C9
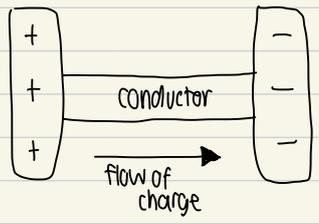
Electric current = the flow of charge carriers
   ↳ measure in amperes or amps (A)
→ charge can be either positive or negative
→ in electrical wires, the current is the flow of electrons, e^-

conductor
flow of charge

☆ e^- flow from $\ominus \rightarrow \oplus$

conventional current = flow of positive charge from positive terminal of a cell to the negative terminal
    ↳ However, this was described before electric current was really understood

e^- flow
conventional current
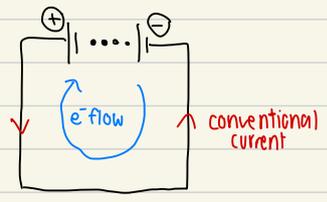
Quantisation of Charge:
• the charge on charge carriers is quantised
• charge can be $\oplus$ or $\ominus$
    ↳ single proton = single positive charge
    ↳ single electron = single negative charge
• $1e^- = -1.60 \times 10^{-19} C$
• $1p^+ = +1.60 \times 10^{-19} C$

Another definition of current = charge passing through a circuit per unit time

charge (C)
$Q = It$
time (s)
current (A)

Calculation Current in a Current Carrying Conductor:
• in a conductor, current is due to the movement of charge carriers
• these charge carriers can be $\oplus$ or $\ominus$, however the current is always taken to be in the same direction.
→ in conductor, the charge carrier is usually free e^-

POSITIVE CHARGE CARRIERS

NEGATIVE CHARGE CARRIERS
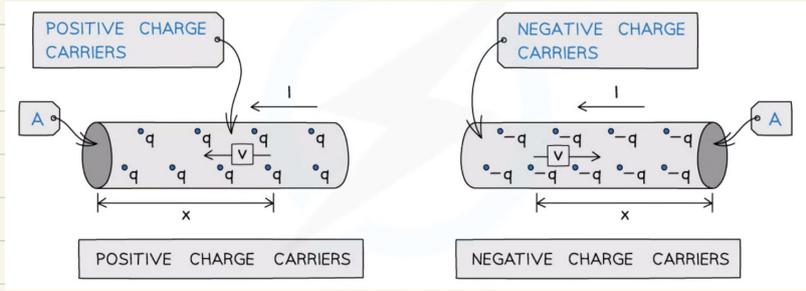
• the drift speed = the average speed the charge carriers are travelling through the conductor (this value is quite slow)
• Since the number density of charge carriers is so large, we still see the current flow happen instantaneously

cross-sectional area (m^2)
average drift speed of charge carriers (ms^{-1})
$$I = Anvq$$
charge of each charge carriers (C)
current (A)
number density of charge carriers (m^{-3})

Potential Differences:
potential difference = energy transferred per unit charge flowing from one point to another
→ energy transfer is from electrical energy into other forms
→ measured in volts (V) which is the same as JC^{-1}
• potential difference or voltage is measured using a voltmeter

work done (J)
$$V = \frac{W}{Q}$$
potential difference (V)
charge (C)

Electrical Power:

$$\underset{(w)}{\overset{\text{power}}{\curvearrowright}} P = I \underset{\text{current (A)}}{V} \overset{\overset{\text{potential differences /voltage}}{(V)}}{\curvearrowleft}$$

→ using $\underline{V = IR}$: $P = I^2 R$, $P = \dfrac{V^2}{R}$ ⭐

Resistance:

measured
in ohms
(Ω)

resistance = opposite to current = the ratio of the potential difference across to the current in it → $R = \dfrac{V}{I}$

From $V = IR$, the higher the resistance, the lower the current

• copper = good conductor because copper has a low electrical resistance

Ohm's Law:

Ohm's Law states that for a conductor at a constant temperature, the current through it is proportional to the potential differences across it

→ constant temperature implies constant resistance

  ↳ • so resistor obeys Ohm's law

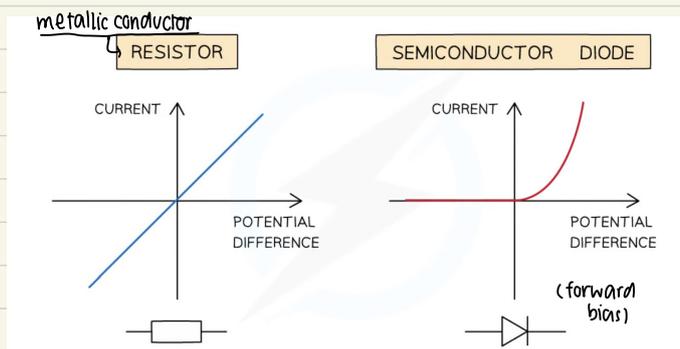   • a filament lamp does not obey
      Ohm's law

$$V = I \underset{\text{potential differences}}{\underset{(V)}{R}} \overset{\overset{\text{current (A)}}{}}{\underset{\text{resistance } (\Omega)}{}}$$

∴ as long as temp. is constant, Ohm's Law is obey

metallic conductor
↳ RESISTOR

SEMICONDUCTOR   DIODE

### metallic conductor (such as resistor):

  − obeys Ohm's law $(I \propto V)$

    ↳ this is shown by straight line graph through the origin
   (linear)

Semiconductor diode:

• diode only allow current to flow in single direction

• when current is in the direction of the arrowhead symbol, this is forward bias.

• when diode is switched around, it does not conduct and is called reverse bias.

• non-linear graph

(forward bias)

(reverse bias)
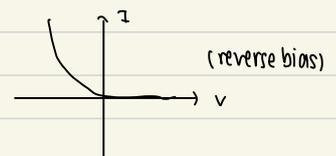
filament lamp:

• as the current increases, the temperature of the filament increases

• since the filament is a metal, the higher the temperature causes an increase in resistance

• resistance oppose the current, causing the current to increase at a slower rate

→ linear = resistance constant

→ non-linear (curve) = resistance increases

FILAMENT LAMP
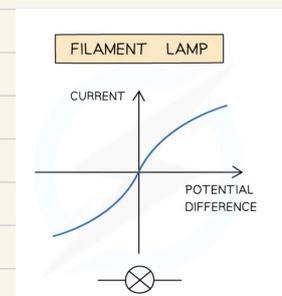
Resistance and temperature

• all solids are made up of vibrating atoms

→ the higher the temperature, the faster these atoms vibrate

• electric current is the flow of e^- in a material

→ the e^- collide with the vibrating atoms which impedes their flow, hence the current decreases

  ↳ if current ↓, then resistance ↑

∴ temperature ↑, resistance ↑

Resistivity

- As free e^- move through a metal wire, they collide with <u>ions</u> which get in their way
  → as a result, they transfer some, or all of their E_k on collision, which causes electrical heating
- since current = flow of charge → the ions resisting their flow = resistance

From the equation:

- the longer the wire, the greater its resistance
- the thicker the wire, the smaller its resistance
- the higher the resistivity of a material, the higher its resistance
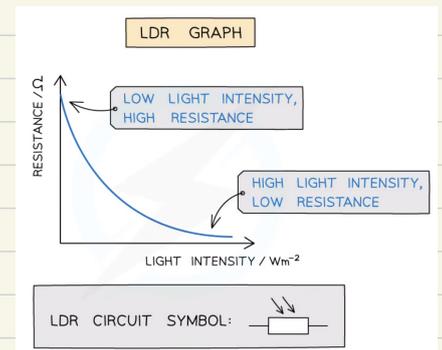
$$R = \frac{\rho L}{A}$$

resistivity (Ωm)
length (m)
cross-sectional area (cm^2)
resistance (Ω)

Light-dependent resistor (LDR):

- LDR is non-ohmic conductor + sensory resistor
- its resistance automatically changes depending on the light energy falling onto it (illumination)
- as light intensity increases, the resistance of LDR decreases

LDR GRAPH

RESISTANCE / Ω

LOW LIGHT INTENSITY, HIGH RESISTANCE

HIGH LIGHT INTENSITY, LOW RESISTANCE

LIGHT INTENSITY / Wm^{-2}

LDR CIRCUIT SYMBOL:

Thermistor:

- Thermistor is non-ohmic conductor + sensory resistor
- its resistance changes depending on its temperature
- as the temperature increases, the resistance of a thermistor decreases

THERMISTOR GRAPH

RESISTANCE / Ω

LOW TEMPERATURE, HIGH RESISTANCE

HIGH TEMPERATURE, LOW RESISTANCE

TEMPERATURE (°C)

THERMISTOR CIRCUIT SYMBOL: