Current of Electricity

Electric current is rate of flow of charge

$$\text{current} = \frac{\text{Charge}}{\text{time}}$$

$$I = \frac{Q}{t} \begin{array}{l} \rightarrow \text{coulomb} \\ \rightarrow \text{seconds} \end{array}$$

unit = Ampere

$1A = 1\ Cs^{-1}$

Charge carriers (electron) are quantized (whole no.) quantization simply means the values are not continious but rather descrete

Since fractions of electrons cannot move the amount of charge transfer is always a whole number multiple of the charge of an electron.

$Q = ne$ — electronic charge $(1.6 \times 10^{-19} C)$

Q → Charge

n → whole no.

Define Coulomb

The coulomb is the charge passed when a current of one ampere flow for 1 second.

$$Q = It$$

$$C = As$$

Q. An ion beam is passing through vaccum. If the beam current is $20 \mu A$. Calculate the total number of ions passing any fixed point in the beam per second.

$$\frac{20 \times 10^{-6}}{1.6 \times 10^{-19}} = 1.25 \times 10^{14}$$

Transport equation

$I = nAeV$

n = carries density (number of charge carriers in unit volume)

A = area of the conductor

e/q = charge of an electron

v = drift velocity of free electron.

Carrier Density (n)

In conductors → There are always a remarkable number of free electrons i.e. the carrier density (n) is large. There is no change with the effect of temperature.

Semi Conductor → They have very few free electrons at normal temperature. As temperature increases number of free electrons i.e. carrier density (n) increases. So at low temperature, they behave as insulators and at high temperatures they behave as conductors eg. silicon, graphite.

Insulators → they do not have any free electrons whatever the temperature is. i.e $n = 0$ or negligible.

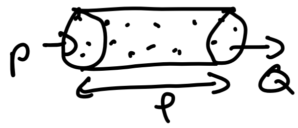
Drift velocity

When potential difference is applied between the ends of a conductor, free electrons drift very slowly in the opposite directions of the conventional current. The average displacement of charge carriers in 1 second is called drift velocity.

* When voltage increases, drift velocity increases, hence current increases.
* If temperature increases (voltage constant) drift velocity decreases because electrons collide more frequently with the fixed ions, therefore current decreases (Resistance increases)

Equation

lets consider a current carrying wire of length 'l' and cross sectional area 'A'. It contains 'n' electrons per unit volume.



An electron travels length 'l' of wire in time 't'. In this time, all the electrons emerge from the surface Q.

so number of electrons within the cylinder $= nV$

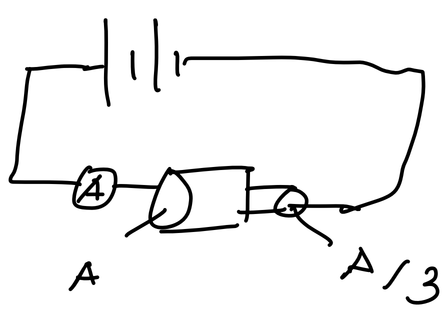
$= nAl$

Charge of these electrons $= nAlq$

current $I = \frac{\text{charge}}{\text{time}} = \frac{nAlq}{t}$ | $\frac{l}{t} = v$

$I = nAvq$

Q1. Find the ratio of drift velocity in the thick wire to the thin wire.



$I = nAve$ $\quad v = \frac{I}{nAe}$ $\quad v = \frac{1}{A}$

$$\frac{v_x}{v_y} = \frac{\frac{\cancel{I}}{\cancel{n}A_x\cancel{e}}}{\frac{\cancel{I}}{\cancel{n}A_y\cancel{e}}}$$

$$\frac{A_y}{A_x} \Rightarrow \frac{\frac{1}{3}}{1}$$

$\frac{A}{3} : \cancel{Ax}\,A$

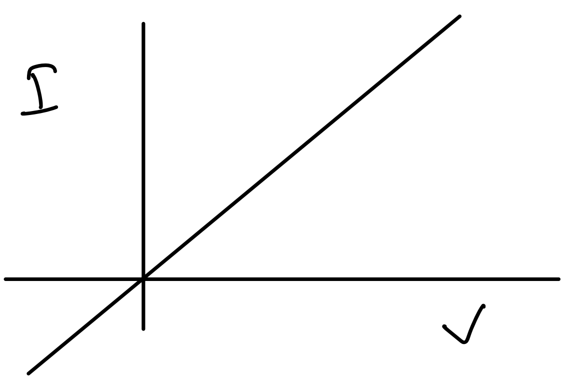
$A_y : A_x$

$1 : 3$

$v_x : v_y = 1 : 3$

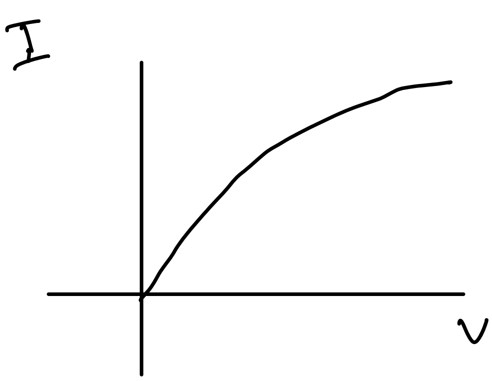
I-V graph

1) Ohmic conductor



I increases with same proportional to pd.
temperature constant.

2) Filament

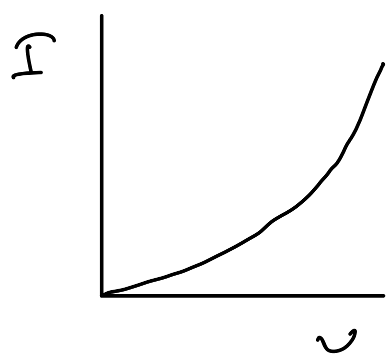


As voltage increases, current increases but filament gets hot (temperature increases) so resistance ($R = \frac{V}{I}$) increases.

in terms of $I = nAve$

At higher temperature nAe doesn't change, the fixed ions vibrate more vigorously due to increase in temperature. The free electron collide more often so v decreases hence I decreases.

3) thermistor



voltage increases so current increases hence temperature increases so $R = \frac{V}{I}$ decreases.

In terms of $I = nAev$

As temperature increases, more electrons become free from the atoms and drift velocity decreases slightly, consequently current increases ie. resistance ($R = \frac{V}{I}$) decreases.

$n \uparrow\uparrow\uparrow$ $v \downarrow$

Different situations (drift velocity)

i) $v \propto I$ ie. if current increases, the drift velocity increases.

ii) $v \propto \frac{1}{A}$, the wire is thinner, the electrons move more quickly for a given current.

iii) $v \propto \frac{1}{n}$: In a material with lower n, the mean drift velocity will be greater for a given current.

$$\text{Resistance} = \frac{\text{voltage}}{\text{current}}$$ unit ohms (Ω)

R depends on:

1. Material used

2- Area of cross section $R \propto \frac{1}{A}$

3. length $R \propto l$

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

$$R = \rho \frac{l}{A} \quad / \quad \rho = \text{resistivity}$$

$$\rho = \frac{RA}{l} \qquad \text{unit} = \Omega m$$

Resistivity is defined as the resistance of unit length and unit area of cross section of a material.

Potential difference

The work done or energy transferred to move unit positive charge from one point to another is called potential difference between these two points.

$$p.d = \frac{\text{work done}}{\text{charge}}$$

$$V = \frac{W}{Q} \qquad \text{unit} \rightarrow \text{volts (V)}$$

1 volt $\Rightarrow$ If 1 J of work is done to move unit positive charge from one point

to another, the p.d is 1 volt.

$$\text{p.d} = \frac{\text{energy transferred from electrical forms to other forms}}{\text{charge}}$$

Emf → the work done by the source to move 1 coulomb of charge around a complete circuit.

$$\text{Emf} = \frac{\text{work done}}{\text{charge}}$$ unit (volts) (V)

$$\text{Emf} = \frac{\text{energy converted from non electrical forms to electrical forms}}{\text{charge}}$$

Ohms law

Current in a conductor is directly proportional to potential difference. (when temp is constant).

$V \propto I \qquad V = IR$

Electrical energy and Power

$$p.d = \frac{\text{Energy}}{\text{charge}} \qquad V = \frac{E}{Q}$$

$$E = VQ \qquad V = IR$$

$$E = VIt$$

* $P = VI$ (used for power supplied by source)

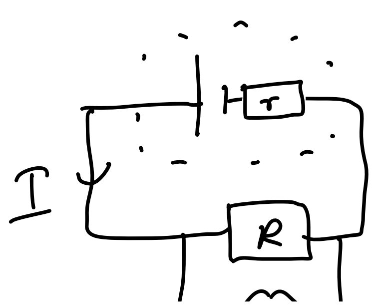
$$E = I^2Rt$$

* $P = I^2R$ (power dissipated in resistor)

DC circuits

Internal resistance of a cell (r)

In real circuits not all the energy given to charge flowing through the cell is dissipated in the external part of the circuit. Some of the energy is dissipated within the cell itself, which has internal resistance.



V_T

Terminal p.d = $IR = V_T$

lost volt = $Ir = V_L$

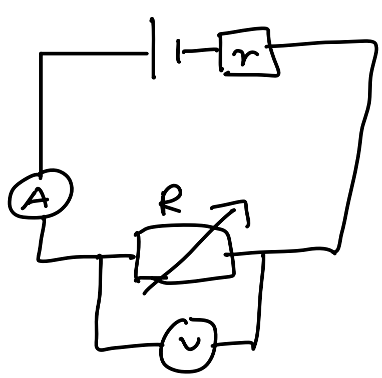
$$\text{Emf} = V_T + V_L$$

$$V_T = \text{Emf} - V_L$$

Total Energy supplied per second = Energy dissipated in external circuit + Energy dissipated in the cell per second

$$EI = V_T I + V_L I$$

Finding emf and internal resistance



By changing the value of R (load resistance) in the circuit and measuring I and p.d (V), internal resistance can be found.

a graph of V against I is plotted

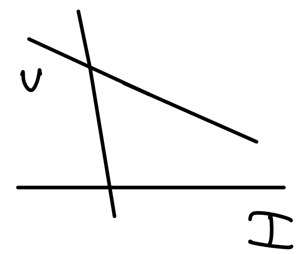
$$V_T = E - Ir$$

$$V_T = -rI + E$$

$$y = mx + c$$

gradient $= -r$

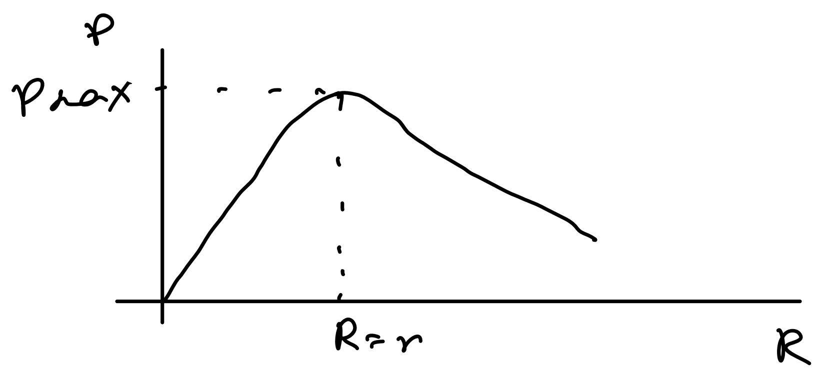
y intercept $=$ emf



Effect of internal resistance on power from battery

Electrical power across load can be determined $P = VI$.

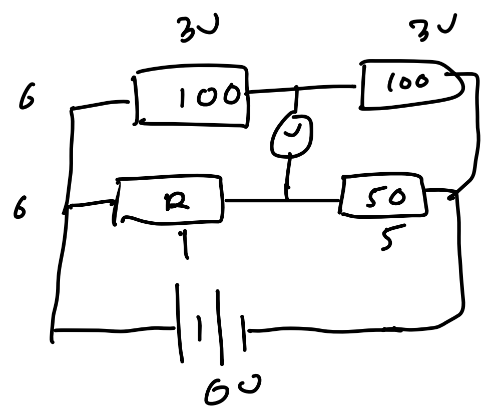
Experiments show that if load resistance is varied, P varies.



From the graph:

Power is maximum when external load is equal to internal resistence if $R = r$

the $P = max.$



$v = 5\Omega$

the voltmeter measures $\underline{2V}$

Find the possible values of R

$$I = V/R$$

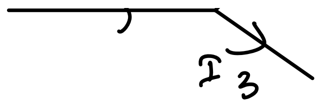
$$\frac{1}{50} = 0.02 \qquad \frac{5}{0.02} = 250\Omega$$

$$\frac{1}{0.1} = 10\Omega \qquad \frac{5}{50} = 0.1$$

Kirchoff's 1st law

the sum of current entering any point in a circuit is equal to the sum of current leaving the same point.

$$I_1 = I_2 + I_3$$



$$\sum I_{in} = \sum I_{out}$$

$$\sum I = 0$$

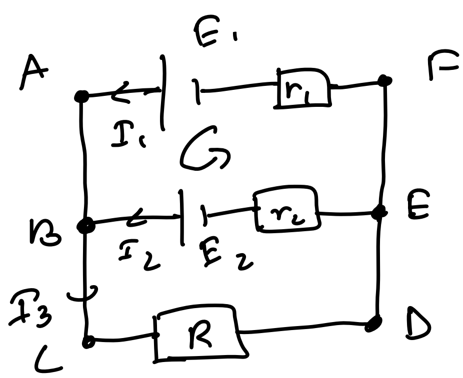
Kirchoff's 1st law is an expression for conservation of charge.

Kirchoff's 2nd Law

It relates the total emf in a closed loop with the total potential difference in that loop.

The algebric sum of emf is equal to the algebric sum of potential difference.

$$\sum emf = \sum p.d$$



loop ABEFA

$$E_1 - E_2 = I_1 r_1 - I_2 r_2$$

loop ACDFA

$I_1 + I_2 = I_3$

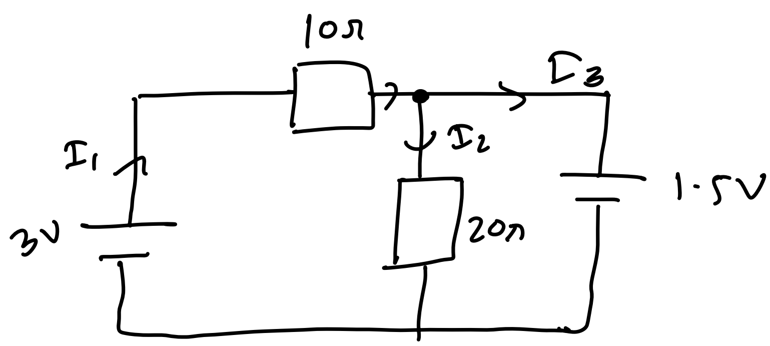
$\Sigma E = \Sigma \, p.d$

$E_1 = I_1 r_1 + I_3 R$

loop BCDEB

$E_2 = I_2 r_2 + I_3 R$

$E_2 = (I_1 + I_2) R + I_2 r_2$



I_1 , I_2 , I_3

$3V = 10 \times I_1 + 20 I_2$

$3V = 10 I_1 + 20 I_2$

$1.5V = 20 I_2$

$$I_2 = 0.075\,A$$

$$3 = 10 I_1 + 20 \times 0.075$$

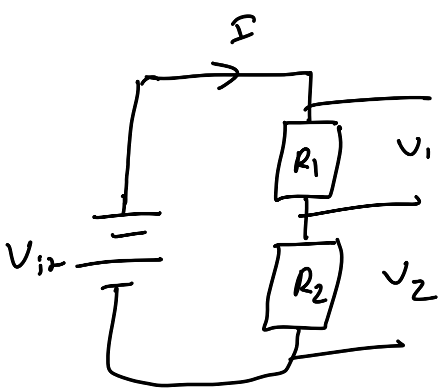
$$I_1 = 0.15\,A$$

$$I_2 + I_3 = I_1$$

$$I_3 + 0.075 = 0.15$$

$$I_3 = 0.075\,A$$

Ans



$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

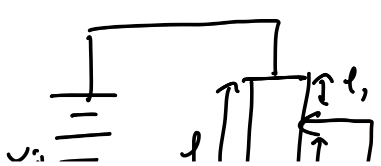
$$I = \frac{V_{in}}{R_1 + R_2}$$

$$V_1 = I \times R_1$$

$$V_1 = \frac{V_{in}}{R_1 + R_2} \times R_1$$

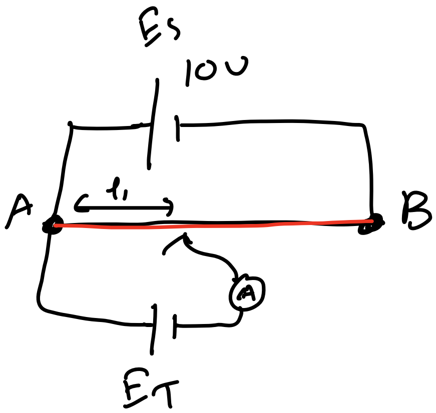
$$V_1 = \left(\frac{R_1}{R_1 + R_2}\right) \times V_{in}$$

$$V_2 = \left(\frac{R_2}{R_1 + R_2}\right) \times V_{in}$$



$V_{out} = \ell_2$

$$\frac{\quad}{l_1 + l_2} \times V_{in}$$



$AB = 100\,cm = l_2$

when $A = 0$

$$\frac{E_T}{E_s} = \frac{l_1}{l_2}$$

$$P = \frac{V^2}{R}$$