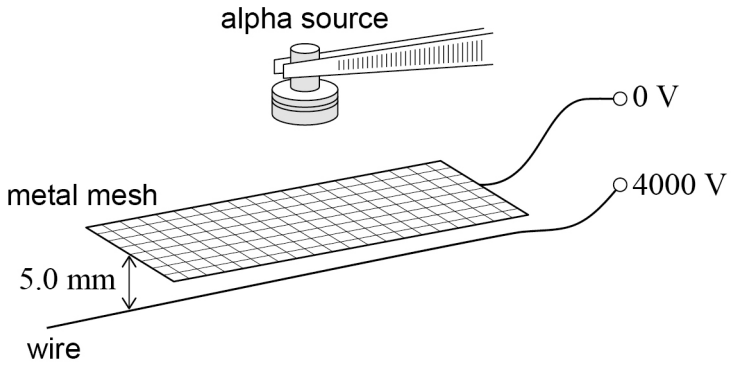
0 4 **Figure 4** shows a spark detector used to detect alpha particles.

Figure 4

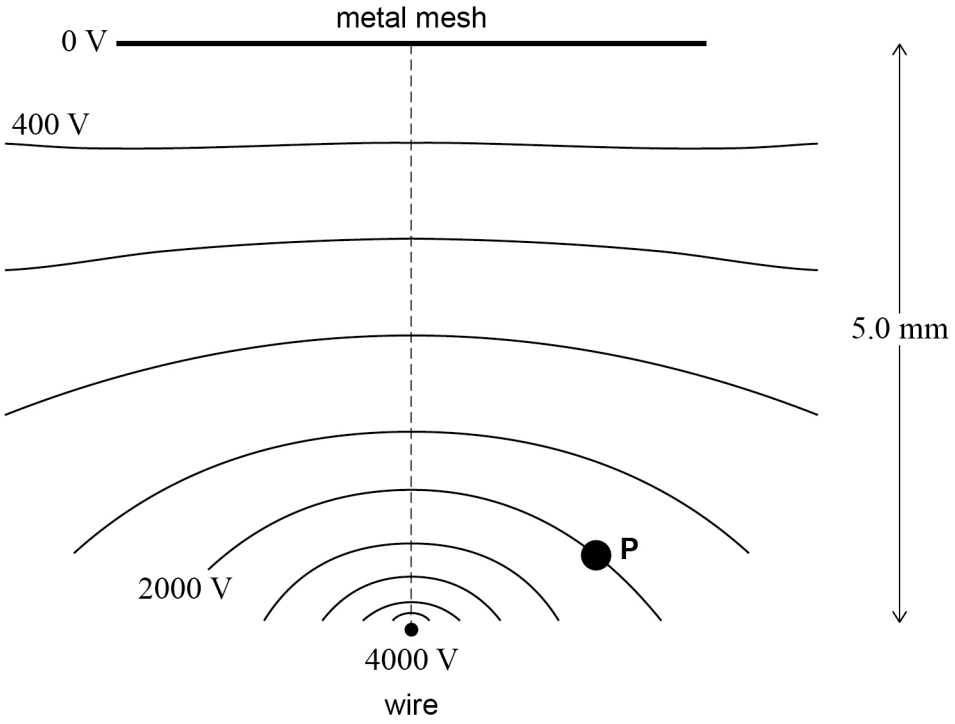


The detector consists of a metal mesh placed $5.0\ \text{mm}$ above a wire.
A potential difference of $4000\ \text{V}$ is applied between the mesh and the wire.

Molecules in the air between the mesh and the wire are ionised by an alpha particle and a spark is produced.

Figure 5 shows equipotentials between the mesh and the wire.

Figure 5

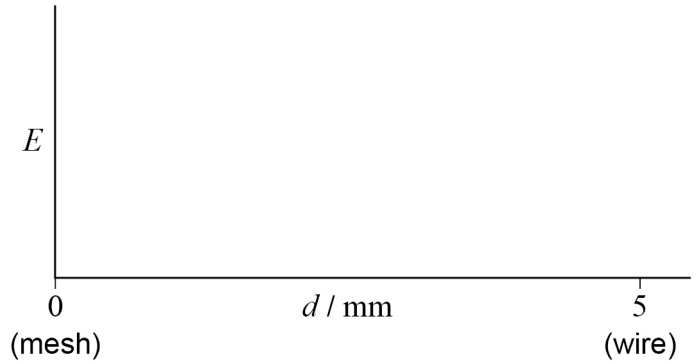


0 4 . 1 **Figure 5** shows a dashed line between the mesh and the wire.

Sketch on **Figure 6** a graph to show how the magnitude E of the electric field strength varies with the distance d from the mesh along this dashed line.
No values are required on the E axis.

[2 marks]

Figure 6



An alpha particle passes through the mesh.
The alpha particle ionises an argon atom at **P** on **Figure 5**, releasing one electron.
The electron and the argon ion have no kinetic energy at **P**.
The electron then travels to the wire and the argon ion travels to the mesh.

0 4 . 2 Calculate the ratio $\frac{\text{speed of electron when it reaches the wire}}{\text{speed of argon ion when it reaches the mesh}}$.

Assume that the air has no effect on the motion of the electron or on the motion of the argon ion.

mass of argon ion = 6.64×10^{-26} kg

[2 marks]

ratio = _____

Question 4 continues on the next page

0 4 . 3 In practice, the air **does** affect the motion of the electron and the motion of the argon ion.

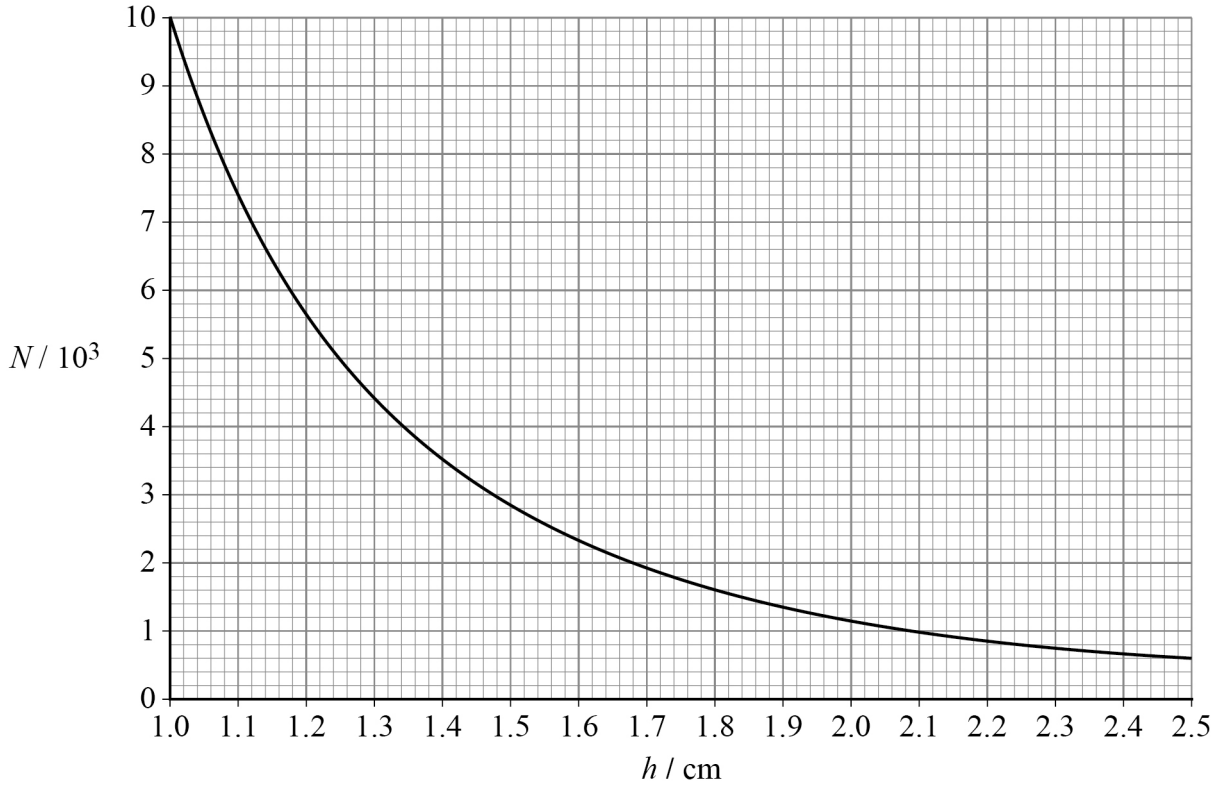
Suggest how the presence of air between the mesh and the wire changes the ratio in Question **04.2**.
No numerical detail is required.

[1 mark]

0 4 . 4 The alpha source in **Figure 4** is moved to different heights h above the mesh.

Figure 7 shows how the number of sparks N produced in 10 minutes varies with h.
No sparks are produced when the source is not present.

Figure 7



Student **A** suggests that the spark rate obeys an inverse-square law.
Student **B** suggests that the spark rate decreases exponentially with h.

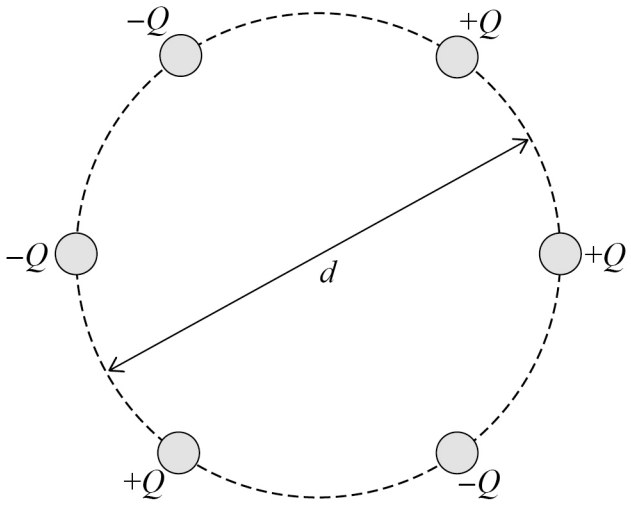
Determine whether either student is correct.

[3 marks]

8

Turn over for the next question

1 4 Six metal spheres, each carrying a charge of magnitude Q, are equally spaced around a circle of diameter d.



What is the magnitude of the field strength at the centre of the circle?

[1 mark]

A 0 ⬭

B $\dfrac{Q}{\pi\varepsilon_0 d^2}$ ⬭

C $\dfrac{2Q}{\pi\varepsilon_0 d^2}$ ⬭

D $\dfrac{4Q}{\pi\varepsilon_0 d^2}$ ⬭

1 5 Two point charges are separated by a distance of $200\ \text{mm}$.
The force of attraction between them is $180\ \mu\text{N}$.
The distance between the point charges is increased by $400\ \text{mm}$.

What is the new force of attraction?

[1 mark]

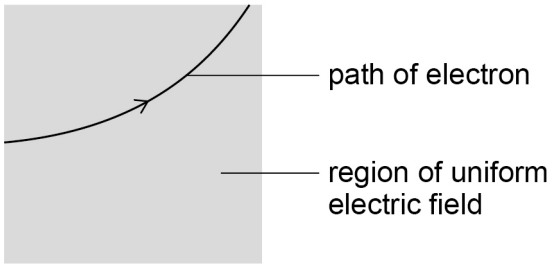
A $20\ \mu\text{N}$ ⬭

B $45\ \mu\text{N}$ ⬭

C $60\ \mu\text{N}$ ⬭

D $90\ \mu\text{N}$ ⬭

1 6 The diagram shows the path of an electron in a uniform electric field.
The electron moves in a vertical plane.



The direction of the electric field is

[1 mark]

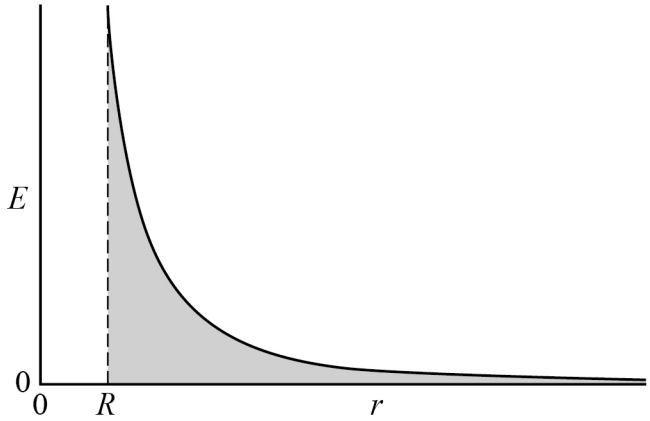
A vertically down the plane. ⬭

B vertically up the plane. ⬭

C horizontally into the plane. ⬭

D horizontally out of the plane. ⬭

1 7 The graph shows the variation of electric field strength E surrounding a charged sphere of radius R. The distance from the centre of the sphere is r.



The total area under the curve from R to infinity is

[1 mark]

A the capacitance of the sphere. ⬭

B the charge held on the sphere. ⬭

C the electric potential of the sphere. ⬭

D the energy needed to remove an electron from the sphere. ⬭

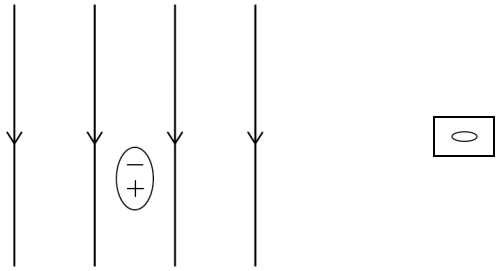
Turn over for the next question

1 8 A polar molecule is in an external electric field.

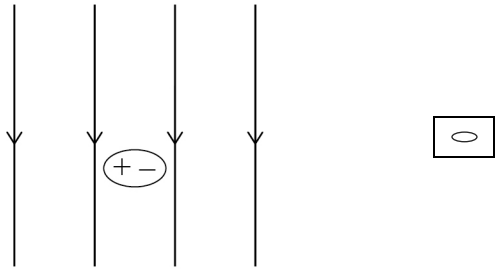
Which diagram shows the orientation of the polar molecule?

[1 mark]

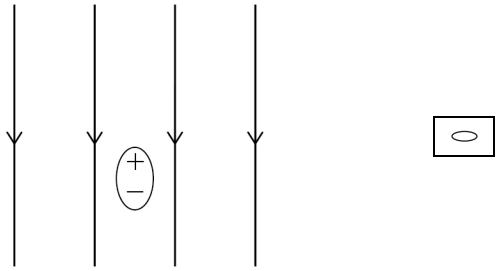
A



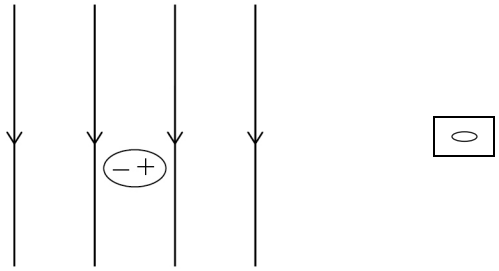
B



C



D



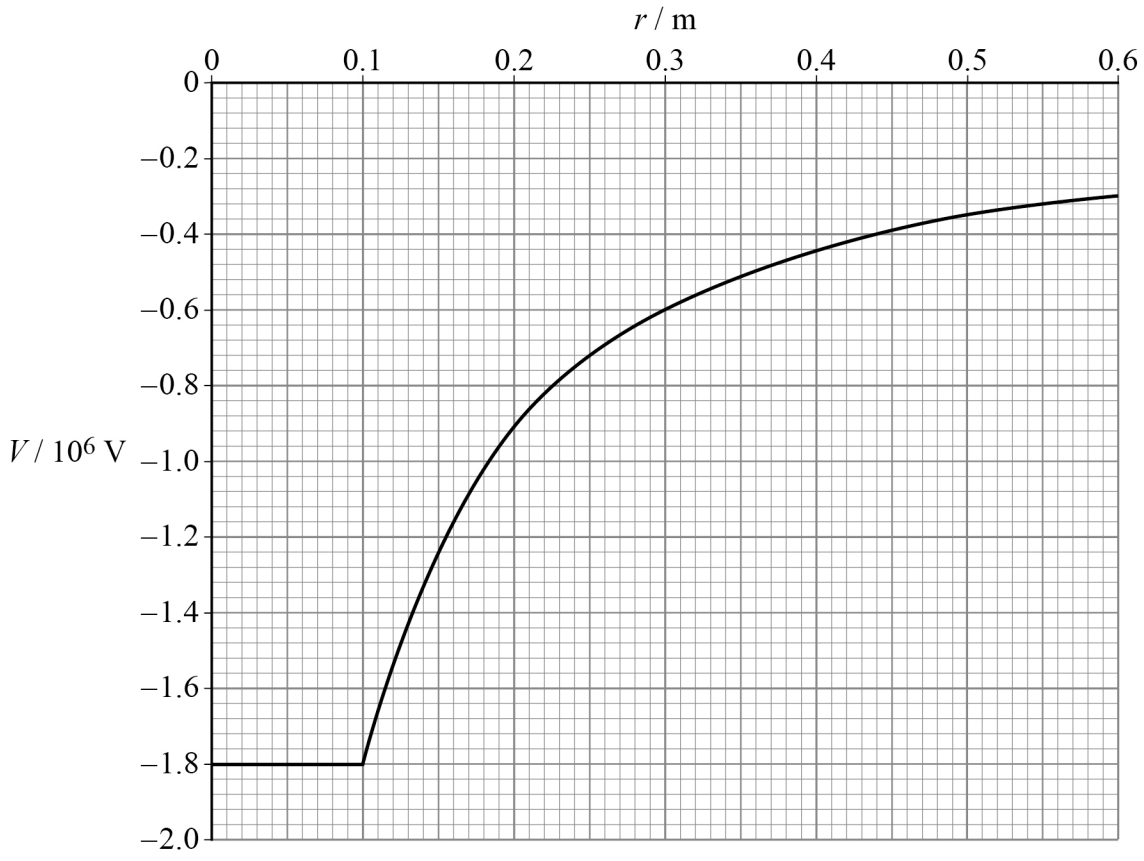
0 3 An isolated solid conducting sphere is initially uncharged.
Electrons are then transferred to the sphere.

0 3 . 1 State and explain the location of the excess electrons.

[2 marks]

Figure 3 shows how the electric potential V varies with distance r from the centre of the sphere.
The radius of the sphere is 0.10 m.

Figure 3



0 3 . 2 The magnitude of the electric field strength E is related to V by $E = \frac{\Delta V}{\Delta r}$.

Determine, using this relationship, the magnitude of the electric field strength at a distance $0.30\ \text{m}$ from the centre of the sphere.

State an appropriate SI unit for your answer.

[4 marks]

electric field strength = _____ unit _____

0 3 . 3 The sphere acts as a capacitor because it stores charge at an electric potential.

Show that the capacitance of the sphere is approximately $1 \times 10^{-11}\ \text{F}$.

[3 marks]

Question 3 continues on the next page

0 3 . 4 Electrons leak away from the sphere with time and the amount of energy stored by the sphere decreases. At one instant, the magnitude of the electric potential of the sphere has fallen to 1.0×10^6 V.

Calculate, for this instant, the change in the energy stored by the sphere.

[3 marks]

change in energy = _____ J

12

1 4 When an electron moves at a speed v perpendicular to a uniform magnetic field of flux density B, the radius of its path is R.

A second electron moves at a speed $\frac{v}{2}$ perpendicular to a uniform magnetic field of flux density $4B$.

What is the radius of the path of the second electron?

[1 mark]

A $\frac{R}{8}$ ⬭

B $\frac{R}{4}$ ⬭

C $2R$ ⬭

D $8R$ ⬭

1 5 A particle of mass m and charge Q is accelerated from rest through a potential difference V. The final velocity of the particle is u.

A second particle of mass $\frac{m}{2}$ and charge $2Q$ is accelerated from rest through a potential difference $2V$.

What is the final velocity of the second particle?

[1 mark]

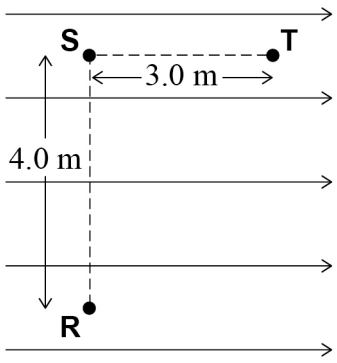
A $\sqrt{2}u$ ⬭

B $2\sqrt{2}u$ ⬭

C $4u$ ⬭

D $8u$ ⬭

1 6 The diagram shows a uniform electric field of strength $15\ \text{V m}^{-1}$.
The length **RS** is perpendicular to the field and the line **ST** is parallel to the field.



What is the total change in electrical potential energy for a charge of $3.0\ \mu\text{C}$ moving from **R** to **T**?

[1 mark]

A $135\ \mu\text{J}$ ⬭

B $180\ \mu\text{J}$ ⬭

C $225\ \mu\text{J}$ ⬭

D $315\ \mu\text{J}$ ⬭

Turn over for the next question