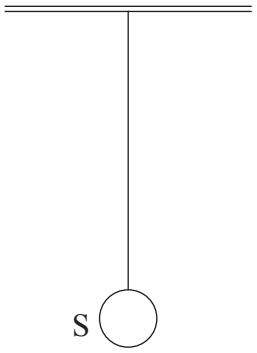
SECTION A

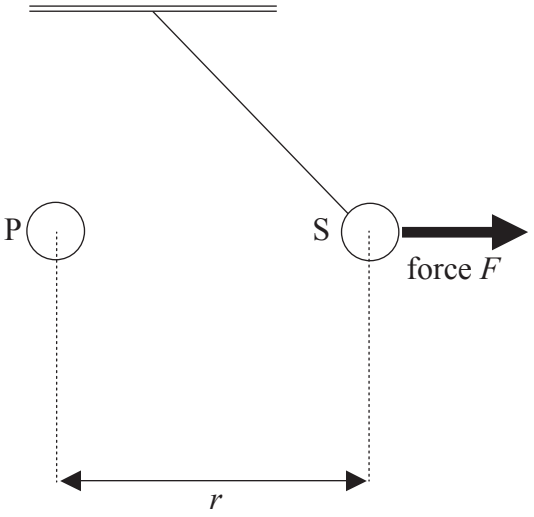
*Answer **all** the questions in the spaces provided.*

A1. This question is about an electrostatics experiment to investigate how the force between two charges varies with the distance between them.

A small charged sphere S hangs vertically from an insulating thread as shown below.



A second identically charged sphere P is brought close to S. S is repelled as shown below.



The magnitude of the electrostatic force on sphere S is F. The separation between the two spheres is r.

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(Question A1 continued)

(a) On the axes below draw a sketch graph to show how, based on Coulomb's law, you would expect F to vary with $\frac{1}{r^2}$. *[2]*

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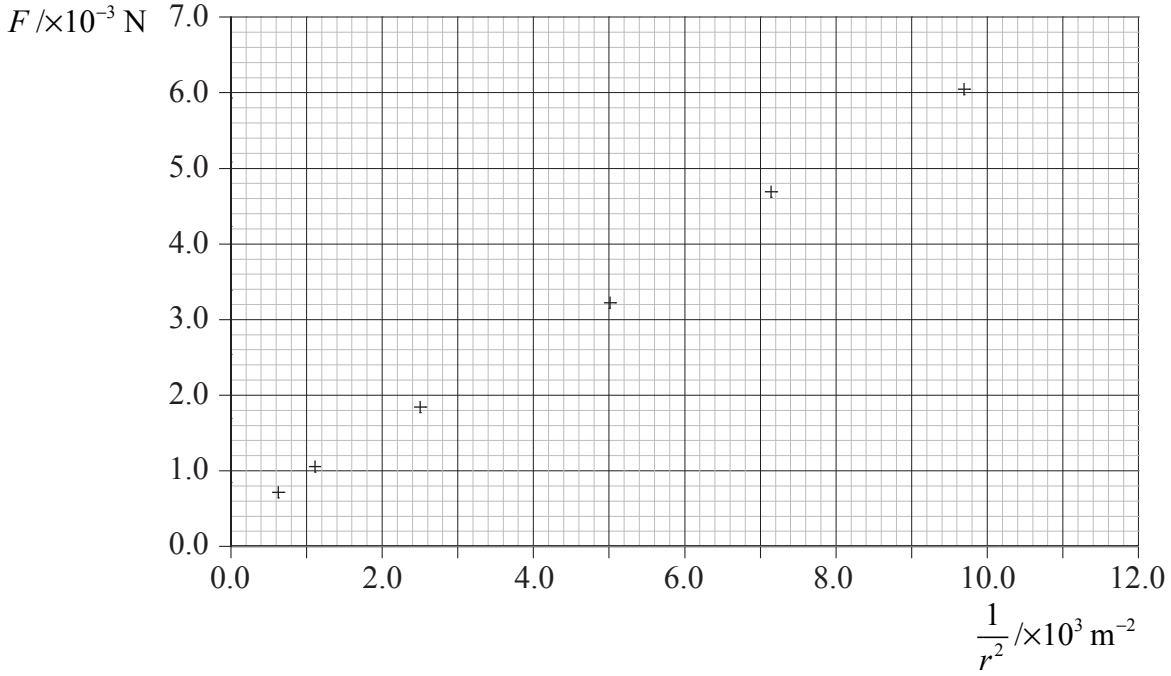
(Question A1 continued)

Values of F are determined for different values of r. The variation with $\frac{1}{r^2}$ of these values is shown below. The estimated uncertainties in these values are negligible.



(b) (i) Draw the best-fit line for these data points. *[2]*

(ii) Use the graph to explain whether, in the experiment, there are random errors, systematic errors or both. *[3]*

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(iii) Calculate the gradient of the line drawn in (b) (i). *[2]*

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(Question A1 continued)

(iv) The magnitude of the charge on each sphere is the same. Use your answer to (b) (iii) to calculate this magnitude. *[4]*

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A3. This question is about electric fields.

(a) Define *electric field strength*. *[2]*

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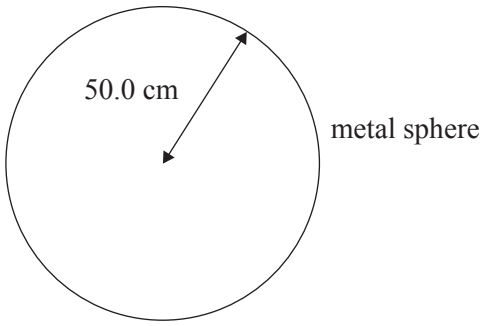
(b) An isolated metal sphere of radius 50.0 cm has a positive charge. On the diagram below draw lines to represent the electric field outside the sphere. *[2]*



A3. This question is about magnetic fields.

(a) Using the diagram below, draw the magnetic field pattern of the Earth. *[2]*

(b) State what other object produces a magnetic field pattern similar to that of the Earth. *[1]*

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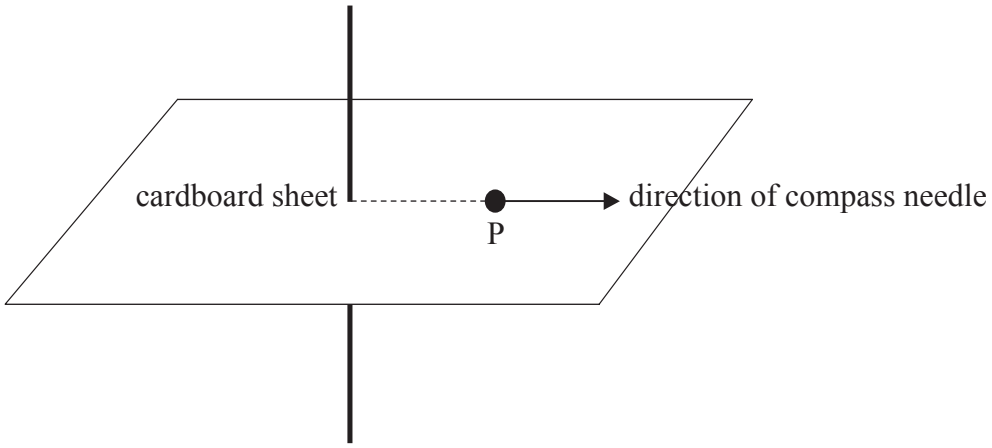
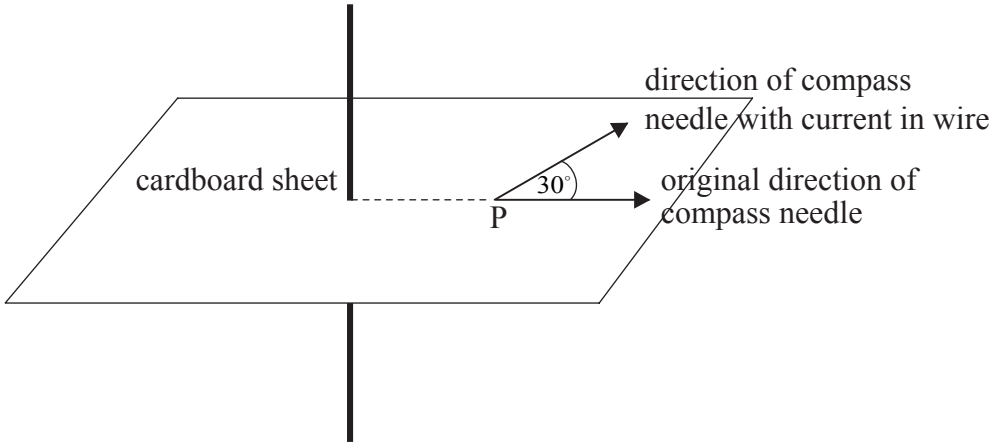
(Question A3 continued)

(c) A long vertical wire passes through a sheet of cardboard that is held horizontal. A small compass is placed at the point P and the needle points in the direction shown.



A current is passed through the wire and the compass needle now points in a direction that makes an angle of 30° to its original direction as shown below.



(i) Draw an arrow on the wire to show the direction of current in the wire. Explain why it is in the direction that you have drawn. *[2]*

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(Question A3 continued)

(ii) The magnetic field strength at point P due to the current in the wire is B_W and the strength of the horizontal component of the Earth's magnetic field is B_E.

Deduce, by drawing a suitable vector diagram, that

$$B_E = B_W \tan 60^\circ.$$ *[2]*

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(iii) The point P is 2.0 cm from the wire and the current in the wire is 4.0 A. Calculate the strength of the horizontal component of the Earth's magnetic field at point P. *[2]*

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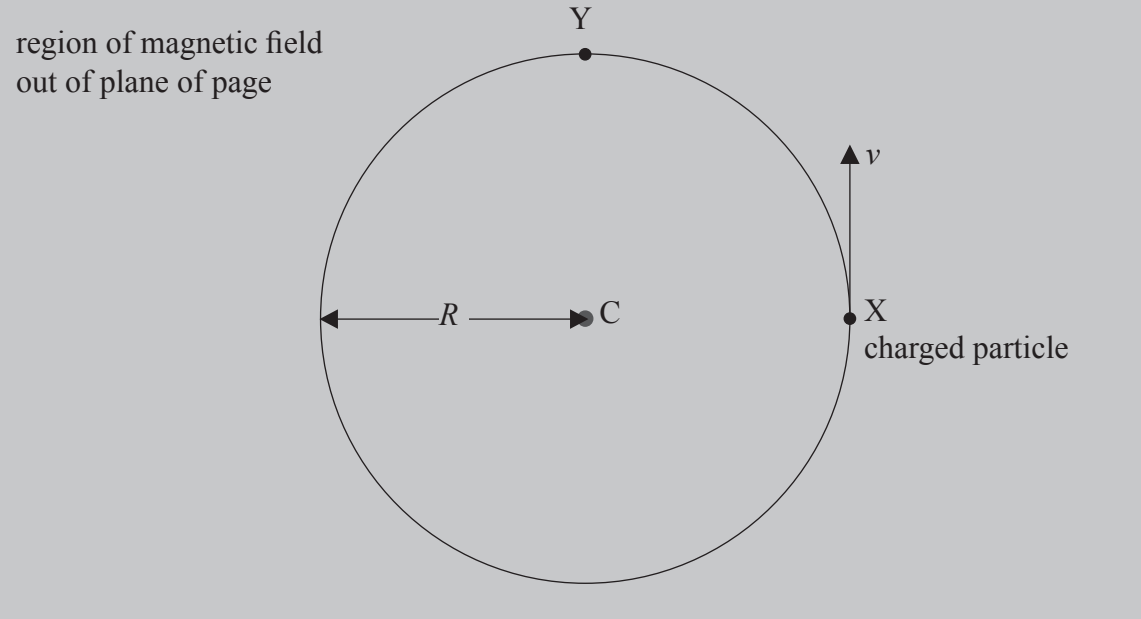
A3. This question is about motion of a charged particle in a magnetic field.

A charged particle is projected from point X with speed v at right angles to a uniform magnetic field. The magnetic field is directed out of the plane of the page. The particle moves along a circle of radius R and centre C as shown in the diagram below.



(a) On the diagram above, draw arrows to represent the magnetic force on the particle at position X and at position Y. *[1]*

(b) State and explain whether

(i) the charge is positive **or** negative. *[1]*

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(ii) work is done by the magnetic force. *[2]*

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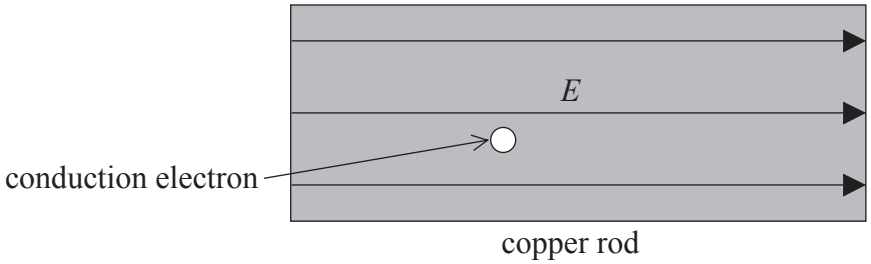
(c) A second identical charged particle is projected at position X with a speed $\frac{v}{2}$ in a direction opposite to that of the first particle. On the diagram above, draw the path followed by this particle. *[2]*

(Question B3 continued)

Part 2 Electrical conduction and the force on a conductor in a magnetic field

(a) The diagram below shows a copper rod inside which an electric field of strength E is maintained by connecting the copper rod in series with a cell. (Connections to the cell are not shown.)



(i) On the diagram, draw an arrow to show the direction of the force on the conduction electron shown. Label this arrow with the letter F. *[1]*

(ii) Describe how the electric field enables the conduction electrons to have a drift velocity in a direction along the copper rod. *[3]*

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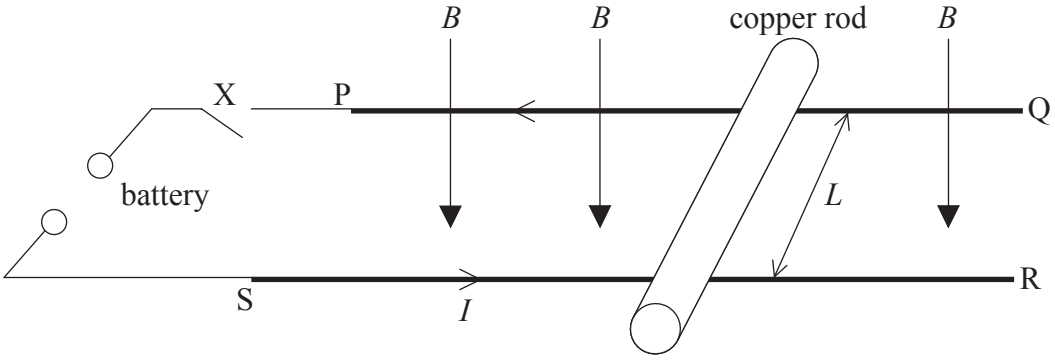
(Question B3, part 2 continued)

(b) A copper rod is placed on two parallel, horizontal conducting rails PQ and SR as shown below. The conducting rails are connected to a battery and switch X.

The rails and the copper rod are in a region of uniform magnetic field of strength B. The magnetic field is normal to the plane of the conducting rods as shown in the diagram below.



The length of the copper rod between the rails is L. The mass of the copper rod is M. Friction between the copper rod and the rails is negligible.

The switch X is now closed and the current in the copper rod is I and in the direction shown in the diagram.

(i) On the diagram, draw an arrow to show the direction of the force F on the copper rod. *[1]*

(ii) Derive an expression in terms of B, L, M and I, for the initial acceleration a of the copper rod. *[2]*

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(Question B3, part 2 continued)

(c) The copper rod in (b) eventually moves with constant speed v. When moving at this constant speed, the power supplied by the battery is equal to rate at which work is done by the force F.

(i) Deduce that the power P supplied by the force F acting on the copper rod when it is moving at constant speed v is given by the expression

$$P = Fv.$$ *[2]*

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(ii) Use the expression in (i) and the data below to determine the speed v. *[3]*

e.m.f. of the battery	= 0.80 V
length of copper rod L	= 0.60 m
field strength B	= 0.25 T

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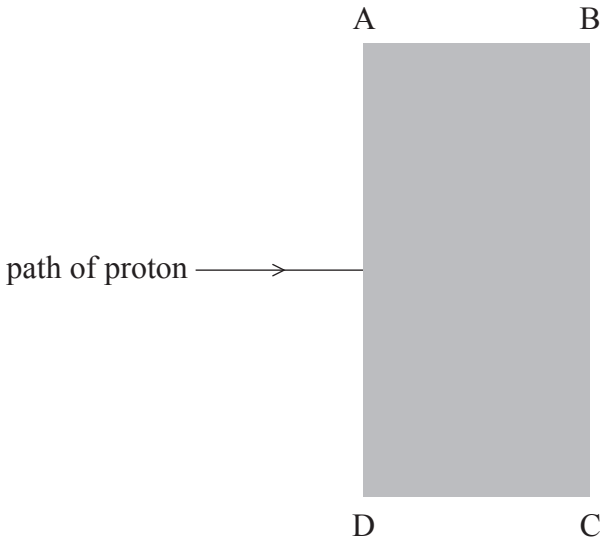
(Question B3, continued)

Part 2 Magnetic and electric fields

A proton is accelerated from rest in a vacuum through a potential difference of 420 V. The proton then enters a region ABCD of uniform magnetic field as shown.



The magnetic field is directed into the plane of the paper. The field strength is 15 mT.

(a) (i) Calculate the speed of the proton as it enters the region of the magnetic field. *[2]*

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(ii) The path of the proton as drawn on the diagram is in the plane of the paper. The proton enters the region ABCD of the magnetic field and leaves through the side BC. On the diagram above, draw the path of the proton within and beyond the region ABCD of the magnetic field. Label the path P. *[2]*

(iii) Determine the magnitude of the force due to the magnetic field that acts on the proton while the proton is in the region ABCD. *[2]*

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(Question B3, part 2 continued)

(b) (i) Define *electric field strength* at a point. *[2]*

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(ii) Determine the magnitude of the electric field strength that would produce a force on a proton that is equal to the force calculated in (a)(iii). *[2]*

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(iii) The electric field calculated in (b)(ii) is applied in the region ABCD. The electric field is arranged such that, when a proton enters the region, the force due to the electric field is opposite in direction to the force due to the magnetic field. Suggest, with a reason, the path that the proton will follow in the region ABCD. *[2]*

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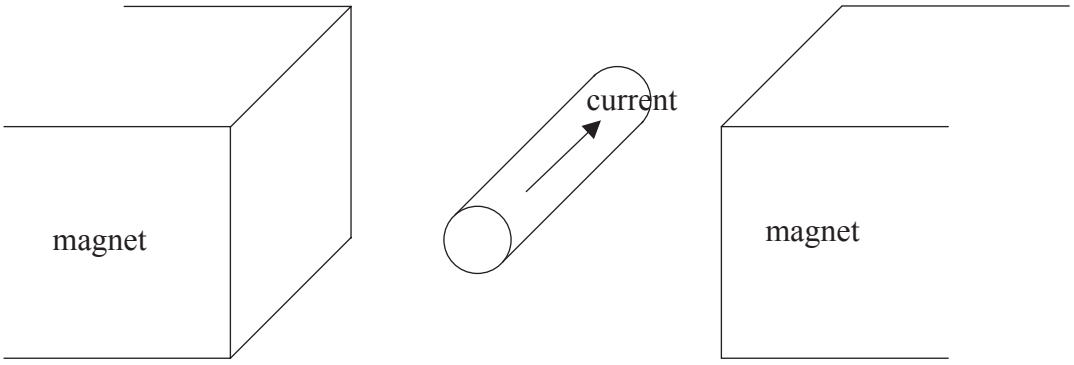
(Question B3, part 2 continued)

Magnetism

(d) A current carrying rod is held horizontally between the poles of a magnet by a magnetic force.



(i) On the diagram above label with the letter N the north pole of the magnet. Explain your choice. *[1]*

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(ii) The weight of the rod is 4.0 N and its length is 0.80 m. The magnitude of the magnetic field strength is 0.20 T. Determine the current in the rod. *[2]*

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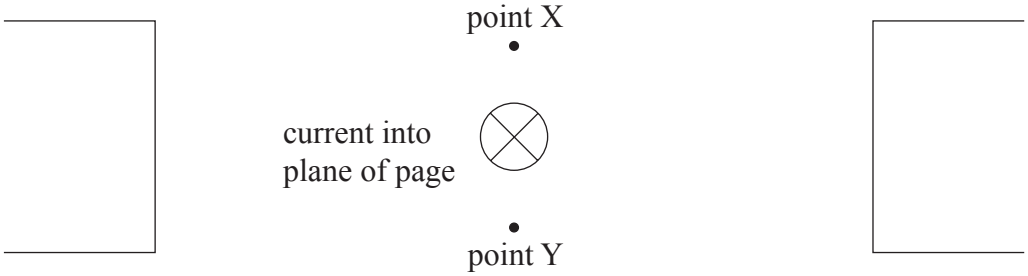
(iii) The diagram below shows two points X and Y that are at equal distances from the current carrying rod in (d).



State and explain at which point (X or Y) the magnetic field strength is greatest. *[2]*

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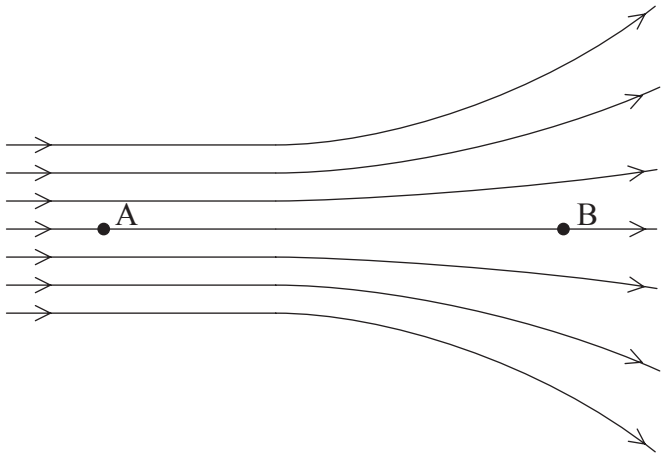
(Question B1 continued)

Part 2 Force fields

(a) Electric fields and magnetic fields may be represented by lines of force. The diagram below shows some lines of force.



(i) State whether the field strength at A and at B is constant, increasing **or** decreasing when measured in the direction from A towards B. *[2]*

at A: . . . . . .

at B: . . . . . .

(ii) Explain why field lines can never touch or cross. *[2]*

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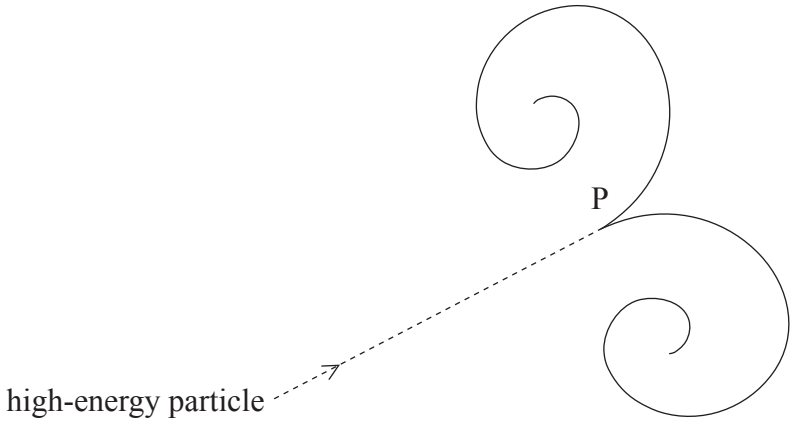
(Question B1, part 2 continued)

(b) A bubble chamber is an apparatus that is used to show the paths of particles. A high-energy particle enters the chamber and, at a point P, there is a reaction that gives rise to two charged particles. The tracks of the particles are shown below.



There is a uniform field of force acting normally to the plane of the paper.

(i) State, and explain, whether the field of force is electric **or** magnetic. *[2]*

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(ii) The path of each of the two particles produced in the reaction is a spiral. One particle is spiralling clockwise, the other anti-clockwise. Suggest why they spiral in opposite directions. *[1]*

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(iii) Outline why each path is a spiral, rather than a circle. *[3]*

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B3. This question is about aspects of electric fields and electric charge.

Fields and electric charge associated with atoms

(a) Define *electric field strength.* *[2]*

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(b) A proton may be considered to be a point charge. For such a proton

(i) sketch the electric field pattern. *[2]*

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(ii) calculate the magnitude of the electric field strength at a distance of 5.0×10^{-11} m from the proton. *[2]*

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(Question B3 continued)

(c) In a simple model of the hydrogen atom, an electron orbits the proton. Both electron and proton are regarded as point charges. The orbital radius of the electron is 5.0×10^{-11} m.

(i) Using your answer to (b)(ii) deduce that the magnitude of the electric force between the electron and the proton is 9.3×10^{-8} N. *[1]*

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(ii) Deduce that the kinetic energy of the electron is 2.3×10^{-18} J. *[3]*

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(iii) The total energy of the electron is –14 eV. Determine the potential energy of the electron in electron volt. *[3]*

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