A Level · OCR · Physics

59 mins · 5 questions

Structured Questions

Electric Fields

Electric Fields / Electric Field Lines / Electric Field Strength / Coulomb's Law / Electric Field Strength of a Point Charge / Electric vs Gravitational Fields / Motion of Charged Particles in an E Field

Medium (4 questions)	/45
Hard (1 question)	/14
Total Marks	**/59**

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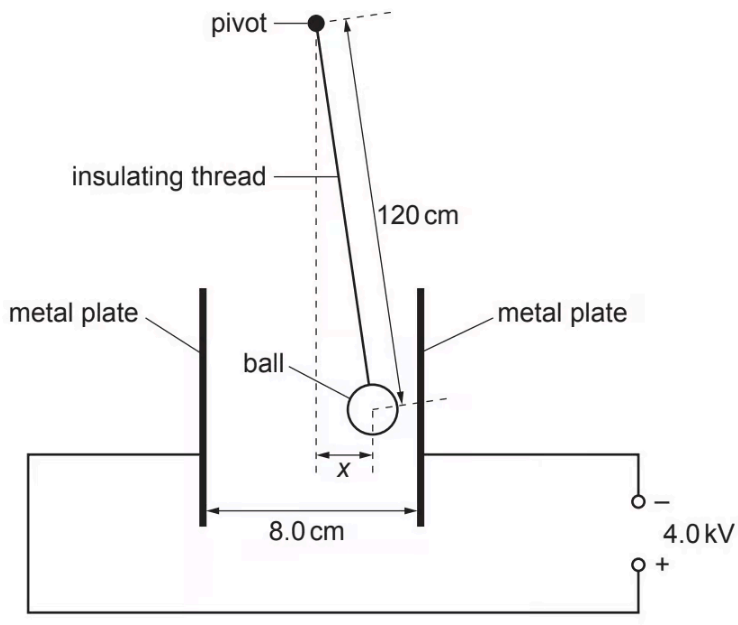
Medium Questions

1 (a) A ball coated with conducting paint has weight 0.030 N and radius 1.0 cm. The ball is suspended from an insulating thread. The distance between the pivot and the centre of the ball is 120 cm.

The ball is placed between two vertical metal plates. The separation between the plates is 8.0 cm. The plates are connected to a 4.0 kV power supply.

The ball receives a positive charge of 9.0 nC when it is made to touch the positive plate. It then repels from the positive plate and hangs in equilibrium at a displacement *x* from the vertical, as shown below. The diagram is **not** drawn to scale.



i) Show that the electric force acting on the charged ball is 4.5×10^{-4} N.

[2]

ii) Draw, on the diagram above, arrows which represent the **three** forces acting on the ball.

Label each arrow with the name of the force it represents.

[2]

iii) By taking moments about the pivot, or otherwise, show that x = 1.8 cm.

[2]

(6 marks)

(b) The ball is still positively charged.

The plates are now moved slowly towards each other whilst still connected to the 4.0 kV power supply. The plates are stopped when the separation is 5.0 cm.

Explain the effect that this has on the deflection of the ball and explain why the ball eventually starts to oscillate between the plates.

[4]

(4 marks)

(c) When the ball oscillates between the plates, the current in the external circuit is 3.2×10^{-8} A.

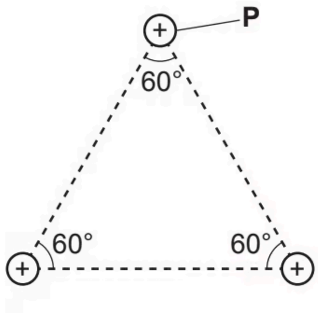
A charge of 9.0 nC moves across the gap between the plates each time the ball makes one complete oscillation.

Calculate the frequency *f* of the oscillations of the ball.

f = ... Hz **[2]**

(2 marks)

2 (a) The diagram below shows the arrangement of the 3 protons inside the nucleus of lithium-6 ($^{6}_{3}\text{Li}$)



The separation between each proton is about 1.0×10^{-15} m.

i) Calculate the magnitude of the repulsive electric force *F* experienced by the proton **P**.

F = ... N **[4]**

ii) On the diagram above, draw an arrow to show the direction of the electric force *F* experienced by **P**.

[1]

iii) Explain how protons stay within the nucleus of lithium-6.

[2]

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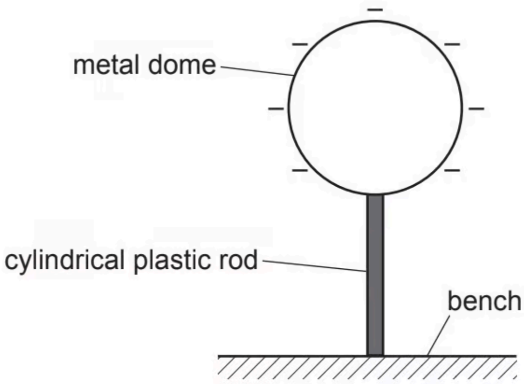
(7 marks)

(b) A spherical metal dome shown below is charged to a potential of −12 kV.



The dome is supported by a cylindrical plastic rod. The radius of the dome is 0.19 m.

i) Show that the magnitude of the total charge Q on the dome is 2.5×10^{-7} C.

[2]

ii) The dome discharges slowly through the plastic rod.

It takes 78 hours for the dome to completely discharge.

1. Show that the mean current I in the plastic rod is about 9×10^{-13} A.

[2]

2. The average potential difference across the plastic rod during discharge is 6000 V. The rod has cross-sectional area 1.1×10^{-4} m^2 and length 0.38 m. Calculate the resistivity ρ of the plastic.

ρ = ... Ω m **[3]**

(7 marks)

3 (a) **Fig. 24** shows two horizontal metal plates in a vacuum.

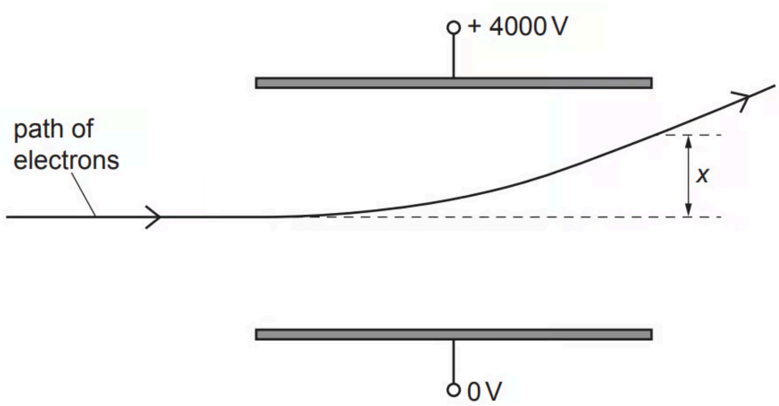


Fig. 24

The diagram is **not** drawn to scale. Electrons travelling horizontally enter the space between the charged plates and are deflected vertically.

The potential difference between the plates is 4000 V. The distance between the plates is 0.08 m. The initial speed of the electrons is 6.0×10^{7} m s^{-1}. The vertical deflection of the electrons at the far end of the plates is *x*.

i) Show that the vertical acceleration a of an electron between the plates is 8.8×10^{15} m s^{-2}.

[3]

ii) The length of each plate is 0.12 m.

Show that the time t taken by the electron to travel this length is 2.0×10^{-9} s.

[1]

iii) Calculate the vertical deflection *x* of the electron.

x = ... m **[2]**

....

....

....

(6 marks)

(b) The arrangement shown in **Fig. 24** is now used to investigate positrons emitted from a radioactive source. The speed of the positrons is also 6.0×10^7 m s^{-1}.

The initial path of the positrons is the same as that of the electrons in **Fig. 24**.

On **Fig. 24**, sketch the path of the positrons between the plates.

[2]

(2 marks)

(c) Beta-minus particles (electrons) emitted from a radioactive source have a range of speeds.

Describe and explain how a uniform magnetic field can be applied in the space between the charged plates to select beta-minus particles with a specific speed. No calculations are required.

[3]

(3 marks)

4 (a) Fig. 20.1 shows a positively charged metal sphere and a negatively charged metal plate.

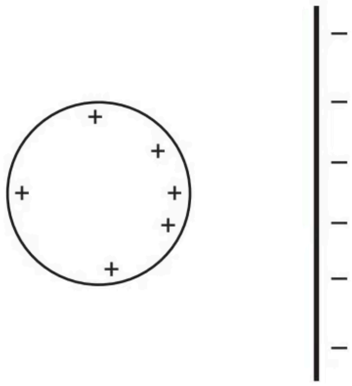


Fig. 20.1

On Fig. 20.1, draw a minimum of **five** electric field lines to show the field pattern between the sphere and the plate.

[2]

....

....

(2 marks)

(b) Define *electric potential* at a point in space.

[1]

....

(1 mark)

(c) A metal sphere is given a positive charge by connecting its surface briefly to the positive terminal of a power supply. The electric potential at the surface of the sphere is + 5.0 kV. The sphere has radius 1.5 cm.

i) Show that the charge Q on the surface of the sphere is 8.3×10^{-9} C.

[2]

ii) Fig. 20.2 shows the charged sphere from **(i)** suspended from a nylon thread and placed between two oppositely charged vertical plates.

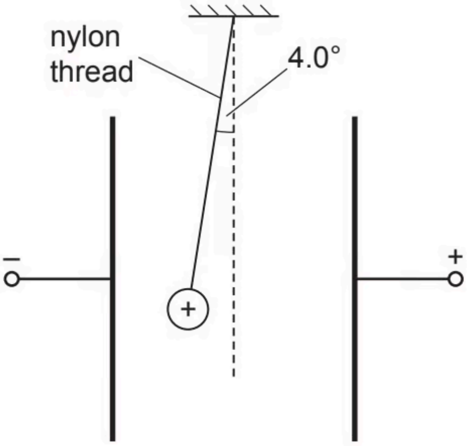


Fig. 20.2 (not to scale)

The weight of the sphere is 1.7×10^{-2} N. The string makes an angle of 4.0° with the vertical.

1. Show that the electric force on the charged sphere is 1.2×10^{-3} N.

[1]

2. Calculate the uniform electric field strength **E** between the parallel plates.

E = ... N C^{-1} **[2]**

(5 marks)

Hard Questions

1 (a) Fig. 22.1 shows two horizontal metal plates in a vacuum.

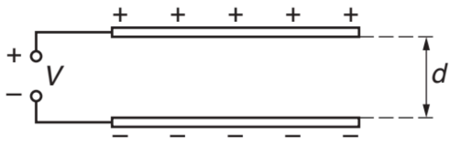


Fig. 22.1

The plates are connected to a power supply. The potential difference *V* between the plates is constant. The magnitude of the charge on each plate is *Q*. The separation between the plates is *d*.

Fig. 22.2 shows the variation with *d* of the charge *Q* on the positive plate.

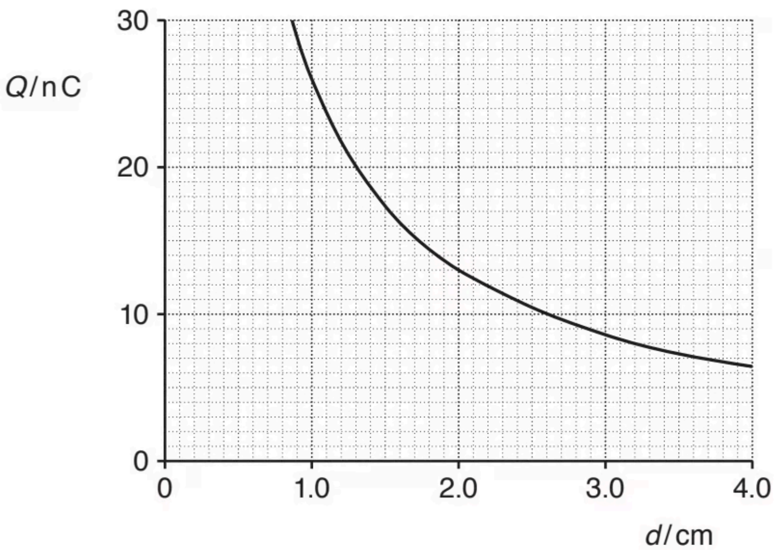


Fig. 22.2

i) Use Fig. 22.2 to propose and carry out a test to show that *Q* is inversely proportional to *d.* Test proposed: Working:

[2]

ii) Use capacitor equations to show that *Q* is inversely proportional to *d*.

[2]

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(4 marks)

(b) Fig. 22.3 shows a negatively charged oil drop between two oppositely charged horizontal plates in a vacuum.

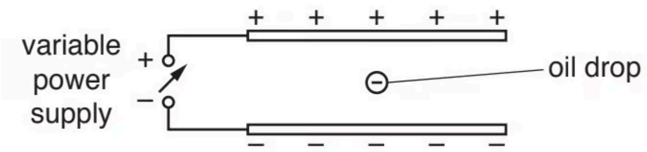

Fig. 22.3

The plates are fixed and connected to a variable power supply. The weight of the oil drop is 1.8×10^{-14} N.

i) The power supply is adjusted so that the potential difference between the plates is 200V when the oil drop becomes **stationary.** State the magnitude of the vertical electric force F_E acting on the charged oil drop.

F_E = ... N **[1]**

ii) The potential difference between the plates is now increased to 600 V. The oil drop accelerates upwards. Calculate the acceleration a of the oil drop.

a = ... ms^{-2} **[3]**

....

....

(4 marks)

(c) Fig. 22.4 shows an arrangement used by a student to investigate the forces experienced by a small length of charged gold foil placed in a uniform electric field.

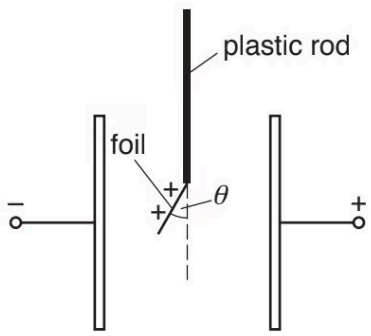

Fig. 22.4

The two vertical metal plates are connected to a high-voltage supply.

The foil is given a positive charge by briefly touching it to the positive plate.

The angle θ made with the vertical by the foil in the electric field is given by the expression $\tan\theta = \dfrac{qE}{W}$

where q is the charge on the foil, E is the electric field strength between the plates and W is the weight of the foil.

The angle θ can be determined by taking photographs with the camera of a mobile phone.

Describe how the student can safely conduct an experiment to investigate the relationship between θ and E. Identify any variables that must be controlled.

[6]

(6 marks)