W-16

12 PHYSICS ATAR
TEST 1 - ELECTRIC FIELDS

NAME: SOLUTIONS MARK: $\frac{}{65}$

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

Multiple Choice [4]

1. (a) When a hard rubber rod is given a negative charge by rubbing it with wool:

A. positive charges are transferred from rod to wool
B. negative charges are transferred from wool to rod
C. positive charges are transferred from wool to rod
D. negative charges are transferred from rod to wool
E. negative charges are created and stored on the rod

(b) A negatively charged insulating rod is brought close to an object that is suspended by a string. If the object is repelled from the rod, we can conclude:

A. The object is positively charged
B. The object is negatively charged
C. The object is an insulator
D. The object is a conductor

(c) Two charges are repelling each other with a force magnitude *F*. If each charge doubled and the distance between the charges becomes four times the original distance, determine the new magnitude of the force. Show your working in the space provided.

A. ½ *F*
B. 4 *F*
C. 2 *F*
D. 16 *F*
E. ¼ *F*

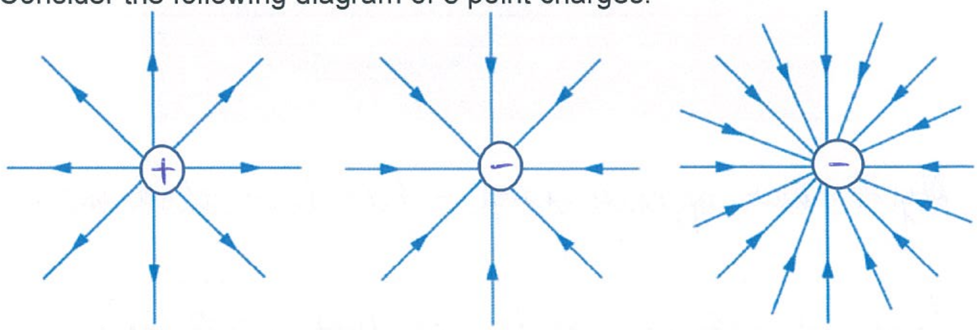
Working:

$F_i = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$

$F_{new} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{(2q_1)(2q_2)}{(4r)^2}$ (1)

$= \frac{4}{16} \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2} = \frac{1}{4} F_i$

2. (a) Consider the following diagram of 3 point charges.



(a) (b) (c)

(i) Show the polarity of the charges on the diagram. [2]

[½ mark off - each mistake]

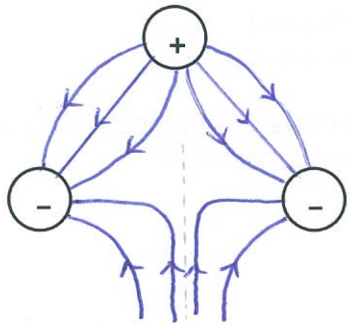
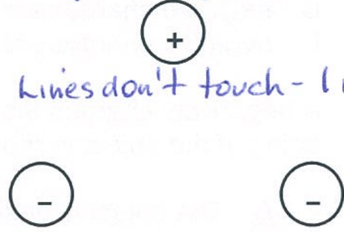
(ii) What can be concluded about the magnitude of the 3 charges? Explain. [2]

• A + B have the same charge magnitude. $(\frac{1}{2})$

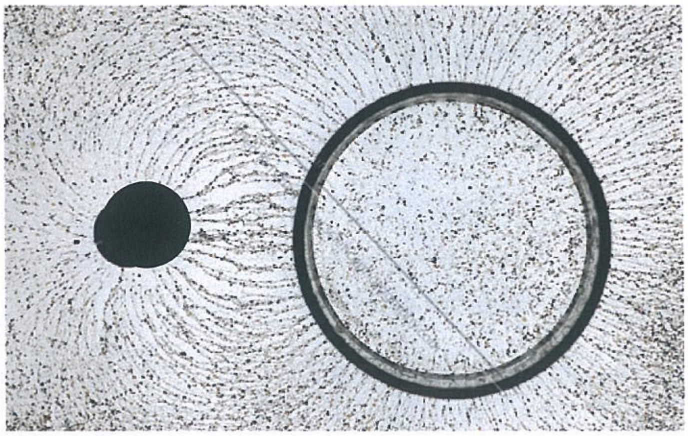
• C has a greater magnitude. $(\frac{1}{2})$

• Charge density is indicated by the number of lines per unit area. (1)

(b) Draw the electric field distribution around the following arrangement of 3 point charges [3]

Working diagram	Resultant diagram
	Direction of arrows - 1 mark Charge density/shape - 1 mark  Lines don't touch - 1 mark.

(c) Explain the characteristics of the picture of the charge distribution shown below. [3]



• Objects have opposite charge - field lines extend one to the other.

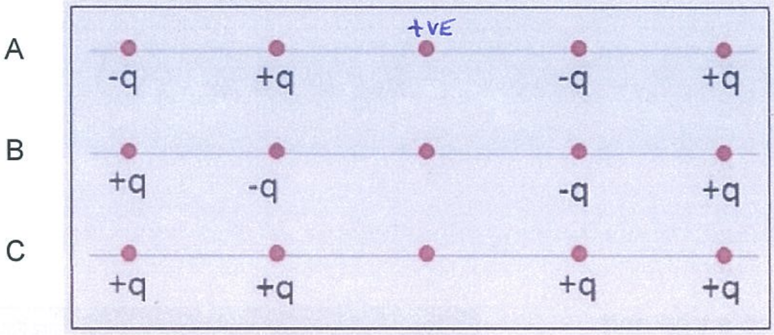
• Large circle acts as a shield - no field evident inside.

• Static charge on each - field lines are perpendicular to the surfaces.

[1 mark each]

3. Evaluate the sketch below, assuming that the dot in the centre of each line is the same charge for each arrangement. The arrangements do not interact with each other and the charges are evenly spaced.

Space for working



$\vec{R}$

No $\vec{R}$

No $\vec{R}$

(a) Determine which central charge has the greatest net force acting on it. [2]

A

(b) Determine the direction of the net force on the central charge from (a) if it is positive. [1]

Right.

4. A student rubs a balloon on their jumper and the holds it near the fur of their cat, as shown below.

(a) Explain why the balloon can cause the cat's hair to stand up. [A diagram may be useful.] [4]

- Balloon becomes charged - e⁻'s are rubbed off for example. (1)
- Balloon attracts the cat fur by induction. (1)
- Charges separate on the fur - e⁻'s are attracted to one side (1)
- Opposite charges attract - fur stands up. (1)

(b) Why would the cat's hair be more likely to stand up on a dry day than on a wet day? [2]

• Dry day - less H_2O in the atmosphere. (1)

• Charge is lost to the H_2O molecules - they are polar. (1)

5. A strong lightning bolt strikes a tree and transfers 25.0 C of charge to Earth.

(a) How many electrons are transferred? [2]

$\# e^- = \frac{25.0}{1.60 \times 10^{-19}}$ (1)

$= \underline{1.56 \times 10^{20}}$ (1)

(b) If the transfer through the tree takes 4.00 ms, what current flows though the tree? [2]

$I = \frac{q}{t}$

$= \frac{25.0}{4.00 \times 10^{-3}}$ (1)

$= \underline{6.25 \times 10^{3}\ A}$ (1)

6. (a) A body having a negative charge of –6.00 μC exerts an ***attractive*** force of 65.0 N on a second charged body that is 5.00 cm away. What is the magnitude and polarity of the second charge? [3]

$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$

q ⟷ 5.00 cm

-6.00×10^{-6} C

$\Rightarrow 65.0 = \frac{1}{4\pi(8.85 \times 10^{-12})} \cdot \frac{q(6.00 \times 10^{-6})}{(5.00 \times 10^{-2})^2}$ (1)

$\Rightarrow \underline{q = 3.01 \times 10^{-6}\ C}$ (positive)

(1) (1)

(b) The charged bodies in (a) then make contact and are returned to the same distance apart. Determine the new force between them. [3]

After touching: $3.01 \mu C$ of charge transfers from $-6.00 \mu C$

Remaining charge splits $\Rightarrow -1.50 \mu C$ each (1)

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$$

$$= \frac{1}{4\pi(8.85\times10^{-12})} \cdot \frac{(1.50\times10^{-6})^2}{(5.00\times10^{-2})^2} \quad (1)$$

$$= \underline{8.09 \text{ N}} \ \underline{\text{repulsion}} \quad (1)$$

7. Point R is 0.400 m from a -2.00×10^{-5} C charge. Find the electric field intensity at point R. [3]

$$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2} \quad (1)$$

$$= \frac{1}{4\pi(8.85\times10^{-12})} \cdot \frac{(2.00\times10^{-5})}{(0.400)^2} \quad (1)$$

$$= \underline{1.12\times10^{6} \text{ NC}^{-1}} \ (\text{Vm}^{-1}) \text{ towards the charge} \quad (1)$$

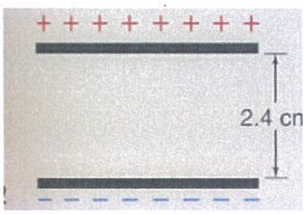
8. The electric field in a particle accelerator has a magnitude of 4.50×10^5 NC^{-1}. How much work is done to move a proton 25.0 cm through that field? [3]

$$W = Vq = Eqd \quad (1)$$

$$= (4.50\times10^{5})(1.60\times10^{-19})(0.250) \quad (1)$$

$$= \underline{1.80\times10^{-14} \text{ J}} \quad (0.113 \text{ MeV}) \quad (1)$$

9. (a) When you apply a potential difference of 125 V between two parallel plates, the field between them is 4.25×10^3 Vm^{-1}. How far apart are the plates? [2]



$E = \frac{V}{d}$

$\Rightarrow \quad d = \frac{V}{E}$ (1)

$= \frac{125}{4.25 \times 10^{3}}$

$= \underline{2.94 \times 10^{-2} \text{ m}}$ (1)

(b) A proton is released from the positive plate. At what speed will it be travelling as it reached the negative plate? Show your working clearly. [3]

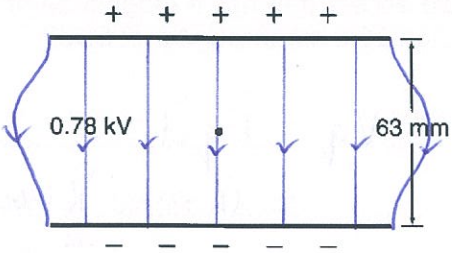
$W = Vq = \frac{1}{2}mv^2$

$\Rightarrow \quad v = \sqrt{\frac{2Vq}{m}}$ (1)

$= \sqrt{\frac{2(125)(1.60 \times 10^{-19})}{1.67 \times 10^{-27}}}$ (1)

$= \underline{1.55 \times 10^{5} \text{ ms}^{-1}}$ (1)

10. In an oil drop experiment, a drop with a mass of 2.22×10^{-15} kg was suspended motionless when the potential difference between the plates that were 630 mm apart was 0.780 kV.



Direction - 1 mark

Even distribution - ½ mark.

End effect - ½ mark.

(a) On the diagram above draw the electric field between the parallel plates. [2]

(b) (i) What was the charge of the drop? Show your working clearly. [4]

Must be -ve.

$\Sigma F_v = 0$

$\Rightarrow \quad F_E = F_W$ (1)

$\Rightarrow \quad Eq = mg$

$\Rightarrow \quad \frac{Vq}{d} = mg$

$\Rightarrow \quad q = \frac{mgd}{V}$ (1) $= \frac{(2.22 \times 10^{-15})(9.80)(0.630)}{(7.80 \times 10^{2})}$ (1)

$= \underline{1.76 \times 10^{-17} \text{ C}}$ (1)

(ii) Does the oil drop have a deficiency or an excess of electrons? Explain briefly. [2]

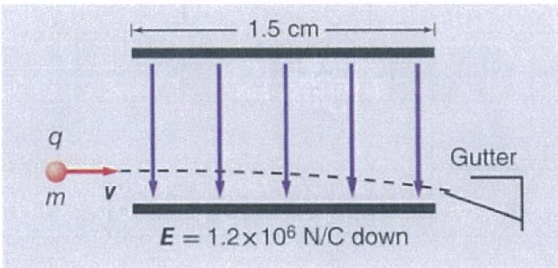
• Excess (1)

• must be negative to experience an upward force due to the electric field. (1)

(c) If the voltage of the bottom plate is –100 V, what is the potential of the top plate? [1]

$\Delta V = 7.80 \times 10^{2}\,V \quad \therefore \quad V_{top} = 6.80 \times 10^{2}\,V$ (1)

11. In an ink-jet printer, drops of ink are given a certain amount of charge before they move between two large, parallel plates. The plates deflect the charged ink particles as shown in Figure below. The plates have an electric field of E = 1.20 x 10^{6} N/C between them and are 1.50 cm long. Drops with a mass m = 0.100 ng and a charge q = 1.00 x 10^{-16} C are moving horizontally at a speed, v = 15.0 m/s, parallel to the plates.



(a) What is the vertical force on the drops? [2]

$F = Eq$

$= (1.20 \times 10^{6})(1.00 \times 10^{-16})$ (1)

$= 1.20 \times 10^{-10}$ N down. (1)

(b) What is their vertical acceleration? [2]

$F = ma \Rightarrow a = \frac{F}{m}$

$= \frac{1.20 \times 10^{-10}}{1.00 \times 10^{-13}}$ (1)

$= 1.20 \times 10^{3}\,ms^{-2}$ down (1)

(c) How long are they between the plates? [2]

Horizontally: $v = \frac{s}{t} \Rightarrow t = \frac{s}{v}$

$= \frac{1.50 \times 10^{-2}}{15.0}$ (1)

$= 1.00 \times 10^{-3}\,s$ (1)

(d) How far are they displaced vertically? $\downarrow +ve$ [2]

$v = ?$

$u = 0\,ms^{-1}$

$a = 1.20\times10^{3}\,ms^{-2}$

$t = 1.00\times10^{-3}\,s$

$s = ?$

$s = ut + \frac{1}{2}at^2$

$= 0 + \frac{1}{2}(1.20\times10^{3})(1.00\times10^{-3})^2$ (1)

$= 6.00\times10^{-4}$ m. down. (1)

12. Two charges of 15.0 pC and 9.00 pC are separated by a distance of 20.0 mm. How far from the smaller charge will the electric field intensity be zero between the two charges? Show your working clearly. [5]

$\longleftarrow 2.00\times10^{-2}\,m \longrightarrow$

A $\longleftarrow a \longrightarrow \bullet \longleftarrow b \longrightarrow$ B

$15.0\times10^{-12}\,C$ $\qquad$ $9.00\times10^{-12}\,C$

$a + b = 20.0\,mm$ — ① (1)

$E_A = E_B$

$\Rightarrow \cancel{\frac{1}{4\pi\epsilon_0}} \cdot \frac{q_A}{r_A^2} = \cancel{\frac{1}{4\pi\epsilon_0}} \cdot \frac{q_B}{r_B^2}$ (1)

$\Rightarrow \frac{15.0\times\cancel{10^{-12}}}{a^2} = \frac{9.00\times\cancel{10^{-12}}}{b^2}$

$\Rightarrow \frac{a^2}{b^2} = \frac{15.0}{9.00}$

$\Rightarrow \frac{a}{b} = 1.291$

$\Rightarrow a = 1.291\,b$ — ② (1)

① $\Rightarrow b = 20.0 - a$

Sub in ② $\Rightarrow a = 1.291(20.0 - a)$ (1)

$\Rightarrow a = 25.82 - 1.291a$

$\Rightarrow 2.291a = 25.82$

$\Rightarrow a = 11.27\,mm$ (1)

$\therefore$ Zero field is 11.3 mm from 15.0 μC charge.