent Power (S):

Apparent Power = S = VI = 230 × 6.901 = **1587.23 VA**

3 b) Two parallel impedances Z_1 = (10 + j8) Ω and Z_2 = (15 – j10) Ω are connected to 230V, 50 Hz AC supply. Using admittance method, calculate branch currents, total current and power factor of whole circuit.

Ans:

Data Given: Z_1 = (10 + j8) Ω = 12.806∠38.66° Ω
Z_2 = (15 – j10) Ω = 18.03∠-33.69° Ω
V = 230∠0° V, f = 50 Hz

$$Y_1 = \frac{1}{Z_1} = \frac{1}{12.806\angle 38.66°} = 0.078\angle -38.66°\ \mho = (0.06 - j0.049)\mho$$

$$Y_2 = \frac{1}{Z_2} = \frac{1}{18.03\angle -33.69°} = 0.055\angle 33.69°\ \mho = (0.046 + j0.031)\mho$$

$Y = Y_1 + Y_2 = G + jB = 0.06 - j0.049 + 0.046 + j0.031 = 0.106 - j0.018$
$= 0.1075\angle -9.64°\mho$

1 Mark for each bit = 4 Marks

(i) Current I_1 flowing through admittance Y_1:

$= V \times Y_1 = (230\angle 0°) \times (0.078\angle -38.66°)$

$I_1 = 17.94\angle -38.66°\ A = (14 - j\ 11.21)\ A$

(ii) Current I_2 flowing through admittance Y_2:

$= V \times Y_2 = (230\angle 0°) \times (0.055\angle 33.69°)$

$I_2 = 12.65\angle 33.69°\ A = (10.53 + j\ 7.02)\ A$

(iii) Total Current (I):

$I = V \times Y = (230\angle 0°) \times (0.1075\angle -9.64°) = \mathbf{24.725\angle -9.64°\ A}$

OR

$I = I_1 + I_2 = (14 - j\ 11.21) + (10.53 + j\ 7.02)$

$= (24.53 - j\ 4.19) = \mathbf{24.89\angle -9.69°\ A}$

(iv) Power factor ($\cos\phi$)

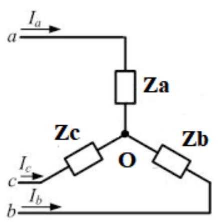
ϕ = voltage ref. angle - current angle = $0 - (-9.64°) = 9.64°$

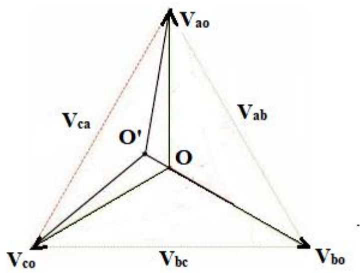
Therefore, Power factor = $\cos(9.64°)$ = **0.986 (lagging)**

3 c) Explain 'Neutral Shift' in case of 3-phase star-connected unbalanced load.

Ans:

Neutral Shift:





1 Mark for phasor diagram

Electrically "Neutral" means no resultant charge or zero potential condition. When three impedances are connected in star, there is a common point "O" where one end of each impedance is connected. This common point is called star point. Other remaining ends are connected to the three-phase supply terminals, as shown above.

When the three-phase supply voltage is balanced and three impedances Z_a, Z_b and Z_c are identical i.e $Z_a = Z_b = Z_c = Z$, then all the three impedances carry equal currents but displaced from each other by 120°. Thus currents are balanced, phase voltages are also balanced and the star point "O" is held at zero potential. Even if this point "O" is not connected to neutral, its potential is zero. Therefore, this point is referred as neutral. In other words we can say that under balanced condition (i.e when both supply voltage and load are balanced), the neutral point appears at physical common or star point "O".

3 Marks for explanation

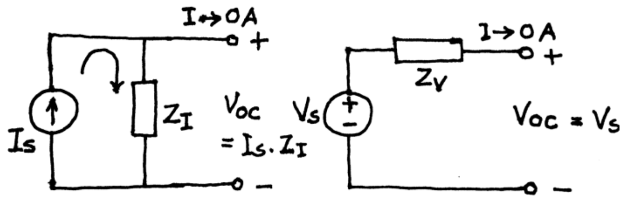
When the three-phase supply voltage is balanced but three impedances Z_a, Z_b and Z_c are not identical i.e $Z_a \neq Z_b \neq Z_c$, then the three impedances carry unequal currents. Thus currents are unbalanced, phase voltages then get unbalanced and the star point "O" can not be maintained at zero potential, rather it has some nonzero potential. Therefore, this point "O" can not be now referred as neutral. However, it is observed that there is some another point O' at which the potential is zero. So this point O' is now referred as neutral. In other words we can say that under unbalanced condition, the neutral point get shifted from star point "O" to some other point O', as shown in the phasor diagram. This is referred as "Neutral Shift".

3 d) With neat circuit diagram, explain how to convert voltage source into current source and vice-versa.

Ans:

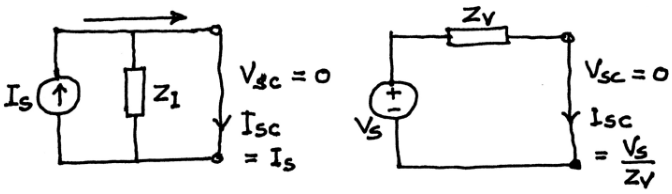
Conversion of voltage source into equivalent current source & vice-versa:

Let V_S be the practical voltage source magnitude and
Z_V be the internal series impedance of the voltage source.
I_S be the equivalent current source magnitude and
Z_I be the internal parallel impedance of current source.



1 mark

The open circuit terminal voltage of voltage source is $V_{OC} = V_S$
The open circuit terminal voltage of current source is $V_{OC} = I_S \times Z_I$
Therefore, we get $V_S = I_S \times Z_I$ ……………………………(1) ½ mark



1 mark

The short circuit output current of voltage source is $I_{SC} = V_S / Z_V$
The short circuit output current of current source is $I_{SC} = I_S$
Therefore, we get $I_S = V_S / Z_V$ ……………………………(2)
Therefore, we get $V_S = I_S \times Z_V$……………………………(3) ½ mark
On comparing eq. (1) and (3), it is clear that $Z_I = Z_V = Z$ ….. …..(4) ½ mark
Thus the internal impedance of both the sources is same, and the magnitudes of the source voltage and current are related by Ohm's law,

$$V_S = I_S \times Z$$ ½ mark

3 e) Using mesh analysis, find current I in the circuit shown in Fig No.2

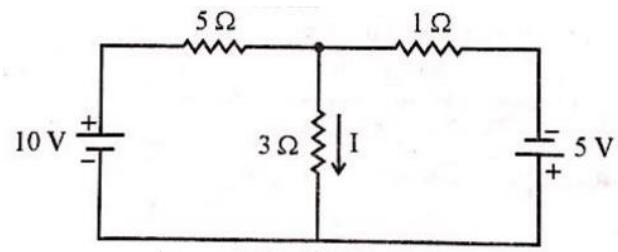
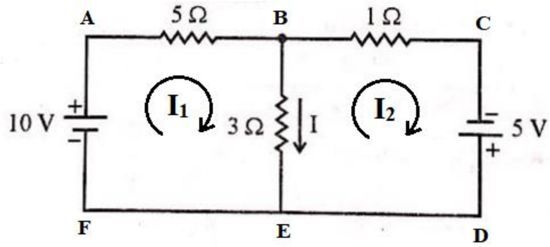


Fig. No. 2

Ans:



By applying KVL to loop ABEFA

$$10 - 5I_1 - 3(I_1 - I_2) = 0$$
$$8I_1 - 3I_2 = 10 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

1 Mark for Eq. 1

By applying KVL to Loop DCBED

$$-5 + 1I_2 + 3(I_2 - I_1) = 0$$
$$-3I_1 + 4I_2 = 5 \quad \ldots\ldots\ldots\ \ldots\ldots\ldots\ldots\ldots (2)$$

1 Mark for Eq. 2

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

$$\begin{bmatrix} 8 & -3 \\ -3 & 4 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 10 \\ 5 \end{bmatrix}$$

$$\therefore \Delta = \begin{vmatrix} 8 & -3 \\ -3 & 4 \end{vmatrix} = 32 - (9) = 23$$

By Cramer's rule,

$$I_1 = \frac{\begin{vmatrix} 10 & -3 \\ 5 & 4 \end{vmatrix}}{\Delta} = \frac{(10 \times 4) - (5 \times -3)}{23} = \frac{40 + 15}{23} = \mathbf{2.39\ A}$$

½ Mark

$$I_2 = \frac{\begin{vmatrix} 8 & 10 \\ -3 & 5 \end{vmatrix}}{\Delta} = \frac{(8 \times 5) - (10 \times -3)}{23} = \frac{40 + 30}{23} = \mathbf{3.043\ A}$$

½ Mark

Current flowing through resistance of 3Ω = (I_2 – I_1) = (3.043 – 2.39)
= 0.653 A from E to B
= -0.653A from B to E

1 Mark

4 Attempt any THREE of the following: **12**

4 a) An inductive coil having resistance of 5Ω and inductance of 0.2 H is connected in series with a capacitor of 20µF. If this combination is connected to 230 V, variable frequency supply, determine:

(i) Resonant frequency
(ii) Quality factor
(iii) Current at resonance
(iv) Voltage across inductive coil at resonance.

Ans:

Data Given: R = 5Ω , L= 0.2 H, C = 20 μF = $20 \times 10^{-6} F$, V=230 V

i) Resonant Frequency:

Resonant frequency = $f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\times3.142\sqrt{0.2\times20\times10^{-6}}}$ = **79.58 Hz** — 1 Mark

ii) Quality factor:

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

Q factor = $\frac{1}{5}\sqrt{0.2/(20\times10^{-6})}$ = **20** — 1 Mark

iii) Current:

At resonance R=Z

∴ Current I =V/Z = 230/5 = **46 A** — 1 Mark

iv) Voltage across inductive coil at resonance:

Inductive reactance of coil at resonance $X_L = 2\pi f_r L$

$X_L = 2\pi(79.58)(0.2) = 100\ \Omega$

Impedance of inductive coil at resonance, $Z = R + jX_L$

$Z = 5+j100 = 100.125\angle 87.14°$

Voltage across inductive coil at resonance, — 1 Mark

$V_L = I Z = 46(100.125)$ = **4605.75 volt**

4 b) A coil having resistance of 10 Ω and inductance of 0.15 H is connected in parallel with R-C series combination having R= 5Ω and C = 20 μF. If supply voltage is 110 V, 50Hz, then

(i) Draw circuit diagram

(ii) Calculate branch currents using impedance method

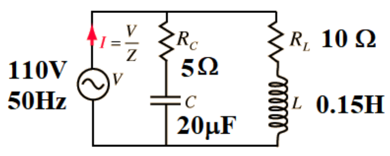
(iii) Power absorbed by the coil

Ans:

Data Given: $R_L = 10\ \Omega$, L= 0.15 H, $R_C = 5\ \Omega$, C = 20 μF = $20 \times 10^{-6} F$

V=110∠0° V, f = 50Hz

Circuit Diagram:



1 Mark for circuit diagram

Branch Currents:

Inductive reactance, $X_L = 2\pi fL = 2\pi\times50\times0.15 = 47.124\ \Omega$

Capacitive reactance, $X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi\times50\times20\times10^{-6}} = 159.155\ \Omega$

Impedance of inductive coil,

$Z_L = R_L + jX_L = 10+j47.124 = 48.17\angle 78.02°\ \ \Omega$

Impedance of R-C series combination,

$Z_C = R_C - jX_C = 5-j159.155 = 159.23\angle -88.20°\ \ \Omega$

Inductive coil current is given by,

$I_L = \frac{V}{Z_L} = \frac{110\angle 0°}{48.17\angle 78.02°}$ = **2.28∠-78.02° A = (0.47-j2.23) A** — 1 Mark for I_L

	Capacitive branch current is given by, $I_C = \frac{V}{Z_C} = \frac{110\angle 0°}{159.23\angle -88.20°}$ **= 0.69∠88.20° A = (0.0217+j0.69) A**	1 Mark for I_C
	Power absorbed by the coil: P_{coil} $=V\times I_L\times\cos\phi_1 = 110\times 2.28\times\cos(78.02)$ = **52.06 watt** **OR** $= (I_L)^2 R_L = (2.28)^2\,(10)$ **= 51.984 watt** **(NOTE: Examiner is requested to ignore the round-off errors)**	1 Mark for P_{coil}
4 c)	Three equal impedances having R = 20 Ω in series with C = 50 μF are connected in delta across 415 V, 3-ph, 50 Hz AC supply. Determine: i) Impedance per phase ii) Phase and line currents iii) Total 3-ph power consumed by load	
	Ans: **Data Given:** $R_{ph} = 20\ \Omega$, $C = 50\ \mu F = 50\times 10^{-6} F$, $V_L = 415$ V , f = 50 Hz	
	X_C per phase $= \frac{1}{2\pi fC} = \frac{1}{2\pi\times 50\times 50\times 10^{-6}}$ = **63.66 Ω**	½ Mark
	∴ **Impedance per phase, Z_{ph}** $= \sqrt{R_{ph}^2 + X_c^2} = \sqrt{20^2 + 63.66^2}$ = **66.73 Ω**	1 Mark
	For delta connected load Phase voltage $=V_{ph} = V_L = 415$ V **Phase current, I_{ph}** $= \frac{V_{ph}}{Z_{ph}} = \frac{415}{66.73}$ = **6.22 A**	½ Mark for I_{Ph}
	Line current, I_L $= \sqrt{3}\times I_{ph} = \sqrt{3}\times 6.22$ = **10.77 A** Load power factor, $\cos\phi = \frac{Rph}{Zph} = \frac{20}{66.73} = 0.2997$ (leading)	1 Mark for I_L
	Total 3-ph Power consumed by load, $P_{3\phi} = \sqrt{3}\times V_L\times I_L\times\cos\phi = \sqrt{3}\times 415\times 10.77\times 0.2997$ =**2320.12 W** **OR** $=3\times Vph\times Iph\times\cos\phi = 3\times 415\times 6.22\times 0.2997$ = **2320.85 W** **(NOTE: Examiner is requested to ignore the round-off errors)**	1 Mark
4 d)	With neat circuit diagram, explain the concept of duality in electric circuit. State any four examples (pairs) of duality in electric circuit. **Ans:** **Concept of duality:**	
	When the two circuit elements are represented by mathematical equations of similar nature, then these elements are called dual elements of each other.	1 Mark
	Examples: (i) A resistance is represented by mathematical equation based on Ohm's law as, R = V/I and the conductance is represented by G = I/V.	
	(ii) A voltage across an inductance is represented by $v = L\frac{di}{dt}$ and the current through a capacitor is represented by $i = C\frac{dv}{dt}$ On comparing the above equations we can form pairs of dual elements or quantities: Resistance R ⟷ Conductance G Inductance L ⟷ Capacitance C Voltage v ⟷ Current i	1 Mark

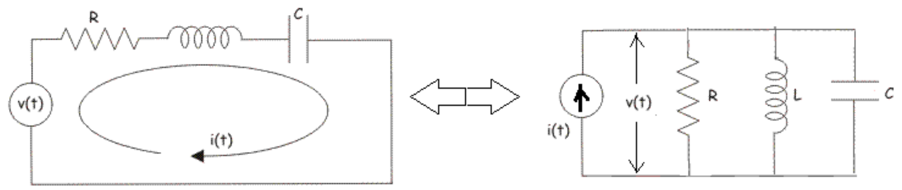
Similarly, we can apply this concept to electric circuits and say that when the two circuits are represented by similar mathematical equations, then such circuits are called dual circuits of each other. 1 Mark

Consider a series R-L-C circuit, the voltage equation can be written as:

v(t) = R.i(t) + $L\frac{di(t)}{dt} + \frac{1}{C}\int i(t)dt$ ………………………….(1)

Consider a parallel R-L-C circuit, the current equation can be written as:

i(t) = $\frac{1}{R}v(t) + C\frac{dv(t)}{dt} + \frac{1}{L}\int v(t)dt$ ………………………….(2)



1 Mark

On comparing equations (1) & (2), it is seen that both the equations are integro-differential equations of similar kind. Therefore, the two circuits are dual circuits. The dual element pairs are:

Voltage source v(t) ⟵⟶ Current source i(t)
Resistance (R) ⟵⟶ Conductance (G = 1/R)
Inductance (L) ⟵⟶ Capacitance (C)
Series Circuit ⟵⟶ Parallel circuit

Examples of duality in electric circuit

- voltage – current
- parallel circuit – series circuit
- resistance – conductance
- voltage division – current division
- impedance – admittance
- capacitance – inductance
- reactance – susceptance
- short circuit – open circuit
- Kirchhoff’s Voltage law – Kirchhoff’s Current law
- Mesh – Node
- Thevenin’s theorem – Norton’s theorem

1 Mark for any four pairs

5 Attempt any TWO of the following: **12**

5 a) An inductive coil having resistance of 10 Ω and inductance of 0.5 H is connected in parallel with a capacitor of 50 μF. Determine:

(i) Parallel resonant frequency.
(ii) Quality factor of parallel circuit
(iii) Power consumed by circuit at resonance, if the supply voltage is 230V.

Ans:

Data Given:

R= 10 Ω, L=0.5 H, C=50 μF, V = 230V

i) Parallel resonant frequency

$f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$ 1 Mark

$= \frac{1}{2\pi}\sqrt{\frac{1}{0.5\times50\times10^{-6}} - \frac{10^2}{0.5^2}}$

= 31.67 Hz 1 Mark

ii) Quality factor of parallel circuit

Q factor = $\frac{2\pi L f_r}{R}$ 1 Mark

$= \frac{2\pi\times0.5\times31.67}{10}$

= 9.949 1 Mark

iii) Power consumed by circuit at resonance:

Reactance of coil = $X_L = 2\pi f_r L = 2\pi(31.67)(0.5) = 99.49\Omega$ 1 Mark

Impedance of coil = $Z = R + j\,X_L = (10 + j99.49) = 99.99\angle 84.26°\Omega$ 1 Mark

OR

Current flowing through rthe coil I = V/Z = 230/99.99 = 2.3A 1 Mark

Power consumed by circuit at resonance = Power consumed by coil resistance = $I^2 R = (2.3)^2(10) =$ **52.9 W** 1 Mark

5 b) Reduce the network shown in Fig. No. 3 by applying Star/Delta or Delta/Star transformation and determine equivalent resistance R_{AB}.

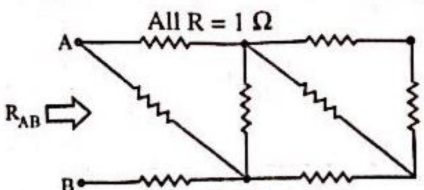
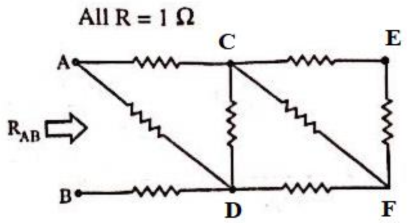


Fig. No. 3

Ans:

(NOTE: This problem can be solved without using Star/Delta or Delta/Star transformations. However, since it is asked to use the transformation, the marks are awarded only if student has solved this problem using at least one Star/Delta or Delta/Star transformation)



The resistance R_{CE} and R_{EF} are in series.

$\therefore R_{CF1} = 1 + 1 = 2\Omega$

There is another path from C to F directly through 1 Ω.

$\therefore R_{CF2} = 1\ \Omega$

Since the two paths from C to F are in parallel,

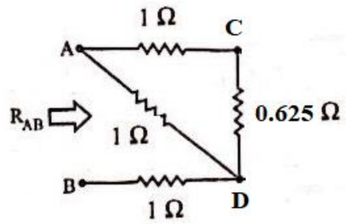
$R_{CF} = R_{CF1} \parallel R_{CF2} = 2\|1 = (2)(1)/(2+1) = 2/3 = 0.667\Omega$

This R_{CF} appears in series with R_{FD}

$\therefore R_{CD1} = R_{CF} + R_{DF} = 0.667 + 1 = 1.667\Omega$

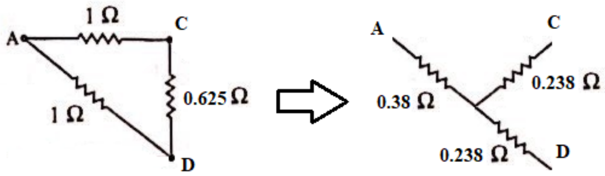
Summer – 2019 Examinations
Model Answer
Subject & Code: ELECTRICAL CIRCUITS (22324)

There is another path from C to D directly through 1 Ω.
$\therefore R_{CD2} = 1\ \Omega$
Since the two paths from C to D are in parallel,
$R_{CD} = R_{CD1} \parallel R_{CD2}$ = 1.667||1 = (1.667)(1)/(1.667+1) = 1.667/2.667 = 0.625Ω

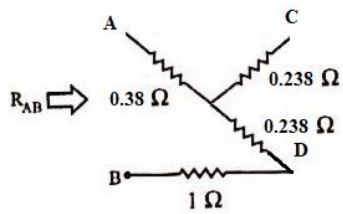


2 Marks

Converting Delta ACD into equivalent Star,
$R_C = (R_{AC}.R_{CD})/(R_{AC}+R_{CD}+R_{DA})$ = (1)(0.625)/(1+0.625+1) = 0.625/2.625
R_C = 0.238Ω
$R_A = (R_{AC}.R_{DA})/(R_{AC}+R_{CD}+R_{DA})$ = (1)(1)/(1+0.625+1) = 1/2.625
R_A = 0.38Ω
$R_D = (R_{CD}.R_{DA})/(R_{AC}+R_{CD}+R_{DA})$ = (0.625)(1)/(1+0.625+1) = 0.625/2.625
R_D = 0.238Ω



3 Marks



$R_{AB} = R_A + R_D + R_{DB}$ = 0.38 + 0.238 + 1 = 1.618Ω
R_{AB} = 1.618 Ω

1 Mark

5 c) For network shown in Fig. No. 4, determine value of R so that maximum power is delivered to it. Also compute the maximum power delivered.

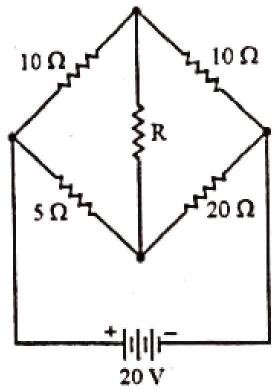
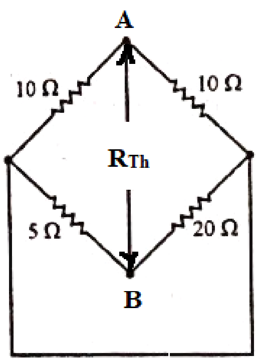
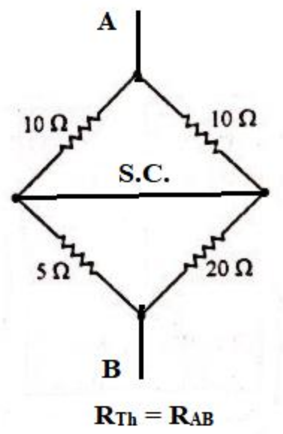


Fig. No. 4

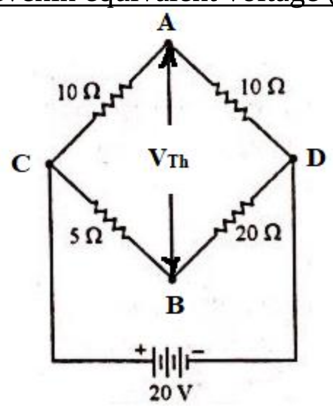
Ans:
According to the maximum power transfer theorem, the maximum power will be transferred to the resistance R only when the value of R is equal to the Thevenin equivalent resistance R_{Th} of the remaining circuit seen between the open-circuited terminals of the resistance R with all internal independent sources replaced by their respective internal resistances, i.e ideal voltage source by short-circuit (S.C.) & ideal current source by open-circuit (O.C.).





From the simplified circuit, we can write,
R_{Th} = (10||10) + (5||20) = (100/20) + (100/25) = 5 + 4 = **9Ω** 2 Marks
∴ For maximum power transfer R = R_{Th} = 9 Ω
Computation of Maximum power delivered:
The current that can flow through R can be determined by using Thevenin theorem. The circuit excluding R can be represented by simple Thevenin equivalent circuit comprising a voltage source V_{Th} in series with resistance R_{Th}.

A) Determination of Thevenin equivalent voltage (V_{Th}):



Current flowing through path CAD: I_1 = 20/(10+10) = 20/20 = 1A
Current flowing through path CBD: I_2 = 20/(5+20) = 20/25 = 0.8A
Voltage between terminals A & D : V_{AD} = I_1 (10) = 1(10) = 10V
Voltage between terminals B & D : V_{BD} = I_2 (20) = 0.8(20) = 16V
It is seen that potential of A is 10V above that of D and potential of B is 16V above that of D. Therefore, point B is at higher potential

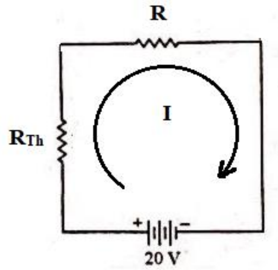
than A by 6V. i.e $V_{Th} = V_{BA} = V_{BD} - V_{AD} = 16 - 10 = 6V$ — 1 Mark for V_{Th}

$$\therefore \mathbf{V_{Th} = 6V}$$

B) Determination of Thevenin equivalent resistance (R_{Th}):
It is already computed above..

$$\therefore \mathbf{R_{Th} = 9\ \Omega}$$

C) Thevenin equivalent circuit :



2 Marks for Thevenin eq. circuit

Circuit current $I = V/(R_{Th}+R) = 20/(9+9) = 20/18 = 1.11A$

Maximum Power delivered to R = $\mathbf{P_{Rmax} = I^2 R}$

$$\mathbf{= (1.11)^2 (9) = 11.09\ watt}$$

1 Mark for max. power

6	**Attempt any TWO of the following:**		**12**

6 a) A series RLC circuit consists of R = 10 Ω, L = 0.5 H and C = 20 μF is connected to 230V, variable frequency supply. Determine:

(i) Resonant frequency
(ii) Voltage magnification
(iii) Current drawn by the circuit
(iv) Voltage across each element
(v) Power factor at resonance
(vi) The power consumed at resonance.

Ans:

i) Resonant Frequency:

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

$$\therefore f_r = \frac{1}{2\pi\sqrt{(0.5 \text{ x } 20\text{x } 10^{-6})}} = \mathbf{50.33\ Hz}$$

ii) Voltage Magnification:

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

$$= \frac{1}{10}\sqrt{\frac{0.5}{20\times 10^{-6}}}$$

$$\mathbf{= 15.81}$$

1 Mark for each bit = 6 Marks

iii) Current drawn by the circuit:

At resonance $R = Z$

$$\therefore \text{Current } I = \frac{V}{Z} = \frac{230}{10} = \mathbf{23\ A}$$

iv) Voltage across each element:

$V_R = I.R = 23\times10 = \mathbf{230V}$

$V_L = I.X_L = I\times2\pi f_r L = 23\times2\pi\times50.33\times0.5 = \mathbf{3636.68V}$

$V_C = I.X_C = I\times1/(2\pi f_r C)$

$= 23\times1/(2\pi\times50.33\times20\text{x } 10^{-6}) = \mathbf{3636.56V}$

v) Power factor at resonance

At Resonance p.f $= \mathbf{1}$

vi) Power at resonance:

At Resonance p.f $= 1$

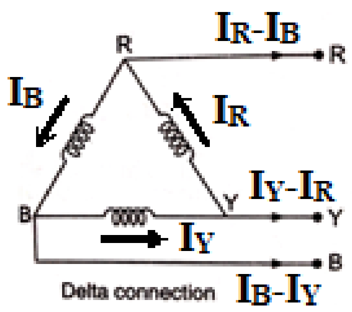
$\therefore \ P = V \times I = 230 \times 23 = \mathbf{5290\ W}$

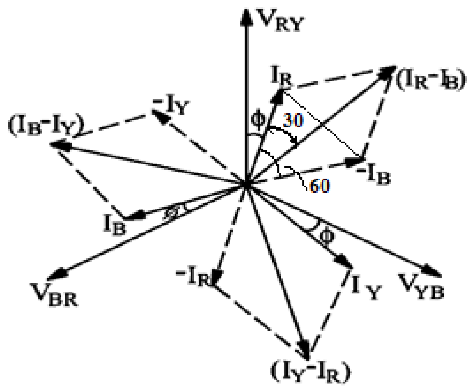
6 b) Draw complete phasor diagram of voltages & currents for balanced delta-connected load and prove the relation between:

(i) Line current and Phase current

(ii) Line voltage and Phase voltage

Ans:





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

1 Mark for circuit diagram

2 Marks for Phasor diagram

(i) Line current and Phase current:

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 $I_{L1} = I_R - I_B$

Current in line Y is $I_{L2} = I_Y - I_R$

Current in line B is $I_{L3} = I_B - I_Y$

Current in line R is found by compounding I_R and I_B and value given by parallelogram in phasor diagram.

Angle between I_R and $-I_B$ is $60°$,

where $|I_R| = |I_B|$ = Phase current I_{ph}

$$I_{L1} = I_R - I_B = 2I_{ph}\cos\left(\frac{60}{2}\right) = 2I_{ph}\frac{\sqrt{3}}{2} = \sqrt{3}I_{ph}$$

$$I_{L2} = I_Y - I_R = 2I_{ph}\cos\left(\frac{60}{2}\right) = 2I_{ph}\frac{\sqrt{3}}{2} = \sqrt{3}I_{ph}$$

$$I_{L3} = I_B - I_Y = 2I_{ph}\cos\left(\frac{60}{2}\right) = 2I_{ph}\frac{\sqrt{3}}{2} = \sqrt{3}I_{ph}$$

As $I_{L1} = I_{L2} = I_{L3} = I_L$

$$\mathbf{I_L = \sqrt{3}I_{ph}}$$

M marks for stepwise derivation of current relationship

(ii) Line Voltage and Phase voltage:

From circuit diagram, it is clear that:

Voltage across Phase R (winding connected between terminals R & Y)

= Voltage between lines R & Y = V_L = Line voltage

$\therefore$ **Phase Voltage = Line Voltage**

$\therefore$ $\mathbf{V_{Ph} = V_L}$

1 Mark for voltage relationship

6 c) Apply superposition theorem to compute current I in the network shown in Fig. No. 5.

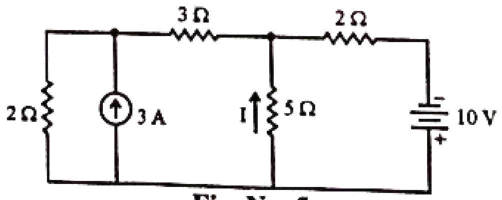
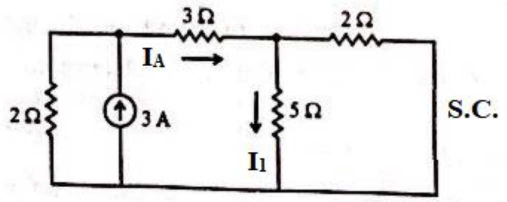


Fig. No. 5

Ans:

(A) Consider current source of 3A acting alone:

The 10V source is replaced by short-circuit (S.C.)



½ Mark for figure

The total resistance appearing across 2Ω (or current source) is given by,

= 3+{5||2}= 3+(10/7) = 31/7 = 4.43Ω

The current I_A = 3×{2/(2+4.43)} = 0.933A

1 Mark for I_A

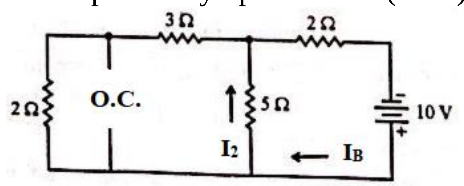
The current through 5Ω due to 3A source alone is given by current division formula as,

1 Mark for I_1

$I_1 = I_A$ (2)/(2+5) = 0.933(2/7) = **0.2666 A (downward)**

(B) Consider voltage source of 10V acting alone:

The 3A source is replaced by open-circuit (O.C.)



½ Mark for figure

The total resistance appearing across 5Ω is given by,

= 3+2 = 5 Ω

The total resistance appearing across 10V source is,

R = 2+(5||5) = 2 + (25/10) = 2+2.5 = 4.5 Ω

The current I_B = V/R = 10/4.5 = 2.22A

1 Mark for I_B

1 Mark for I_2

The current through 5 Ω due to 10V source alone is given by,

$I_2 = I_B$ (5)/(5+5) = 2.22(0.5) = **1.11 A (upward)**

By Superposition theorem, the upward current through 5Ω due to both sources is given by,

1 mark for I

I = $-I_1+I_2$= (-0.2666+ 1.11) = **0.8434A**