3. A -4.2×10^{-6} C charge, is placed between two stationary charges, Q_1 and Q_2, as shown below.

$Q_1 = 2.5 \times 10^{-6}$ C -4.2×10^{-6} C $Q_2 = 7.3 \times 10^{-6}$ C

$\oplus$ $\ominus$ $\oplus$

$\mid\!\longleftarrow$ 0.020 m $\longrightarrow\!\mid\!\longleftarrow$ 0.030 m $\longrightarrow\!\mid$
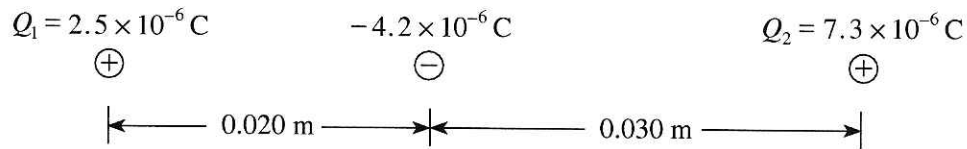
What is the magnitude and direction of the net force on the -4.2×10^{-6} C charge due to the **two** stationary charges?

(7 marks)

$$F_{net} = F_1 + F_2 \qquad\qquad\qquad\qquad\qquad\qquad\qquad \leftarrow \textbf{1 mark}$$

$$F_1 = \frac{kQ_1Q}{R^2} = \frac{9.00 \times 10^9 \times 2.5 \times 10^{-6} \times -4.2 \times 10^{-6}\ C}{(0.02)^2} = -236.25\ \text{N (left)} \qquad \leftarrow \textbf{2 marks}$$
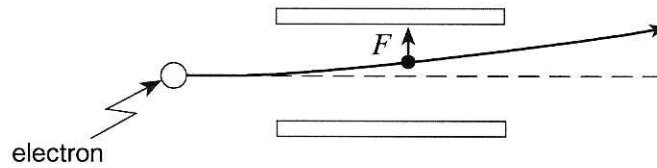
$$F_2 = \frac{kQ_2Q}{R^2} = \frac{9.00 \times 10^9 \times 7.3 \times 10^{-6} \times -4.2 \times 10^{-6}\ C}{(0.030)^2} = -306.6\ \text{N (right)} \qquad \leftarrow \textbf{2 marks}$$

236.25 N   306.6 N

$\longleftarrow$ $\longrightarrow$

$$F_{net} = 306.6 - 236.25 \qquad\qquad\qquad\qquad\qquad\qquad \leftarrow \textbf{1 mark}$$

$$= 70\ \text{N (right)} \qquad\qquad\qquad\qquad\qquad\qquad\qquad \leftarrow \textbf{1 mark}$$

4. An electron passing between parallel plates 0.025 m apart experiences an upward electrostatic force of 5.1×10^{-16} N.

electron

a) What is the magnitude of the electric field between the plates? **(3 marks)**

$$E = \frac{F}{q}$$ ← **1 mark**

$$= \frac{5.1 \times 10^{-16} \text{ N}}{1.6 \times 10^{-19} \text{ C}}$$ ← **$1\frac{1}{2}$ marks**

$$= 3.2 \times 10^3 \text{ N/C}$$ ← **$\frac{1}{2}$ mark**

b) What is the potential difference between the plates? **(2 marks)**

$$E = \frac{V}{d}$$ ← **1 mark**

$$V = Ed$$

$$= 3.2 \times 10^3 \times 0.025$$

$$= 80 \text{ V}$$ ← **1 mark**

c) On the diagram below draw in the connections to the power supply necessary for the electron to experience this upward force. **(2 marks)**

connections
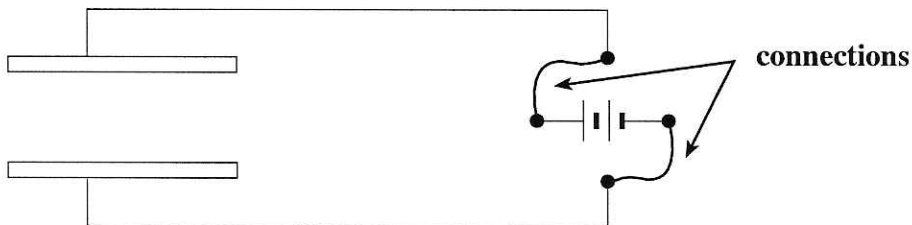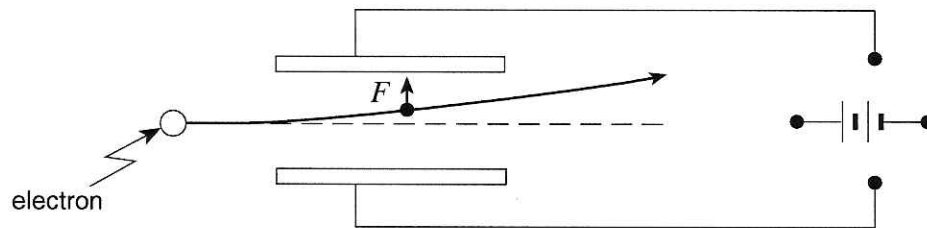
5. Two charges are positioned as shown in the diagram below.

$Q_1 = 8.0\ \mu C$ $\qquad\qquad$ $Q_2 = -2.0\ \mu C$ $\qquad$ A

$\oplus$ (+) $\qquad\qquad\qquad\qquad$ $\ominus$ (–) $\qquad$ •

$|\!\longleftarrow\ \ 4.0\ m\ \ \longrightarrow\!|\!\longleftarrow\ 2.0\ m\ \longrightarrow\!|$
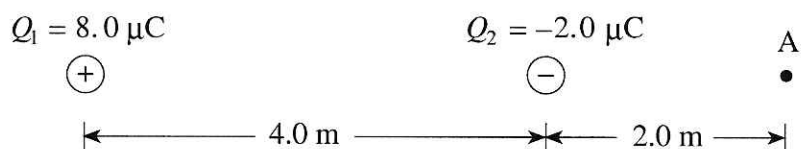
a) Find the magnitude and direction of the electric field at A. (Note: $1.0\ \mu C = 1.0 \times 10^{-6}\ C$)

(4 marks)

$$E_1 = \frac{kQ_1}{r_1^{\,2}} = \frac{9.0 \times 10^9 \times 8.0 \times 10^{-6}}{6.0^2} = 2.0 \times 10^3\ \text{N/C to the right} \qquad \leftarrow 1\tfrac{1}{2}\ \textbf{marks}$$

$$E_2 = 4.5 \times 10^3\ \text{N/C to the left} \qquad\qquad\qquad\qquad\qquad \leftarrow 1\tfrac{1}{2}\ \textbf{marks}$$

$$E = 2.5 \times 10^3\ \text{N/C to the left} \qquad\qquad\qquad\qquad\qquad \leftarrow \textbf{1 mark}$$

b) A charge placed at A experiences a force of $4.0 \times 10^{-3}\ N$ towards the right. What are the magnitude and polarity of this charge? **(3 marks)**
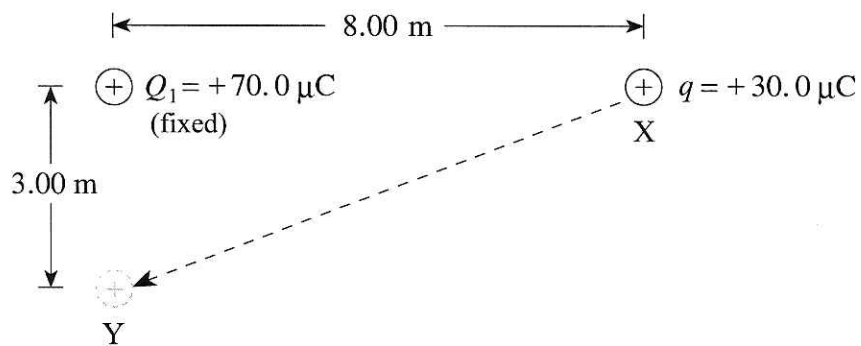
$$E = \frac{F}{q} \rightarrow q = \frac{F}{E} \qquad\qquad \leftarrow \textbf{1 mark}$$

$$= \frac{4.0 \times 10^{-3}\ \text{N}}{2.5 \times 10^3\ \text{N/C}} \qquad \leftarrow \textbf{1 mark}$$

$$= 1.6 \times 10^{-6}\ \text{C, negative} \qquad \leftarrow \textbf{1 mark}$$

Answer: $-1.6 \times 10^{-6}\ C$

6. A charge q of $30.0 \, \mu C$ is moved from point X to point Y.

$$\longleftarrow \quad 8.00 \text{ m} \quad \longrightarrow$$

$\oplus \, Q_1 = +70.0 \, \mu C$ (fixed)

$\oplus \, q = +30.0 \, \mu C$
X

3.00 m

$\oplus$
Y

How much work is done on the $30.0 \, \mu C$ charge? $\left(1 \, \mu C = 1 \times 10^{-6} \text{ C}\right)$ **(7 marks)**

$W = \Delta E$ $\qquad \leftarrow$ **1 mark**

$= E_{p_y} - E_{p_x}$ $\qquad \leftarrow$ **2 marks**

$= \dfrac{kQq}{r_y} - \dfrac{kQq}{r_x}$ $\qquad \leftarrow$ **1 mark**

$= \dfrac{9.00 \times 10^9 \cdot 70.0 \times 10^{-6} \cdot 30.0 \times 10^{-6}}{3.00} - \dfrac{9.00 \times 10^9 \cdot 70.0 \times 10^{-6} \cdot 30.0 \times 10^{-6}}{8.00}$ $\left. \right\} \leftarrow$ **2 marks**

$= (6.3 - 2.4) \text{ J}$

$= 3.9 \text{ J}$ $\qquad \leftarrow$ **1 mark**

7. A small 4.0×10^{-3} kg charged sphere is suspended by a light thread between parallel plates, as shown in the diagram below. When the plates are connected to a 500 V source, the thread makes a 15^0 angle with the vertical.
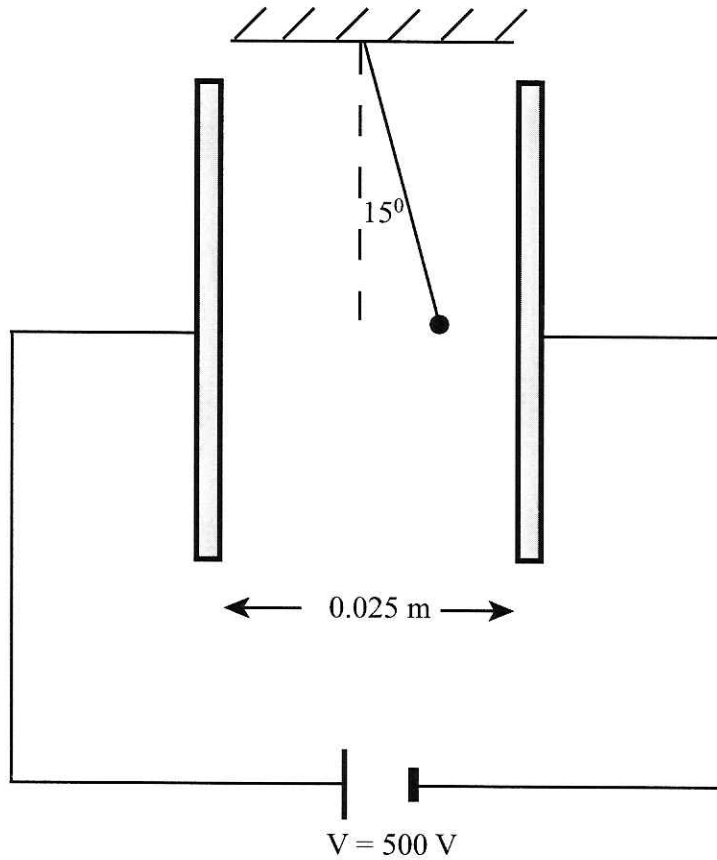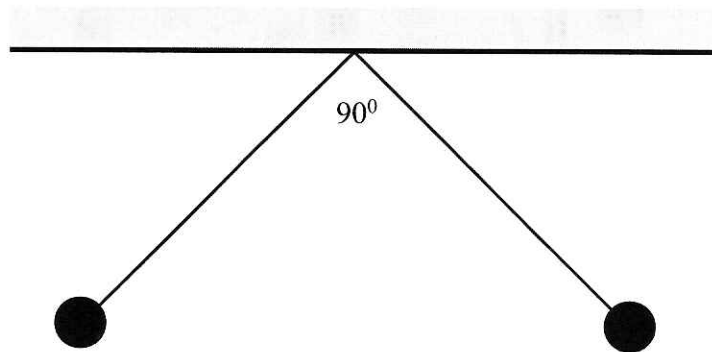

What is the charge on the sphere? **(9 marks)**

$E = \dfrac{V}{d} = \dfrac{500V}{0.025m} = 2.0 \times 10^4 V/m \leftarrow 2\,marks$

$F_e = W \tan 15^0$
$= (4.0 \times 10^{-3})(9.8)(\tan 15^0) \Big\} 4\,marks$
$= 1.05 \times 10^{-2} N$

$F_e = qE$
$q = \dfrac{F_e}{E} = \dfrac{1.05 \times 10^{-2}}{2.0 \times 10^4} \Big\} 3\,marks$
$= 5.3 \times 10^{-7} \ C$

8. Two small, indentically-charged conducting spheres each of mass 2.5×10^{-4} kg hang from the same point on insulating threads of length 0.50 m as shown in the diagram below. If the enclosed angle between the threads is 90^0, what is the charge on each sphere? **(9 marks)**
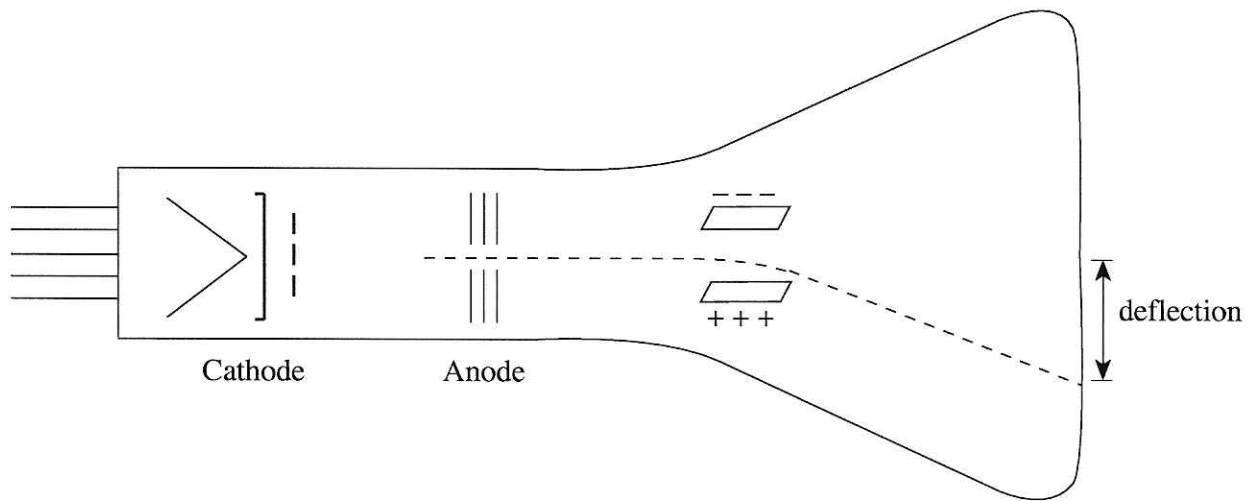

FBD
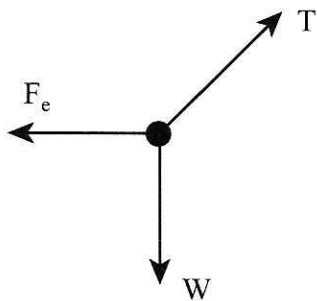
$$\sum F_x = 0$$
$$T_x = F_e$$

$$\sum F_y = 0$$
$$T_y = F_g$$

2 marks

since $\theta = 45^0$

$T_x = T_y$

$F_e = F_g = mg$

2 mark

$$F_e = \frac{kqq}{r^2} = mg$$

$$\therefore q = \sqrt{\frac{mgr^2}{k}} = 3.7 \times 10^{-7} C$$

5 marks

9. In a cathode-ray tube, electrons are accelerated from the cathode towards the anode by an accelerating voltage V_a. After passing through the anode, the electrons are deflected by the two oppositely-charged parallel plates.

If the accelerating voltage V_a is increased, will the deflection increase, decrease, or remain the same? Using principles of physics, explain your answer. **(4 marks)**

The deflection y will decrease.

If V_a is increased, the electrons are given a greater kinetic energy: e.g., $V_a = \dfrac{\Delta E_k}{q}$. Hence, the electrons are moving faster, so they spend less time between the plates. A force accelerates the electrons transversely between the plates; however, as the acceleration occurs for a shorter time, their deflection is reduced; e.g., $y = \dfrac{1}{2}at^2$.