1 A teacher states ‘the repulsive force between 1C of charge on the ground and 1C of charge on a 1000 kg mass is large enough to support the mass when it is 1km above the ground’.

Determine whether the teacher is correct.

(4)

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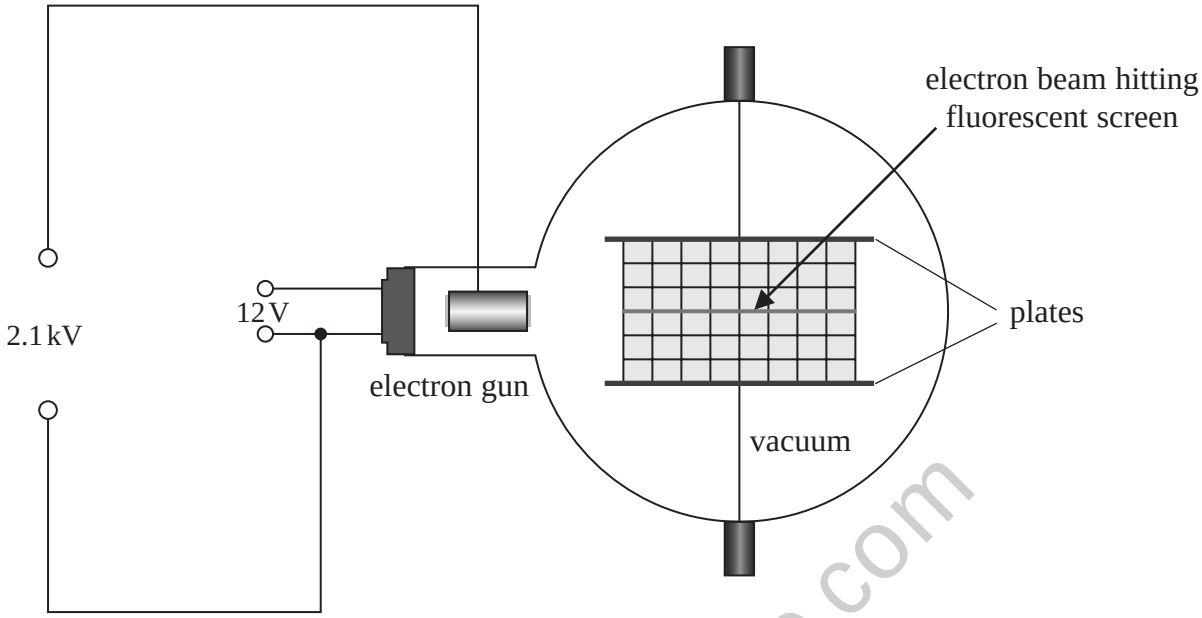
(Total for Question = 4 marks)

2 The diagram shows the parts of an electron deflection tube.



(a) The electron gun consists of a hot metal filament and a positively charged anode.

Explain how this produces a beam of electrons.

(2)

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(b) The potential difference between the hot metal filament and the anode is 2.1 kV.

Calculate the velocity of the electrons as they leave the electron gun.

(3)

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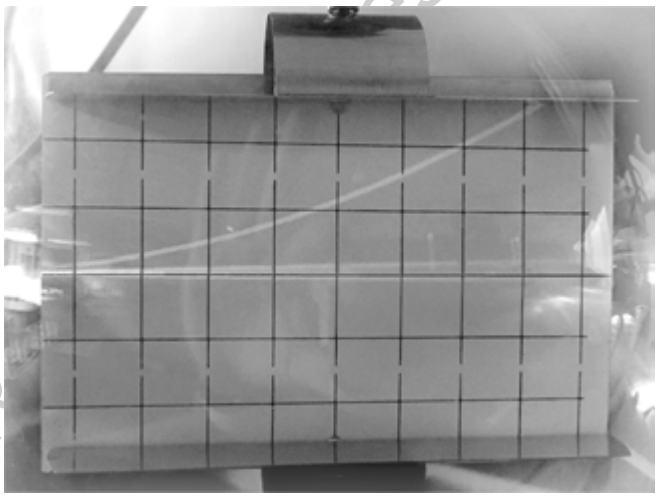
Velocity = ...

(c) The electron beam passes between plates across which a potential difference has been applied. The electron beam is deflected, as shown in the photograph.



On the diagram below, sketch the electric field between the plates.

(2)

(d) A potential difference of 550 V is applied across the plates of another deflection tube. The vertical separation of the plates is 5.0 cm.

(i) Show that the electrostatic force on an electron between the plates is about 2×10^{-15} N.

(3)

(ii) The electrons in the beam enter the region between the plates with a horizontal velocity of $2.2 \times 10^{7}\,\text{m s}^{-1}$.

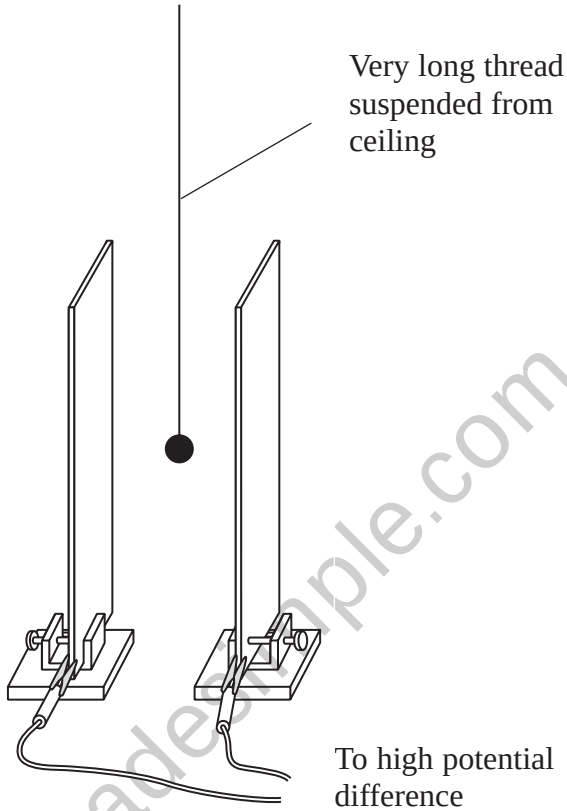
Determine the vertical deflection of the beam after travelling 10 cm horizontally between the plates.

(4)

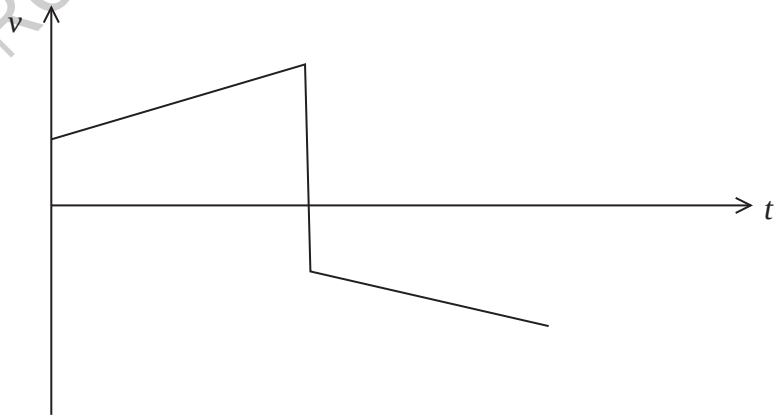
Vertical deflection = ...

(Total for Question 2 = 14 marks)

***3** A student has been asked to talk to her class about electric fields. As part of her presentation she hangs a table tennis ball, covered in a carbon coating, between two parallel plates connected to a high potential difference.



She pulls the ball across so that it touches one of the plates and then releases it.
The ball then continues to bounce between the two plates.
She sketches a graph of velocity v of the ball with time t from the time the ball leaves a plate until it returns.



Explain the shape of the velocity-time graph for the ball from when it leaves one plate until it returns to the same plate. Ignore the weight of the ball.

(4)

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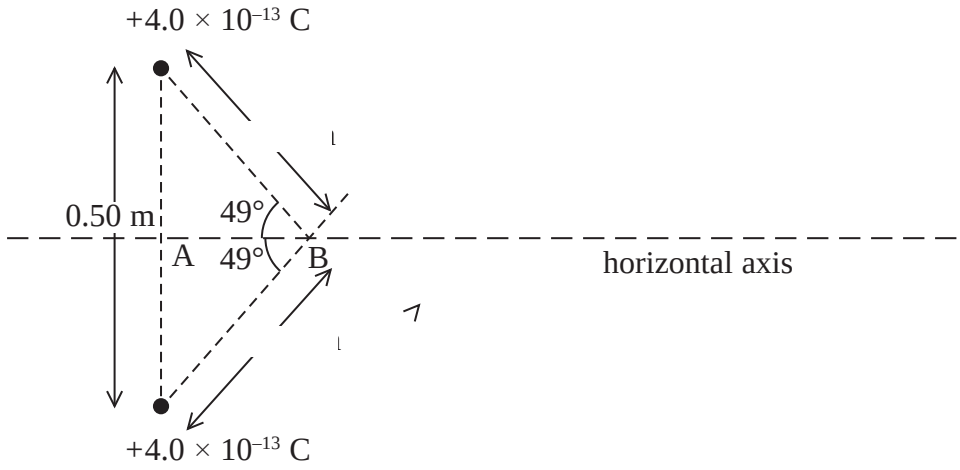
(Total for Question 3 = 4 marks)

4 Two small point charges are separated by a short distance as shown in the diagram.



(a) Calculate the resultant electric field strength at B, a distance of 0.33 m from each charge.

(4)

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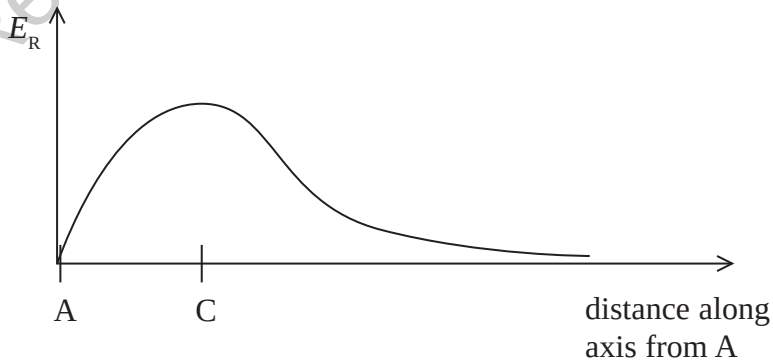
Resultant electric field strength = ...

(b) The graph shows how the resultant electric field strength E_R varies with distance along the horizontal axis from point A. A maximum occurs at point C.



Explain why E_R is zero at A and decreases with distance at large distances from A.

(2)

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(c) The electric field strength at C is 0.044 N C^{-1}.
A positive ion enters the electric field travelling along the axis towards the right. The ion has a speed of 1500 m s^{-1} at point A.

(i) Calculate the maximum acceleration of the ion as it passes through the field.

mass of ion = 6.6×10^{-27} kg
charge on ion = 3.2×10^{-19} C

(3)

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Maximum acceleration = ...

(ii) Sketch a graph to show how the speed of the ion varies as it travels along the axis from A until it is well beyond C. Mark positions A and C on the graph.

(3)

(Total for Question 5 = 12 marks)

5 (a) Coulomb's law for the force F between point charges Q_1 and Q_2, which are a distance r apart, is given by

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$$

Express the unit of ε_0 in base units.

(3)

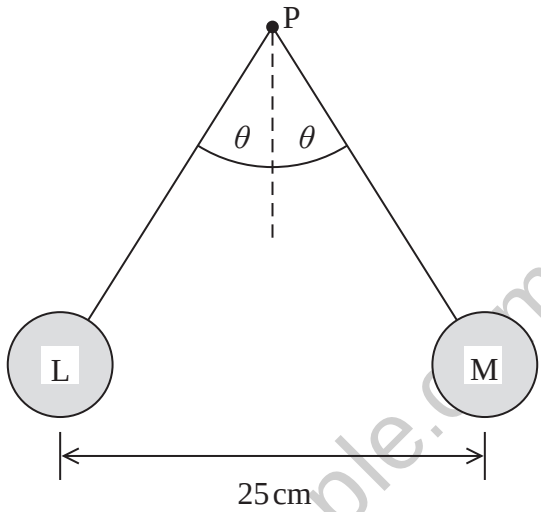
(b) Electric fields are caused by both point charges and by parallel plates with a potential difference across them.

Describe the difference between the electric field caused by a point charge and the electric field between parallel plates. Your answer should include a diagram of each type of field and reference to electric field strength.

(5)

(c) Two small spheres L and M are attached to non-conducting threads and suspended from a point P. Each sphere is given an equal positive charge of 4.0×10^{-7} C. The spheres hang in equilibrium as shown in the diagram.

The mass of each sphere is 2.7 g.



By considering the forces acting on one of the spheres, calculate the tension in the thread and the angle θ.

(6)

Tension =

θ =

(Total for Question 6 = 14 marks)