Let n be the density of positive charges within the wire (number of charges per unit volume). The number of charges within a length L of cross-sectional area A is $N = nAL$ and so the force on this length of wire is:

$$F = (nAL)qE$$

But $qE = qvB$, so:

$$F = (nAL)qvB$$

$$F = (nAqv)BL$$

Using $nAqv = I$, we get:

$$F = BIL$$

as expected! (Recall that here $\sin\theta = 1$.)

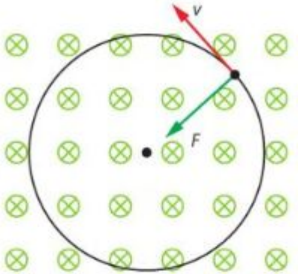
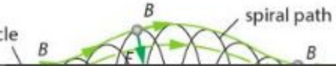


Figure 5.62 A charge in a magnetic field moves in a circle.

Motion of charges in magnetic fields

When the velocity of a charge is at right angles to the magnetic field, the path followed by the charge is a circle, as shown in Figure **5.62**. The centripetal force is provided by the magnetic force, which is at right angles to the velocity.

(Special cases involve motion along a straight line if the velocity is parallel to the field, or helical if the velocity is at some angle to the field, Figure **5.63** – see exam-style question **15** at the end of the topic.)



Consider a charge q moving with speed v at right angles to a magnetic

A closer look at the magnetic force on a current-carrying wire

Consider a wire carrying a current in a region of magnetic field. Figure **5.61** shows one electron (green dot) that moves with speed v inside the wire. The electron experiences a magnetic force that pushes it downwards. The magnetic force on the moving charges makes electrons accumulate at the bottom of the wire, leaving an excess positive charge at the top of the wire.

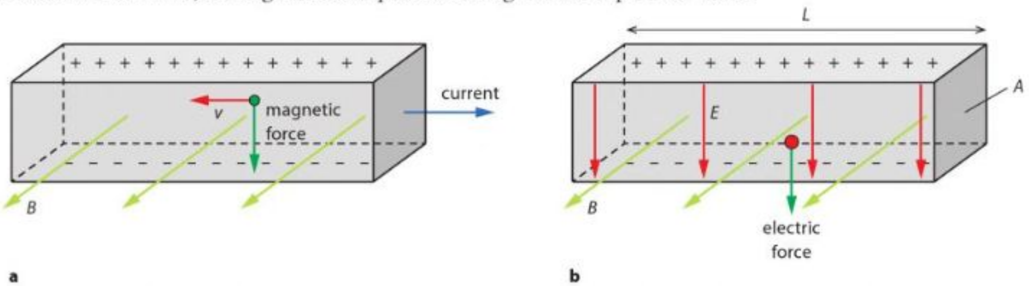
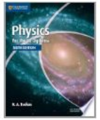


Figure 5.61 **a** Electrons in the wire experience a magnetic force. **b** The electric force on the fixed positive charges means there is a force on the wire itself.

The positive and negative charges at the top and bottom of the wire exert an electric force on the electrons so that no new electrons move towards the bottom of the wire: the magnetic force on the electrons is balanced by an electric force, $qE = qvB$.

So, since the magnetic force on the electrons is balanced by an electric force neither of these forces is responsible for the force on the entire wire. The electric field E between the top and bottom sides of the wire exerts an **electric** force on the fixed positive charges inside the wire (the protons in the nuclei). It is this force that acts on the wire.



Let n be the density of positive charges within the wire (number of charges per unit volume). The number of charges within a length L of cross-sectional area A is $N = nAL$ and so the force on this length of wire is:

$$F = (nAL)qE$$

But $qE = qvB$, so:

$$F = (nAL)qvB$$

$$F = (nAqv)BL$$

Using $nAqv = I$, we get:

$$F = BIL$$

as expected! (Recall that here $\sin\theta = 1$.)

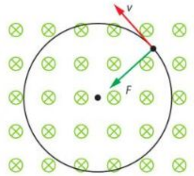


Figure 5.62 A charge in a magnetic field moves in a circle.

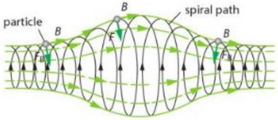


Figure 5.63 A charge enters a region of magnetic field at an angle. It follows a helical path wrapping around the field lines.

Motion of charges in magnetic fields

When the velocity of a charge is at right angles to the magnetic field, the path followed by the charge is a circle, as shown in Figure **5.62**. The centripetal force is provided by the magnetic force, which is at right angles to the velocity.

(Special cases involve motion along a straight line if the velocity is parallel to the field, or helical if the velocity is at some angle to the field, Figure **5.63** – see exam-style question **15** at the end of the topic.)

Consider a charge q moving with speed v at right angles to a magnetic field B. The force on the charge is $F = qvB$ at right angles to the velocity. The charge moves in a circle of radius R, and so by Newton's second law:

$$qvB = m\frac{v^2}{R}$$

Rearranging, we get:

$$R = \frac{mv}{qB}$$