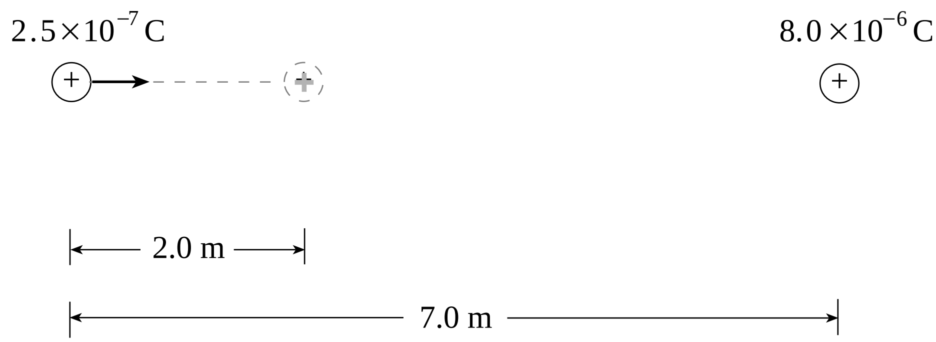
ELECTROSTATICS
PROVINCIAL EXAMINATION ASSIGNMENT
ANSWER KEY / SCORING GUIDE

PART A: Multiple Choice (each question worth ONE mark)

Q	K	Q	K
1.	B	24.	B
2.	B	25.	B
3.	C	26.	B
4.	C	27.	B
5.	A	28.	A
6.	B	29.	A
7.	B	30.	B
8.	C	31.	C
9.	A	32.	A
10.	D	33.	D
11.	C	34.	A
12.	C	35.	A
13.	B	36.	B
14.	C	37.	A
15.	B	38.	C
16.	C	39.	A
17.	D	40.	B
18.	C	41.	D
19.	C	42.	B
20.	B	43.	D
21.	C	44.	A
22.	C	45.	B
23.	A	46.	C

1. a) A 2.5×10^{-7} C charge is initially located 7.0 m from a fixed 8.0×10^{-6} C charge. What is the minimum amount of work required to move the 2.5×10^{-7} C charge 2.0 m closer as shown?

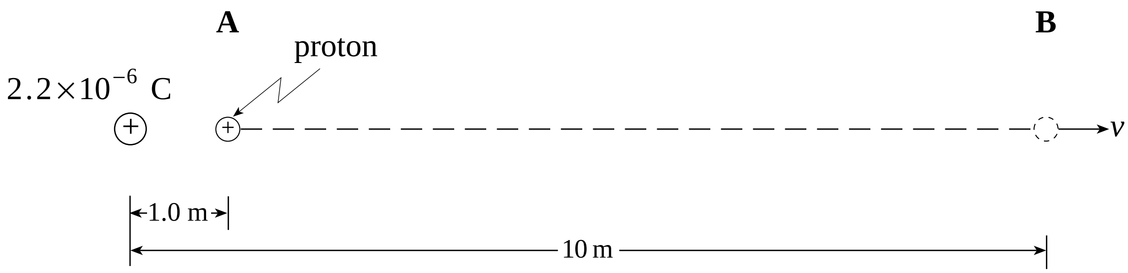


$W = \Delta E_p$	**2 marks**	**OR**	$= q\Delta V$
$W = \frac{kQQ}{5} - \frac{kQQ}{7}$	**1 mark**		$= q\left(\frac{kQ}{r_2} - \frac{kQ}{r_1}\right)$
$= .0036 - .0026$	**1 mark**		$= 2.5\times10^{-7}\left(\frac{kQ}{5} - \frac{kQ}{7}\right)$
$W = 1.0\times10^{-3}$ J	**1 mark**		$= 1.0\times10^{-3}$ J

(b) If the 2.5×10^{-7} C charge is moved a further 2.0 m closer to the 8.0×10^{-6} C charge, will the additional work required be less than, the same as or greater than the work required in (a)? Using principles of physics, explain your answer. **(4 marks)**

The work required will be greater than in (a). The force acting on the 2.5×10^{-7} C charge is greater, therefore the work required to move the same distance will also be greater.

2. A proton is located at **A,** 1.0 m from a fixed $+2.2\times10^{-6}$C charge.



a) What is the change in potential energy of the proton as it moves to **B**, 10 m from the fixed charge? **(5 marks)**

$$\Delta E_p = \frac{kqQ}{r_2} - \frac{kqQ}{r_1}$$ ← **2 marks**

$$\Delta E_p = \left(\frac{9\times10^9\left(1.6\times10^{-19}\right)\left(2.2\times10^{-6}\right)}{10}\right) - \left(\frac{9\times10^9\left(1.6\times10^{-19}\right)\left(2.2\times10^{-6}\right)}{1.0}\right)$$ ← **2 marks**

$$\Delta E_p = -2.9\times10^{-15}\,\text{J}$$ ← **1 mark**

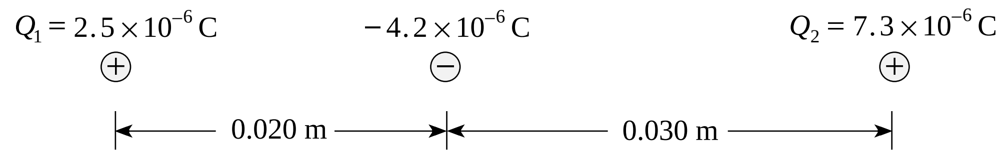
b) If the proton started from rest at **A**, what would be its speed at **B**? **(2 marks)**

$$\Delta E_p = E_k = \frac{1}{2}mv^2$$ ← **1 mark**

$$2.9\times10^{-15} = \frac{1}{2}\left(1.67\times10^{-27}\right)v^2$$ ← **½ mark**

$$v = 1.9\times10^6\,\text{m/s}$$ ← **½ mark**

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



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)**

$F_{net} = F_1 + F_2$ ← **1 mark**

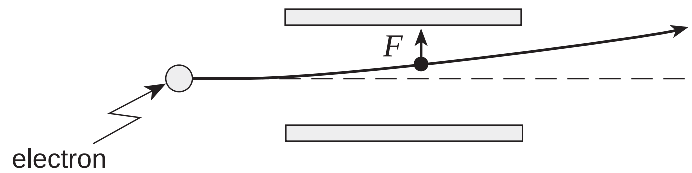
$F_1 = \dfrac{kQ_1Q}{R^2} = \dfrac{9.00\times10^9 \times 2.5\times10^{-6} \times -4.2\times10^{-6}\ \text{C}}{(0.02)^2} = -236.25\ \text{N}\ \ (\text{left})$ ← **2 marks**

$F_2 = \dfrac{kQ_2Q}{R^2} = \dfrac{9.00\times10^9 \times 7.3\times10^{-6} \times -4.2\times10^{-6}\ \text{C}}{(0.030)^2} = -306.6\ \text{N}\ \ (\text{right})$ ← **2 marks**

$F_{net} = 306.6 - 236.25$ ← **1 mark**

$= 70\ \text{N}\ \ (\text{right})$ ← **1 mark**

4. An electron passing between parallel plates $0.025\ \text{m}$ apart experiences an upward electrostatic force of $5.1\times10^{-16}\ \text{N}$.



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

$E = \dfrac{F}{q}$ ← **1 mark**

$= \dfrac{5.1\times10^{-16}\ \text{N}}{1.6\times10^{-19}\ \text{C}}$ ← **1 $\frac{1}{2}$ marks**

$= 3.2\times10^{3}\ \text{N/C}$ ← **$\frac{1}{2}$ mark**

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

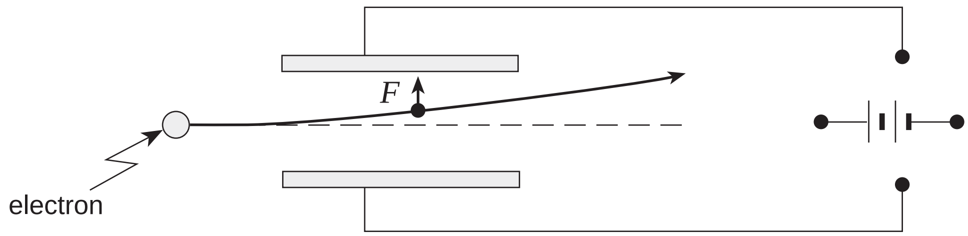
$E = \dfrac{V}{d}$ ← **1 mark**

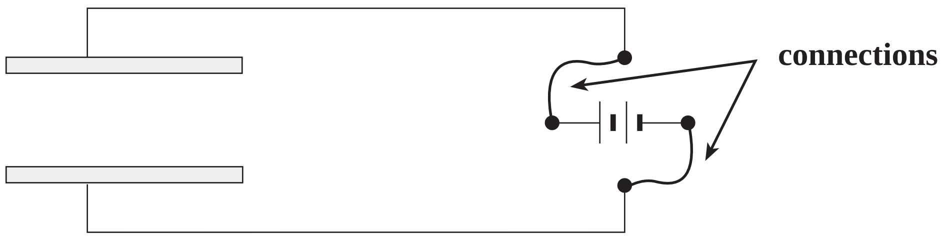
$V = Ed$

$= 3.2\times10^{3}\times0.025$

$= 80\ \text{V}$ ← **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)**





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

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)

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

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

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

b) A charge placed at A experiences a force of 4.0×10^{-3} N towards the right. What are the magnitude and polarity of this charge?
(3 marks)

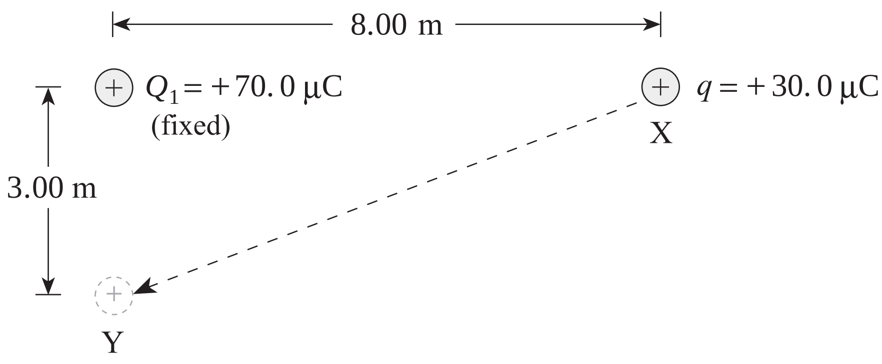
$$E = \frac{F}{q} \rightarrow q = \frac{F}{E} \qquad \leftarrow \mathbf{1\ mark}$$

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

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

Answer: -1.6×10^{-6} C

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



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

$W = \Delta E$ ← **1 mark**

$= E_{p_y} - E_{p_x}$ ← **2 marks**

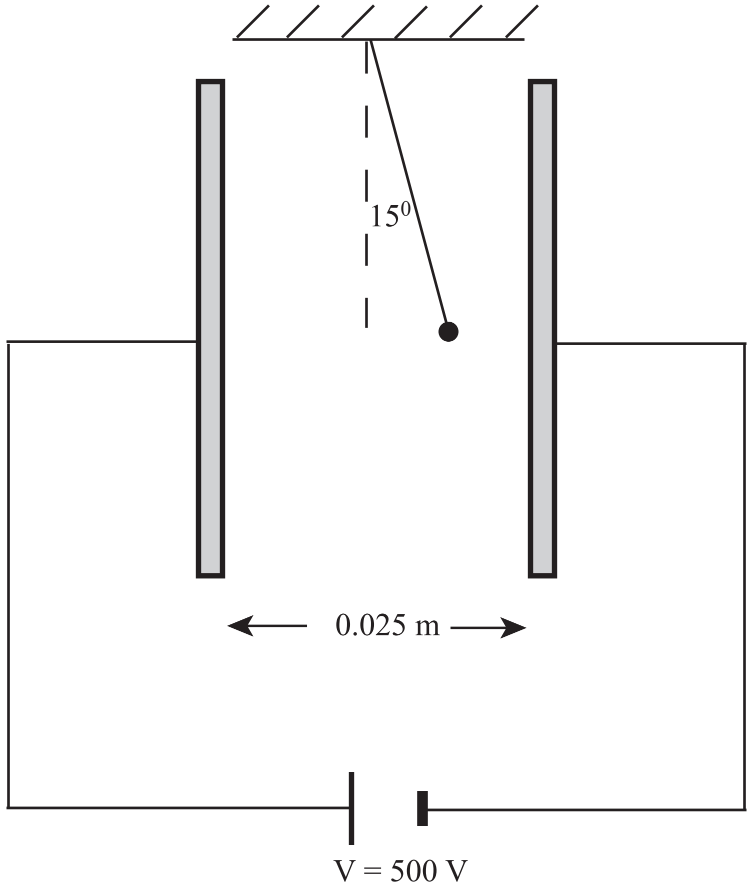
$= \frac{kQq}{r_y} - \frac{kQq}{r_x}$ ← **1 mark**

$= \frac{9.00 \times 10^9 \cdot 70.0 \times 10^{-6} \cdot 30.0 \times 10^{-6}}{3.00} - \frac{9.00 \times 10^9 \cdot 70.0 \times 10^{-6} \cdot 30.0 \times 10^{-6}}{8.00}$

$= (6.3 - 2.4)\ J$ } ← **2 marks**

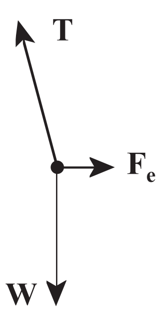
$= 3.9\ J$ ← **1 mark**

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)**

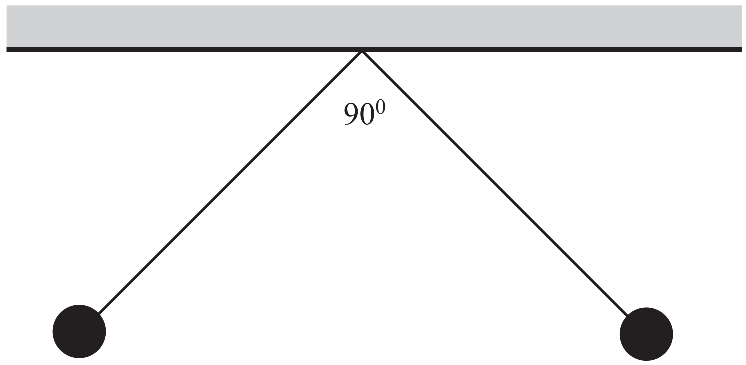
$$E = \frac{V}{d} = \frac{500\text{V}}{0.025\text{m}} = 2.0 \times 10^4 \text{ V/m} \leftarrow 2 \text{ marks}$$



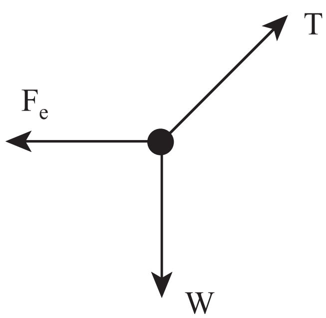
$$\left.\begin{aligned} F_e &= W \tan 15^0 \\ &= (4.0 \times 10^{-3})(9.8)(\tan 15^0) \\ &= 1.05 \times 10^{-2}\text{ N} \end{aligned}\right\} \text{4 marks}$$

$$\left.\begin{aligned} F_e &= qE \\ q &= \frac{F_e}{E} = \frac{1.05 \times 10^{-2}}{2.0 \times 10^4} \\ &= 5.3 \times 10^{-7}\text{ C} \end{aligned}\right\} \text{3 marks}$$

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

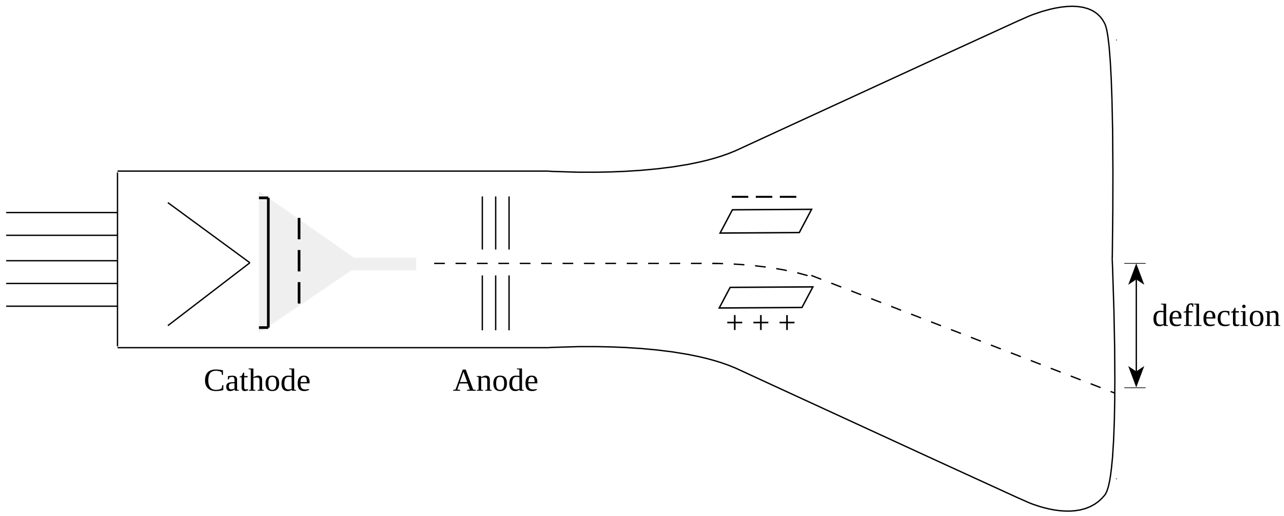


$$\left.\begin{array}{l}\sum F_x = 0 \\ T_x = F_e \\ \\ \sum F_y = 0 \\ T_y = F_g\end{array}\right\}\ 2\ \text{marks}$$

$$\left.\begin{array}{l}\text{since}\ \ \theta = 45^0 \\ T_x = T_y \\ F_e = F_g = mg\end{array}\right\}\ 2\ \text{mark}$$

$$\left.\begin{array}{l}F_e = \dfrac{kqq}{r^2} = mg \\ \\ \therefore q = \sqrt{\dfrac{mgr^2}{k}} = 3.7 \times 10^{-7}\,C\end{array}\right\}\ 5\ \text{marks}$$

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., $V_a = \frac{\Delta E_k}{q}$. 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., $y = \frac{1}{2}at^2$.