SPICE

SPICE is a general purpose simulation program that simulates different circuit and can perform various analysis of electrical and electronic circuits including time domain response, frequency response, ~~and~~ total power dissipation, determination of nodal voltage and branch current in a circuit, transient analysis and determination of transfer function etc.

The full form of SPICE is Simulation Program with Integrated Circuit Emphasis/Analysis.

PSPICE is one form of SPICE for personal computers available in different operating system such as DOS, Windows and UNIX.

The SPICE was first developed at University of California, Berkeley in mid 1970.

It is used as a tool for analysis, design and for testing of integrated, electrical and electronic circuits.

In PSPICE we don't write the circuit equation, but describe the circuit using ASCII text.

Structure of circuit file

Title: One line for problem identification, eg. Transcient Analysis

Element Statement: These identify element types, element values and node to node connection.

Control Statement: This specify types of analysis, eg. DC, AC or transient analysis, frequency analysis.

End Statement: Indicates the end of data flow.

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The basic Structure of Element Statement

Each element in the circuit have a specific element statement which contains the element name, the circuit nodes to which the elements are connected and values of the parameter.

Element name

R → Register
L → Inductor
C → Capacitor
D → Diode
V → Independent Voltage Source
I → Independent Current Source
Q → BJT
B → FET

There are 4 dependent Sources —

G → Voltage Control Current Source
E → Voltage Control Voltage Source
F → Current Control Current Source
H → Current Control Voltage Source

K → Coupling factor

Nodes: It is a junction point of 2 circuit elements or source.

Any Value → 1-999
0 → datum node (Reference Node)

The node must be non-negative.

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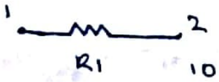
Values of an Element:



10 → for 10Ω

10K → for 10KΩ

10M → for 10MΩ

pico → p 10^{-12}

micro → μ 10^{-6}

nano → n

milli → m

Kilo → K

Giga → G

Tera → T

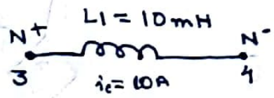
Mega → Meg

Representation of Different Component in SPICE:

Resistor:

Name	N+	N-	Value
R1	1	2	10K

Inductor:

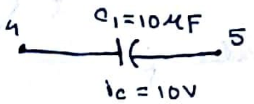


Name	N+	N-	Value	Ic
L1	3	4	10m	10

→ Initial Condition (Should be written if needed / stated)

Don't write if not given

Capacitor:



Name	N+	N-	Value	IC
C1	4	5	10μ	10

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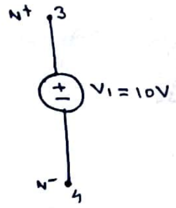
Energy Source:

i) Independent Voltage Source:



Name	N^+	N^-	Type	Value
V1	3	4	DC	10

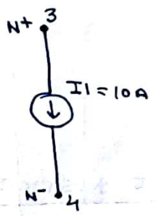
AC Source

$V_S = 10\angle 45^\circ \rightarrow$ Is $10 \angle -45^\circ$ → Value: 10 −45

$= 10\sin(\omega t + 45^\circ)$

Name	N^+	N^-	Type	Value	
Vs	3	4	AC	10	45
				magnitude	Angle

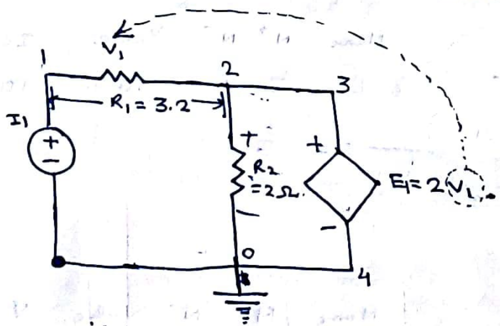
ii) Independent Current Source:



Name	N^+	N^-	Type	Value	
I1	3	4	DC	10	} For DC Current Source
Is	3	4	AC	10 45	} For AC Current Source

iii) Dependent Source

a) Voltage control Voltage Source:



→ Symbol of Dependent Voltage Source

→ Symbol of Dependent ~~Volt~~ Current Source

E is changed by changing the value of another voltage source V_1.

Name	N^+	N^-	Nc^+	Nc^-	Gain Value
E1	3	4	2	0	2

Nc^+ → Controlling Voltage +ve Node

Nc^- → Controlling Voltage −ve Node

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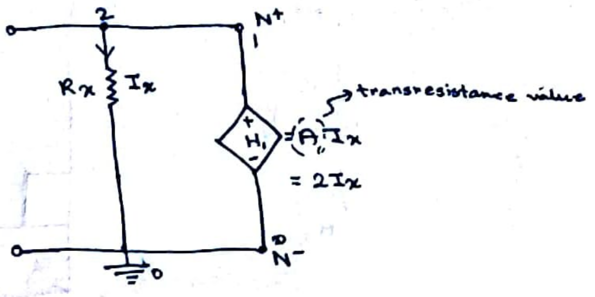
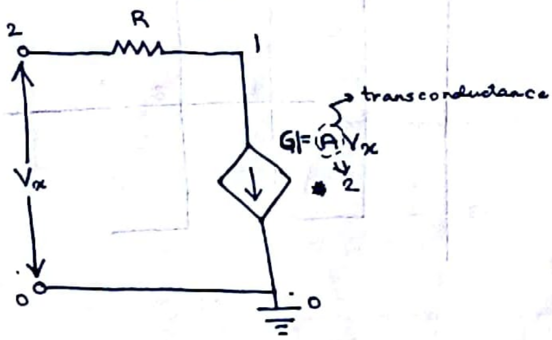
b) Current Control ~~Current~~ Voltage Source:



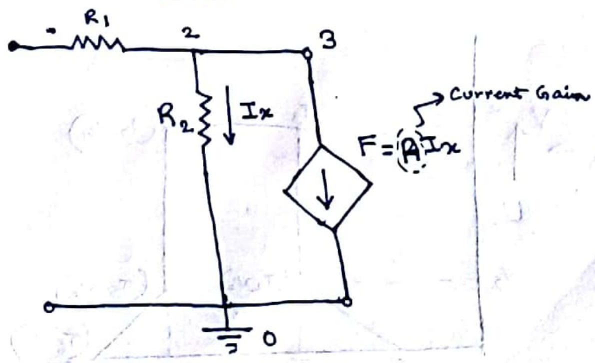
Name	N+	N-	NC+	NC-	A
H1	1	0	2	0	2

c) Voltage Control Current Source:



Name	N+	N-	NC+	NC-	A
G1	1	0	2	0	2

d) Current Control Current Source:



Name	N+	N-	NC+	NC-	Gain Value
F1	3	0	2	0	A

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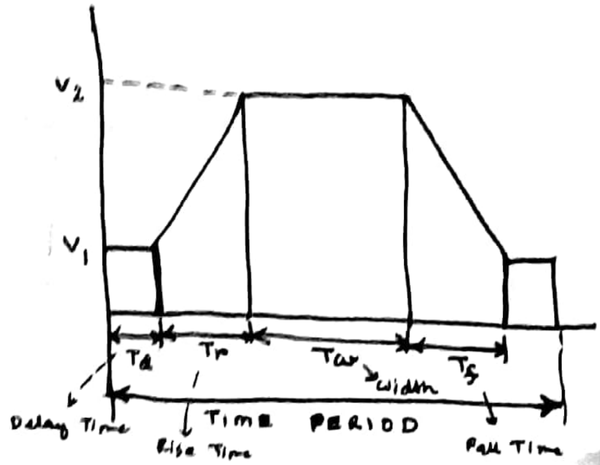
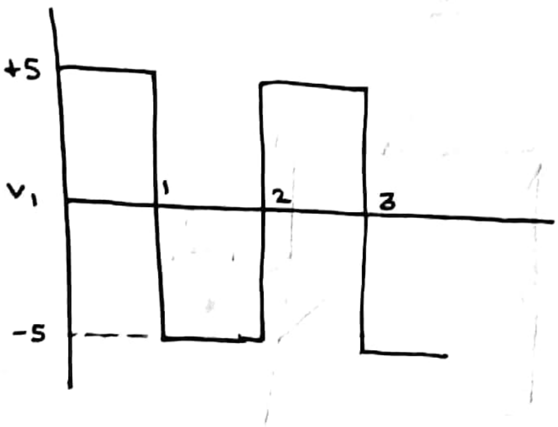
Pulse Source



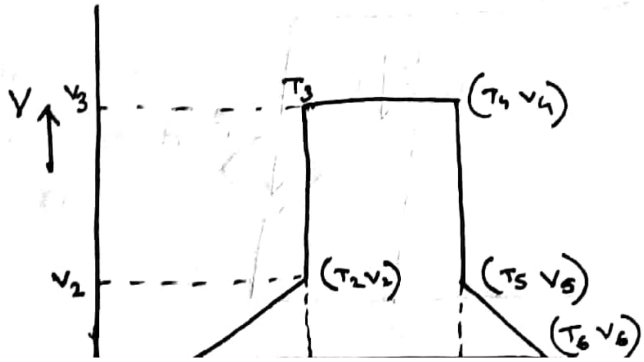
Voltage label N^+ N^- :
C1 1 2

PULSE (V1 V2 Td Tr Tf Tw PERIOD)



V1 1 2 PULSE(-5 +5 1NS 1NS 1NS, 1S 2S)

Piecewise Linear Independent Source (PWL)



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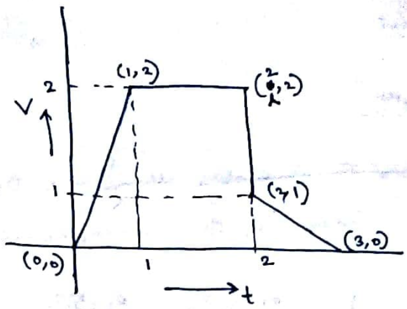
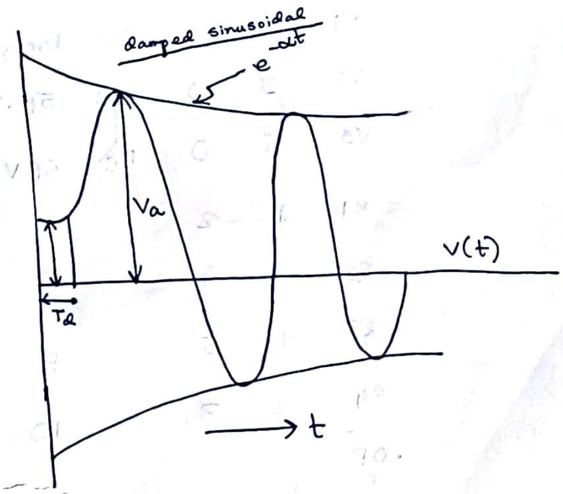


V1 N^+ N^- PWL(00, 12, 22, 21, 30)

SIN Source

$$V(t) = V_0 + V_a e^{-(t-T_d)\alpha}\left[\sin 2\pi f(t-T_d) - \theta\right]$$



V_0 is the DC Offset Voltage

V_a is the peak voltage

f = frequency

T_d = delay time

α = damping factor

θ = phase delay

V(name) N^+ N^- SIN(V_0 V_a f T_d α θ)

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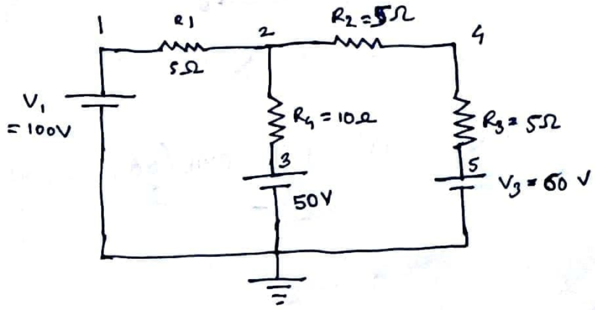
Control Statement

1. DC Analysis:

i) .OP → ~~Used to find the~~ find ~~them~~ the DC operating points of all independent sources, means the node voltages.



V1	1	0	DC	100 V
V2	3	0	DC	50 V
V3	5	0	DC	60 V
R1	1	2		5
R2	2	4		5
R3	4	5		5
R4	2	3		10

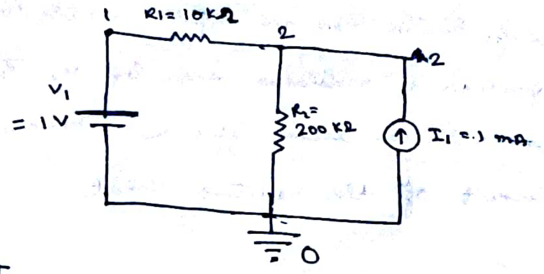
.OP

.End

ii) .DC → To vary the voltage source / current source amplitude from starting value to final value with an increment.

.DC <source name> <initial value> <final value> <increment>

.DC V1 1V 10 V 1V



~~For vary the~~

~~Unit~~

WAP and find the voltage between nodes 1 and 2, and the current through V1, where the voltage source V1 varies from 1 to 10V, in steps of 2V.

~~DC V1 1V 10V 2V~~

DC CIRCUIT

V1	1	0	DC	1V
R1	1	2		10K
R2	2	0		200K
I1	0	2	DC	1mA

- .DC V1 1V 10V 2V
- PRINT DC V(1,2), I(V1)
- End

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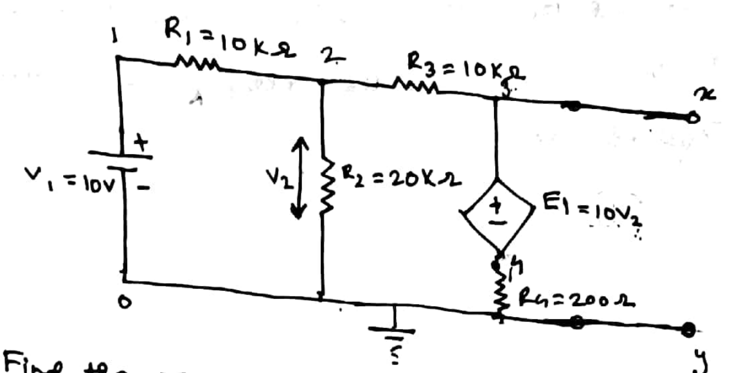
iii) .TF → Gives ~~do~~ a Transfer function from an input variable to output variable and produces a resistance seen by the two voltage sources. It can also give a Thevenin's Equivalent Circuit of the resistive circuit.

.TF <output variable> <input source name>



Find the Thevenin's Equivalent Circuit across xy.

THEVENIN EQUIVALENT ~~DC CIRCUIT~~ CIRCUIT

V1	1	0	DC	10V	
~~E1~~	+				
E1	3	4	2	0	10
R1	1	2		10K	
R2	2	~~3~~0		20K	
R3	2	3		10K	
R4	4	0		200	

.TF V(3,0) V1 ····→ Input Voltage

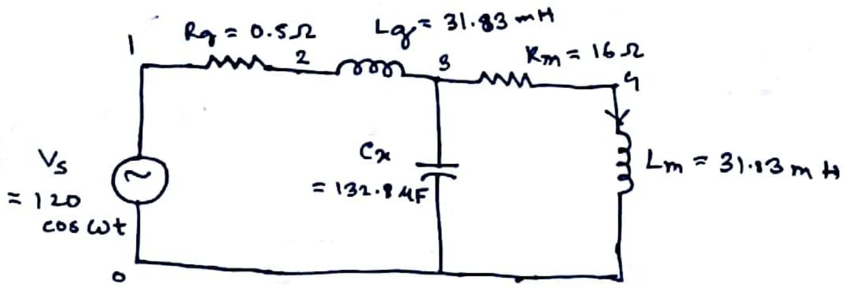
• End

2. AC Analysis:

i) .AC → Obtain frequency analysis.

.AC <sweep type> <no. of points> <starting frequency> <stop frequency>

~~LINEAR~~
LIN (linear)
OCT (octave)
DEC (decade)



Find the voltage across 2 inductor and capacitor.

AC CIRCUIT

Vs	1	0	AC	120	0
Rg	1	2		0.5	
Lg	2	3		31.83m	IC = 0
Rm	3	4		16	
Lm	4	0		31.83m	IC=0
Cx	3	0		132.8μF	IC = 0

~~cost~~
(cos ωt)
sin

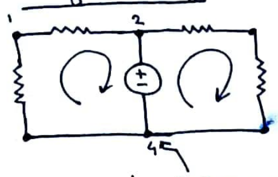
.AC LIN 10 ~~60~~ 60 70

.PRINT AC ~~VM~~ VM(2,3), VP(2,3), IM(LM), IP(LM), VM(CX), VP(CX)

.End

Circuit Theory

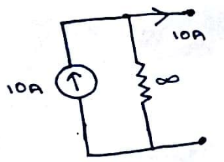
Graph Theory



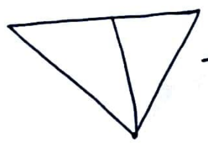
Reference Node

1. Graph?
2. How to draw a graph?
   i) ckt elements are to be replaced by line segments
   ii) Energy Sources are to be replaced by their internal impedance
   a) for ideal voltage source short ckt
   b) for ideal current source, open ckt

Ideal Voltage Source → Zero Internal Resistance



Ideal Current Source



→ Undirected Graph

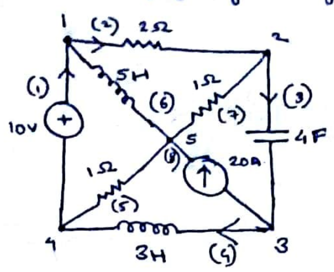
- If directions are present → Oriented/Directed Graph

- If no direction is given and we want to draw a directed graph, then we can choose any direction as per our choice.

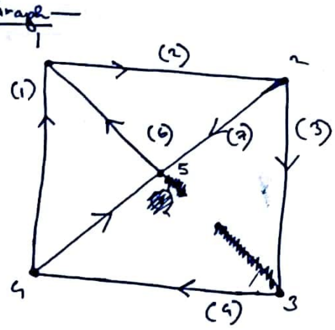
Rank of a graph: $(n-1)$ → no. of nodes

Subgraph: Will have ~~subset~~ subset of the total nodes and edges.

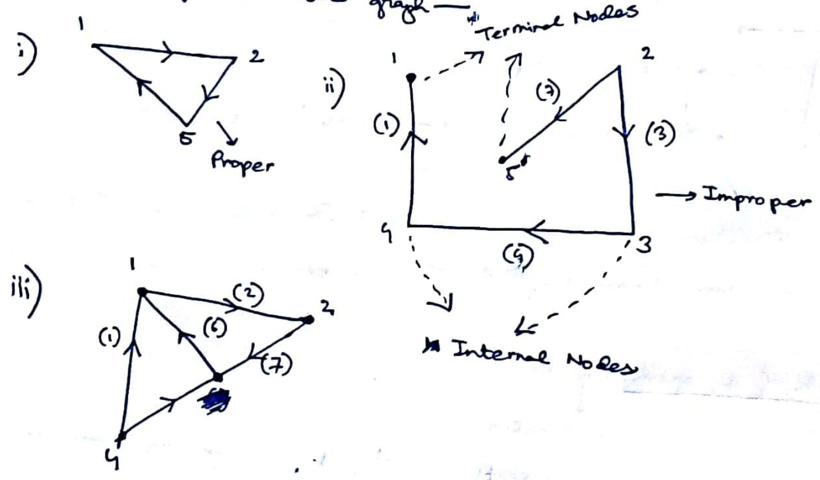
• Draw the graph of the given circuit —



Graph —

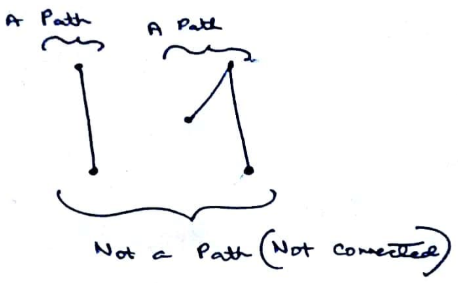


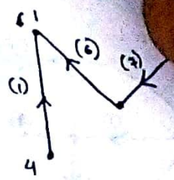
Subgraph of the above graph —



Proper Subgraph → No. of Nodes and Branches ~~and~~ are strictly less than that of the main graph.

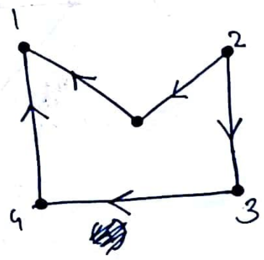
A Path is a subgraph consisting of an ordered sequence of branches having two terminal nodes at two ends ~~nodes~~ and having all remaining nodes as internal nodes.





A Path

If two terminal nodes of a path coincide with each other, a closed path is formed which is called a <u>loop</u>.



loop

loop

Properties of Loop:

i) Loop is a subgraph

ii) All the nodes present in the loop are internal nodes.

iii) No. of nodes and no. branches are equal in a loop

iv) There exists two paths between any pair of nodes.

v) Minimum two branches are required to form a loop.

<u>Tree</u> is a subgraph having all the nodes of the original graph, but no loop will be present.

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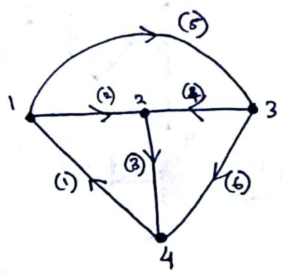
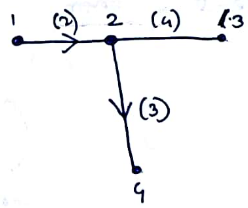
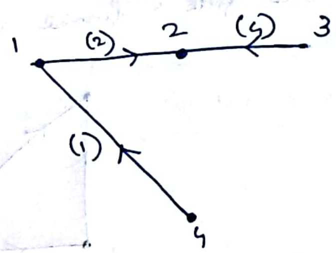


Draw some trees

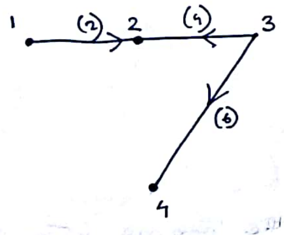
i)



ii)



iii)

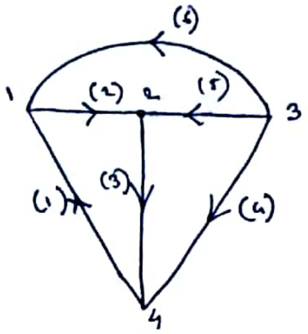


Properties of tree:

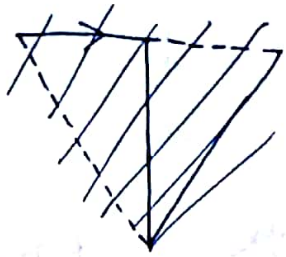
1) Tree is a connected subgraph.
2) All the nodes should be present, but no loops should be present
3) No. of branches present in a tree is (n-1), where n is the no. of nodes.
4) There exists only 1 path between any pair of nodes.
5) Rank of the tree is (n-1).
6) Every connected graph will have atleast one tree.

Co - Tree

branch



Graph 1



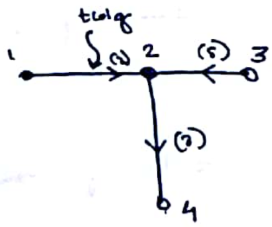
no. of nodes = n

no. of branches = b

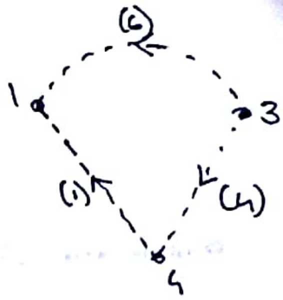
no. of ~~twig~~ twig = $n-1$

no. of link = $b-(n-1)$

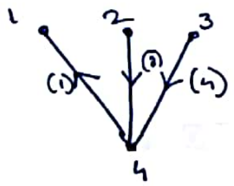
$= b-(n+1)$



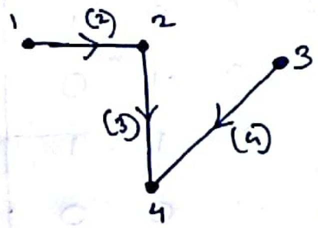
Tree no. 1



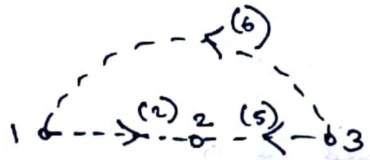
Co-tree of tree no. 1



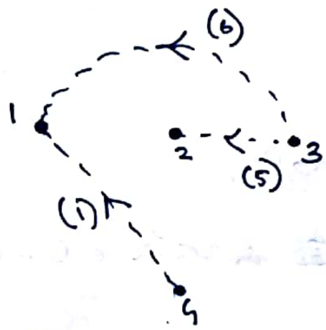
Tree no. 2



Tree no. 3



Co-Tree of Tree no. 2



Co-Tree of Tree no. 3

Co-Tree is the remaining part of the graph that is left once the Tree is removed from the original graph.

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Complete Incidence Matrix (CIM)

$$A_a = \begin{bmatrix} & \\ & \end{bmatrix}_{n \times b}$$

Each element a_{hk} (h → no. of node, k → no. of branch) $= +1$ if branch k is connected to node h and directed away from node h

$= -1$ if " " " " " " " directed towards node h

$= 0$ if branch k is not connected to node h

Consider Graph (1),

$$A_a = \begin{array}{c|cccccc} & (1) & (2) & (3) & (4) & (5) & (6) \\ \hline 1 & -1 & 1 & 0 & 0 & 0 & -1 \\ 2 & 0 & -1 & 1 & 0 & -1 & 0 \\ 3 & 0 & 0 & 0 & 1 & 1 & 1 \\ 4 & 1 & 0 & -1 & -1 & 0 & 0 \end{array}$$

Properties of CIM :

1) Rank of CIM is $(n-1)$.
2) Sum of the entries in each column should be 0.
3) Determinant of CIM of any closed loop is 0.

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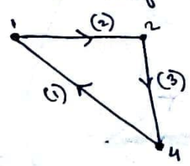
Take any closed loop—



$$
\begin{array}{c} \\ 1 \\ 2 \\ 4 \end{array}
\begin{array}{c}
\begin{array}{ccc} (1) & (2) & (3) \end{array} \\
\begin{bmatrix} -1 & -1 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & -1 \end{bmatrix}
\end{array}
$$

$\therefore$ Determinant

$= -1(-1-0) - 1(1-0)$

$= 1 - 1$

$= 0$

Reduced Incidence Matrix

A → Notation

$$A = [\ \ ]_{(n-1)\times b}$$

A row from CIM may be absent here.

For nodal analysis, one node is selected as reference node, and hence it is omitted. In this case we use RIM.

For RIM, sum of each column $\neq 0$.

$$
A = \begin{bmatrix}
1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \\
0 & 1 & 0 & 0 & -1 & 1 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & -1 & 1 & -1 \\
0 & 0 & 0 & 1 & 0 & 0 & -1 & 0
\end{bmatrix} \rightarrow \text{RIM}
$$

$$
A_a = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{array}
\begin{array}{c}
\begin{array}{cccccccc} (1) & (2) & (3) & (4) & (5) & (6) & (7) & (8) \end{array} \\
\begin{bmatrix}
1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \\
0 & 1 & 0 & 0 & -1 & 1 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & -1 & 1 & -1 \\
0 & 0 & 0 & 1 & 0 & 0 & -1 & 0 \\
-1 & -1 & -1 & -1 & 0 & 0 & 0 & 0
\end{bmatrix}
\end{array} \rightarrow \text{CIM}
$$

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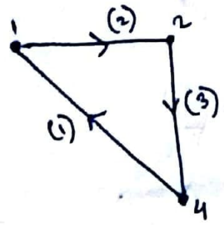
Take any closed loop—



$$\begin{array}{c|c} & (1) \quad (2) \quad (3) \\ \begin{matrix}1\\2\\4\end{matrix} & \begin{bmatrix} -1 & -1 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & -1 \end{bmatrix} \end{array}$$

$\therefore$ Determinant

$= -1(-1-0) -1(1-0) + 0$

$= 1-1$

$= 0$

Reduced Incedence Matrix

$A = [\ ]_{(n-1)\times b}$

A → Notation

A row from CIM may be absent here.

For nodal analysis, one node is selected as reference node, and hence it is omitted. In this case we use RIM.

For RIM, sum of each column $\neq 0$.

$$A = \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & -1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & -1 & 1 & -1 \\ 0 & 0 & 0 & 1 & 0 & 0 & -1 & 0 \end{bmatrix} \rightarrow \text{RIM}$$

$$A_a = \begin{array}{c|c} & (1) \quad (2) \quad (3) \quad (4) \quad (5) \quad (6) \quad (7) \quad (8) \\ \begin{matrix}1\\2\\3\\4\\5\end{matrix} & \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & -1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & -1 & 1 & -1 \\ 0 & 0 & 0 & 1 & 0 & 0 & -1 & 0 \\ -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 \end{bmatrix} \end{array} \rightarrow \text{CIM}$$

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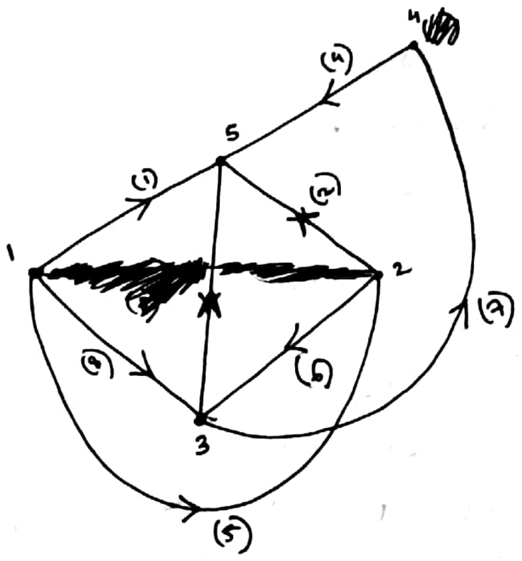
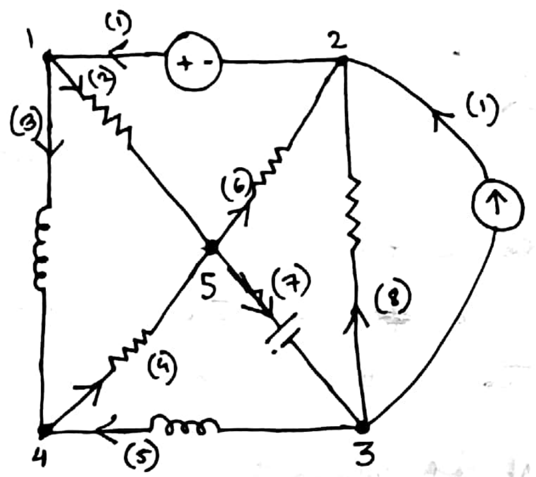
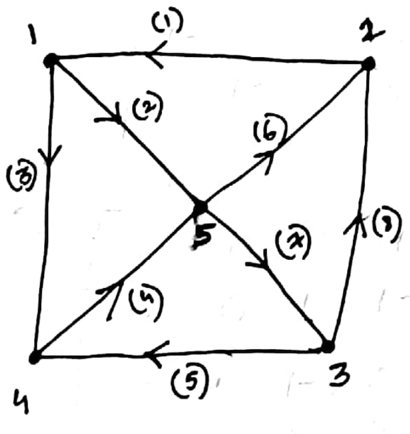




Draw the graph.
Then find CIM.



$$A_a = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{array} \begin{array}{c} \begin{array}{cccccccc} (1) & (2) & (3) & (4) & (5) & (6) & (7) & (8) \end{array} \\ \begin{bmatrix} -1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & -1 & 0 & -1 \\ 0 & 0 & 0 & 0 & 1 & 0 & -1 & 1 \\ 0 & 0 & -1 & 1 & -1 & 0 & 0 & 0 \\ 0 & -5 & 0 & -1 & 0 & 1 & 1 & 0 \end{bmatrix} \end{array}$$

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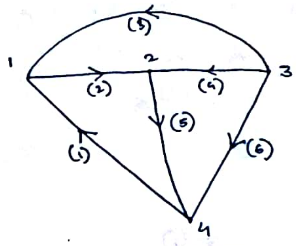
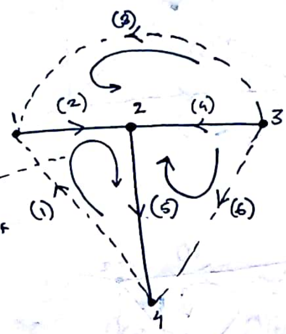
Tie-Set Matrix or Fundamental loop Matrix or f-loop Matrix



Step 1: Select a tree

Step 2: Connect one link at a time to form a loop.



loop current direction ~~to the~~ of the link (1)

Tie Set 1 [1 2 5]

Tie Set 3 [2 3 4]

Tie Set 6 [6 4 5]

Tie Set Matrix B = $\left[\quad \right]_{\underbrace{(b-n+1)}_{\text{no. of links}} \times b}$

b_{hk} = +1 when branch k is present in tie set h and direction of current is same as that of k.

tie set no — h; branch — k

= −1 when branch k is present in ~~the~~ tie set h and direction of current is same as the branch k

= 0 branch is not present

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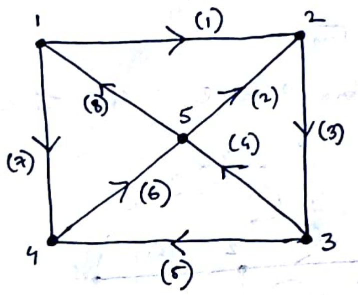
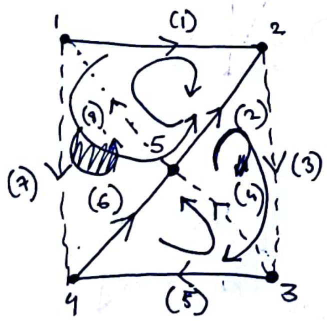
$$
B = \begin{array}{c} \\ TS1 \\ TS3 \\ TS6 \end{array}
\begin{array}{c}
\begin{array}{cccccc} (1) & (2) & (3) & (4) & (5) & (6) \end{array} \\
\begin{bmatrix} 1 & 1 & 0 & 0 & 1 & 0 \\ 0 & 1 & 1 & -1 & 0 & 0 \\ 0 & 0 & 0 & -1 & -1 & 1 \end{bmatrix}
\end{array}
$$

2.



Tree 1:



Tie set 4 [4 5 6]

Tie set 8 [8 1 2]

Tie set 7 [7 2 6 1]

Tie set 3 [3 2 6 5]

$$
B = \begin{array}{c} \\ TS4 \\ TS8 \\ TS7 \\ TS3 \end{array}
\begin{array}{c}
\begin{array}{cccccccc} (1) & (2) & (3) & (4) & (5) & (6) & (7) & (8) \end{array} \\
\begin{bmatrix} 0 & 0 & 0 & 1 & -1 & -1 & 0 & 0 \\ 1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 \\ -1 & 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 & 1 & 1 & 0 & 0 \end{bmatrix}
\end{array}
$$

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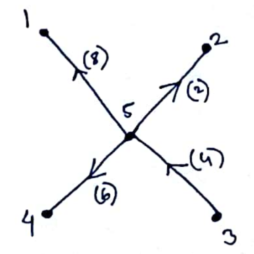
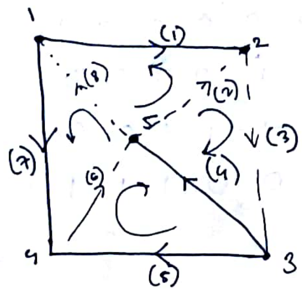
Tree 2:



Tree 3:



Tree 3:

Tie set 6 [6 4 5]

Tie set 8 [8 7 5 4]

Tie set 2 [2 1 7 5 4]

Tie set 3 [3 5 7 1]

$$B = \begin{array}{c} \\ TS6 \\ TS8 \\ TS2 \\ TS3 \end{array} \begin{array}{c} \begin{array}{cccccccc} (1) & (2) & (3) & (4) & (5) & (6) & (7) & (8) \end{array} \\ \begin{bmatrix} 0 & 0 & 0 & -1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & -1 & 0 & 1 & 1 \\ -1 & 1 & 0 & 1 & -1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & -1 & 0 \end{bmatrix} \end{array}$$

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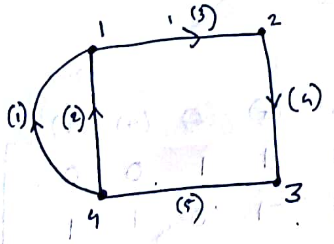
Tree 2:

Tri set 1 [1 2 8]
Tri set 3 [3 4 2]
Tri set 5 [5 6 4]
Tri set 7 [6 7 8]

$$B = \begin{array}{c} \\ \text{Tri Set 1} \\ \text{Tri Set 3} \\ \text{Tri set 5} \\ \text{Tri Set 7} \end{array} \begin{array}{c} \begin{array}{cccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \end{array} \\ \left[\begin{array}{cccccccc} 1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \end{array}\right] \end{array}$$

Fundamental Cut Set Matrix or f-cut Set Matrix

~~Minimum~~ ? Minimal set of branches, removing which the rank of the graph is reduced by 1, and the graph is divided into 2 parts.

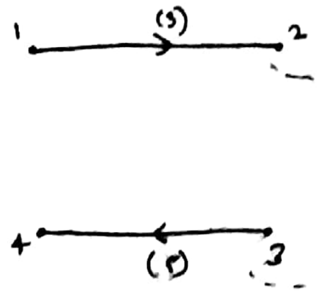


$\therefore$ Rank $= n-1 = 4-1 = 3$

i) Suppose branch [1 2 4] is removed.

→ Fundamental Cut Set

∴

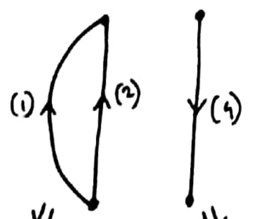


→ Rank = 2-1 = 1

→ Rank = 2-1 = 1

∴ Rank = 1+1 = 2 → decreases by 1

ii)



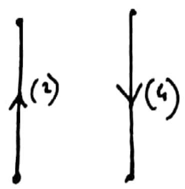
[3 5] → Fundamental Cut Set

Rank 1 Rank 1

∴ Rank = 1+1

= 2

iii)



[1 3 5] → Not a fundamental cut-set ∵ a subset [3 5] forms a fundamental cut set.

Rank = 1+1=2

How to identify f-cut set?

<u>Step 1:</u> Select a Tree

<u>Step 2:</u> Consider one twig at a time, remove that twig along with other links

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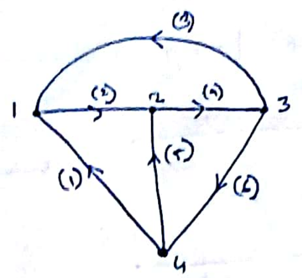
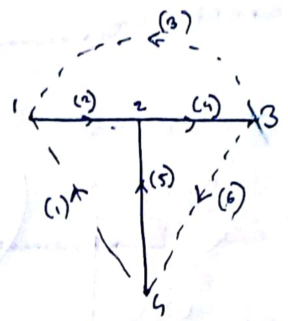
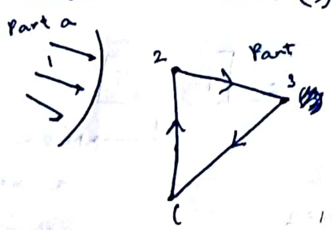
1.





i) Consider twig (2).

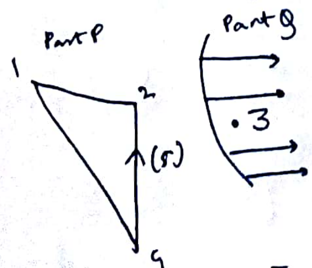
Remove its ~~links~~ links (3) and (1).



f- cut set 2 [3 2 1]

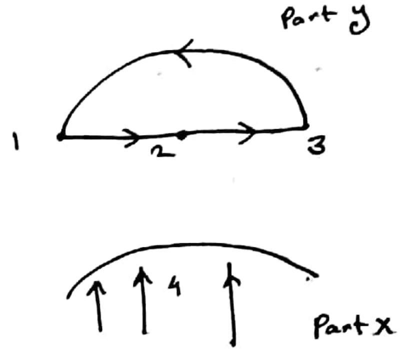
ii) Consider twig (4).

Remove links (3) and (6)



f cut set 4 [3 4 6]

iii) Consider twig (5).
Remove links (1) and (6).



f cut set 5 [1 6 5]

~~Fundamental Cut set Matrix or f cut set Matrix~~

$Q = q_{ik}$ = +1 present in cut set i, direction is same

(i: cut set no; k: branch no.)

= −1 " " " " i, ~~absent~~. dir. is opposite

= 0 absent in cut set i

$$
Q = \begin{array}{c} \\ fc\,2 \\ fc\,4 \\ fc\,5 \end{array}
\begin{array}{c}
\begin{array}{cccccc} (1) & (2) & (3) & (4) & (5) & (6) \end{array} \\
\begin{bmatrix} -1 & 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 1 & 0 & -1 \\ 1 & 0 & 0 & 0 & 1 & -1 \end{bmatrix}
\end{array}
$$

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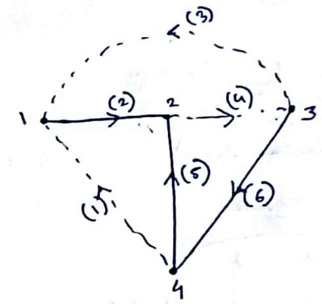
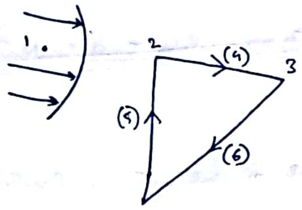
2.



i) Consider twig (2).

Remove (3) and (1)

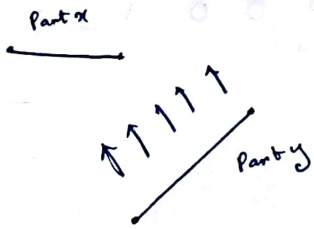


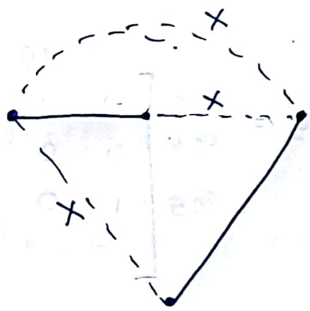
cut set 2 [2 1 3]

ii) Consider twig (5)

Remove (1), (4), (3).

Cut set 5 [5 4 1 3]

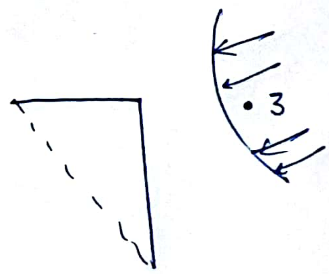




iii) Consider twig (6).

Remove (3), (4).

cut set 6 [6 4 3]



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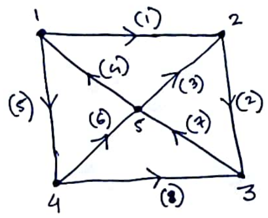
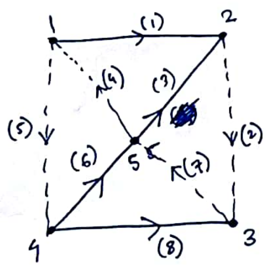
$$Q_f = \begin{array}{c} \\ fc2 \\ fc5 \\ fc6 \end{array} \begin{array}{c} \begin{array}{cccccc} (1) & (2) & (3) & (4) & (5) & (6) \end{array} \\ \left[\begin{array}{cccccc} -1 & 1 & -1 & 0 & 0 & 0 \\ 1 & 0 & 1 & -1 & 1 & 0 \\ 0 & 0 & 1 & -1 & 0 & 1 \end{array}\right] \end{array}$$

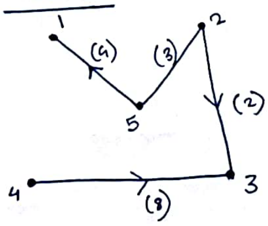
3.



Tree 1



Tree 2



~~Tree 1~~

~~1) Consider twig (1).~~

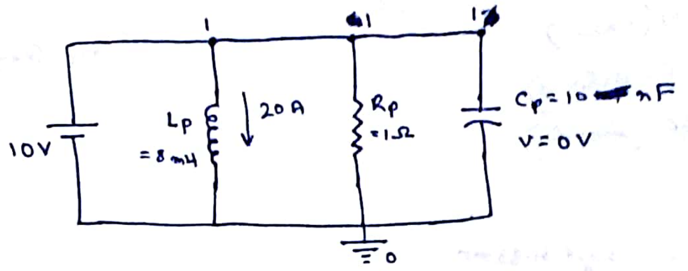
3. <u>Transient Analysis</u>:

.TRAN T_{step} T_{stop} UIC

increment size → T_{step}; final value → T_{stop}; UIC → Using Initial Conditions

↓

To perform transient analysis or transient response of the circuit.



$\frac{L}{R} = \tau_1$

$T_2 = RC$

Whichever of τ_1 and τ_2 is T_{step}, i.e. the increment. Other one is the T_{stop}.

Title: Transient Response

RP 1 0 1

LP 1 0 8m IC = 20 A

CP 1 0 10n IC = 0 V

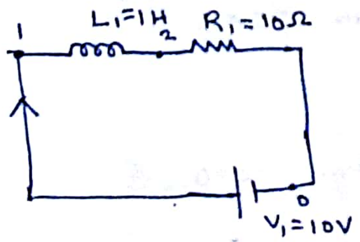
V 1 0 DC 10

.TRAN $\frac{\text{lower } \tau}{10}$ higher $\tau \times 10$ UIC

.PROBE

.End

i)



$\tau = \frac{L}{R} = \frac{1}{10} = 0.1$

Title: Transient Response of RL Circuit

V1 1 0 DC 10

L1 1 2 1

R1 2 0 10

.TRAN 0.01 1 UIC

.PROBE

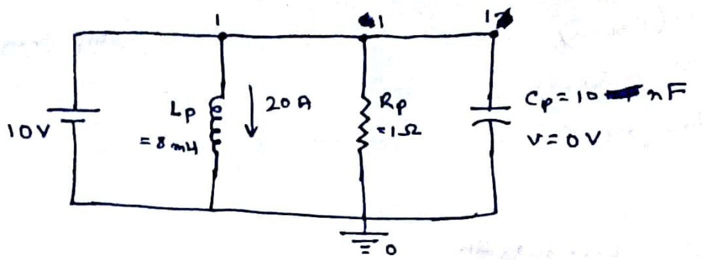
3. Transient Analysis:

increment size final value Using Initial Conditions

.TRAN T_{step} T_{stop} UIC

↓

To perform transient analysis or transient response of the circuit.



Title: Transient Response

Rp 1 0 1

Lp 1 0 8m IC = 20A

Cp 1 0 ~~10m~~ 10n IC = 0 V

V 1 0 DC 10

.TRAN $\frac{\text{lower } \tau}{10}$ higher $\tau \times 10$ UIC

.PROBE

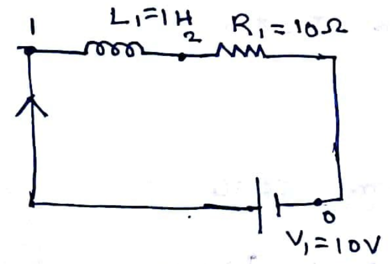
.End

$\frac{L}{R} = \tau_1$

$T_2 = RC$

Whichever of τ_1 and τ_2 is T_{step}, i.e. the increment. Others one is the T_{stop}.

i)



$\tau = \frac{L}{R} = \frac{1}{10} = 0.1$

Title: Transient Response of RL Circuit

V1 1 0 DC 10

L1 1 2 1

R1 2 0 10

.TRAN 0.01 1 UIC

.PROBE

.END

Output Commands

1) .PRINT:

.PRINT DC I(R1)/ VM(1,2) VP(1,2)
.PRINT AC IM(R1) IP(R1)

2) .PLOT:

Plot the output variables.

.PLOT DC I(R1)
.PLOT AC IM(R1) IP(R1)
.PLOT TRAN I(R1)

3) .PROBE:

·Storing all variables in the file.

·PROBE <output variable>

.PROBE command generates a data file for viewing the analysis on the computer.
The .PROBE tells PSPICE to write the result of the DC, AC or Transient simulation.

If .PROBE is followed by the output variables, it only ~~said~~ save the output of those signals.

.PROBE alone means saving all the signals to the data file.

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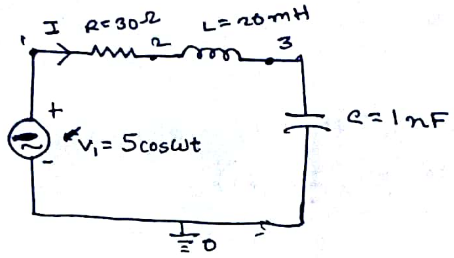
i)



In the RLC Series circuit, find the magnitude and phase of I when the source frequency is ~~not~~ varied from 40-60 KHz in 100 steps.

Title: RLC Series Circuit

V1 1 0 AC 5 0 (magnitude, phase)

R 1 2 30

L 2 3 20m

C 3 0 1n

.AC LIN 100 40K 60K

.PROBE IM(V1) IP(V1)

.END

$\tau_1 = \frac{L}{R} = \frac{20 \times 10^{-3}}{30}$

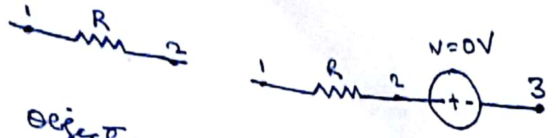
$= 0.66 \times 10^{-3}$

$= 0.66\,m$

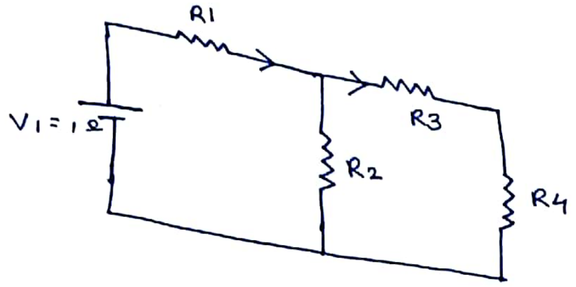
$\tau_2 = R \times C = 30 \times 1 \times 10^{-9}$

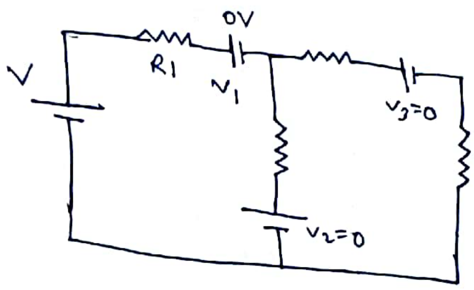
$= 30\,n$

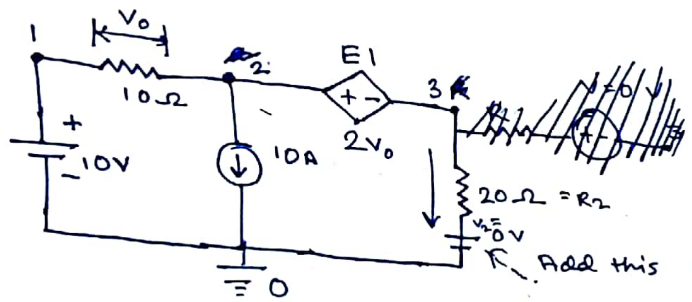
Dummy Source



The objective of this dummy source along with .OP command is to get the value of current through the branch where the dummy source is present.







Find the current through 20Ω resistance.

Title : ~~Dum~~

```
V1  1  0  DC  10
R1  1  2  10
I1  2  0  DC  10
E1  2  3  1  2  2
R2  3  0  20
V2  4  0  DC  0V
.OP
.END
```

Module 1

Network Analysis

Basic Elements

1. Resistance $\rightarrow$ from Ohm's Law $V = IR$
2. Inductance $\rightarrow$ from Faraday's Law of EM Induction,

flux $\phi = LI$

$$\frac{d\phi}{dt} = L\frac{dI}{dt}$$

$$\Rightarrow \underset{\text{emf induced}}{e} = L\frac{di}{dt}$$

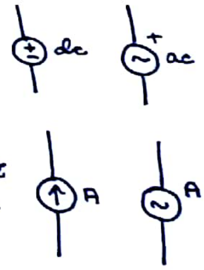
3. Capacitance $\rightarrow$ $q \propto v$

$\Rightarrow q = cv$

$\Rightarrow \frac{dq}{dt} = c\frac{dv}{dt}$ | $i = c\frac{dv}{dt}$

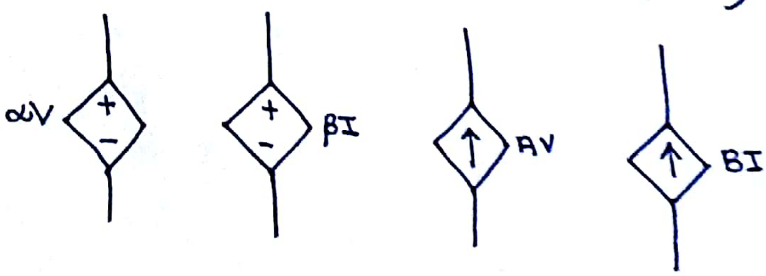
Types of Sources

1. Independent — Voltage Source, Current Source



2. Dependent

a) Voltage Controlled Voltage Source (VCVS)
b) Voltage Controlled Current Source (VCCS)
c) Current Controlled Voltage Source (CCVS)
d) Current Controlled Current Source (CCCS)



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Basic Laws

1. Ohm's Law
2. KVL → Mesh or Loop Analysis
3. KCL → Node Analysis

Basic Properties

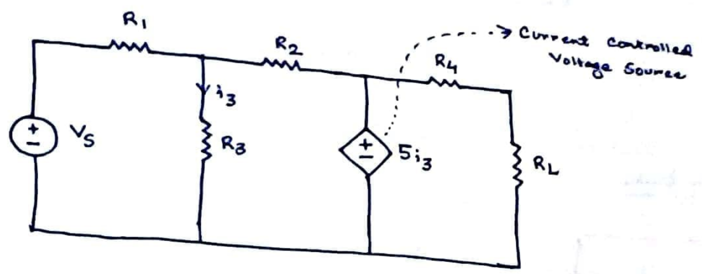
Circuit should be

i) Linear : V v/s I plot comes as linear; semiconductor elements like diode, Transistor make a circuit non-linear.

ii) Active : The circuit must contain some activation source.

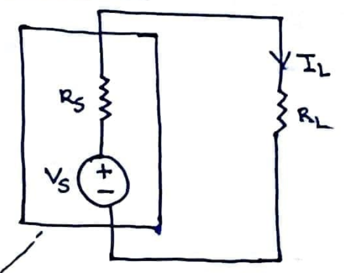
iii) Bilateral : Current can flow in either direction.

Ideal Voltage Source : Internal resistance is zero.



Source Conversion

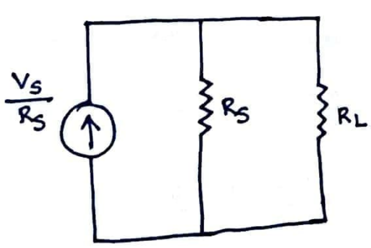
1) Voltage to Current :



practical voltage source; internal resistance = R_S

$$I_L = \frac{V_S}{R_S + R_L}$$

$$\cancel{I_L} = \left(\frac{V_S}{R_S}\right)\left(\frac{R_S}{R_S + R_L}\right)$$



Basic Laws

1. Ohm's Law
2. KVL → Mesh or Loop Analysis
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Basic Properties

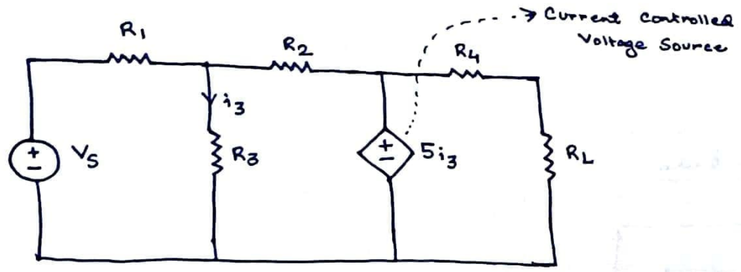
Circuit should be

i) Linear : V v/s I plot comes as linear; semiconductor elements like diode, transistor make a circuit non-linear.

ii) Active : The circuit must contain some activation source.

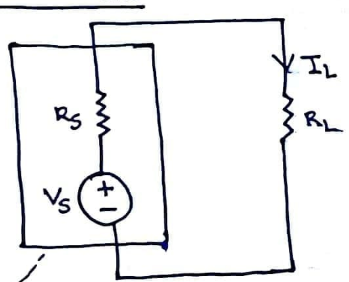
iii) Bilateral : Current can flow in either direction.

Ideal Voltage Source : Internal resistance is zero.



Source Conversion

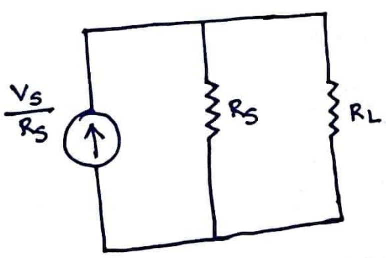
1) Voltage to Current :



practical voltage source; internal resistance = R_S

$$I_L = \frac{V_S}{R_S + R_L}$$

$$\cancel{R_L} = \left(\frac{V_S}{R_S}\right)\left(\frac{R_S}{R_S + R_L}\right)$$

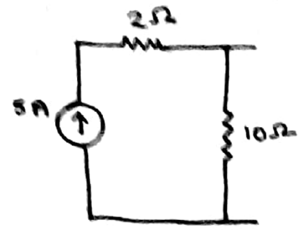


2) Current to Voltage

$$V = I_L R_L$$

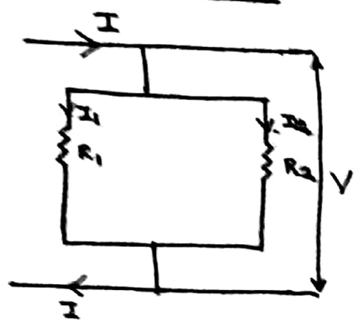
$$= I \frac{R_B}{R_B + R_L} R_L$$

$$= \underbrace{(I R_B)}_{V_B} \frac{R_L}{R_B + R_L}$$



← Conversion To Voltage Source not possible if the 2Ω resistor is present

Current Division Rule



$$V = I_1 R_1 = I_2 R_2$$

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

$$I = \frac{V}{R_{eq}} = \frac{I_1 \cancel{R_1} (R_1 + R_2)}{\cancel{R_1} R_2}$$

$$\therefore I_1 = I \left(\frac{R_2}{R_1 + R_2} \right)$$

$$\therefore I_2 = I \left(\frac{R_1}{R_1 + R_2} \right)$$

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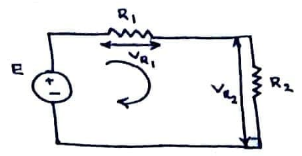
Voltage Division Rule



$$I = \frac{E}{R_1 + R_2}$$

$$VR_1 = IR_1 = \frac{ER_1}{R_1 + R_2}$$

$$VR_2 = IR_2 = \frac{ER_2}{R_1 + R_2}.$$

Node Analysis (Application of KCL)

1. The objective is to compute all branch currents.
2. Applicable to individual non-reference node of a given circuit.
3. To write current equation, it is assummed that the respective node potential is always higher than the other node potentials appearing in the equation.
4. The node ~~point~~ pair equations to be solved to find the branch currents.

Mesh Analysis

1. Objective is to find out the branch currents as well as the voltage across different elements.
2. Applicable to seperate closed path of a circuit.
3. For each closed path one current is assumed to flow either in clockwise or in anti-clockwise direction.
4. The polarities of drops across each element has to be found out by the assumed direction of current.

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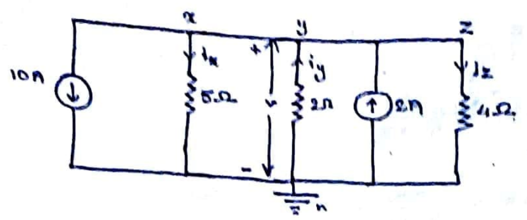
5. Next we can apply KVL for each closed loop and the loop equations have to be solved to find the branch currents and voltages.

Problems:

1.



Find v and the magnitude and direction of unknown currents in branches xn, yn and zn.

Using KCL,

$10 + i_x + i_z = 2 + i_y$

$\Rightarrow 10 + \frac{v}{5} + \frac{v}{4} = 2 - \frac{v}{2}$ --> ∵ current is flowing from − side to +ve side, the sign must be reversed.

$\Rightarrow \frac{v}{5} + \frac{v}{4} + \frac{v}{2} = -8$

$\Rightarrow \frac{4v + 5v + 10v}{20} = -8$

$\Rightarrow 19v = -160$

$\Rightarrow v = -\frac{160}{19} = -8.42\ V$ (Ans)

$\therefore i_x = \frac{v}{5} = \frac{-8.42}{5} = -1.68\ A$ (Ans)

$i_y = \frac{-v}{2} = 4.21\ A$ (Ans)

$i_z = -2.1\ A$ (Ans)

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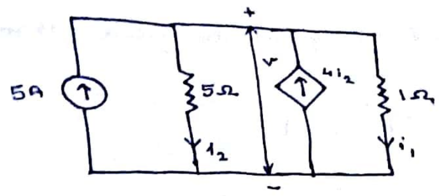
2.



Find the value of v and the currents.

Ans: $v = 12.5\,V$, $i_2 = 2.5\,A$, $4i_2 = 10\,A$

Using KCL,

$$5 + 4i_2 = i_2 + i_1$$

$$\Rightarrow 5 + 4 \cdot \frac{v}{5} = \frac{v}{5} + \frac{v}{1}$$

$$\Rightarrow 5 + \frac{3v}{5} - v = 0$$

$$\Rightarrow \frac{3v - 5v}{5} = -5$$

$$\Rightarrow -2v = -25$$

$$\Rightarrow v = 12.5 \text{ (Ans)}$$

$$\therefore i_2 = \frac{12.5}{5} = 2.5\,A \text{ (Ans)}$$

$$\therefore 4i_2 = 10\,A \text{ (Ans)}$$

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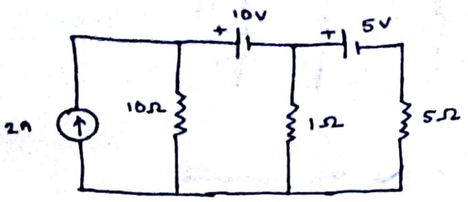
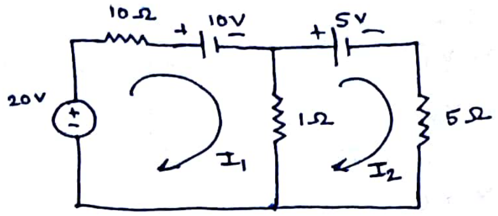
3. Find the current and power dissipated through 5Ω resistor.



4.



KVL in Loop 1

$$\therefore\ 20 - 10I_1 - 10 - (I_1 - I_2).1 = 0 \ \ldots\ldots (1)$$

$$-5 - 5I_2 - (I_2 - I_1).1 = 0 \ \ldots\ldots (2)$$

KVL in Loop 2

$\therefore$ From (1),

$$20 - 10I_1 - 10 - I_1 + I_2 = 0$$

$$\Rightarrow\ 11I_1 - I_2 = 10 \ \ldots (3)$$

From (2),

$$-5 - 5I_2 - I_2 + I_1 = 0$$

$$\Rightarrow\ I_1 - 6I_2 = 5 \ \ldots (4)$$

$$66I_1 - 6I_2 = 60$$

$$\underline{\overset{-}{\ }I_1 \overset{+}{-} 6I_2 = \overset{-}{5}}$$

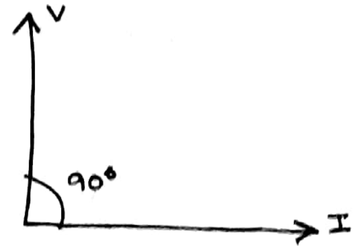
$$65I_1 = 55$$

$$\Rightarrow\ I_1 = \frac{55}{65}$$

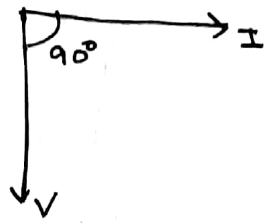
$$\therefore\ \frac{55}{65} - 6I_2 = 5$$

$$\Rightarrow\ 6I_2 = \frac{55}{65} - 5 \ \Rightarrow\ I_2 = -0.692\ A$$

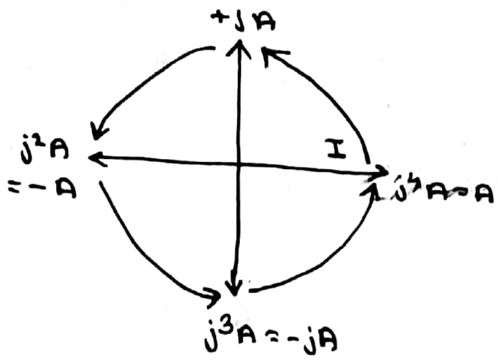
Inductor → Current lags voltage by 90° or voltage leads current by 90°.



Capacitor → Current leads voltage by 90° or voltage lags current by 90°.



<u>j- operator</u>



$L \Rightarrow X_L = 2\pi f L$ +j Inductor

−j Capacitor

$c \Rightarrow X_c = 2\pi f c$

\+ means inductor

\- means capacitor

$(3 + j4)\ \Omega$

~~Rect~~

Rectangular Form

Polar Form $M\angle\theta$

• Conversion from ~~to~~ Polar ~~[illegible]~~ to Rectangular form and vice versa.

For multiplication and division, polar form is better.
For addition and subtraction, rectangular form is better.

$10\angle 60^\circ \times m_1\angle\theta_1$

$(10\times m_1)\angle(60^\circ+\theta_1)$

$47.16\angle -53.13$

Problems:

1.

Find the magnitude of the current dependent source, and the through 2Ω resistor.

Loop 1:

$i_1 = -2A$

Loop 2:

$2i_2 + 5i + (i_2 - i_1).1 = 0$

Loop 3:

$i_3 \times 1 + (i_3 - i_1).1 - 5i = 0$

However, $i = i_1 - i_3$

$i = (-2 - i_3)$

$\Rightarrow i_3 + i_3 - i_1 + 10 + 5i_3 = 0$

$\Rightarrow 7i_3 + 2 + 10 = 0$

$\Rightarrow 7i_3 = -12$

$\Rightarrow i_3 = \frac{-12}{7}$ (Ans)

$2i_2 + 5(-2 - i_3) + (i_2 + 2).1 = 0$

$\Rightarrow 2i_2 + 5(-2 + \frac{12}{7}) + i_2 + 2 = 0$

$\Rightarrow 3i_2 = -0.57$

$\Rightarrow i_2 = 0.19A$ (Ans)

$\therefore i = -2 + \frac{12}{7}$

$= \frac{-2}{7}$

$= -0.29A$ (Ans)

$\therefore 5i = 5\times(-0.29)$

$= 1.45\ A$ (Ans)

- For multiplication and division, polar form is better.
- For addition and subtraction, rectangular form is better.

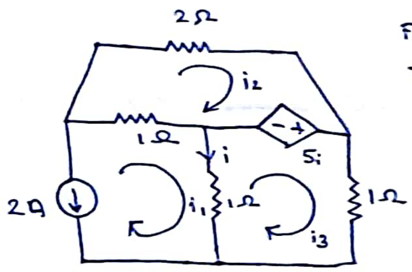
$$10\angle 60^\circ \times M_1 \angle\theta_1$$
$$\downarrow$$
$$(10\times m_1)\angle(60^\circ+\theta_1)$$

$47.26\angle -57.15$

$\cancel{57.13}$

Problems:

1\.



Find the magnitude of the ~~to~~ current dependent source, and the through 2Ω resistor.

loop 1:

$i_1 = -2A$

loop 2:

$$2i_2 + 5i + (i_2 - i_1).1 = 0$$

loop 3:

$$i_3 \times 1 + (i_3 - i_1).1 - 5i = 0$$

$\Rightarrow i_3 + i_3 - i_1 + 10 + 5i_3$

$=$

However, $i = i_1 - i_3$

$i = (-2 - i_3)$

$\Rightarrow 7i_3 + 2 + 10 = 0$

$\Rightarrow 7i_3 = -12$

$\Rightarrow i_3 = \frac{-12}{7}$ (

$$2i_2 + 5(-2 - i_3) + (i_2 + 2).1 = 0$$

$$\Rightarrow 2i_2 + 5\left(-2 + \frac{12}{7}\right) + i_2 + 2 = 0$$

$$\Rightarrow 3i_2 = -0.57$$

$$\Rightarrow i_2 = 0.19A\ (Ans)$$

$\therefore i = -2 + \frac{12}{7}$

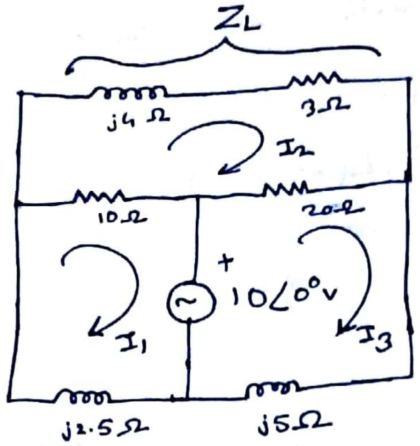
$= \frac{-2}{7}$

$= -0.29$

$\therefore 5i = 5 \times (-0.29)$

$= 1.45 A$

2.



Find the current ~~flowing~~ flowing through Z_L using mesh analysis.

loop 1:

$$(10+j2.5).I_1 - 10I_2 - 0\times I_3 = -10\angle 0^\circ$$

loop 2:

$$-10I_1 + (33+j4)I_2 - 20I_3 = 0$$

$$10(I_2 - I_1) + 20(I_2 - I_3) + (33+j4)I_3 = 0$$

loop 3:

$$20(I_3 - I_2) + j5\Omega\, I_3 = 10\angle 0^\circ$$

$$\Rightarrow 0\times I_1 - 20I_2 + (20+j5)I_3 = 10\angle 0^\circ$$

$$\begin{bmatrix} (10+j2.5) & -10 & 0 \\ -10 & (33+j4) & -20 \\ 0 & -20 & (20+j5) \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} -10 \\ 0 \\ 10 \end{bmatrix}$$

$$I_2 = \frac{\Delta_2}{\Delta}$$

$$\begin{array}{r} 12.5 \\ \times 200 \\ \hline 5000 \end{array}$$

$\cancel{=}\ \cancel{-10}$

$$\begin{bmatrix} (10+j2.5) & -10 & 0 \\ -10 & 0 & -20 \\ 0 & 10 & (20+j5) \end{bmatrix}$$

$$= (10+j2.5)(200) + (-10)(\cancel{-100} + 200 + j50) + 0$$

$$= 2000 + \cancel{5000}\ j500\ \cancel{+200} - 2000 - j500 + 0$$

$$= 0$$

$$\therefore I_2 = \frac{0}{\Delta} = 0\,A \text{ (Ans)}$$

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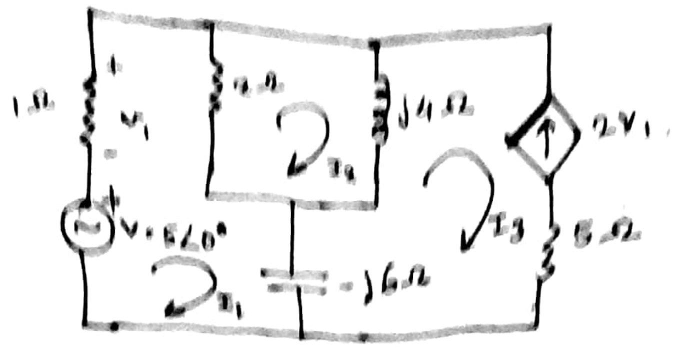

Find the current through capacitor.

loop 3

$I_3 = -2V_1$

loop 1

$V_1 = I_1 \times 1$

$\cancel{I_3 = -2I_1}$

$\Rightarrow \cancel{I_3 +}$

loop 3

$I_3 = -2I_1$

$\Rightarrow I_3 + 2I_1 = 0$

loop 1

$$5\angle 0° = (\overset{2\Omega + 1\Omega}{3} - j6)\, I_1 - 2\, I_2 - (-j6)\, I_3$$

loop 2

$$-2I_1 + (2 + j4)\, I_2 - j4 I_3 = 0$$

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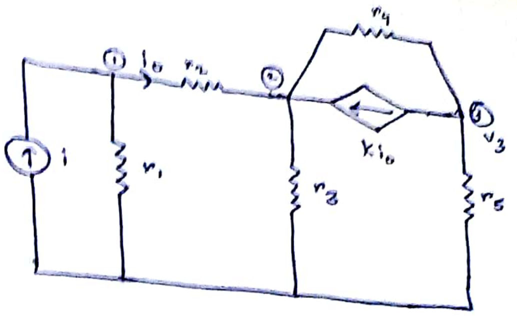
4.



At Node 1:

$$\frac{v_1}{r_1} + \frac{v_1 - v_2}{r_2} = i$$

At Node 2:

$$\frac{v_2 - v_1}{r_2} + \frac{v_2}{r_3} + \frac{v_2 - v_3}{r_4} = ki_0$$

At Node 3:

$$\frac{v_3}{r_5} + \frac{v_3 - v_2}{r_4} = -ki_0$$

$$\begin{bmatrix} \left(\frac{1}{r_1} + \frac{1}{r_2}\right) & \left(\frac{1}{r_2}\right) & 0 \\ -\frac{1}{r_2} & \left(\frac{1}{r_2} + \frac{1}{r_3} + \frac{1}{r_4}\right) & \left(-\frac{1}{r_4}\right) \\ 0 & -\frac{1}{r_4} & \left(\frac{1}{r_4} + \frac{1}{r_5}\right) \end{bmatrix}$$

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