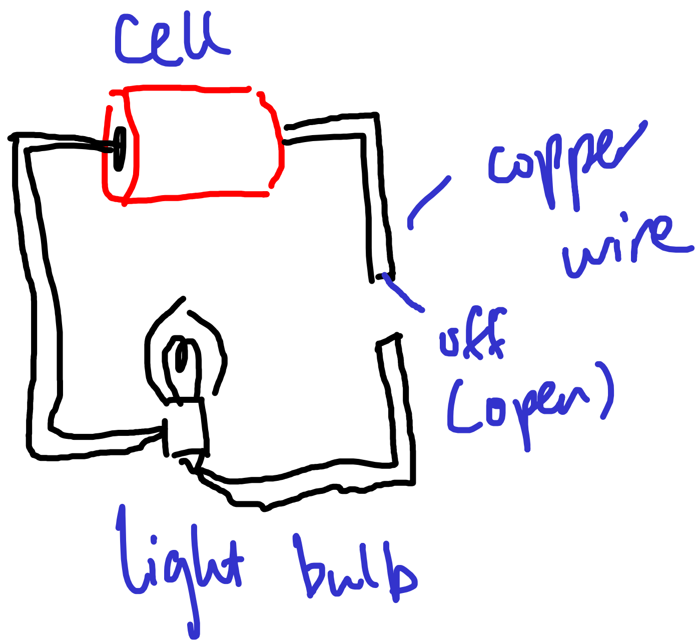
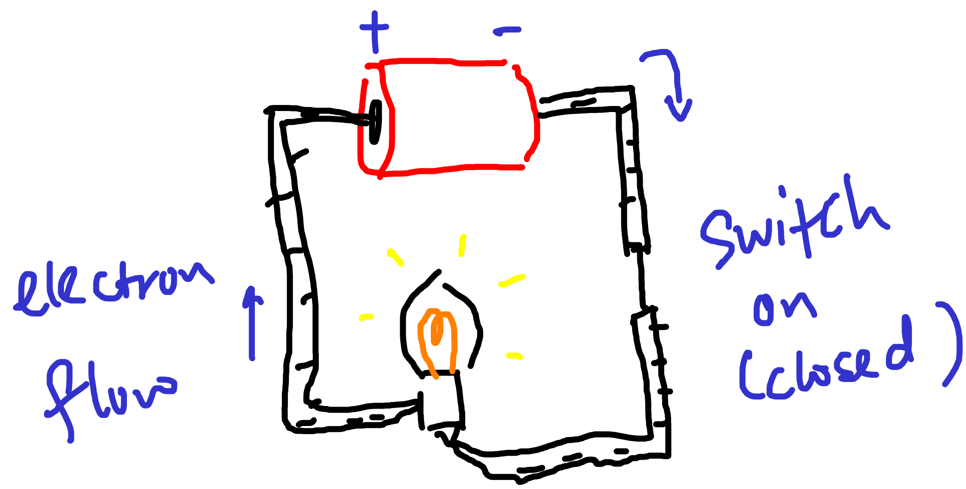
state that current is a rate of flow of charge and that it is measured in amperes

Electric Current

Dr K M Hock



Electrons in copper start to flow when switch is closed.



The rate of flow of electric charge is called an electric current.

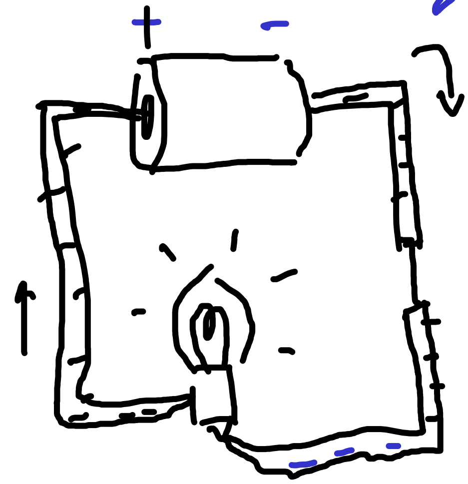
It is measured in units of amperes (A)

Conventional Current

Dr K M Hock

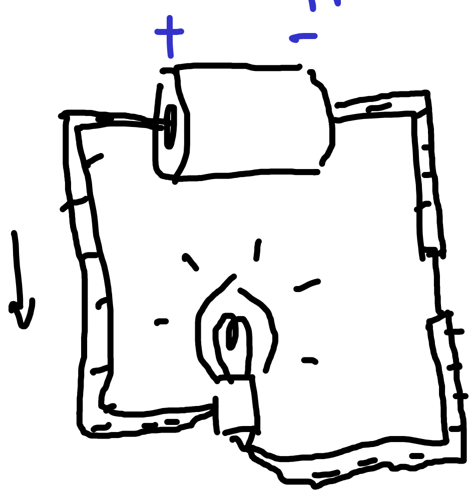
When e^- flows one way:

electron flow



current flows the opposite way:

current flow



switch on (closed)

Electricity discovered before electrons.

Current direction was random choice.

now called <u>Conventional current.</u>

recall and apply the relationship charge = current × time to new situations or to solve related problems

Electric Current Formula

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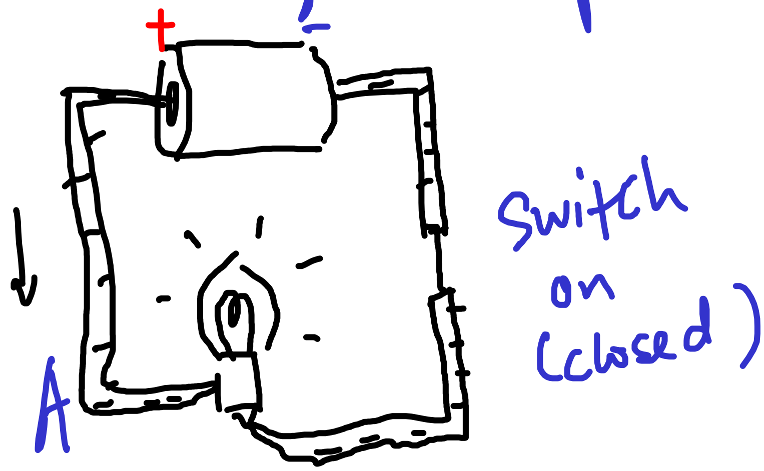
e.g. 0.5C of charge flows past A in 2s



The rate of flow is 0.5C ÷ 2s

= 0.25 A.

Current = rate of flow of electric charge past a point in a circuit.

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

Q - - charge

t - - time

→ charge = current × time

$$\boxed{Q = It}$$

e.g. a circuit has a current of 0.2A.

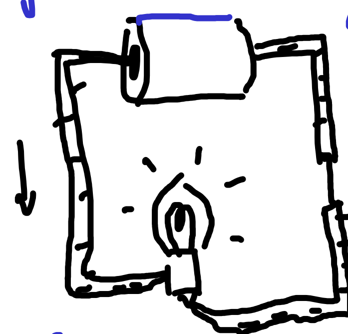
How much charge flows past the cell in 3s?

define electromotive force (e.m.f.) as the work done by a source in driving a unit charge around a complete circuit

Electromotive Force

Dr K M Hock

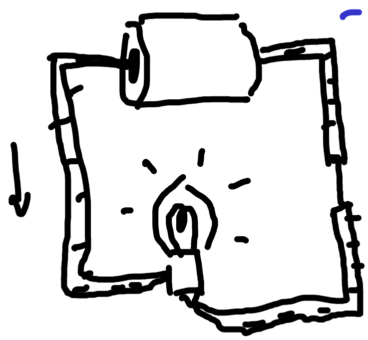
The cell must do work to push charge around circuit



because wire has resistance.

e.g. suppose the cell does 3 J of work to push 2 C of charge round circuit once.

Then $3J \div 2C = 3J/C$ is work done per unit charge
$= 3V$



Electromotive Force (e.m.f.) = work done by a source in driving unit charge round complete circuit.

$$\text{emf} \quad \boxed{E = \frac{W}{Q}} \quad \begin{matrix} \text{work} \\ \text{charge} \end{matrix}$$

(unit = Volt (V))

e.m.f. in series

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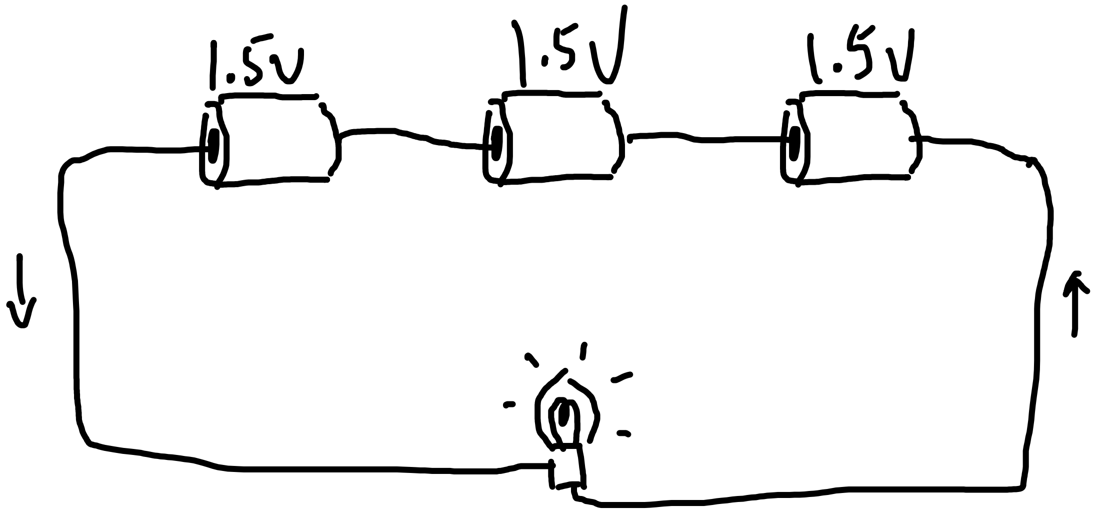
e.g. how much work is done by all the cells when they drive 1C of charge around complete circuit.



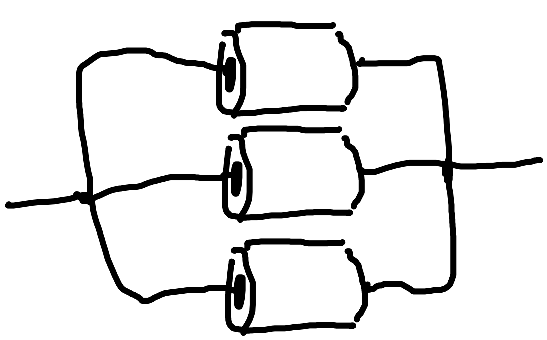
Each cell does 1.5 J of work on 1C.

All cells do 1.5 J + 1.5 J + 1.5 J = 4.5 J

∴ total e.m.f. = 1.5V + 1.5V + 1.5V = 4.5V

Note: can just add only when all cells are in series (in a row).

e.g



If in parallel, do not add.

Potential Difference

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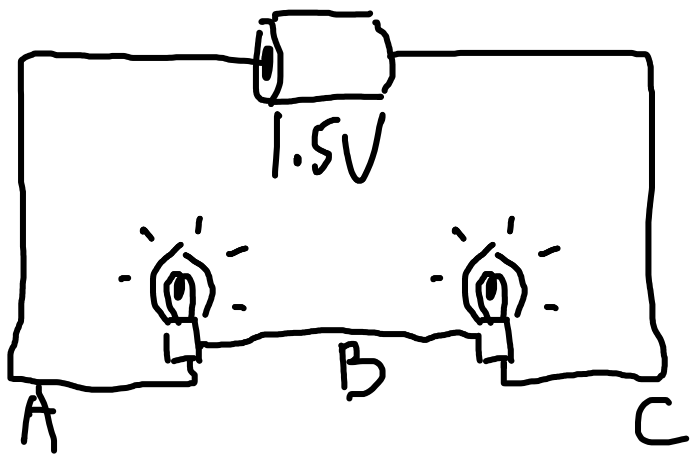
e.g. It takes 0.75 J of work to bring 1C of charge thru' each bulb.



If wire resistance so small we can neglect, then 1C of charge moving from A to B needs 0.75 J of work.

This work is called potential difference (p.d.) between A and B. → 0.75 J/C = 0.75 V.

p.d. across a component --- e.g. light bulb.

= work done to drive unit charge thru' the component

define the p.d. across a component in a circuit as the work done to drive a unit charge through the component
state Ohm's Law

Resistance

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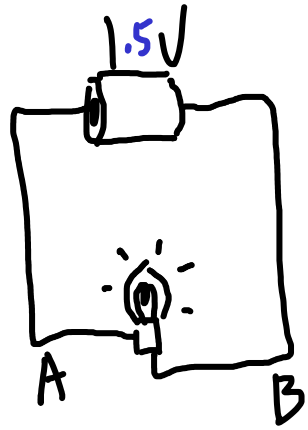
e.g. when there is a p.d. between two points like A, B, and a conductor joining them, a current flows.



But the conductor, like wire, light bulb, can give some resistance, like friction.

Ohm's discovered this relation:

$$\boxed{\text{resistance} = \frac{\text{p.d.}}{\text{current}}}$$ Ohm's law

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

e.g. more resistance means less current (for the same p.d.).

state the definition that resistance = p.d. / current
apply the relationship R = V/I to new situations or to solve related problems

Ohm's law

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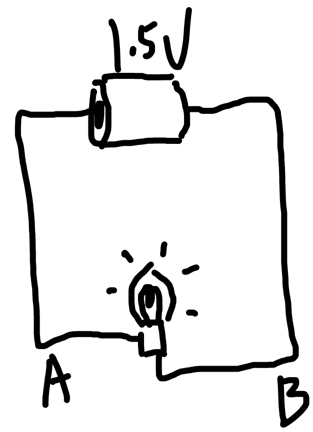
e.g. when a battery of e.m.f. 1.5V is connected to a light bulb, a current of 0.1 A flows. What is the resistance of the bulb?



Answer.

$$R = V/I = \frac{1.5\,V}{0.1\,A} = 15\,\Omega$$

Ohm (unit)

Note: Here, we assumed that there is no resistance in wire or cell

As no work is done to move charges thru' cell or wire, the e.m.f. is same as p.d. across AB.

describe an experiment to determine the resistance of a metallic conductor using a voltmeter and an ammeter, and make the necessary calculations

Measuring Resistance

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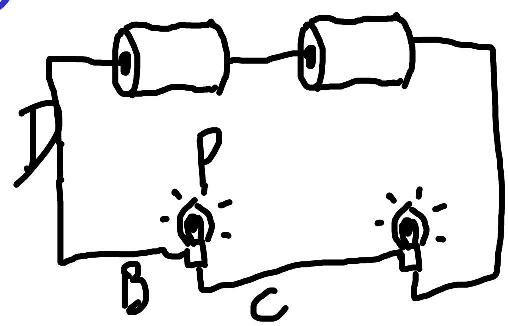
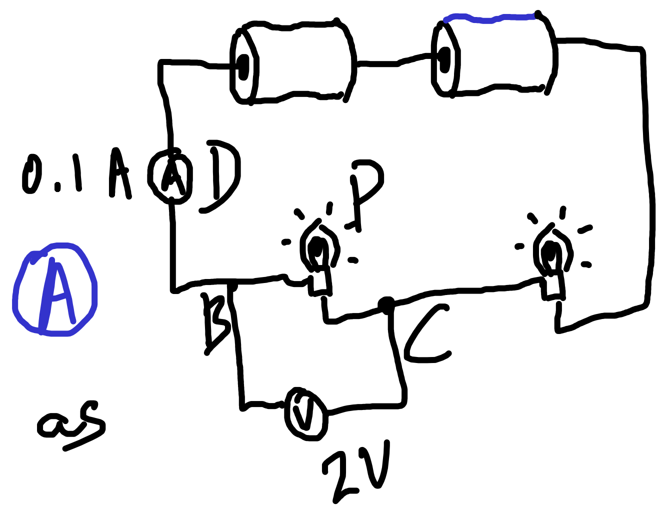
e.g. a setup to measure resistance of lamp P. Need to know p.d. across BC and current thru' lamp.



Use Ⓥ Voltmeter to measure p.d.
symbols Ⓐ ammeter to measure current

Connect this way:



1. Must cut wire and connect to 2 sockets on Ⓐ
2. Current at D same as current at lamp P.
3. Ⓐ very low resistance - hardly disturbs original current.
4. Ⓥ connected to B, C to measure the p.d.
5. Ⓥ very high resistance - little current diverted from circuit.

recall and apply the formulae for the effective resistance of a number of resistors in series and in parallel to new situations or to solve related problems

Resistors in Series

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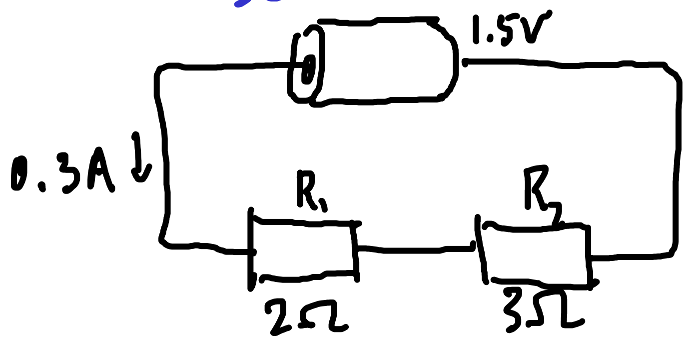
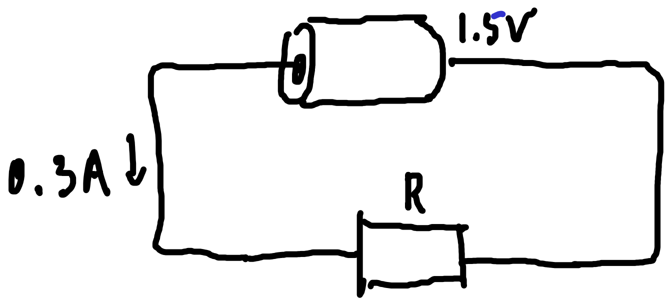
e.g. Connect 2 pieces of conductors R_1, R_2 that have some resistance to a cell.



Call them resistors. I then want replace them by 1 single resistor that gives the same current.

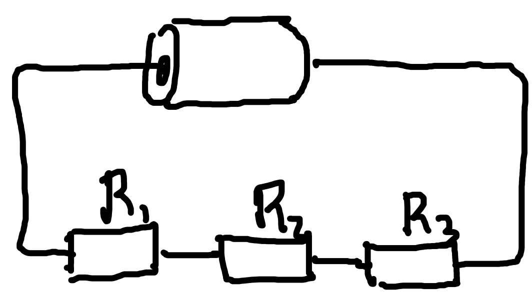


What is the effective resistance R?

Formula $\boxed{R = R_1 + R_2}$

$= 2 + 3 = 5\Omega$

What about 3 resistors:



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

recall and apply the formulae for the effective resistance of a number of resistors in series and in parallel to new situations or to solve related problems

Resistors in Parallel

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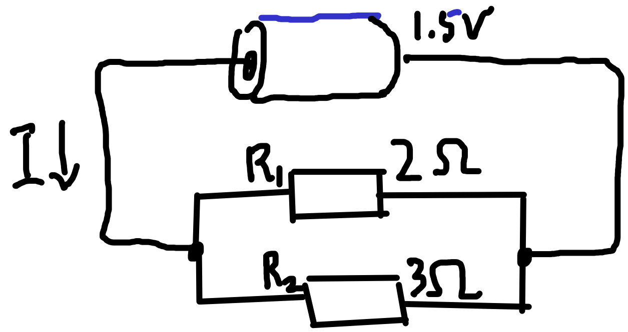
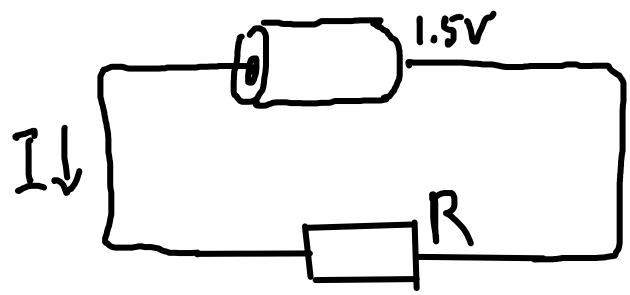
e.g. Connect 2 resistors to a cell like this:



If I replace by a single resistor R, what resistance would give the same current I as before?



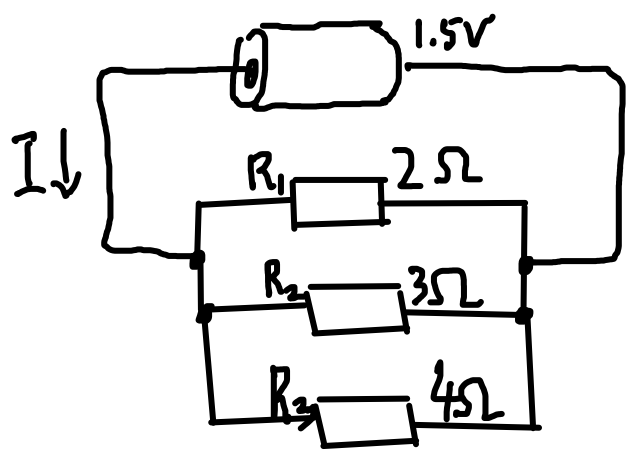
Formula: $\boxed{\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}}$ → $\frac{1}{R} = \frac{1}{2} + \frac{1}{3} = \frac{5}{6}$

$R = \frac{6}{5}\ \Omega$

smaller than R_1, R_2!

What about 3 resistors?

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

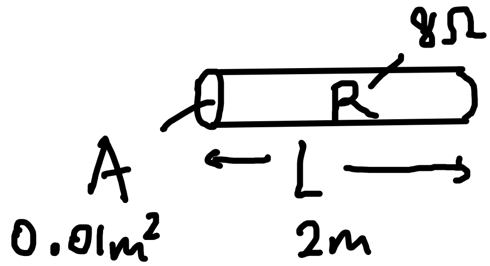


recall and apply the relationship of the proportionality between resistance and the length and cross-sectional area of a wire to new situations or to solve related problems

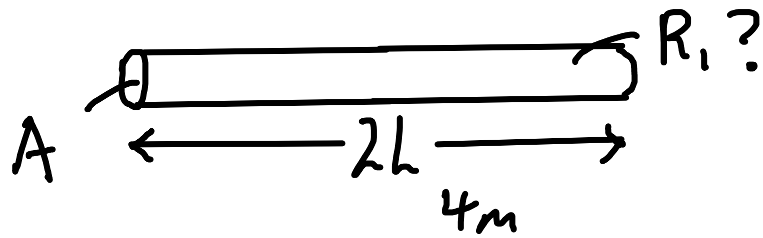
Resistivity

Dr K M Hock

e.g. a long piece of conductor with uniform cross-section has a resistance of $R = 8\Omega$.



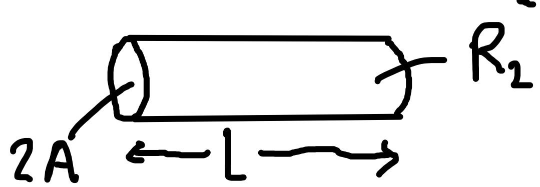
e.g. another piece of the same material is 2 times the length. What is the new resistance R_1?



Formula: $\boxed{\text{resistance} \propto \text{length}}$

$R_1 = 2 \times 8$
$= 16\,\Omega$

e.g. another piece of the same material is 2 times the cross-sectional area.
What is the new resistance R_2?



Formula: $\boxed{\text{resistance} \propto \dfrac{1}{\text{area}}}$

$R_2 = \dfrac{8}{2}$
$= 4\,\Omega$

Combined: $\boxed{R = \rho \dfrac{L}{A}}$

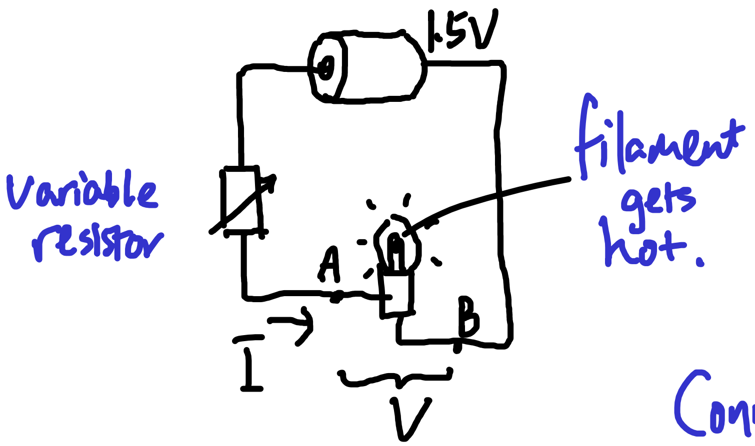
constant of proportion (resistivity)

describe the effect of temperature increase on the resistance of a metallic conductor

Effect of Temperature

Dr K M Hock

e.g. Connect cell to filament lamp. Insert a device whose resistance can be adjusted (maybe by turning a knob).



Let V = p.d. across AB (lamp)

Let I = current.

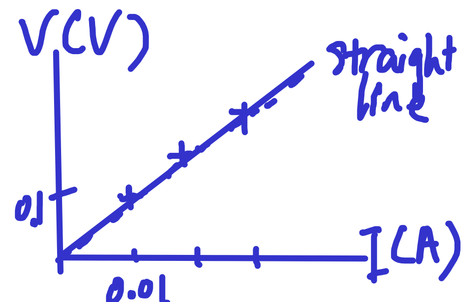
Connect (V), (A) to measure them

e.g. lamp resistance $R = 10\,\Omega$

Since Ohm's law is $V = IR$, can also calculate V if we measured I only. e.g.

I (A)	0.01	0.02	0.03
V (V)	0.1	0.2	0.3

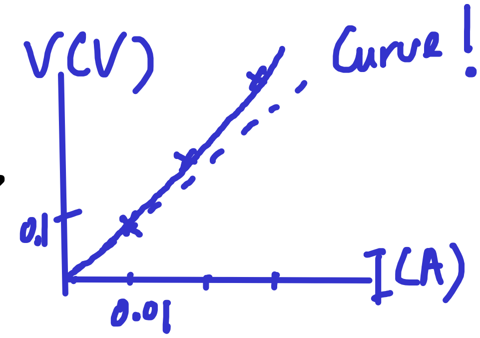
Plot →



But if I actually measure with (V), (I), V gets smaller that calculation, e.g.:

I (A)	0.01	0.02	0.03
V (V)	0.1	0.21	0.33

Plot →



(Check $R = \frac{V}{I}$:)

R (Ω)	10	10.5	11

<u>Resistance increases!</u>

Can happen when metal (like lamp filament) <u>gets hot</u>.

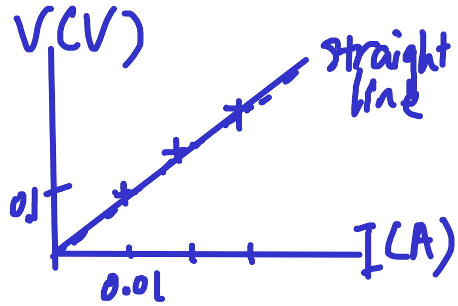
sketch and interpret the I/V characteristic graphs for a metallic conductor at constant temperature, for a filament lamp and for a semiconductor diode

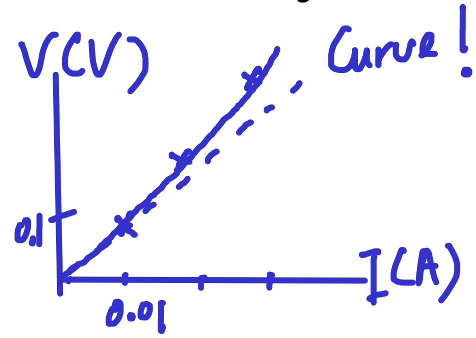
I/V Characteristic Graphs

Dr K M Hock

Recall the previous graphs:

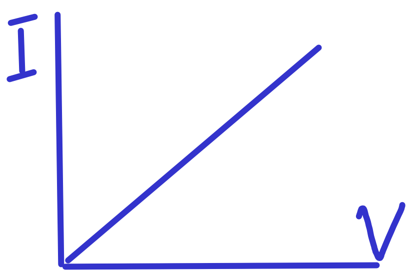
(If temperature same) (when it gets hotter)



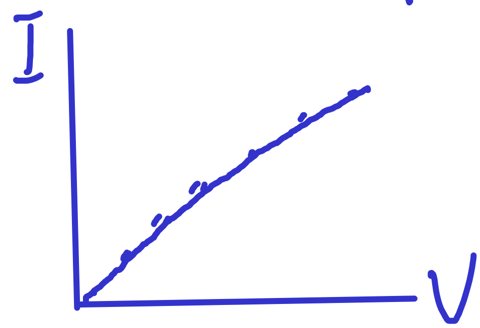


Flip them like this:

metallic conductor at constant temperature



filament lamp



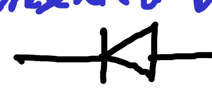
Many conductors give these shapes when their I, V are measured, plotted.

I/V characteristic

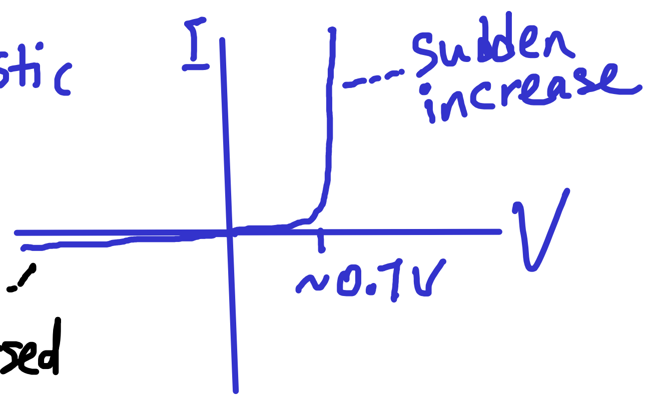
A special device called diode:

(may look like this)

(represented by this symbol)



has a strange I/V characteristic



negative V, I means.... cell, current direction reversed show an understanding of the use of a diode as a rectifier

Diode as a Rectifier

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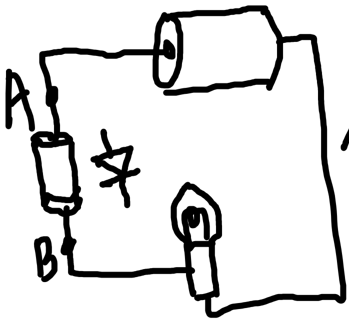
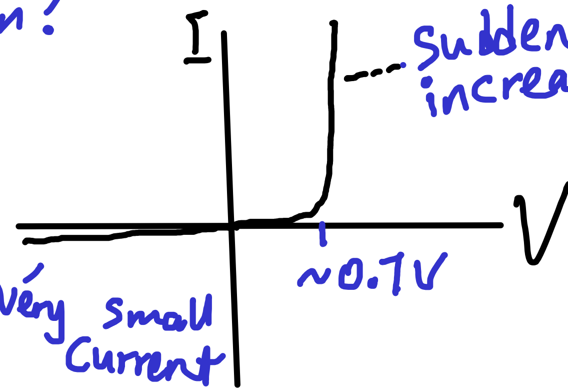
What does this graph mean?



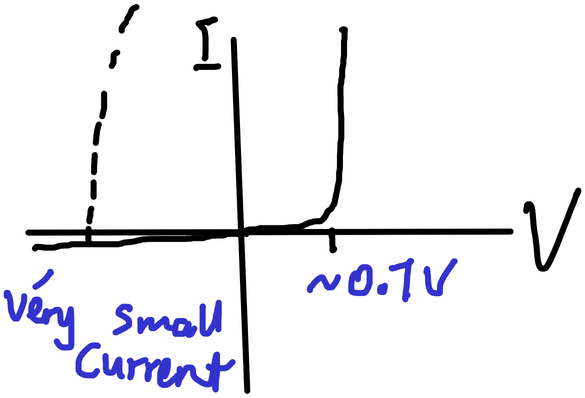
positive direction on graph



sudden increase

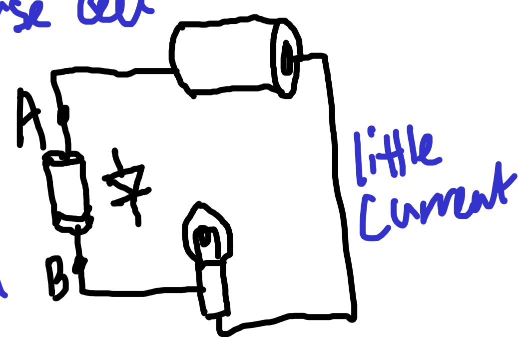
As long as p.d. across diode (AB) > 0.7V, diode will be like wire with v. small resistance
→ sudden increase in IV characteristic

If cell reversed, there is very little current,



as if circuit is open (switched off).

reverse cell



positive direction on graph

Can use diode as

A rectifier allows current to flow in one direction only.