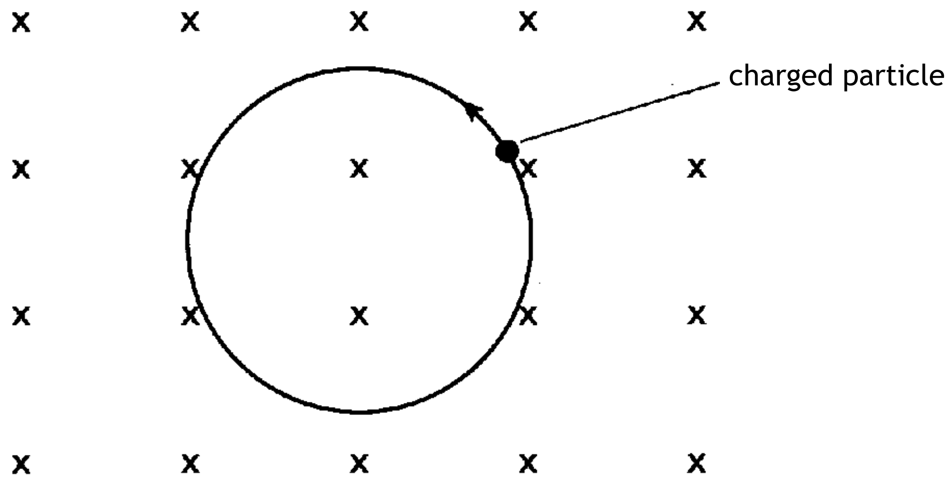
Homework – Particles from Space

1. A charged particle moves with a speed of $2{\cdot}0 \times 10^6$ ms^{-1} in a circular orbit in a uniform magnetic field, as shown.



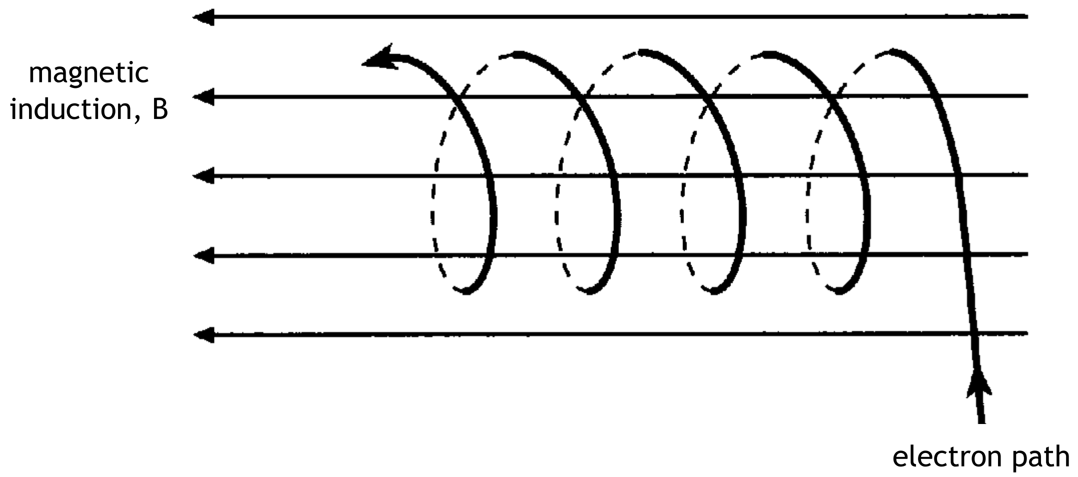
(a) The magnetic induction is 1·5 T and is directed into the page. The circular orbit has a radius of 13·9 mm.

(i) State whether the charge on the particle is positive or negative.

(ii) Calculate the charge to mass ratio, $\frac{q}{m}$, of the particle in Ckg^{-1}.

(iii) Identify the charged particle.
You must justify your answer with appropriate calculations.

(b) An electron enters a uniform magnetic field at an angle to the magnetic field lines as shown.



State the name of the path taken.
Explain how the shape of the electron path in the magnetic field arises.

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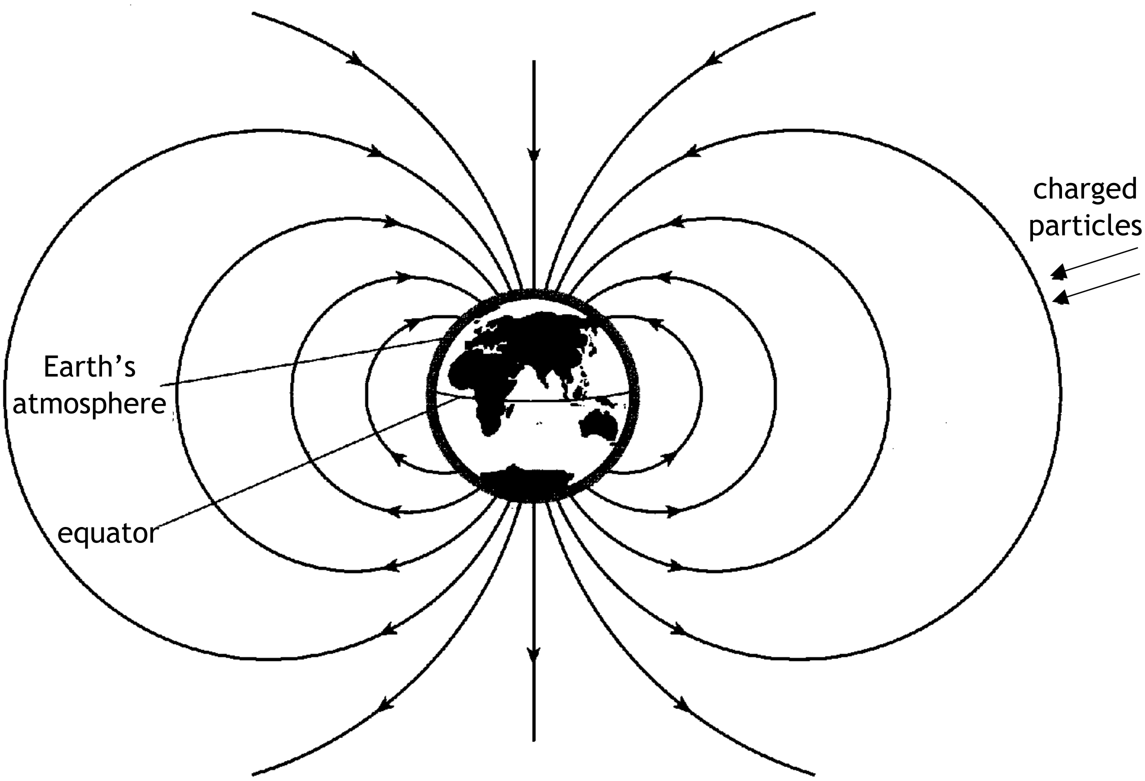
(c) Charged particles which enter the Earth's atmosphere near the North Pole collide with air molecules. The light emitted in this process is called the Aurora Borealis.

The Earth's magnetic field is indicated by continuous lines which show the magnetic field direction in the region surrounding the Earth.

The extent of Earth atmosphere is also shown.



Charged particles approach the Earth in the direction shown.

Explain why these particles do not cause an aurora above the Equator.

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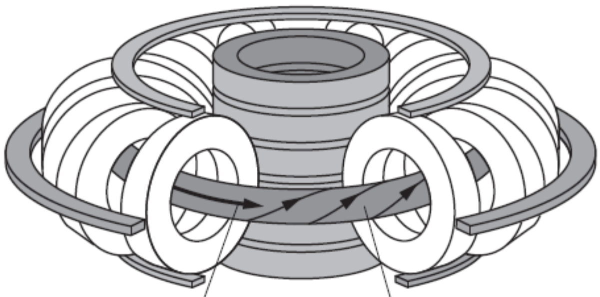
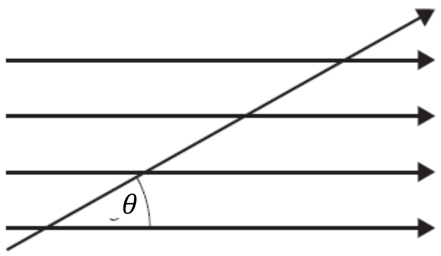
2. Research is currently being carried out into nuclear fusion as a source of energy. One approach uses a magnetic field to contain ionised gas, known as plasma in a hollow doughnut-shaped ring. A simplified design is shown below.



The motion of a charged gas particle is determined by the angle θ between its velocity v and the magnetic induction B as shown in the diagram below.



(a) In the case where $\theta = 90°$ the particles undergo circular motion, perpendicular to the magnetic field.

(i) Show that for a charged particle of mass m, charge q and velocity v in a field of magnetic induction B, the radius of rotation is given by

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

(ii) A deuterium is ion is moving with a velocity of $2{\cdot}4 \times 10^7$ ms^{-1} perpendicular to the magnetic field. The maximum diameter of the circular motion, permitted by the design is 0·50 m.

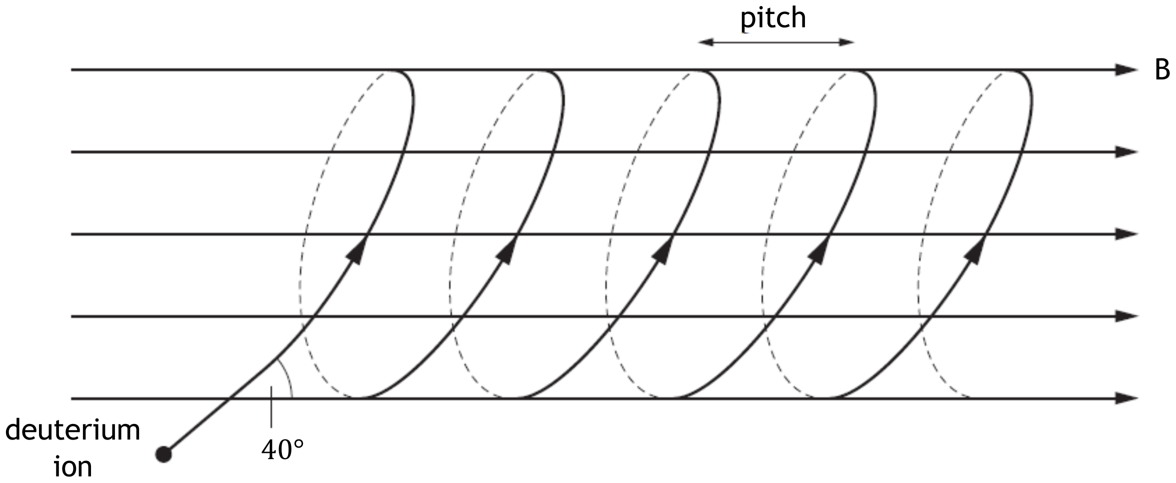
Properties of ions present in the plasms are given in the table below.

ion	symbol	mass (x 10^{-27} kg)	charge (x 10^{-19} C)
Hydrogen	H^+	1·686	1·60
Deuterium	D^+	3·343	1·60
tritium	T^+	5·046	1·60

Calculate the magnetic induction B required to constrain the deuterium ion within the maximum permitted diameter.

(iii) Calculate the maximum period of rotation for this deuterium ion.

(b) Another deuterium ion is travelling at $2{\cdot}4 \times 10^7$ ms^{-1} at an angle of 40° to the direction of magnetic induction. This results in the ion undergoing helical motion as shown below.



(i) Explain why the period of rotation for this deuterium ion is the same as in (a) (iii).

The distance between adjacent loops in the helix is called the pitch.

(ii) Calculate the pitch of the helical motion.