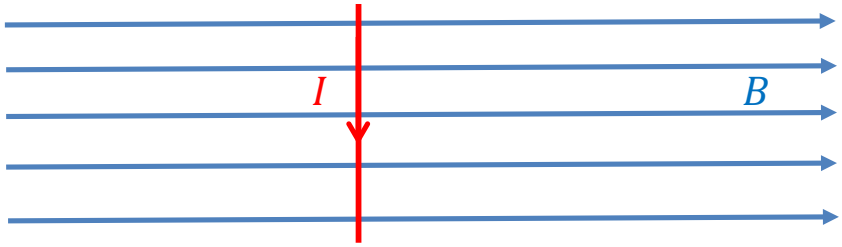
7.12 Moving charges in a magnetic field

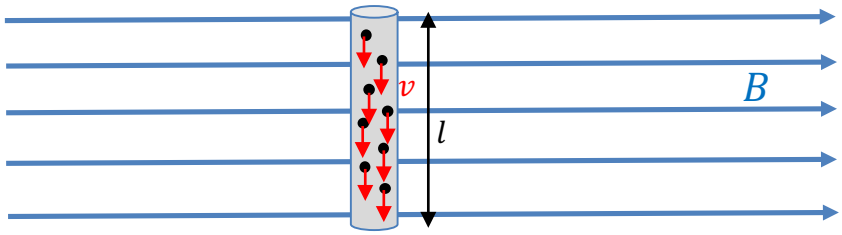
In section 7.10 we saw that a current-carrying wire in a magnetic field experiences a force. We can use Flemming's Left Hand Rule to determine the direction this force acts. In the diagram below, point your first finger to the right, and your second finger downwards. You should find that your thumb points upwards. This is the direction that the force acts.



Current is the flow of positive charge. The force is actually acting on the charge carriers in the wire.

(1) What are the charge carriers in the wire? What charge do they have?

Consider a length l of wire at right angles to a uniform magnetic field with magnetic flux density B.



Current is the rate of flow of charge:

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

(2) If there are n electrons with charge e in a length l of wire, and they flow with a velocity v, show that current I is given by the following expression:

$$I = \frac{nev}{l}$$

We have seen from section 7.10, that the force on a current-carrying wire is given by the expression:

$$F = BIl\sin\theta$$

(3) Substitute $I = \frac{nev}{l}$ in this equation, above, and simplify.

(4) Write an expression for the force on one electron.

(5) In the diagram below an electron enters a uniform magnetic field with a velocity v. The magnetic field is orientated into the page. What direction is the force on the electron? Sketch the path the electron will take.

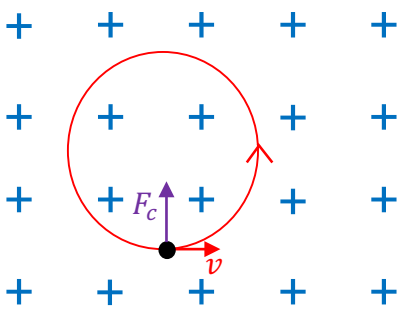
(6) The magnetic flux density is 500mT and the electron velocity is $3x10^4 ms^{-1}$. What is the force on the electron?

In general, the expression for the force on a charge Q moving with a velocity v magnetic field is given by:

$$F = BQv \sin\theta$$

(7) What is the force when the charge is stationary?

If a charge enters a uniform magnetic field at right angles to the field it follows a circular path. The force on the charge provides the centripetal force.



The centripetal force F_c is given by the expression:

$$F_c = \frac{mv^2}{r}$$

where m=mass, v=velocity, r=radius.

(8) Given that the force on a charge Q moving with velocity v, at right angles to a uniform magnetic field is F=BQv, equate this to the centripetal force and simplify to find an expression for r.

(9) A proton moving with velocity $v=3x10^6 ms^{-1}$, enters a magnetic field of 1.5T, at right angles to the field direction. What is the radius of path it follows?

(10) How long does it take the proton to complete one revolution? (the period)

(11) Given that the proton continues circling, with no loss of speed, what is the frequency of revolution?

(12) Write an expression for the frequency of revolution of a charge Q, moving with velocity v in a uniform magnetic field B.