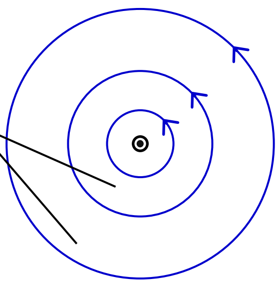
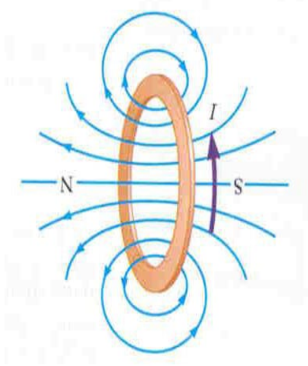
Magnetic Fields

1.

spacing increases with distance from wire to indicate weaker field

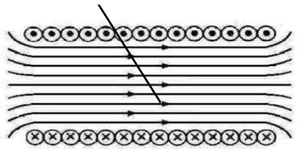


Long Straight Wire



Flat Circular Coil

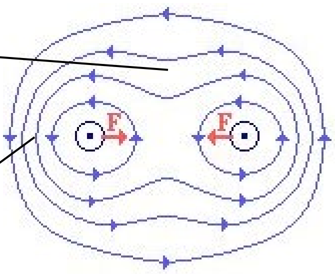
Parallel equidistant lines to indicate uniform field



Long Solenoid

2. lines spacing wider to indicate weaker field strength

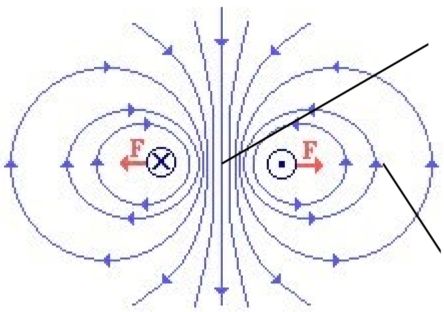
lines more closely spaced to indicate stronger field strength



(a) Currents in the same direction

lines more closely spaced to indicate stronger field strength

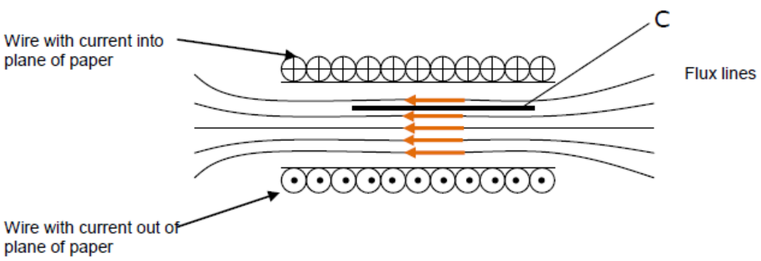
lines spacing wider to indicate weaker field strength



(b) Currents in opposite directions

3. **i.** Directed to the left (by the right hand grip rule)

ii Current carrying conductor should be placed parallel to the field lines.



Magnetic force on current-carrying conductors

4. D. Magnetic field is parallel to motion of electron, θ is either 0° or 180°.
Using $F = BIL \sin\theta$, no electromagnetic force is experienced by the electron.

5. C. Using Fleming's left hand rule.

6.

$$F_1 = BIL \sin 90^o$$

$$\Rightarrow 8.0 \times 10^{-3} = BIL \quad \text{---------(1)}$$

$$F_2 = \left(\frac{B}{2}\right) I (L \sin 60°)$$

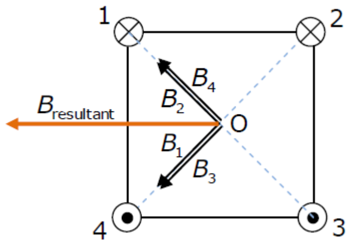
$$= \frac{8.0 \times 10^{-3} \times \sin 60°}{2}$$

$$= 3.5 \times 10^{-3}\,\text{N} = 3.5\,\text{mN}$$

7. Ans: B. Wires X and Z each exert a leftward force on Y.

8. Ans: A.

Use the Right Hand Grip rule at each wire to find the direction of magnetic field due to each wire on point O. Thereafter, do a vector sum of all 4 magnetic field vectors to confirm that the resultant field points to the left.



9. i Let BF = CE = d and BC = FE = L
For rotational equilibrium,
Anti-clockwise moment due to magnetic force = Clockwise moment due to weight

$$BIL\sin 90^o \times \frac{d}{2} = mg\frac{d}{2}$$

$$B = \frac{mg}{IL}$$

ii

$$B = \frac{mg}{IL}$$

$$\mu_o nI = \frac{mg}{IL}$$

$$I = \sqrt{\frac{mg}{\mu_o nL}}$$

$$= \sqrt{\frac{(0.10 \times 10^{-3})(9.81)}{(4\pi \times 10^{-7})(1800)(0.025)}}$$

$$= 4.17\ \text{A}$$

10. With no current, the reading of 142.0 g is the mass of the horse shoe magnet.

With a current of 2.0 A in the wire from X to Y, a magnetic force F_B acts upwards on the wire XY. By Newton's 3rd Law, there is an equal and opposite (downwards) force on the pan, causing the reading on the top pan balance to increase.

$$F_B = BIL\sin 90° = (144.6 - 142.0)\times 10^{-3} \times 9.81$$
$$B(2.0)L = (144.6 - 142)\times 10^{-3} \times 9.81$$
$$\Rightarrow BL = 0.0127$$

When a current of 3.0 A flows from Y to X, the magnetic force on the wire will act downwards. By Newton's 3rd Law, there is an equal and opposite (upwards) force on the pan, causing the reading on the top pan balance to decrease.

$$F_B^{'} = B(3.0)L\sin 90°$$
$$(142.0 - m^{'})(10^{-3})(9.81) = 3 \times (0.0127)$$
$$\Rightarrow m^{'} = 138.1\,\text{g}$$

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11 (a) (i) Force per unit length = $BI\sin\theta$

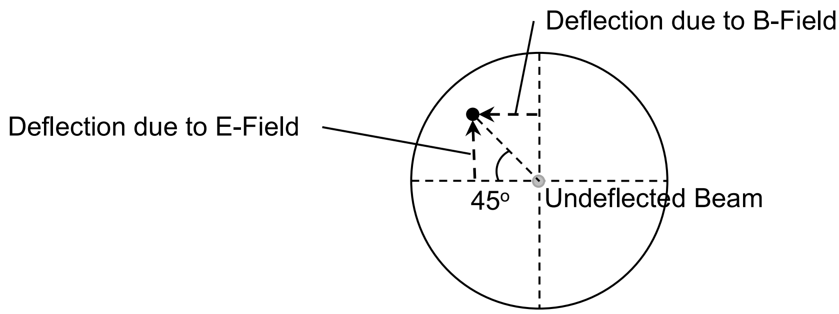
(ii) By Fleming's LHR, the force is directed into the plane of the paper.

(b) (i) Magnetic field due to current in the upper loop is normal to the current in the lower loop.
This causes a magnetic force to be exerted on the lower loop.
Based on Newton's 3rd law, a magnetic force is also exerted on the upper loop which is of the same magnitude but opposite in direction.
Since currents are in the same direction for both loops, by Fleming's left hand rule, the forces are attractive and the loops attract each other.

(ii) $B = 2 \times 10^{-7} I / (0.75 \times 10^{-2}) = 2.67 \times 10^{-5} I$
Force by weight = $0.26 \times 10^{-3} \times 9.81 = 2.55 \times 10^{-3}$ N
Force by weight = magnetic force exerted on the loop = BIL
$2.55 \times 10^{-3} = (2.67 \times 10^{-5} I)(I)(2\pi \times 4.7 \times 10^{-2})$
$I = 18$ A

Magnetic force on moving charges

12



- Electrons move towards observer's eye.
- Hence, conventional current is into the plane of this paper.
- Using Fleming's LH rule, electron deflects to the left (due to the magnetic field) as shown above.

13 i Assuming that the charged particles enter at an angle 90° to the magnetic field. Since the magnetic force on the charged particle provides the centripetal force, By Newton's 2nd law:

$$F_B = F_C$$
$$Bev\sin 90^\circ = m\frac{v^2}{r}$$
$$v = \frac{Ber}{m}$$

ii If the particles were electrons,

$$v = \frac{(6.0\times10^{-5})(1.6\times10^{-19})(50000)}{(9.11\times10^{-31})}$$
$$= 5.27\times10^{11}\ \mathrm{m\ s^{-1}}$$

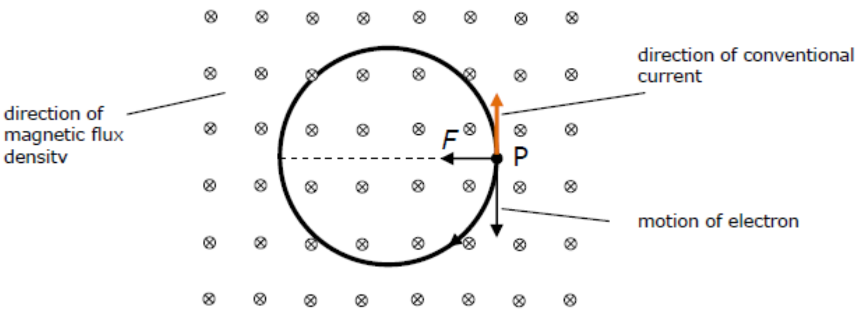
Since no particles travels faster than the speed of light (3.0×10^{8} m s^{-1}), it is not possible for the particles to be electrons.

iii Considering the proton:

$$v = \frac{(6.0\times10^{-5})(1.6\times10^{-19})(50000)}{(1.67\times10^{-27})}$$
$$= 2.87\times10^{8}\ \mathrm{m\ s^{-1}} < c$$

Hence one possible particle that could have caused the aurora could be the proton.

14 (a) Clockwise circular path passing through P.



(b) i

$$F = Bqv\sin\theta$$
$$= (1.5 \times 10^{-3})(1.60 \times 10^{-19})(2.9 \times 10^{7})\sin 90^{o}$$
$$= 6.96 \times 10^{-15}\ \mathrm{N}$$

ii Since the magnetic force on the electron provides the centripetal force,

$$F_B = F_C$$
$$Bqv = m\frac{v^2}{r}$$
$$\therefore r = \frac{mv}{Bq}$$
$$= \frac{(9.11 \times 10^{-31})(2.9 \times 10^{7})}{(1.5 \times 10^{-3})(1.60 \times 10^{-19})}$$
$$= 0.11\ \mathrm{m}$$

iii Time for half period = dist ÷ speed
= $(\pi \times 0.11) \div (2.9 \times 10^{7})$
= 1.19×10^{-8} s

iv

$$\text{Kinetic Energy} = \frac{1}{2}mv^2$$
$$= \frac{1}{2}(9.11 \times 10^{-31})(2.9 \times 10^{7})^2$$
$$= 3.83 \times 10^{-16}\ \mathrm{J}$$

(c) Loss in Electric P.E. = Gain in K.E. of the electron

$e\Delta V = 3.83 \times 10^{-16}$

$\Delta V = 2390$ V

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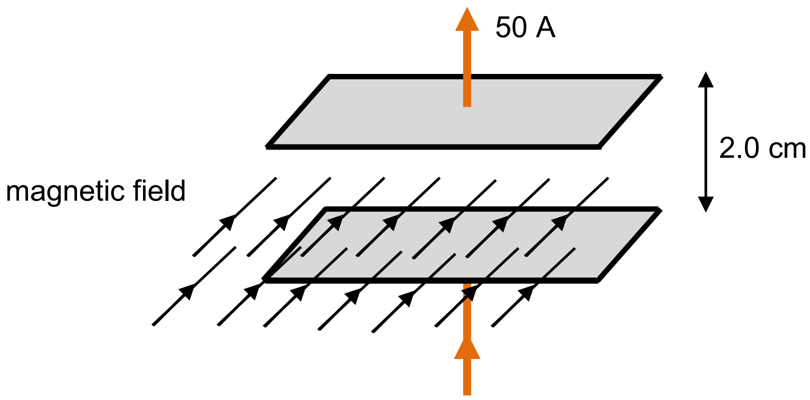
15 (a) i

$$R = \frac{\rho\,\ell}{A}$$
$$= \frac{(4.8 \times 10^{-8})(0.02)}{(0.05 \times 0.02)} = 9.6 \times 10^{-7}\ \Omega$$

ii $V = IR$

= $(50)(9.6 \times 10^{-7}) = 4.8 \times 10^{-5}$ V

(b) i



Sodium positive ions flow in the direction of the conventional current. By Fleming's Left hand rule, the magnetic force exerted on the liquid is directed to the left.

ii F = $BIL\sin\theta$
= (0.12)(50)(0.02) sin90° = 0.12 N

(c) The electromagnetic force acting from right to left exerts a pressure on the cross-sectional area of the horizontal tube.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{0.12}{0.020 \times 0.020}$$

This pressure causes the height of the liquid in the left column to be greater than the height of the liquid in the right column by

$$\Delta h \times \rho \times g = \frac{0.12}{0.020 \times 0.020}$$

$$\Rightarrow \quad \Delta h \times 9.6 \times 10^2 \times 9.81 = \frac{0.12}{0.020 \times 0.020}$$

$$\Rightarrow \quad \Delta h = 0.032 \text{ m}$$

(d) Advantage: It involves no moving physical parts and hence little wear and tear; maintenance free. Or less noise

Disadvantage: It involves the need to handle relatively high currents which poses a safety hazard.
It can only be used if the fluid is highly conductive.

Crossed Fields

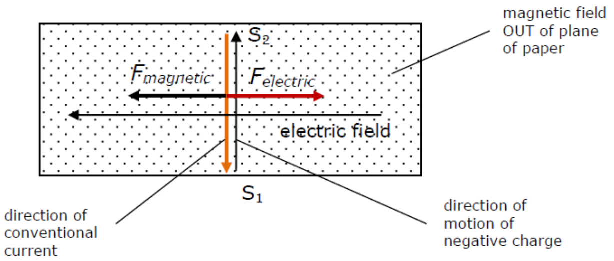
16 (a) Loss in Electric P.E. = Gain in K.E.

$$QV = \frac{1}{2}Mv^2$$

$$v = \sqrt{\frac{2QV}{M}}$$

(b) i Leftwards.

Electric field must be directed to the left so that the electric force on the negative charge is directed to the right (opposite in direction to the electromagnetic force).



ii Based on Fleming's LHR, the electromagnetic force on the negatively charged particles is directed to the left.
With the electric field directed to the left, the electric force on the negatively charged particles is directed to the right.
When these two forces are of the same magnitude (but in opposite directions), the resultant will be zero. Based on Newton's 1st law, the particles will travel with constant velocity in a straight line.
Because the electromagnetic force depends on the speed of the charged particles, there is only one speed in which the electromagnetic force acted on the charged particles is equal to the electric force.

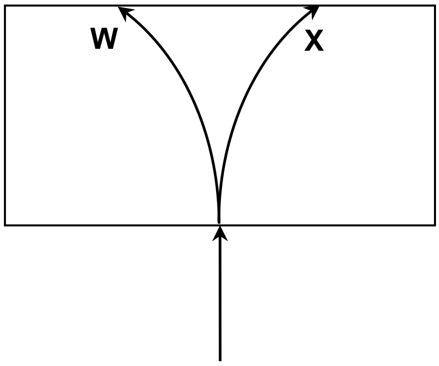
iii In order for the particles to pass through undeviated,

$$F_B = F_E$$

$$B_1Qv = QE$$

$$v = \frac{E}{B_1}$$

iv

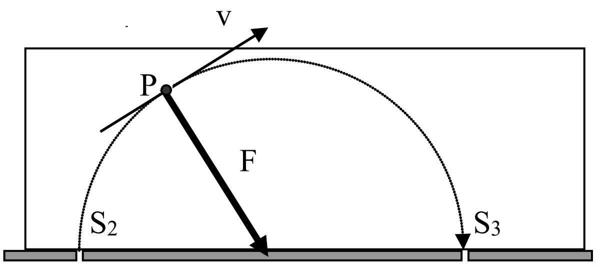


If the speed is greater than *v* (for W), then the electromagnetic force (=Bqv) is larger than the electric force (=Eq which is independent of *v*). Net force on the charge is to the left; charge deviates to the left.

Conversely (for X), if the velocity is less than *v*, now the electromagnetic force is less than the electric force and the charge deflects to the direction of the electric force.

(c) i Into the plane of the paper.

ii



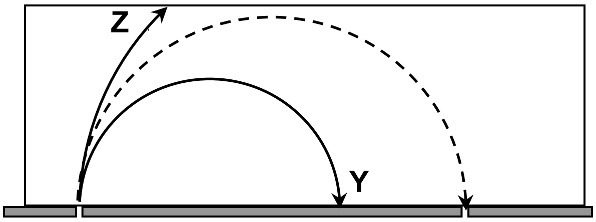
iii Since the magnetic force on the charged particles provides the centripetal force,

$$F_B = F_C$$

$$B_2 Q v = M\frac{v^2}{R}$$

$$R = \frac{Mv}{B_2 Q} = \frac{v}{B_2\left(\frac{Q}{M}\right)_1}$$

iv



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