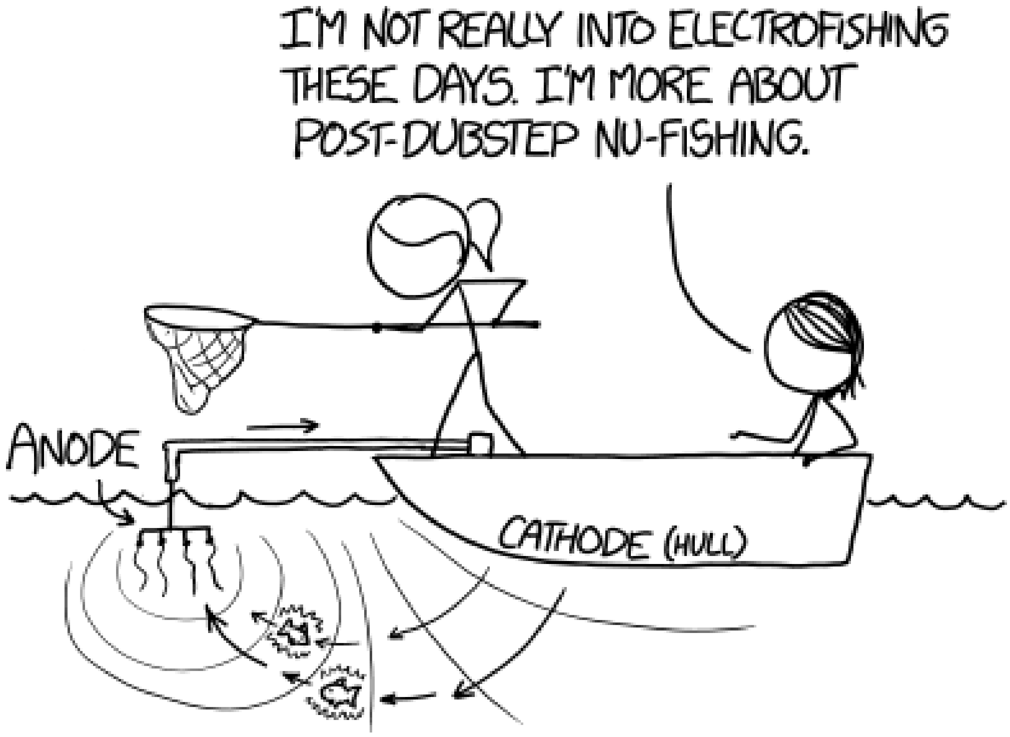
Advanced Higher Physics

Past Paper Questions

3.1 Fields



11. (a) State what is meant by the term *electric field strength*. **1**

(b) A, B, C and D are the vertices of a square of side 0·12 m.

Two +4·0 nC point charges are placed at positions B and D as shown in Figure 11A.

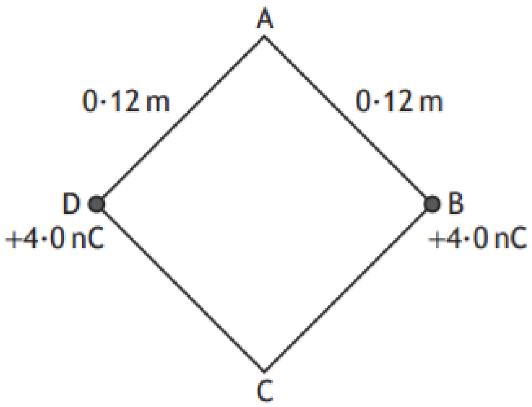


Figure 11A

(i) Show that the magnitude of the electric field strength at position A is $3{\cdot}5 \times 10^{3}\ \mathrm{N\,C^{-1}}$. **3**

(ii) A +1·9 nC point charge is placed at position A.

Calculate the magnitude of the force acting on this charge. **3**

(iii) State the direction of the force acting on this charge. **1**

(iv) A fourth point charge is now placed at position C so that the resultant force on the charge at position A is zero.

Determine the magnitude of the charge placed at position C. **4**

12. A velocity selector is used as the initial part of a larger apparatus that is designed to measure properties of ions of different elements.

The velocity selector has a region in which there is a uniform electric field and a uniform magnetic field. These fields are perpendicular to each other and also perpendicular to the initial velocity v of the ions.

This is shown in Figure 12A.

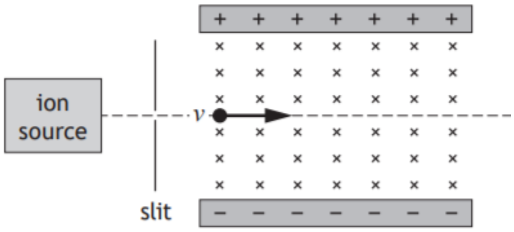


Figure 12A

A beam of chlorine ions consists of a number of isotopes including $^{35}Cl^{+}$.

The magnitude of the charge on a $^{35}Cl^{+}$ ion is $1{\cdot}60 \times 10^{-19}$ C.

The magnitude of electric force on a $^{35}Cl^{+}$ chlorine ion is $4{\cdot}00 \times 10^{-15}$ N.

The ions enter the apparatus with a range of speeds.

The magnetic induction is 115 mT.

(a) State the direction of the magnetic force on a $^{35}Cl^{+}$ ion. **1**

(b) By considering the electric and magnetic forces acting on a $^{35}Cl^{+}$ ion, determine the speed of the $^{35}Cl^{+}$ ions that will pass through the apparatus without being deflected. **3**

(c) $^{35}Cl^{+}$ ions that are travelling at a velocity less than that determined in (b) are observed to follow the path shown in Figure 12B.

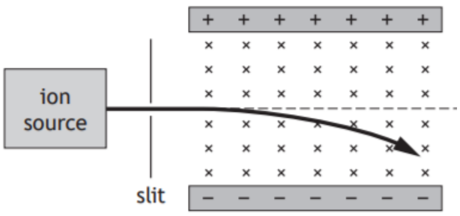


Figure 12B

Explain, in terms of their velocity, why these ions follow this path. **2**

(d) $^{37}Cl^{2+}$ ions are also present in the beam. $^{37}Cl^{2+}$ ions have a greater mass and a greater charge than $^{35}Cl^{+}$ ions. Some $^{37}Cl^{2+}$ ions also pass through the apparatus without being deflected.

State the speed of these ions.

You must justify your answer. **2**

10. (*a*) A teacher investigates the electric field between two parallel metal plates X and Y using the apparatus shown in Figure 10A.

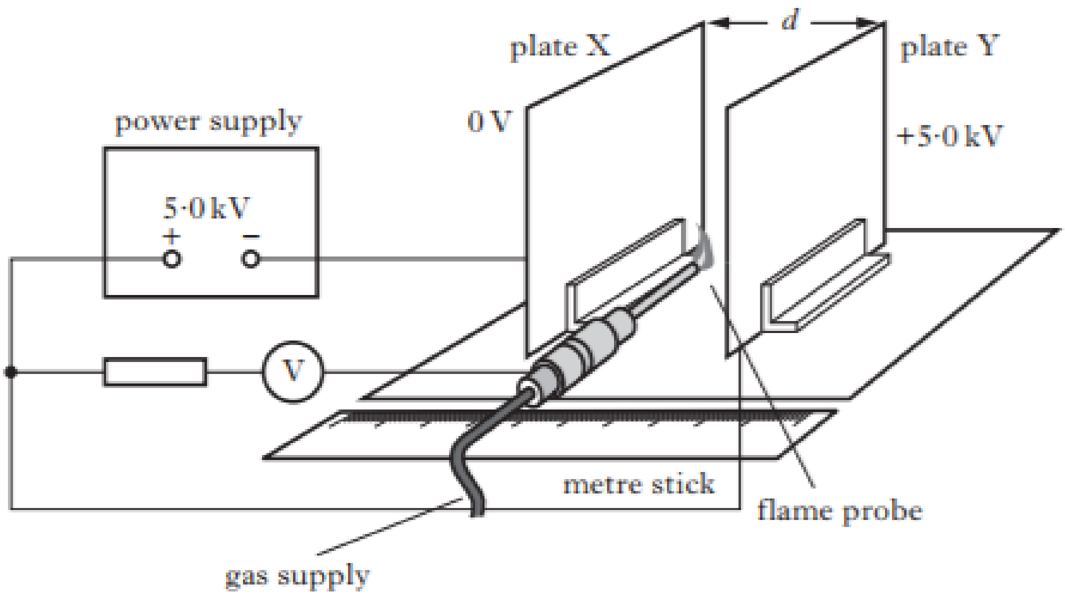


Figure 10A

The plates are connected to a 5·0 kV supply and are separated by a distance d.

A calibrated flame probe and voltmeter measure the potential relative to plate X. The probe is placed at different points between the plates. The distance from plate X and the potential at each point are measured.

The results are used to plot the graph shown in Figure 10B.

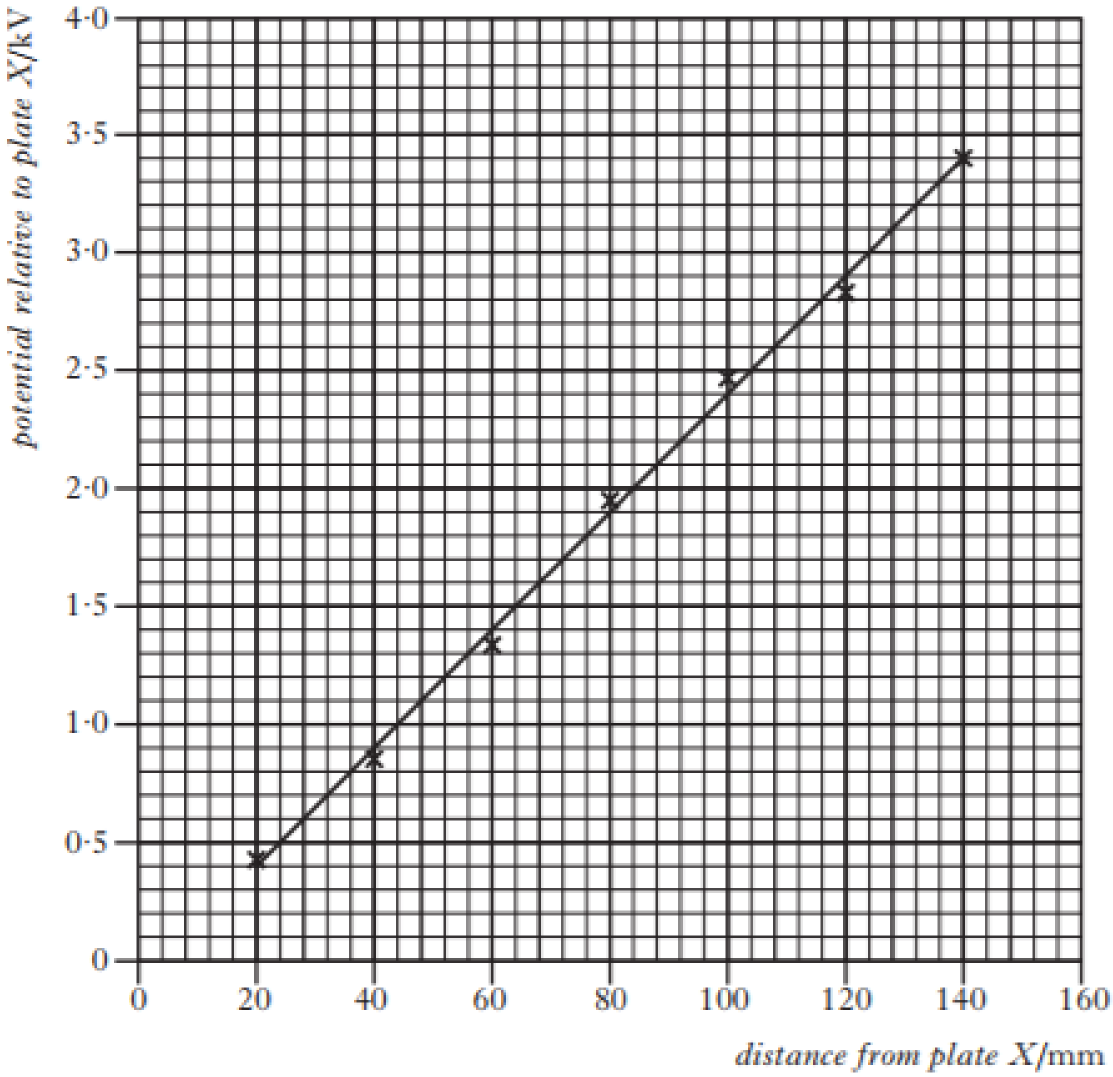


Figure 10B

(i) The electric field strength in the region between the plates is considered to be uniform. Explain the meaning of the term *uniform electric field*. **1**

(ii) Using information from the graph, determine the electric field strength between the plates. **2**

(iii) Calculate the separation d of the plates. **2**

(iv) In theory the best fit line for this graph should pass through the origin. Suggest why the line on the graph in Figure 10B does not pass through the origin. **1** (*b*) In an experiment to investigate the deflection of alpha particles in an electric field a potential difference is applied across two parallel metal plates.

An alpha particle moving horizontally enters the region between the plates.

The alpha particle is deflected vertically by a distance *s* as shown in Figure 10C.

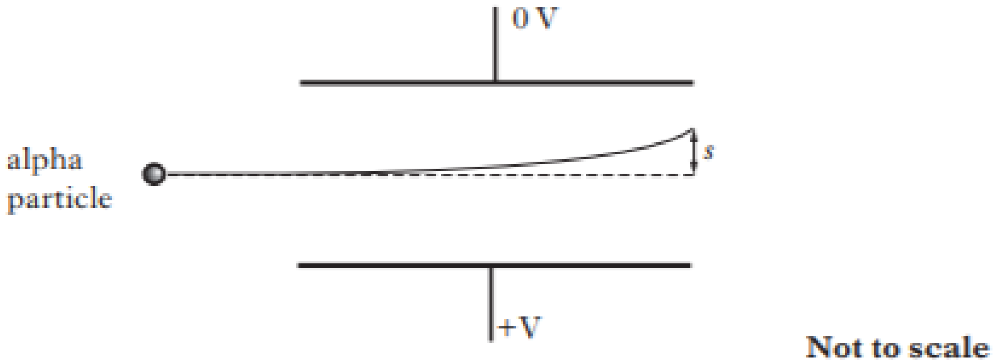


Figure 10C

The separation of the parallel plates is now increased. An alpha particle enters the electric field at the same point and with the same velocity as before.

What effect does this have on the magnitude of the deflection *s*?

You must justify your answer. **2**

(8)

2015 Revised Advanced Higher

Marks

11. A geomagnetic reversal is a change in polarity of the Earth's magnetic field. On average this happens every 300 000 years. Reversals can take in excess of 1000 years to complete. During a previous reversal, the strength of the Earth's magnetic field dropped to 5% of its present value.

Figure 11 shows a computer simulation of the Earth's magnetic field during a reversal.

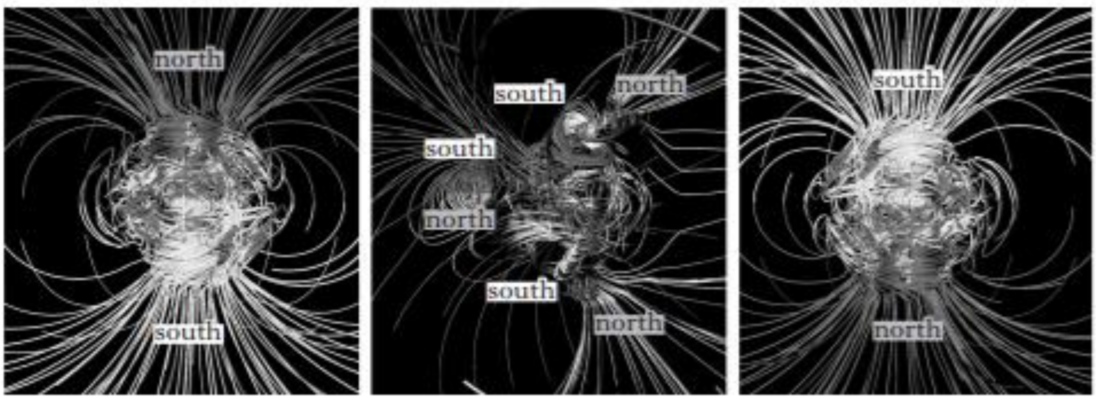


Figure 11

Use your knowledge of Physics to comment on the possible effects of such a reversal. **(3)**

2015

10. (a) Two point charges Q_1 and Q_2 are separated by a distance of 0·60 m as shown in Figure 10A. The charge on Q_1 is −8·0 nC. The electric field strength at point X is zero.

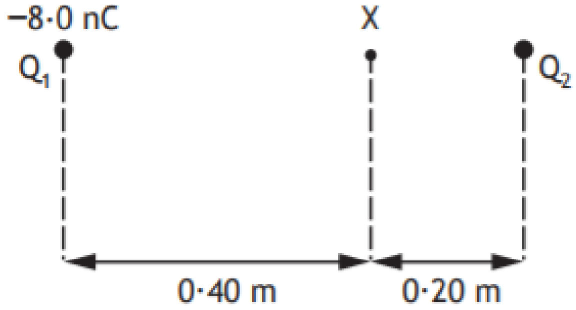


Figure 10A

(i) State what is meant by *electric field strength*. **1**

(ii) Show that the charge on Q_2 is −2·0 nC. **2**

(iii) Calculate the electrical potential at point X. **5**

(b)

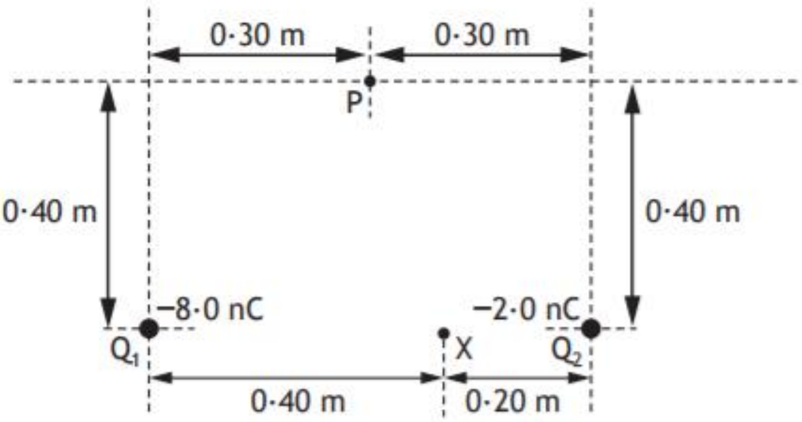


Figure 10B

(i) Calculate the electrical potential at point P. **3**

(ii) Determine the energy required to move a charge of +1·0 nC from point X to point P. **4**

Marks

12. Two students conduct a series of experiments to investigate electric and magnetic fields.

The students measure the electric field around a positive point charge Q. They measure the electric field strength E and the electric potential V at points X and Y as shown in Figure 12A.

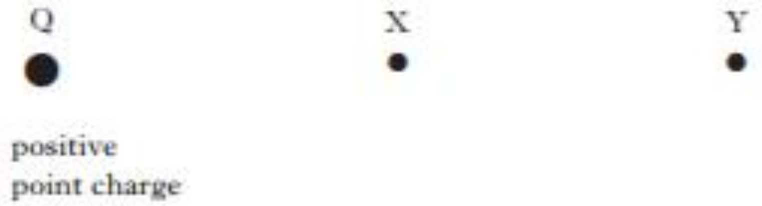


Figure 12A

The results of one set of measurements are shown in the table.

	X	Y
E / N C^{-1}	3·6	
V / V	7·2	3·6

(*a*) The first student predicts that the electric field strength at Y will be 1·8 N C^{-1}, the second predicts it will be 0·9 N C^{-1}.

Which student has made the correct prediction?

You must justify your answer. **2**

11. In a nuclear power station liquid sodium is used to cool parts of the reactor. An electromagnetic pump keeps the coolant circulating. The sodium enters a perpendicular magnetic field and an electric current, I, passes through it. A force is experienced by the sodium causing it to flow in the direction shown in Figure 11.

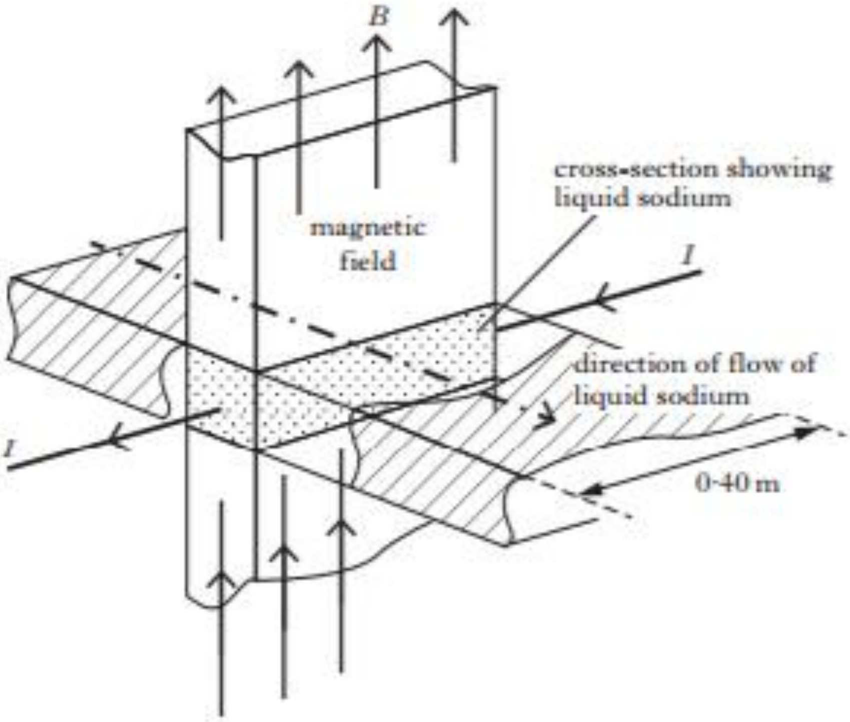


Figure 11

The magnetic induction B is 0·20 T. The current I in the sodium is 2·5 A and is perpendicular to the magnetic field.

(*a*) Calculate the force acting on the 0·40 m length of sodium within the magnetic field. **2**

(*b*) The pump is moved during maintenance and as a result the direction of the magnetic field is changed so that it is no longer perpendicular to the current. What effect does this have on the rate of flow of sodium passing through the pump?

You **must** justify your answer. **2**

(*c*) An engineer must install a long, straight, current carrying wire close to the pump and is concerned that the magnetic induction produced may interfere with the safe working of the pump.

The wire is 750 mm from the pump and carries a current of 0·60 A.

Show by calculation that the magnetic induction at this distance is negligible. **2**

(6)

Revised 2013

Marks

12. A student is investigating the electrical potential around a point charge Q. Point P is at a distance of $(0{\cdot}65 \pm 0{\cdot}02)$ m from Q as shown in Figure 12. The potential at point P is $(2{\cdot}1 \pm 0{\cdot}1)$ V.

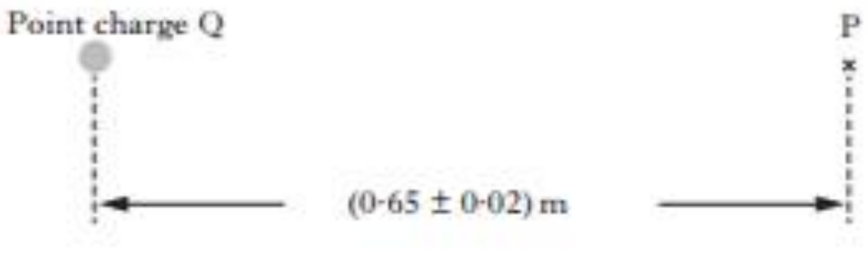


Figure 12

(*a*) Calculate the value of the point charge Q. **2**

(*b*) Calculate the absolute uncertainty in the charge. **2**

(4)

Traditional 2013

8. In 1909 Robert Millikan devised an experiment to investigate the charge on a small oil drop. Using a variable power supply he adjusted the potential difference between two horizontal parallel metal plates until an oil drop was held stationary between them as shown in Figure 8.

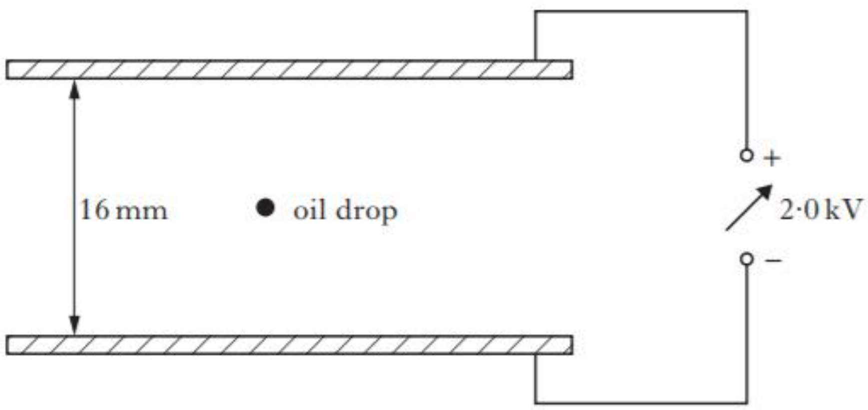


Figure 8

(*a*) What was Millikan's main conclusion from this experiment? **1**

(*b*) Draw a labelled diagram showing the forces acting on the stationary oil drop. **1**

(*c*) The parallel plates are fixed 16 mm apart. In one experiment the charge on the oil drop was found to be $2{\cdot}4 \times 10^{-18}$ C.

Calculate the mass of the oil drop. **3**

(5)

9. The charge Q on a hollow metal sphere is $(-15 \cdot 0 \pm 0 \cdot 4)\,\mu C$. The sphere has a radius r of $(0 \cdot 65 \pm 0 \cdot 02)\,m$.

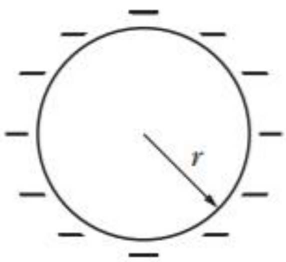


Figure 9

(a) Calculate the electrostatic potential at the surface of the metal sphere. **2**

(b) Calculate the absolute uncertainty in the electrostatic potential. **2**

(c) State the electrostatic potential at the centre of the sphere. **1**

(5)

Traditional 2012

Marks

5. (a) An uncharged conducting sphere is suspended from a fixed point X by an insulating thread of negligible mass as shown in Figure 5A. A charged plate is then placed close to the sphere as shown in Figure 5B.

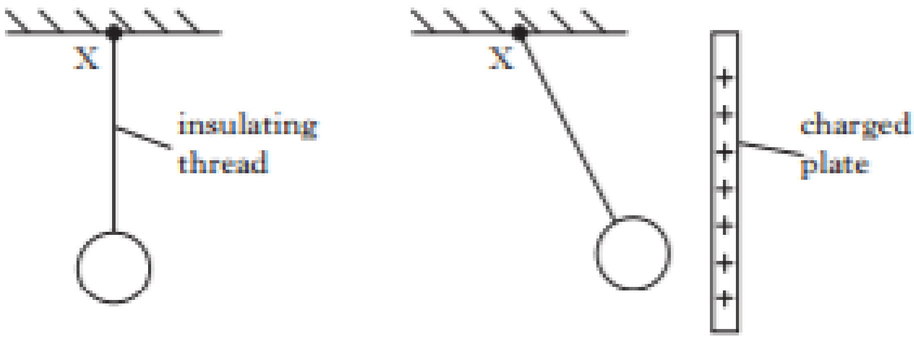


Figure 5A Figure 5B

Explain why the uncharged sphere is attracted to the charged plate. You may use a diagram to help explain your answer. **1** (*b*) The sphere is now given a negative charge of 140 nC and placed between a pair of parallel plates with a separation of 42 mm as shown in Figure 5C.

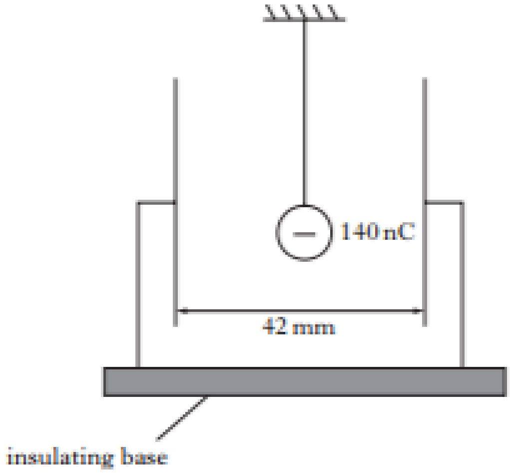


Figure 5C

When a potential difference is applied to the plates the sphere is deflected through an angle θ as shown in Figure 5D.

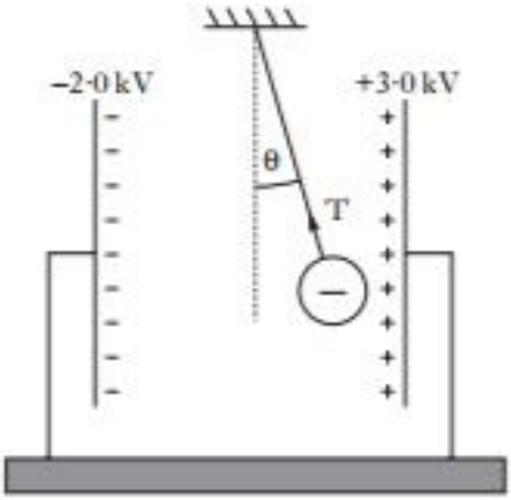


Figure 5D

(i) Calculate the electric field strength between the plates. **2**

(ii) Calculate the electrostatic force acting on the sphere due to the electric field. **2**

(iii) The mass of the sphere is $4{\cdot}0 \times 10^{-3}$ kg.

Calculate the magnitude and direction of the tension T in the supporting thread. **3**

(*c*) The plates are now moved a short distance to the right without touching the sphere. The distance between the plates is unchanged.

Does the angle θ increase, decrease or stay the same? Justify your answer. **2**

(10)

Marks

5. A helium-filled metal foil balloon with a radius of 0·35 m is charged by induction. The charge Q on the surface of the balloon is +120 μC. The balloon is considered to be perfectly spherical.

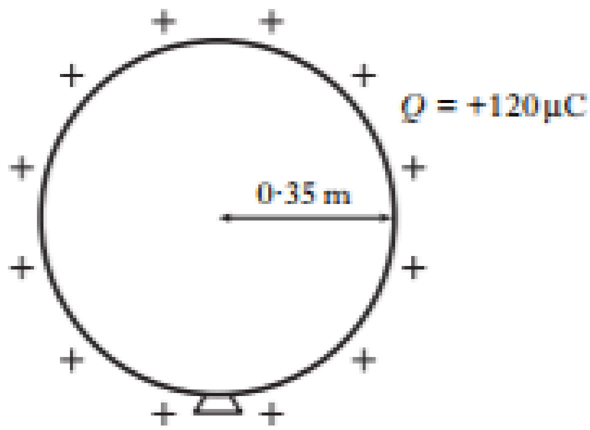


Figure 5A

(a) (i) Using diagrams, or otherwise, describe a procedure to charge the balloon by induction so that an evenly distributed positive charge is left on the balloon. **2**

(ii) Calculate the electric field strength at the surface of the balloon. **2**

(iii) Sketch a graph of the electric field strength against distance from the centre of the balloon to a point well beyond the balloon's surface. No numerical values are required. **1**

(b) Two parallel charged plates are separated by a distance d. The potential difference between the plates is V.

Lines representing the electric field between the plates are shown in Figure 5B.

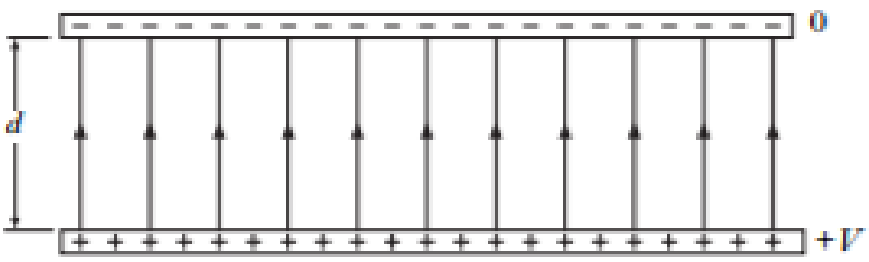


Figure 5B

(i) By considering the work done in moving a point charge q between the plates, derive an expression for the electric field strength E between the plates in terms of V and d. **2**

Marks

7. (*a*) Two very long straight wires X and Y are suspended parallel to each other at a distance r apart. The current in X is I_1 and the current in Y is I_2 as shown in Figure 7A.

Figure 7A

(i) State the direction of the magnetic force acting on wire X. **Justify your answer**. **2**

(ii) The wires are separated by a distance of 360 mm and each wire carries a current of 4·7A. Calculate the force per unit length which acts on each wire. **2**

(*b*) A student investigating the force on a current carrying wire placed perpendicular to a uniform magnetic field obtains the following measurements and uncertainties.

Force (N)	0·0058 0·0061 0·0063 0·0057 0·0058 0·0062 Scale reading uncertainty Calibration uncertainty	 ± 1 digit ± 0·00005 N
Current (A)	Reading Absolute uncertainty	1·98 A ± 0·02 A
Length (m)	Reading Absolute uncertainty	0·054 m ± 0·0005 m

(i) From this data, calculate the magnetic induction, B. **3**

(ii) Calculate the absolute uncertainty in the value of the force. **3**

(iii) Calculate the overall absolute uncertainty in the value of the magnetic induction. **3**

(13)

Marks

6. A hollow metal sphere, radius 1·00 mm, carries a charge of $-1{\cdot}92 \times 10^{-12}$ C.

(*a*) Calculate the electric field strength, *E*, at the surface of the sphere. **2**

(*b*) Four students sketch graphs of the variation of electric field strength with distance from the centre of the sphere as shown in Figure 6A.

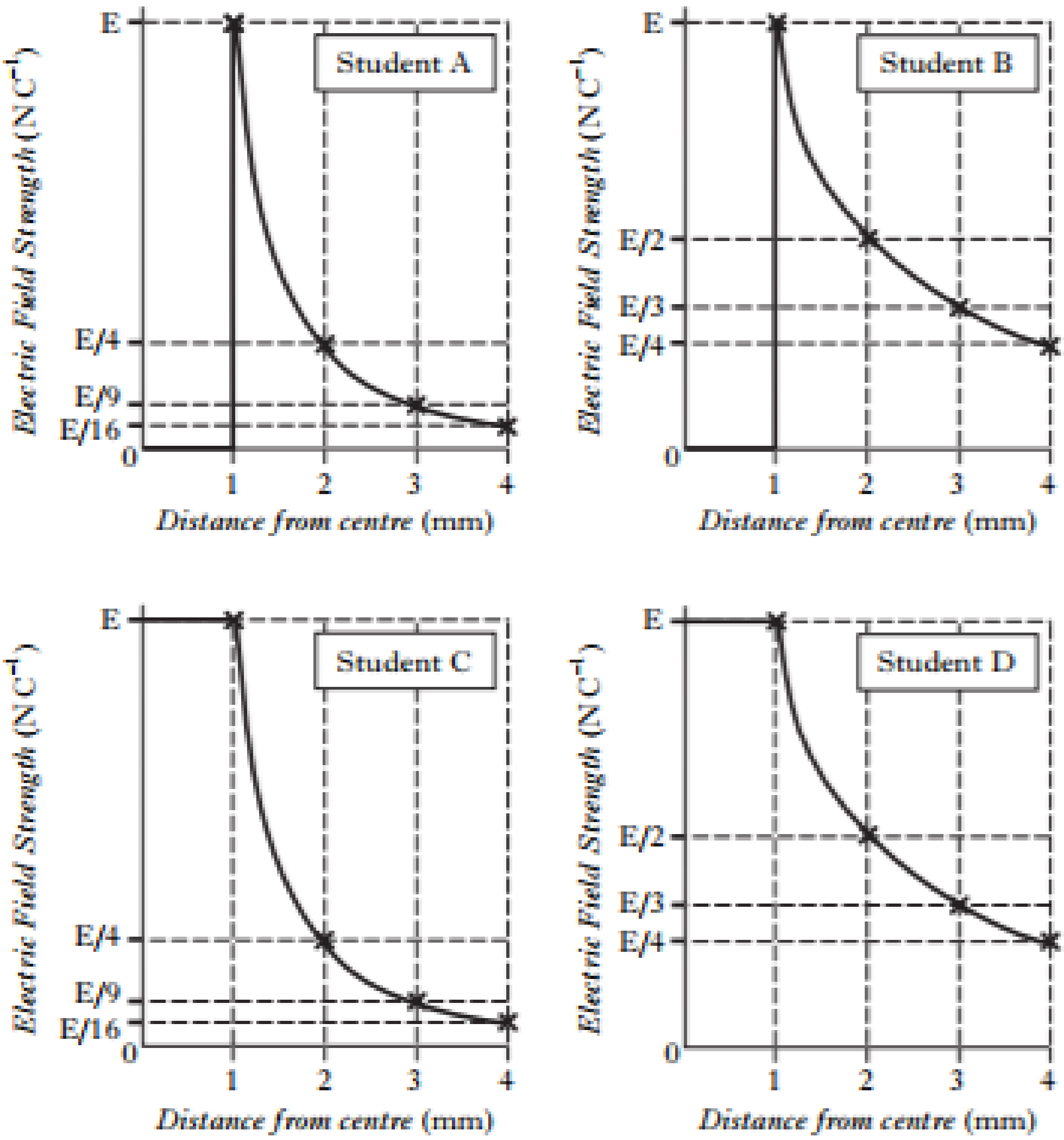


Figure 6A

(i) Which student has drawn the correct graph? **1**

(ii) Give **two** reasons to support your choice. **2**

Marks

6. **(continued)**

(*c*) Four point charges, Q_1, Q_2, Q_3 and Q_4, each of value $-2{\cdot}97 \times 10^{-8}$ C, are held in a square array. The hollow sphere with charge $-1{\cdot}92 \times 10^{-12}$ C is placed 30·0 mm above the centre of the array where it is held stationary by an electrostatic force.
The hollow sphere is 41·2 mm from each of the four charges as shown in Figure 6B.

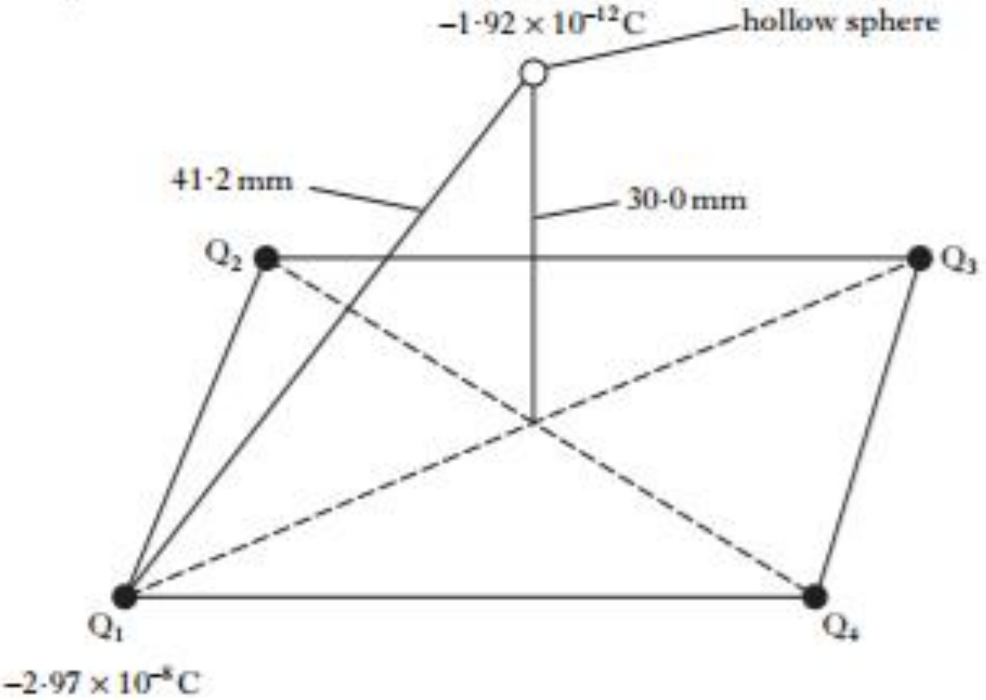


Figure 6B

(i) Calculate the magnitude of the force acting on the sphere due to charge Q_1. **2**

(ii) Calculate the vertical component of this force. **2**

(iii) Calculate the resultant electrostatic force on the sphere due to the whole array. **1**

(iv) Calculate the mass of the sphere. **2**

(12)

[Turn over

4. (*a*) A point charge of +4·0 μC is shown in Figure 4A.

Figure 4A

(i) Copy Figure 4A and draw the electric field lines around this point charge. **1**

(ii) A point charge of −2·0 μC is now placed at a distance of 0·10 m from the first charge as shown in Figure 4B.

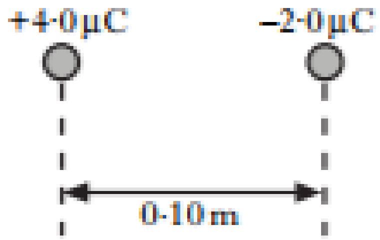


Figure 4B

Explain why the electric field strength **is not** zero at any point between these two charges. **2**

(iii) Point P is 0·24 m to the right of the second charge as shown in Figure 4C.

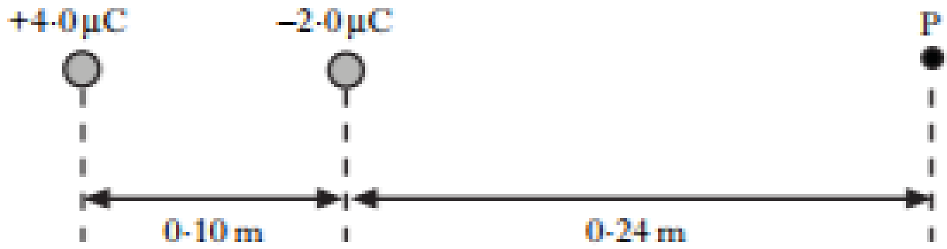


Figure 4C

Calculate the electric field strength at point P. **3**

(*b*) Two like charges experience a repulsive electrostatic force.

Explain why two protons in a nucleus do not fly apart. **2**

Marks

8. A student uses a probe to measure the magnetic induction near a long straight current carrying conductor PQ, as shown in Figure 8A.

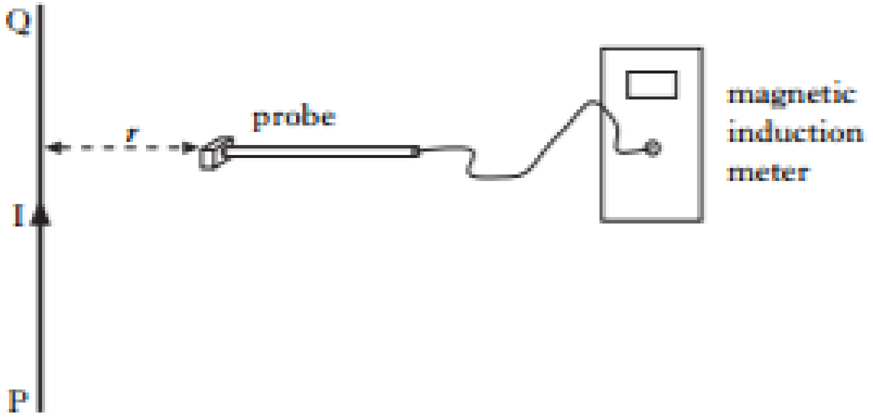


Figure 8A

The following data is obtained.

Distance r/m	Magnetic induction B/T
0·25	$1{\cdot}7 \times 10^{-7}$

(*a*) Calculate the current in the conductor PQ. **2**

(*b*) The unit of magnetic induction is the tesla. Define *one tesla*. **1**

(*c*) A second long straight conductor RS carrying a current of 2 A is placed at a distance of 0·25 m from the first conductor PQ, as shown in Figure 8B.

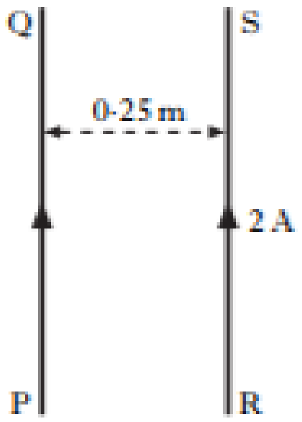


Figure 8B

Calculate the magnitude of the force per metre acting on conductor RS. **2**

(5)

[Turn over

Marks

5. (*a*) Two point charges Q_1 and Q_2 each has a charge of $-4{\cdot}0\,\mu C$. The charges are $0{\cdot}60$ m apart as shown in Figure 7.

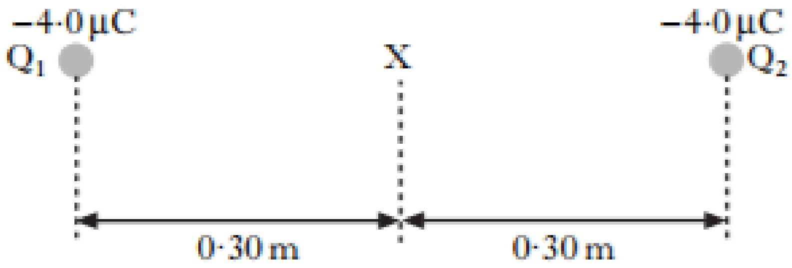


Figure 7

(i) Draw a diagram to show the electric field lines between charges Q_1 and Q_2. **1**

(ii) Calculate the electrostatic potential at point X, midway between the charges. **2**

(*b*) A third point charge Q_3 is placed near the two charges as shown in Figure 8.

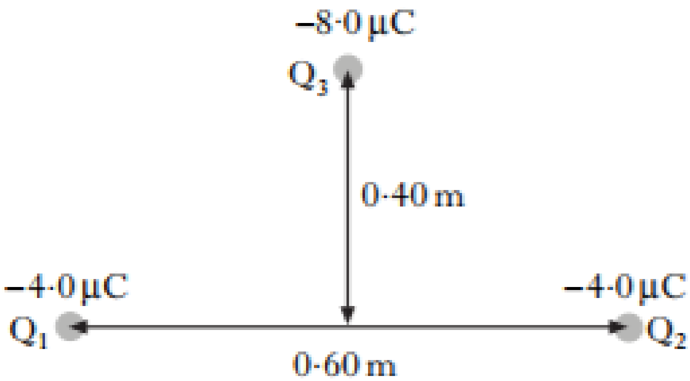


Figure 8

(i) Show that the force between charges Q_1 and Q_3 is $1{\cdot}2$ N. **2**

(ii) Calculate the **magnitude** and **direction** of the resultant force on charge Q_3 due to charges Q_1 and Q_2. **2**

(7)

Marks

8. (*a*) Two protons are separated by a distance of 22 μm.

(i) Show by calculation that the gravitational force between these protons is negligible compared to the electrostatic force. **4**

(ii) Why is the strong force negligible between these protons? **1**

(*b*) A particle of charge q travels directly towards a fixed stationary particle of charge Q.

At a large distance from charge Q the moving particle has an initial velocity v.

The moving particle momentarily comes to rest at a distance of closest approach r_c as shown in Figure 13.

Figure 13

Show that the initial velocity of the moving particle is given by

$$v = \sqrt{\frac{qQ}{2\pi\varepsilon_0 m r_c}}$$

where the symbols have their usual meaning. **2**

(*c*) An alpha particle is fired towards a target nucleus which is fixed and stationary. The initial velocity of the alpha particle is $9{\cdot}63 \times 10^6\ \mathrm{m\,s^{-1}}$ and the distance of closest approach is $1{\cdot}12 \times 10^{-13}$ m.

(i) Calculate the charge on the target nucleus. **3**

(ii) Calculate the number of protons in the target nucleus. **2**

(iii) The target is the nucleus of an element. Identify this element. **1**

(13)

Marks

5. (a) Figure 5 shows a point charge of +5·1 nC.

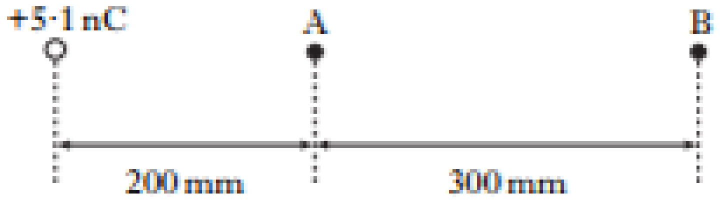


Figure 5

Point A is a distance of 200 mm from the point charge.
Point B is a distance of 300 mm from point A as shown in Figure 5.

(i) Show that the potential at point A is 230 V. **1**

(ii) Calculate the potential difference between A and B. **2**

(b) A conducting sphere on an insulating support is some distance away from a negatively charged rod as shown in Figure 6.

Figure 6

Using diagrams, or otherwise, describe a procedure to charge the sphere positively by induction. **2**

Marks

6. The shape of the Earth's magnetic field is shown in Figure 8.

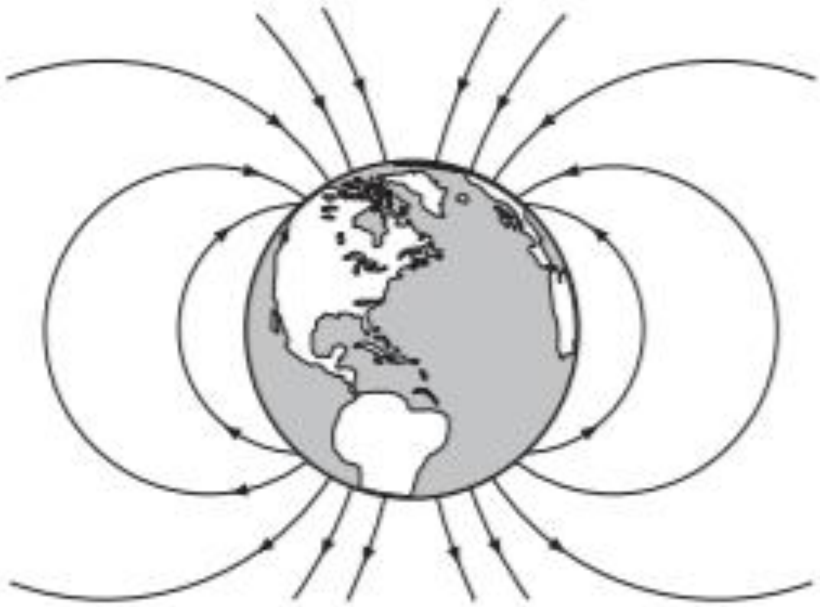


Figure 8

At a particular location in Scotland the field has a magnitude of $5{\cdot}0 \times 10^{-5}$ T directed into the Earth's surface at an angle of 69° as shown in Figure 9.

Figure 9

(*a*) Show that the component of the field perpendicular to the Earth's surface is $4{\cdot}7 \times 10^{-5}$ T. **1**

Marks

6. (continued)

(*b*) At this location a student sets up a circuit containing a straight length of copper wire lying horizontally in the North – South direction as shown in Figure 10.

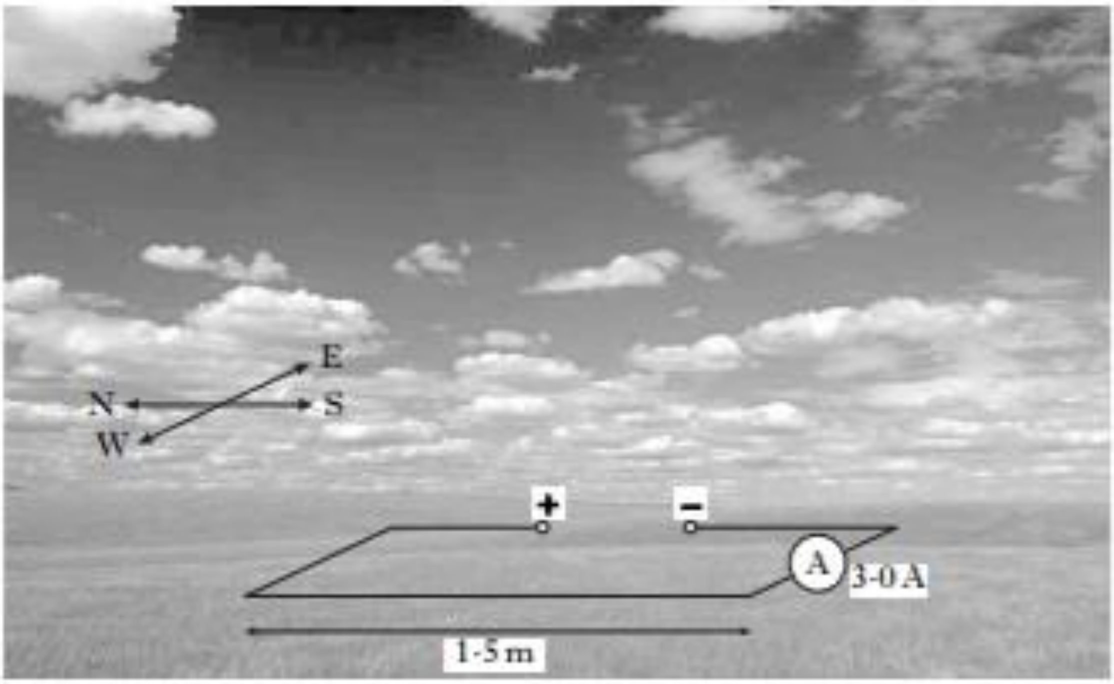


Figure 10

The length of the wire is 1·5 m and the current in the circuit is 3·0 A.

(i) Calculate the magnitude of the force acting on the wire due to the Earth's magnetic field. **2**

(ii) State the direction of this force. **1**

(*c*) The wire is now tilted through an angle of 69° so that it is parallel to the direction of the Earth's magnetic field.

Determine the force on the wire due to the Earth's magnetic field. **1**

(*d*) A long straight current carrying wire produces a magnetic field. The current in this wire is 3·0 A.

(i) Calculate the distance from the wire at which the magnitude of the magnetic field is $5 \cdot 0 \times 10^{-5}$ T. **2**

(ii) Describe the shape of this magnetic field. **1**

(8)

Marks

5. (*a*) A charged metal sphere has a diameter of 0·36 m. The electrostatic potential at the surface of the sphere is $+2{\cdot}8 \times 10^5$ V.

(i) Show that the charge on the sphere is $+5{\cdot}6 \times 10^{-6}$ C. **2**

(ii) State the electrostatic potential at a point 0·10 m from the **centre** of the sphere. **1**

(iii) (A) Calculate the electric field strength at the surface of the sphere.

(B) Sketch a graph of the electric field strength against distance from the centre of the sphere to a point well beyond the sphere's surface. No numerical values are required. **3**

(*b*) Two identical spheres, each carrying a charge of $+5{\cdot}6 \times 10^{-6}$ C, are now placed as shown in Figure 8.

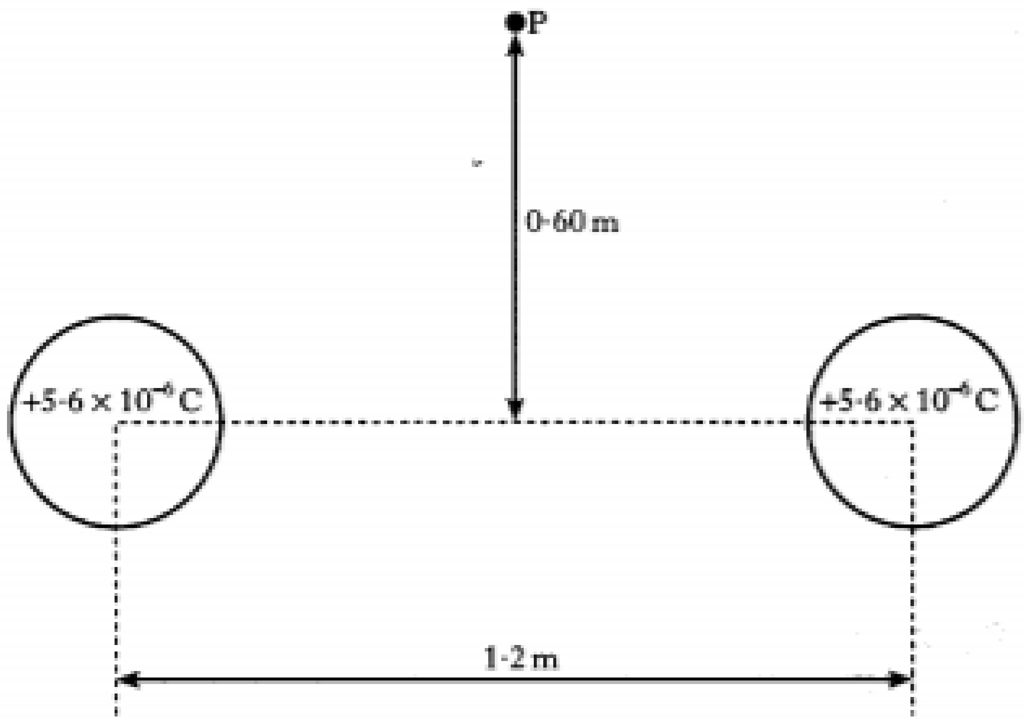


Figure 8

Point P is 0·60 m vertically above the mid-point of the line joining the centres of the two spheres.

Determine the magnitude and direction of the electric field strength at point P. **4**

Marks

6. The print head of an ink-jet printer fires a tiny drop of ink of mass $1{\cdot}2 \times 10^{-12}$ kg as it scans across the paper. The drop carries a charge of $-1{\cdot}6 \times 10^{-12}$ C and enters the space between a pair of parallel plates at a speed of $20\,\mathrm{m\,s^{-1}}$, as shown in Figure 9.

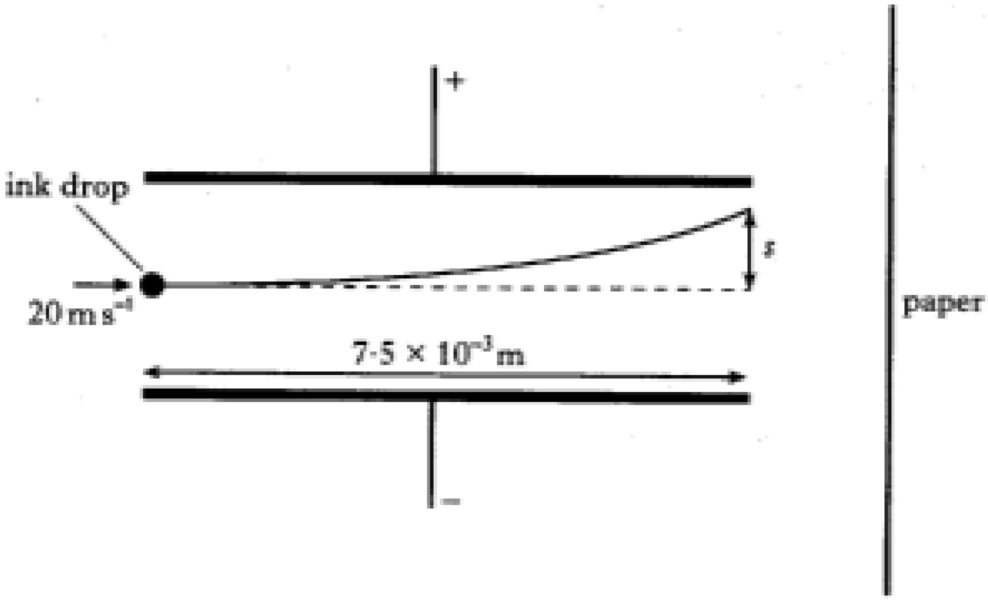


Figure 9

The length of the plates is $7{\cdot}5 \times 10^{-3}$ m and the electric field strength between them is $2{\cdot}5 \times 10^{4}\,\mathrm{N\,C^{-1}}$.

(*a*) Calculate the magnitude of the electrostatic force acting on the ink drop as it passes between the plates. **2**

(*b*) Show, by calculation, that the gravitational force acting on the drop is negligible compared to the electrostatic force. **2**

(*c*) Calculate the deflection *s* of the drop as it leaves the region between the plates. **4**

(*d*) Calculate the number of excess electrons on the ink drop. **2**

(10)

[Turn over

Marks

5. (*a*) Two point charges with values $+4{\cdot}0\,\mu C$ and $-6{\cdot}0\,\mu C$ are placed $5{\cdot}0\,mm$ apart. Point X lies on the line between the charges as shown in Figure 7.

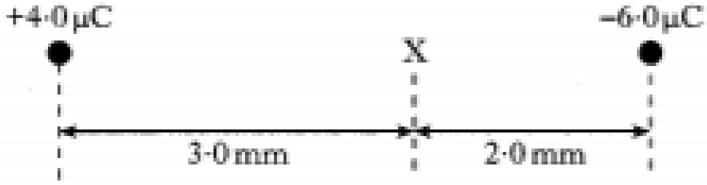


Figure 7

(i) Calculate the magnitude of the electric field strength at point X. **2**

(ii) State the direction of the electric field at point X. **1**

(*b*) A hollow uncharged metal cylinder is placed midway between two parallel plates which are connected to a d.c. power supply as shown in Figure 8.

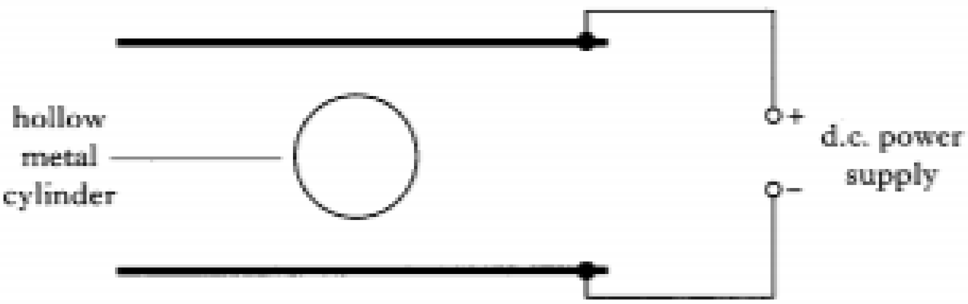


Figure 8

(i) Copy and complete the above diagram showing:

(A) the electric field lines in the space between the parallel plates; **2**

(B) the charge distribution induced on the cylinder. **1**

(ii) Coaxial cable consists of a central wire surrounded by a metal mesh, as shown in Figure 9.

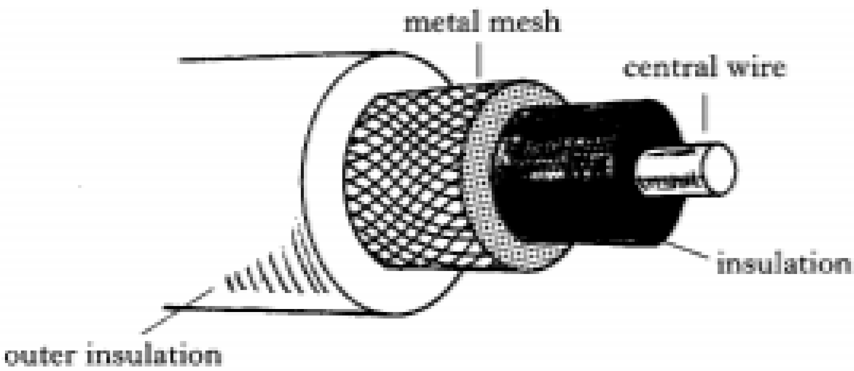


Figure 9

Explain why coaxial cable is designed in this way. **1**

(7)

Marks

6. (*a*) (i) Define the term *electric field strength*.

(ii) Two parallel plates are separated by distance *d*. The potential difference between the plates is *V*.

Derive the expression for the electric field strength *E* between the plates in terms of *V* and *d*. **3**

(*b*) The electric field pattern between two parallel metal plates is shown in Figure 6.

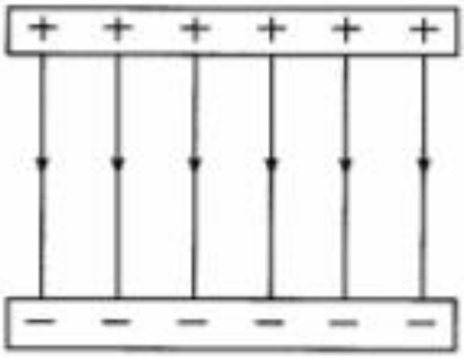


Figure 6

An uncharged, conducting sphere is placed between the plates as shown in Figure 7.

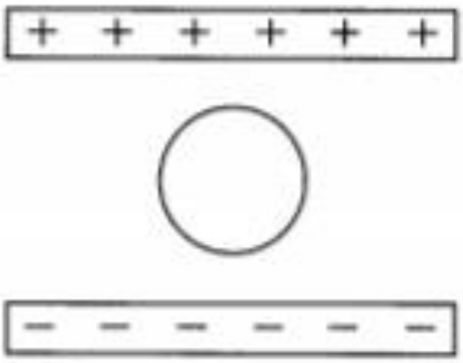


Figure 7

(i) Copy and complete Figure 7 to show the electric field pattern between the plates.

(ii) On your diagram, show the charge distribution on the sphere.

(iii) State the value of the electric field strength inside the sphere. **4**

(7)

Marks

a) State Coulomb's law for the electrostatic force between two point charges. 1

b) The two identical conducting spheres R and S, shown in Figure 8, are initially uncharged.

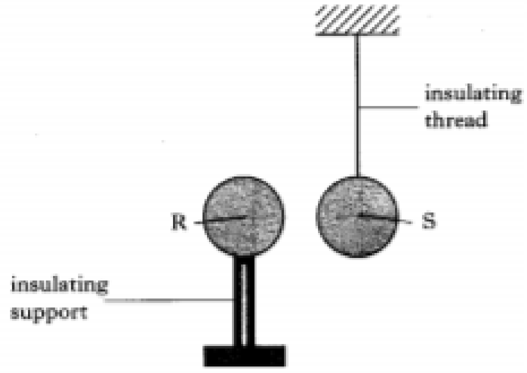


Figure 8

Describe how sphere R can be given a positive charge and sphere S an equal negative charge by induction, using a positively charged insulating rod. 2

c) Two identical conducting spheres X and Y shown in Figure 9 have equal and opposite charges.

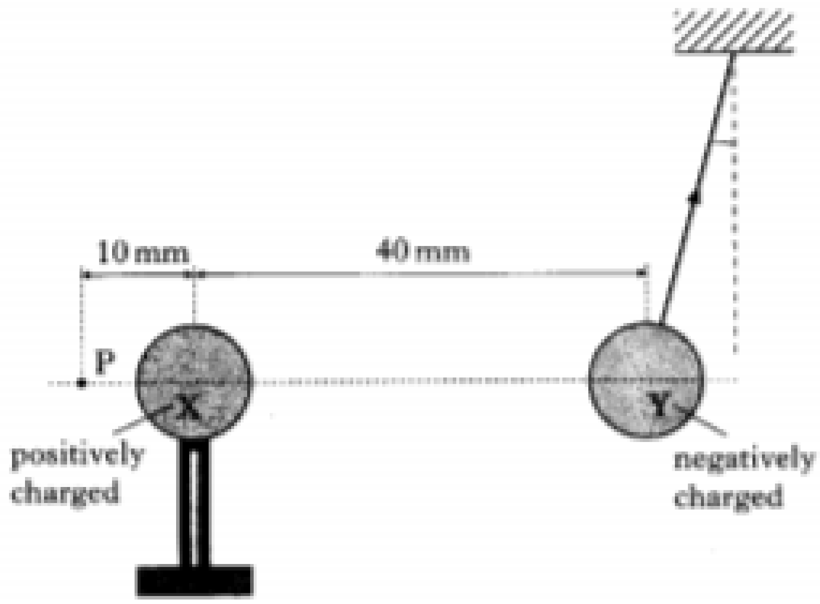


Figure 9

(i) The force between the spheres is $3{\cdot}0 \times 10^{-5}$ N.
By considering the spheres as point charges separated by a distance of 40 mm, show that the charge on each sphere is 2·3 nC.

(ii) Calculate the electrostatic potential at point P, 10 mm from X, as shown in Figure 9.

7. (c) (continued)

(iii) In reality, the spheres are not point charges.

Draw a sketch to show how charge is distributed on each sphere when the spheres are in the positions shown in Figure 9. **6**

(*d*) Sphere Y has mass $2{\cdot}5 \times 10^{-5}$ kg and hangs at an angle α to the vertical, as shown in Figure 10. The horizontal force acting on the sphere is $3{\cdot}0 \times 10^{-5}$ N.

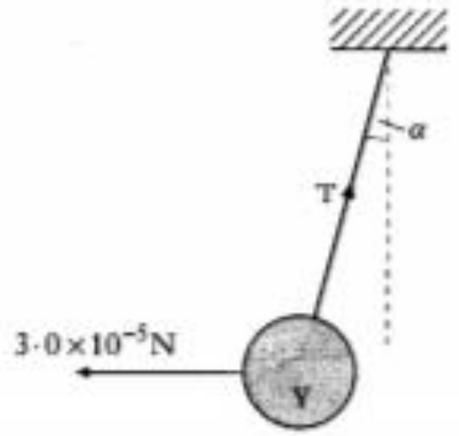


Figure 10

The mass of the thread is negligible.

(i) Calculate the tension T in the thread.

(ii) Calculate the size of angle α. **4**

(13)

Marks

8. A particle of mass m and charge q is fired with speed v into a magnetic field of uniform magnetic induction B. The particle enters the field at point X and follows a semicircular path, before leaving the field at point Y, as shown in Figure 11.

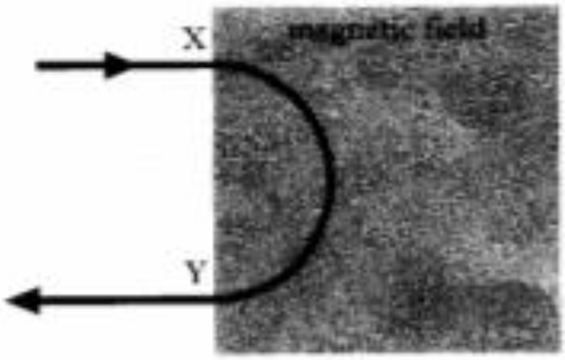


Figure 11

(a) Show that the radius r of the semicircular path is given by

$$r = \frac{mv}{qB}.$$ 2

(b) Using the above relationship, show that the time taken for the particle to follow the semicircular path in the magnetic field is independent of the speed of the particle. 2

(c) An electron with speed $2{\cdot}0 \times 10^6\ \text{m s}^{-1}$ is fired, as shown in Figure 11, into a magnetic field of uniform magnetic induction $5{\cdot}0\ \text{mT}$. Calculate the time during which the electron is in the magnetic field. 2

(6)

Marks

5. (*a*) State what is meant by the electric field strength at a point. **1**

(*b*) An arrangement for an electron gun is shown in Figure 9.

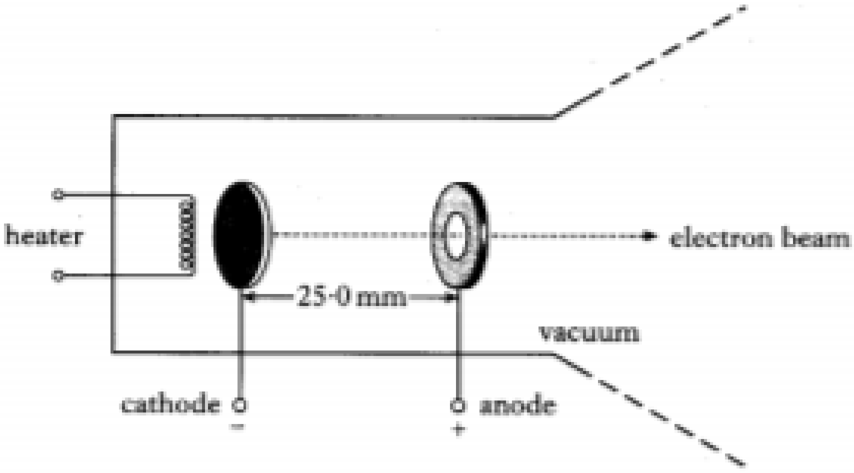


Figure 9

The electric field strength between the cathode and the anode has a constant value of $750\,\mathrm{N\,C^{-1}}$. The distance between the anode and the cathode is 25·0 mm.

(i) Show that the acceleration of an electron between the cathode and the anode is $1{\cdot}32 \times 10^{14}\,\mathrm{m\,s^{-2}}$.

(ii) Assuming that the electrons have negligible velocity at the cathode, calculate the speed of the electrons as they emerge from the anode. **4**

(*c*) The relativistic mass of a particle is given by

$$m = \frac{m_0}{\sqrt{(1 - \frac{v^2}{c^2})}}$$

where the symbols have their usual meanings.

An electron is moving with velocity $1{\cdot}5 \times 10^8\,\mathrm{m\,s^{-1}}$.

(i) Calculate the relativistic mass of this electron.

(ii) Calculate its relativistic energy. **4**

(*d*) In a scattering experiment, a beam of alpha particles is fired at a tungsten target.

The kinetic energy of an alpha particle is $1{\cdot}17 \times 10^{-12}\,\mathrm{J}$.

A tungsten nucleus has a charge of $+74e$.

Calculate the distance of closest approach between the alpha particle and the nucleus.

Relativistic effects can be ignored. **3**

(12)

Marks

6. A single rectangular loop of wire is arranged vertically in the uniform magnetic field between the poles of a magnet as shown in Figure 10. The loop is free to spin about axis XY.

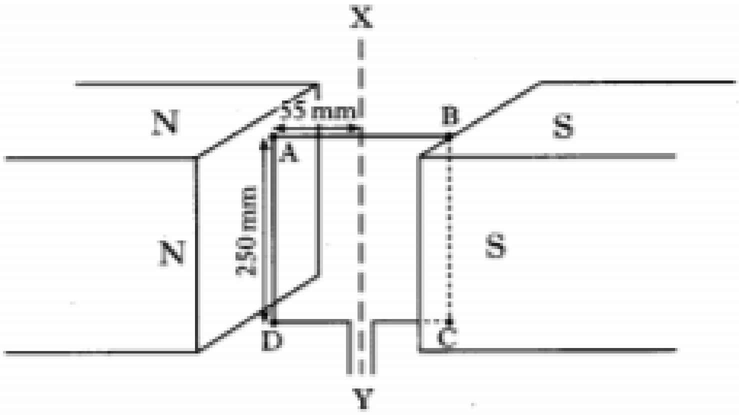


Figure 10

Sides AD and BC of the rectangle are 250 mm in length and each is 55 mm from the axis of rotation.

The loop of wire carries a current of 0·40 A.

The magnetic induction of the field is 0·60 T.

(*a*) Calculate the size of the magnetic force acting on side AD. **2**

(*b*) Figure 11 shows the loop when **viewed from above**.

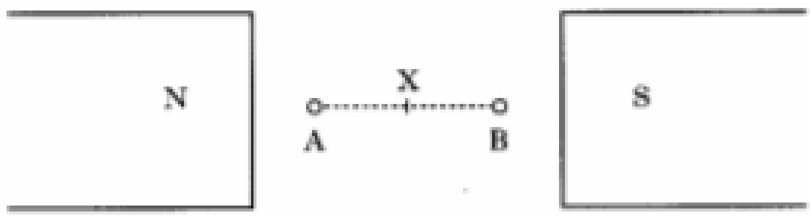


Figure 11

Calculate the magnitude of the torque acting on the loop. **2**

(*c*) The loop is turned through 30° to the position shown in Figure 12.

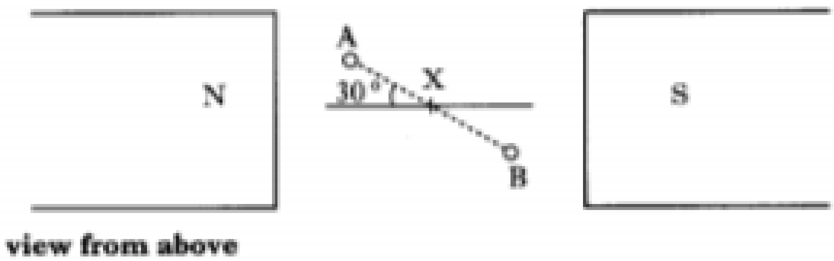


Figure 12

Calculate the magnitude of the torque now acting on the loop. **2**

Marks

6. (continued)

(*d*) The magnet is replaced by another magnet with the poles shaped as shown in Figure 13.

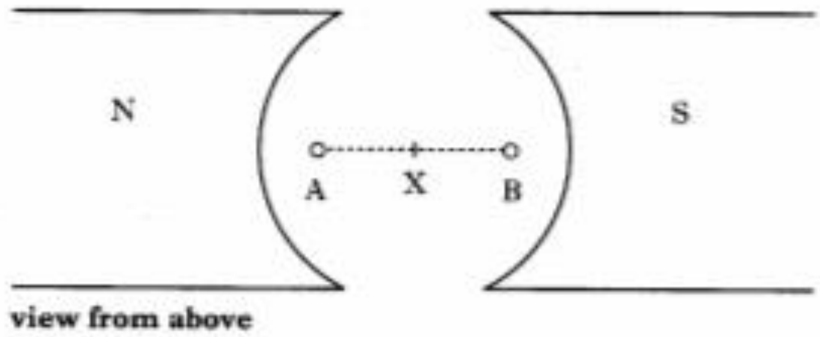


Figure 13

Explain how this arrangement reduces variation in the torque as the loop turns. **1**

(7)

Marks

8. Electrons are fired through a vacuum containing a region of uniform electric and magnetic fields. The fields are at right angles to each other.

The initial direction of travel of the electrons is shown in Figure 15.

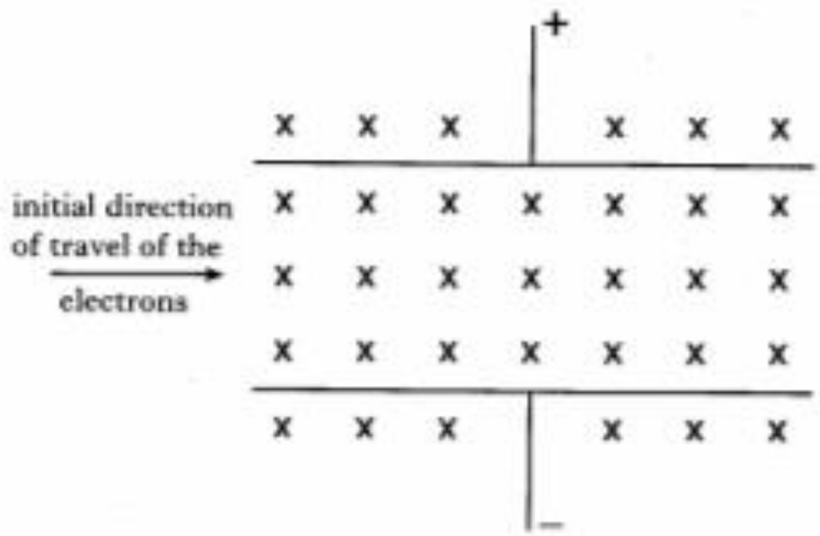


Figure 15

The field strengths are adjusted until the path of the electrons is a straight line.

(*a*) (i) In terms of electric and magnetic forces, explain why the path of an electron is a straight line.

(ii) The electric field strength is $4{\cdot}2 \times 10^{3}$ N C^{-1} and the magnetic field has a magnetic induction of $2{\cdot}8 \times 10^{-3}$ T.

Calculate the speed of the electrons. **3**

(*b*) Alpha particles are now fired in the same direction through the above electric and magnetic fields.

The alpha particles are also found to travel in a straight line. How does the speed of the alpha particles compare to the speed of the electrons in part (*a*)?

You must justify your answer. **2**

(*c*) The electric field is switched off leaving only the magnetic field. Alpha particles and then electrons with the same velocity are fired, in the same direction as before, into this region.

Sketch the approximate paths followed by the alpha particles and electrons. **2**

(7)

Marks

6. (*a*) Calculate the magnitude of the electrostatic force between two protons separated by a distance of 0·010 mm. **2**

(*b*) Despite the electrostatic force of repulsion, the protons in an atomic nucleus do not fly apart.

(i) Name the force which holds protons together in a nucleus.

(ii) Explain why this force has negligible effect on the protons in part (*a*). **2**

(*c*) In a Rutherford scattering experiment, an alpha particle with a velocity of $2·0 \times 10^6\,m\,s^{-1}$ is fired at a target of gold foil in a vacuum. The mass of an alpha particle is $6·7 \times 10^{-27}$ kg and the atomic number of gold is 79.

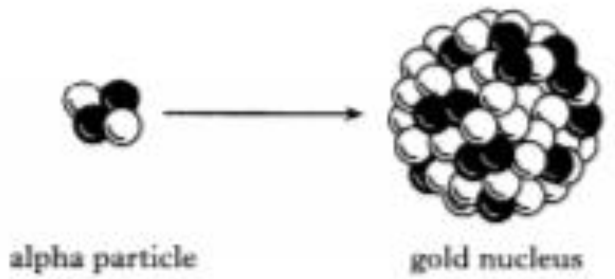


Figure 4

Calculate the distance of closest approach for a head-on collision between the alpha particle and a gold nucleus. **4**

(8)

Marks

7. In a cathode ray tube, electrons emitted from the cathode are accelerated from rest through a potential difference of 2·0 kV, as shown in Figure 5.

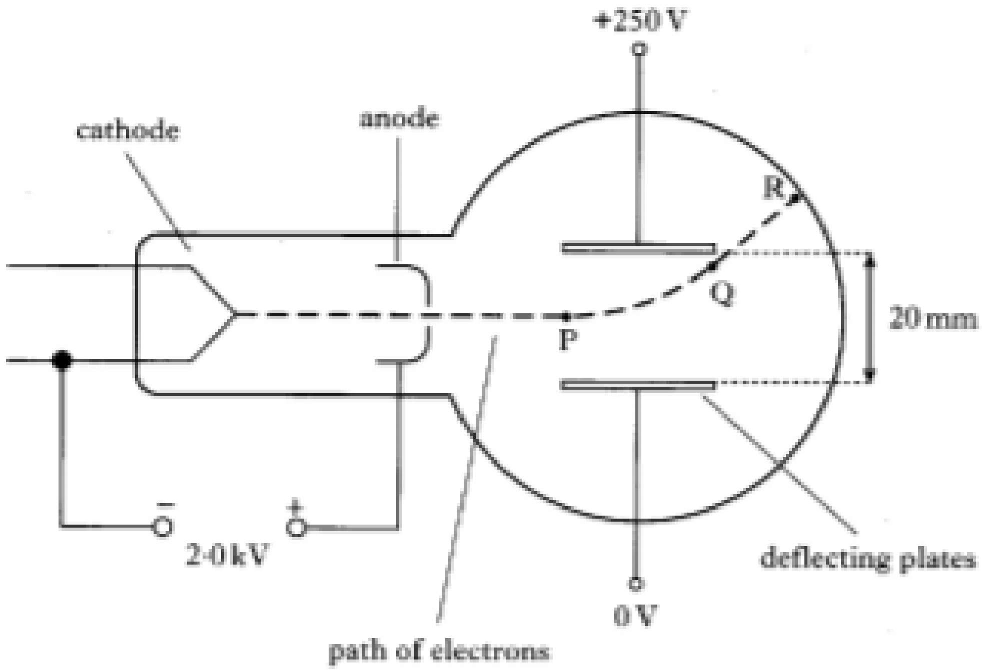


Figure 5

(*a*) Calculate the speed of the electrons as they reach the anode. **2**

(*b*) After leaving the anode, the electrons pass between two parallel deflecting plates separated by 20 mm. The potential difference between the deflecting plates is 250 V.

The electrons follow path PQR.

(i) By considering the forces acting on the electrons, explain the shape of the path between:

(A) P and Q;

(B) Q and R.

Assume gravitational effects to be negligible.

(ii) Calculate the acceleration of the electrons between the deflecting plates. **6**

(*c*) The moving electrons can also be deflected by a magnetic field.

(i) Explain why electrons travelling perpendicularly to a uniform magnetic field follow a circular path.

(ii) Find the magnitude **and** direction of the magnetic induction required to balance the electrostatic force on the electrons in part (*b*), so that zero deflection would be produced. **4**

(12)

Marks

5. (*a*) Two positive point charges, each of magnitude 3·0 nC, are situated 0·20 m apart in air. Position X is midway between the two charges and Y is 0·10 m beyond the second charge, as shown in Figure 10.

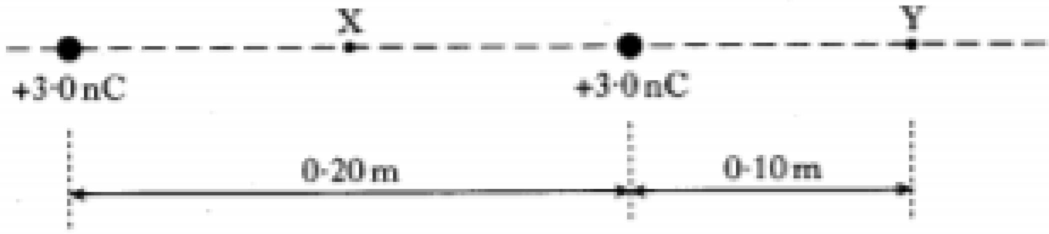


Figure 10

(i) Calculate the electric field strength:

(A) at X;

(B) at Y.

(ii) State what is meant by the term "electrostatic potential at a point".

(iii) Calculate the potential difference between X and Y. **8**

(*b*) The charges on three separate oil droplets are measured as

$-4{\cdot}5 \times 10^{-19}$ C; $-8{\cdot}0 \times 10^{-19}$ C; $-3{\cdot}2 \times 10^{-19}$ C.

Explain which one of these measurements is suspect. **2**

(10)

Marks

7. In a mass spectrometer, a positive ion passes through an electric field between two parallel plates P_1 and P_2 and through a narrow slit S as shown in Figure 13. The plates are 40 mm apart and there is a uniform magnetic field of magnetic induction B between the plates and in the region beyond the slit.

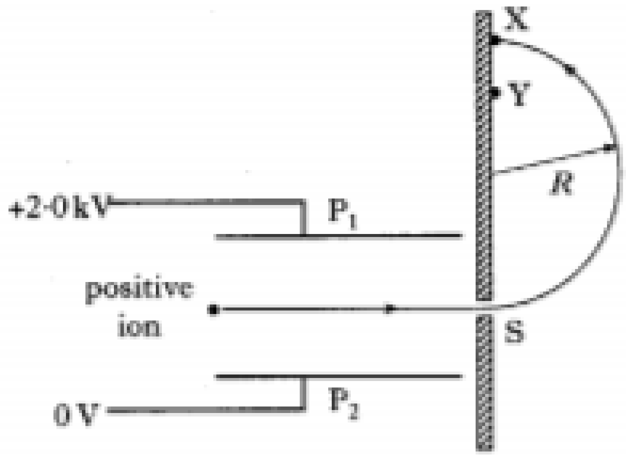


Figure 13

The ion travels with a uniform speed v in a straight line between the plates and moves into a semicircular path of radius R after it passes through the slit.

(a) State the direction of the magnetic induction B. **1**

(b) Show that the velocity v of the ion is given by

$$v = \frac{5 \cdot 0 \times 10^4}{B}$$ **2**

(c) (i) Explain why the ion follows a semicircular path in the region beyond the slit.

(ii) Show that the radius R of the semicircular path is given by

$$R = \frac{mv}{BQ}$$

where m = mass of the ion
and Q = the charge on the ion.

(iii) The ion reaches the point X in the region beyond the slit.
Use the following data to calculate the distance SX.

Mass of the ion = $3 \cdot 65 \times 10^{-26}$ kg
Charge on the ion = $+1 \cdot 6 \times 10^{-19}$ C
Magnetic induction = 0·50 T **6**

Marks

7. (continued)

(*d*) A second ion, with the same positive charge as the first ion, passes between the parallel plates and through slit S. The second ion travels in a semicircular path and reaches the point Y shown in Figure 13.

(i) Explain why the speed of this ion is the same as the first ion.

(ii) How does the mass of the second ion compare with the mass of the first ion? **Justify your answer**. **4**

(13)

[Turn over