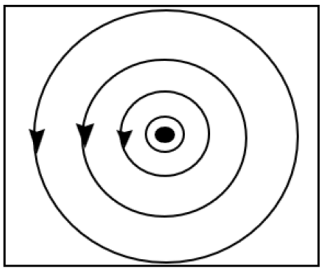
1

(a) **(i)**



(ii) 1. Current in each wire creates a magnetic field at the other wire
Current in wire perpendicular to magnetic field causes a force

(ii) 2. By Newton's third law, the pair of forces are equal in magnitude.

(b) **(i)** The force acting per unit current per unit length on a conductor placed perpendicular to the magnetic field.

(ii) Into the page

(iii) Magnetic force is always normal to direction of motion of electrons by Flemming's Left Hand Rule. Since magnetic force is the only force acting on the electrons as gravitational force is negligible, it provides for the centripetal force.

(iv) Magnetic force provides for the centripetal force

$$F_B = F_C$$
$$Bqv = \frac{mv^2}{r}$$
$$r = \frac{mv}{Bq}$$
$$= \frac{(9.11 \times 10^{-31})(1.70 \times 10^7)}{4.80 \times 10^{-3} \times 1.60 \times 10^{-19}} = 0.02017\ m$$
$$d = 2r = 4.03\ cm$$

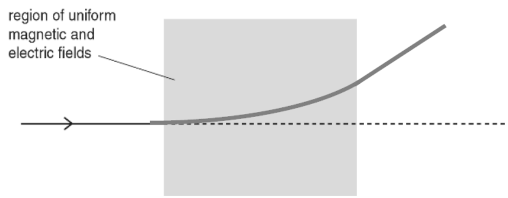
(v)

$$t = \frac{distance}{speed}$$
$$= \frac{\pi d}{2v} = \frac{\pi(0.0403)}{2 \times 1.70 \times 10^7} = 3.723 \times 10^{-9}\ s$$

(vi) (Due to electric field directed into the page, electron experiences electric force out of the page.) In the direction out of the page:

$$F_{out} = ma_{out} = qE$$
$$a_{out} = \frac{qE}{m}$$
$$v_{out} = a_{out}t = \frac{qEt}{m}$$
$$= \frac{1.60 \times 10^{-19} \times 1800 \times 3.723 \times 10^{-9}}{9.11 \times 10^{-31}} = 1.177 \times 10^7\ m\ s^{-1}$$
$$v^2 = v_x^2 + v_{out}^2 = (1.70 \times 10^7)^2 + (1.177 \times 10^7)^2$$
$$v = 2.068 \approx 2.07 m\ s^{-1}$$

(c)



2

(a) uniform electric and magnetic fields normal to each other AND
charged particle enters region normal to both fields
correct B direction w.r.t. E for zero deflection
For no deflection, $v = E/B$

(b) $r = mv \,/\, Bq$, so B proportional to m
$B = (0.680) \times (87/86) = 0.6879\,T$
$\Delta B = 7.9 \times 10^{-3}\,T$

3

(a) **(i)** Vertically downwards

(ii) magnetic force on sphere is always perpendicular to its velocity. Hence, no work done by force and no change in kinetic energy and speed.

(b) $mg = qE$

$$E = \frac{mg}{q} = \frac{(1.6 \times 10^{-12})(9.81)}{0.27 \times 10^{-9}} = 5.8\,N\,C^{-1}$$

(c) Magnetic force provides centripetal force

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

$$B = \frac{1.6 \times 10^{-10} \times 0.78}{0.27 \times 10^{-9} \times 3.4} = 0.14\,T$$

4

(a) **(i)** The component of velocity perpendicular to the magnetic field results in a magnetic force on the electron, which is always perpendicular to the motion. Hence, the electron rotates in a circular path.
The component of velocity parallel to the magnetic field remains constant. Hence, the electron travels at constant velocity along the direction of magnetic field. The combination of both components of velocity of the electron results in a helical path.

(ii) $F_B = Bqv \sin 20°$

$$v = \frac{4.3 \times 10^{-14}}{0.088(1.6 \times 10^{-19}) \sin 20°}$$

$v = 8.93 \times 10^{6}\,m\,s^{-1}$

(ii) Magnetic force provides centripetal force to the electron’s component of velocity perpendicular to the magnetic field.

$F_B = F_c$
$Bqv = mv\omega$

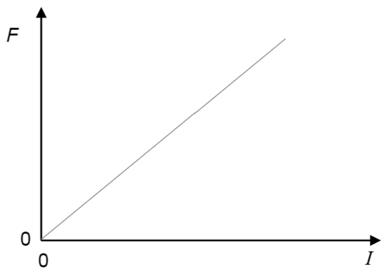
$$T = \frac{2\pi m}{Bq}$$
$$p = v\cos 20° \left(\frac{2\pi m}{Bq}\right)$$
$$= \frac{8.93 \times 10^{6} \cos 20° \,(2\pi)(9.11 \times 10^{-31})}{0.088(1.60 \times 10^{-19})}$$
$$= 3.4 \times 10^{-3}\ m$$

(b) The pair of forces generate a torque. The maximum output torque is $F \times d$

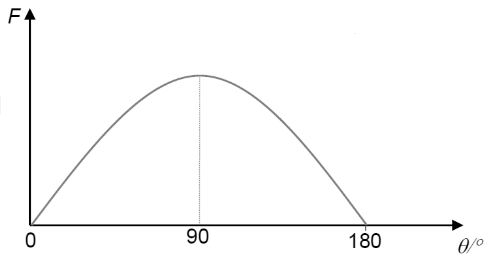
$$\tau = Fd = NBIl \times d = NBIA$$
$$B = \frac{\tau}{NIA} = \frac{395}{1200 \times 96 \times 6.1 \times 10^{-3}} = 0.562\ T$$

5

(a) **(i)**



(ii)



(b) **(i)** There is a magnetic force on the electrons due to the magnetic field and this force is normal to both the magnetic field and direction of electron motion. Hence the electrons will experience an acceleration perpendicular to its motion, causing the direction of velocity to change and they will not travel in a straight line.

(ii) From S to R or from P to Q

6

(a) **(i)** Charged particles moving perpendicular to a magnetic field will experience a resultant magnetic force perpendicular to its motion. Hence no work is done. By Newton's 2nd Law, the acceleration of the particles is in the same direction as the resultant force. The direction of the particles changes but not its speed. By Newton's 1st law, upon exit, the particles will move in a straight line.

(ii) Magnetic force provides for the centripetal force

$$F_B = F_C$$
$$Bqv = \frac{mv^2}{r}$$
$$r = \frac{mv}{Bq}$$

$$= \frac{(2.66 \times 10^{-26})(4500)}{(2 \times 10^{-3})(1.6 \times 10^{-19})} = 0.374\ m$$

(b) $r = \frac{mv}{Bq} = \frac{\rho}{Bq}$
$\rho = Bqr = (2 \times 10^{-3})(1.6 \times 10^{-19})(0.2)$
$= 6.4 \times 10^{-23}\ kg\ m\ s^{-1}$

7

(a) Electric forces act on, both moving and stationary charges while magnetic forces act on only moving charges.

(b) **(i)** By Flemings left hand rule, the magnetic force on the electron acts downwards. Hence the electric force on the electron should act upwards, and plate P will be positive with respect to plate Q.

(ii) $F_M = Bqv$
$= (48 \times 10^{-3})(1.6 \times 10^{-19})(5.2 \times 10^{6})$
$= 4.0 \times 10^{-13}\ N$

(iii) When the potential decreases, the electric field strength and hence the electric force on the electron decreases. Upon entering the field, the downwards magnetic force is larger than the upward electric force and hence there is a net downward force. The electron is deflected downwards.
As the electron path curves downwards, the subsequent net force is the resultant of the upward electric force and the magnetic force tangential to the motion of the electron. The path curves further downwards.

(c) **(i)** When there is a current in the coil, by right hand grip rule, there is field set up around each loop such that the magnetic flux passes from left to right. The fields from each of the loops overlap to set up a close to uniform field between them.

(ii) $$B = 0.72\mu_0 \frac{NI}{r} = \frac{(0.72)(4\pi \times 10^{-7})(130)(1.3)}{\frac{2.9 \times 10^{-2}}{2}}$$
$= 1.298 \times 10^{-3} = 1.3\ mA$

(iii) Magnetic force provides for centripetal force
$$Bqv = \frac{mv^2}{r}$$
$$r = \frac{mv}{Bq}$$
$$= \frac{(9.11 \times 10^{-31})(5.2 \times 10^{6})}{(1.3 \times 10^{-3})(1.6 \times 10^{-19})}$$
$= 2.28\ cm$

(d) **(i)** The electron moves in a helical path.

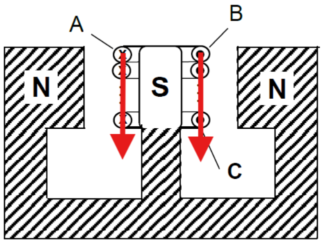
(ii) The horizontal component of velocity is parallel to the direction of the B field, hence remains unchanged. By Flemings left hand rule, a magnetic force acts on the electron perpendicular to the B field and its perpendicular component of velocity. This provides the centripetal force causes the electron to chart out a circular path in the plane perpendicular to the B field. The motion of the electron is the vector sum of the horizontal and perpendicular components of velocity, hence a helical path.

(iii) When current I is increased, the magnetic flux density B increases. Since r is inversely proportional to B as m, v and q are constants, this causes radius of the helical path to decrease.

8

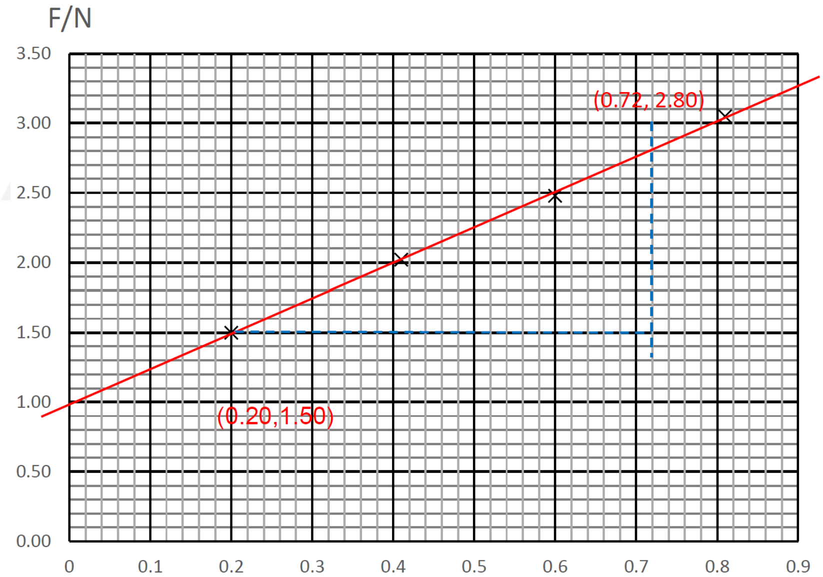
(a) Magnetic flux density B is the force acting per unit current per unit length on a wire carrying a current that is normal to the magnetic field.

(b) **(i)**



The current flows perpendicular to the magnetic flux density at all parts of the coil. Hence the current carrying conductor will experience a magnetic force. The direction of the magnetic force can be deduced by Fleming's Left Hand Rule.

(ii)



Gradient $= \frac{2.80-1.50}{0.72-0.20}$

$= \frac{1.30}{0.52} = 2.5$

Force per unit current $= \frac{F}{L} = 2.5\ N\ A^{-1}$

$F = (2.5)(A) + c$
$1.50 = (2.5)(0.20) + c$
$c = 1.00\ N$
Zero error, $c = 1.00\ N$

(iii) $\frac{F}{I} = BL$
$2.5 = B(50 \times 2\pi \times 0.025)$
$B = 0.637\ T$

9

(a) **(i)** The magnetic force acting on the charged particle provides the centripetal force for the charged particle to move in uniform circular motion.

$$Bqv = mv\omega$$
$$T = \frac{2\pi m}{Bq}$$

The circular motion is horizontal, so the net vertical force is zero.

$$mg = qE$$
$$\frac{m}{q} = \frac{E}{g}$$

$$T = \frac{2\pi E}{Bg}$$

(ii) $$T = \frac{2\pi(150)}{0.50 \times 9.81} = 192\ s$$

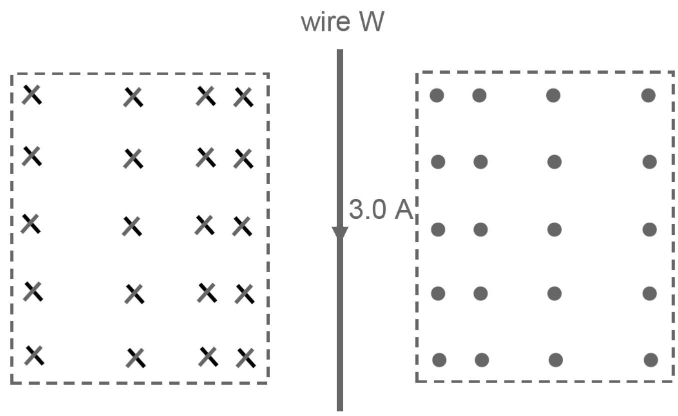
(b) When the electric field is removed, the only vertical force acting on the charged particle is its weight. Hence, the particle falls with uniform acceleration g.

The magnetic force still provides the centripetal force for the charged particle to movie in uniform horizontal circular motion, resulting in the charged particle moving in a helical path in which the distance between adjacent loops increases as the particle falls.

Using Fleming's Left-hand Rule, the charged particle will continue to move in a clockwise circle when viewed from the top of its helical path.

10

(a)



(b) **(i)** $$B = \frac{\mu_0 I}{2\pi d} = \frac{(4\pi \times 10^{-7})(3.0)}{2\pi(40.0 \times 10^{-2})}$$
$$= 1.5 \times 10^{-6}\ T$$

(ii) $$\frac{F}{L} = BI$$
$$= (1.5 \times 10^{-6})(1.0)$$
$$= 1.5 \times 10^{-6}\ N\ m^{-1}$$

(iii) By Right Hand Grip Rule, the magnetic field produced by the current in wire W acts perpendicular to wire Y and out of the plane of paper.

By Fleming's Left Hand Rule, the direction of the magnetic force on Y by W acts away from wire W. By Newton 3rd law, the direction of the magnetic force on W by Y is opposite to that on wire Y.

Therefore there is a repulsive force acting between the two wires.

(iv) Let y be the distance to the right of wire Y.

$$B_{due\ to\ Y} = B_{due\ to\ W}$$

$$\frac{\mu_0(1.0)}{2\pi y} = \frac{\mu_0(3.0)}{2\pi(40.0 \times 10^{-2} + y)}$$

$$\frac{1.0}{y} = \frac{3.0}{40.0 \times 10^{-2} + y}$$

$$y = 20.0\ cm$$

position: 20.0 cm to the right of wire Y.