Chettinad College of Engineering & Technology
Approved by AICTE-New Delhi and Affiliated to Anna University-Chennai

Academic Year 2023 -2024

Notes of Lesson

Year/Semester: I/II	**Department** : ECE	**Unit** : I to V
Date: 06.03.2024	**Subject Code/Title :** EC3251/ Circuit Analysis	**Total Hours** :60 Hrs
	Faculty Name : Mrs.A.Karthikeyani	**Subject Credit : 4**

Unit-I DC Circuit Analysis

UNIT-I - DC Circuit Analysis

Basic Components of electric circuits, charge, current, Voltage and Power, Voltage and current Sources. Ohm's Law. Kirchoff's current law, Kirchoff's voltage Law - The single Node - Pair circuit, series and parallel Connected Independent Sources, Resistors in series and parallel, voltage & current division, Nodal Analysis, Mesh Analysis

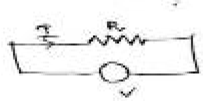
Ohm's Law:

"The Ratio between potential difference across 2 terminals of a conductor & current through it remains constant, when the physical conditions of the conductor remain unchanged. Here the physical condition is temperature."

$$\frac{V}{I} = \text{constant}$$

$$\frac{V}{I} = R$$

$$\boxed{V = I \times R}$$



$$P = V \cdot I = I^2 R = \frac{V^2}{R}$$

Charge (Q):

⇒ "The amount of charge passing a point in the circuit"

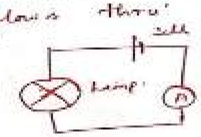
$$\boxed{Q = I \times t} \qquad [\, Q = C \cdot V \,] \; C \rightarrow \text{capacitor}$$

Problem No: 3

Given that the current is 0.3A. Calculate the charge flowing in the circuit in 20 seconds.

$$Q = 0.3 \times 20 = 6C$$

P.No: 4: A current of 2A flows thru' a bulb for 3 minutes. Calculate the amount of charge that flows thru' the bulb in this time.



$$Q = 2 \times 180 = 360C \qquad [180 = 3 \times 60 sec]$$

Current: (I)

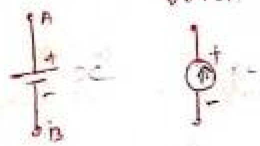
$$V = IR \qquad [\, I = V/R \,]$$

$$I = Q/t$$

$$\boxed{P = V \times I}$$

Source

- Volt/.
  - Ideal Volt/.
  - practical Volt/.
- Current
  - Ideal current
  - practical current



Circuit Responses: α

Element	'V'	I
'R' (Ω)	$V = IR$	$I = V/R$
'L' (H)	$V = L\frac{di}{dt}$	$I = \frac{1}{L}\int V\,dt$
'C' (F)	$V = \frac{1}{C}\int I\,dt$	$I = C\frac{dV}{dt}$

Resistors in series & parallel.

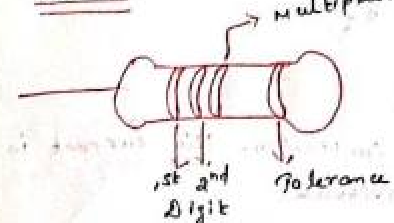
Resistor:

⇒ Used to reduce current flow, adjust signal levels, to divide voltages, bias active elements and terminate transmission lines.

⇒ Passive Component.

= Ω (K, M)

Colour Coding:



Black	Brown	R	O	Y	Green G	B	V	Gray G	W
B	B	R	O	Y	G	B	V	G	W
0	1	2	3	4	5	6	7	8	9 → –
	±1%	±2%	±3%	±4%	±0.5%	±0.25%	±0.1%	±0.05%	

Gold : (Multiplier) = $\times 10^{-1}$; Tolerance = ±5%.

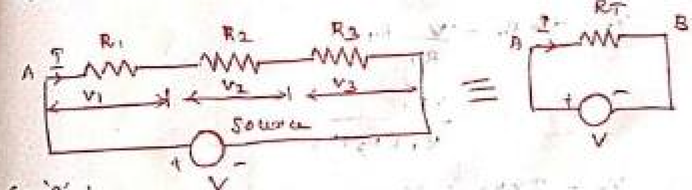
Silver : " = $\times 10^{-2}$; " = ±10%.

Combinations:

Series [current same, voltage different]

⇒ If the 'R' connected to end-end, it is said to be series.

Consider the below circuit



Eq. 'R' :

By ohm's law:

V = Applied voltage

I = source current

$V_1 = IR_1$

$V_2 = IR_2$

$V_3 = IR_3$

$\therefore V = V_1 + V_2 + V_3$

$= IR_1 + IR_2 + IR_3 = I(R_1 + R_2 + R_3)$

$V = I \times R_T$

$R_T = R_1 + R_2 + R_3$

Salient points:

(1) In the series combination, the current is same

(2) Voltage is distributed.

(3) $R_T >$ Individual 'R'.

(4) powers are additive.

(5) $V = \underbrace{V_1 + V_2 + V_3}_{\text{voltage drops}}$

(6) $R_T = R_1 + R_2 + \dots + R_n$.

Voltage Division:

W.K.T, $R_T = R_1 + R_2 + R_3$

$$I = \frac{V}{R_T} = \frac{V}{R_1 + R_2 + R_3}$$

$$V_1 = I \times R_1 = \frac{V}{R_T} R_1$$

$$= \frac{VR_1}{R_1 + R_2 + R_3}$$

$$V_2 = I \times R_2 = \frac{V}{R_T} R_2 = \frac{VR_2}{R_1 + R_2 + R_3}$$

$$V_3 = I \times R_3 = \frac{VR_3}{R_T} = \frac{VR_3}{R_1 + R_2 + R_3}$$

Applications:

1. Wherever need of variable volt., var. 'R' (rheostat) is connected in series with the load.

Eg: A fan regulator

2. Decoration lights (min. voltage)

3.

Drawbacks:

(1) If circuit breaks, no current flow.

(2) Not practicable for lighting circuit (Lamps = each 230V) 'Dim'

(3)

(5) The lamps in a set of christmas tree lights are connected in series. If there are 20 lamps and each lamp has resistance of 25Ω, calculate the total resistance of the set of lamps and hence calculate the current taken from a supply of 230 volts

Solution:

Supply voltage $= V = 230V$

$R = 25\Omega$

$n = 20$

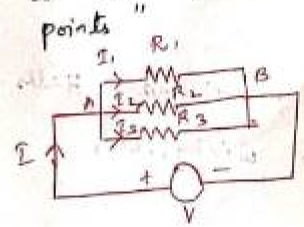
$R_T = n \times R = 20 \times 25 = 500\Omega$

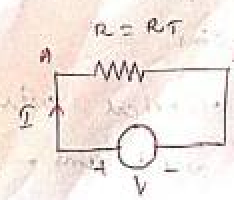
$$\therefore I = V/R_T = \frac{230}{500} = 0.46A$$

$$\therefore \boxed{I = 0.46A}$$

Parallel:

"If one end of all the resistors is joined to a common point and the other ends are joined to another common point, it is said to be parallel combination between 2 common points"





By ohm's law,

$$I_1 = \frac{V}{R_1} \; ; I_2 = \frac{V}{R_2} \; ; I_3 = \frac{V}{R_3}$$

$$\therefore I = V/R$$

$$I = I_1 + I_2 + I_3$$

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\cancel{V}/R = \cancel{V}\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$$

$$\frac{1}{R} = 1/R_1 + \frac{1}{R_2} + \frac{1}{R_3}$$

Salient points:

(1) 'V' is same across all elements.

(2) 'I' thru' various 'R' ⇒ different.

(3) Total 'R' < Individual 'R'.

(4) Power are additive.

(5) Conductance "

Adv/:

(1) Electrical appliances of diff. power ratings may be rated for the same 'V'.

Eg: Tube lights, Bulb, fridge, fan, motor.

(2) Doesn't affect other branch circuit if a break occur on any of the circuit

Applications:

(1) Electrical wiring in cinema Halls, auditoriums, house wiring, etc.,

Current division:

Let, Total current = I

current thru' $R_1 = I_1$

" $R_2 = I_2$

$$I_2 R_2 = I_1 R_1$$

$$\therefore I_2 = I_1 R_1/R_2$$

$$\therefore I = I_1 + I_2 = I_1 + I_1 \frac{R_1}{R_2}$$

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

$$I R_2 = I_1 (R_1 + R_2)$$

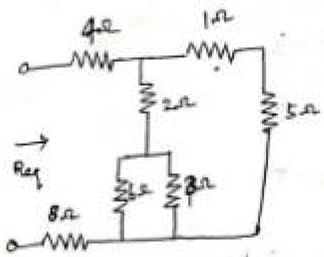
$$\Rightarrow I_1 = \frac{I R_2}{R_1 + R_2} \; ; I_2 = \frac{I R_1}{R_1 + R_2}$$

Network Terminology:

Branch:

" A part of the n/w which connects the various points of the network with one another "

(6) Find R_{eq} for the circuit shown in fig



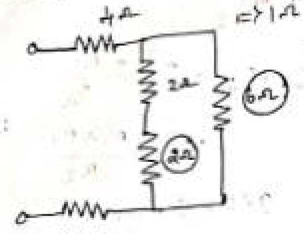
Soln: ⇒ 6Ω & 3Ω resistors are in parallel $[6\Omega \| 3\Omega]$

⇒ 1Ω & 5Ω 'R' are in series

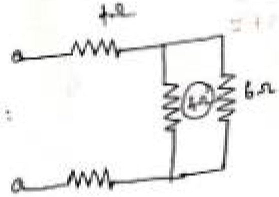
$= 1+5 = 6\Omega$

$$\left[\; = \frac{6\times3}{6+3} = 18/9 = 2\Omega \right]$$

Step 1:

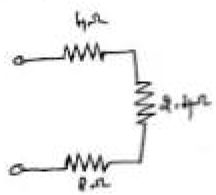


Step 2:



2Ω & 2Ω 'R' are in series

Step 3: $4\Omega \| 6\Omega$ 'R' $= \frac{4\times6}{4+6} = \frac{24}{10} = 2.4\Omega$

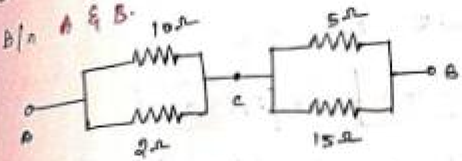


4Ω, 2.4Ω & 8Ω are in series.

$\therefore \; 4 + 2.4 + 8 = 14.4\Omega$

$\therefore \boxed{R_{eq} = 14.4\Omega}$

(7) Determine the R_{eq} of the circuit of fig: B/n A & B.



Soln:

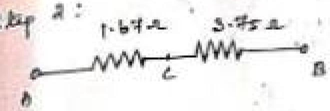
Step 1:

$10\Omega \| 2\Omega$; $5\Omega \| 15\Omega$

$= \frac{10\times2}{10+2}$; $= \frac{5\times15}{5+15}$

$= \frac{20}{12} = 1.67\Omega$; $= \frac{75}{20} = 3.75\Omega$

Step 2:

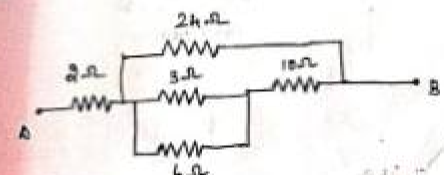


⇒ 1.67Ω Series with 3.75Ω

$\therefore \; R_{eq} = 1.67\Omega + 3.75\Omega$

$\boxed{R_{eq} = 5.42\Omega}$

(8) Find R_{eq}:



Step 1:

$3\Omega \| 6\Omega = \frac{3\times6}{3+6} = \frac{18}{9} = 2\Omega$

↓

2Ω Series with 10Ω

$= 2 + 10 = 12\Omega$

⇓

Step 2:

Resultant 'R' is ∥le with 24Ω

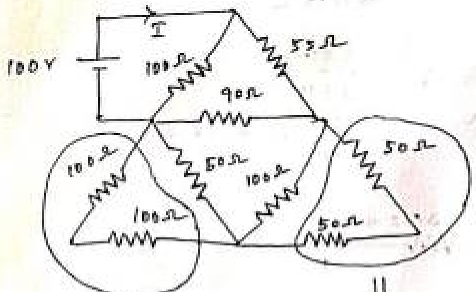
$\therefore \; 12 \| 24 = \frac{12\times24}{\;} = 8\Omega$

Step 3:

2Ω series with $8\Omega = \underline{10\Omega}$

$\therefore \boxed{R_{eq} = 10\Omega}$ (or) $\boxed{R_{AB} = 10\Omega}$

(9) Find the total current taken from the source.

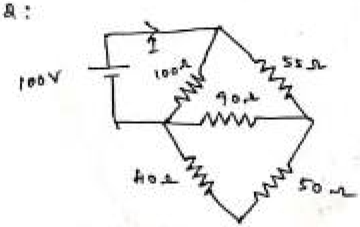


Step 1:

Series → $100+100$ → $[200 \| 50] = 200\Omega$ ⇓ $= \frac{200\times 50}{200+50} = 40$

Series. → $50+50 = 100\Omega$ $[100\Omega \| 100\Omega]$ ⇓ $= \frac{100\times 100}{100+100} = 50$

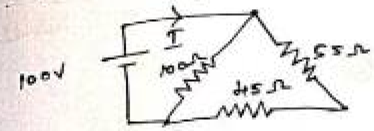
Step 2:



40Ω series with $50\Omega = 40+50 = 90\Omega$ ⇓ $90 \| 90$

$\therefore \frac{90\times 90}{90+90} = \frac{8100}{180} = 45\Omega$

Step 3:



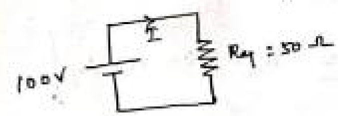
$\cancel{45 \| 55 = \frac{45\times 55}{45+55} =}$

45Ω series with $55\Omega = 45+55 = 100\Omega$

$100\Omega \| 100\Omega = \frac{100\times 100}{100+100} = 50\Omega$

$\therefore \boxed{R_{eq} = 50\Omega}$

Step 3:

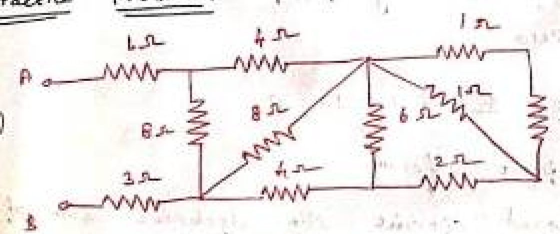


$I = \frac{V}{R_{eq}} = \frac{100}{50} = \underline{2A}$

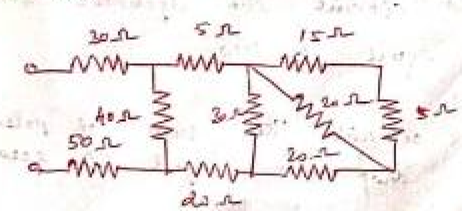
$\therefore \boxed{\text{Total current} = 2A}$

Practice Problem: Find R_T

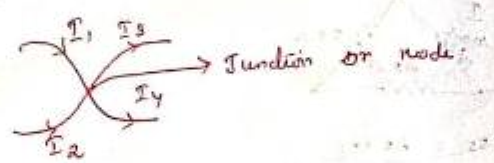
(1)



(2)



Kirchoff's current Law (KCL) [K's first Law]



" The algebraic sum of current meeting at a junction (or) node is equal to zero".

Let I_1, I_2, I_3 & I_4 ⇒ current flow thru' the conductors.

∴ current entering +ve
current leaving −ve

∴ $\boxed{I_1 + I_2 - I_3 - I_4 = 0}$

∴ $I_1 + I_2 = I_3 + I_4$

$\boxed{\text{current entering} = \text{current leaving}}$

Kirchoff's Voltage Law (KVL) [K's second Law]

" The algebraic sum of electromotive forces plus the algebraic sum of voltage across the impedances, in any closed electrical circuit is equal to zero."

Mathematically, $\Sigma \text{emf} + \Sigma IR = 0$

Statement in different forms:

→ In any closed circuit, the algebraic sum of all the voltages is equal to zero.

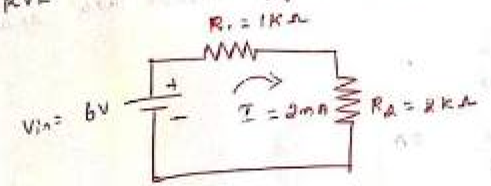
(or)

In a closed circuit, the sum of potential rise & potential drop is equal to zero.

(or)

In any closed circuit (or) closed loop, the sum of potential rise is equal to potential drop.

10. For the given circuit in figure, check whether KVL is verifying or not.



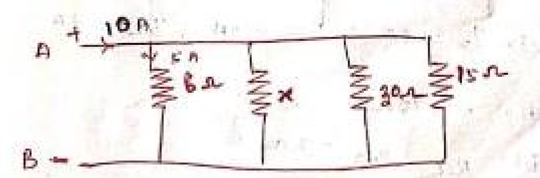
Voltage across R_1; $V_1 = IR_1 = 2 \times 10^{-3} \times 1 \times 10^{3}$
$= 2V$

Voltage across R2 : $V_2 = IR_2 = 2 \times 10^{-3} \times 2 \times 10^{3}$
$= 4V$

∴ potential rise $V_{in} = V_1 + V_2$
$= 2 + 4$
$= 6V$

Hence KVL is verified.

11. In the circuit shown in figure, calculate
(i) The current in other resistors.
(ii) The value of unknown resistance 'x'.
(iii) Req. across A−B.



Solution: [Hint: All the 'R' are in parallel ∴ 'V'

(i) Given current thru' 6Ω = 5A

(I = 10A) ∴ 'V' across 6Ω = 5 × 6 = 30V [Ohm's

Again, by ohm's law, the current thru'

$$I_{30} = \frac{30}{30} = 1A$$

$$I_{15} = \frac{30}{15} = 2A$$

$$I_6 = 6A$$

By KCL;

$$I = I_6 + I_x + I_{30} + I_{15}$$

$$10 = 5 + I_x + 1 + 2$$

$$\boxed{I_x = 2A}$$

(ii) $\therefore x = \frac{30}{2} = 15\Omega$

(iii) R_{eq}:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$= \frac{1}{6} + \frac{1}{15} + \frac{1}{30} + \frac{1}{15}$$

$$\frac{1}{R_{eq}} = 1/3. \Rightarrow \boxed{R_{eq} = 3\Omega}$$

∴ Ans: (i) $I_x = 2A$; $I_{30} = 1A$; $I_{15} = 2A$

(ii) $x = 15\Omega$

(iii) $R_{eq} = R_{AB} = 3\Omega$

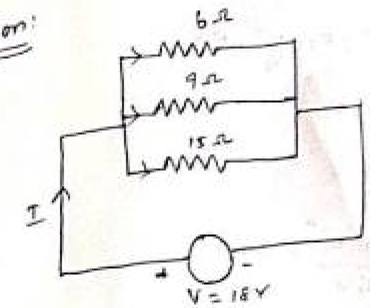
(1A) 3 resistors of 6Ω, 9Ω & 15Ω are connected in parallel to a 18V supply. Calculate

(a) the current in each branch of the network

(b) the supply current

(c) the total resistance of the network.

Solution:



(a) current in each branch:

By ohm's law applied to each 'R',

$$\therefore I_6 = \frac{18}{6} = 3A$$

$$I_9 = \frac{18}{9} = 2A$$

$$I_{15} = \frac{18}{15} = \frac{6}{5} = 1.2A$$

(b) ∴ By KCL,

Supply current = Source current

$$I_{source} = I_6 + I_9 + I_{15}$$

$$= 3 + 2 + 1.2$$

$$= 6.2A$$

(c)

$$R_{eq} = \frac{V}{I_{source}} = \frac{18}{6.2} = 2.9\Omega$$

$$\boxed{R = 2.9\Omega}$$

(or)

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= 1/6 + 1/9 + 1/15$$

$$= \cancel{15 + 4}\ 2.903$$

Practice Problems:

(1) A parallel n/w consists of 3 resistors 4Ω, 8Ω & 32Ω. If the current in the resistor is 2A, what are the currents in other resistors? Ans: $I_1 = 4A$; $I_3 = 0.5A$.

Since the resistors are connected in parallel voltage across them is the same.

Soln: i.e., $I_1 R_1 = I_2 R_2 = I_3 R_3$

$$I_1 R_1 = I_2 R_2$$

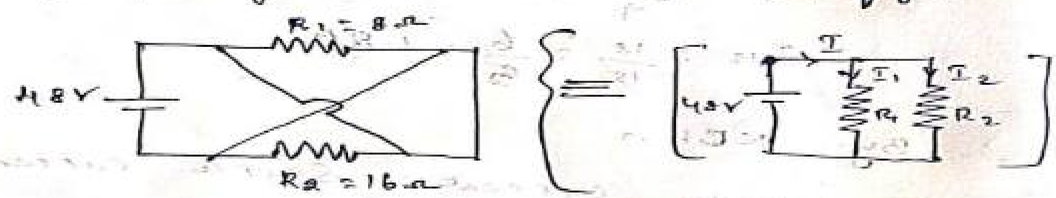
$$I_1 = \frac{I_2 R_2}{R_1}$$

$$I_1 = \frac{2 \times 8}{4} = 4A$$

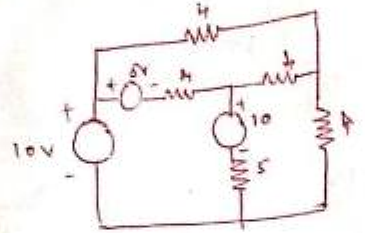
$$I_3 R_3 = I_2 R_2$$

$$I_3 = \frac{I_2 R_2}{R_3} = \frac{2 \times 8}{32} = 0.5A$$

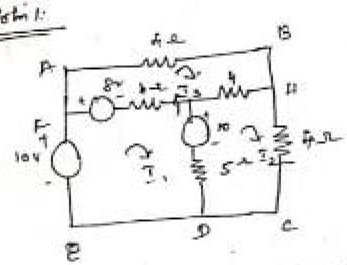
(2) Calculate the current supplied by the battery in the given circuit of the fig.



14. Find the current flowing thro' 5Ω 'R' for the n/w shown below by using mesh analysis.



Soln:



Apply KVL to loop 1 (FGDEF),

$$-\cancel{10}+8+4(I_1-I_3)+\cancel{10}+5(I_1-I_2)=0$$

$$9I_1-5I_2-4I_3=0 \longrightarrow (1)$$

Apply KVL to loop 2 (GHCDG)

$$4(I_2-I_3)+4I_2+5(I_2-I_1)-10=0$$

$$-5I_1+13I_2-4I_3=10 \longrightarrow (2)$$

Apply KVL to loop 3 (ABHGFA)

$$4I_3+4(I_3-I_2)+4(I_3-I_1)-8=0$$

$$\boxed{-4I_1-4I_2+12I_3=8} \longrightarrow (3)$$

$$\Rightarrow \cancel{I_1+I_2-3I_3=-2} \longrightarrow (4)$$

Cramer's Rule,

$I_1=\frac{D_1}{D}$; $I_2=\frac{D_2}{D}$ [We need to find I across 5Ω 'R'] ↓ So, I_1 & I_2 is enough

$$\begin{bmatrix} 9 & -5 & -4 \\ -5 & 13 & -4 \\ -4 & -4 & 12 \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}=\begin{bmatrix} -8 \\ 10 \\ 8 \end{bmatrix}$$

$$\therefore I_1=\frac{D_1}{D}=\cancel{592}=\frac{216}{592}=0.364A$$

$$I_2=\frac{760}{592}=1.283A$$

$$\therefore I_2-I_1=1.283-0.364$$

$$=0.919A$$

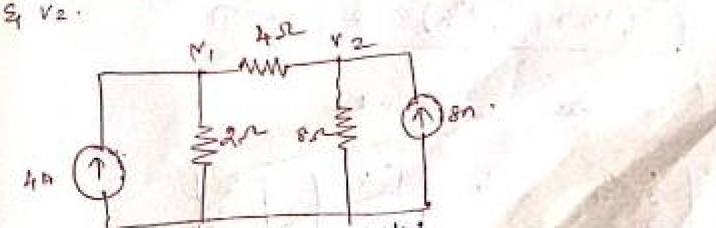
$$\therefore \boxed{\text{The total } I_5=0.919A}$$

Nodal Analysis:

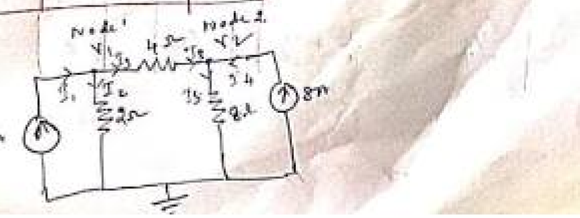
15. Find the node voltages in the given circuits using node method (or) nodal analysis.

(or)

Write the node equilibrium equation for the network shown below. Also find the node voltage V_1 & V_2.



Solution:



Apply KCL at node 1,

current entering & leaving are at node 1,

$$I_1 - I_2 - I_3 = 0$$

$$4 - \left(\frac{V_1 - 0}{2}\right) - \left(\frac{V_1 - V_2}{4}\right) = 0$$

$$4 - \frac{V_1}{2} - \frac{V_1}{4} + \frac{V_2}{4} = 0$$

$$-\left(\frac{1}{2} + \frac{1}{4}\right)V_1 + \frac{V_2}{4} = -4$$

$$\boxed{\left(\frac{1}{2} + \frac{1}{4}\right)V_1 - \frac{V_2}{4} = 4} \rightarrow 1$$

Apply KCL at node 2,

$$I_3 - I_5 + I_4 = 0$$

$$\frac{V_1 - V_2}{4} - \left(\frac{V_2 - 0}{8}\right) + 8 = 0$$

$$\frac{V_1}{4} - \frac{V_2}{4} - \frac{V_2}{8} + 8 = 0$$

$$\left(\frac{1}{4}\right)V_1 - \left(\frac{1}{4} + \frac{1}{8}\right)V_2 = -8$$

(or)

$$\boxed{-\left(\frac{1}{4}\right)V_1 + \left(\frac{1}{4} + \frac{1}{8}\right)V_2 = 8} \rightarrow 2$$

∴ In matrix format,

$$\begin{bmatrix} \frac{1}{2}+\frac{1}{4} & -\frac{1}{4} \\ -\frac{1}{4} & \frac{1}{4}+\frac{1}{8} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 4 \\ 8 \end{bmatrix}$$

By Crammer's Rule,

$$V_1 = \frac{\Delta_1}{\Delta} \; ; \; V_2 = \frac{\Delta_2}{\Delta}$$

$$\Delta = \begin{vmatrix} \frac{2+1}{4} & -\frac{1}{4} \\ -\frac{1}{4} & \frac{2+1}{8} \end{vmatrix} = \begin{vmatrix} \frac{3}{4} & -\frac{1}{4} \\ -\frac{1}{4} & \frac{3}{8} \end{vmatrix}$$

$$= \frac{3}{4}\left(\frac{3}{8}\right) - \left(-\frac{1}{4}\right)\left(-\frac{1}{4}\right) = \frac{9}{32} - \frac{1}{16} = \frac{9-2}{32} = \frac{7}{32}$$

$$= 0.22$$

$$\Delta_1 = \begin{vmatrix} 4 & -\frac{1}{4} \\ 8 & \frac{3}{8} \end{vmatrix} = 4\left(\frac{3}{8}\right) - \left(-\frac{1}{4}\right)(8)$$

$$= \frac{12}{8} + \frac{8}{4} = \frac{12+16}{8} = \frac{28}{8} = 3.5$$

$$\Delta_2 = \begin{vmatrix} \frac{3}{4} & 4 \\ -\frac{1}{4} & 8 \end{vmatrix} = \frac{3}{4}(8) - 4\left(-\frac{1}{4}\right) = \frac{\overset{6}{\cancel{24}}}{4} + \frac{4}{4}$$

$$= 7$$

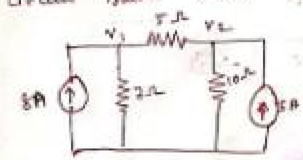
$$\therefore V_1 = \frac{\Delta_1}{\Delta} = \frac{3.5}{0.22} = 15.9\text{ V}$$

$$V_2 = \frac{\Delta_2}{\Delta} = \frac{7}{0.22} = 31.82\text{ V}$$

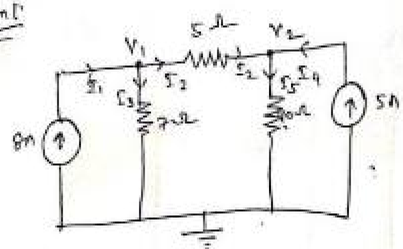
Node voltages:

∴ $V_1 = 15.9\text{V}$; $V_2 = 31.82\text{V}$

16. Find the current flowing through each 'R' for the circuit shown below by nodal analysis.



Soln:



Apply KCL at node 1,

$$I_1 - I_2 - I_3 = 0$$

$$8 - \left(\frac{V_1 - V_2}{5}\right) - \frac{V_1}{7} = 0$$

$$8 - \frac{V_1}{5} + \frac{V_2}{5} - \frac{V_1}{7} = 0$$

$$-\left(\tfrac{1}{5} + \tfrac{1}{7}\right)V_1 + \frac{V_2}{5} = 8$$

$$\boxed{\left(\tfrac{1}{5} + \tfrac{1}{7}\right)V_1 - \frac{V_2}{5} = 8} \rightarrow (1)$$

Apply KCL at node 2,

$$I_2 + I_4 - I_5 = 0$$

$$\frac{V_1 - V_2}{5} + 5 - \frac{V_2}{10} = 0$$

$$\frac{V_1}{5} - \frac{V_2}{5} + 5 - \frac{V_2}{10} = 0$$

$$\frac{V_1}{5} - \left(\frac{1}{5} + \tfrac{1}{10}\right)V_2 = -5$$

$$\boxed{-\frac{V_1}{5} + \left(\tfrac{1}{5} + \tfrac{1}{10}\right)V_2 = 5} \rightarrow (2)$$

matrix formation,

$$\begin{bmatrix} \tfrac{1}{5} + \tfrac{1}{7} & -\tfrac{1}{5} \\ -\tfrac{1}{5} & \tfrac{1}{5} + \tfrac{1}{10} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 8 \\ 5 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} \frac{1}{5} + \frac{1}{7} & -\tfrac{1}{5} \\ -\tfrac{1}{5} & \tfrac{1}{5} + \tfrac{1}{10} \end{vmatrix} = \begin{vmatrix} \frac{12}{35} & -\tfrac{1}{5} \\ -\tfrac{1}{5} & \tfrac{3}{10} \end{vmatrix}$$

$$= \frac{12}{35}\left(\tfrac{3}{10}\right) - \left(-\tfrac{1}{5}\right)\left(-\tfrac{1}{5}\right) = \frac{36}{350} - \tfrac{1}{25}$$

$$\boxed{\Delta = 0.063}$$

$\therefore \Delta_1 = 3.4$; $\Delta_2 = 3.314$

$$V_1 = \frac{3.4}{0.0628} = 54.14\,V$$

$$V_2 = \frac{3.314}{0.0628} = 52.77\,V,$$

ct: at each R',
current thru' 5Ω,

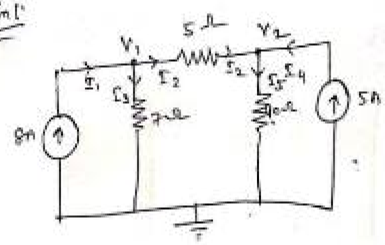
$$I_2 = \frac{V_1 - V_2}{5} = \frac{54.14 - 52.77}{5} = 0.274A$$

$$\boxed{I_2 = 0.274A}$$

$$I_3 = \frac{V_1}{7} = \frac{54.14}{7} \Rightarrow 7.734A \Rightarrow \boxed{I_3 = 7.734A}$$

$$I_5 = \frac{V_2}{10} = \frac{52.77}{10} \Rightarrow \boxed{I_5 = 5.277A}$$

Soln:



Apply KCL at node 1,

$$I_1 - I_2 - I_3 = 0$$

$$8 - \left(\frac{V_1 - V_2}{5}\right) - \frac{V_1}{7} = 0$$

$$8 - \frac{V_1}{5} + \frac{V_2}{5} - \frac{V_1}{7} = 0$$

$$-\left(1/5 + 1/7\right)V_1 + \frac{V_2}{5} = -8$$

$$\boxed{\left(1/5 + 1/7\right)V_1 - \frac{V_2}{5} = 8} \rightarrow (1)$$

Apply KCL at node 2,

$$I_2 + I_4 - I_5 = 0$$

$$\frac{V_1 - V_2}{5} + 5 - \frac{V_2}{10} = 0$$

$$\frac{V_1}{5} - \frac{V_2}{5} + 5 - \frac{V_2}{10} = 0$$

$$\frac{V_1}{5} - \left(\frac{1}{5} + 1/10\right)V_2 = -5$$

$$\boxed{-\frac{V_1}{5} + \left(1/5 + 1/10\right)V_2 = 5} \rightarrow (2)$$

matrix formation,

$$\begin{bmatrix} 1/5 + 1/7 & -1/5 \\ -1/5 & 1/5 + 1/10 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 8 \\ 5 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} \frac{1}{5} + \frac{1}{7} & -1/5 \\ -1/5 & 1/5 + 1/10 \end{vmatrix} = \begin{vmatrix} \frac{12}{35} & -1/5 \\ -1/5 & 3/10 \end{vmatrix}$$

$$= \frac{12}{35}\left(3/10\right) - \left(-1/5\right)\left(-1/5\right) = \frac{36}{350} - 1/25$$

$$\boxed{\Delta = 0.063}$$

$\therefore \Delta_1 = 3.4$; $\Delta_2 = 3.314$

$$V_1 = \frac{3.4}{0.0628} = 54.14\,V$$

$$V_2 = \frac{3.314}{0.0628} = 52.77\,V.$$

$\therefore$ at each 'R',
current through 5Ω,

$$I_2 = \frac{V_1 - V_2}{5} = \frac{54.14 - 52.77}{5} = 0.274A$$

$$\boxed{I_2 = 0.274A}$$

$$I_3 = \frac{V_1}{7} = \frac{54.14}{7} \Rightarrow 7.734A \Rightarrow \boxed{I_3 = 7.734A}$$

$$I_5 = \frac{V_2}{10} = \frac{52.77}{10} \Rightarrow \boxed{I_5 = 5.277A}$$