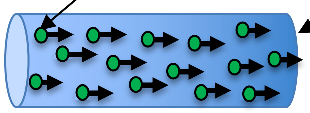
5.1.4 Drift velocity

Current is a measure of the charge that flows past a point per unit time.

videos

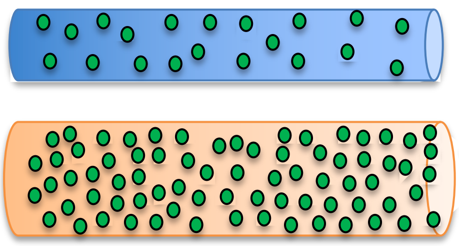
Consider a length of cylindrical conducting material.



Normally, charge carries (such as delocalized electrons in metals) will be moving around randomly throughout the material. However, when a potential difference is applied across the ends of a length of the material, they will feel a force. They accelerate in the direction of this force, but are slowed when they collide with other particles (e.g. metal ions). The mean drift velocity (v) of the charge carriers is a measure of the average distance they travel per unit time in the direction of the force. As there is a net transfer of charge, a current is produced.

(1)✐Other than the applied potential difference, what factors would influence the size of the current?

Consider the following:



We have two wires with different diameters and made out of different materials. The thicker wire has a greater number of charge carriers per unit volume (n).

(2)✐If the charge carriers, in the diagram above, have the same mean drift velocity, in which wire would you observe a bigger current, and why?

In metals, the charge carriers are delocalised electrons. Electrons have a charge $e = -1.6 \times 10^{-19}C$.

In some materials (e.g. ions in solution), the charge carriers may have a different charge (e.g. a copper ion Cu^{2+} has a charge of $= +3.2 \times 10^{-19}C$). The charge that flows will be proportional to the density of charge carriers (n) and the charge (q) that they carry.

The rate of flow of charge (current) depends on the density of charge carriers n (number of charge carriers per unit volume), the charge on each charge carrier q, the cross-sectional area A, and the mean drift velocity of the charges v.

$$I = nqvA$$

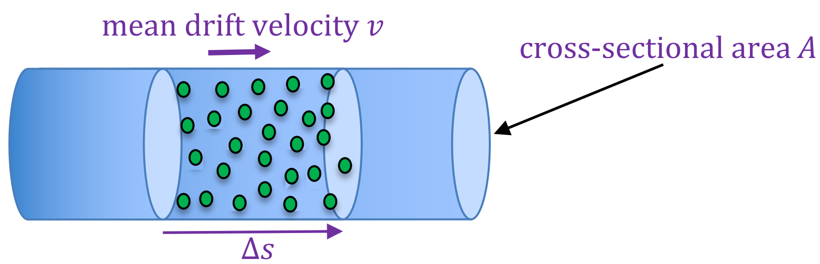
If the charge carrier is an electron, then the equation can be written:

$$I = nevA$$

where e = charge on an electron = $-1.6 \times 10^{-19}C$

(3)✐A current of 2A flows through a copper wire with a diameter of 0.274mm. What is the mean drift velocity of the electrons? For copper, the charge carrier density $n = 8.5 \times 10^{28}m^{-3}$*.*

Deriving the formula



Consider a section of wire, above. The green dots represent electrons. They are drifting to the right as a result of a potential difference applied to the ends of the wire. Their mean displacement in one second is given by:

$$\Delta s = v \times 1 = v$$

The number of charge carriers that pass a certain point in one second is given by:

$$N = volume\ \times\ charge\ carrier\ density$$
$$N = (\Delta s \times A) \times n$$

The amount of charge that flows past a certain point in one second (the current) is given by:

$$I = Ne = \Delta s \times A \times n \times e = vAne$$

or:

$$I = nevA$$

(4)✐Charge carriers in a semiconductor have a charge carrier density = $3.5 \times 10^{24}m^{-3}$*. The charge carriers have a charge of* $1.6 \times 10^{-19}C$*. What is the mean drift velocity, if the cross-sectional area =* $1.00 \times 10^{-6}m^2$*, and a current of 1A is flowing?*