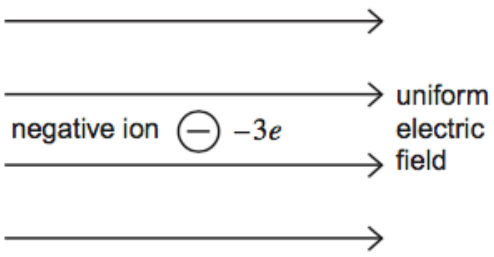
1)

(a) **Figure 1** shows a negative ion which has a charge of $-3e$ and is free to move in a uniform electric field. When the ion is accelerated by the field through a distance of $63\,\text{mm}$ parallel to the field lines its kinetic energy increases by $4.0 \times 10^{-16}\,\text{J}$.

Figure 1



(a) (i) State and explain the direction of the electrostatic force on the ion.

[2 marks]

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(a) (ii) Calculate the magnitude of the electrostatic force acting on the ion.

[2 marks]

magnitude of electrostatic force ..... N

(a) (iii) Calculate the electric field strength.

[1 mark]

electric field strength ..... N C^{-1}

2)

(a) State, in words, Coulomb's law.

[2 marks]

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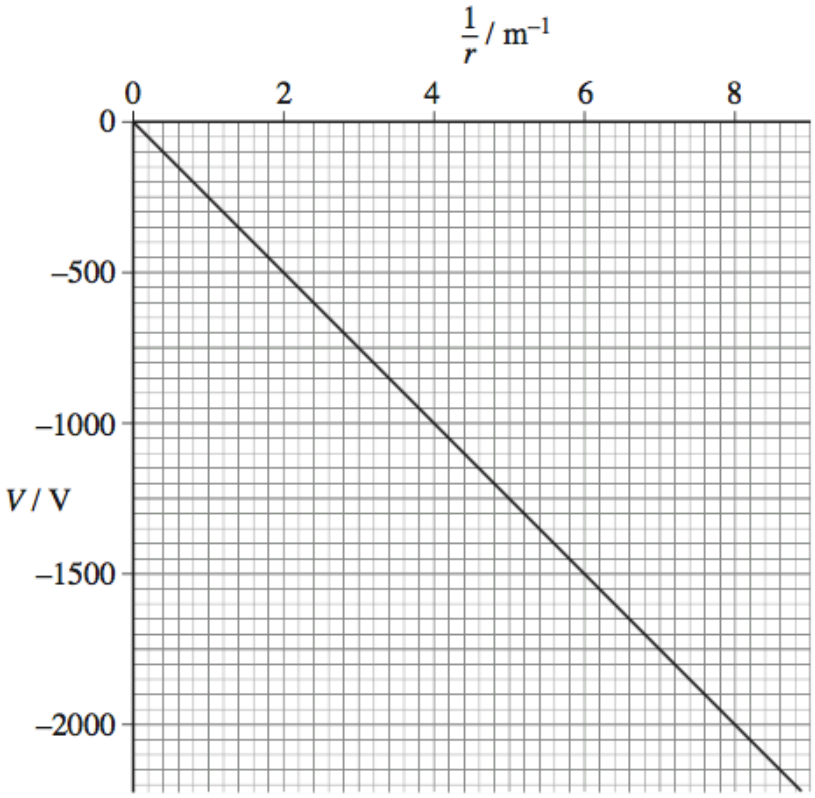
(b) **Figure 3** shows how the electric potential, V, varies with $\frac{1}{r}$, where r is the distance from a point charge Q.

Figure 3



State what can be deduced from the graph about how V depends on r and explain why all the values of V on the graph are negative.

[2 marks]

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(c) (i) Use data from the graph (**Figure 3**) to show that the magnitude of Q is about 30 nC.

[2 marks]

(c) (ii) A +60 nC charge is moved from a point where $r = 0.20$ m to a point where $r = 0.50$ m. Calculate the work done.

[2 marks]

work done ..... J

(c) (iii) Calculate the electric field strength at the point where $r = 0.40$ m.

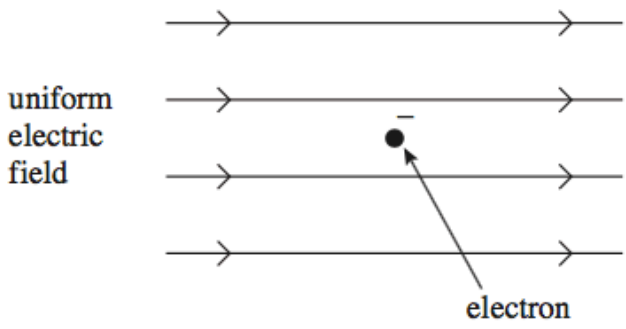
[2 marks]

electric field strength ..... V m^{-1}

3)

(a) **Figure 2** shows an electron at a point in a uniform electric field at an instant when it is stationary.

Figure 2



(a) (i) Draw an arrow on **Figure 2** to show the direction of the electrostatic force that acts on the stationary electron.

(1 mark)

(a) (ii) State and explain what, if anything, will happen to the magnitude of the electrostatic force acting on the electron as it starts to move in this field.

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(2 marks)

(b) **Figure 3a** shows a stationary electron in a non-uniform electric field. **Figure 3b** shows a stationary proton, placed in exactly the same position in the same electric field as the electron in **Figure 3a**.

Figure 3a

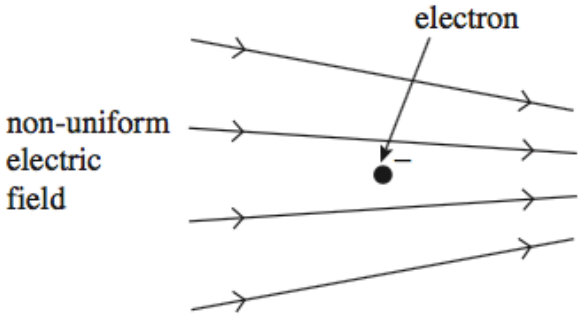
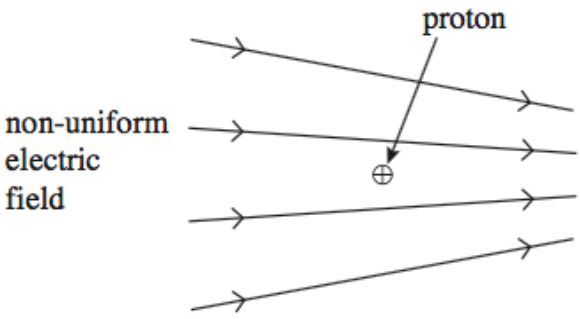


Figure 3b



(b) (i) State and explain how the electrostatic force on the proton in **Figure 3b** compares with that on the electron in **Figure 3a**.

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(2 marks)

(b) (ii) Each of the particles starts to move from the positions shown in **Figure 3a** and **Figure 3b**. State and explain how the magnitude of the **initial** acceleration of the proton compares with that of the electron.

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(2 marks)

(b) (iii) Describe and explain what will happen to the acceleration of each of these particles as they continue to move in the electric field.

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(2 marks)

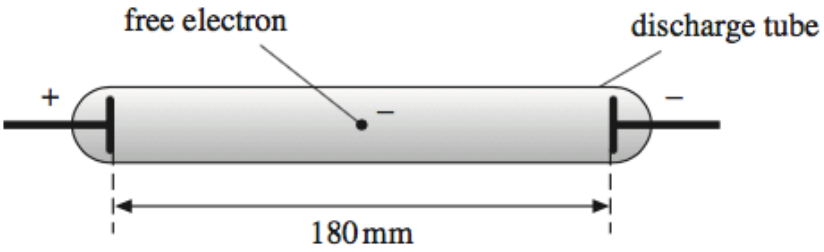
(c) The line spectrum of neon gas contains a prominent red line of wavelength 650 nm.

(c) (i) Show that the energy required to excite neon atoms so that they emit light of this wavelength is about 2 eV.

(3 marks)

(c) (ii) An illuminated shop sign includes a neon discharge tube, as shown in **Figure 4**.
A pd of 4500 V is applied across the electrodes, which are 180 mm apart.

Figure 4



Assuming that the electric field inside the tube is uniform, calculate the minimum distance that a free electron would have to move from rest in order to excite the red spectral line in part (c).

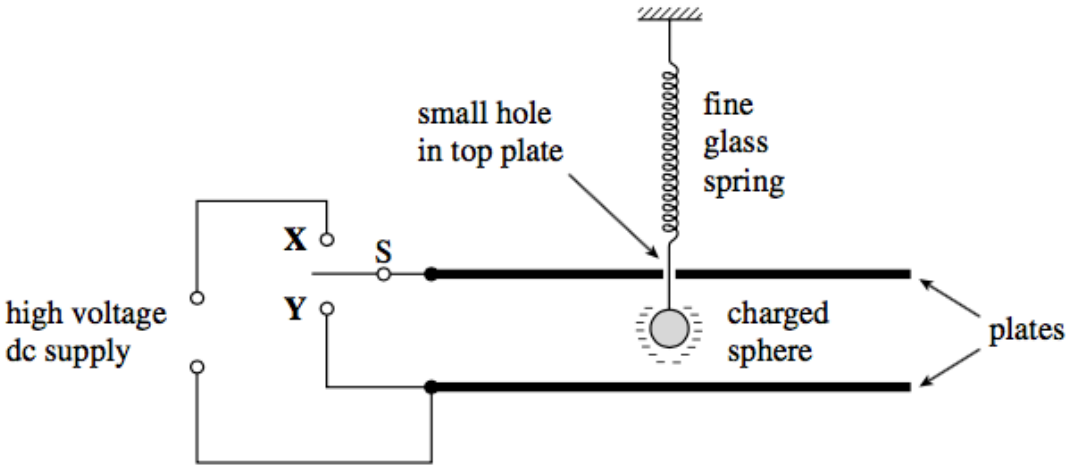
answer = ... m

(3 marks)

4)

A small negatively charged sphere is suspended from a fine glass spring between parallel horizontal metal plates, as shown in **Figure 1**.

Figure 1



(a) Initially the plates are uncharged. When switch S is set to position **X**, a high voltage dc supply is connected across the plates. This causes the sphere to move vertically upwards so that eventually it comes to rest 18 mm higher than its original position.

(a) (i) State the direction of the electric field between the plates.

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(1 mark)

(a) (ii) The spring constant of the glass spring is $0.24\,\text{N m}^{-1}$. Show that the force exerted on the sphere by the electric field is $4.3 \times 10^{-3}\,\text{N}$.

(1 mark)

(a) (iii) The pd applied across the plates is 5.0 kV. If the charge on the sphere is -4.1×10^{-8} C, determine the separation of the plates.

answer = ... m

(3 marks)

(b) Switch S is now moved to position **Y**.

(b) (i) State and explain the effect of this on the electric field between the plates.

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(2 marks)

(b) (ii) With reference to the forces acting on the sphere, explain why it starts to move with simple harmonic motion.

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(3 marks)

5)

(a) State, in words, Coulomb's law.

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(2 marks)

(b) **Figure 3** shows two point charges of +4.0 nC and +6.0 nC which are 68 mm apart.

Figure 3

(b) (i) Sketch on **Figure 3** the pattern of the electric field surrounding the charges.

(3 marks)

(b) (ii) Calculate the magnitude of the electrostatic force acting on the +4.0 nC charge.

magnitude of force ..... N

(2 marks)

(c) (i) Calculate the magnitude of the resultant electric field strength at the mid-point of the line joining the two charges in **Figure 3**.
State an appropriate unit for your answer.

electric field strength ..... unit .....

(4 marks)

(c) (ii) State the direction of the resultant electric field at the mid-point of the line joining the charges.

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(1 mark)

6)

(a) Define the electric potential at a point in an electric field.

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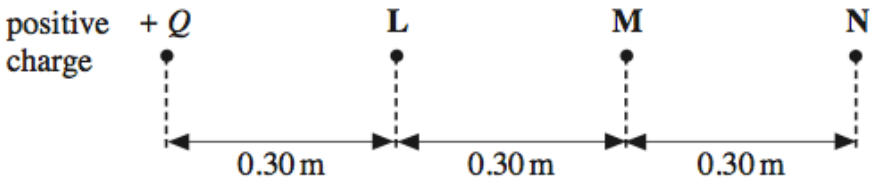
(3 marks)

(b) **Figure 1** shows part of the region around a small positive charge.

Figure 1



(b) (i) The electric potential at point **L** due to this charge is + 3.0 V. Calculate the magnitude Q of the charge. Express your answer to an appropriate number of significant figures.

answer = ... C

(3 marks)

(b) (ii) Show that the electric potential at point **N**, due to the charge, is +1.0 V.

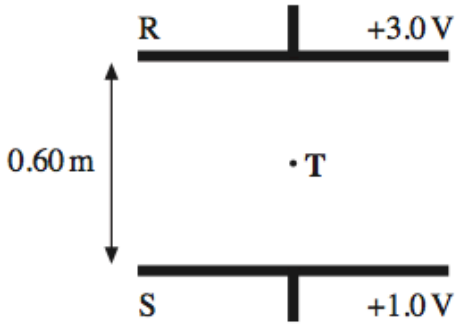
(1 mark)

(b) (iii) Show that the electric field strength at point **M**, which is mid-way between **L** and **N**, is 2.5 V m^{-1}.

(1 mark)

(c) R and S are two charged parallel plates, 0.60 m apart, as shown in **Figure 2**. They are at potentials of + 3.0 V and + 1.0 V respectively.

Figure 2



(c) (i) On **Figure 2**, sketch the electric field between R and S, showing its direction.

(2 marks)

(c) (ii) Point **T** is mid-way between R and S.
Calculate the electric field strength at **T**.

answer = ... V m^{-1}

(1 mark)

(c) (iii) Parts (b)(iii) and (c)(ii) both involve the electric field strength at a point mid-way between potentials of + 1.0 V and + 3.0 V. Explain why the magnitudes of these electric field strengths are different.

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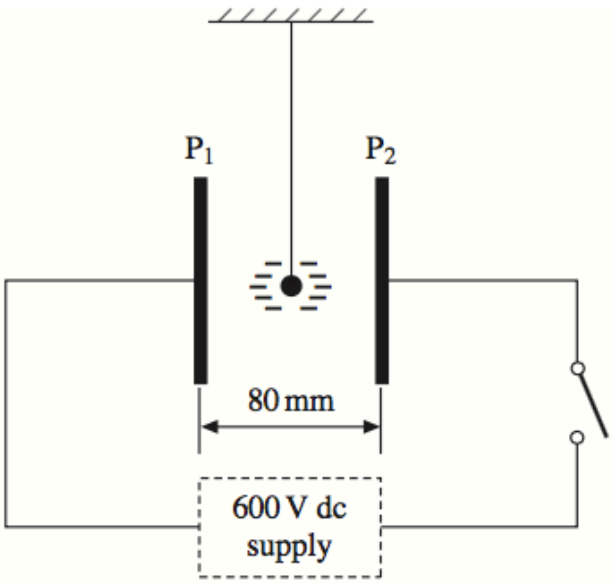
(1 mark)

7)

Figure 3 shows a small polystyrene ball which is suspended between two vertical metal plates, $\mathbf{P_1}$ and $\mathbf{P_2}$, 80 mm apart, that are initially uncharged. The ball carries a charge of –0.17 μC.

Figure 3



(a) (i) A pd of 600 V is applied between $\mathbf{P_1}$ and $\mathbf{P_2}$ when the switch is closed. Calculate the magnitude of the electric field strength between the plates, assuming it is uniform.

answer = ... V m^{-1}

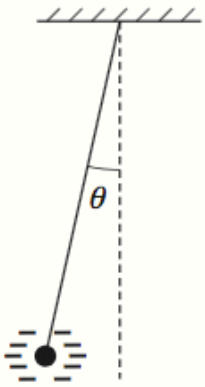
(2 marks)

(a) (ii) Show that the magnitude of the electrostatic force that acts on the ball under these conditions is 1.3 mN.

(1 mark)

(b) Because of the electrostatic force acting on it, the ball is displaced from its original position. It comes to rest when the suspended thread makes an angle θ with the vertical, as shown in **Figure 4**.

Figure 4



(b) (i) On **Figure 4**, mark and label the forces that act on the ball when in this position.

(2 marks)

(b) (ii) The mass of the ball is 4.8×10^{-4}kg. By considering the equilibrium of the ball, determine the value of θ.

answer = ...degrees

(3 marks)

8)

Gravitational fields and electric fields have many features in common but also have several differences. For both radial and uniform gravitational and electric fields, compare and contrast their common features and their differences.

In your answer you should consider:

- the force acting between particles or charges
- gravitational field strength and electric field strength
- gravitational potential and electric potential.

The quality of your written communication will be assessed in your answer.

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(6 marks)