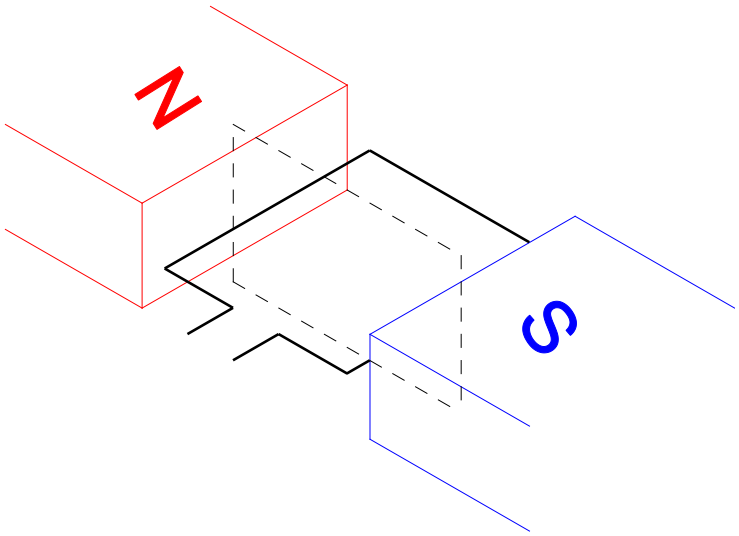
# Question

1.




a) A diagram of a DC motor is shown above. It consists of a permanent magnet and a coil of wire. The cross section marked on the diagram above is shown below. In which direction will the motor turn initially?

b) After 90° of rotation in the direction found in part a), why will the coil's rotation begin to slow down? What can be done to prevent this?

c) Draw the graph of the magnitude of the moment (i.e. the component of the force perpendicular to the point of turn) against the angle of rotation. Assume that, at the current position (as shown in both diagrams above), the angle is 0°.

d) In AC motors, the permanent magnets are replaced by electromagnets and the direction of the magnetic field is constantly switching. How do engineers ensure that the force on the coil, which also runs AC, is always in the correct direction?

# Hints

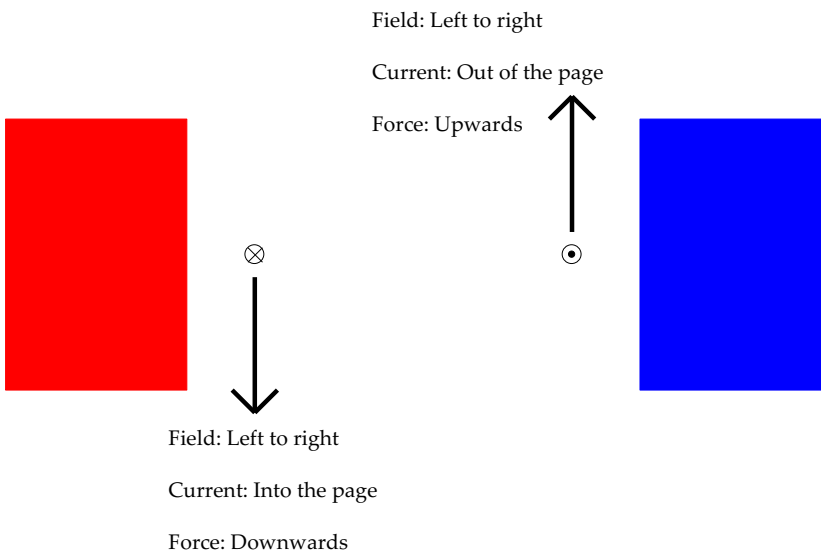
Question 1

a) Use the 'left-hand rule'.
b) Consider how the direction of the force acting on the coil changes as the motor rotates, and the direction the force should act in, in order to maintain rotation in the intended direction (found in part a)).
c) Is the force always perpendicular to the pivot?
d) Think about the phase of the AC in the electromagnet and the coil (i.e. in both the electromagnet and the coil, in which direction should the current be travelling at any given point in time to allow continuous rotation?).

# Suggested answers

## Question 1

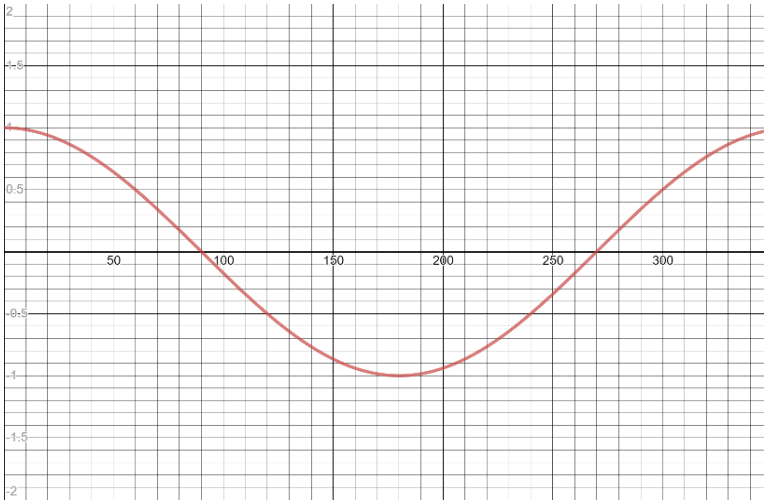
a) Using the left-hand rule, the forces will act as shown below. Therefore, the coil will turn anti-clockwise.




b) Since the force on the coil is always perpendicular to the field and the direction of the current, it always points upwards or downwards, as the current will always act out of, or into, the page.

- Consider the left-hand wire, the current of which is going into the page, in the diagram above, after 90° of rotation:
- The moment applied by the force shifts from an anti-clockwise moment to a clockwise one.
    - This causes a moment on the coil in the opposite (clockwise) direction, which would slow the motor down sufficiently to prevent it from completely rotating.
    - As a result, the direction of current needs to be switched after 90° to keep the moment in the correct direction.

c)




- The maximum torque applied occurs when the coil is horizontal; the force applied is exactly perpendicular to the coil.
    - This occurs at 0°, 180° and 360° - the graph resembles that of *cos(x)*.

d) The same phase AC is used within the electromagnet and coil, such that the force always applies the correct moment. As a result, the current and the magnetic field are always in the direction which results in a net force being applied; this produces a net moment in the intended direction.