CHAPTER 23

DIRECT CURRENT CIRCUITS

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Electric Current:-

↳ Flow of charge per unit time through a conductor is called electric current. It is denoted by 'I' and given by;

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

Where, Q = Charge & t = time

The SI unit of current is Coulomb/second or ampere(A). Ammeter is used to measure electric current.

One Ampere:-

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

If q = 1 Coulomb and t = 1 second, then I = 1 C/s = 1 A

Thus, current is said to be one ampere if one Coulomb of charge is flowing through conductor in one second.

⇒ Formula of current can be also written as,

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

Where, n = no. of free electron in conductor
e = charge of electron

$$\text{or, } I = nef \quad \left[\because f = \frac{1}{t}\right]$$

$$\text{or, } I = ne.\frac{\omega}{2\pi} \quad [\because \omega = 2\pi f]$$

$$\Rightarrow \boxed{I = \frac{nev}{2\pi r}} \quad \left[\because \omega = \frac{v}{r}\right]$$

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* An electron move in a Circle of radius 10 cm with a Constant speed of 5×10^6 m/s. Find the electric current at a point on the circle. [Ans:- 1.27×10^{-12} A]

Solution:-

Here; Radius of Circle $(r) = 10\,cm = 0.1\,m$, Speed $(v) = 5\times10^6$ m/s

Now,

$$\text{Current}(I) = \frac{neV}{2\pi r} = \frac{1\times1.6\times10^{-19}\times5\times10^6}{2\times\pi\times0.1} = \frac{40}{\pi}\times10^{-13} = 1.27\times10^{-12}\,A$$

Thus, electric current is 1.27×10^{-12} Ampere. #

Types of Current:-

↳ There are two types of Current. They are:-

i) Alternating Current.
ii) Direct Current.

[i] Alternating Current:-

↳ The Current whose magnitude and direction change periodically is called alternating Current. It is produced by generator.

If we plot the graph between current and time the nature of graph is obtained as below;

(ii) Direct Current (DC):-

↳ The Current whose magnitude and direction remains constant is called D. Current. It is produced by battery.

If we plot the graph between Current and time, the nature of graph is obtained as;

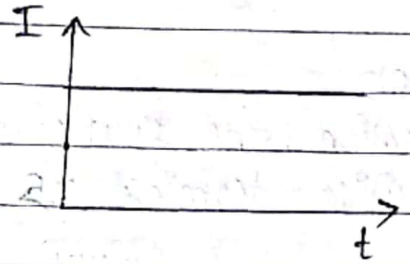

fig:- Direct Current

Direction of Current:-

↳ Before the discovery of electron, it was belived that the flow of current is due to motion of positive charge. After the discovery of electron it is known that the flow of current in conductor is due to flow of electron present in it.

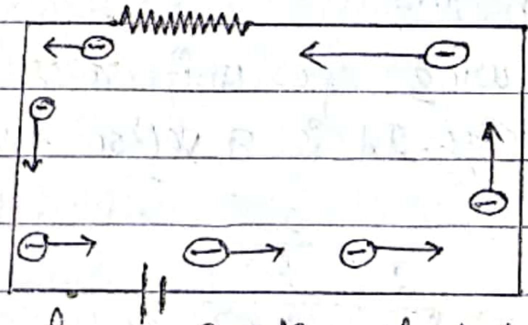

fig:- Direction of electron flow

* Conventional direction:-

↳ In Conventional direction, the flow of current is from positive terminal to negative terminal as shown in figure below:-

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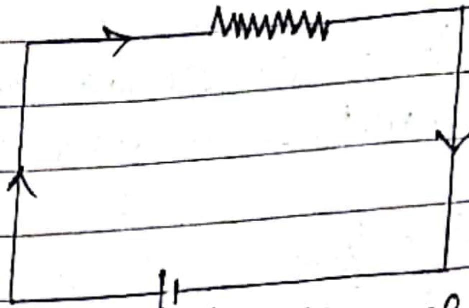


fig:- Conventional direction of current.

* **Actual direction:-**

↳ In actual direction, the flow of current is from negative terminal to positive terminal as shown in figure below:-

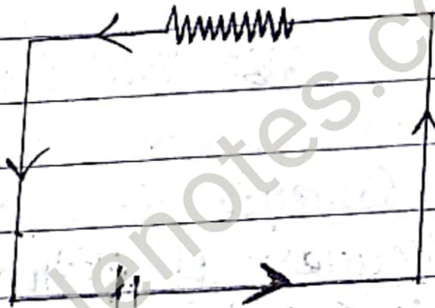


fig:- Actual direction of Current

Note:- Still we use Conventional direction in our study.

Current Density:-

↳ Current flowing per unit area of the Conductor is Called Current density. It is a vector quantity denoted by $\vec{J}$.

Numerically,

$$\vec{J} = \frac{I}{A}$$

$$\Rightarrow \boxed{I = \vec{J} \cdot \vec{A}}$$

The, SI unit of Current density is Am^{-2}. Since, Current is dot product of two vector, therefore Current is scalar quantity.

Mechanism of metalic Conduction and drift velocity:-

In the absence of electric field, the electron are in random motion due to which average velocity of free electron will be zero. Hence, there is no any current in conductor.

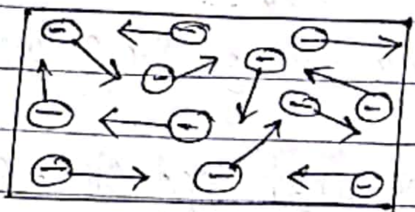


fig:- Random motion of free electron in a metalic crystal in the absence of electric field.

When the electric field is applied by connecting battery, then free electron (is act by electrostatic force. Due to electrostatic force each free electron) get accelerated in the opposite dire-ction to the field. Hence, the free electron gain velocity and K.E. These electrons however collides with atoms of conductor. During the collision the electron give up their energy to the atoms and their velocity decrease.

However, the electron again accelerate and make collision with atoms. Due to repeated collision the free electron gain a constant average velocity opposite to the direction of the electric field. This average velocity gained by free electron in a conductor when this conductor is subjected to electric field is called drift velocity.

Relation between Current and drift velocity:-

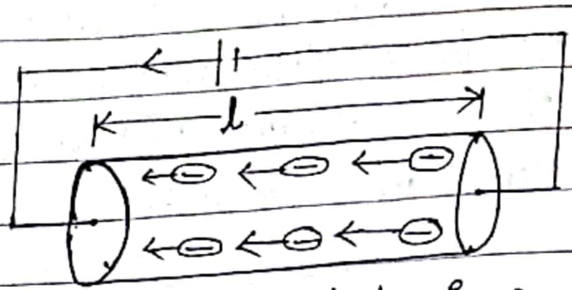


fig:- Electron passing through the Conductor in an applied field.

Let 'l' and 'A' be the length and cross-section area of a conductor respectively as shown in figure above. Also, let 'n' be the number of free electron per unit volume of a Conductor and 'e' be the charge of each free electron.

Now, volume of Conductor $(V) = Al$

$\therefore$ No. of free electron in Conductor $= n.Al$

When the conductor is subjected to the electric field then 'Q' be the charge flowing through it in time 't'.

Let 'V_d' be the drift velocity of free electron.

Then,

total charge flowing through Conductor $(Q) = nAle$

Now, Current through Conductor, $I = \frac{Q}{t} = \frac{nAle}{t}$

$$\therefore I = nAV_de \quad [\because V_d = \frac{l}{t}]$$

So, Drift velocity, $\boxed{V_d = \frac{I}{nAe}}$

and, Current Density,

$$J = \frac{I}{A} = \frac{nAV_de}{A}$$

$$\Rightarrow \boxed{J = nV_de}$$ #

Imp # Ohm's Law:-

↳ At constant physical condition (temperature, mechanical strain etc) current flowing through conductor is directly proportional to potential difference between two ends.

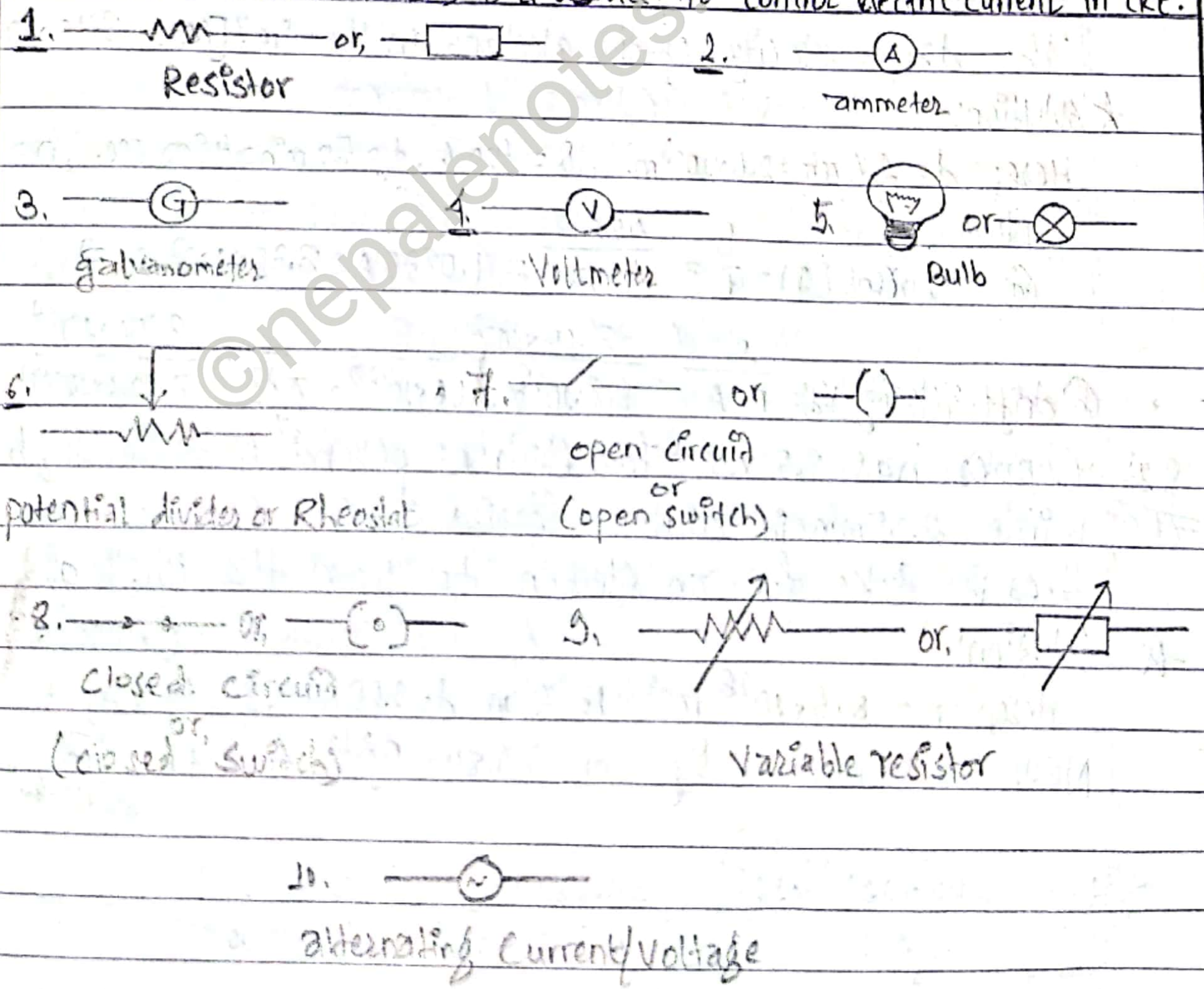
i.e, $V \propto I$

or, $\boxed{V = RI}$ ----(i)

Where, R is a constant of proportionality called the resistance of the conductor. The above equation (i) is mathematical form of ohm's law.

Note:-

Rheostat (a variable resistor) is a device to control electric current in ckt.



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Numericals:-

Q.1) A Current of 5A is passing through a metallic wire of cross-Section area 4×10^{-6} m^2. If the density of charge carries in the wire is 5×10^{26} m^{-3}. Find the drift Speed of the electron. (Ans: 1.56×10^{-2} m/s)

Solution:-

Here, Current (I) = 5 A, Cross-sectional area (A) = 4×10^{-6} m^2
density of electron (n) = 5×10^{26} m^{-3}. drift speed (v_d) = ?

Now;

We know $v_d = \frac{I}{neA} = \frac{5}{5\times10^{26}\times1.6\times10^{-19}\times4\times10^{-6}} = 1.56\times10^{-2}$ m/s

Thus, drift Speed of the electron is 1.49×10^{-2} m/s. #

Q.2) A Silver Wire 2.6 mm in diameter transfers a charge of 420 C in 80 minutes. Silver Contain 5.8×10^{28} free electrons per cubic meter (a) What is the current in the wire? (b) What is the drift velocity of the electrons in the wire? [Ans:- 8.75×10^{-2} A & 1.77×10^{-6} m/s]

Solution:-

Here; $d = 2.6$ mm $= 2.6\times10^{-3}$ m, $Q = 420$ C, $t = 80$ min $= 4800$ sec., $n = 5.8\times10^{28}$

Now,

(a) current (I) $= \frac{Q}{t} = \frac{420}{4800} = 0.0875\text{ A} = 8.75\times10^{-2}$ A #

(b) drift velocity (v_d) $= \frac{I}{neA} = \frac{8.75\times10^{-2}}{5.8\times10^{28}\times1.6\times10^{-19}\times\frac{\pi d^2}{4}} = \frac{3.77\times10^{-11}}{\pi(2.6\times10^{-3})^2} = 1.77\times10^{-6}$ m/s #

Q.3) Copper has 8.5×10^{28} free electrons per m^3. A 71 cm length of copper wire 2.05mm in diater Carries 4.84 A Current. How much time does it take for an electron to travel the length of wire? [Ans: 6567 sec]

Solution:-

Here, $n = 8.5\times10^{28}$ m^{-3}, $l = 71$ cm, $d = 2.05$ mm, $I = 4.84$ A; $t = ?$

Now, we know, $I = Q/t$ or, $4.84 = \frac{nAle}{t}$ $\Rightarrow t = \frac{8.5\times10^{28}\times A\times0.71\times1.6\times10^{-19}}{4.84}$

$\Rightarrow t = \frac{4.97\times10^{-1}\times10^{-7}}{\frac{\pi d^2}{4}} = \frac{19.88\times10^{-8}}{\pi(2.05\times10^{-3})^2} = \frac{6.328\times10^{-8}}{4.2025\times10^{-6}} = 1.50577\times10^{-2}$ Sec.

$\Rightarrow t = \frac{2\times10^9\times\pi(2.05\times10^{-3})^2}{4} = 0.5\times10^9\times\pi(4.2025\times10^{-6}) = 6591.925$ Sec. #

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Imp # Experimental verification of Ohm's Law:-

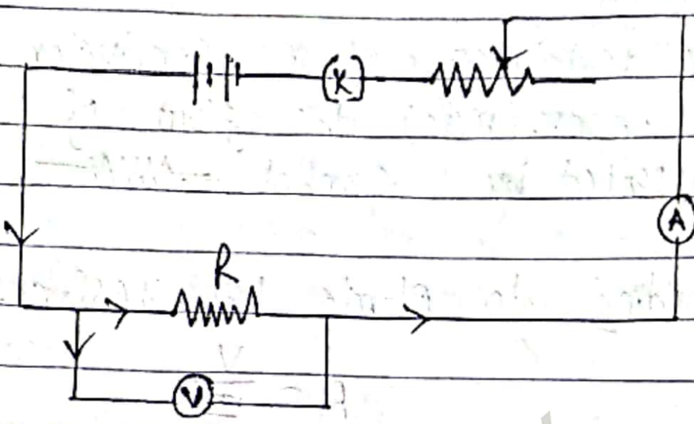


fig:- Experimental arrangement for the verification of Ohm's law.

Ohm's law can be verified by using a circuit as shown in figure above.
In above circuit, resistor of resistance (R), ammeter (A), battery, rheostat (Rh) and key (K) are connected in series where as voltmeter is connected parallel with resistor.
When, key (K) is closed then current is flowing through the circuit. By adjusting rheostat at different position corresponding value of voltmeter reading and ammeter reading are noted. If we plot a graph between voltmeter reading and ammeter reading a straight line passing through origin will be obtained which verifies Ohm's law.

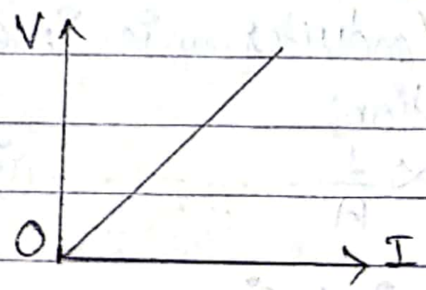
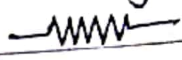
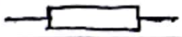


fig:- Relation between voltage and current from above graph.
We conclude, $\boxed{V \propto I}$

Resistor is an electrical Component used to limit current flow

Resistance:-

↳ The resistance of a conductor is defined as its ability to oppose (resist) the flow of charge through it. It is represented by symbol  or, .

According to Ohm's Law, resistance of Conductor;

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

The SI unit of resistance is V/A or Ohm (Ω).

One Ohm:-

$$\text{One Ohm} = \frac{1 \text{ Volt}}{1 \text{ ampere}}$$

Thus, the resistance of Conductor is said to be one ohm if one ampere current flows through it under a potential difference of one volt.

Resistivity or Specific Resistance:-

↳ It was found that resistance of Conductor is directly proportional to it's length.

i.e, $R \propto l$ ------ (i)

And, resistance of Conductor is inversely proportional to area of Cross-section;

i.e, $R \propto \frac{1}{A}$ ---------- (ii)

Combining eqn (i) & (ii);

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

$$\text{or,} \quad R = \frac{\rho l}{A}$$

Where, ρ is a proportionality constant, called resistivity or specific resistance of the material of conductor.

If $l = 1m$ and $A = 1m^2$ then $\boxed{R = \rho}$
Hence, specific resistance of conductor is numerically equal to the resistance of conductor of unit length having unit area of cross-section.

The SI unit of specific resistance is Ωm.

Conductance:-

↳ The reciprocal of resistance of conductor is called it's conductance. It is denoted by C and given by;

$$C = \frac{1}{R}$$

The SI unit of conductance is Ω^{-1}.

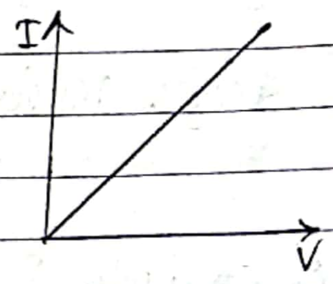
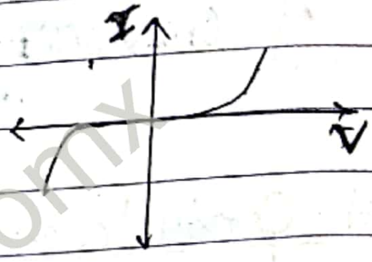
Conductivity:-

↳ The reciprocal of resistivity of conductor is called it's conductivity. It is denoted by 'σ' and given by;

$$\sigma = \frac{1}{\rho}$$

The SI unit of conductivity is $\Omega^{-1} m^{-1}$.

Difference between Ohmic and non-Ohmic Conductor:-

	Ohmic Conductor		Non-Ohmic Conductor
i	That Conductor which strictly Obey Ohm's Law is Called Ohmic conductor.	i	That Conductor which doesn't Obey Ohm's Law is Called non-ohmic Conductor.
ii	The graph between potential difference & current is Linear. 	ii	The graph between potential difference and Current is non-Linear. 
iii	e.g.:- metal, Copper Sulphate etc.	iii	e.g.:- Neon gas, dil. H_2SO_4 etc.

Combination of Resistors:-

(i) parallel Combination of resistors:-

↳ Two or more resistors are said to be in parallel Combination if one end of all resistors Connected to one Common point and another end of resistor Connected to another point such that potential differences across each resistors remains Same.

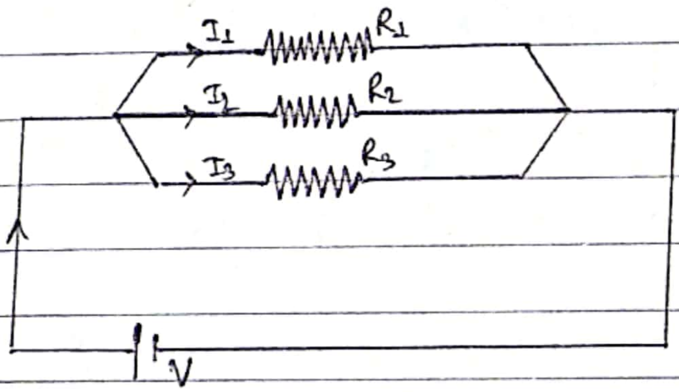


fig:- parallel Combination of resistors.

Suppose three resistors of resistance R_1, R_2 & R_3 Connected in parallel with a battery of potential difference 'v' as shown in figure above. As we know that, in a parallel combination of resistors potential difference across each resistor is same. Let I_1, I_2 and I_3 be the Current flowing through R_1, R_2 & R_3 respectively. Then by Ohm's law;

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

If 'I' be the total current flowing in the circuit;

$$\Rightarrow I = I_1 + I_2 + I_3 = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} = V\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$$

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

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

Hence, in parallel combination of resistors, the reciprocal of equivalanto resistance is equal to the sum of reciprocal of individual resistance.

(ii) Series Combination of resistors:-

↳ Resistors are said to be in series, if they are connected together end to end.

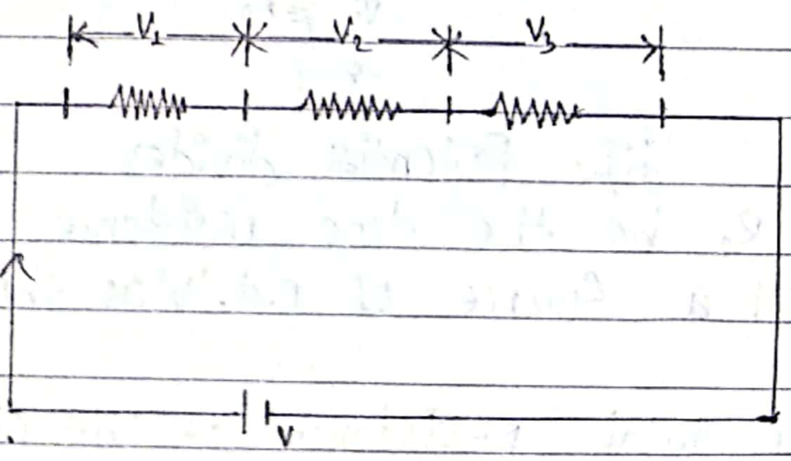


Fig:- Series Combination of resistors.

Suppose, three resistors of resistance R_1, R_2 and R_3 are connect-ed in the series with a battery of p.d. 'V'. Let 'I' be the current through three resistors. Let V_1, V_2 & V_3 be the p.d. across R_1, R_2 & R_3 respectively.
From Ohm's law;
$V_1 = I \cdot R_1$, $V_2 = I \cdot R_2$ & $V_3 = I \cdot R_3$
As we know 'V' be the total p.d. of circuit.

So; $V = V_1 + V_2 + V_3$

or, $V = IR_1 + IR_2 + IR_3$

or, $V/I = R_1 + R_2 + R_3$

$\Rightarrow \boxed{R = R_1 + R_2 + R_3}$

Thus, in series combination of resistors, the equivalent resistance is equal to the sum of all individual resistance.

Potential divider:-

↳ The arrangement of two resistors in series with a p.d. source is called potential divider. It is called so because the two resistors divide potential of the source between them;

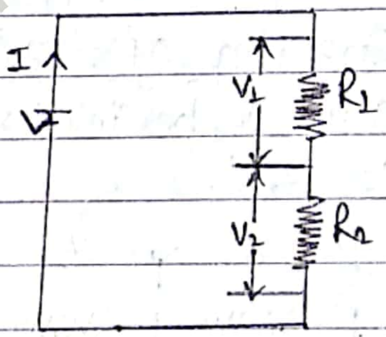


fig:- Potential divider

Let; R_1 & R_2 be the two resistance connected in series with a source of p.d. 'V' as shown in figure above.

Now, the total resistance of the circuit is;

$$R = R_1 + R_2$$

Then, Current through the circuit;

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

Again, p.d. across R_1 is,

$$V_1 = IR_1 = \frac{V}{R_1+R_2} \times R_1$$

or, $$\boxed{V_1 = \frac{R_1}{R_1+R_2} \times V} \text{ ------ (i)}$$

Again, p.d. across R_2 is;

$$V_2 = IR_2 = \frac{V}{R_1+R_2} \times R_2$$

or, $$\boxed{V_2 = \frac{R_2}{R_1+R_2} \cdot V} \text{ ------ (ii)}$$

Dividing eqn (i) & by (ii); we got;

$$\Rightarrow \boxed{\frac{V_1}{V_2} = \frac{R_1}{R_2}} \#$$

Current divider:-

↳ The arrangement of two resistors in parallel with a p.d. source is called current divider. It is called so because two resistors divide current produced by the source between them.

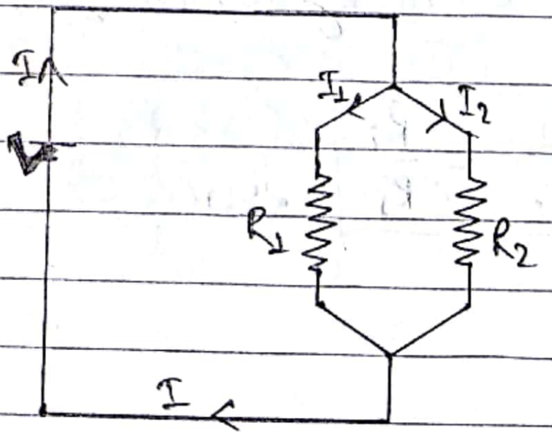


fig: Current divider

Let us Considered R_1 & R_2 be two resistance Connected parallel with a source of p.d. 'V' and 'I' be the total Current in the Circuit as shown in figure above:

As, R_1 & R_2 are in parallel so, total resistance be:

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

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

Then potential difference of the circuit;

$$V = IR$$
$$= I \frac{R_1 R_2}{R_1 + R_2}$$

Now, Current through resistance R_1 is;

$$I_1 = \frac{V}{R_1} = I \frac{R_1 R_2}{R_1 + R_2} \times \frac{1}{R_1}$$

$$\Rightarrow \boxed{I_1 = I \cdot \frac{R_2}{R_1 + R_2}} \text{ ---- (i)}$$

Similarly, Current through R_2 is;

$$\boxed{I_2 = I \frac{R_1}{R_1 + R_2}} \text{ ---- (ii)}$$

Dividing eq^n(i) by (ii); we get;

$$\Rightarrow \boxed{\frac{I_1}{I_2} = \frac{R_2}{R_1}} \quad \#$$

Difference between Electro motive force & p.d.:-

Electro Motive Force (emf)	Potential difference (p.d.)
i. The amount of energy supplied by a cell to move a unit positive charge in the closed circuit is called emf of the cell.	i. The amount of work done by a cell during the movement of a unit positive charge in the circuit is called p.d. of cell.
ii. It is denoted by 'E'.	ii. It is denoted by 'V'.
iii. It is measured in open circuit.	iii. It is measured in closed circuit.
iv. It depends on the internal resistance of the cell. i.e. $E = I(R+r)$	iv. It is independent on the internal resistance of the cell. i.e. $V = IR$
v. It is a cause of potential difference.	v. It is an effect of electro motive force.

Internal resistance:-

↳ Electric cell is a device which converts chemical energy into electrical energy. An electric cell contains two metallic rods immersed in a liquid contained in a vessel. The liquid is called electrolyte and the rods are called electrodes or plates.

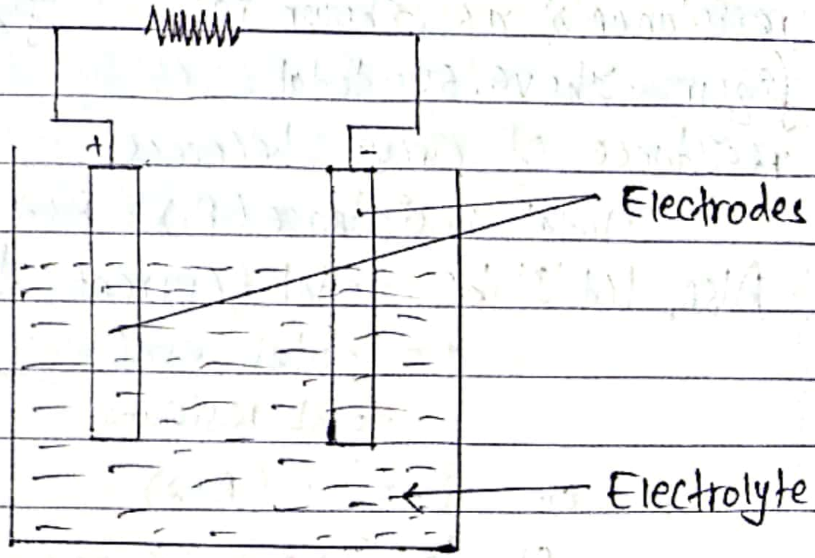


fig: Cell

The electrolyte between two electrodes of cells offers certain amount of resistance when a current flows through it. Thus, resistance is called internal resistance of the cell. It is denoted by 'r' and given by;

$$r = \left(\frac{E-V}{V}\right)R$$

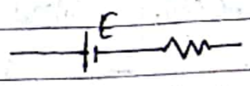


fig:- representation of internal resistance of a cell.

The internal resistance of cell depends upon the following factors:-

i) nature, temperature & concentration of electrolyte.
ii) Separation between the electrods.
iii) area of immersed portion of electrods.

Circuit Formula [Relation between E, V & r] :-

↳ Let us consider a resistance 'R' is connected in series with a cell of e.m.f. 'E' and internal resistance 'r' as shown in figure above. So total resistance of circuit becomes:

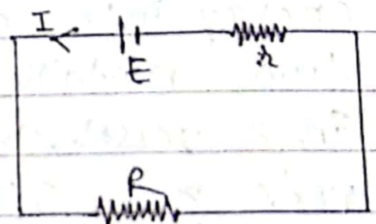


fig:- Current flowing through a closed circuit.

$$\text{Total resistance } (R_T) = R + r$$

Also, let 'I' be total current through the circuit;

$$I = \frac{\text{total emf}}{\text{total resistance}} = \frac{E}{R+r} \text{ ------ (i)}$$

or, $E = I(R+r)$

or, $E = IR + Ir$ --- (ii)

From Ohm's law;

$$V = IR \quad \text{----- (iii)}$$

Using eqn (iii) in eqn (ii), we get;

$$E = V + Ir$$

$$\boxed{V = E - Ir} \quad \text{---- (iv)}$$

In open Circuit; $I = 0$

$$\therefore \boxed{V = E}$$

Thus, in open circuit, the 'emf' of the cell is equal to it's p.d.

From eqn (iv), $\boxed{I = \frac{E-V}{r}}$ ---- (v)

From eqn (i) & (iv);

$$\frac{E}{R+r} = \frac{E-V}{r}$$

or, $Er = (R+r)(E-V)$

or, $Er = R(E-V) + r(E-V)$

or, $r[\cancel{E} - \cancel{E} + V] = R(E-V)$

$\Rightarrow \boxed{r = \frac{E-V}{V} \cdot R}$ ---- (vi)

This eqn (vi) is the relation between emf, terminal p.d; and internal resistance of a cell.

Emf & terminal p.d. of a cell during Charging & discharging:

★ During discharging, the current is supplied by a battery in the direction of its emf as shown in figure below:-

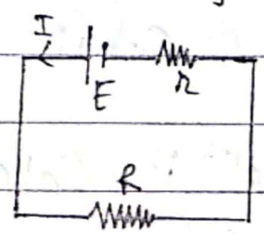


fig:- discharging of cell.

$E = V + Ir$

$\boxed{V = E - Ir}$

Thus, the p.d. of cell during discharging is smaller than it's emf.

During charging; the current is supplied to a battery against the direction of it's emf as shown in figure below:-

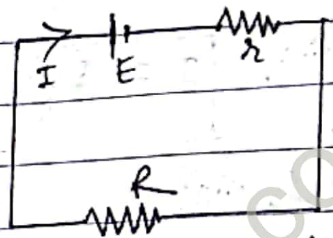


fig:- Charging of cell.

$\boxed{V = E + Ir}$

Thus; the p.d. of cell during charging is greater than it's emf.

Joule's law of heating:-

→ According to this law, the amount of heat produced 'H' in a conductor due to flow of current is;

i) directly proportional to square of current, $H \propto I^2$

ii) directly proportional to the resistance of conductor, $H \propto R$ and,

iii) directly proportional to time for which current is passed, $H \propto t$;

i.e., $H \propto I^2Rt$

or, $H = I^2Rt$ Joule

or, $H = \frac{I^2Rt}{J}$ Calorie

Where, $J = \boxed{4.18/4.2}$ Cal^{-1} is called Joule's mechanical equivalent of heat.

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Experimental verification of Joule's Law of heating:-

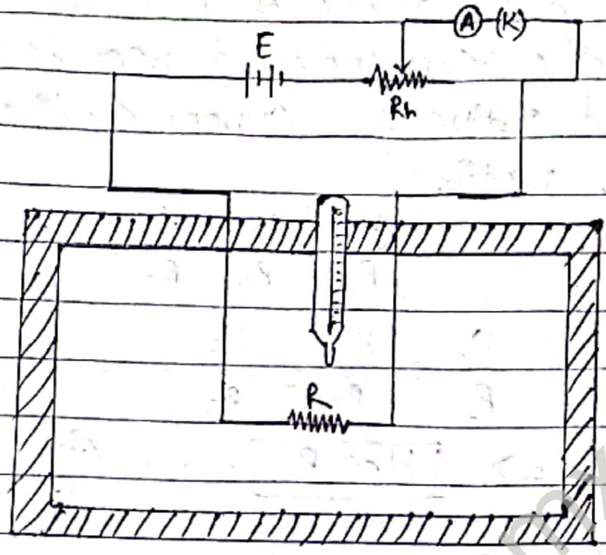

fig:- Experimental arrangement of Joule's law of heating

The Experimental arrangement of Joule's law of heating is shown in figure above. It consists of Calorimeter which $(2/3)$rd of it's volume is filled with water. A themometer is used to measure temperature. A resistance wire Connected with Source is kept inside the Calorimeter. A rheostat is Connected in the Circuit to change the current.

① To verify $H \propto I^2$:-

* Change the value of Current, I_1, I_2, I_3 ----and Calculate the corresponding heat developed H_1, H_2, H_3 ---for fixed value of resistance and time.
* Evaluate ratio: $\frac{H_1}{I_1^2}, \frac{H_2}{I_2^2}, \frac{H_3}{I_3^2}, ----$

We get. $\frac{H_1}{I_1^2} = \frac{H_2}{I_2^2} = \frac{H_3}{I_3^2} = ------$ Constant

$\Rightarrow \boxed{H \propto I^2}$ ------(i)

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② To verify $H \propto R$:-

* Change the value of resistance R_1, R_2, R_3 ---- and Calculate the Corresponding heat developed H_1, H_2, H_3 ----- For fixed value of current & time.
* Evaluate ratio;

$$\frac{H_1}{R_1}, \frac{H_2}{R_2}, \frac{H_3}{R_3}, \text{-----}$$

We get; $\frac{H_1}{R_1} = \frac{H_2}{R_2} = \frac{H_3}{R_3}$ ----- $=$ Constant

$\Rightarrow \boxed{H \propto R}$ ---- (ii)

③ To verify $H \propto t$:-

* Change the time t_1, t_2, t_3 ---- and Calculate the Corresponding heat developed H_1, H_2, H_3 ---- for the fixed value of resistance & current.
* Evaluate ratio: $\frac{H_1}{t_1}, \frac{H_2}{t_2}, \frac{H_3}{t_3}$, -----

We get;

$$\frac{H_1}{t_1} = \frac{H_2}{t_2} = \frac{H_3}{t_3} \text{-----} = \text{Constant}$$

$\Rightarrow \boxed{H \propto t}$ ---- (iii)

Combining eq^n (i), (ii) & (iii); we get;

$\boxed{H \propto I^2 Rt}$ ---- (iv)

This expression verifies Joule's law of heating.

Derivation of Joule's Law (Heat developed in a wire)

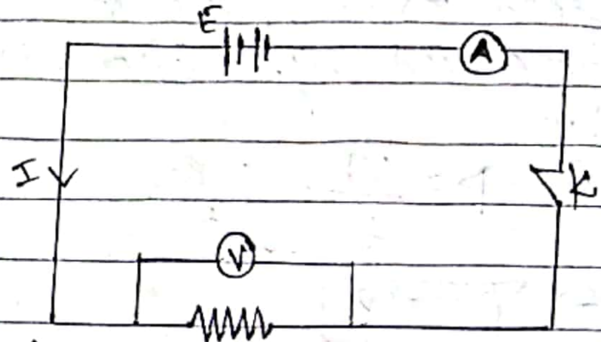


fig:- closed circuit diagram

Let us consider 'R' be the resistance and 'I' be the current passing in the circuit above.

We know, the p.d. is amount of work done during moving unit charge from one point to another point in circuit.

If 'W' be amount of work done in moving 'q' charge.

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

or, $\boxed{W = Vq}$ ------(i)

From Ohm's law;

$V = IR$ ---(ii)

Also, $q = It$ ------(iii)

Using eq^n (ii) & (iii) in eq^n (i); we get;

$W = IRIt$

$\boxed{W = I^2Rt}$

This is amount of workdone which appears in the form of heat across the resistance 'R'.

$\therefore \boxed{H = W = I^2Rt}$

It is also called electrical energy consumed.

Power:-

→ It is defined as the rate at which electrical energy consumed by resistor. It is donoted by 'p' & given by;

$$p = \frac{W}{t} = \frac{I^2Rt}{t}$$

$$\Rightarrow \boxed{p = I^2R}$$

$p = I^2R$
or, $p = IR.R$
$\Rightarrow \boxed{p = VR}$

OR//

$p = I^2R$
or, $p = \frac{I^2R^2}{R}$
$\Rightarrow \boxed{p = \frac{V^2}{R}}$

Numericals:-

Q.① The resistance of a conductor is 10 ohm at 50°c & 15 ohm at 100°c. Calculate it's resistance at 0°c?

A Soln:-

Given; $R_1 = 10\,\Omega$
$t_1 = 50°c$
$R_2 = 15\,\Omega$
$t_2 = 100°c$
$R_0 = ?$

We have,

$$R_1 = R_0(1 + \alpha t_1) \quad \text{---(i)}$$

$$R_2 = R_0(1 + \alpha t_2) \quad \text{---(ii)}$$

Dividing eqⁿ(i) by (ii), we get;

$$\frac{R_1}{R_2} = \frac{1+\alpha t_1}{1+\alpha t_2}$$

or, $\frac{\cancel{10}^{2}}{\cancel{15}_{3}} = \frac{1+\alpha.50}{1+\alpha.100}$

or, $2+200\alpha = 3+150\alpha$

or, $50\alpha = 1$

or, $\alpha = \frac{1}{50} = 0.02°C$

Using value of α in eqⁿ(i), we get;

$10 = R_0(1+0.02\times50)$

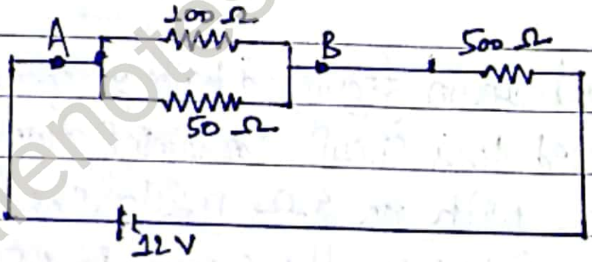
$R_0 = \frac{10}{1+1}$

$= 5\ \Omega$

$\therefore \boxed{R_0 = 5\ \Omega}$

Thus, at 0°C the resistance of a conductor is 5 Ω. #

Q② What is the p.d. across 100 Ω resistor in the circuit given below:-



A Solution:-

The effective resistance of 100 Ω and 50 Ω be,

$$\frac{1}{R_{AB}} = \frac{1}{100}+\frac{1}{50} = \frac{50+100}{50\times100} = \frac{15\cancel{0}}{500\cancel{0}}$$

$\therefore R_{AB} = \frac{500}{15} = \frac{100}{3}\ \Omega$

$\therefore$ Total resistance of the ckt;

$R = (R_{AB}+500)\ \Omega$

$= \left(\frac{100}{3}+500\right)\Omega$

$= \frac{1000}{3}\ \Omega$

$= 533.33\ \Omega$

Then, total current in ckt,

$I = \frac{V}{R} = \frac{12}{533.33} = 0.0225\ A$

Now,

$V_{AB} = I\ R_{AB}$

$= 0.0225 \times \frac{100}{3}$

$= 0.75\ V$

#

Q3. An electric heating element to dissipate 480 watts on 240V mains is to be made from nichrome wire of 1mm diameter. Calculate the length of wire required if the resistivity of nichrome is $1.1 \times 10^{-6}\ \Omega$ m.

Solution:-

power(P) = 480 watt

P.d. (V) = 240 V

Length of wire (l) = ?

resistivity (ρ) = $1.1 \times 10^{-6}\ \Omega$m.

diameter (d) = 1 mm = 10^{-3} m.

We have, $P = \frac{V^2}{R}$

$\Rightarrow R = \frac{V^2}{P} = \frac{(240)^2}{(480)^2} = 120\ \Omega$

Again,

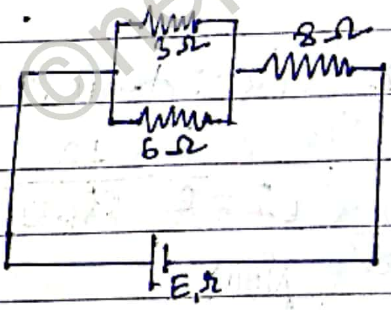
$R = \frac{\rho l}{A}$

So, $l = \frac{RA}{\rho} = \frac{R\left(\frac{\pi d^2}{4}\right)}{\rho}$

$= \frac{120 \times 3.14 \times 10^{-6}}{4 \times 1.1 \times 10^{-6}}$

$= 85.6$ m #

Q4. As shown in figure, a battery of emf 24V and internal resistance 'r' is connected to a circuit containing two parallel resistors of 3Ω & 4Ω in series with an 8Ω resistor. The current flowing in the 3Ω is 0.8A. Calculate the current in 6Ω resistor & the 'r' of the cell?



Soln:- p.d. across 6Ω = p.d. across 3Ω

$I_2 6 = I_1 . 3$

$\Rightarrow I_2 = \frac{0.8 \times 3}{6} = 0.4$ A

So, the total current: $I = I_1 + I_2$

$\Rightarrow I = (0.8 + 0.4)A = 1.2$ A

The combined resistor of 3Ω and 6Ω R_1 is given by;

$R_1 = \frac{6 \times 3}{6+3} = \frac{18}{9} = 2\ \Omega$

Total resistance of ckt,

$R = (2+8)\Omega = 10\ \Omega$

We have, $E = I(R+r)$

$I = \frac{E}{R+r}$

or, $1.2 = \frac{24}{10+r}$

$\Rightarrow \boxed{r = 10\ \Omega}$

Hence, current through 6Ω = 0.4 A and internal resistance of cell = $10\ \Omega$ #