ELECTROSTATICS
PROVINCIAL EXAMINATION ASSIGNMENT

ANSWER KEY / SCORING GUIDE

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

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

\[ W = \Delta E_p \quad 2 \text{ marks} \quad \text{OR} \quad = q\Delta V \]

\[ W = \frac{kQ_1 Q_2}{r_2} - \frac{kQ_1 Q_2}{r_1} \quad 1 \text{ mark} \quad = q \left( \frac{kQ_1}{r_2} - \frac{kQ_2}{r_1} \right) \]

\[ = 0.0036 - 0.0026 \quad 1 \text{ mark} \quad = 2.5 \times 10^{-7} \left( \frac{kQ_1}{5} - \frac{kQ_2}{7} \right) \]

\[ W = 1.0 \times 10^{-3} \text{ J} \quad 1 \text{ mark} \quad = 1.0 \times 10^{-3} \text{ J} \]

(b) If the $2.5 \times 10^{-7}$ C charge is moved a further 2.0 m closer to the $8.0 \times 10^{-6}$ 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. \( 4 \text{ marks} \)

The work required will be greater than in (a). The force acting on the $2.5 \times 10^{-7}$ 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 $+2.2 \times 10^{-6} \text{C}$ charge.

\[ \text{A proton} \]

\[ \text{B} \]

\[ 2.2 \times 10^{-6} \text{C} \]

\[ 1.0 \text{m} \]

\[ 10 \text{m} \]

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

\[
\Delta E_p = \frac{kQ}{r_2} - \frac{kQ}{r_1}
\]

\[
\Delta E_p = \left( \frac{9 \times 10^9 (1.6 \times 10^{-19}) (2.2 \times 10^{-6})}{10} \right) - \left( \frac{9 \times 10^9 (1.6 \times 10^{-19}) (2.2 \times 10^{-6})}{1.0} \right)
\]

\[
\Delta E_p = -2.9 \times 10^{-15} \text{J}
\]

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

\[
\Delta E_p = E_k = \frac{1}{2}mv^2
\]

\[
2.9 \times 10^{-15} = \frac{1}{2} \left(1.67 \times 10^{-27}\right)v^2
\]

\[
v = 1.9 \times 10^6 \text{m/s}
\]
3. A $-4.2 \times 10^{-6}$ C charge, is placed between two stationary charges, $Q_1$ and $Q_2$, as shown below.

$$Q_1 = 2.5 \times 10^{-6} \text{ C} \quad Q_2 = 7.3 \times 10^{-6} \text{ C}$$

What is the magnitude and direction of the net force on the $-4.2 \times 10^{-6}$ C charge due to the two stationary charges? (7 marks)

$$F_{net} = F_1 + F_2$$ ← 1 mark

$$F_1 = \frac{kQ_1Q}{R^2} = \frac{9.00 \times 10^9 \times 2.5 \times 10^{-6} \times -4.2 \times 10^{-6} \text{ C}}{(0.02)^2} = -236.25 \text{ N} \text{ (left)}$$ ← 2 marks

$$F_2 = \frac{kQ_2Q}{R^2} = \frac{9.00 \times 10^9 \times 7.3 \times 10^{-6} \times -4.2 \times 10^{-6} \text{ C}}{(0.030)^2} = -306.6 \text{ N} \text{ (right)}$$ ← 2 marks

$$\begin{align*}
236.25 \text{ N} & \quad 306.6 \text{ N} \\
\end{align*}$$

$$F_{net} = 306.6 - 236.25$$ ← 1 mark

$$= 70 \text{ N} \text{ (right)}$$ ← 1 mark
4. An electron passing between parallel plates 0.025 m apart experiences an upward electrostatic force of $5.1 \times 10^{-16}$ N.

![Diagram of electron passing between parallel plates with electric field F upwards.]

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

\[
E = \frac{F}{q} \\
= \frac{5.1 \times 10^{-16} \text{ N}}{1.6 \times 10^{-19} \text{ C}} \\
= 3.2 \times 10^3 \text{ N/C}
\]

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

\[
E = \frac{V}{d} \\
V = Ed \\
= 3.2 \times 10^3 \times 0.025 \\
= 80 \text{ V}
\]
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.

\[ Q_1 = 8.0 \, \mu C \quad Q_2 = -2.0 \, \mu C \]

\[ \begin{array}{c}
\downarrow \\
4.0 \, m \\
\end{array} \quad \begin{array}{c}
\uparrow \\
2.0 \, m \\
\end{array} \quad A \]

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)

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

\[ E_2 = 4.5 \times 10^3 \, \text{N/C to the left} \quad \leftarrow 1\frac{1}{2} \, \text{marks} \]

\[ E = 2.5 \times 10^3 \, \text{N/C to the left} \quad \leftarrow 1 \, \text{mark} \]

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

(3 marks)

\[ E = \frac{F}{q} \quad \rightarrow \quad q = \frac{F}{E} \quad \leftarrow 1 \, \text{mark} \]

\[ = \frac{4.0 \times 10^{-3} \, \text{N}}{2.5 \times 10^3 \, \text{N/C}} \quad \leftarrow 1 \, \text{mark} \]

\[ = 1.6 \times 10^{-6} \, \text{C, negative} \quad \leftarrow 1 \, \text{mark} \]

Answer: \( -1.6 \times 10^{-6} \, \text{C} \)
6. A charge \( q \) of 30.0 \( \mu \text{C} \) is moved from point X to point Y.

\[ Q_1 = +70.0 \, \mu\text{C} \quad \text{(fixed)} \]

\[ q = +30.0 \, \mu\text{C} \]

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

\[
W = \Delta E
\]

\[
= E_{py} - E_{px}
\]

\[
= \frac{kQq}{r_y} - \frac{kQq}{r_x}
\]

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

\[
= (6.3 - 2.4) \, \text{J}
\]

\[
= 3.9 \, \text{J}
\]
A small $4.0 \times 10^{-3}$ 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)

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

$$F_e = W \tan 15^0 = (4.0 \times 10^{-3}) \times 9.8 \left(\tan 15^0\right) \leftarrow 4 \text{ marks}$$

$$q = \frac{F_e}{E} = \frac{1.05 \times 10^{-2}}{2.0 \times 10^4} = 5.3 \times 10^{-7} \text{ C} \leftarrow 3 \text{ marks}$$
8. Two small, indentically-charged conducting spheres each of mass $2.5 \times 10^{-4}$ 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)

![Diagram of two charged spheres](image)

**FBD**

\[
\begin{align*}
\sum F_x &= 0 \\
T_x &= F_e \\
\sum F_y &= 0 \\
T_y &= F_g
\end{align*}
\]

since $\theta = 45^0$

\[
\begin{align*}
T_x &= T_y \\
F_e &= F_g = mg
\end{align*}
\]

\[
F_e = \frac{kqq}{r^2} = mg
\]

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

- 10 -
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., $y = \frac{1}{2}at^2$. 