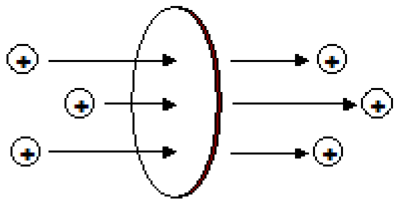
CURRENT ELECTRICITY

Time rate of flow of charge through a cross-section is called ***electric current***. Suppose, a charge Δq passes through a given cross section or area in a short time Δt, then the electric current is

I=ΔqΔt



More precisely, the instantaneous current at a given time *t* is

I=limΔt→0ΔqΔt=dqdt

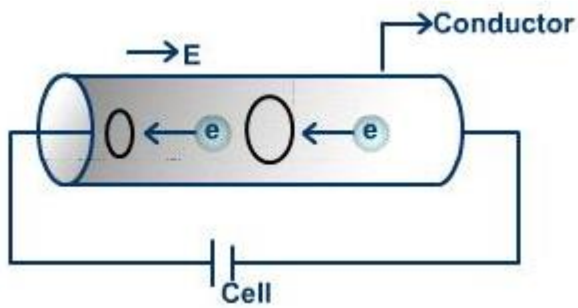
If the current is steady (i.e., it does not change with time), then the charge *q* flowing through is just proportional to time *t*, and we have

I=qt (for steady current)

The **SI unit** of current is 'ampere' [A]. The system of units is such that *one ampere is equal to one coulomb per second*, 1A=1C1s
Electric current being one of the base or fundamental quantities in SI units,
Dimension of current = [A]

Drift Velocity

The drift velocity is the average velocity that a particle, such as an electron, attains due to an electric field.



When conductor is subjected to an electric field E, each electron experience a force.
F=-eE
and acquires an acceleration
a = F/m = - eE/m -----(i)

Here m = mass of election, e = charge, E = electric field.

The average time difference between two consecutive collisions is known as relaxation time of election.

$$\bar{\tau} = \frac{\tau_1 + \tau_2 + -- + \tau_n}{n} \quad \text{... (ii)}$$

As $v = u + at$ (from equations of motion.)

The drift velocity v_d is defined as —

$$v_d = \frac{v_1 + v_2 + \cdots + v_n}{n}$$

$$v_d = \frac{(u_1 + u_2 + \cdots + u_n) + a(\tau_1 + \tau_2 + \cdots + \tau_n)}{n}$$

$$v_d = 0 + \frac{a(\tau_1 + \tau_2 + \cdots + \tau_n)}{n}$$

($\because$ average thermal velocity = 0)

$$\therefore \quad v_d = 0 + a\tau$$

$$v_d = -\left(\frac{eE}{m}\right)\tau \quad \text{[from (1)] 2}$$

(ii) According to drift velocity expression, relaxation time is the time interval between successive collisions of an electron on increasing temperature, the electrons move faster and more collisions occur quickly. Hence, relaxation time decreases with increase in temperature which implies that drift velocity also decreases with temperature.

Relation between current and drift velocity

- Consider in the wire that there are n free electrons per unit volume moving with the drift velocity v_d
- In the time interval Δt each electron advances by a distance $v_d\Delta t$ and volume of this portion is $Av_d\Delta t$ and no of free electron in this portion is $nAv_d\Delta t$ and all these electrons crosses the area A in time Δt
- Hence charge crossing the area in time Δt is
  $\Delta Q = neAv_d\Delta t$
  or
  $I = \Delta Q/\Delta t = neAv_d$

Ohm's Law

Ohm’s law states that the current (I) flowing through a conductor is directly proportional to the potential difference (V) across the ends of the conductor,provided physical conditions of the conductors such as temperature,mechanical strain etc. Are kept constant i.e. $I \alpha V$

Or $V \alpha I$ or $V= RI$

Or $V/I=R$=a constant

Where R is known as resistance of the conductor. It depends upon the length ,shape and the nature of the material of the conductor. The variation between potential difference (V) and current (I) through a conductor is a straight line.

Deduction of Ohm’s Law:

As drift velocity is given by V

d=eEt/m

But Electric field across the conductor of length l is

$E=V/l$

Thus V

d=e V/ml

Also, $I=Anev$

By putting value of v

in the equation of I we get

$I=Ane(eV/ml)=(Ane^2/ml)V$

Or $V/I=ml/Ane^2=R$

Where R is a constant for a given conductor. It is known as the resistance of the conductor.

Thus $V=RI$

Ohmic and non Ohmic device

Ohm’s law states that‘The current flowing through a conductor is directly proportional to the potential difference V across its ends, provided the temperature and physical conditions of the conductor remain the same’.

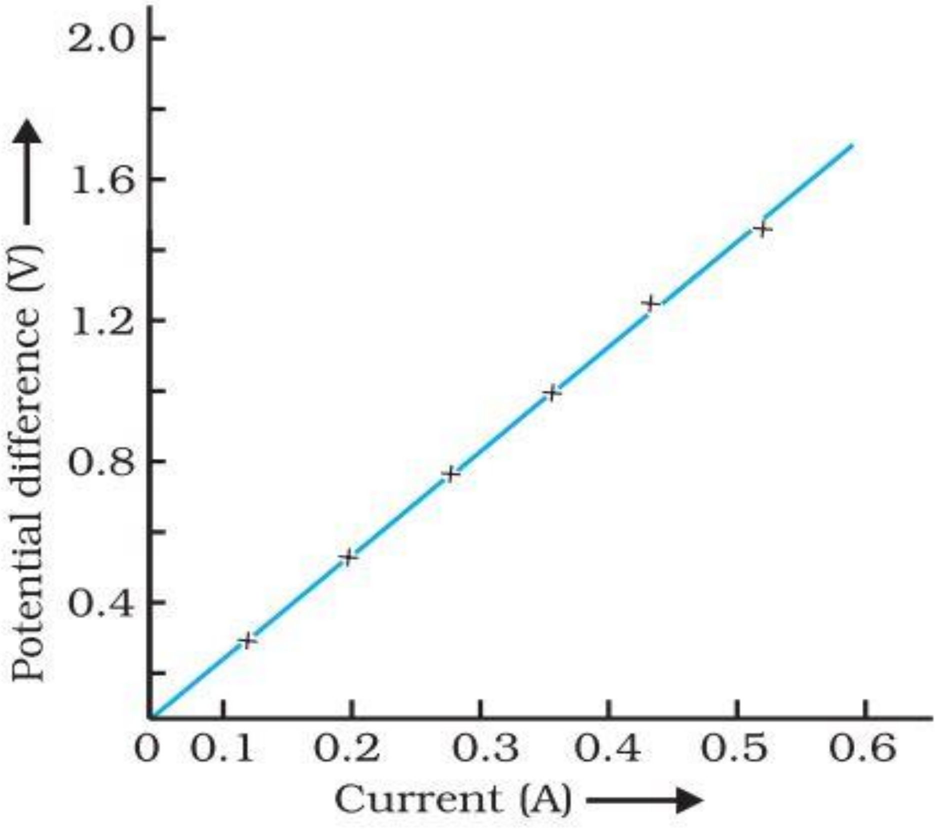
Hence,

The device which follows ohm's law for all voltages across it is called as an **ohmic device.**(i.e under constant physical conditions such as temperature, the resistance is constant for all currents that pass through it).

Examples of ohmic devices are : a wire, heating element or a resistor.

The device that does not follow ohm's law is known as a **non-ohmic device** (i.e the resistance is different for different currents passing through it).

Examples of non ohmic devices are: thermistors, crystal rectifiers, vacuum tube etc.

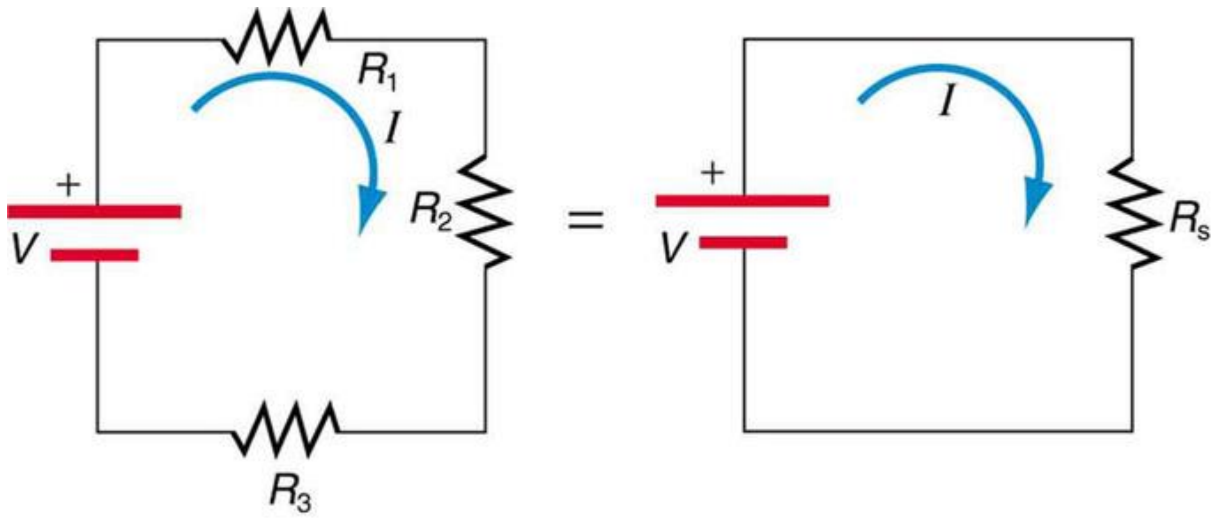


Resistance: The resistance of a conductor is the ratio of the P.D across its ends to the strength of a current flowing through it.

Unit: ohm (Ω)

Resistors in Series

Resistors are in series whenever the flow of charge, or the current, must flow through components sequentially



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According to Ohm’s law, the voltage drop, V, across a resistor when a current flows through it is calculated by using the equation V=IR, where I is current in amps (A) and R is the resistance in ohms (Ω).

So the voltage drop across R_1 is $V_1=IR_1$, across R_2 is $V_2=IR_2$, and across R_3 is $V_3=IR_3$. The sum of the voltages would equal: $V=V_1+V_2+V_3$, based on the conservation of energy and charge. If we substitute the values for individual voltages, we get:

$V=IR_1+IR_2+IR_3V=IR_1+IR_2+IR_3$

or

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

This implies that the total resistance in a series is equal to the sum of the individual resistances. Therefore, for every circuit with *N* number of resistors connected in series:

$R_s(series)=R_1+R_2+R_3+\ldots+R_N$.

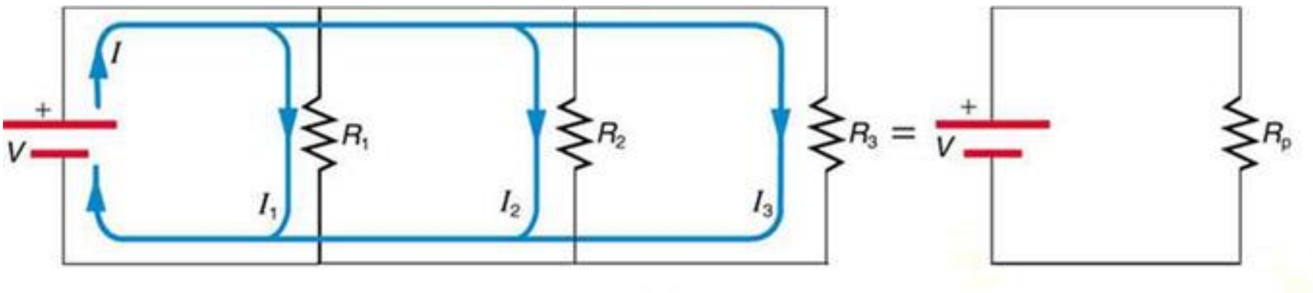
Since all of the current must pass through each resistor, it experiences the resistance of each, and resistances in series simply add up.

Resistors in Parallel

The total resistance in a parallel circuit is equal to the sum of the inverse of each individual resistance.

Ohm‘s Law and Parallel Resistors

Each resistor in the circuit has the full voltage. According to Ohm’s law, the currents flowing through the individual resistors are I_1= =V/R_1, I_2= V/R_2, and I_3= =V/R_3. Conservation of charge implies that the total current is the sum of these currents:



$I=I_1+I_2+I_3$.

Substituting the expressions for individual currents gives:

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

Or

$V/R_P=V\ (1/R_1+1/R_2+1/R_3)$

This implies that the total resistance in a parallel circuit is equal to the sum of the inverse of each individual resistances. Therefore, for every circuit with nn number or resistors connected in parallel,

$1/R_P=1/R_1+1/R_2+1/R_3$

This relationship results in a total resistance that is less than the smallest of the individual resistances. When resistors are connected in parallel, more current flows from the source than would flow for any of them individually, so the total resistance is lower.

Colour code of carbon resistors

- Commercially resistors of different type and values are available in the market but in electronic circuits carbon resistors are more frequently used
- In carbon resistors value of resistance is indicated by four coloured bands marked on its surface as shown below in figure

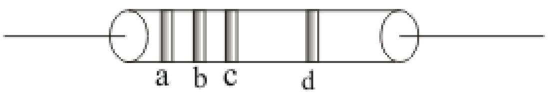


Figure 4:- Carbon resistor with strips

- The first three bands a,b.c determine the value of the resistance and fourth band d gives the tolerance of the resistance
- The colour of the first and second band respectively gives the first and second significant figure of the resistance and third band c gives the power of the ten by which two significant digits are multiplied for obtaining the value of the resistance
- value of different colurs for making bands in carbon resistors are given below in the table

Colur	Figure(first and second band)	Multiplier(for third band)	tolerance
Black	0	1	-
Brown	1	10	-
Red	2	10^2	-
Orange	3	10^3	-
Yellow	4	10^4	-
Green	5	10^5	-
Blue	6	10^6	-
Violet	7	10^7	-
Gray	8	10^8	-
white	9	10^9	-
Gold	-	10^{-1}	5%
Silver	-	10^{-2}	10%
no Colour	-	-	20%

For example in a given resistor let first strip be brown ,second strip be red and third be orange and fourth be gold then resistance of the resistor would be
$12X\ 10^3$ +_ 5%