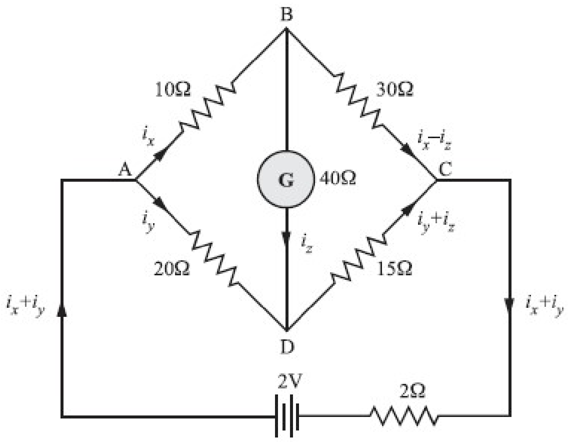
CMR INSTITUTE OF TECHNOLOGY	

Sub:	Network Analysis	Code:

Scheme and solution

	Marks
1. A wheatstone bridge ABCD is arranged as follows: AB = 10Ω, BC = 30Ω, CD = 15Ω and DA = 20Ω. A 2V battery of internal resistance 2Ω is connected between points A and C with A being positive. A galvanometer of resistance 40Ω is connected between B and D. Find the magnitude and direction of the galvanometer current.	[10]



Applying KVL clockwise to the loop ABDA, we get

$$10i_x + 40i_z - 20i_y = 0$$
$$\Rightarrow \quad 10i_x - 20i_y + 40i_z = 0$$

Applying KVL clockwise to the loop BCDB, we get

$$30(i_x - i_z) - 15(i_y + i_z) - 40i_z = 0$$
$$\Rightarrow \quad 30i_x - 15i_y - 85i_z = 0$$

Finally, *applying KVL clockwise to the loop ADCA*, we get

$$20i_y + 15(i_y + i_z) + 2(i_x + i_y) - 2 = 0$$
$$\Rightarrow \quad 2i_x + 37i_y + 15i_z = 2$$

Putting equations (1.23),(1.24) and (1.25) in matrix form, we get

$$\begin{bmatrix} 10 & -20 & 40 \\ 30 & -15 & -85 \\ 2 & 37 & 15 \end{bmatrix} \begin{bmatrix} i_x \\ i_y \\ i_z \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 2 \end{bmatrix}$$

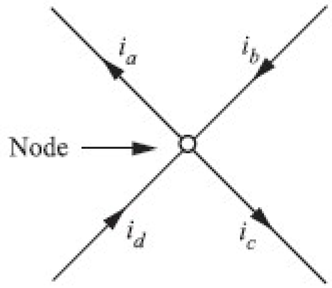
Using Cramer's rule, we find that

$$i_z = \mathbf{0.01\ A\ (Flows\ from\ B\ to\ D)}$$

2*5 steps=10M

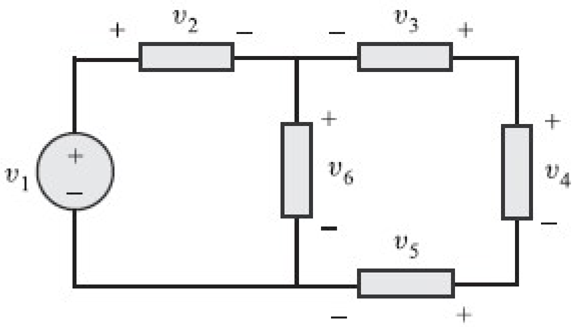
a.State and explain KCL and KVL using any electrical circuit of your choice. [4] [6]

Kirchhoff's Current Law
The first law is Kirchhoff's current law(KCL), which states that the algebraic sum of currents entering any node is zero.



$$i_a - i_b + i_c - i_d = 0$$

Kirchhoff's Voltage Law
Kirchhoff's voltage law(KVL) states that the algebraic sum of voltages around any closed path in a circuit is zero.



$$-v_6 - v_3 + v_4 + v_5 = 0$$

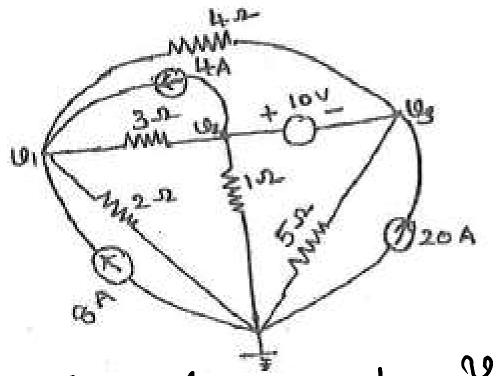
Statements:1*2=2M
Example circuit 1*2=2M

b.State and explain superposition theorem along with the procedure to apply.
In any linear circuit containing multiple independent sources, the current or voltage at any point in the network may be calculated as algebraic sum of the individual contributions of each source acting alone.

$$i_1 \rightarrow v_1$$
$$i_2 \rightarrow v_2$$
$$i_1 + i_2 \rightarrow v_1 + v_2$$

……………………3M
Action Plan:
(i) In a circuit comprising of many independent sources, only one source is allowed to be active in the circuit, the rest are deactivated (turned off).
(ii) To deactivate a voltage source, replace it with a short circuit, and to deactivate a current source, replace it with an open circuit.
(iii) The response obtained by applying each source, one at a time, are then added algebraically to obtain a solution.
……………………….3M

Determine all node voltages in the circuit shown using nodal analysis. [10]



Nodal analysis at v_1

$$\frac{v_1-v_2}{3}+\frac{v_1}{2}+\frac{v_1-v_3}{4}-8-4=0$$

$$v_1\left(\frac{1}{3}+\frac{1}{2}+\frac{1}{4}\right)-\frac{v_2}{3}-\frac{v_3}{4}=12 \quad \text{— (1)}$$

3 m

$$v_2-v_3=10 \quad \text{— (2)}$$

At super node

$$\frac{v_2-v_1}{3}+\frac{v_2}{1}+4+\frac{v_3-v_1}{4}+\frac{v_3}{5}-20=0$$

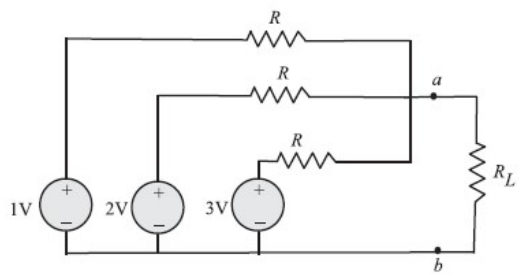
$$v_1\left(-\tfrac{1}{3}-\tfrac{1}{4}\right)+v_2\left(1+\frac{1}{3}\right)+v_3\left(\tfrac{1}{5}+\tfrac{1}{5}\right)=16$$

4 m

$$\boxed{\begin{aligned}v_1&=18.29\,v\\ v_2&=17.696\,V\\ v_3&=7.696\,V\end{aligned}}$$

3 m

a. For the circuit shown , find R such that the maximum power delivered to the load is 3 mW. [6]



[4]

$$P_{\max}=\frac{V_t^2}{4R_t}$$

……………2M

Then, applying KCL at node a, we get

$$\frac{V_t - 1}{R} + \frac{V_t - 2}{R} + \frac{V_t - 3}{R} = 0$$

……..2M

$$\frac{1}{R_t} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} = \frac{3}{R}$$

$$R_t = \frac{R}{3}\,\Omega$$

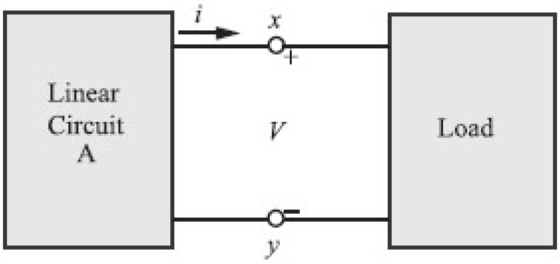
$$P_{\max} = \frac{2^2}{4 \times \frac{R}{3}} = \frac{3}{R} = 3 \times 10^{-3}$$

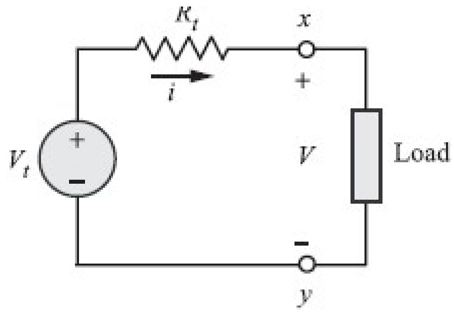
$$R = 1\ \mathrm{k}\Omega$$

………2M

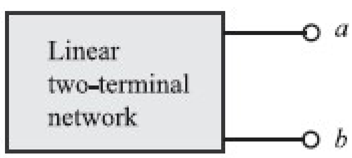
b. Explain Thevinin's theorem and Norton's theorem by considering any circuit as an example

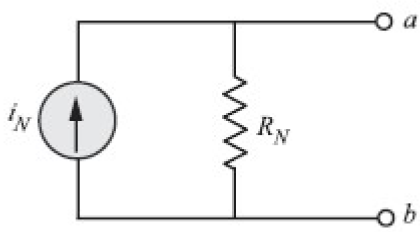
A linear two–terminal circuit can be replaced by an equivalent circuit consisting of a voltage source Vth in series with a resistor Rth, Where Vth is the open–circuit voltage at the terminals and Rth is the input or equivalent resistance at the terminals when the independent sources are turned off or Rth is the ratio of open–circuit voltage to the short–circuit current at the terminal pair.





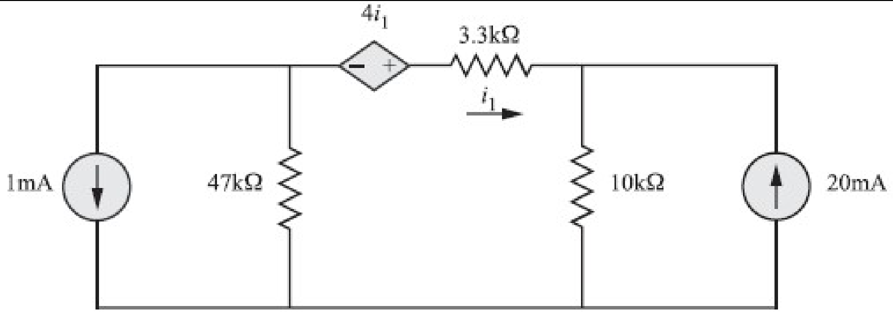
Norton's theorem states that a linear two-terminal network can be replaced by an equivalent circuit consisting of a current source i in parallel with resistor R, where i is the short-circuit current through the terminals and R is the input or equivalent resistance at the terminals when the independent sources are turned off. If one does not wish to turn off the independent sources, then R is the ratio of open circuit voltage to short–circuit current at the terminal pair.



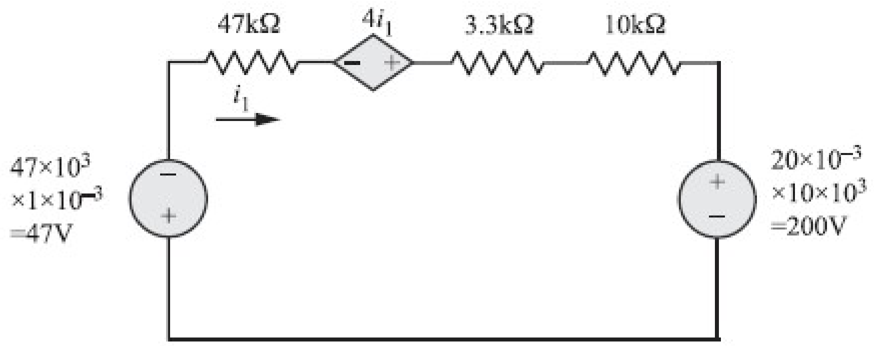


2*2=4M

a. Find current i1 using source transformation for the circuit shown	[8]



[2]



………4M

Using KVL to the above circuit,

$$47 + 47\times10^3 i_1 - 4i_1 + 13.3\times10^3 i_1 + 200 = 0$$

Solving, we find that

$$i_1 = -\mathbf{4.096\ mA}$$

……………4M

b.Explain bilateral and unilateral networks with an example for each.

A Unilateral network is one whose properties or characteristics change with the direction. An example of unilateral network is the semiconductor diode, which conducts only in one direction.

A bilateral network is one whose properties or characteristics are same in either direction. For example, a transmission line is a bilateral network, because it can be made to perform the function equally well in either direction.

1*2=2M

In the network shown in fig. 6, the load Z_L is connected between terminals A and B. Find the value of the load Z_L such that it receives the maximum power. Also find the value of maximum power. [10]

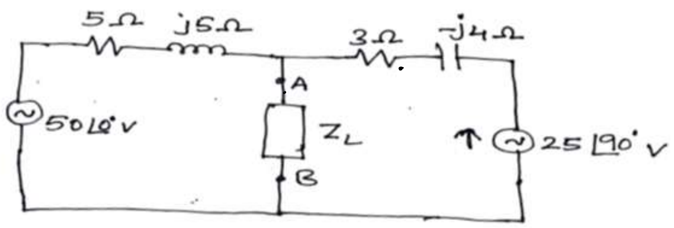
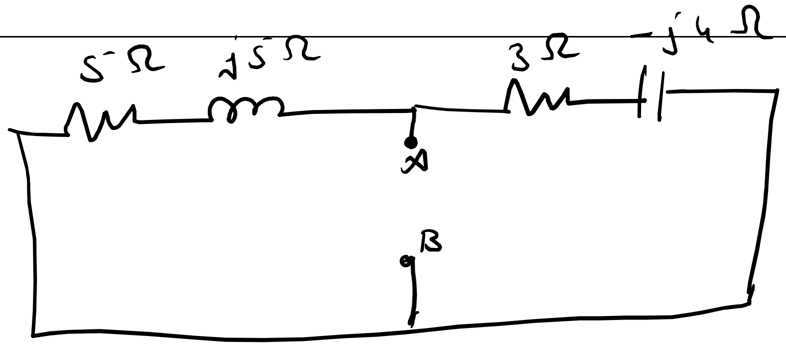


fig. 6.

To find Z_L that receives maximum power, we need to find Z_{th} by deactivating all sources.



$$Z_{th} = (5 + j5) \parallel (3 - j4)$$

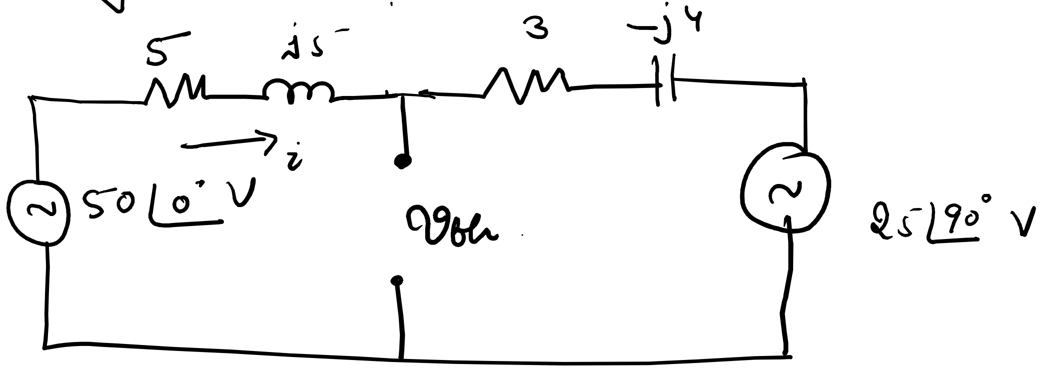
$$= 4.23 - 1.153j \ \Omega$$

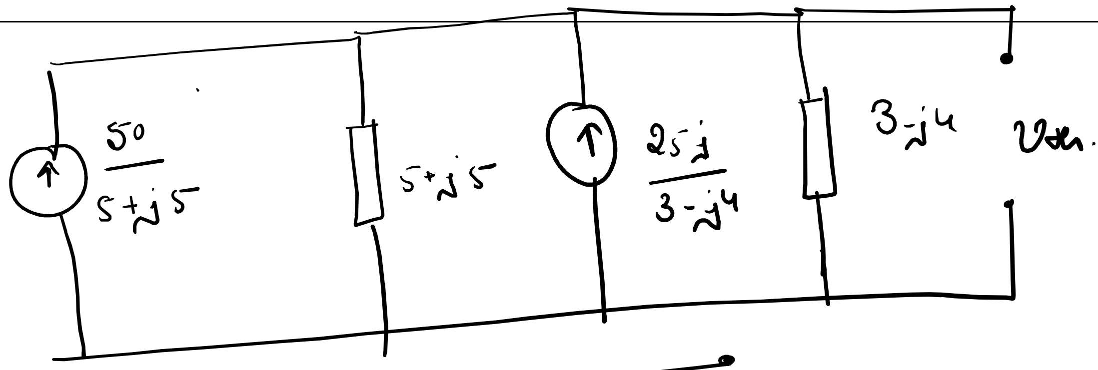
Z_L for maximum power transfer

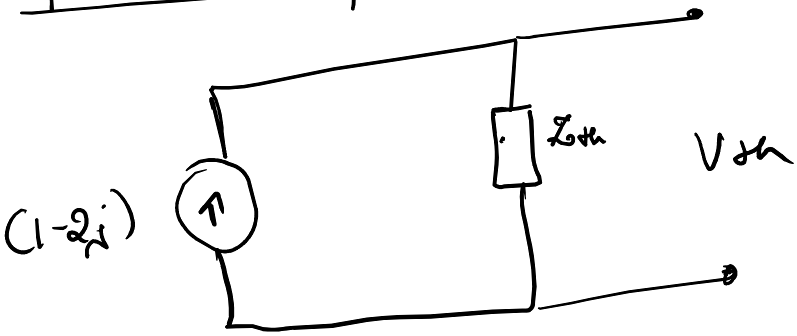
$$Z_L = Z_{th}^{*} = 4.23 + 1.53j \ \Omega$$

3M

To find V_{th},





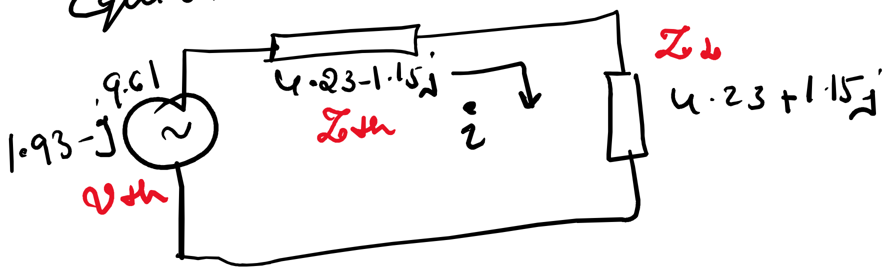


$$Z_{th} = (3-j4) \parallel (5+j5) = 4.23-1.15j$$

$$Z_L = Z_{th}^* = 4.23+1.15j$$

$$V_{th} = (1-2j)(4.23+1.15j) = 1.93 - j9.61$$

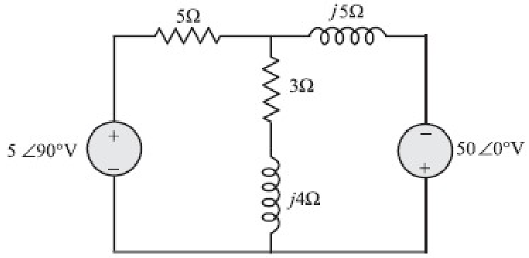
Equivalent circuit is



$$i = \frac{V_{th}}{Z_{th}+Z_L} = 1.16\angle -78^\circ \text{ A}$$

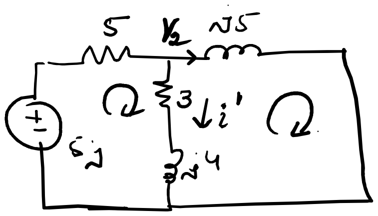
$$P_{max} = i^2 \cdot Re(Z_L) = 1.16^2 \times (4.23)$$
$$= \underline{5.69W}$$

a. Find the current through 3 + j4 Ω using superposition theorem.	[8]



[2]

Activate $5\angle 90° \Rightarrow 5j$



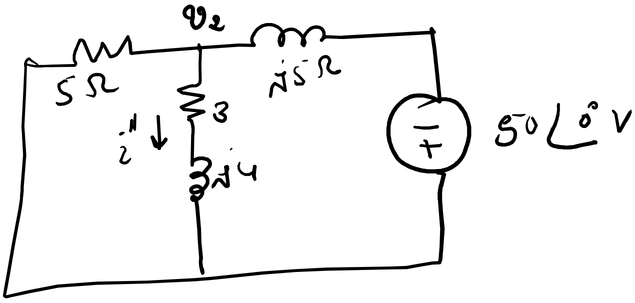
$$\frac{V_2}{3+4j} + \frac{V_2-5j}{5} + \frac{V_2}{5j} = 0$$

$$V_2(0.32-0.36) = 1j$$

$$V_2 = -1.552 + 1.379j$$

$$i' = 0.034 + 0.413j$$

To find i'', Activate $50\angle 0°$ V



$$\frac{V_2}{5} + \frac{V_2}{3+j4} + \frac{V_2+50}{j5} = 0$$

$$\Rightarrow V_2 = \frac{+10j}{0.32-0.36j} = -15.52 + 13.793j$$

$$i'' = \frac{V_2}{3+4j} = 0.344 + 4.138j$$

$$i = i' + i'' = 0.37848 + 4.55136j$$

$$= 4.56\angle 85.246° \text{ A}.$$

Two cases of activating circuits:2*3=6M
Addition of two currents: 2M

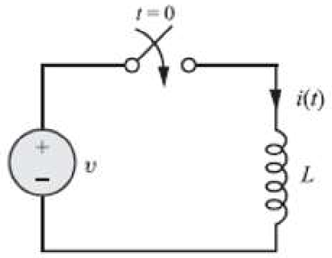
b. Explain active and passive elements with an example for each.
An element is said to be passive if the total energy delivered to it from the rest of the circuit is either zero or positive. Eg:Resistor
An active two-terminal element that supplies energy to a circuit is a source of energy.

Eg:Voltage source

1*2=2M

a..Explain initial conditions of an electric circuit consisting i)Only inductor ii)Only capacitor	[8]
b.What is transient analysis of an electrical circuit?	[2]

- The inductor : The switch is closed at t=0



Current through inductor is

$i = \frac{1}{L}\int_{-\infty}^{t} v\,d\tau$ —— ①

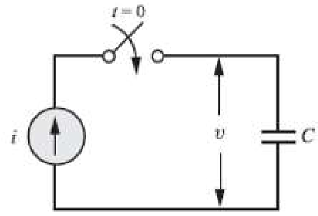
$i_{(t)} = \frac{1}{L}\int_{-\infty}^{0^-} v\,d\tau + \frac{1}{L}\cancel{\int_{0^-}^{0^+} v\,d\tau} + \frac{1}{L}\int_{0^+}^{t} v\,d\tau$ 0

$i(t) = i(0^-) + \frac{1}{L}\int_{0^+}^{t} v\,d\tau$ —— ④ ⇒ current in an inductor cannot change instantaneously.

$\Rightarrow i(0^+) = i(0^-)$

The capacitor

When switch is closed at t=0, current i(t) flows through the circuit.



Voltage across capacitor C is

$v(t) = \frac{1}{C}\int i(t)\,dt$ —— ①

$v(t) = \frac{1}{C}\int_{-\infty}^{t} i(t)\,dt$ —— ②

$v(t) = \underbrace{\frac{1}{C}\int_{-\infty}^{0^-} i(t)\,dt}$ $+ \frac{1}{C}\cancel{\int_{0^-}^{0^+} i(t)\,dt}$ 0 $+ \frac{1}{C}\int_{0^+}^{t} i(t)\,dt$

$v(t) = v(0^-) + \frac{1}{C}\int_{0^+}^{t} i(t)\,dt$ —— ③

when $t = 0^+$ eqn ③ ⇒

$v(0^+) = v(0^-) + \frac{1}{C}\cancel{\int_{0^+}^{0^+} i(t)\,dt}$ 0

$v(0^+) = v(0^-)$

⇒ Voltage across capacitor does not change instantaneously.

2*4=8M

Transient analysis is a type of electrical simulation that analyzes how a circuit's voltage and current waveforms change over time in response to a change in input. This analysis can help determine how a circuit behaves under different conditions, how quickly it reaches a steady state, and how it handles transient events like spikes, surges, or faults.

………………..2M

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