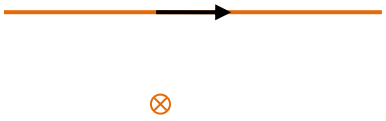
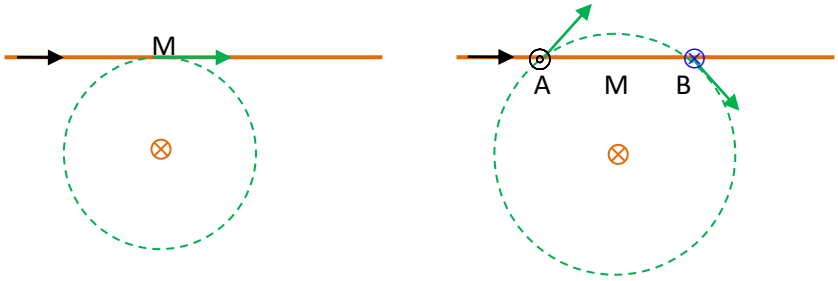
Teacher notes
Topic D

Magnetic force between perpendicular wires

Consider the setup in the figure below. A wire carries a current into the page. A second wire carries the same current along the page to the right.



What force is exerted on the wires?



The left diagram shows the magnetic field produced by the lower wire at M, the mid-point of the top wire. The magnetic field (green arrow) is parallel to the current and so at the part of the wire near M there is no magnetic force. The diagram on the right shows the magnetic field (green arrows) at points A and B of the top wire due to the lower wire. This means that at A the force is out of the page and at B into the page. Thus there is a net force into the page on the wire to the right of M and an equal but opposite force to the left of M. The overall net force on the wire is therefore zero. By Newton's third law the net force on the lower wire is also zero.

However, there is a torque on each wire. Assuming for simplicity that the lower wire is fixed, the top wire will rotate counterclockwise about M as viewed from the top. At an instant of time the two wires will be parallel and there will be a force of attraction between them. But this force acts for an interval of time that is zero, so it has no effect. After a quarter of a revolution the forces on the top wire are reversed so the wire now rotates clockwise. This means that the two wires will eventually settle parallel to each other if some small frictional force opposes the motion.

Last point: the rotation of the wires requires energy. Where does the energy come from?