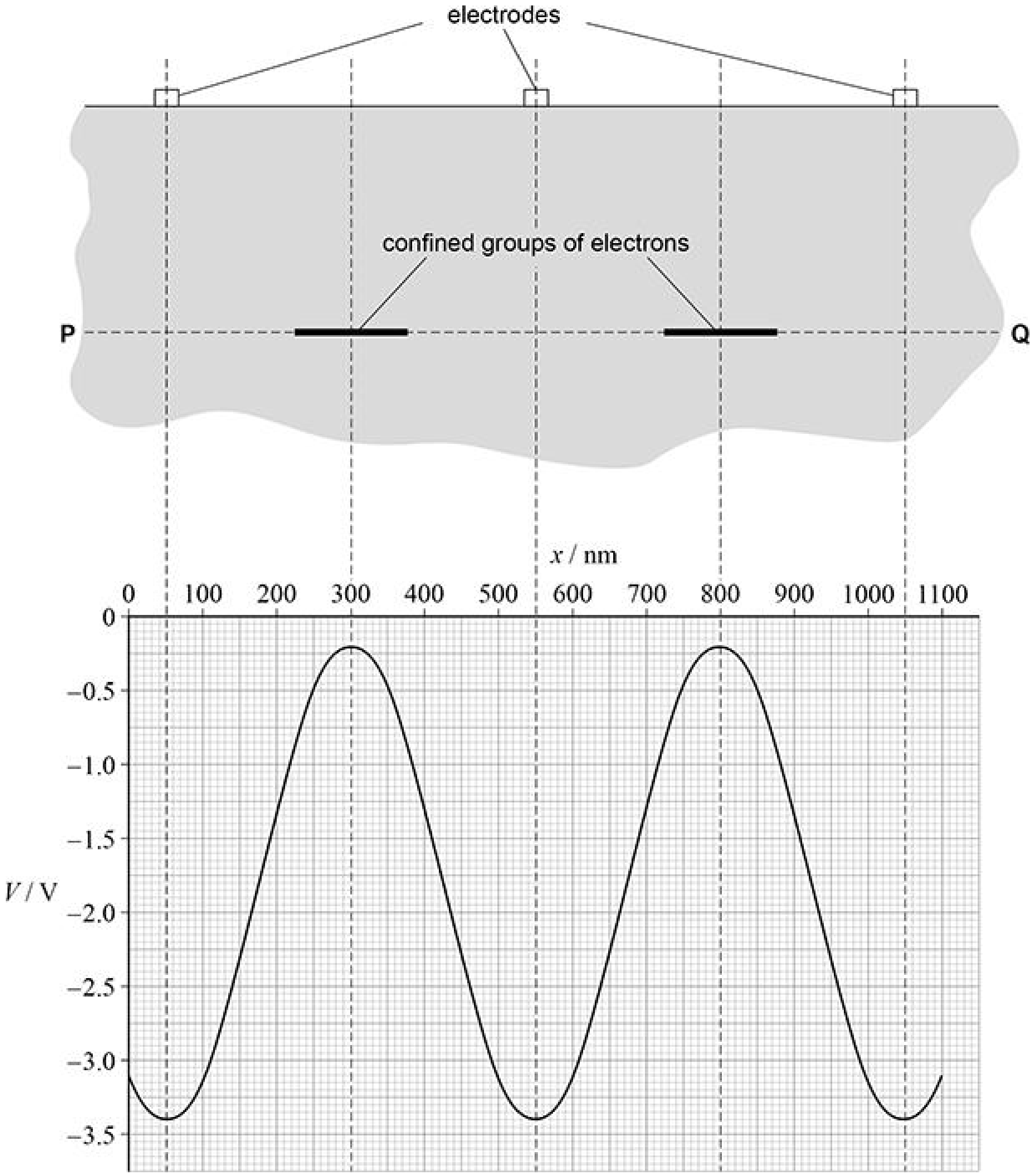
Q1.

(a) The electric potential at a point in an electric field is −4.0 V.

Explain what is meant by this statement.

(3)

The figure below shows an arrangement for confining groups of electrons to small regions inside a block of gallium arsenide.



Electrons can only move along the line **PQ** in the block.

When a suitable electric potential is applied to the electrodes, the electrons are confined to the regions shown in above figure.

The graph in the figure above shows how the electric potential V varies with distance x along **PQ**.

(b) Determine, using the graph above, the maximum magnitude of the electric field.
State an appropriate unit for your answer.

maximum magnitude = ____________________ unit ____________

(4)

(c) An electron at rest at x = 300 nm gains kinetic energy and moves to x = 800 nm.

Determine the minimum kinetic energy required by the electron.

minimum kinetic energy = ____________________ J

(2)

(d) One of the confined electrons is at x = 350 nm.

Discuss the subsequent motion of this electron due to the variation in electric potential shown in above figure.
Assume that the electron starts from rest.

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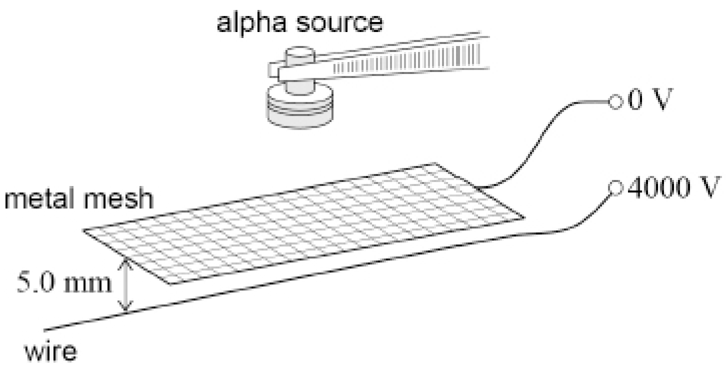
(3)

(Total 12 marks)

Q2.

Figure 1 shows a spark detector used to detect alpha particles.

Figure 1

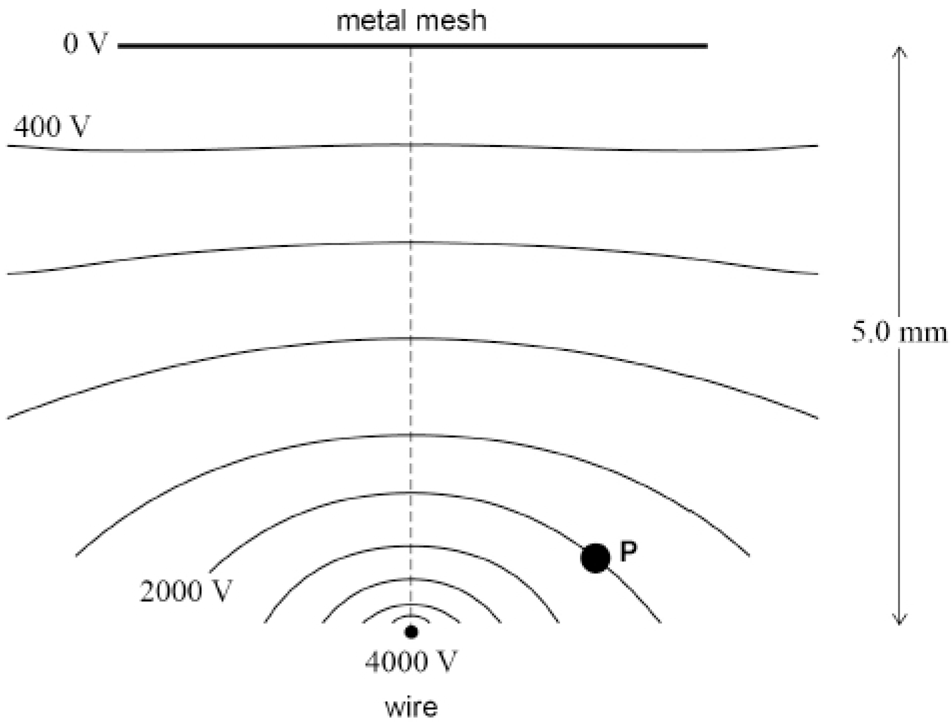


The detector consists of a metal mesh placed 5.0 mm above a wire.
A potential difference of 4000 V is applied between the mesh and the wire.

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

Figure 2 shows equipotentials between the mesh and the wire.

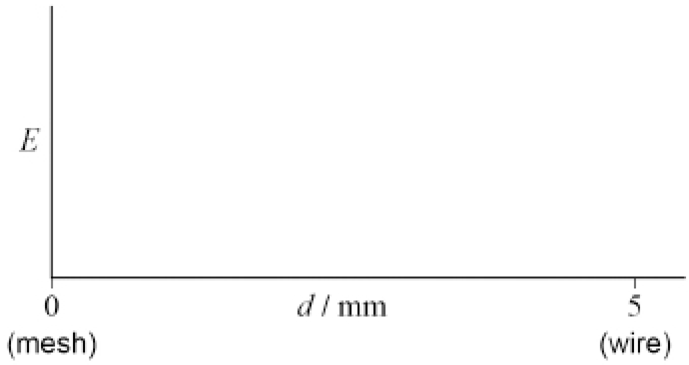
Figure 2



(a) **Figure 2** shows a dashed line between the mesh and the wire.

Sketch on **Figure 3** 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.

Figure 3



An alpha particle passes through the mesh.
The alpha particle ionises an argon atom at **P** on **Figure 2**, 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.

(2)

(b) 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

ratio = ____________________

(2)

(c) 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 part (b).
No numerical detail is required.

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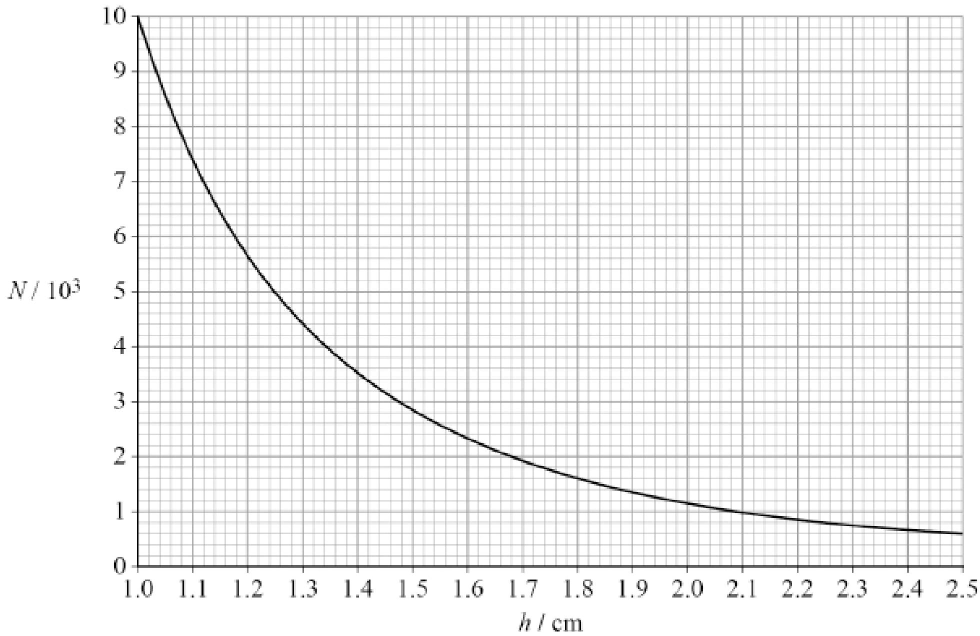
(1)

(d) The alpha source in **Figure 1** is moved to different heights h above the mesh.

Figure 4 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 4



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.

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(3)
(Total 8 marks)

Q3.

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

(a) State and explain the location of the excess electrons.

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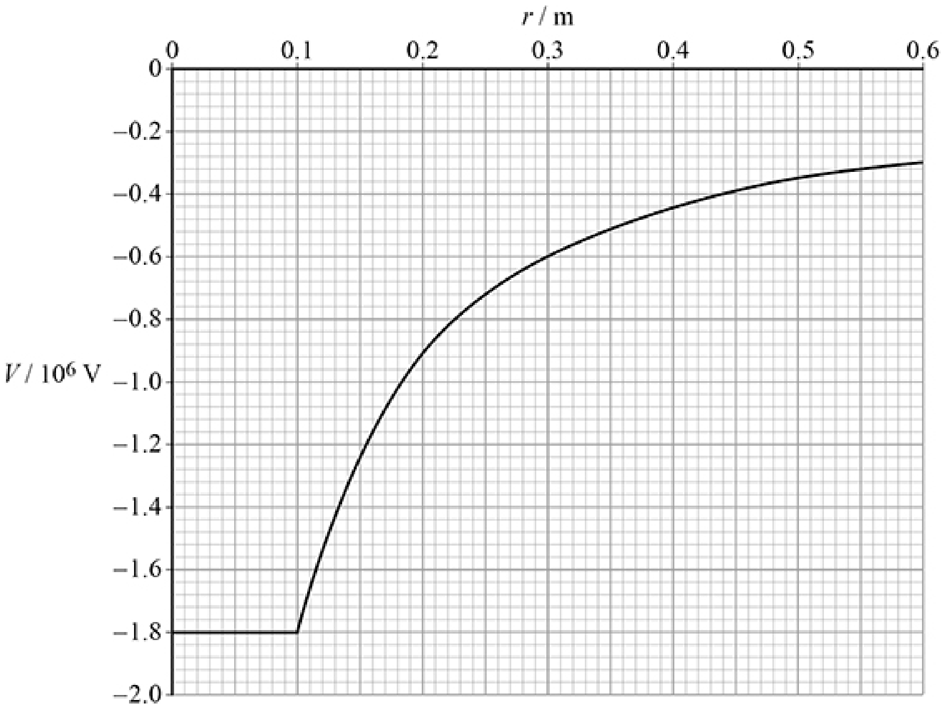
(2)

The figure below 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.



(b) 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 m from the centre of the sphere.

State an appropriate SI unit for your answer.

electric field strength = ____________________ unit __________

(4)

(c) The sphere acts as a capacitor because it stores charge at an electric potential.

Show that the capacitance of the sphere is approximately 1×10^{-11} F.

(3)

(d) 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.

change in energy = _______________ J

(3)

(Total 12 marks)