Linear Circuit Analysis

j)

Ohm's law :- Lecture-2

This law gives relationship b/w the voltage, current &, the resistance of a DC circuit. This law was discovered by German physicist Dr. George ohm in 1827. Know as ohm's law.

This law states that:-
"at a constant temprature, the electrical current flowing through a conductor is directly prop to the voltage across it and inversly proportional to the resistance". i.e

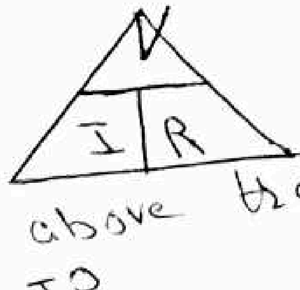
$$I \propto V$$

&, $I \propto \frac{1}{R}$

$$\boxed{V = IR}$$

→ By knowing and two values of the voltage, current or resistance quantities, we can use ohm's law to find the 3rd missing value.

ohm's law Traingle:-



find the above traingle:-

i) $V = IR$

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

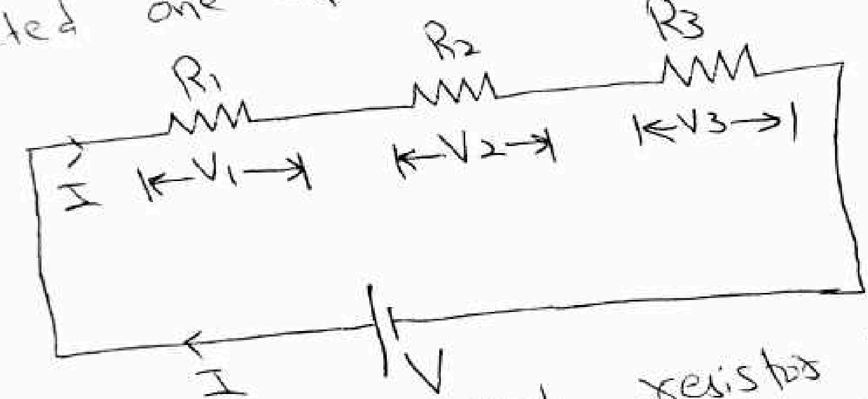
c):- $R = \frac{V}{I}$

a) Ohmic devices - which obeys ohm's law i.e current flowing through such materials increases as we increase the supply voltage across it such as resistors or cables

b) Non-ohmic devices:-
Devices that does not obey ohm's law such as transistors or diodes.

SERIES CIRCUIT:-

" A series circuit is one in which several resistances are connected one after the other" as shown in the below fig:-



The current through each resistor is same denoted by I). The chain of small lights used for the decoration purposes is good example of series ckt.

Let V_1, V_2 & V_3 be the voltages across the terminals of R_1, R_2 and R_3 respectively. Then:-

$$V = V_1 + V_2 + V_3$$

Now according to ohm's law:-

$$V_1 = IR_1$$
$$V_2 = IR_2$$
$$V_3 = IR_3$$

$\therefore\ V = IR_1 + IR_2 + IR_3$

$V = I(R_1 + R_2 + R_3)$

Applying ohm law to overall circuit

$V = IR_{eq}$

where $R_{eq} = R_1 + R_2 + R_3$

i.e total or Req resistance of the series ckt is equal to the sum of the resistances connected in series.

Characteristics of Series Circuit:-

1) The same current flows through each resistance means there is only one path for the flow of current.

2) The supply voltage (V) is the sum of the individual voltage drops across the resistances.

i.e $V = V_1 + V_2 + \ldots V_n$

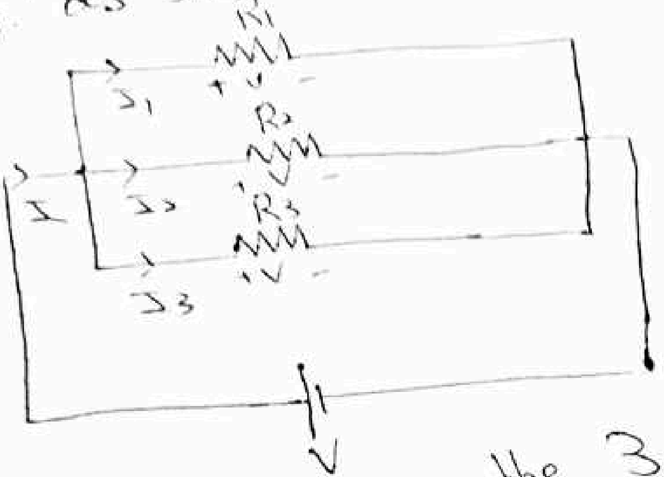
3) The equivalent resistance is equal to the sum of the individual resistances.

4) The equivalent resistance is the largest of all the individual resistances

i.e $R_{eq} > R_1$, $R_{eq} > R_2, \ldots, R_{eq} > R_n$.

Parallel Circuit:-

"That ckt which has two or more paths for the flow of current" as shown in the fig below:-



→ In the above ckt, the 3 resistances R_1, R_2 & R_3 are connected in parallel and combination is connected across a source of voltage "V".

→ In parallel ckt, current passing through each resistor is different. current passing through R_1 is I_1, through R_2 is I_2 and through R_3 is I_3.

• The voltage across the two ends of each resistors is the same and equal to the supply voltage (V).

Now lets see the current distribution.

$$V = I_1R_1 \, , \quad V = I_2R_2 \, , \quad V = I_3R_3$$

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

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

$$I = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

applying ohm's law on overall ckt:-

$$I = \frac{V}{R_{eq}}.$$

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

Characteristics of Parallel circuit:

1):- The same potential difference gets across all the resistances in parallel ckt.

2):- The total current gets divided into the number of paths and is equal to the sum of all the the individual currents.

i.e $I = I_1 + I_2 + \ldots + I_n$

3):- The equivalent resistance is the smallest of all the resistances.

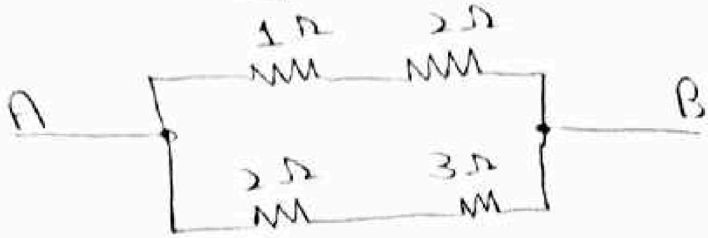
i.e $R < R_1$, $R < R_2$, ... , $R < R_n$.

Note:-

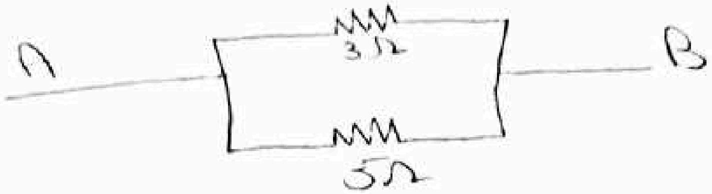
The equivalent resistance is smaller than the smallest of all the resistances connected in parallel.

Q1:- Find the equivalent resistance b/w two point A &(i) B shown in the fig below.

Fig →

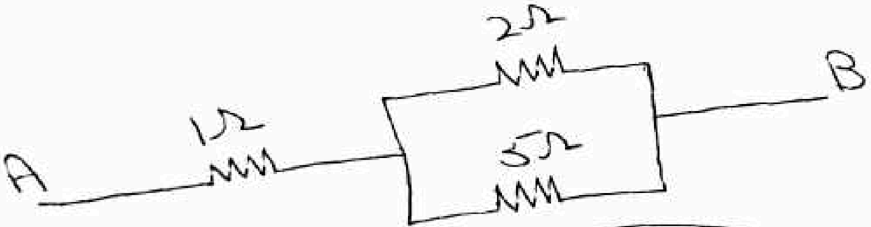


Sol:-



$$R_{AB} = \frac{3 \times 5}{3+5} = \frac{15}{8} = \boxed{1.875\,\Omega}$$

Q2:- Find the equivalent resistance b/w the two points A & B shown in the fig below:-

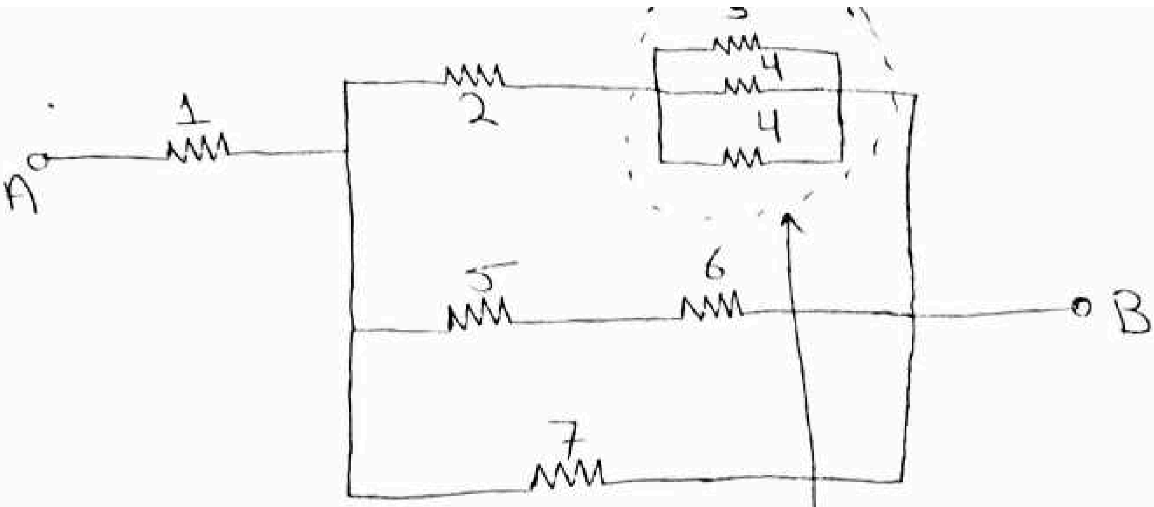


$$\frac{2 \times 5}{2+5} = \frac{10}{7} = 1.42$$

Sol:-

$$R_{AB} = 1 + 1.42 = \boxed{2.42\,\Omega}$$

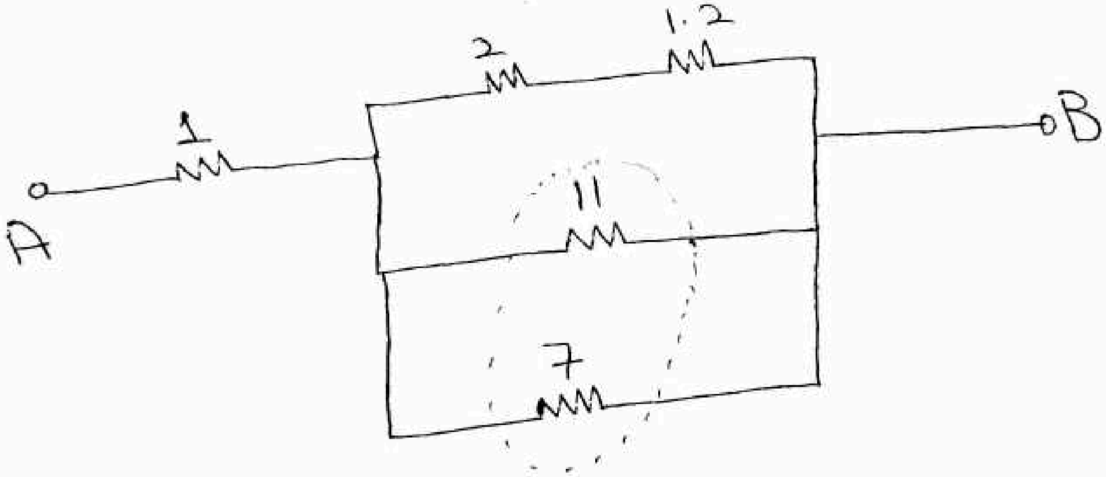
Q:-

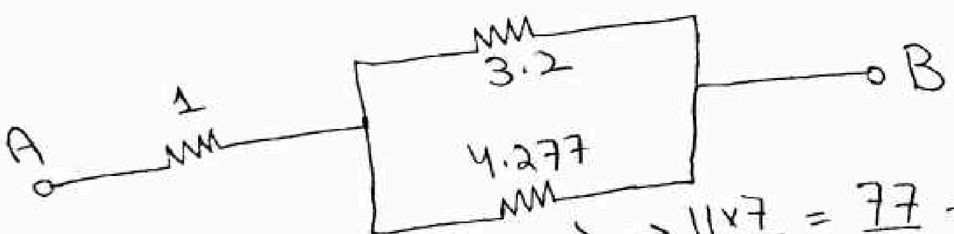


Sol^n:-

$= \frac{3\times 4}{3+4} = \frac{12}{7} = 1.714$

$\frac{1.714\times 4}{1.714+4} = \frac{6.856}{5.714} = 1.2$



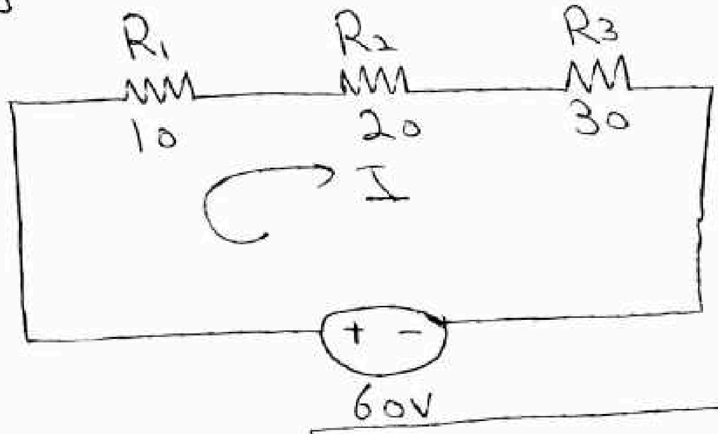


$\frac{11\times 7}{11+7} = \frac{77}{18} = 4.277$

$\frac{3.2\times 4.277}{3.2+4.277} = 1.8304$

$R_{AB} = 1+1.83 = \boxed{2.83\Omega}$

Q:- Find the voltage across the 3 resistors shown (3). in the fig below:-



Sol:- As $V = IR$

Here

$V = IR_1 + IR_2 + IR_3$

$V = I(R_1 + R_2 + R_3)$

$$I = \frac{V}{R_1 + R_2 + R_3} = \frac{60}{10+20+30} = 1A$$

Now

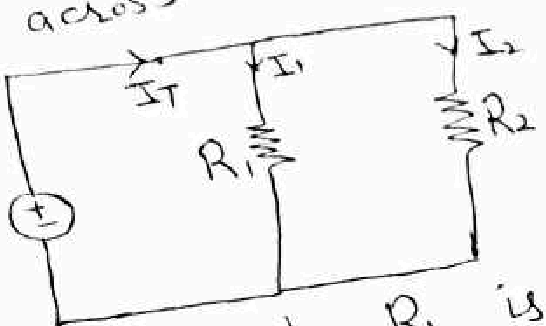
$V_{R1} = IR_1 = 1 \times 10 = \boxed{10V}$

$V_{R2} = IR_2 = 1 \times 20 = \boxed{20V}$

$V_{R3} = IR_3 = 1 \times 30 = \boxed{30V}$

Current Division in parallel circuit of Resistors:-

Consider a parallel ckt of two resistors (R_1) and (R_2) connected across a source of voltage (V).



current through R_1 is I_1 & R_2 is I_2, while total current drawn from source is (I_T).

$I_T = I_1 + I_2$ —— ①

but $\therefore$ $I_1 = \frac{V}{R_1}$ & $I_2 = \frac{V}{R_2}$

i.e $V = I_1 R_1 = I_2 R_2$

$I_1 R_1 = I_2 R_2$

$$I_1 = I_2\left(\frac{R_2}{R_1}\right)$$ putting in eq (1)

(1) $\Rightarrow$ $$I_T = I_2\left(\frac{R_2}{R_1}\right) + I_2$$

$$I_T = I_2\left(\frac{R_2}{R_1} + 1\right)$$

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

$$\boxed{I_2 = I_T\left(\frac{R_1}{R_1 + R_2}\right)}$$

Now from (1):- $I_1 = I_T - I_2$

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

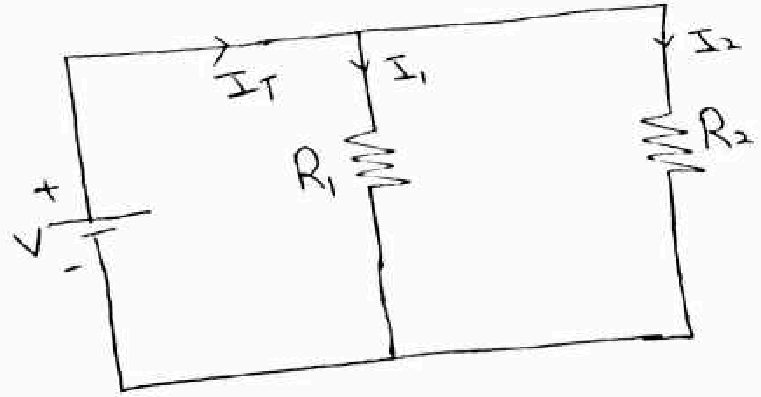
$$I_1 = I_T\left[1 - \frac{R_1}{R_1 + R_2}\right]$$

$$I_1 = I_T\left[\frac{\not{R_1} + R_2 - \not{R_1}}{R_1 + R_2}\right]$$

$$\boxed{I_1 = I_T\left[\frac{R_2}{R_1 + R_2}\right]}$$

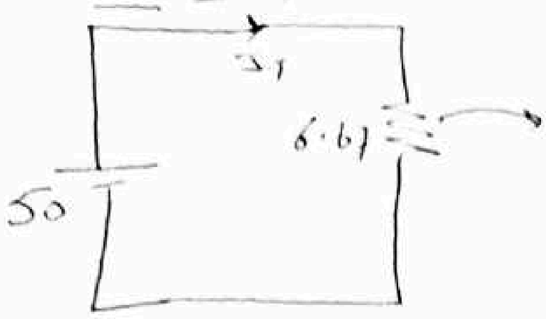
Q:- Find the magnitudes of total current, current through R_1 and R_2 if:-

$R_1 = 10\Omega$, $R_2 = 20\Omega$, & $V = 50V$.



Soln:

1st method:-



$\frac{10 \times 20}{10+20} = 6.67\Omega$

$I_T = \frac{V}{R_{eq}} = \frac{50}{6.67} = 7.5A$

2nd method:-

As per current division rule:-

$I_1 = I_T\left(\frac{R_2}{R_1+R_2}\right) = 7.5\left(\frac{20}{10+20}\right) = 5A$

$I_2 = I_T\left(\frac{R_1}{R_1+R_2}\right) = 7.5\left(\frac{10}{10+20}\right) = 2.5A$

It can be verified that $I_T = I_1 + I_2$.