PHY-101

Lecture # 26

Currents & Circuits

(1) Electric current:

Rate of flow of charges

$$i = \frac{dq}{dt}$$

=> If current is constant

then $q = i \times t$

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

$$1\,\text{Ampere} = \frac{1\,\text{Coulomb}}{1\,\text{second}}$$

Other units of current.

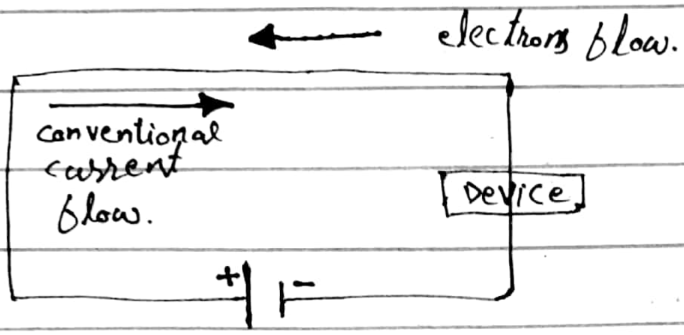
$1\,mA = 10^{-3}\,A$

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

$1\,nA = 10^{-9}\,A$

$1\,pA = 10^{-12}\,A.$

(2) Direction of Current.



(3) How current (charges) flow?

Because something forces it around a circuit.

Something mean EMF

But

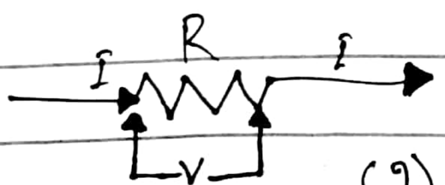
EMF is not actually a force
It is potential difference b/w 2 parts of a circuit.

$$EMF = V = V_a - V_b$$

How much current flow?

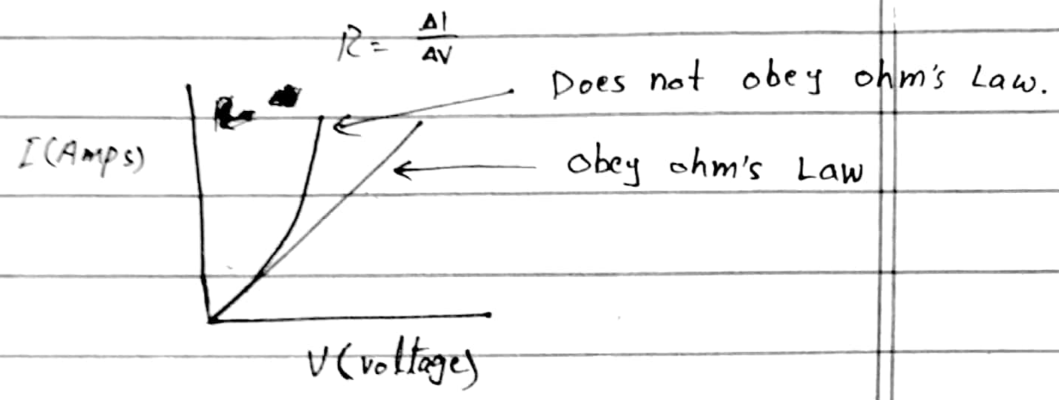
$$I \propto V \Rightarrow V = IR$$

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

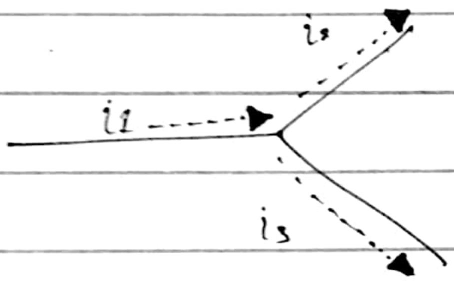


(2)

(4)



(5) Charges are always conserved
so current is conserved as well.



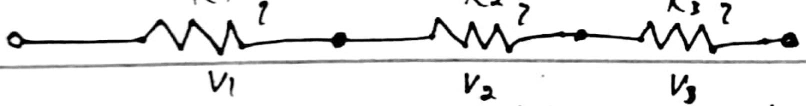
$i_1 = i_2 + i_3$

(6) Resistors in Series:

* current is same
* Potential Drop.

$V_1 = iR_1$, $V_2 = iR_2$

$V_3 = iR_3$

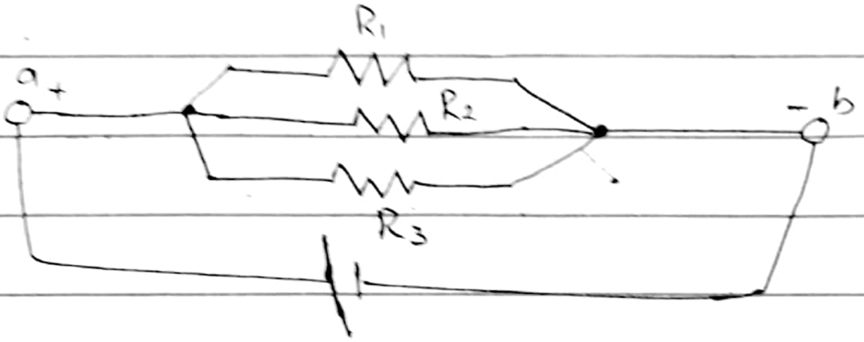


$V = V_1 + V_2 + V_3 = iR_1 + iR_2 + iR_3$

$\cancel{i}R_{eq} = \cancel{i}(R_1 + R_2 + R_3) \Rightarrow R_{eq} = R_1 + R_2 + R_3$

(7) Resistor in Parallel:

- ★ Same voltage
- ★ Current Drop.



$$\boxed{i = \frac{V}{R_{eq}}} \quad i_1 = \frac{V}{R_1}, \quad i_2 = \frac{V}{R_2}, \quad i_3 = \frac{V}{R_3}$$

$$i = i_1 + i_2 + i_3$$

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

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

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

OR

$$\frac{1}{R_e} = \frac{R_2R_3 + R_1R_3 + R_1R_2}{R_1 R_2 R_3}$$

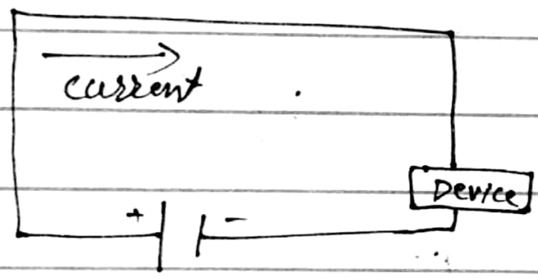
$$R_{eq} = \frac{R_1 R_2 R_3}{R_2R_3 + R_1R_3 + R_1R_2}$$

Correction

★ EMF is No Force

★ It is the energy that every unit of charge is given so it can go around a closed circuit.

Animation



V (EMF)

What produces EMF?

- Chemical processes (Battery)
- Changing magnetic field (Generator)
- Light (Solar cells)
- Heat (Thermoelectricity)

(8) Current flows When work is done on a charge (dq)

Work Done = $dW = Vdq \rightarrow (1)$

$i = \frac{dq}{dt} = dq = idt$

Put dq in (1)

$dW = Vidt. \rightarrow (2)$

Put $V = iR$ in (2)

$dW = iRidt$

$dW = i^2Rdt \rightarrow (3)$

We know that

Power = $\frac{\text{Work Done}}{\text{time taken.}}$

OR

$P = \frac{dW}{dt} \rightarrow (4)$

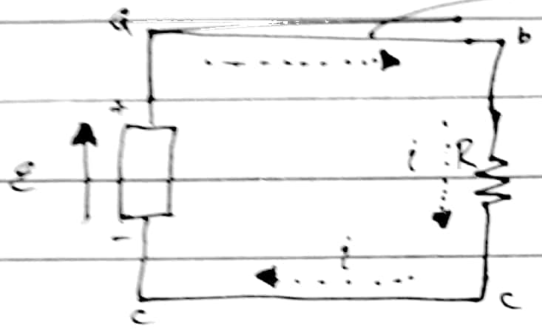
Put dW in (4)

$P = \frac{i^2R\cancel{dt}}{\cancel{dt}}$

$P = i^2R$

Kirchoff's Law:

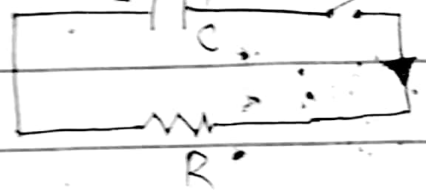
"The sum of the potential differences encountered in moving around a closed circuit is zero"



$$V_a - iR + \mathcal{E} = V_a$$

$$-iR + \mathcal{E} = 0$$ Internal Resistance ??

(ix) Application of Kirchoff's Law on a given circuit.



~~Total~~ Total voltages accros a circuit is given bellow.

$$V_c + V_R = 0 \longrightarrow (I)$$

$q = CV \Rightarrow V_c = \frac{q}{C}$, $V_R = iR$

Put V_c & V_R in (I)

$$\frac{q}{C} + iR = 0$$

Diff w.r.t time

$$\frac{1}{C}\frac{dq}{dt} + \frac{di}{dt}R = 0$$

$$\Rightarrow \frac{1}{C} i + \frac{di}{dt} = 0$$

$$\frac{di}{dt}R = -\frac{1}{C} i \Rightarrow$$

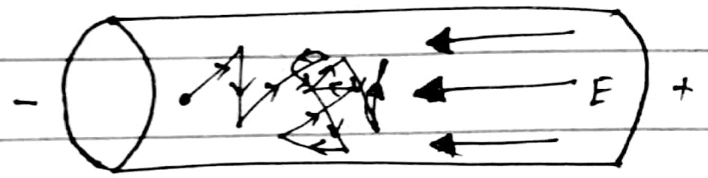
$$\frac{di}{dt} = -\frac{1}{CR} i$$

This equation thas solution:

$$i = i_0 e^{-\frac{1}{RC}}$$

(11) Do yourself As point (10)

(12) Drift velocity:



(13) Let a wire has:

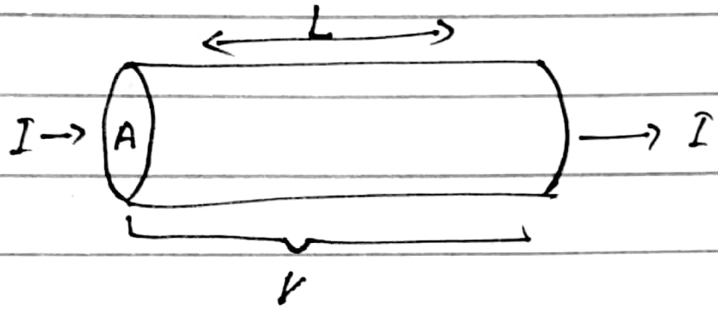
number of charges per unit length = n

crossectional area = A

Length = L

Then

Charge in this section of wire = $\boxed{q = (nAL)e}$ → ①



$$\boxed{\therefore t = \frac{L}{V_d}} \rightarrow ②$$

$$\boxed{\therefore i = \frac{q}{t}} \rightarrow ③$$

Put the value of 'q' from ① in ③ and ~~we~~ get i from ②

$$i = \frac{(nAL)e}{L/V_d} = \frac{nALe}{L/V_d}$$

$$\boxed{i = nAeV_d} \rightarrow (A)$$

$$\boxed{V_d = \frac{i}{nAe}} \rightarrow ④$$

∴ Current density $= j = \dfrac{\text{Current}}{\text{Area}}$

$$\boxed{j = \frac{i}{A}} \rightarrow (S)$$

Put the value of 'i' from (A) in (S)

$$\therefore j = \frac{nAev_d}{A}$$

$$j = nev_d$$

If 'j' varies inside a volume, Then

$$i = \int \vec{j} \cdot d\vec{A}$$

The End

Sd

خدا حافظ