Name:

Date:

# MAGNETIC FIELDS
# TEST 2

# A2-Level

Mark | Grade

## PHYSICS

For this paper you must have:

- Ruler
- Pencil and Rubber
- Scientific calculator, which you are expected to use when appropriate

## Instructions

- Answer all questions
- Answer questions in the space provided
- All working must be shown

## Information

- The marks for the questions are shown in brackets

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

first situation ______________________________________________

______________________________________________

______________________________________________

______________________________________________

second situation ______________________________________________

______________________________________________

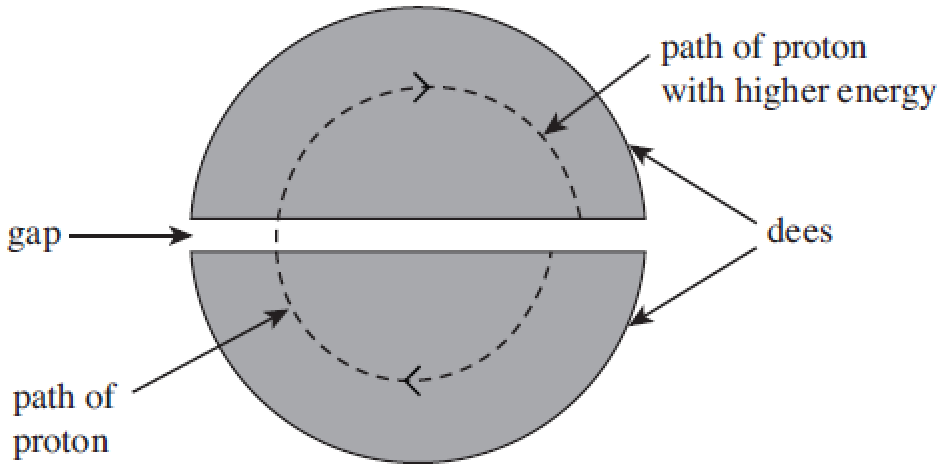
______________________________________________

**(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.

___________________________________________________________________

**(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.

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

**(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)**

**2** (a) State Lenz's law.

______________________________________________

______________________________________________

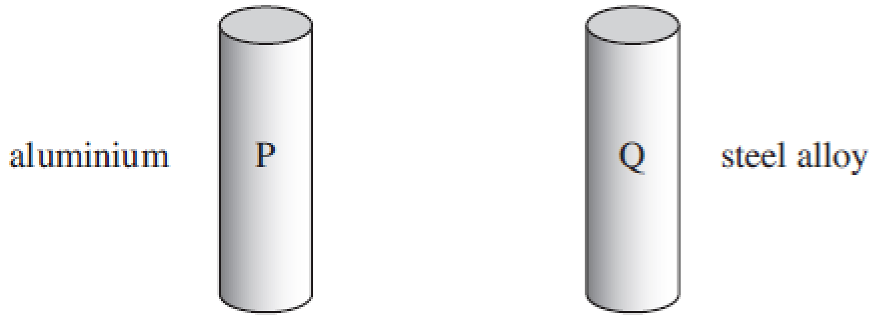
______________________________________________

______________________________________________

**(2)**

(b) **Figure 1** shows two small, solid metal cylinders, **P** and **Q**. **P** is made from aluminium. **Q** is made from a steel alloy.

**Figure 1**




(i) The dimensions of **P** and **Q** are identical but **Q** has a greater mass than **P**. Explain what material property is responsible for this difference.

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**(1)**

(ii) When **P** and **Q** are released from rest and allowed to fall freely through a vertical distance of 1.0 m, they each take 0.45 s to do so. Justify this time value and explain why the times are the same.

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

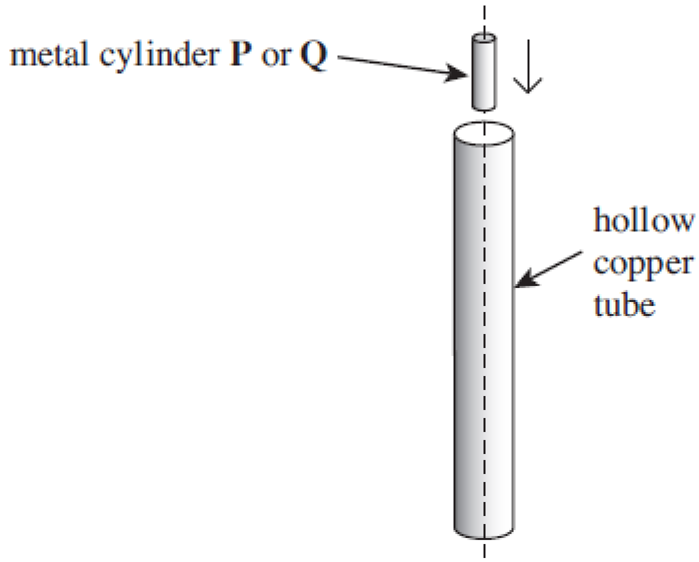
______________________________________________________________________

______________________________________________________________________

**(2)**

(c) The steel cylinder **Q** is a strong permanent magnet. **P** and **Q** are released separately from the top of a long, vertical copper tube so that they pass down the centre of the tube, as shown in **Figure 2**.

**Figure 2**




The time taken for **Q** to pass through the tube is much longer than that taken by **P**.

(i) Explain why you would expect an emf to be induced in the tube as **Q** passes through it.

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

**(2)**

(ii) State the consequences of this induced emf, and hence explain why **Q** takes longer than **P** to pass through the tube.

___

___

___

___

___

___

___

___

**(3)**

(d) The copper tube is replaced by a tube of the same dimensions made from brass. The resistivity of brass is much greater than that of copper. Describe and explain how, if at all, the times taken by **P** and **Q** to pass through the tube would be affected.

P: ___

___

___

___

Q: ___

___

___

___

**(3)**

**(Total 13 marks)**

**3** 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.

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

**(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.

___

___

___

___

___

**(2)**

**(Total 12 marks)**

**4** (a) The equation $F = BQv$ may be used to calculate magnetic forces.

(i) State the condition under which this equation applies.

___

___

**(1)**

(ii) Identify the physical quantities that are represented by the four symbols in the equation.

$F$ ___

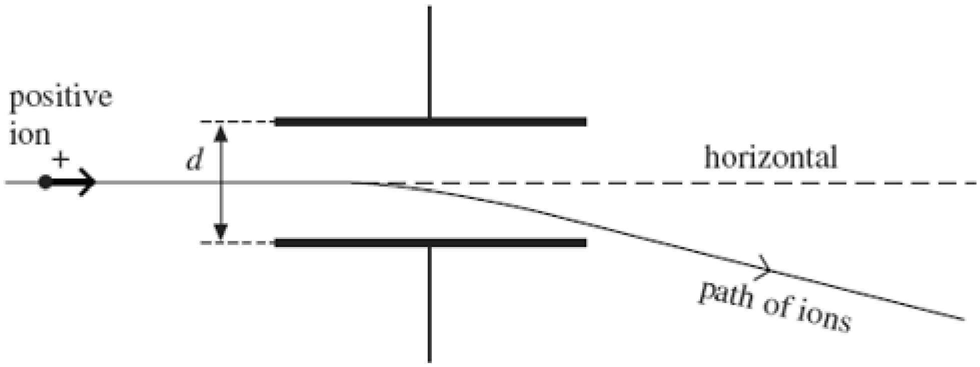
$B$ ___

$Q$ ___

$v$ ___

**(1)**

(b) The figure below shows the path followed by a stream of identical positively charged ions, of the same kinetic energy, as they pass through the region between two charged plates. Initially the ions are travelling horizontally and they are then deflected downwards by the electric field between the plates.




While the electric field is still applied, the path of the ions may be restored to the horizontal, so that they have no overall deflection, by applying a magnetic field over the same region as the electric field. The magnetic field must be of suitable strength and has to be applied in a particular direction.

(i) State the direction in which the magnetic field should be applied.

___________________________________________________________________

**(1)**

(ii) Explain why the ions have no overall deflection when a magnetic field of the required strength has been applied.

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

**(2)**

(iii) A stream of ions passes between the plates at a velocity of $1.7 \times 10^5 ms^{-1}$. The separation *d* of the plates is 65 mm and the pd across them is 48 V. Calculate the value of *B* required so that there is no overall deflection of the ions, stating an appropriate unit.

answer = ______________________

**(4)**

(c) Explain what would happen to ions with a velocity higher than $1.7 \times 10^5 ms^{-1}$ when they pass between the plates at a time when the conditions in part (b)(iii) have been established.

______________________________________________________________

______________________________________________________________

______________________________________________________________

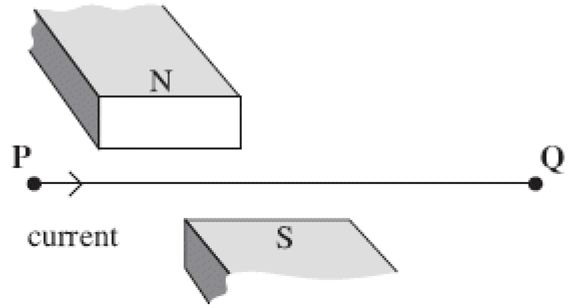
______________________________________________________________

______________________________________________________________

**(2)**

**(Total 11 marks)**

**5** The figure below shows a horizontal wire, held in tension between fixed points at **P** and **Q**. A short section of the wire is positioned between the pole pieces of a permanent magnet, which applies a uniform horizontal magnetic field at right angles to the wire. Wires connected to a circuit at **P** and **Q** allow an electric current to be passed through the wire.




(a) (i) State the direction of the force on the wire when there is a direct current from **P** to **Q**, as shown in the figure above.

___________________________________________________________________

**(1)**

(ii) In a second experiment, an alternating current is passed through the wire. Explain why the wire will vibrate vertically.

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

**(3)**

(b) The permanent magnet produces a uniform magnetic field of flux density 220 mT over a 55 mm length of the wire. Show that the maximum force on the wire is about 40 mN when there is an alternating current of rms value 2.4 A in it.

**(3)**

(c) The length of **PQ** is 0.40 m. When the wire is vibrating, transverse waves are propagated along the wire at a speed of 64 m $s^{-1}$. Explain why the wire is set into large amplitude vibration when the frequency of the a.c. supply is 80 Hz.

___

___

___

___

___

___

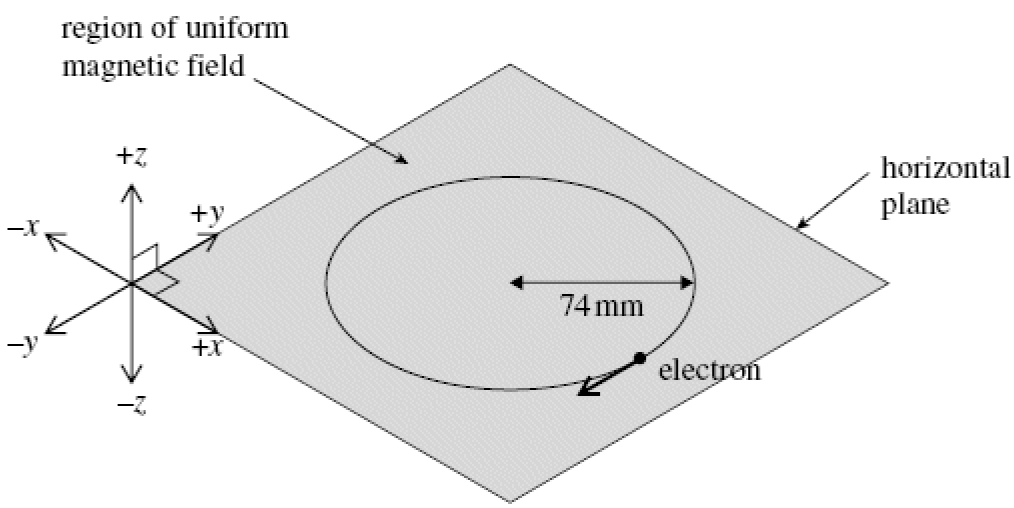
___

___

**(3)**

**(Total 10 marks)**

**6** When travelling in a vacuum through a uniform magnetic field of flux density 0.43 m T, an electron moves at constant speed in a horizontal circle of radius 74 mm, as shown in the figure below.




(a) When viewed from vertically above, the electron moves clockwise around the horizontal circle. In which one of the six directions shown on the figure above, +*x*, –*x*, +*y*, –*y*, +*z* or –*z*, is the magnetic field directed?

direction of magnetic field ______________________

**(1)**

(b) Explain why the electron is accelerating even though it is travelling at constant speed.

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**(2)**

(c) (i) By considering the centripetal force acting on the electron, show that its speed is $5.6 \times 10^{6}$ m $s^{-1}$.

**(2)**

(ii) Calculate the angular speed of the electron, giving an appropriate unit.

answer = ______________________

**(2)**

(iii) How many times does the electron travel around the circle in one minute?

answer = ______________________

**(2)**

**(Total 9 marks)**

**7** Two charged particles, **P**$_1$ and **P**$_2$, follow circular paths as they move at right angles to the same uniform magnetic field. Both particles are travelling at the same speed.

The radius of the path travelled by **P**$_1$ is twice the radius of the path travelled by **P**$_2$.

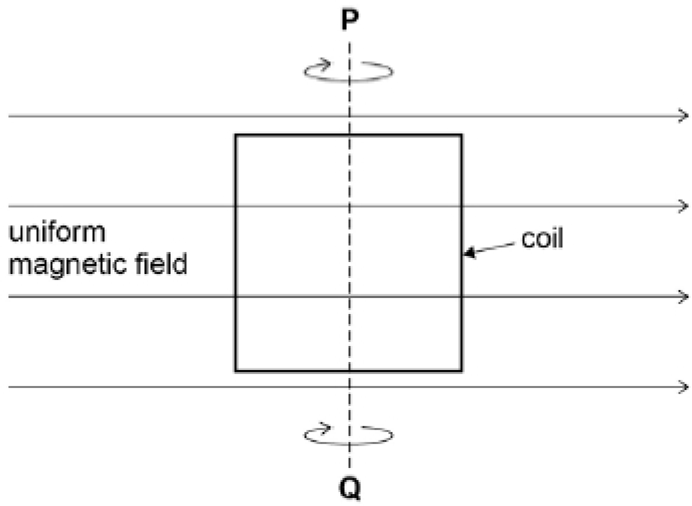
The mass of **P**$_1$ is $m$ and its charge is $q$.

What is the mass of **P**$_2$ and the charge of **P**$_2$?

| | **Mass of P$_2$** | **Charge of P$_2$** | |
|---|---|---|---|
| **A** | $2m$ | $q$ | ☐ |
| **B** | $2m$ | $2q$ | ☐ |
| **C** | $\sqrt{2}\,m$ | $\sqrt{2}\,q$ | ☐ |
| **D** | $m$ | $2q$ | ☐ |

**(Total 1 mark)**

**8** A rectangular coil of area $A$ has $N$ turns of wire. The coil is in a uniform magnetic field of flux density $B$ with its plane parallel to the field lines.



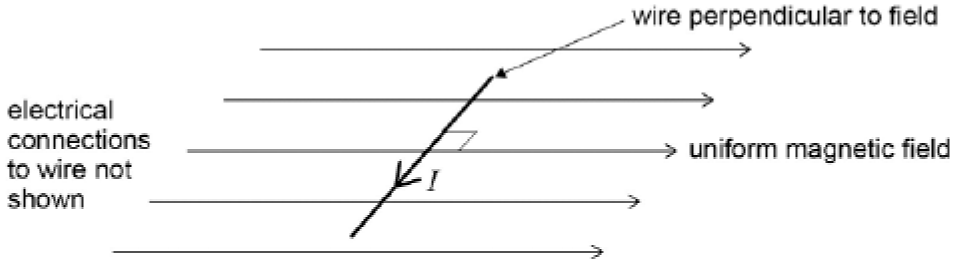

The coil is then rotated through an angle of 30° about axis **PQ**.

What are the correct initial value and correct final value of the magnetic flux linkage?

| | **Initial magnetic flux linkage** | **Final magnetic flux linkage** | |
|---|---|---|---|
| **A** | 0 | $\frac{1}{2}BAN$ | ○ |
| **B** | 0 | $BAN$ | ○ |
| **C** | $BAN$ | $\frac{1}{2}BAN$ | ○ |
| **D** | $BAN$ | $BAN$ | ○ |

**(Total 1 mark)**

**9** A horizontal straight wire of length 0.30 m carries a current of 2.0 A perpendicular to a horizontal uniform magnetic field of flux density $5.0 \times 10^{-2}$ T. The wire 'floats' in equilibrium in the field.




What is the mass of the wire?

**A** $8.0 \times 10^{-4}$ kg

**B** $3.1 \times 10^{-3}$ kg

**C** $3.0 \times 10^{-2}$ kg

**D** $8.2 \times 10^{-1}$ kg

**(Total 1 mark)**

**10** 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)**