ELECTRICITY

- The intrinsic (fundamental) property of a particle because of which it experiences force in electromagnetic field is called electric charge.
- Positive charge experiences force in the direction of the electric field (+ to -) while Negative charge experiences force in the direction opposite to electric field.
- It's ~~si unit~~ SI unit is a derived unit (coloumb (c))

Charge carriers

- The charged particles which contribute to an electric current are known as charge carriers. For eg:- electrons, protons, ions - when they are in motion.
- Current is due to the flow of charged particles.
- Sometimes current is due to both positive and negative charges. For ex:- flow of charged particles ~~of~~ through a solution (electrolyte) which contains both +ve and -ve ion. In this case the ions move in opp. direction when the solution is connected to a cell
- Mostly current is due to the flow of -ve particles in conductors.
- Sometimes it is also due to flow of +ve particles in particle accelerators

- Each electron carries about -1.6×10^{-19} C and proton carries ~~about~~ $+1.6 \times 10^{-19}$ C.
The magnitude of this charge is represented by 'e'
$e = 1.6 \times 10^{-19}$ C ~~Ism~~

- This is the smallest possible unit of charge and is called elemantary charge (e)
- ~~1.6×10^{19} electrons carry 1 C of charge.~~

$e = 1.6 \times 10^{-19}$ C

$1\,C = \dfrac{1}{1.6 \times 10^{-19}}\, e$

$\therefore 1\,C = 6.25 \times 10^{18}\, e$

- 6.25×10^{18} electrons carry 1C charge.

- Zn^{++} ion has a charge of $+2e$, SO_4^{2-} has a charge of $-2e$.
- By this, we can say that charge is quantized. It means that charge can only come in amounts which are integer multiples of the elementary charge.

i.e. $Q = \pm Ne$ (where N is an integer (1,2,3,4) and e is elementary charge.

- This means 1.5e can't exist.

- The only exception is in the case of the fundamental particles called quarks, which are the building blocks of a protons, neutrons & electrons.
- Quarks have fractional charge $\pm \frac{1}{3}e$ or $\pm \frac{2}{3}e$.
- However, their sum is either 0 or a multiple of e.

Proton has two up $(+\frac{2}{3})$ and one down $(-\frac{1}{3})$ quarks.

Charge of proton $= +\frac{2}{3} + \frac{2}{3} - \frac{1}{3}$

$= \frac{4}{3} - \frac{1}{3}$

$= +1$

Neutron has one up and two down quarks.

- Quarks can't exist alone, they are bonded by gluons, and if we apply energy to break the gluons, they'll use ~~those~~ that energy to form more quarks & gluons, so quantization of charge is not violated

Conservation of Charge:

- It states that, "the algebraic sum of all the electric charges in any closed (isolated) system is always constant."
- In a closed system, there can be loss and gain of charge but the net charge is always the same.
- Thus, charge is not created or destroyed; it is ~~just~~ merely transferred from one body to another.

Eg:- Ionization of $CuSO_4$ in a solution.

$CuSO_4 \longrightarrow Cu^{2+} + SO_4^{2-}$

charge before ionization = 0

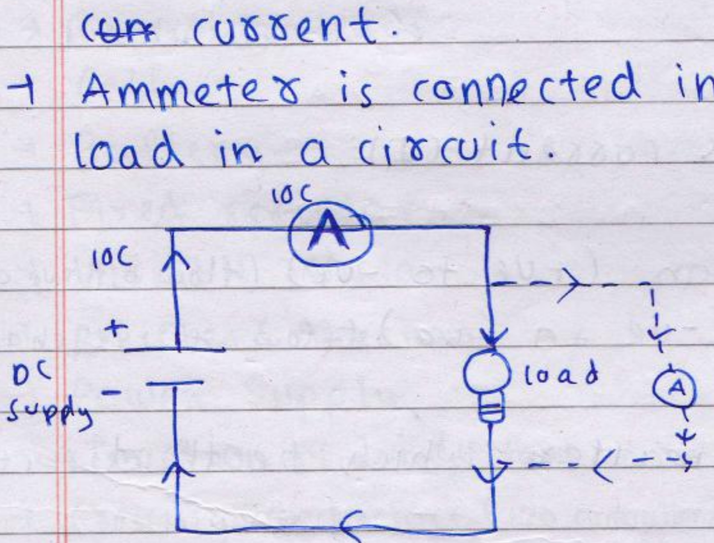
charge after ionization = 0

Flow of charge in conductor.

$2C \xrightarrow{1s} 2C$ By law of conservation of charge.

Electric current (I)

- It is the rate of flow of electric charge past a point.
- If Q coloumb charge passes through a point in an electric circuit in time t, then the electric current (I) = Q/t.
- Its SI unit is Ampere (coloumb/second)
- ~~1 Ampere current~~ Ampere is fundamental unit even though it looks like it is derived. It is general convention.
- 1 Ampere current is the rate at which charge passes a point in a circuit is 1 coloumb in a time of 1 second.
- Ammeter is the instrument to measure electric ~~cur~~ current.
- Ammeter is connected in series with an electric load in a circuit.



[This dotted ~~w~~ apparatus is incorrect because it will not measure 10C charge].

An ideal ammeter has zero resistance so that when it is connected in series with the electric load, it won't distub the flow of electric current through the load. But this is not practical so we use ammeter which has very low resistance

From the definition of electric current, we have.

$I = Q/t$

or $Q = I \times t$

or $\Delta Q = I \times \Delta t$

(Where ΔQ is the charge which flows during a time Δt and I is the current.)

∴ 1 Coloumb charge is when 1 Ampere current passes through a point in 1 second.

Ampere (A) is fundamental unit while Coloumb (C) is derived unit, and both are SI units.

First ampere was identified then current was defined in terms of ampere which is why ampere is funda-mental while

Direction of electric current (I):

1) Conventional direction (+ve to -ve) (flow of +ve charge)
2) Actual direction (-ve to +ve) (flow of -ve charge)

The result is same no matter which be the direction.

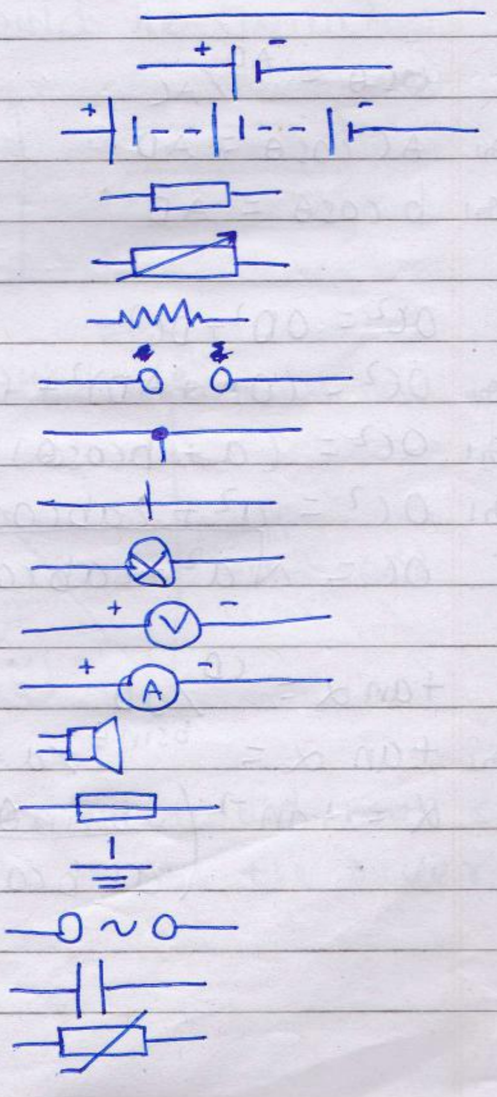
We follow conventional direction

Circuit Diagram

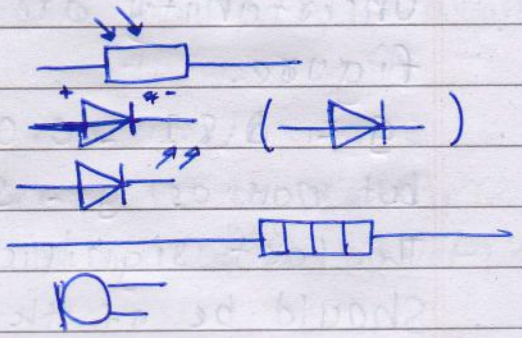
- A schematic diagram of an electric circuit that helps to get the idea as how the electric circuit works is called circuit diagram.
- According to Intl. Electro-technical commission (IEC), a part of set of conventional symbols for electrical components are there.
- (IEC is an intl. org. that establishes agreements on electrical symbols, safety standars, working ~~pa~~ practices etc so as to avoid misunderstanding.)

Connecting leads (leads have insulators, wires are naked. (Fixed resistor's resistance is fixed, variable's is changable

- Connecting leads
- Cell
- Battery
- Fixed resistor
- Variable resistor
- Resistor (American)
- Power Supply
- Junction of conductors
- Crossing conductors (no connection)
- Filament lamp
- Voltmeter
- Ammeter
- Loudspeaker
- Fuse
- Earthing
- Alternating signal
- Capacitor
- Thermistor



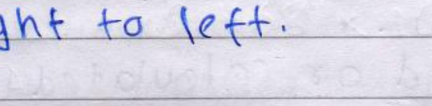
ELECTRICTY. . . .



- Light-Dependent resirtor
- Semiconductor diode
- Light-emitting diode
- Electric heater
- Microphone

Drift velocity (vd):

- The conduction of electricity in metal is due to the presence of free electrons which leave their nucleus
- These free electrons have thermal energy which depends on the metal's temperature and are in thermal equilibrium with the rest of the conductor.
- These free electrons are thus in random motion.
- Since, these free electrons flow randomly in all directions, there is no net charge flow in any direction.
- If we consider any cross-section of the conductor, the rate at which they pass through it from left to right is equal to that at which they pass from right to left.



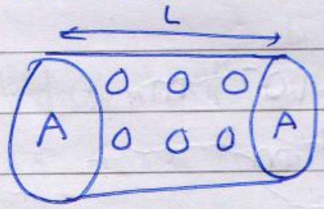
Here when an electric potential is applied, a force is experienced by the electrons. This causes the electrons to accelerate and its velocity increases. thus increasing its kinetic energy. So -ve to +ve becomes the direction of drifting of the electrons.

The electron's KE decreases during collision and is transferred to the atoms making the conductor hotter unless it's a superconductor. There is acceleration of e^- between two colisions and again it becomes 0 and so on. So the average acceleration of the e^- is 0 and it's avg. velocity is constant.

→ Due to repeated collisions, the ~~veloci~~ avg electrons drift in the direction opposite of the electric field with a constant avg. velocity which is called drift-velocity.

→ Hence, drift velocity is the constant avg. velocity attained by the free electrons in a conductor under the influence of an external electric field applied across the conductor.

Relation between drift velocity (V_d) and Electric current (I)



[when electrons move, battery is connected it they covers L in time t]

$n = N/V$ where N is no. of free electrons carrying elementary charge e and V is the conductor volume (A×L) and n is the electron density

No. of free electrons (N) = nAL

Total charge Q of free electrons = nALe = Ne

$V_d = L/t$

$I = Q/t$

or, $I = \frac{\cancel{NAL}\ nALe}{t}$

or, $I = nAe \times \frac{L}{t}$

or, $I = nAe\,V_d$

$\therefore I = V_d\, enA$ ---- (i)

Calculate the mean V_d of electrons in a Cu wire of ~~d = 1~~ diameter 1.0 mm with 5.0 A current. The electron no. density for copper is $8.5 \times 10^{22}\,cm^{-3}$

~~$n_e = 8.5 \times 10^{22}\,cm^{-3} = 8.5 \times 10^{28}\,m^{-3}$~~

~~$I = 5.0\,A$~~

~~$A = \pi r^2 = 22/7 \times 1/1000 = 3.14 \times 10^{-6}\,m^2$~~

~~$\therefore V_d = \frac{I}{enA} = 1.17 \times 10^{-7}\,ms^{-1}$~~

$d = 10^{-3}\,m$

$A = \pi d^2/4 = 22/7 \times 10^{-3}/4 = 7.85 \times 10^{-4}\,m$

$n = 8.5 \times 10^{22}\,cm^{-3} = 8.5 \times 10^{28}\,m^{3}$

$e = 1.6 \times 10^{-19}\,C$

$V_d = \frac{I}{enA} = 0.468 \times 10^{-3}\,ms^{-1} = 0.47\,mms^{-1}$

$\therefore$ The drift velocity is very small.

What is the time required for the electrons to traverse a 1m Cu wire.

$t = 1/0.468 \times 10^{-3} = 2136.75s \approx 35$ minutes

Drift velocity is in order of $10^{-4}\ ms^{-1}$ but avg. thermal speed of electrons is in order of $10^{6}\ ms^{-1}$.

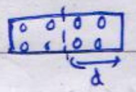
VVIP It is possible for electric bulb in our house to emit light instantly even though Vd is so less because when the power is supplied to the bulb, the electric field is created instantly in the conductor, and thus all electrons experience a force and move. The field is set up approaching the speed of light, and thus the electrons near to the bulb also move instantly.

$V_d \propto I$ $\qquad V_d \propto 1/n$ $\qquad \left[V_d = \dfrac{I}{enA} \right]$ e is constant

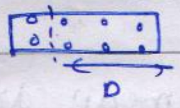
$V_d \propto 1/A$

1) $V_d \propto I$

If current increases, drift velocity increases.

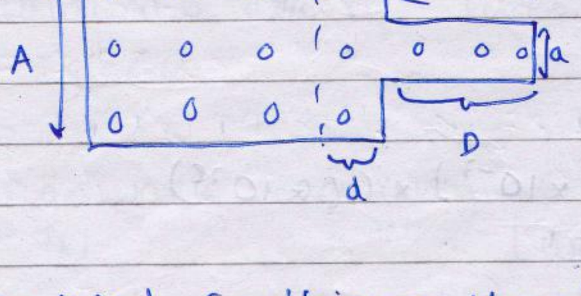

I = 4A

D > d.


I = 6A

2) $V_d \propto 1/A$

If wire is thinner, drift velocity is more for a given current, because when wire is thinner, there as less free electrons, so less electrons must travel more distance.



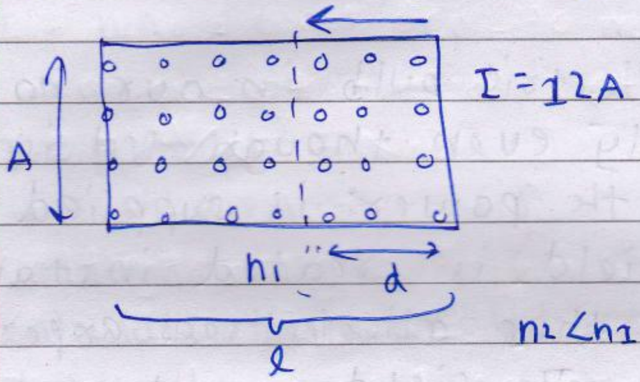
If I = 3 A

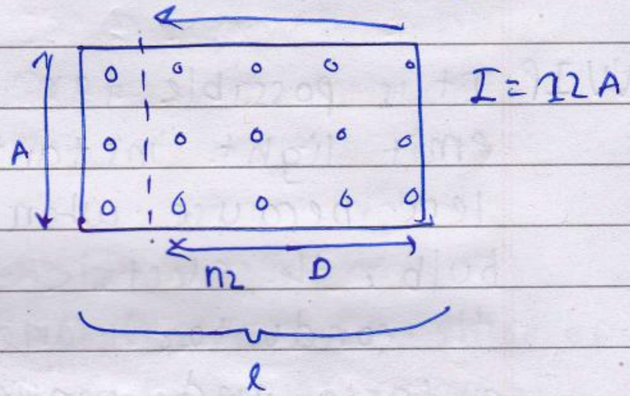
Here D > d. So thinner the wire, more the drift velocity.

3) $V_d \propto 1/n$

This depends from conductor to conductor.

If electron number density is less, drift velocity is more.





$n_2 < n_1$

Here $D > d$, so $V_d \propto 1/n$

The current in copper wire of cross-sectional area $1.1 \times 10^{-7}\ m^2$ is 3.0 A. The number of free electrons per m^3 is $8.0 \times 10^{28}\ m^{-3}$.

i) Describe what is meant by term mean drift velocity of electrons in the wire.

The mean drift velocity of electrons means the mean displacement of the electrons per unit time under the influence of external electric fields.

ii) Calculate mean drift velocity.

$I = V_d e n A$

or, $V_d = \dfrac{I}{enA}$

or, $V_d = \dfrac{3.0}{(1.6 \times 10^{-19}) \times (1.1 \times 10^{-7}) \times (8.0 \times 10^{28})}$

$\therefore V_d = 2.1 \times 10^{-3}\ ms^{-1}$

iii) Name the charge carries responsible for current in metal & electrolyte.
- Electrons & ions.

Electromotive force (emf) and Potential Difference(pd

- Emf is the amount of energy gained by 1C charge when it passes through the source to travel through the circuit is called emf (ε) of that source.
- It's SI unit is J/C or Volt(V).
- $\varepsilon = 10\ J/C = 10\ V$ ॥

- The potential difference between any two points in a circuit is the amount of electrical energy converted into other forms of energy when one coloumb of charge passes from one point to the other.

- Let E be the energy gained by Q coloumbs of charge as it passes through the source then.. Q coloumbs gain E energy and 1 coloumb gains E/Q energy.
- Let E be the energy lost by Q coloumbs of charge as it passes ~~throu.~~ between two points then. 1 coloumb charge loses E/Q energy.

$\therefore$ PD = E/Q ॥

- Doing work is a way of transferring energy.
- E = W $\therefore e = W/Q$ (work done per unit charge)
- The total work done by the source to move 1C of charge round the complete circuit is emf.

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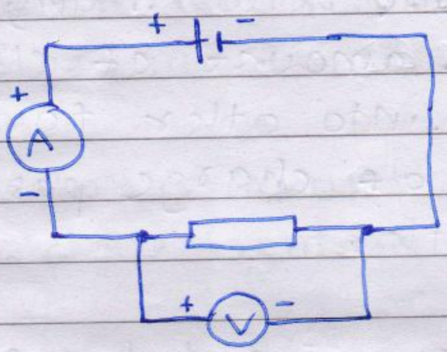
- Potential difference between two points is the work done in moving unit charge from one point to other.
- Let w be work done to move Q coloumbs of charge from one pt. - another pt.

$\therefore$ P.D = W/Q

Voltmeter

- It is a device used to measure potential difference between two points in a circuit.
- An ideal voltmeter must have infinite resistance.
- It should be connected in parallel.



If voltmeter has a very high resistance, charges flow to load and not to voltmeter so load works.

ELECTRICITY...

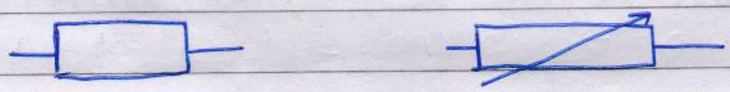
Electric resistance (R)

electric component

- The property of a conductor or a resistor to resist the flow of electrons is called electric resistance.
- A resistor is an electrical component made to have a specific value of resistance between its ends is called a resistor.
- The resistance of any electrical component is defined as the ratio of potential difference accross it to the current through it.

  $R = V/I \therefore V = IR$...
- It's SI unit is ohm (Ω). (V/A)
- Large units are $k\Omega$ and $M\Omega$

  $1k\Omega = 10^3\ \Omega$, $1M\Omega = 10^6\ \Omega$



fixed resistor   variable resistor

- 1 Ω resistance is when the potential difference across two ends of a resistor is 1V and drives a current of 1 A through it.
- Cause of electrical resistance is the collision of charge carriers with vibrating atoms/ions.
- When collision occurs kinetic energy is lost and thus energy is dissipated in form of heat.

Internal resistance (r)

- The resistance of a cell or a power supply to the flow of charge carriers through it is called internal resistance.
- This happens due to presence of conductors and chemicals inside the power supply.
- Potential difference across internal resistance cell are called lost volts (v) which can't be utilized
- Terminal potential difference is amount of electrical energy converted into other forms of energy when 1C of charge passes from one terminal to other.

$\mathcal{E} = V + v$

Energy supplied per coloumb by cell ($\mathcal{E}$) = Energy transferred per coloumb to external circuit (V) + Energy wasted per coloumb in cell's internal resistance (v)

$\therefore$ emf ($\mathcal{E}$) = useful volts (V) + lost volts (v)

$\mathcal{E} = V + v$

or $\mathcal{E} = IR + v \qquad \because V = IR$

or $\mathcal{E} = IR + Ir \qquad \because v = Ir$

or $\mathcal{E} = I(R + r)$

$\therefore I = \dfrac{\mathcal{E}}{R + r}$

$\therefore$ current $= \dfrac{\text{emf}}{\text{Total resistance}}$

Electrical Power

The rate of doing work is called power.

$$\text{Power (P)} = \frac{\text{work done (W)}}{\text{Time (t)}}$$

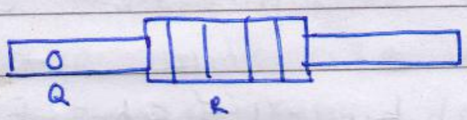
Since, doing work is a way of transferring energy,

$P = E/t$.

Thus, power of a device is the rate at which it transfers energy.

Its SI unit is watt (W)

The power of an electrical device is 1 watt when 1 joule energy is transferred in 1 second.



Let the device be a heater with resistance R and W is the amount of work done to move Q coloumbs of charge through it.

Then pd. $V = W/Q$

$W = VQ$

This is the amount of energy transferred by Q coloumbs of charge to the device.

$P = W/t = VQ/t = V \times Q/t = VI = V \times V/R = V^2/R$

$\therefore P = VI$

$\therefore P = I^2R$

$\therefore P = V^2/R$

$\therefore$ Energy ~~transformed~~ = Power × time

$E = IVt$

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ELECTRICITY...

Factors affecting resistance of a metallic conductor.

The resistance arises due to collision of free electrons with vibrating atoms. It is affected by :- The temperature and presence of impurities.

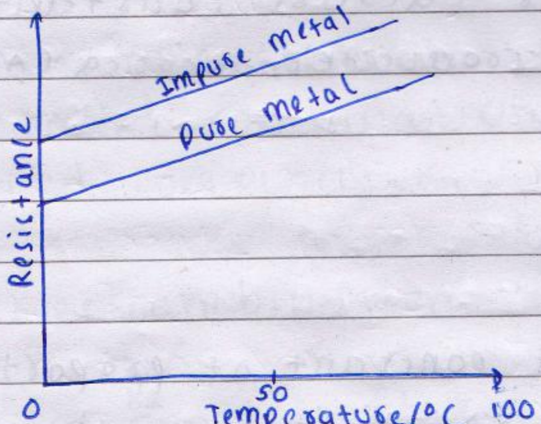
1. Temperature :- When temp. increases atoms have higher KE and electrons pass with more collision, losing more energy, and thus creating higher resistance.

What about semiconductors?

Metals have a high electron number density, typically 10^{28} or $10^{29}\ m^{-3}$. But for semiconductors they have lower values $10^{23}\ m^{-3}$. But insulators have very less electron number density.
At low temperatures, there are few delocalized or free electrons in semiconductors. For conduction to occur, electrons must have sufficient energy to free themselves from atom they are bound ~~do~~ to.
Thus at higher temperatures more electrons are freed and thus conductivity is higher. Thus in semi-conductors, as temp. increases, resistance decreases, quite opposite to that of electrons.

At the same time there'll be more collisions, but this effect is negligible compared with increase in conduction.

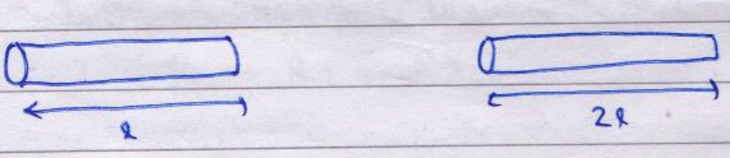
2. The presence of impurities :- If metals contains impurities, some of the atoms will be of different sizes (bigger). Again, this disrupts the flow of electrons and thus presence of impurities increases resistance



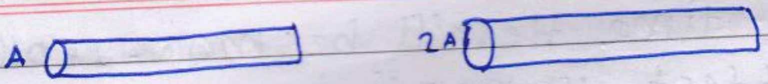
The graph is increasing linear from 0°C to 100°C.
This resistance increases gradually from close to absolute 0 to melting point

Resistance of metallic conductor depends on:

1) Length of metallic wire (L)
2) Cross sectional area (A) of metallic wire.
3) The material the wire is made of



If length is longer, coillision is more, thus more loss of energy and a higher resistance
Thus under all other factors constant,
Resistance (R) $\propto$ length (l)
$R \propto l$ --- (i)



A thicker wire with more cross-sectional area offers less resistance as there is more cross section for e^- to pass through the wire. Eg ÷ If only 1C charge can pass through A ~~maybe~~ 2C will pass through 2A thus doubling the current and giving less resistance.

Thus, under all other factors constant,
Resistance (R) $\propto$ 1/ cross-sectional area (A)
$R \propto 1/A$ - - - (ii)

From (i) and (ii)
$R \propto l/A$
$\therefore R = \rho \frac{l}{A}$ where ρ is constant of proportionality known as resistivity of the material of wire.

Thus under all other factors constant, ~~to~~ wire with higher resistivity offers more resistance.
Eg ÷ Cu is a better conductor than steel.

Resistivity (ρ):

$\rho = RA/l$
If $l = 1m$, $A = 1m^2$
$\rho = R$
Thus, resistivity of a material is numerically equal to the resistance of the conductor having unit length and unit cross-sectional area

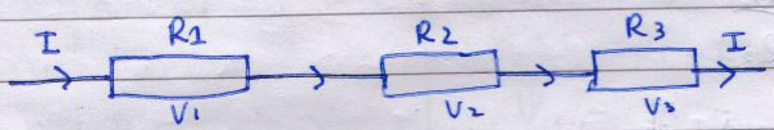
Its SI unit is Ωm
It is independent of the dimension of the wire.
It is only dependent on nature of material and the temperature. (same as resistance).

Combination of resistors

We can combine resistors of different values to form resistors with new resistances.

- Series combination
- Parallel combination
- Mixed combination

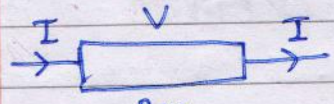
Series combination



- Connected end-to-end such that same current flows through each of them but energy gradually decreases. (p.d is different).

$V = V_1 + V_2 + V_3$ [Principle of conservation....]
or $V = IR_1 + IR_2 + IR_3$
$\therefore V = I(R_1 + R_2 + R_3)$ ---(i)

Let Req be the equivalent resistance of all resistors represented by a single resistance.



$V = IR_{eq}$ ---(ii)
$\therefore R_{eq} = R_1 + R_2 + R_3$

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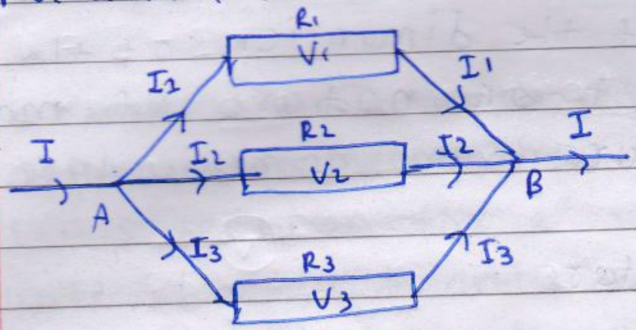
Parallel combination



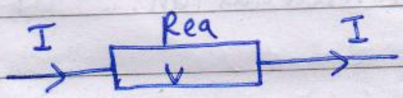
+ Here current divides but potential difference across all resistors is same.
  i.e. $V_1 = V_2 = V_3$
  Because A and B are common points.
+ If resistances are same i.e. ~~V1=~~ $R_1 = R_2 = R_3$
  then $I_1 = I_2 = I_3$.

$I = I_1 + I_2 + I_3$ [Conservation of charge]

or, $I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$

or, $I = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$

Let Rea be the resistance of all resistors represe-nted by a single resistor

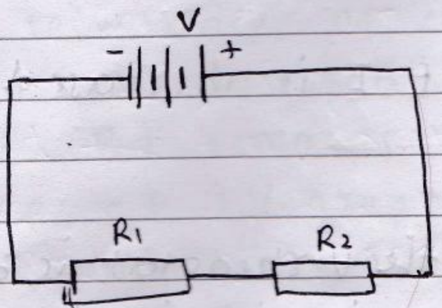


$V = I\,Rea$

$\therefore I = V.(1/Rea)$

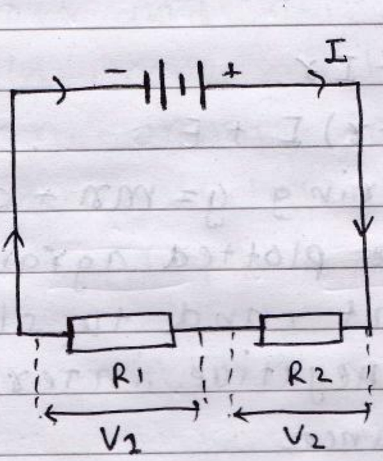
$\therefore \frac{1}{Req} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Potential divider / Voltage divider



A potential divider is an arrangement of resistors in series connected across fixed pd. which provides a convenient way of getting variable pd. out of given fixed pd.

+ A simple potential divider ~~can~~ circuit can be constructed by connecting two resistors in series and joining the combination across given fixed p.d.



$$I = V / R_1 + R_2$$

$$V_1 = IR_1$$

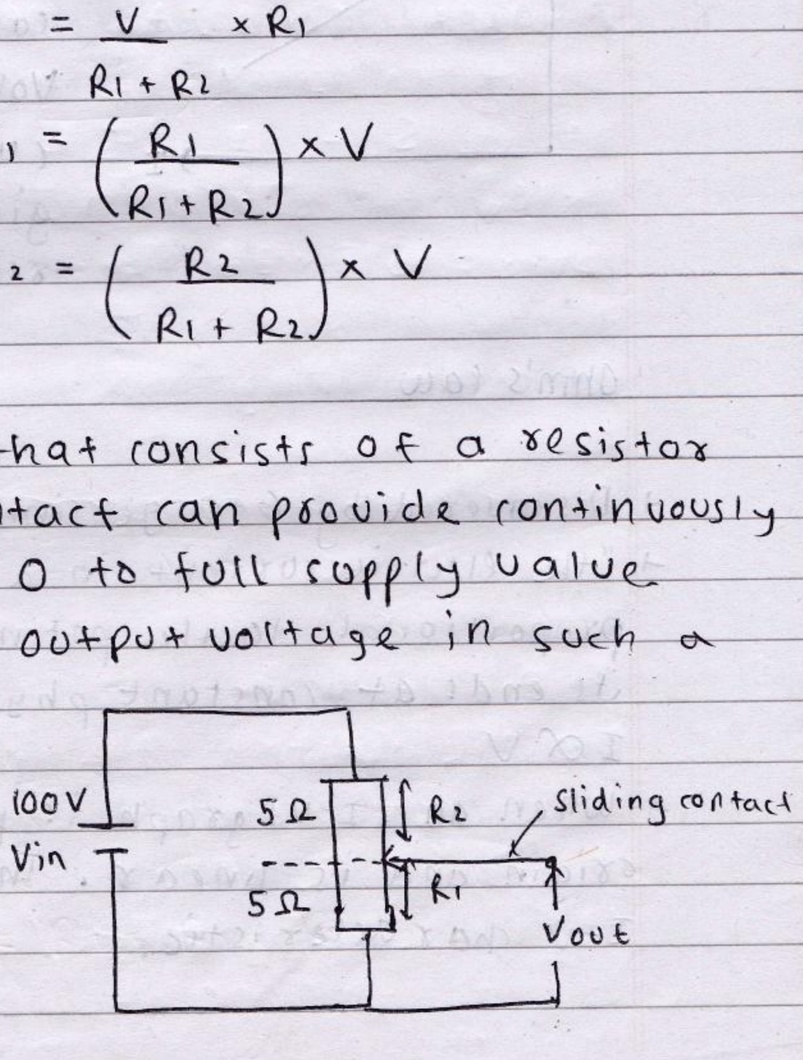
$$= \frac{V}{R_1 + R_2} \times R_1$$

$$\therefore V_1 = \left(\frac{R_1}{R_1 + R_2}\right) \times V$$

$$\therefore V_2 = \left(\frac{R_2}{R_1 + R_2}\right) \times V$$

A potential divider that consists of a resistor with a sliding contact can provide continuously variable p.d from 0 to full supply value.
We can calulate the output voltage in such a circuit by:-

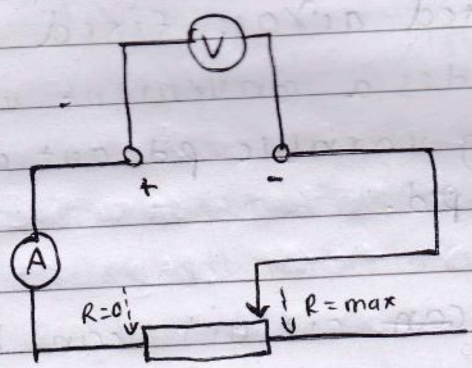
$$V_{out} = \frac{R_1}{R_1 + R_2} \times V_{in}$$



$E = V + Ir$

$\therefore V = E - Ir$

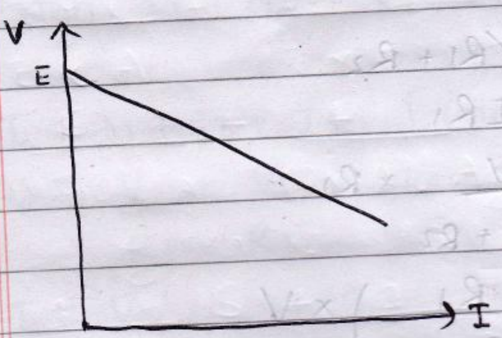
Experiment shows that if I is increased, V decreases.



rheostat (variable resistor)

When the rheostat is altered current in circuit changes, and measurements can be recorded of the circuit current (I) and terminal p.d. (V).

The graph shows the behavior



$V = E - Ir$

or $V = (-r) I + E$

comparing $y = mx + c$

Voltage plotted against current, and the slope gives negative internal resistance

Ohm's law

- Discovered by George Simon Ohm in 1827 AD
- "the electric current in a conductor is directly proportional to the potential difference across its ends at constant physical conditions."

$I \propto V$

- When an (I-V) graph is plotted it passes through origin and is linear. This graph is known as an I-V characteristic.

Date
Page

- Where R is a constant of proportionality known as resistance of conductor.
- If I is doubled, V is also doubled but V/I (R) remains constant.
- Slope of IV graph gives $1/R$ $\therefore R = 1/m$
- If connection of to metal conductor (polarity) is reversed, the graph will be symmetric but passes through $-V$ and $-I$.

Ohmic conductor

- Conductors which obey Ohm's law are ohmic conductors and their resistances are ohmic resistances.
- Gold, copper silver.
- Non-ohmics don't follow Ohm's law. Eg:- Semiconductors, thermistors, transistors. Their I-V graph is a curve.

ELECTRICITY ASSIGNMENT

4a) The output of a heater is 2.5 kW when connected to a 220 V ~~circuit~~ supply.

i) Calculate resistance of heater

$P = V^2/R$

or, $2500 = 220^2/R$

or, $R = 48400/2500$

$\therefore R = 19.36\ \Omega = 19\ \Omega$

ii) The heater is made from a wire of cross-sectional area $2.0 \times 10^{-7}\ m^2$ and resistivity $1.1 \times 10^{-6}\ \Omega m$. Calculate the wire's length.

$R = \rho l/A$

or, $19.36 = (1.1 \times 10^{-6} / 2.0 \times 10^{-7})\, l$

or, $19.36 = 5.5\, l$

$\therefore l = 3.52\ m = 3.5\ m$

b) Supply voltage is changed to 110 V.

i) Calculate power output of heater, assuming no change in wire's resistance.

$P = V^2/R$

or, $P = 110^2/19.36$

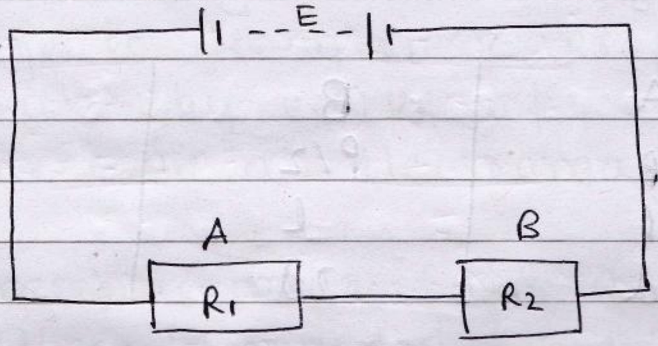
or, $P = 12100/19.36$

$\therefore P = 625\ W$

ii) State and explain one way that the wire of the heater could be changed to give same power as in (a).

$P = V^2/R$ Under constant V, A and ρ, we can
or, $P = \dfrac{V^2}{\rho l/A}$ say Power $\propto \dfrac{1}{\text{length}}$
or, $P = \dfrac{V^2 A}{\rho l}$ $\therefore$ The length of the wire can be reduced by cutting it to increase power to get 2500 W.

6. Two resistors A and B have resistances as hown



The battery has emf E and zero internal resistance

a) State the energy transformation that occurs in

i) the battery
→ No energy transformation as battery has zero internal resistance.

ii) the resistors
→ Energy gets converted into heat inside the resistors. For resistor A, $(R_1/R_1+R_2)\,E$, is converted while in resistor B, $(R_2/R_1+R_2)\,E$ is converted.

b) The current in the circuit is I.
State rate of energy transformation in

i) the battery
→ zero because the battery has no energy transformation due to zero internal resistance.

ii) the resistor A
→ I, because current is the rate at which charges passes through a point in a given time.

c) The resistors are made from metal wires. Their data is given.

resistor	A	B
resistivity	ρ	$\rho/2$
length	l	l
diameter	d	$2d$

Determine ratio of $\dfrac{\text{power dissipated in A}}{\text{power dissipated in B}}$

$$\text{Ratio} = \frac{\cancel{I^2} R_1}{\cancel{I^2} R_2}$$ [Current is ~~constant~~ same for resistors in series]

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

$$= \frac{\rho \dfrac{l}{\pi d^2/4}}{\dfrac{\rho}{2} \dfrac{l}{\cancel{4}\pi d^2/\cancel{4}}} = \frac{\dfrac{4\rho l}{\pi d^2}}{\dfrac{\rho l}{2\pi d^2}} = \frac{4\cancel{\rho l}}{\cancel{\pi d^2}} \times \frac{2\cancel{\pi d^2}}{\cancel{\rho l}} = 8 \text{ //.}$$

d) the resistors are connected in parallel now. Determine ratio $\frac{\text{power dissipated in A}}{\text{power dissipated in B}}$

$$\text{Ratio} = \frac{V^2/R_1}{V^2/R_2} = \frac{V^2}{R_1} \times \frac{R_2}{V^2}$$ [Potential diff. is ~~consta~~ same for resistors in parallel]

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

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

$$= 1/8 \;//.$$

6a) Define charge.
→ Charge is the intrinsic property of objects/particles by virtue of which they experience a force in an electromagnetic field.

b) A heater is made from a wire of resistance 18 Ω and connected to a 240 V power supply ~~wh~~ The heater is switched on for 2.6 Ms. Calculate

i) power transformed in heater

$$\text{power} = V^2/R$$
$$= 240^2/18$$
$$= 57600/18$$
$$= 3200 \text{ W} \;//$$

ii) Current in the heater

Power = Voltage × Current

or, $3200 = 240 \times I$

or, $I = 3200/240$

$\therefore I = 40/3\ A = \cancel{13\ A}$ or, $13.3\ A$ //

iii) the charge passing through heater in this time.

$I = Q/t$

or, $Q = It$

or, $Q = 40/3 \times (2.6 \times 1000 \times 1000)$

$\therefore Q = 3.47 \times 10^{7}\ C$ //

iv) the no. of electrons per second passing a point in the heater

$Q = Ne$

or, $N = Q/e$

or, $N = 3.47 \times 10^{7} / 1.6 \times 10^{-19}$

or, $N = 2.168 \times 10^{26}$ electrons per 2.6 Ms.

or, $N = \dfrac{2.168 \times 10^{26}}{2.6 \times 1000 \times 1000}$

$\therefore N =$

$I = Q/t$

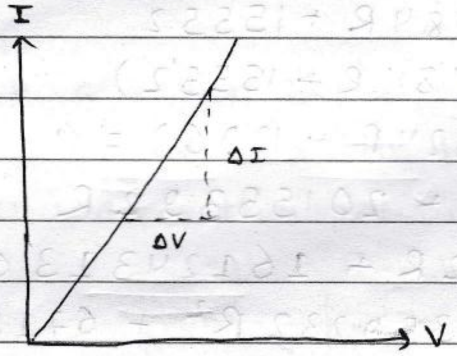
or, $It = Ne$

or, $N = It/e$

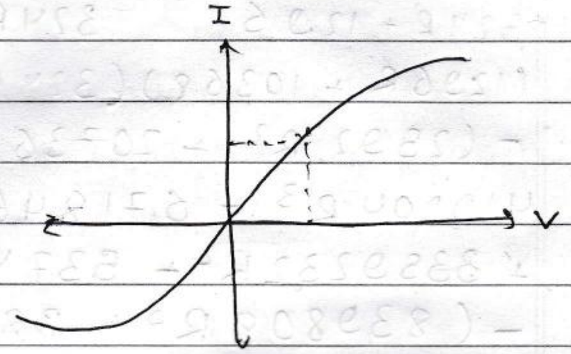
or, $N = \dfrac{(40/3 \times \overset{1}{\cancel{2.6 \times 10^{6}}})}{(1.6 \times 10^{-19})}$

$\therefore N = 8.33 \times 10^{19}\ s^{-1}$ //

Ohmic conductors — Non ohmic conductors



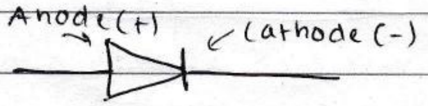
Slope = $1/R$



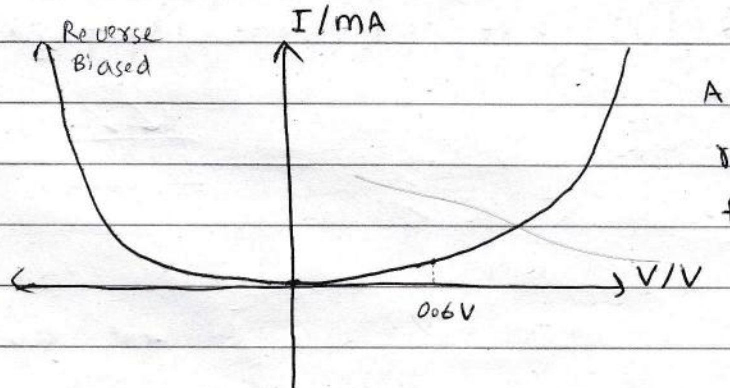
I-V characteristics of filament

Filament lamp is non-ohmic as it attains high temperatures which alters its resistance as well. (1750°C)

+ Diode (Semiconductor)



Electric ~~curr~~ device used to facilitate one way passing of current. It is non-ohmic. Forward biased, positively biased. This property is used to make rectifiers. Rectifiers are devices which help convert AC to DC.



After 0.6V current increases rapidly, but upto 0.6V the current in diode is very less. This is called threshold voltage. (Knee Voltage)
Diode will easily burn out at high currents.

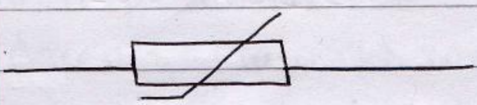
It is non ohmic, as upto 0.6V, resistance is very high, however after that resistance becomes very low.

+ Light emitting Diode (LEDs)

They are highly energy efficient

Threshold voltage is more than 0.6 V

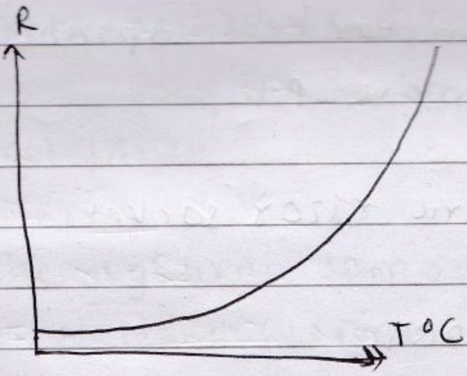
+ Thermistor



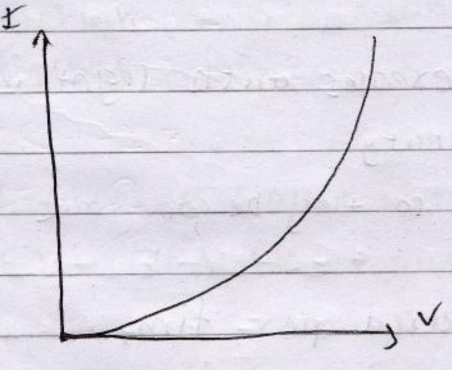
Thermal resistor, changes resistance exponentially for even small changes in temperature. $R \propto T$.

Generally made from metallic oxides / semiconductors
PTC thermistor and NTC thermistor
(Positive temp. coefficient), (Negative temp. coefficient)
$R \propto T$ $\quad\quad$ $R \propto 1/T$

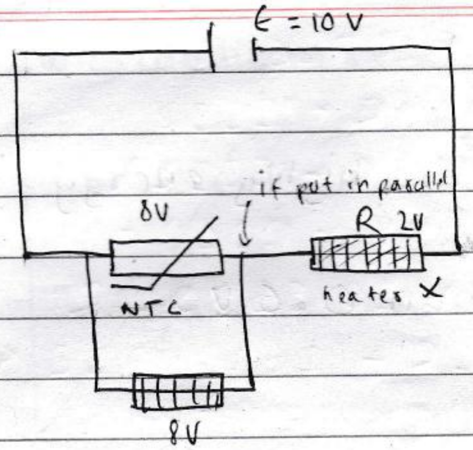
At around 100 - 150°C will the resistance increase sharply.



NTC, 2000 Ω at 30°C
≈ 10 Ω at 100°C
Thus, NTCs are made up of semiconductors while PTCs are made of conductors.



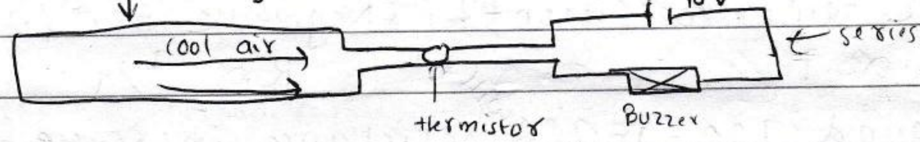
NTC - thermistor



At cold the NTC may take 8V due to high resistance and heater may not work with 2V.
If put in parallel heater will work.

Uses of thermistors

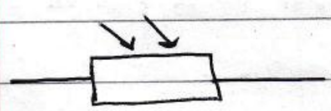
- Water temp. sensors in cars and ice sensors on aircraft.
- Baby alarms:



If baby stops breathing thermistor heats up and R↑, thus buzzer beeps. as it gets more pd.

- Fire sensors
- Overload protection in electric razor sockets.

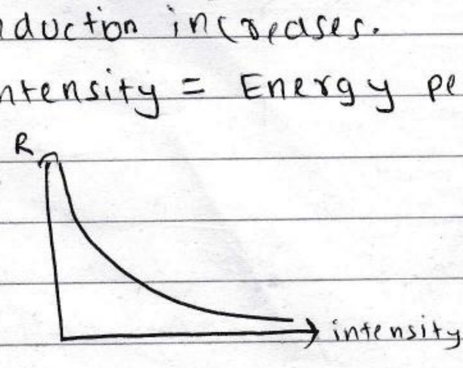
Light Dependent Resistor (LDR)

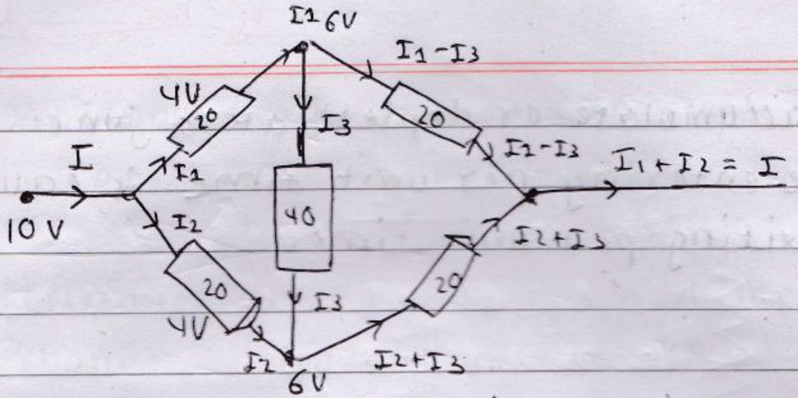


Resistance decreases with light intensity
$R \propto 1/\text{intensity}$

Light energy gives e^- energy, so they become free. thus conduction increases.

Intensity = Energy per unit area per time.





Resistors in this circuit are in whetstone bridge
$40\,\Omega$ resistor is of no use.
Since potential of both points is same, current doesn't flow through it.
But this only works if all resistances except middle have same value. If one of $20\,\Omega$ resistors was $30\,\Omega$, we should consider $40\,\Omega$ as wel.

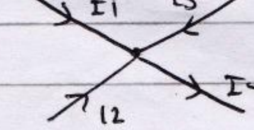
Kirchhoff's laws

- Kirchhoff's first / current / junction law
- Kirchhoff's second / voltage / loop law.

First law

"The algebraic sum of the currents at any junction of an electric current is zero."
Junction is a pt. where three or more conductors meet.
$\sum I = 0$.

- If current flows into junction, then I is +ve
- If current flows out of junction, then I is -ve.



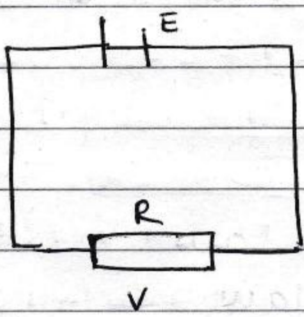
$+I_1 + I_2 + I_3 - I_4 = 0$ .. Principle of conservation
$\therefore I_1 + I_2 + I_3 = I_4$ .. of charge.

"Sum of currents entering any pt. in a circuit is equal to sum of currents leaving that pt."

No charge can accumulate or deplete at a junction, so total charge entering per unit time is equal to total charge exiting per unit time.

Second law

"The algebraic sum of the emfs and pds in any closed loop of an electric circuit is 0."
Based on principle of conservation of energy.
"The sum of emfs ~~is equal to~~ around any loop in a circuit is equal to sum of pds around the loop."



$\sum (E+V) = 0$

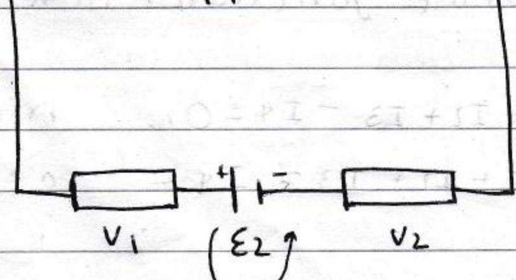
or, $\sum E - \sum V = 0$ [Emf is gain, pd is loss of energy]

$\therefore \sum E = \sum V$

Energy gained by 1C charge passing through emf is energy lost by 1C charge passing through component.

Sign convention

Rise in potential should be taken as +ve and fall in potential must be taken as -ve.
emf is +ve and pd is -ve.



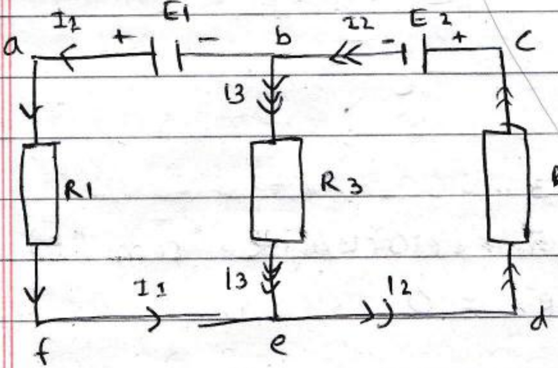
$+\varepsilon_1 - V_1 - \varepsilon_2 - V_2 = 0$

$\therefore \varepsilon_1 = \varepsilon_2 + V_1 + V_2$

high potential to low potential

Emf rule: when moving through (+ve to -ve), change in potentisal is -ve, while -ve to +ve is +ve

Resistance rule: Moving in direction of current, change in potentisol is -IR.



Find I_1, I_2 and I_3.

Chose current direction randomly.

At junction b, $I_2 = I_1 + I_3$ ----(i)

We have three loops, (a, b, e, f, a), (bcdeb) and (abcdefa).

We need two eq^ns, so lets select abefa & bcdeb.

In loop abefa, lets use counterclockwise direction.

We use Kirchhoff's secondlaw,

$E_1 - I_1R_1 + I_3R_2 = 0$ -----(ii)

In loop bcdeb, lets use ~~coun~~ clockwise direction.

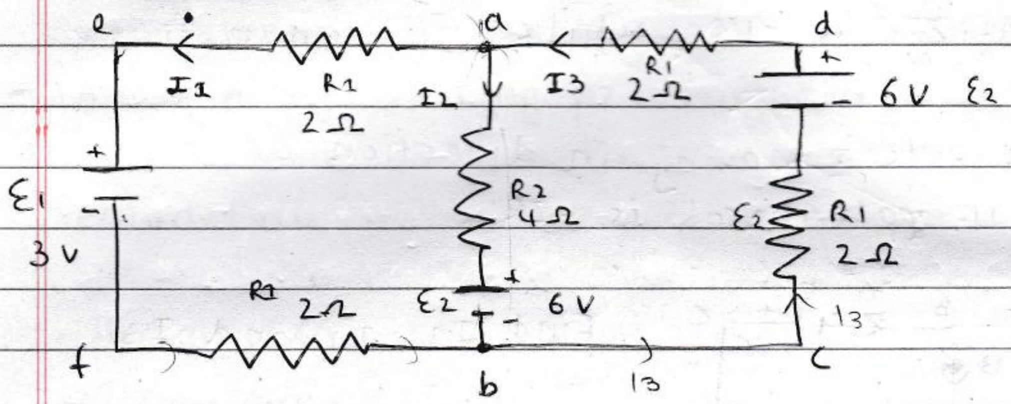
$E_2 + I_2R_2 + I_3R_3 = 0$ ----(iii) $\rightarrow I_2R_2 = \cancel{-E_3R_3}$

$$\frac{I_1R_1 - E_1}{R_2} = \frac{-E_2 - I_2R_2}{R_3}$$

or, $$I_1R_1 - E_1 = \frac{-E_2R_2 - I_2R_2^2}{R_3}$$

∴ $$I_1 = \frac{E_1R_3 - E_2R_2 - I_2R_2^2}{R_1}$$

Find mg. and direction of current in each branch



In junction a, $I_1 + I_2 = I_3$ ..

In loop aefb moving counterclockwise from (•)

$\mathcal{E}_2 - \mathcal{E}_1 - I_1 R_1 + I_2 R_2 - I_1 R_1 = 0$

or, $-\mathcal{E}_1 + 2 I_1 R_1 - I_2 R_2 = 0$

or, $-3 + 4 I_1 - 4 I_2 = 0$ ← $I_1 - I_2 = +3/4$

In loop abcd moving counter clockwise from a.

$-I_2 R_2 - \cancel{\mathcal{E}_2} - I_3 R_1 + \cancel{\mathcal{E}_2} - I_3 R_1 = 0$

or, $4 I_3 + 4 I_2 = 0$

or, $I_2 + I_3 = 0$ ..

$I_2 + \frac{3}{4} + I_2 = -I_2$

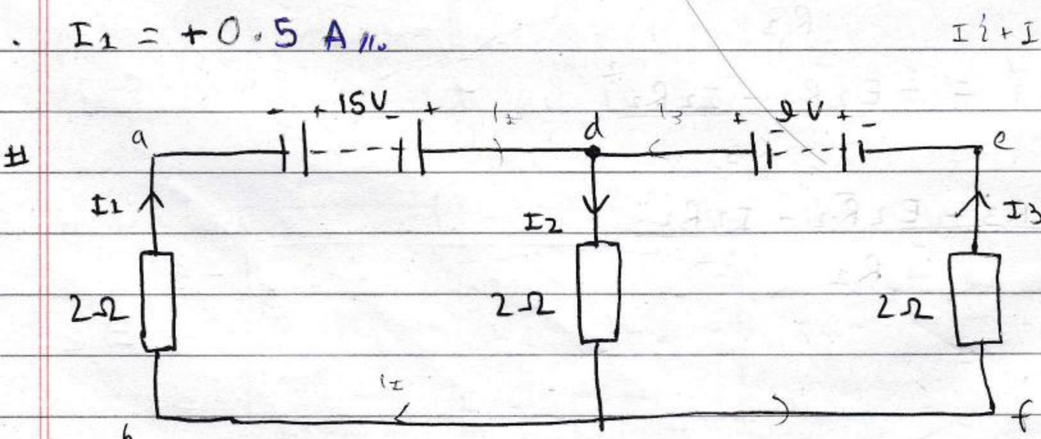
or, $3 I_2 = -3/4$

$\therefore$ $I_2 = -0.25$ A ← Direction is opposite.

$\therefore$ $I_3 = +0.25$ A

$\therefore$ $I_1 = +0.5$ A ..

#



$I_2 = I_1 + I_3$

$7.5 - I_1 = 2I_1 - 3$

a, $3I_1 = 10.5$

$\therefore I_1 = 3.5$ A.

$\frac{10.5}{3}$

$I_2 - I_1 - I_1 = -3$

$I_2 = 2I_1 - 3$

$I_1 + I_3 = I_2$

$I_3 - I_1 = -3$

$+15 - 2I_2 - 2I_1 = 0$ ~~I_3~~

$I_1 + I_2 = 7.5$

$7.5 - I_1$

$+9 - 2I_2 - 2I_3 = 0$

$I_2 + I_3 = 4.5$

$7.5 - I_1 = 3.5 - I_3$

a $4 = I_1 - I_3$

a $4 = I_1 - I_2 - I_1$

$\therefore I_2 = -4$ A.

$I_2 + I_3 = 4.5$

$I_2 + I_1 = 7.5$

$I_3 - I_1 = -3$

$I_2 - I_1 + I_1 = -3$

$I_2 = 2I_1 - 3$

$2a - 3 = 7.5 - a$

$3a = 4.5$ $a = 1.5$

At junction abcd, starting from a.

$15 - 2I_2 - 2I_1 = 0$

or $I_1 + I_2 = 7.5$

At junction dcfe, starting from e.

$9 - 2I_2 - 2I_3 = 0$

∴ $I_2 + I_3 = 4.5$

$\cancel{I_1 + 2I_3 = 4.5}$

or $\cancel{7.5 - I_2 + 2I_3 = 4.5}$

or $\cancel{7.5 - I_1 - I_3 + 2I_3 = 4.5}$

$7.5 - I_1 = 4.5 - I_3$

or $3 = I_1 - I_3$

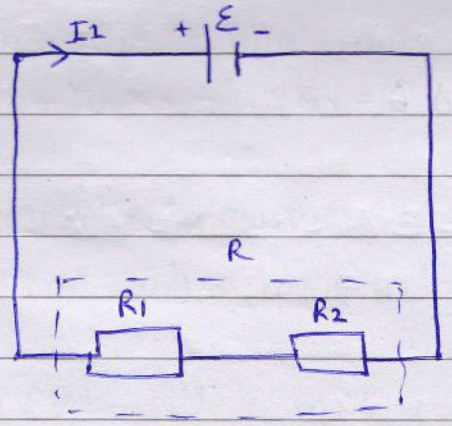
or $3 = I_2 - 2I_3$

or $3 = 4.5 - I_3 - 2I_3$

∴ $I_3 = 0.5$ A

∴ $I_2 = 4.0$ A

∴ $I_1 = 3.5$ A



$-\mathcal{E} - I_1R_1 - I_1R_2 = 0$

or $\mathcal{E} + I_1R_1 + I_1R_2 = 0$

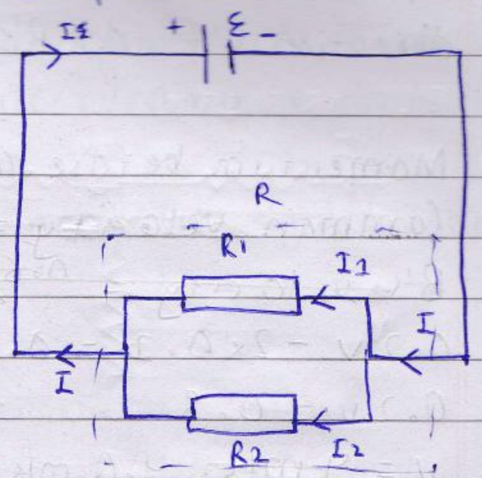
$-\mathcal{E} - I_1R = 0$

or $\mathcal{E} + I_1R = 0$

$\cancel{\mathcal{E}} + I_1R_1 + I_1R_2 = \cancel{\mathcal{E}} + I_1R$

∴ $R = R_1 + R_2$

For parallel.



$-\mathcal{E} - IR = 0$ ∴ $\mathcal{E} + IR = 0$

$-\mathcal{E} - I_1R_1 = 0$ $\quad -\mathcal{E} - I_2R_2 = 0$

$I_1R_1 = I_2R_2 = IR$

$IR = I_1R_1$

$R = \frac{I_1R_1}{I_1 + I_2}$

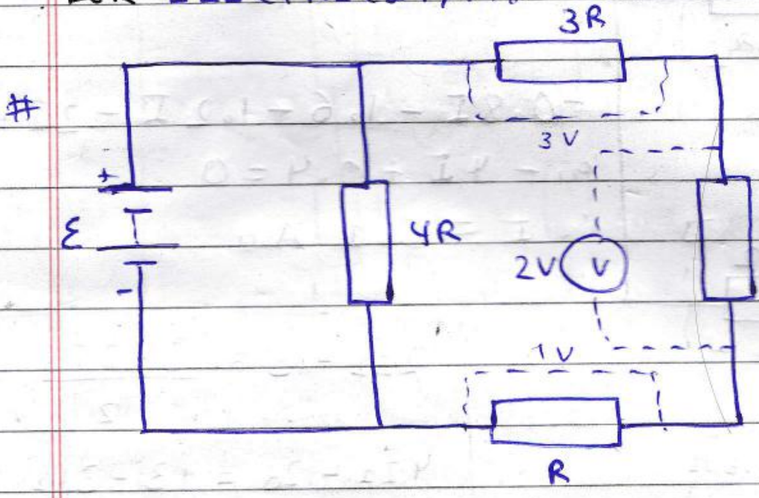
$\frac{1}{R} = \frac{I_1 + I_2}{I_1R_1}$

$\frac{1}{R} = \frac{I_1}{I_1R_1} + \frac{I_2}{I_1R_1}$

$\frac{1}{R} = \frac{1}{R_1} + \frac{I_2}{I_2R_2}$ $[I_1R_1 = I_2R_2]$

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

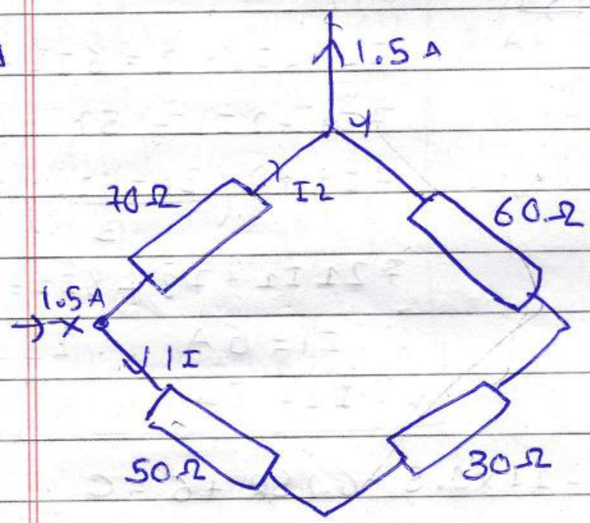
~~For~~ ELECTRICITY...

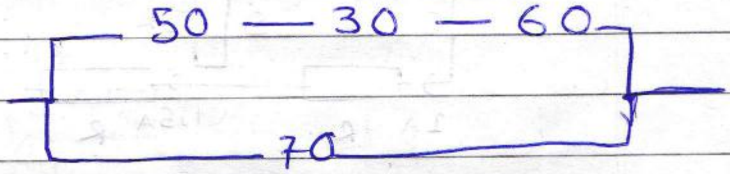


pd across 3R – 3V, R – 1V

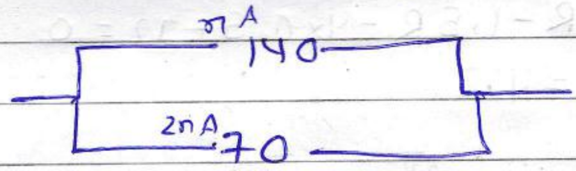
They are in parallel, so, pd = 3+2+1 = 6 V

∴ E = 6 V





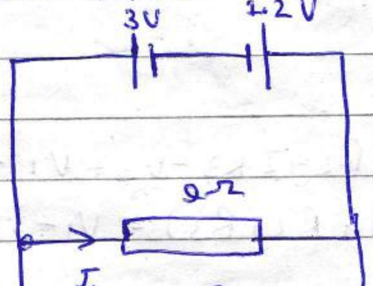
This is in parallel



$x + 2x = 1.5$

∴ $x = 0.5$ A — current across 30 Ω resistor

∴ $2x = 1$ A



$E_{net} = 3 - 1.2 = 1.8$ V

$I = \frac{1.8}{6} = 0.3$ A

$x + \cancel{3}2x = 0.3$ A

∴ $x = 0.1$ A – current in 18 Ω

∴ $2x = 0.2$ A – current in 9 Ω

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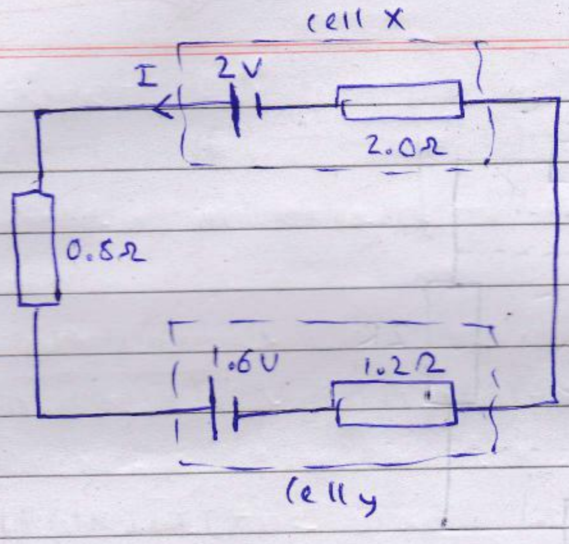


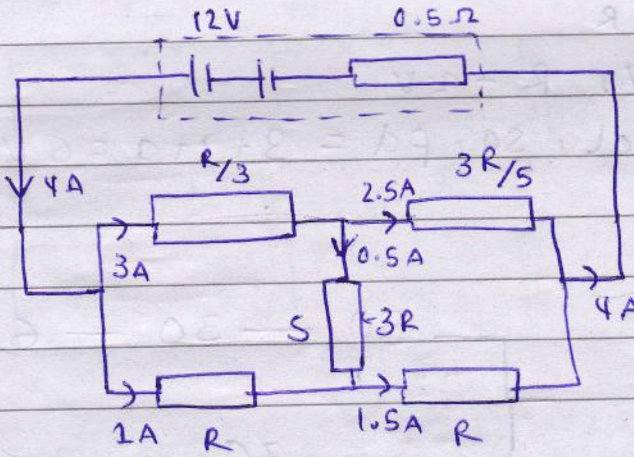
Current in cell x = ?

$-0.8I - 1.6 - 1.2I - 2I + 2 = 0$

$-4I + 0.4 = 0$

$\therefore I = 0.1\ A$

#



$-R - 1.5R - 4\times 0.5 + 12 = 0$

$\therefore R = 4\Omega$

$2I_1 - 13 = \frac{13 - 3I_2}{2}$

$4I_1 - 26 = 13 - 3I_2$

$4I_1 + 3I_2 = 39$

$\frac{-I_1 - 2I_2 + 13}{3} = 2I_1 - 13$

$-I_1 - 2I_2 + 13 = 6I_1 - 39$

$7I_1 + 2I_2 = 52$

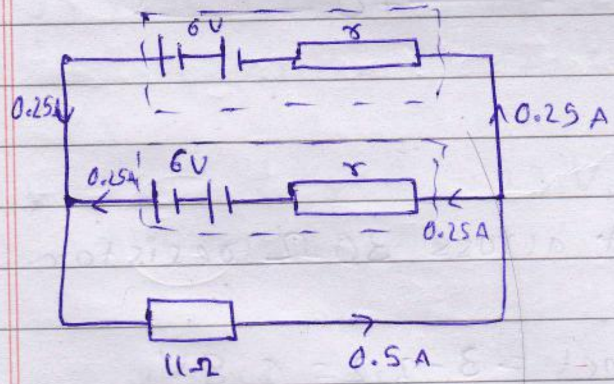
$7I_1 + 2\left(\frac{39 - 4I_1}{3}\right) = 52$

$21I_1 + 78 - 8I_1 = 156$

$\therefore I_1 = 6A \quad \therefore I_3 = -1A$

$\therefore I_2 = 5A$

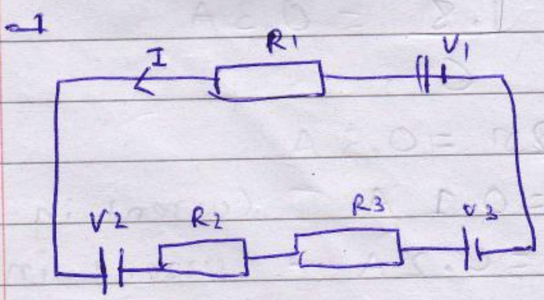
#



$-11\times 0.5 - 0.25r + 6 = 0$

$\therefore r = 2\Omega$

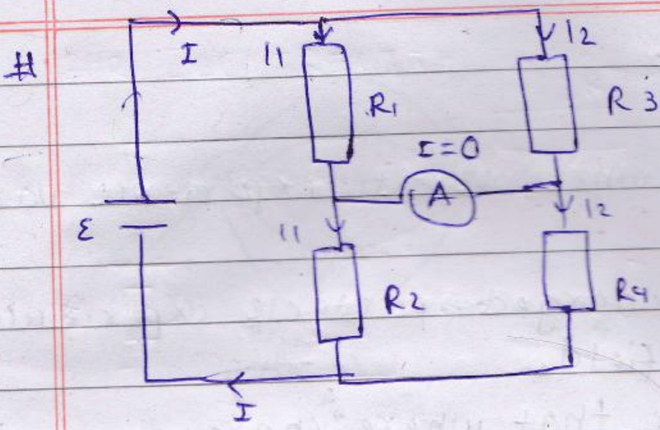
#



$-V_2 - IR_2 - IR_3 - V_3 + V_1 - IR_1 = 0$

$I(R_1 + R_2 + R_3) = V_1 - V_2 - V_3$

#



$-I_1R_1 - I_1R_2 + \varepsilon = 0$

$\varepsilon = I_1(R_1+R_2)$

$-I_2R_3 - I_2R_4 + \varepsilon = 0$

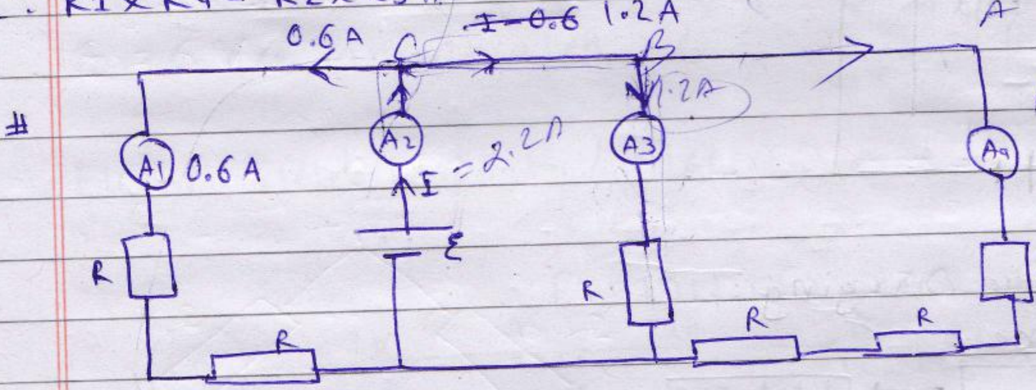
$\varepsilon = I_2(R_3+R_4)$

$I_1R_1 = I_2R_3 \;,\; I_1R_2 = I_2R_4$

$\frac{\cancel{I_2}R_3}{R_1} = \frac{\cancel{I_2}R_4}{R_2}$

$\therefore R_1 \times R_4 = R_2 \times R_3$

#



$A_1, A_3, A_4 = ?$

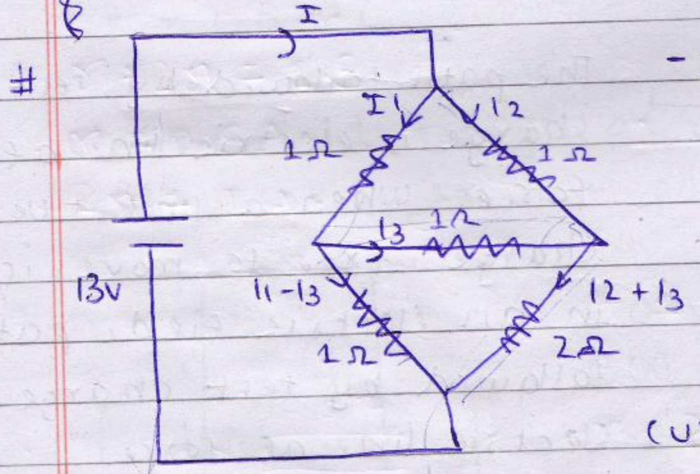
$-0.6R - 0.6R + \varepsilon = 0$

$\therefore \varepsilon = 1.2R$

$I - 0.6 = 1.2$

$I = 1.8\,A$

#



$-\cancel{I_2 - I_1 + I_3}\; -I_1 - (I_1 - I_3) + 13 = 0$

or, $-\cancel{\varepsilon}\, I_3 = -13\,A$

$-I_2 - 2(I_2 + I_3) + 13 = 0$

or, $-3I_2 + 39 = 0$

$\therefore I_2 = 13\,A$

current in $2\Omega = 0A$

$\therefore$ Total $I = 39\,A$

$\therefore R =$

$-I_1 - I_3 - (I_2 + I_3) + 13 = 0$

or, $-I_1 - 2I_3 - I_2 + 13 = 0$

$\therefore I_2 = 26\,A$

$-I_1 - I_3 - 2I_2 - 2I_3 + 13 = 0$

$-I_1 - I_1 + I_3 + 13 = 0$

$-2I_1 + I_3 + 13 = 0$

$-I_2 - 2I_2 - 2I_3$

$-3I_2 - 2I_3 + 13$

ELECTRICITY NUMERICALS

1. A silver wire 2.6 mm in diameter transfers 420C in 80 min. It contains 5.8×10^{28} free electrons per m^3. what is current and drift velocity.

$2.6mm = 2.6/1000\ m = 2.6 \times 10^{-3}\ m$

$A = \pi d^2/4 = 22/7 \times (2.6 \times 10^{-3})/4 = 5.31 \times 10^{-6}\ m^2$

$\cancel{V} = n = 5.8 \times 10^{28}\ e/m^3$

$e = 1.6 \times 10^{-19}\ C$

$\therefore I = 420/80 \times 60 = 0.0875\ A = 8.75 \times 10^{-2}\ A$

$\therefore Vd = I/enA = 8.75 \times 10^{-2}/(1.6 \times 10^{-19}) \times (5.8 \times 10^{28}) \times (5.31 \times 10^{-6})$

$= 1.78 \times 10^{-6}\ ms^{-1}$

2. Two resistors of $1200\ \Omega$ and $800\ \Omega$ are connected in series with emf 24 V. What is pd across each resistor

$\therefore V_{1200} = 1200/1200+800 \times 24 = 14.4\ V$

$\therefore V_{800} = 800/1200+800 \times 24 = 9.6\ V$

3. A cell of emf 18 V has $3\ \Omega$ internal resistance. Terminal pd is 15 V when connected to a resistor. Find its resistance.

$V_T = R/R+3 \times 18$

or, $15 = R/R+3 \times 18$

or, $15R + 45 = 18R$

or, $3R = 45$

$\therefore R = 15\ \Omega$

4. A battery with negligible internal resistance is connected to resistor and 0.4 A exists. When 5Ω is added in series, current becomes 0.2 A. What is battery's emf.

$I_1 = E/R$ $\qquad\qquad$ $I_2 = E/R+5$

or, $0.4R = E$ $\qquad\qquad$ or, $0.2R + 1 = E$

or, $R = E/0.4$ $\qquad\qquad$ or, $0.2 \times E/0.4 + 1 = E$

or, $0.5E + 1 = E$

$\therefore E = 2V$

5. Find resistance of hollow cylinder of 1m length and inner and outer radii 1 mm and 2mm with $2.0 \times 10^{-8}\ \Omega m$.

$1mm = 1 \times 10^{-3}\ m$

$2mm = 2 \times 10^{-3}\ m$

$l = 1m$

$A = \pi r_2^2 - \pi r_1^2 = 22/7\left((2\times10^{-3})^2 - (1\times10^{-3})^2\right) = 9.43\times10^{-6}\ m^2$

$\therefore R = \rho \frac{l}{A} = (2\times10^{-8}) \times \frac{1}{(9.43\times10^{-6})} = 2.12 \times 10^{-3}\ \Omega$

6. A battery of 2V emf and $\overset{0.5}{\cancel{3}}\ \Omega$ internal resistance is connected across 9.5 Ω. How many electrons cross through a cross section of resistance in 1 s.

$I = 2/0.5+9.5 = 0.2\ A$

0.2 C passes in 1s.

$\therefore$ No. of electrons $= \frac{0.2}{1.6\times10^{-19}} = 1.25 \times 10^{18}\ e/s$

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7. A battery drives 1 A current round a circuit consisting two 2 Ω resistors in parallel. When resistors are in series, current in 0.4 A. Calculate emf and internal resistance.

$I_1 = E/1+R$

or, $1+R = E$

$\therefore R = E-1$

$\therefore R = 1\,\Omega$

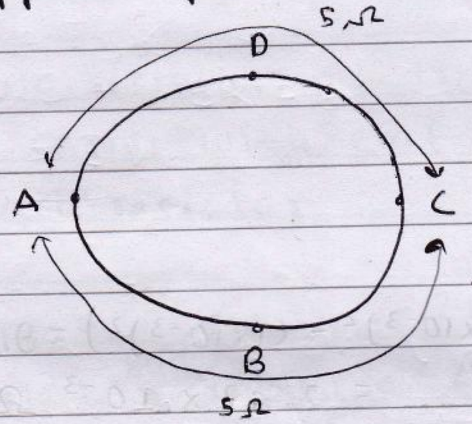
$I_2 = E/4+R$

or, $1.6 + 0.4R = E$

or, $1.6 + 0.4E - 0.4 = E$

$\therefore E = 2\,V$

8. A wire of 10 Ω resistance is bent to form a circle. Find its resistance between two diametrically opposite points.



If C is cut, total resistance is $5+5 = 10\,\Omega$.

Now resistance between A and C will be in parallel,

$\therefore R = 1/5 + 1/5$

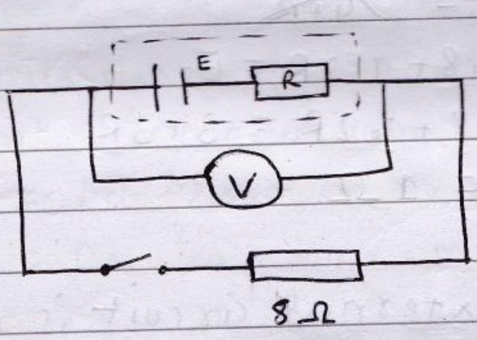
$= 2.5\,\Omega$

9. A uniform wire of 100 Ω resistance is melted and recasts in a wire of length double that of original length. What is resistance.

$R_1 = \rho l/A$ or, $\rho l/A = 100$

$R_2 = \rho \frac{2l}{V/2l} = \rho \frac{2l}{A/2} = 4\rho \frac{l}{A} = 400\,\Omega$

10. A cell is connected in series with $8\,\Omega$ resistor and a switch. A high resistance voltmeter is connected across cell and reads 3.6 V when switch is open and 3.2 V when closed. Find emf and internal resistance



$V_{open} = 3.6\,V$

$V_{closed} = 3.2\,V$

$V_{closed} = \frac{8}{8+R} \times E$

or, $25.6 + 3.2R = 8E$

$\therefore E = \frac{25.6 + 3.2R}{8}$

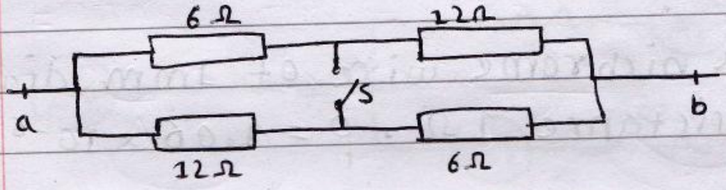
$V_{open} = \frac{R}{R} \times \cancel{3.6}\ E$

or, $3.6 = 1 \times E$

$\therefore E = 3.6\,V$

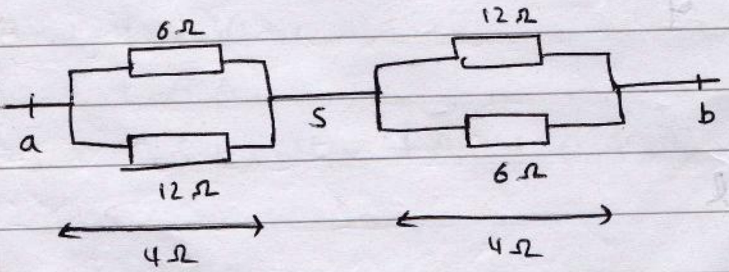
$\therefore R = 1\,\Omega$

11. Find equivalent resistance between a and b when switch is open and closed.



$\frac{1}{R_{open}} = \frac{1}{6+12} + \frac{1}{6+12}$

$\therefore R_{open} = 9\,\Omega$



If switch closed

$\therefore R_{closed} = 4 + 4 = 8\,\Omega$

12. A battery drives 3 A current round a circuit consisting two 2Ω resistors in parallel. When resistors are in series, current is 1.2 A. Find emf and internal resis...

$I_1 = E/1+R$ $\qquad$ $I_2 = E/4+R$

or $3+3R = E$ $\qquad$ or $4.8 + 1.2R = E$

$\therefore E = 6V$ $\qquad$ or $4.8 + 1.2R = 3+3R$

$\therefore R = 1\Omega$

13. When resistance of an external circuit is increased from 1Ω to 2Ω the terminal pd across cell increases from 1.5 to 2.0 V. Find emf & int. resis.

$V_1 = R_1/R_1+R \times E$ $\qquad$ $V_2 = R_2/R_2+R \times E$

or $1.5 = 1/1+R \times E$ $\qquad$ or $2 = 2/2+R \times E$

or $1.5 + 1.5R = E$ $\qquad$ or $4 + 2R = 2E$

$\therefore E = 3V$ $\qquad$ or $4+2R = 3+3R$

$\therefore R = 1\Omega$

14. Find length of a nichrome wire of 1mm diameter so as to make resistance 1Ω. $\rho = 1.06 \times 10^{-6}\ \Omega m$

$1mm = 1 \times 10^{-3}\ m$

$A = \frac{\pi d^2}{4} = \frac{22/7 \times (1\times10^{-3})^2}{4} = 7.85 \times 10^{-7}\ m^2$

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

or $1 = \frac{(1.06 \times 10^{-6})\ l}{(7.85 \times 10^{-7})}$

$\therefore l = 0.74m = 74\ cm$

15. A copper rod of 20 cm length and $2mm^2$ CSA is joined with similar Al rod. Find resistance of combination between ends. $\rho_{cu} = 1.7 \times 10^{-8}\ \Omega m$. $\rho_{Al} = 2.6 \times 10^{-8}\ \Omega m$.

$20\,cm = 0.2\,m$

$2mm^2 = 2/1000 \times 1/1000 = \cancel{2} \times 10^{-6}\ m^2$

$R_{cu} = \rho_{cu}\, l/A = (1.7 \times 10^{-6}) \times 0.2/2 \times 10^{-6} = \cancel{8.5 \times 10^{-9}\ \Omega}$ $1.7 \times 10^{-3}\ \Omega$

$R_{Al} = \rho_{Al}\, l/A = (2.6 \times 10^{-8}) \times 0.2/2 \times 10^{-6} = \cancel{1.3}\ 2.6 \times 10^{-3}\ \Omega$

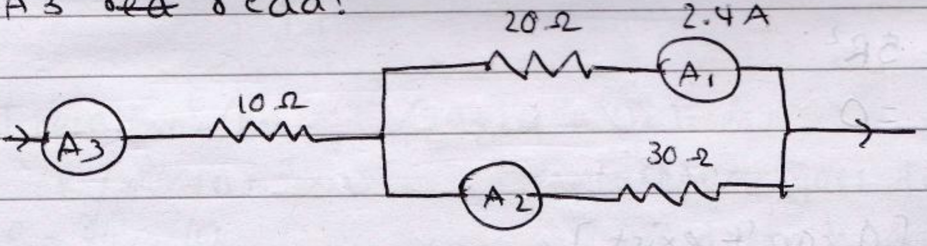
$\frac{1}{R} = \frac{1}{R_{cu}} + \frac{1}{R_{Al}}$

or, $\frac{1}{R} = \frac{1}{\ } \ 972.85$

$\therefore R = 1 \times 10^{-3}\ \Omega$

$\therefore R = 1.0\ m\Omega$ ..

16. If reading of A1 is 2.4 A, what will ~~be~~ A2 and A3 ~~red~~ read?



$\frac{20}{1/2.4} = \frac{30}{1/A_2}$ [As $A_2 \propto 1/R$]

or, $20 \times 2.4 = 30 A_2$

$\therefore A_2 = 1.6\ A$ ..

$\therefore A_3 = 1.6 + 2.4 = \cancel{4A}\ 4.0\ A$ ..

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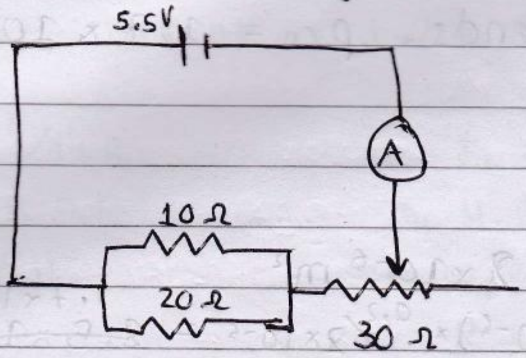
17. Resistance of rheostat is 30 Ω. Find min. and max. currents through ammeter as rheostat is varied.



$I = 5.5/(30 + 20/3) = 0.15$ A

$\therefore I_{min} = 0.15$ A [constant I]

$I = 5.5/(0 + 20/3) = 0.825$ A

$\therefore I_{max} = 0.82$ A [constant I]

18. An ideal battery sends 5A current in a resistor. When 10 Ω is connected in parallel, current is 6A. Find first resistance.

$V = IR$

or, $E = 5R$.

$V = IR$

or, $E = 6 \times 10R/(10+R)$

$\frac{60R}{10+R} = 5R$

or, $60R = 50R + 5R^2$

or, $5R^2 - 10R = 0$

or, $R^2 - 2R = 0$

$\therefore R = 2\,\Omega$ [0 can't exist]

19. Resistors of 4 Ω and 12 Ω are in parallel across 6 V battery with 1 Ω internal res. Find total resistance, current supplied by battery and in each resistor.

$1/R = 1/4 + 1/12$

$\therefore R = 3\,\Omega$

$\therefore R_{eq} = 1 + 3 = 4\,\Omega$

$\therefore I = E/R_{eq} = 6/4 = 1.5$ A

Let's consider 4 Ω as 3 12 Ω's in ||

$I_{\text{in each } 12\Omega} = 1.5/4 = 0.375$ A

$\therefore I_{12\Omega} = 0.375$ A

$\therefore I_{4\Omega} = 3 \times 0.375 = 1.125$ A

20. A battery of 4V and 2Ω internal res. is joined to 8Ω resistor. Calculate terminal pd. What resistor in series would produce 3.6 V term. pd.

$V_{terminal_1} = \frac{8}{8+2} \times 4 = 3.2\ V$

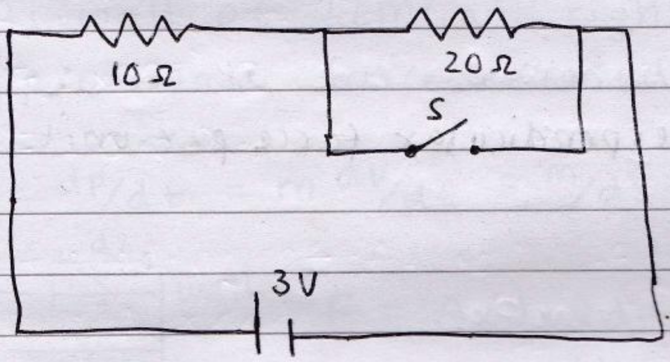
$V_{terminal_2} = \frac{8+R}{8+2+R} \times 4$

or, $3.6 = \frac{8+R}{10+R} \times 4$

or, $36 + 3.6R = 32 + 4R$

$\therefore R = 10\Omega$

21. Consider circuit, find current through 10Ω res. when switch is open and closed.



$I_{open} = E/R_{eq} = \frac{3}{10+20} = 0.1\ A$

$1/R = 1/10 + 1/20$

$\therefore R = 20/3\ \Omega$

$\therefore I = 3 \times 3/20 = 0.45\ A$

Divides in 1 : 2 ratio,

$1n + 2n = 0.45$

$\therefore n = 0.15\ A$

$\therefore I_{closed} = 2n = 0.3\ A$

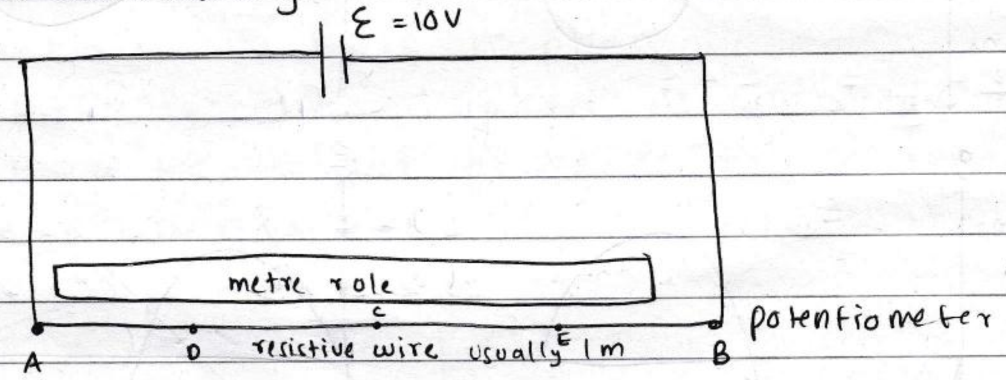
current goes for easy way so dosen't pass through 20 Ω when switch is closed.

$I_{closed} = \frac{3}{10} = 0.3\ A$

ELECTRICITY . . .

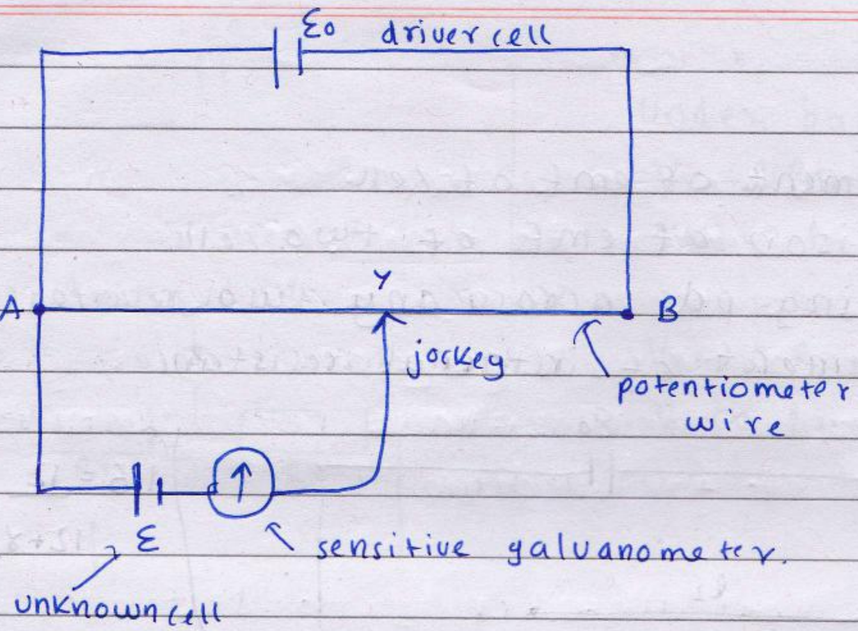
Potentiometer

- Electromotive force of cell can't be accurately measured by a voltmeter. It only gives approx. value.
- To measure it accurately we use potentiometer. The only other alternative is an ideal voltmeter with infinite resistance.
- Potentiometer is a device used for comparing potential differences.
- It can be used to measure emf of cell, provided you ~~have~~ already have a source whose emf is known accurately.



The wire must have uniform cross section, low temp. coefficient of resistance and high resistivity like manganin, constantan etc.
Low temp. coefficient of resistance - High temp. change causes low resistance change.

Driver cell ε is connected across AB so that steady current is maintained in AB. Thus the potential/voltage decreases steadily across AB but pd increases steadily.
$V_A = 10V$, $V_B = 0V$, $V_C = 5V$, $V_D = 7.5V$, $V_E = 2.5V$



Potential difference across any sector of the potentiometer wire is directly proportional to the length of that sector. This is principle of potentiometer.

The galvanometer is there to measure the presence of current. For instance if Y was mid-point, pd across A and Y, $V_{AY} = 12 - 6 = 6\ V$ $[\mathcal{E}_0 = 12V]$
Now if galvanometer shows no deflection $\mathcal{E} = 6V$ as the two emf's effect is nullified.

This is how a potentiometer works. Galvanometer shows deflection when current flows.

Potentiometer only works when and if $\mathcal{E}_0 > \mathcal{E}$

$V = IR$

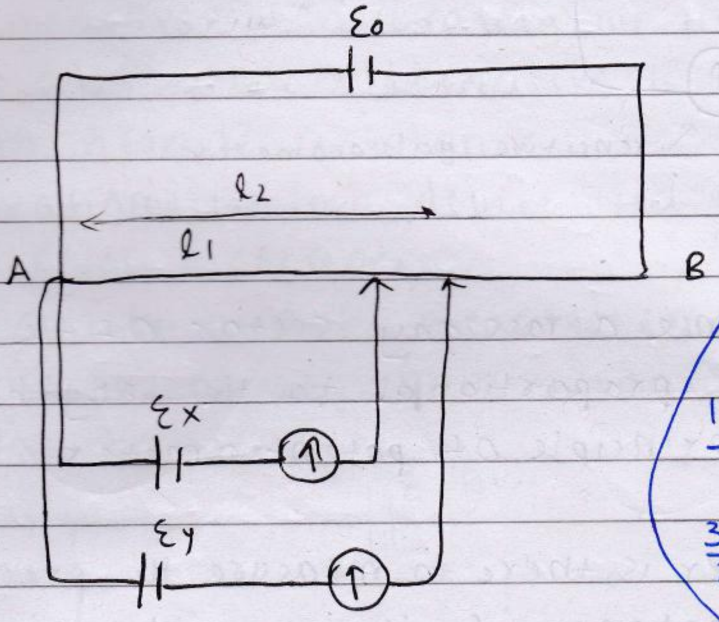
or $V = I\rho \frac{l}{A}$

or $V = \frac{I\rho}{A} l$

$\therefore V \propto l$ [Valid for constant I]

Uses

- Measurement of emf of cell
- Comparison of emf of two cells.
- Comparing pds across any two resistors.
- Measurement of internal resistance.



$1.6 = \frac{12}{12+r} \times A$

$1.5 = \frac{9}{9+r} \times A$

$\frac{1.5(9+r)}{9} = \frac{1.6(12+r)}{12}$

$\frac{3}{2} + \frac{1}{6}r = \frac{8}{5} + \frac{2}{15}r$

$\frac{1}{30}r = \frac{1}{10}$

$r = 3\,\Omega$

$A = 2\,V$

$\mathcal{E}_x \propto l_1 \qquad \mathcal{E}_x = Kl_1$ ---- (i)

$\mathcal{E}_y \propto l_2 \qquad \mathcal{E}_y = Kl_2$ ---- (ii)

$V = IR$

or, $1.6 = I \times 12$

$\therefore I =$

$A = $

Dividing (i) and (ii)

$$\frac{\mathcal{E}_x}{\mathcal{E}_y} = \frac{l_1}{l_2}$$

$$\therefore \mathcal{E}_x = \frac{l_1}{l_2}\mathcal{E}_y$$

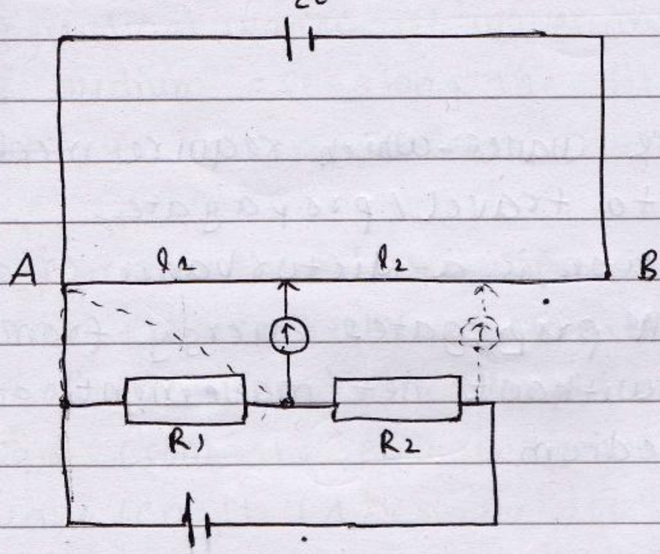
This is helpful if either $\mathcal{E}_x$ or $\mathcal{E}_y$ is known.

$V = IV$
$V = IR$
$1 = I \times 6$
$\therefore I = 1/6$ A

$V = I(R+r)$
or, $1.5 = 1/6(12+r)$
$\therefore r =$

$A = 1/6(12+r)$
$6A = 12 + r$
$r = 6A - 12$

$1.5 = \frac{12}{12+r} \times A$



Under balanced condition

$V_1 = IR_1$ ---(i)

$\therefore V_1 \propto l_1$ ~~$V_1 =$~~

$V_2 = IR_2$ ---(ii)

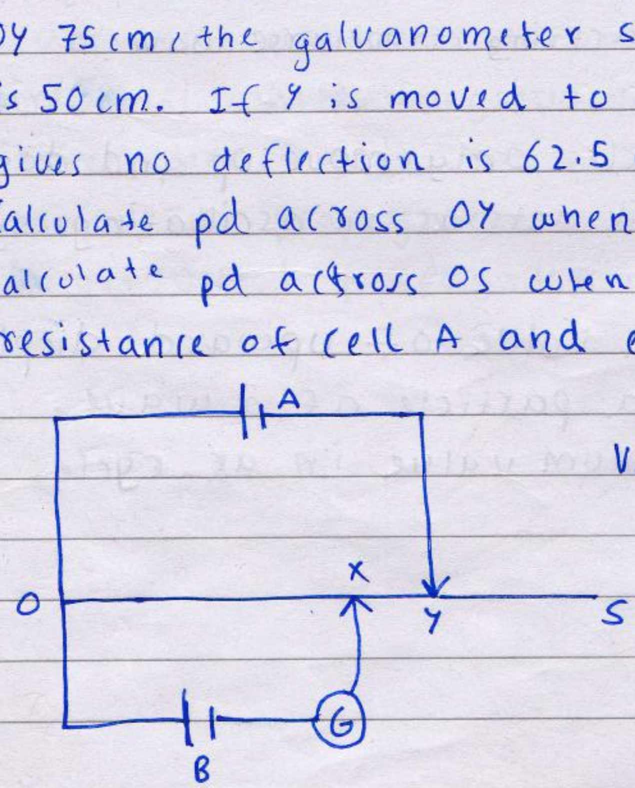
$\therefore V_2 \propto l_2$

Dividing (i) and (ii)

$\frac{V_1}{V_2} = \frac{l_1}{l_2}$ As $V = IR$, $V_1 = IR_1$, $V_2 = IR_2$

$\therefore V_1 = \frac{l_1}{l_2} V_2$ // $\therefore R_1 = \frac{l_1}{l_2} R_2$ //

\# Cells A and B and a galvanometer G are connected to a slide wire OS. by two sliding contacts X and Y as shown. Slide wire OS is 1.0 m long and has 12 Ω resistance. with OY 75 cm, the galvanometer shows no deflection when OX is 50 cm. If Y is moved to touch at S, value of OX which gives no deflection is 62.5 cm. emf of cell B is 1.0 V. Calculate pd across OY when OY is 75 cm with G balanced. Calculate pd acrross OS when Y touches S. The internal resistance of cell A and emf of cell A.



V_{oy} ~~A~~ $= \frac{OY}{OX} B$

$\frac{V_{oy}}{A} = \frac{75}{50} \times 1$

$\therefore$ ~~$A = 1.5 V$~~ //

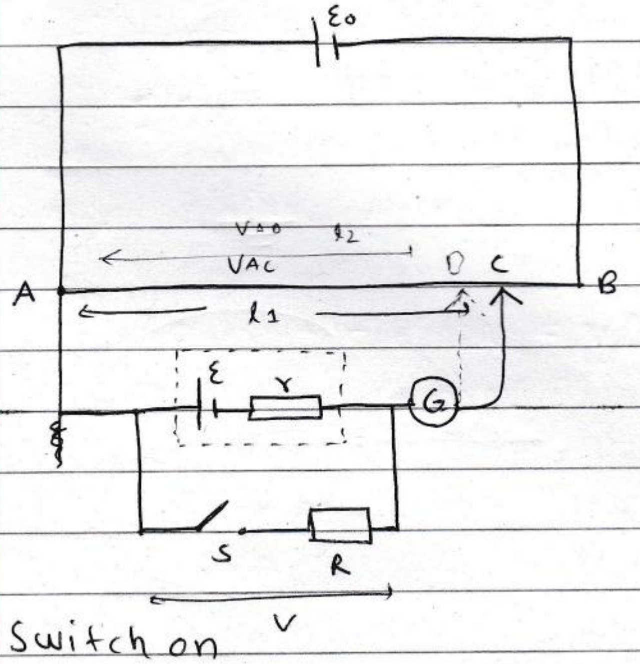
$\therefore V_{oy} = 1.5 V$ //

$V_{oy} = \frac{100}{62.5} \times 1$

$\therefore V_{oy} = 1.6 V$ //

POTENTIOMETER...

Determination of internal resistance of a cell.



(i) Switch off

At balancing point C galvanometer has no deflection.

$\varepsilon = V_{AC}$, $V_{AC} \propto l_1$

$\therefore \varepsilon \propto l_1$ ---(i)

(ii) Switch on

There will be flow of current which is balanced by moving jockey to D.

$V = V_{AD}$, where V is terminal pd of ε.

$V_{AD} \propto l_2$

$\therefore V \propto l_2$ ---(ii)

Dividing (i) by (ii)

$$\frac{\varepsilon}{V} = \frac{l_1}{l_2}$$

or, $$\frac{V + Ir}{V} = \frac{l_1}{l_2}$$

or, $$\frac{IR + Ir}{IR} = \frac{l_1}{l_2}$$

or, $$1 + \frac{r}{R} = \frac{l_1}{l_2}$$

or, $$r = \left(\frac{l_1}{l_2} - 1\right) R$$

= In an experiment to determine the internal resistance of a cell of emf 1.08 V, the balance point in the open circuit is 80 cm. If the cell is shunted with a resistance of 5 Ω, the balance point is 65 cm. What is internal resistance.

$\therefore r = \left(\frac{l_1}{l_2} - 1\right) R = \left(\frac{80-65}{65}\right) \times 5 = \frac{15}{65} \times 5 = \frac{15}{13} = 1.15 \Omega$

$\varepsilon_0 = I + \quad \varepsilon = I + r$

$I \alpha l_1$

$\varepsilon \alpha l_1$

$\varepsilon \alpha l_2$

$\frac{\varepsilon}{V} = \frac{l_1}{l_2}$ $\quad$ $V+Ir$ $\quad$ $\frac{R+r}{R} = \frac{l_1}{l_2}$

$\frac{1+r}{R} = \frac{l_1}{l_2}$