Unit-1 (D.C Circuits)

Rajeev Saini
A.P in ECE Deptt.

* **Charged Body** :- Ordinarily, every substance or body is electrically neutral, as all the atoms of the body contain equal no. of electrons and protons.

→ The body that contains unequal numbers of electrons and protons is said to be electrically charged.

→ If a body contains electrons more than its normal number then the body is said to be negatively charged

→ Similarly a body containing electrons less than its normal number is said to be positively charged.

• Unit of charge → Coulomb = charge on 628×10^{16} electrons.

* **Electric current** :- A continuous flow of electrons in an electric circuit is called electric current.

mathematically; current, $I = \frac{Q}{t}$

So unit of current $= \frac{\text{Coulomb}}{\text{sec}}$ or Ampere (A)

If $Q = 1$ Coulomb
$t = 1$ Second ; then
$I = 1A$.

Thus, a wire is said to carry a current of one ampere when charge flows through it at the rate of one coulomb per second.

* **Electric Potential :-** when a body is charged, either electrons are supplied to it or they are removed from it. In both the cases, work is done. This work done is stored in the body in the form of electric potential.

Thus the body has the ability to do work by exerting a force of attraction or repulsion on the other charged particles.

→ So, the capacity of a charged body to do work is called electric potential.

→ The measure of electric potential is the work done to charge a body to one coulomb, i.e

$$\text{electric potential} = \frac{\text{work done}}{\text{charge}}$$

or

$$V = \frac{W}{Q} \quad \text{if } W = 1 \text{ Joules};$$

$$Q = 1 \text{ coulomb}$$

then $V = 1$ volt.

- Hence a body is said to have an electric potential of 1 volt if one joule of work is done to charge the body to one coulomb

* **Potential Difference :-** The difference in the electric potential of two charged bodies is called potential difference.

OR

Potential difference between two points in an electric circuit is the difference in their electrical state which tends to cause flow of electric current between them.

Unit → volt

* Electromotive force (E.M.F) :- It is the force that causes an electric current to flow in an electric circuit.

unit of emf → volt.

* Resistance :- Resistance may be defined as that property of a substance which opposes (or restricts) the flow of an electric current (or electrons) through it.

Unit of Resistance → ohm (Ω)

* Laws of Resistance :- The resistance (R) of a wire depends upon the various factors given below:

(i) It is directly proportional to its length, l i.e

$$R \propto l$$

(ii) It is inversely proportional to its area of cross section, a i.e $R \propto \frac{1}{a}$

(iii) It depends upon the nature (i.e atomic structure) of the material of which the wire is made.

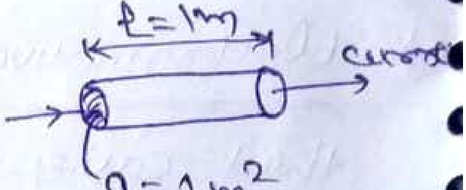
(iv) It also depends upon the temperature of wire.

So $R \propto \frac{l}{a}$ or $R = \rho \frac{l}{a}$ ($\rho \rightarrow$ Rho)

where $\rho \rightarrow$ constant of proportionality called resistivity.

if $l = 1m$; $a = 1m^2$ as shown in fig.

then $R = \rho$



• Hence, the resistance offered by one meter length of wire (of given material) having an area of cross section of one square meter is called the resistivity of the material.

Unit of resistivity, $\rho = \frac{Ra}{l} = \frac{ohm \times m^2}{m} =$ ohm-m

→ The resistivity of a material is also known as specific resistance of that material.

* <u>Conductance</u> :- The ease to the flow of current is called conductance. Denoted by letter G. Unit → mho ($\mho$)

It is reciprocal of resistance i.e.

$$G = \frac{1}{R} = \frac{1 \times a}{\rho l} = \sigma \frac{a}{l}$$

where $\frac{1}{\rho} = \sigma$ i.e conductivity.

Unit of conductivity, $\sigma = \frac{Gl}{a} = \frac{mho \times m}{m^2} =$ mho/m.

* Numerical :- The resistance of a conductor 1 mm^2 in cross-section and 20m long is 0.346 Ω. Determine the specific resistance of the conductor material.

Sol :-
$$R = 0.346\,\Omega$$
$$a = 1\,mm^2 = 1 \times 10^{-6}\,m^2$$
$$\text{specific resistance, } \rho = \frac{R \times a}{l} = \frac{0.346 \times 1 \times 10^{-6}}{20}$$
$$= 1.73 \times 10^{-8}\,\Omega m. \text{ Ans}$$

* Ohm's Law → states that the current flowing between any two points of a conductor (or circuit) is directly proportional to the potential difference across them, provided physical conditions i.e temperature etc. do not change.

mathematically ; $I \propto V$ or $\frac{V}{I} = \text{Constant}$

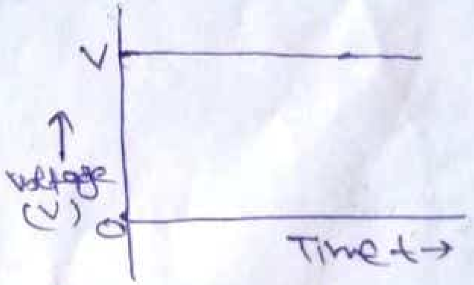
This Constant is called the resistance (R) of the Conductor (or circuit)

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

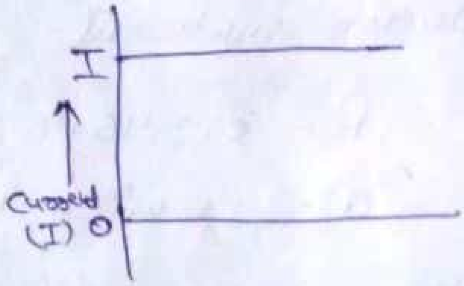
also $V = IR$; $I = \frac{V}{R}$

* Types of Supply → There are two types of supply → (1) DC supply.
(2) AC supply.

① DC supply → The voltage of or current from batteries or solar cells is direct in the sence that the polarity remains the same.

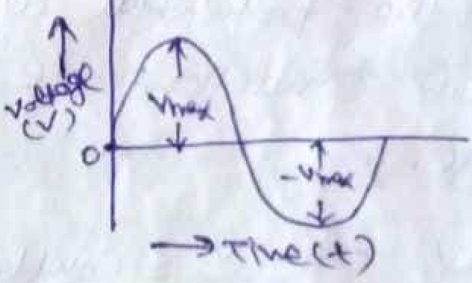


(DC voltage)

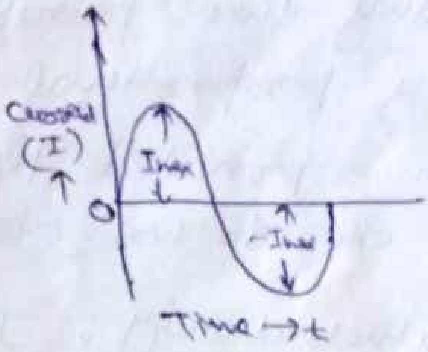


(DC current)

② AC supply → A current (or voltage) is called alternating if it periodically changes its direction and magnitude.



(AC voltage)



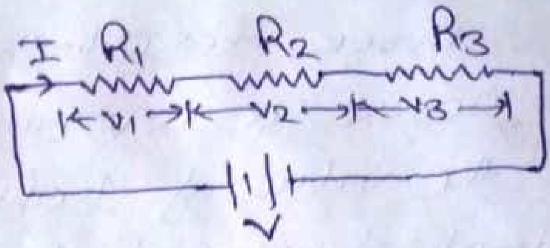
(AC current)

* D.C. circuits :- The closed path in which direct current flows is called d.c circuit.

→ Series Circuit :- when the resistors are connected end to end, so that they form only one path for the flow of current, then resistors are said to be connected in series & such ckts are known as series ckts

(4)

Let resistors R_1, R_2 & R_3 be connected in series as shown in fig.



(fig.)

According to ohm's law

voltage drop across R_1, $V_1 = IR_1$

" " " R_2, $V_2 = IR_2$

" " " R_3, $V_3 = IR_3$

voltage drop across whole ckt

$$V = IR_1 + IR_2 + IR_3$$

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

whole ckt resistance, say R

$\therefore$ Effective resistance of series ckt,

$$R = R_1 + R_2 + R_3$$

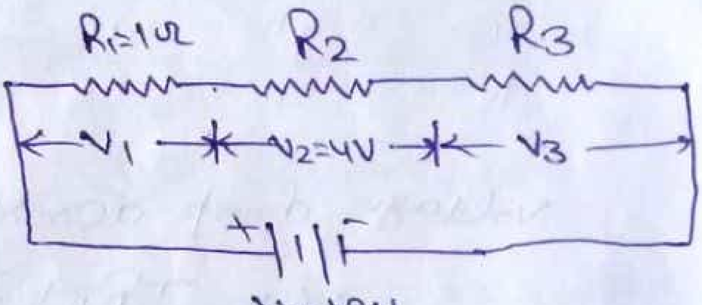
Thus when a number of resistors are connected in series, the equivalent resistance is given by the arithmetic sum of their individual resistances. i.e $R = R_1 + R_2 + R_3 + \cdots R_n$

→ From the above discussion for a series circuit we conclude that

1. Same current flows through all parts of the ckt.
2. Applied voltage is equal to the sum of the voltage drops across different parts of ckt.
3. Different resistors have their individual voltage drops.
4. voltage drops, resistances and powers are additive

e.g - Three resistors are connected in series across a 12V battery. The first resistor has the value of 1 ohm, second has a voltage drop of 4V and third has a power dissipation of 12W. Calculate the value of each resistance and circuit current.

Sol :- Let I is the current flowing thro. R_1, R_2 + R_3.



Now $V_1 = IR_1$

$= I$ volts

$V_2 = IR_2 = 4V$

$V_3 = \frac{\text{Power dissipation}}{I} = \frac{12}{I}$

Since $V = V_1 + V_2 + V_3$

$12 = I + 4 + \frac{12}{I}$

or $I^2 - 8I + 12 = 0$

or $(I-6)(I-2) = 0$

or $I = 6$ or $2A$.

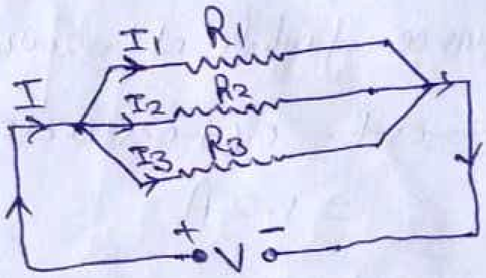
when $I = 6A$; $R_2 = \frac{4}{6} = \frac{2}{3}\,\Omega$ and $R_3 = \frac{P}{I^2} = \frac{12}{36} = \frac{1}{3}$

i.e $R_1 = 1\Omega$; $R_2 = \frac{2}{3}\,\Omega$ & $R_3 = \frac{1}{3}\,\Omega$

when $I = 2A$; $R_2 = \frac{4}{2} = 2\,\Omega$ & $R_3 = \frac{P}{I^2} = \frac{12}{4} = 3\,\Omega$

i.e $R_1 = 1\Omega$; $R_2 = 2\Omega$ & $R_3 = 3\Omega$.

* **Parallel circuits :-** The circuit in which one end of all the resistors is joined to a common point and the other ends are also joined to another common point so that different current flows through them is called parallel circuit.



Acc. to Ohm's law
current in resistor R_1

$$I_1 = \frac{V}{R_1}$$

current in R_2, $I_2 = \frac{V}{R_2}$

" " R_3, $I_3 = \frac{V}{R_3}$

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

or $\frac{I}{V} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ (where R is equivalent resistance of whole ckt.)

i.e Reciprocal of total resistance = sum of reciprocal of individual resistances.

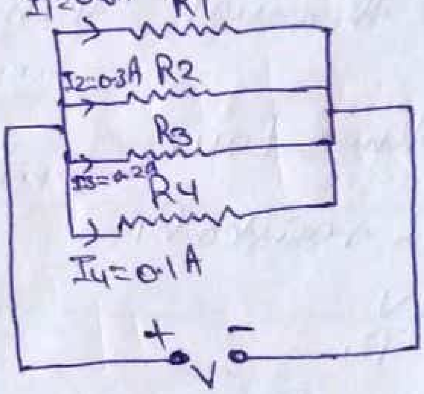
Also $G = G_1 + G_2 + G_3 + \cdots + G_n$.

→ From the above discussions for a parallel ckt we conclude that

1. Same voltage acts across all branches of the ckt.
2. Different resistors have their individual currents.
3. Total ckt. current is equal to sum of individual currents thro. the various resistors.

e.g. – The equivalent resistance of four resistors joined in parallel is 20Ω. The current flowing through them are 0.6, 0.3, 0.2 and 0.1 ampere. Find the value of each resistor.

Sol :-



Eq. Resistance of whole ckt = 20Ω

Total current = 0.6 + 0.3 + 0.2 + 0.1

$= 1.2\,A$

So PD across ckt

$$V = 20 \times 1.2 = 24\,V$$

Resistance $R_1 = \frac{V}{I_1} = \frac{24}{0.6} = 40\,\Omega$

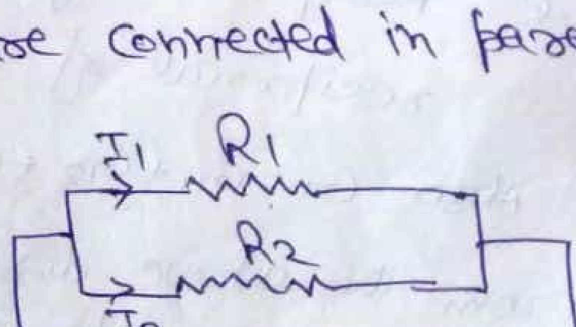
$R_2 = \frac{V}{I_2} = \frac{24}{0.3} = 80\,\Omega$

$R_3 = \frac{V}{I_3} = \frac{24}{0.2} = 120\,\Omega$

$R_4 = \frac{V}{I_4} = \frac{24}{0.1} = 240\,\Omega$.

→ Division of current in parallel ckts :-

(i) when two resistors are connected in parallel



Acc. to ohm' Law

$I_1 R_1 = I_2 R_2 = V$

or

$\frac{I_1}{I_2} = \frac{R_2}{R_1}$ Hence current in each branch of a ||el ckt is inversely proportional to its resistance respectively.

$$I_1R_1 = I_2R_2 = IR = V$$

total resistance of ckt.

Total current.

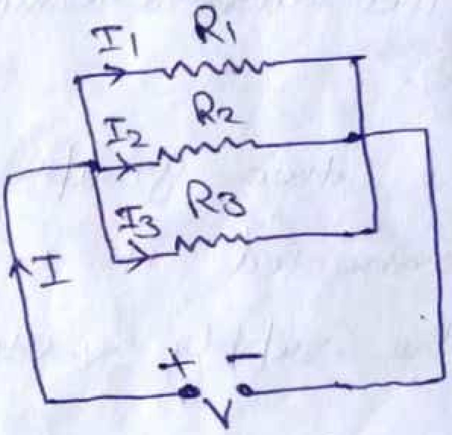
Rajeev saini
ECE Deptt.

$$R = \frac{R_1R_2}{R_1+R_2}$$

Now, $I_1R_1 = IR = I \cdot \frac{R_1R_2}{R_1+R_2}$

or $I_1 = I \cdot \frac{R_2}{R_1+R_2}$, similarly $I_2 = I \cdot \frac{R_1}{R_1+R_2}$

(ii) when three resistors are connected in ||el:-



$$I_1R_1 = I_2R_2 = I_3R_3 = IR = V$$

Now $R = \frac{R_1R_2R_3}{R_1R_2+R_2R_3+R_3R_1}$

$\therefore$ $I_1R_1 = IR = I \cdot \frac{R_1R_2R_3}{R_1R_2+R_2R_3+R_3R_1}$

or $I_1 = I \cdot \frac{R_2R_3}{R_1R_2+R_2R_3+R_3R_1}$

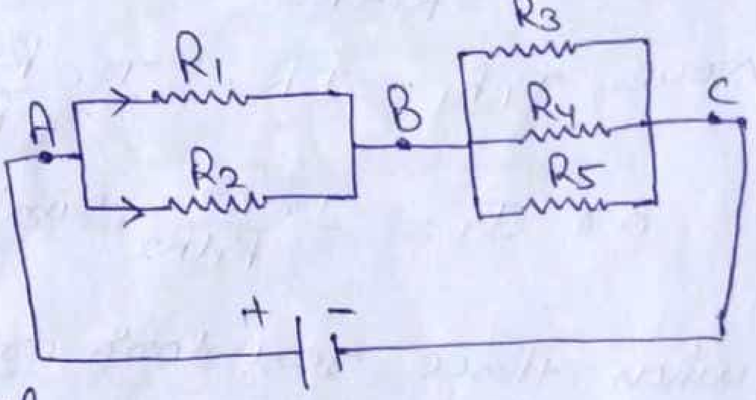
Similarly

$$I_2 = I \cdot \frac{R_1R_3}{R_1R_2+R_2R_3+R_3R_1}$$

& $I_3 = I \cdot \frac{R_1R_2}{R_1R_2+R_2R_3+R_3R_1}$

* Series - Parallel circuit :-

The circuit in which series and parallel circuits are connected in series is called series - parallel circuit.



- R_1 & R_2 are in ||el across terminal AB
- R_3, R_4 & R_5 are in ||el across terminal BC.
- The two groups of resistors R_{AB} and R_{BC} are connected in series with each other across the supply voltage of V volts.

Now equivalent resistance of Branch AB,

$$\frac{1}{R_{AB}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\text{or } R_{AB} = \frac{R_1 R_2}{R_1 + R_2}$$

Similarly,

$$\frac{1}{R_{BC}} = \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}$$

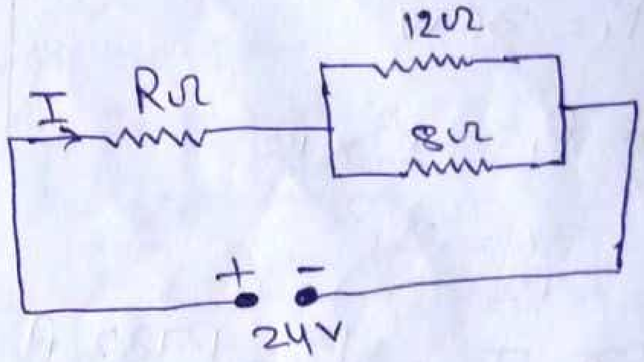
$$= \frac{R_4R_5 + R_3R_5 + R_3R_4}{R_3R_4R_5}$$

$$\text{or } R_{BC} = \frac{R_3R_4R_5}{R_3R_4 + R_4R_5 + R_5R_3}.$$

Total or effective resistance of circuit, $R = R_{AB} + R_{BC}$

Eg → A resistor R is connected in series with a parallel circuit comprising of two resistances 12 and 8 ohms respectively. The total power dissipated in the circuit is 96 watts when applied voltage is 24 V. Calculate value of R.

Sol :-



Total power dissipated, $P = 96W$;
Applied voltage, $V = 24V$

Current supplied to the circuit, $I = \frac{P}{V} = \frac{96}{24} = 4A$.

Now equivalent resistance of two resistances connected in ||el say R_p.

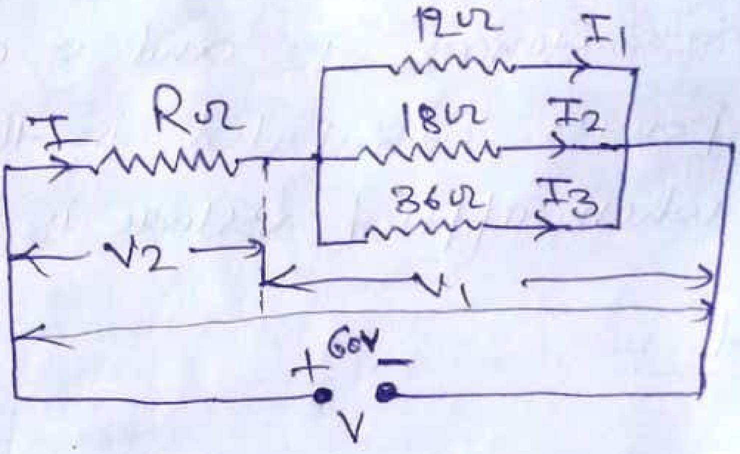
$$\frac{1}{R_p} = \frac{1}{12} + \frac{1}{8} = \frac{2+3}{24} = \frac{5}{24}$$

or $R_p = \frac{24}{5} = 4.8$ ohms.

→ Effective resistance of the circuit, $R_{eff} = \frac{V}{I} = \frac{24}{4}$
$= 6\Omega$.

So $R = R_{eff} - R_p = 6 - 4.8 = 1.2$ ohms. Ans

Eg → A circuit consists of three resistances of 12 ohms, 18 ohms and 36 ohms respectively joined in parallel is connected in series with a fourth resistance. The whole circuit is supplied at 60V and it is found that power dissipated in 12 ohm resistance is 36W. Determine the value of fourth resistance.



Sol :- Power dissipated in 12 ohm resistor,

$P_1 = 36\,W$

so $P_1 = I_1^2 \times 12$

$\frac{36}{12} = I_1^2$

or $I_1 = \sqrt{3} = 1.732\,A$

& $V_1 = I_1 \times 12 = 1.732 \times 12 = 20.785\,V$

$V_2 = 60 - V_1 = 60 - 20.785 = 39.215\,V$

Now current in 18Ω resistor, $I_2 = \frac{V_1}{18} = \frac{20.785}{18}$
$= 1.155\,A$

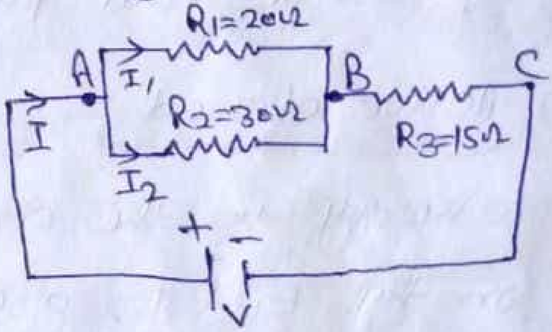
" " 36Ω " , $I_3 = \frac{20.785}{36} = 0.577$

Total current, $I = I_1 + I_2 + I_3$
$= 1.732 + 1.155 + 0.577 = 3.464\,A$

∴ value of series Resistor, $R = \frac{V_2}{I} = \frac{39.215}{3.464} = 11.32\,\Omega$

e.g :- Two resistances of 20 Ω and 30 Ω respectively are connected in parallel. These two ||lel resistances are further connected in series with a resistance of 15 Ω. If the current thr. the 15 Ω resistance is 3A.

Find (a) The currents through the 20 Ω & 30 Ω resistances
(b) voltage across whole ckt.
(c) The total power consumed.



Sol :- Equivalent resistance of branch AB,

$$R_{AB} = \frac{20 \times 30}{20+30} = \frac{600}{50} = 12\,\Omega$$

Effective resistance of ckt, $R_{eff} = R_{AB} + R_{BC}$
$= 12 + 15 = 27\,\Omega$

Circuit current, I = current thr. 15 Ω resistance

i.e $I = 3A$.

(b) voltage ~~drop~~ across whole ckt,

$$V = I R_{eff} = 3 \times 27 = 81\,V \quad \underline{Ans}$$

(c) Total power consumed, $P = VI = 81 \times 3 = 243$ watts
<u>Ans</u>

(a) voltage drop across branch AB,

$$V_{AB} = I R_{AB} = 3 \times 12 = 36\,V$$

So current through 20 Ω resistance,

$$I_1 = \frac{V_{AB}}{R_1} = \frac{36}{20} = 1.8\,A. \quad \underline{Ans.}$$

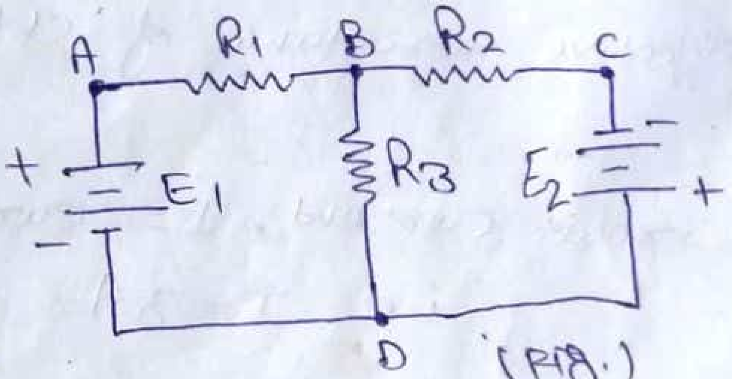
current thr. 30 Ω resistance,

$$I_2 = \frac{V_{AB}}{R_1} = \frac{36}{30} = 1.2\,A. \quad \underline{Ans.}$$

* Some terms used in network terminology before discussing the theorems :-

(1) Circuit :- A circuit is a closed conducting path through which an electric current either flows or is intended to flow. Circuit consists of active and passive elements in it.

(2) Active element :- The element which supplies energy to the circuit is called active element. In fig. E_1 & E_2 are active elements.



(Fig.)

(3) Passive element :- The element which receives energy is called passive element (such as resistor, inductor and capacitor). In fig. R_1, R_2 & R_3 are passive elements. These are also known as parameters of the network.

(4) Node :- A node is a point in the network where two or more circuit elements are joined. In fig. A, B, C & D are the nodes

(5) Junction :- A junction is a point in the network where three or more circuit elements are joined. In fact, it is a point where current is divided. In fig. B & D are the junctions.

(6) Branch :- The part of a network which lies between two junction points is called branch. In fig. DAB, BCD and BD are the three branches

(7) Loop :- The closed path of a network is called a loop. In fig. ABDA, BCDB, & ABCDA are loops

(8) Mesh :- The most elementary form of a loop which can not be further divided is called a mesh. In fig. ABDA and BCDB are two meshes but ABCDA is the loop.

* Classification of Circuit elements:-

(1) Bilateral elements:-

In these elements, the voltage-current relation may not change for current flowing in both directions. That is, even if the direction of current is changed, voltage-current relation remains the same.

Examples: Resistor, inductor and capacitor.

(2) Unilateral elements:-

In these elements, the voltage-current relation may change for current flowing in both directions. That is, if the direction of current is changed, voltage current relation is also changed.

Examples: Diode, vaccume tubes & transistors.

(3) Linear elements:-

The elements which obey the principle of superposition and homogeneity are called linear elements. The elements having linear voltage and current relation are called linear elements.

Examples:- Resistor, inductor and capaciters.

(4) Non-linear elements:- Rajeev Saini (ECE ...)

The elements which do not obey the principle of superposition and homogeneity are called non-linear elements. These are the elements which do not satisfy linear voltage and current relationship.

Examples: Diode, transistors.

(5) Lumped elements:- If we can separate the circuit elements physically, then they are called the lumped elements.

Examples: Resistor, inductor and Capacitor.

(6) Distributed elements:- If we can not separate the circuit elements for electrical purpose, then they are called distributed elements.

Examples: Transmission Line, cable.

The electrical transmission Line has resistance, inductance and Capacitance in a distributed manner throughout its length.

* Kirchhoff's Laws :-

→ Kirchhoff's current law :- It states that in any electrical network, the algebraic sum of all the currents meeting at a point or junction is zero.

mathematically ; $\Sigma I = 0$

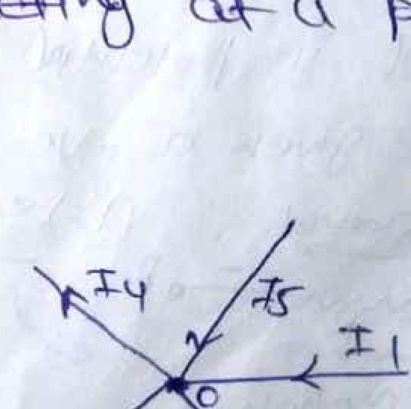


Fig. 1

Assuming the Incoming currents as +ve & out going currents as -ve.

Applying KCL to junction O in fig 1, we get

$$I_1 - I_2 - I_3 - I_4 + I_5 = 0$$

or $I_1 + I_5 = I_2 + I_3 + I_4$

i.e. sum of Incoming currents = sum of outgoing currents

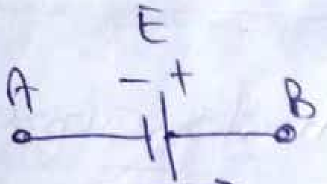
→ <u>Kirchhoff's voltage Law (KVL)</u> → In a closed circuit or mesh, the algebraic sum of all the e.m.fs plus the algebraic sum of all the voltage drops (i.e. product of current and resistances) is zero.

In other words, $\sum IR \,(\text{or } V) + \sum \text{e.m.f} = 0$

- <u>Sign Conventions</u> :-

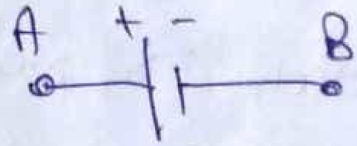
(a) <u>Sign of E.M.F</u> →

→ Rise in potential should be given a +ve sign.



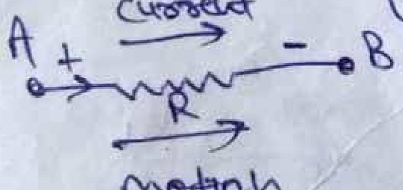
Rise in potential
+E

→ Fall in potential should be given a −ve sign.

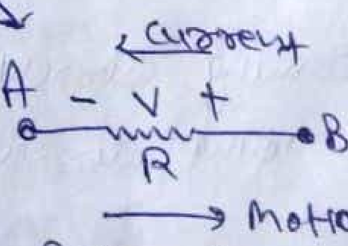


Fall in potential
−E.

(b) <u>Sign of IR drop</u>



Fall in voltage
$-V = -IR$



Rise in voltage
$+V = +IR$