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Chapter-1

* Effects of Currents *

Electricity

The property of rubbed substances due to which they attract light object is called Electricity. The Electricity developed by rubbing or Friction is called Frictional or static electricity. The rubbed substances which show this property of attraction are said to have become electrically charged.

Electric charge

Electric charge is an intrinsic property of elementary particles of matter which gives rise to electric force between various object. Electric Charge is a scalar quantity. It SI unit is Coulomb.

~~Charge are two types~~

Positive charge- The charge develop on a glass rod when rubbed with silk is called Positive charge.
Ex- Glass rod, cat skin & woollen clothes etc.

Negative charge- The charge developed on a plastic rod when rubbed with wool is called Negative charge.
Ex- silk cloth, ebonite rod etc.

Like charges repeal and unlike charges attract each other.

1 Coloumb

When 1 ampere current flow in one second in a conductor then following charge is called 1 Coloumb.

Properties of charge

Additivity → The total charge of a system is the algebraic sum of all the individual charges located at different points inside the system

$$q = q_1 + q_2 + q_3 \dots + q_n$$

Quantization of electric charge. The experimental effect that electric charge occures in decrease amount instead continuous amount is called Quantization of electric charge. The Quantization of electric charge means that the total charge of a body is always in integal multiple of a basic Quantam of charge.

$$q = ne$$

Where q is a charge, e charge on electron and n is number of electrons.

How many electron in 1 Coloumb charge?

$$q = ne$$

$$n = \frac{q}{e}$$

$$n = \frac{1}{1.6 \times 10^{-19}}$$

$$\therefore n = \frac{10 \times 10^{19}}{16}$$

$$n = .625 \times 10^{19}$$

$$n = .625 \times 10 \times 10^{18}$$

$$n = .625 \times 10^{18}$$ Joule

A comb drop through person's hair on a dry day causes 10^{12} electrons to live the person's ear and stick to the comb. Calculate the charge carried by the comb?

$$q = ne$$

$$q = 10^{12} \times 1.6 \times 10^{-19}$$

$$q = 1.6 \times 10^{-19+12}$$

$$q = 1.6 \times 10^{-7}$$ Joule

Conservation of charge

The total charged of an isolated system remain constant. The electric charge can neither be created nor be destroyed they can only be transfer from one body to another

$$_{92}U^{235} + {}_0n^1 \longrightarrow {}_{56}Ba^{142} + {}_{36}Kr^{92} + 3\,{}_0n^1 + \text{Energy}$$

$$92 + 0 \rightarrow 56 + 36 + 0$$

$$92 = 92$$

141
92
234

56
36
92

Electric Potential

The Electric potential at a point in an electric field is the amount of work done in moving a unit positive charge from infinity to that point against the electrostatic forces. It is denoted by 'V'. The SI unit of Electric potential is Volt.

$$V = \frac{W}{q}$$

Electric Potential difference

The Potential difference between two points in an electric field may be defined as the amount of work done in moving a unit positive charge from one point to other against the electrostatic forces.

A• q   •B ← q

$$V_A - V_B = \frac{W}{q}$$

1 Volt

$$V = \frac{W}{q}$$

W = 1 Joule

q = 1 Coloumb

V = 1 Volt

Potential difference is 1 volt if 1 Joule of work has to be done in moving a positive charge of 1 Coloumb from one point to the other against the electrostatic force.

The Potential difference is measured by volt meter. The volt meter is always connected in parellel with a component across which the potential difference is to be mesured.

A particle with a charge of 2.5 C is take from a point A at a potential of 60 Volt to another point B at a potential of 130 Volt. Calculate the work done.

$q = 2.5C$

$V_A = 60 \text{ Volt}$

$V_B = 130 \text{ Volt}$

$W = ?$

$$V_B - V_A = \frac{W}{q}$$

$$130 - 60 = \frac{W}{2.5}$$

$$70 = \frac{W}{2.5}$$

$W = 70 \times 2.5$ Joule.

$W = 175$ Joule

Electric current.

It is defined as the rate of flow of electric charge.

$$I = \frac{q}{t}$$

$$q = It$$

$q = ne$

$It = ne$

$n = \frac{It}{e}$

The SI unit of electric current is ampere.

$1 mA = 10^{-3} A$

$1 \mu A = 10^{-6} A$

Cur

1 Ampere

$q = 1 C$, $t = 1$ sec $I = 1 A$

The current flowing through a conductor is said to be 1 Ampere If a charge of 1 Coloumb flow in 1 second.

A current of 0.5 Ampere is drawn by a filament of an electric bulb for ~~ten~~ 10 min. Find the amount of charge that flow through the circuit.

$I = 0.5$ Ampere

$t = 10$ min → $10 \times 60 = 600$ sec

$q = It$

$q = 0.5 \times 600$

$q = 300 C$

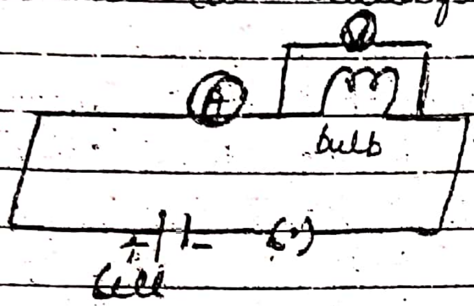
Note- • Electric current is a scaler quantity. Its flow positive to the negative terminal of the battery and opposite to the movement of the electron.

• Electric current is measured by ammeter and for weak current we used galvanometer.

• Ammeter is always connected in series in a Circuit through which the current is to be measured.

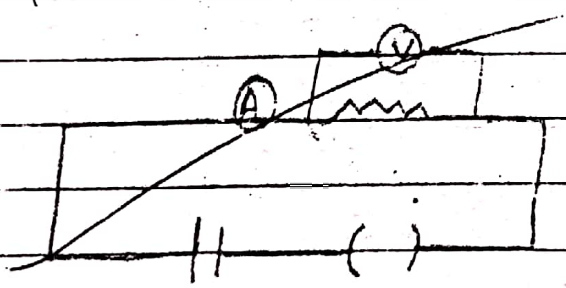
Electric Circuit

A continuous and close path of an electric current ~~Circuit~~ is called an electric circuit.
A circuit is always a continuous close pa



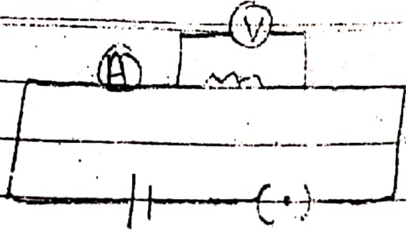
Type of Electric Circuit

Open circuit- [The electric current] If their is disconnection in any part of the electric circuit due to which no current flow their circuit is said to be an open Circuit.



Open Circuit

Close circuit- If there is no discontainuity in the circuit and current can flow from one part another part of the circuit. Then the circuit is said to be close circuit.

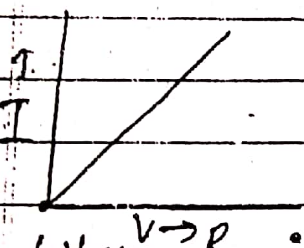


Closed circuit

Ohm's law Important :

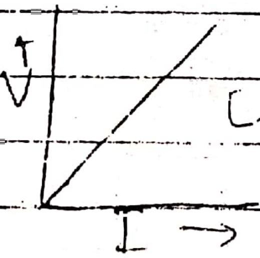
George Ohm gives a relation between potential difference, current and resistance.
"The current flowing through a metalic conductor is directly propotional to the potential difference across it's end provided the physical conditions remain constant.
If V is applied potential difference I is the current then

$I \propto V$ → at constant pressure & temperature.
$V \propto I$
$V = RI$
$R = \frac{V}{I}$ ⇒ slope of the graph.
slope of the graph = $\frac{Y \text{ axis}}{X \text{ axis}}$



$\frac{1}{\text{slope of the graph}}$

Where R is a constant called resistance of the conductor.



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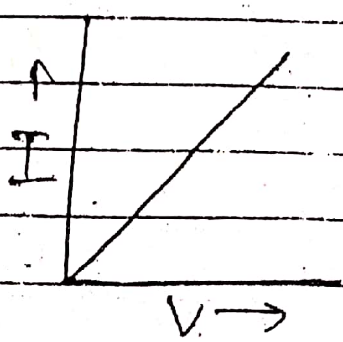


$R = \frac{1}{\text{slope of the graph}}$

Using the following data draw a graph between V and I.

V	I
2.5	0.1
5	0.2
10	0.4
15	0.6
20	0.8
25	1

Ques- Infer how current varies with potential difference. Does this graph verify OHM's Law? Give reason for your answer.

$V = IR$

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

$R_1 = \frac{2.5}{0.1} = 25\Omega$

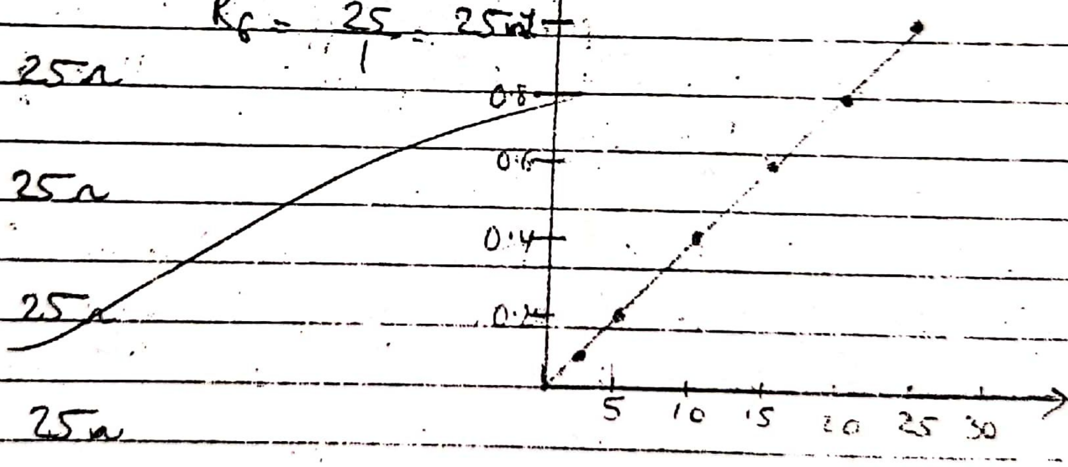
$R_2 = \frac{5}{0.2} = 25\Omega$

$R_3 = \frac{10}{0.4} = 25\Omega$

$R_4 = \frac{15}{0.6} = 25\Omega$

$R_5 = \frac{20}{0.8} = 25\Omega$

$R_6 = \frac{25}{1} = 25\Omega$



Ohmic conductor

A conductor for which voltage current is a straight line or a conductor which obey OHM's Law is called Ohmic conductor. The conductor for which V/I graph is not a straight line are called non-Ohmic conductor.

Using the following data draw a graph between V and I.

V	I
2.5	0.1
5	0.2
10	0.4
15	0.6
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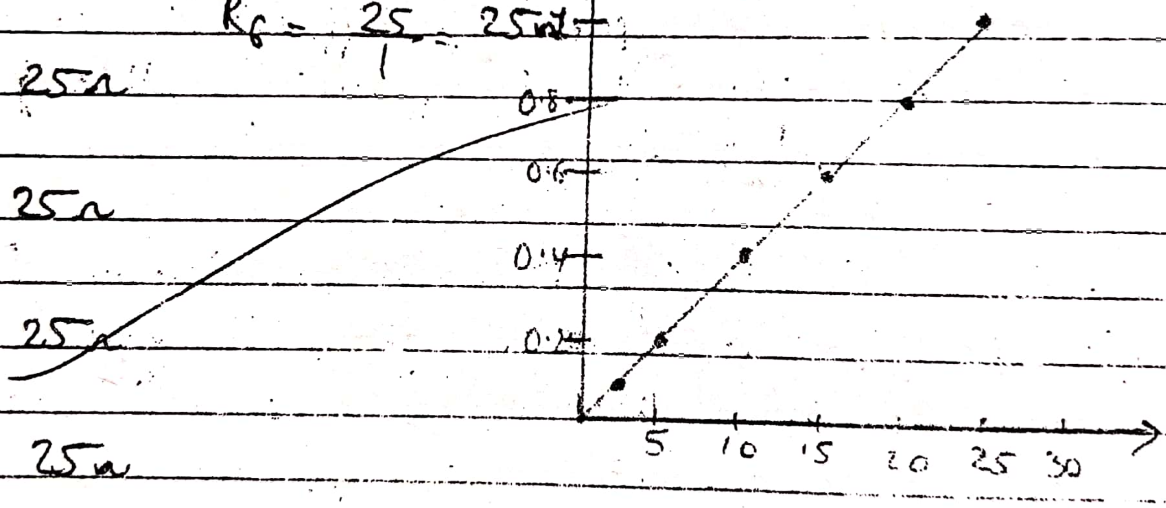

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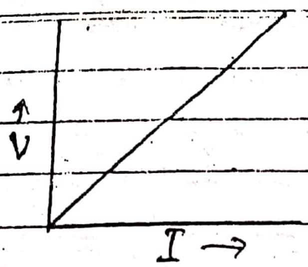
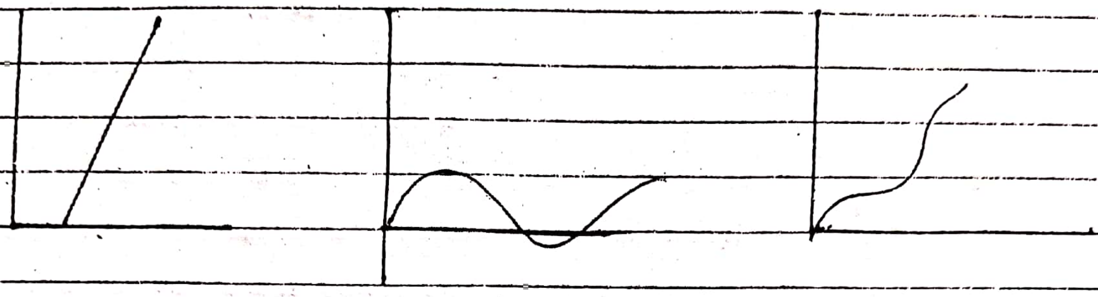


Ohmic conductor



Non-ohmic conductor

Resistance

The resistance R of a conductor it defined as the ratio of the potential difference 'V' across it. To the current 'I' flowing throught it.

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

The SI unit of Resistance is OHM Ω (omega)
Resistance is the property of a wire when we increases and decreases 'V' and 'I' are does not change.

1 OHM

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

V = 1 volt I = 1 ampere

R = 1 Ω

Classification of material on the basis of Resistivity

Conductor

Material that allow the flow of electricity easily are called Conductors. They have very low Resistivity in the range of 10^{-8} ohm meter to 10^{-6} Ohm meter. Ex- Copper and aluminium.

Alloys

An alloy is a combination of two or more elements in which at least one element is metal. Alloy have high resistivity in the range 10^{-8} ohm meter to 10^{10} ohm meter.

Ex- Nichrome (nichrome is used for electric heater, electric Iron toaster because Nichrome have high resistivity and high melting point.

Insulator

Material that do not conduct electricity are called Insulator. The Resistivity of insulator are very high in the order of 10^{10} Ohm meter 10^{17} Ω meter. Ex- Rubber, glass etc.

Semi conductors

Materials who resistivity lies in between the resistivity of conductors and insulators are called Semi-conductors. The Resistivity of semi-conductor decreases with increasing in temperature. The Semi-Conductors have the resistivity order of 10^{-5} Ω meter to 10^{-2} Ω meter.

Ex- Germanium, Silicon etc.

Factors on which the resistance of a Conductor is depands

The resistance of a uniform metalic conductor is directly prapotional to its length. ⇒

$R \propto l \rightarrow (i)$

The Resistance of conductor is inversely propotional to the area of ~~conductor~~ cross-section.

$R \propto \frac{1}{A} \rightarrow (ii)$

Resistance is also depend upon the nature of the material and temperature of the material. For a conductor the resistance increases with increasing in temperature.

From eq^n (i) and (ii)

$R \propto \frac{l}{A}$

$R = \rho \frac{l}{A}$

Where Rho(ρ) is a constant it is called resistivity or specific resistance.

Resistivity

$R = \rho \frac{l}{A}$

$l = 1m$

$A = 1m^2$

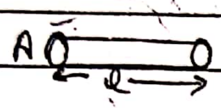
$R = \rho$

Resistivity of a material is numerically equal to the resistance of a conductor of unit length and unit (ρ) cross-section area of that material at a certain ~~temperature~~ temperature.

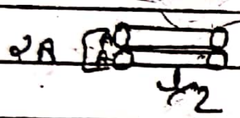
$R = \rho \frac{l}{A} = \rho \frac{l}{\pi r^2} = \rho \frac{l}{\pi (\frac{d}{2})^2}$

The SI unit of resistivity is ~~meter~~ ohm meter.

⇒ A Nichrome wire of flow of resistance is doubled on it. Calculate the new resistance of the wire.



$R_1 = \rho \frac{l}{A} \longrightarrow (i)$



$R_2 = \rho \frac{\frac{l}{2}}{2A}$

$R_2 = \rho \frac{l}{4A} \longrightarrow (ii)$

eq(2) divided by eq(1)

$\frac{R_2}{R_1} = \frac{\rho \frac{l}{4A}}{\rho \frac{l}{A}}$

$\frac{R_2}{R_1} = \frac{1}{4}$

$R_2 = \frac{R_1}{4}$

$R_2 = \frac{4}{4}$ ∴ $R_2 = 1 \Omega$

⇒ An aluminium rod with a square cross-section is 1.3 m long and 2.6 mm on edge. (a) what is the resistance between its ends? (b) what must be the diameter of cylindrical copper rod of length 1.3 m if its resistance is to be the same as that of the aluminium rod. (given $\rho_{Al} = 2.75 \times 10^{-8}\ \Omega m$)
($\rho_{cu} = 1.69 \times 10^{-8}\ \Omega m$)

a] $R = \frac{\rho l}{A}$

$R = \frac{2.75 \times 10^{-8} \times 1.3}{(2.6 \times 10^{-3})^2}$

$R = 5.29 \times 10^{-3}\ \Omega$

b] $R = \rho_{cu} \frac{l}{A}$

$A = \frac{\rho l}{R}$

$\pi r^2 = \frac{\rho l}{R}$

$r = \sqrt{\frac{\rho_c\, l}{R \times \pi}}$

$\rho c = 1.69 \times 10^{-8}\ \Omega$

$l = 1.3 m$

$R = 5.29 \times 10^{-3}$

$r = 1.13 \times 10^{-3}\ m$

$d = 1.13 \times 10^{-3} \times 2$

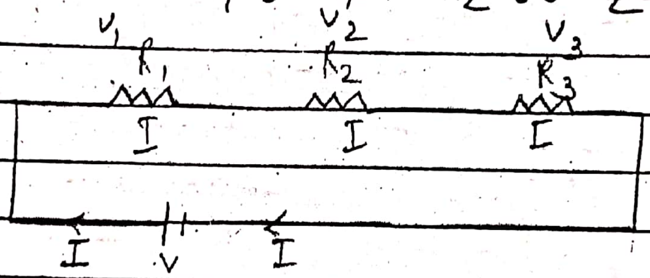
$d = 2.26 \times 10^{-3}$

Combination of resistances

There are two type of combination of resistance such as →

(i) **Resistors in Series**

Two or more Resistors are said to be in series if same current pass through them when some potential difference is applied across the combination. When two or more resistances are connected end to end they are said to be connected in series. Three Resistances R_1, R_2, R_3 connected in series. A battery of 'V' Volts has been applied in this series combination. Suppose the potential difference across the resistance R_1 is V_1, R_2 is V_2, R_3 is V_3.



$V = IR$

$V_1 = IR_1$

$V_2 = IR_2$

$V_3 = IR_3$

$$V = V_1 + V_2 + V_3$$

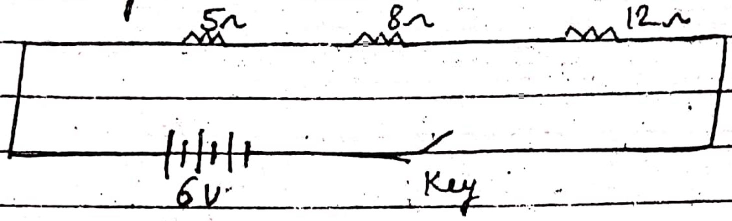
$$IR = IR_1 + IR_2 + IR_3$$

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

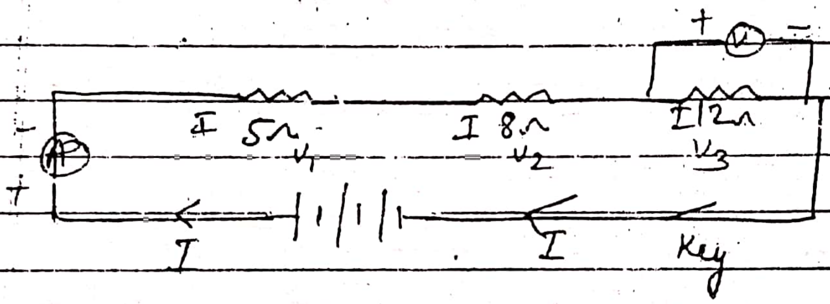
$$R = R_1 + R_2 + R_3$$

→ Draw the Diagram of circuit having a battery of three cells of 2 volts each is 5Ω, 8Ω resistor and 12Ω resistor and a plug are connected in series.
(b) Redraw the above the circuit putting to measure the current through the resistor and a Voltmeter to measure the potential difference across the 12Ω resistor. What would be the reading in the ammeter and Voltmeter.

(a)



(b)



$R = R_1 + R_2 + R_3$

$R = 5 + 8 + 12$

$R = 25\Omega$

$V = IR$

$I = \frac{V}{R} = \frac{6}{25}$

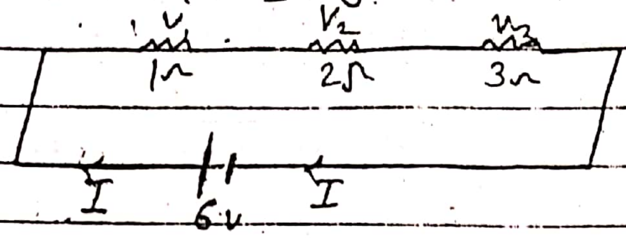
$I = .24\,A$

$V_3 = I\,R_3$

$V_3 = 0.24 \times 12$

$V_3 = 2.88\,V$

⇒ Find out V_1, V_2, V_3 and total current of the ckt.



$R = R_1 + R_2 + R_3$

$R = 1 + 2 + 3$

$R = 6\,\Omega$

$V = IR$

$I = \frac{V}{R} = \frac{6}{6} = 1A$

$V_1 = I = 1$, $R = 1$, $V = 1 \times 1$, $V = 1$ Volt

$V_2 = R = 2$, $I = 1$, $V = 2 \times 1$, $V = 2$ Volt

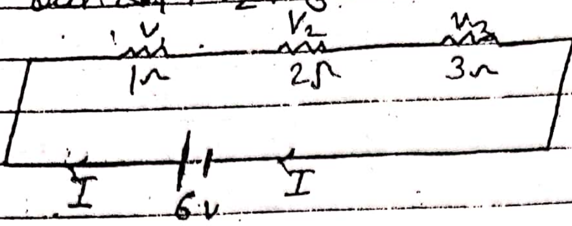
$V_3 = R = 3$, $I = 1$, $V = 3 \times 1$, $V = 3$ Volt

Parallel Combination.

In parllel Combination one end of it's resistor is connected to one point and the other end is connected to another point.

Whean a number of resistances are connected in parllel then the potential difference across it's resistance is the same which is equal to the Voltage of the battery applied. But the current flowing through all the individual parllel resistances taken together it is equal to the current flowing in the circuit as a whole.

⇒ Find out V_1, V_2, V_3 and total current of the ckt.



$R = R_1 + R_2 + R_3$

$R = 1 + 2 + 3$

$R = 6\Omega$

$V = IR$

$I = \frac{V}{R} = \frac{6}{6} = 1A$

$V_1 = I = 1$
$R = 1$
$V = 1 \times 1$
$V = 1$ Volt

$V_2 = R = 2$
$I = 1$
$V = 2 \times 1$
$V = 2$ Volt

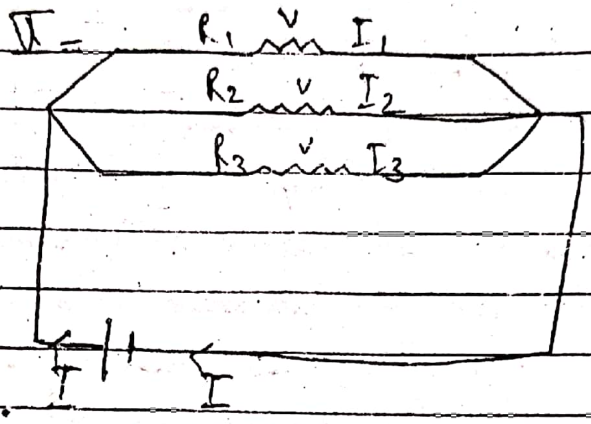
$V_3 = R = 3$
$I = 1$
$V = 3 \times 1$
$V = 3$ Volt

Parallel Combination.

In parllel Combination one end of it's resistor is connected to one point and the other end is connected to another point.

Whean a number of resistances are connected in parllel then the potential difference across it's resistance is the same which is equal to the Voltage of the battery applied. But the current flowing through all the individual parllel resistances taken together is equal to the current flowing in the circuit as a whole

Consider three resistor of resistances R_1, R_2, R_3 are connected in parllel. Let V the potential applied across the combination. Which is equal to the potential difference across.
Let I be the total current across the combination.



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

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

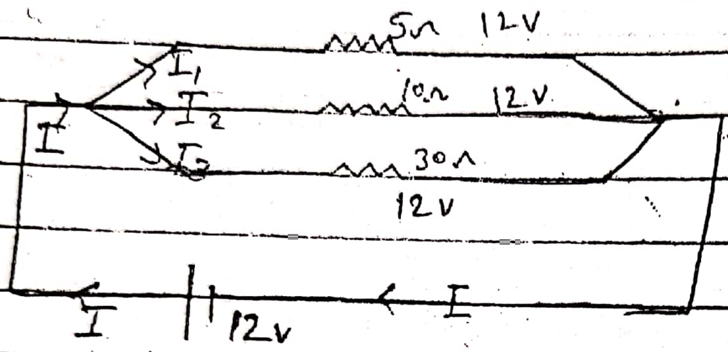
$$I = I_1 + I_2 + I_3$$

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

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

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

⇒ Three resistor of resistances 5Ω, 10Ω, 30Ω respectively are connected parllel to a battery of 12 Volt. Calculate (a) The current through each resistor (b) The total current in the circuit and (c) The total resistance of the circuit.



$$\frac{1}{R} = \frac{1}{5} + \frac{1}{10} + \frac{1}{30} = \frac{6+3+1}{30} = \frac{10}{30} = \frac{1}{3}$$

$$R = 3\Omega$$

$V = IR$

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

$I = \frac{12}{3}$

$I = 4A$

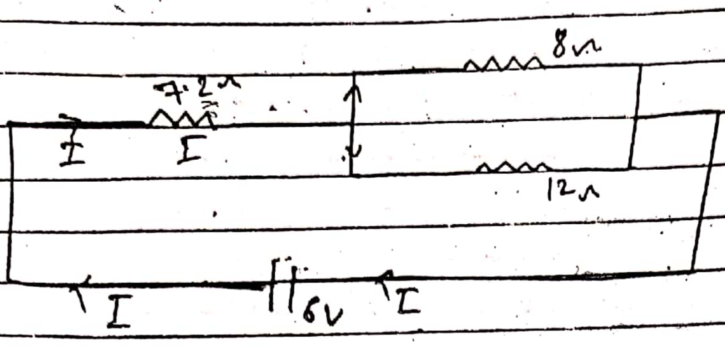
$V = I_1 R_1$

$I_1 = \frac{V}{R_1} = \frac{12}{5} = 2.4 A$

$I_2 = \frac{V}{R_2} = \frac{12}{10} = 1.2 A$

$I_3 = \frac{V}{R_3} = \frac{12}{30} = 0.4 A$

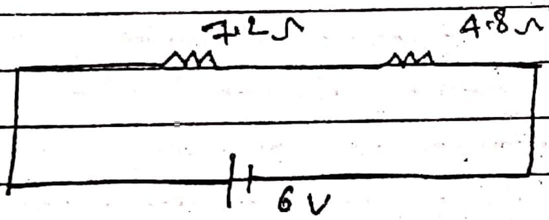
⇒ What is the total Resistance (b) What is the total current.



(i) $R' = \frac{8 \times 12}{8 + 12}$

$R' = \frac{96}{20}$

$R' = 4.8\,\Omega$



$R = 7.2 + 4.8$

$R = 12\,\Omega$

$V = IR$

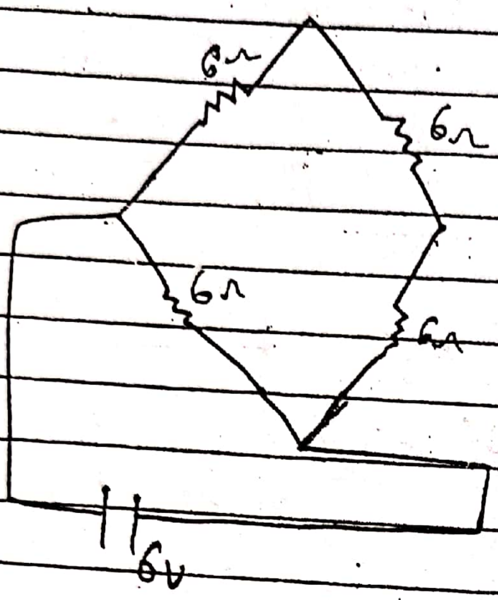
$I = \frac{V}{R}$

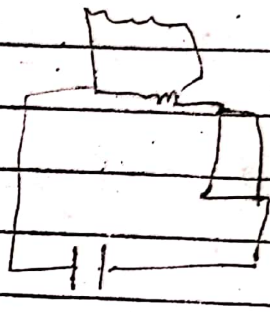
1500

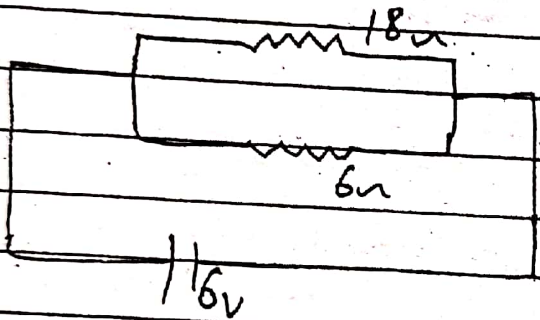
(ii) $I = \frac{6}{12}$

$I = 0.5A$

Find out the total current in a circuit.







$$\frac{1}{R} = \frac{1}{18} + \frac{1}{6}$$

$$\frac{1}{R} = \frac{1+3}{18}$$

$$\frac{1}{R} = \frac{4}{18}$$

$$R = \frac{18}{4} = \frac{9}{2}$$

$$R = 4.5\Omega$$

$$V = IR$$

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

$$I = \frac{60}{4,5}$$

$$I = \frac{60}{45} = \frac{4}{3}$$

$$I = 1.33A$$