Q1. Which one of the following statements is correct?

An electron follows a circular path when it is moving at right angles to

A a uniform magnetic field.

B a uniform electric field.

C uniform electric and magnetic fields which are perpendicular.

D uniform electric and magnetic fields which are in opposite directions.

(Total 1 mark)

Q2. Two electrons, X and Y, travel at right angles to a uniform magnetic field.
X experiences a magnetic force, F_{X}, and Y experiences a magnetic force, F_{Y}.

What is the ratio $\frac{F_X}{F_Y}$ if the kinetic energy of X is half that of Y?

A $\frac{1}{4}$

B $\frac{1}{2}$

C $\frac{1}{\sqrt{2}}$

D 1

(Total 1 mark)

Q3. Charged particles, each of mass m and charge Q, travel at a constant speed in a circle of radius r in a uniform magnetic field of flux density B.
Which expression gives the frequency of rotation of a particle in the beam?

A $\frac{BQ}{2\pi m}$

B $\frac{BQ}{m}$

C $\frac{BQ}{\pi m}$ ⬭

D $\frac{2\pi BQ}{m}$ ⬭

(Total 1 mark)

Q4. The path followed by an electron of momentum p, carrying charge $-e$, which enters a magnetic field at right angles, is a circular arc of radius r.

What would be the radius of the circular arc followed by an α particle of momentum $2p$, carrying charge $+2e$, which entered the same field at right angles?

A $\frac{r}{2}$

B r

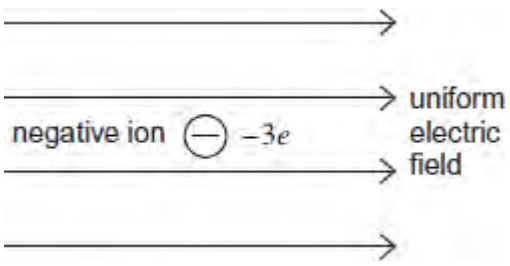
C $2r$

D $4r$

(Total 1 mark)

Q5.(a) **Figure 1** shows a negative ion which has a charge of $-3e$ and is free to move in a uniform electric field. When the ion is accelerated by the field through a distance of 63 mm parallel to the field lines its kinetic energy increases by 4.0 × 10sup class="xsmall">–16 J.

Figure 1



(i) State and explain the direction of the electrostatic force on the ion.

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(2)

(ii) Calculate the magnitude of the electrostatic force acting on the ion.

magnitude of electrostatic force ..... N

(2)

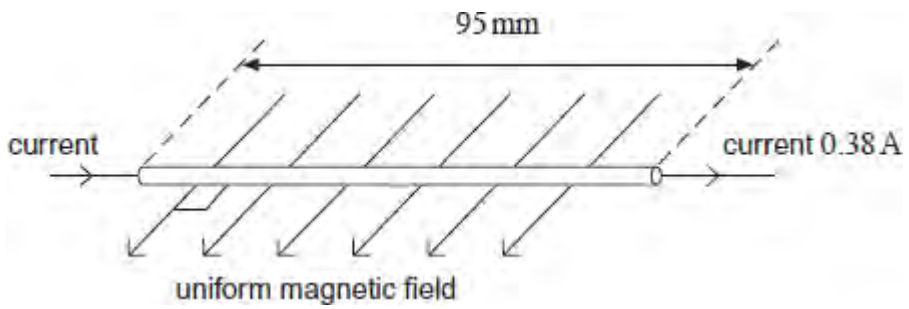
(iii) Calculate the electric field strength.

electric field strength ..... NC^{-1}

(1)

(b) **Figure 2** shows a section of a horizontal copper wire carrying a current of 0.38 A. A horizontal uniform magnetic field of flux density B is applied at right angles to the wire in the direction shown in the figure.

Figure 2



(i) State the direction of the magnetic force that acts on the moving electrons in the wire as a consequence of the current and explain how you arrive at your answer.

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(2)

(ii) Copper contains 8.4×10^{28} free electrons per cubic metre. The section of wire in **Figure 2** is 95 mm long and its cross-sectional area is 5.1×10^{-6} m^2. Show that there are about 4×10^{22} free electrons in this section of wire.

(1)

(iii) With a current of 0.38 A, the average velocity of an electron in the wire is5.5×10^{-6} m s^{-1} and the average magnetic force on one electron is 1.4×10^{-25} N. Calculate the flux density B of the magnetic field.

flux density ..... T

(2)

(Total 10 marks)

Q6.(a) (i) State **two** situations in which a charged particle will experience no magnetic force when placed in a magnetic field.

first situation.....

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second situation.....

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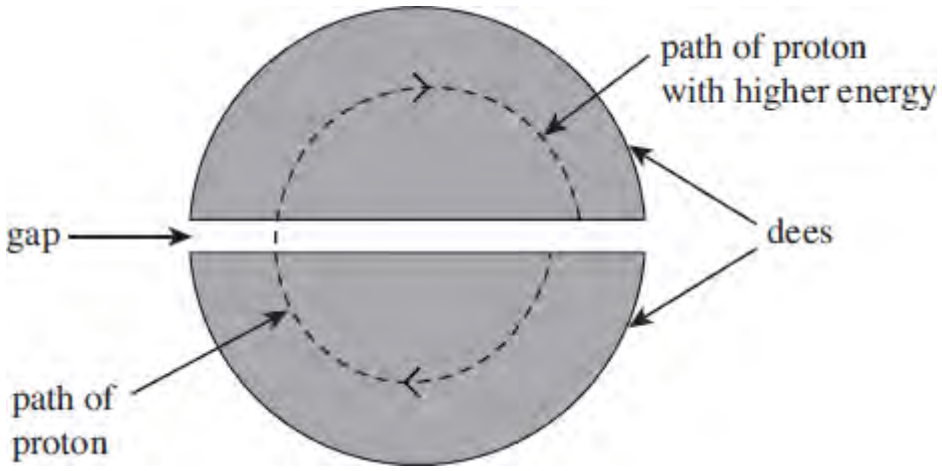
(2)

(ii) A charged particle moves in a circular path when travelling perpendicular to a uniform magnetic field. By considering the force acting on the charged particle, show that the radius of the path is proportional to the momentum of the particle.

(2)

(b) In a cyclotron designed to produce high energy protons, the protons pass repeatedly between two hollow D-shaped containers called 'dees'. The protons are acted on by a uniform magnetic field over the whole area of the dees. Each proton therefore moves in a semi-circular path at constant speed when inside a dee. Every time a proton crosses the gap between the dees it is accelerated by an alternating electric field applied between the dees. The diagram below shows a plan view of this arrangement.



(i) State the direction in which the magnetic field should be applied in order for the protons to travel along the semicircular paths inside each of the dees as shown in the diagram above.

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(1)

(ii) In a particular cyclotron the flux density of the uniform magnetic field is 0.48 T. Calculate the speed of a proton when the radius of its path inside the dee is

190 mm.

speed ..... ms^{-1}

(2)

(iii) Calculate the time taken for this proton to travel at constant speed in a semicircular path of radius 190 mm inside the dee.

time ..... s

(2)

(iv) As the protons gain energy, the radius of the path they follow increases steadily, as shown in the diagram above. Show that your answer to part (b)(iii) does not depend on the radius of the proton's path.

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(2)

(c) The protons leave the cyclotron when the radius of their path is equal to the outer radius of the dees. Calculate the maximum kinetic energy, in Me V, of the protons accelerated by the cyclotron if the outer radius of the dees is 470 mm.

maximum kinetic energy ..... Me V

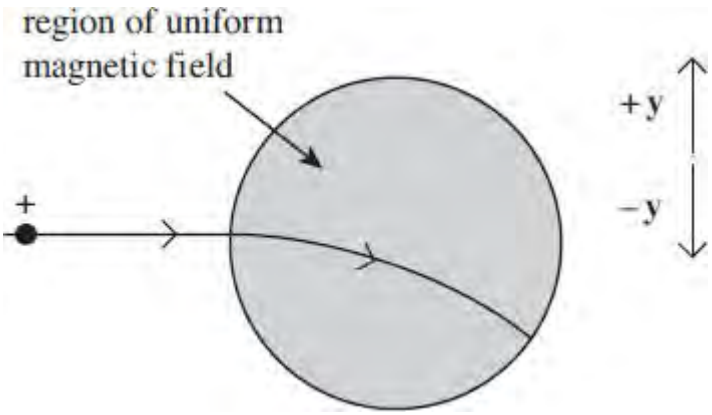
(3)
(Total 14 marks)

Q7. Which line, **A** to **D**, in the table correctly describes the trajectory of charged particles which enter separately, at right angles, a uniform electric field, and a uniform magnetic field?

	uniform electric field	**uniform magnetic field**
A	parabolic	circular
B	circular	parabolic
C	circular	circular
D	parabolic	parabolic

(Total 1 mark)

Q8. A beam of positive ions enters a region of uniform magnetic field, causing the beam to change direction as shown in the diagram.



What is the direction of the magnetic field?

A out of the page and perpendicular to it

B into the page and perpendicular to it

C in the direction indicated by $+y$

D in the direction indicated by -*y*

(Total 1 mark)

Q9. The Large Hadron Collider (LHC) uses magnetic fields to confine fast-moving charged particles travelling repeatedly around a circular path. The LHC is installed in an underground circular tunnel of circumference 27 km.

(a) In the presence of a suitably directed uniform magnetic field, charged particles move at constant speed in a circular path of constant radius. By reference to the force acting on the particles, explain how this is achieved and why it happens.

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(4)

(b) (i) The charged particles travelling around the LHC may be protons. Calculate the centripetal force acting on a proton when travelling in a circular path of circumference 27 km at one-tenth of the speed of light. Ignore relativistic effects.

answer = ... N

(3)

(ii) Calculate the flux density of the uniform magnetic field that would be required to produce this force. State an appropriate unit.

answer = ... unit .....

(3)

(c) The speed of the protons gradually increases as their energy is increased by the LHC.
State and explain how the magnetic field in the LHC must change as the speed of the protons is increased.

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(2)
(Total 12 marks)

Q10. When a β particle moves at right angles through a uniform magnetic field it experiences a force *F*. An α particle moves at right angles through a magnetic field of twice the magnetic flux density with velocity one tenth the velocity of the β particle. What is the magnitude of the force on the α particle?

A 0.2 *F*
B 0.4 *F*
C 0.8 *F*
D 4.0 *F*

(Total 1 mark)

Q11. Charged particles, each of mass m and charge Q, travel at a constant speed in a circle of radius r in a uniform magnetic field of flux density B. Which expression gives the frequency of rotation of a particle in the beam?

A $\frac{BQ}{2\pi m}$

B $\frac{BQ}{m}$

C $\frac{BQ}{\pi m}$

D $\frac{2\pi BQ}{m}$

(Total 1 mark)

Q12. Two charged particles, P and Q, move in circular orbits in a magnetic field of uniform flux density. The particles have the same charge but the mass of P is less than the mass of Q. T_P is the time taken for particle P to complete one orbit and T_Q the time for particle Q to complete one orbit. Which one of the following is correct?

A $T_P = T_Q$

B $T_P > T_Q$

C $T_P < T_Q$

D $T_P - T_Q = 1$

(Total 1 mark)