CORPUS CHRISTI COLLEGE
SEQUERE DOMINUM

ATAR Year 12 Physics 2016

TEST 1 Charged Particles in E Fields 5.0%

NAME: Soln

Data: See Data Sheet
Approx. marks shown.

(65 marks)

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

1. Multiple Choice [4]

(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

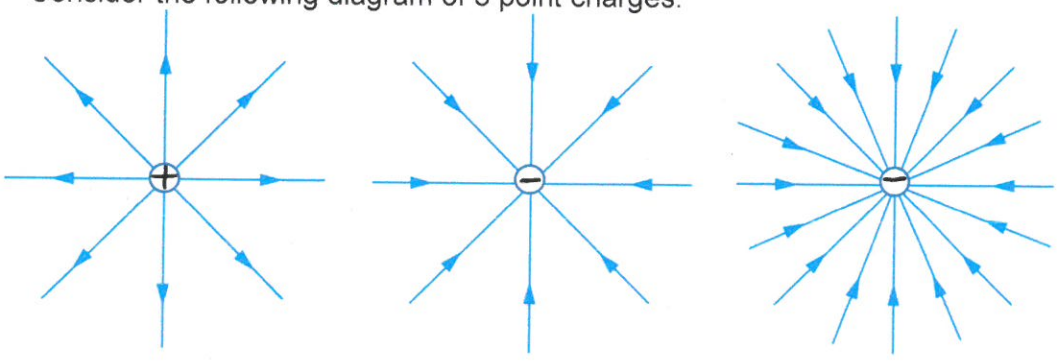
(c) Two charges are repelling each other with a force magnitude *F*. If each charge doubled and the distance between the charges becomes four times the original distance, determine the new magnitude of the force. Show your working in the space provided.

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

Working: $F = k\frac{q_1 q_2}{r^2}$ ✓

$New\ F = k\frac{(2q_1)(2q_2)}{(4r)^2} = \frac{4kq_1q_2}{16r^2} = \frac{1}{4}k\frac{q_1q_2}{r^2}$

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



(a) (b) (c)

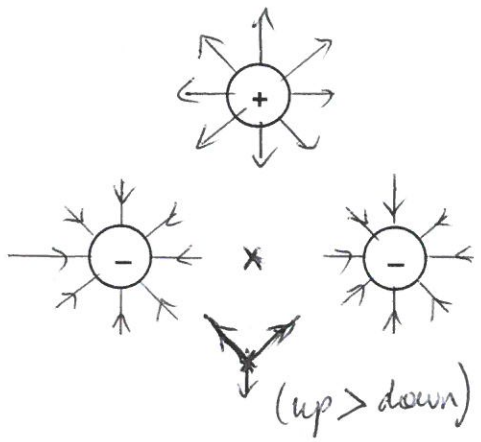
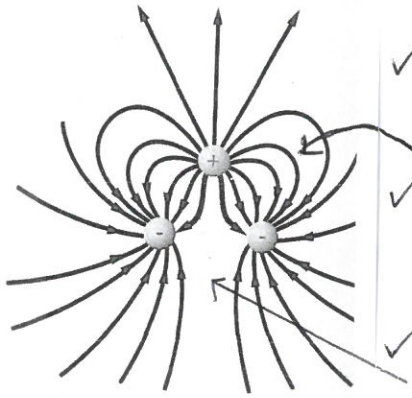
✓ $-\frac{1}{2}$ per error.

(i) Show the polarity of the charges on the diagram. [1]

(ii) What can be concluded about the magnitude of the 3 charges? Explain. [1]

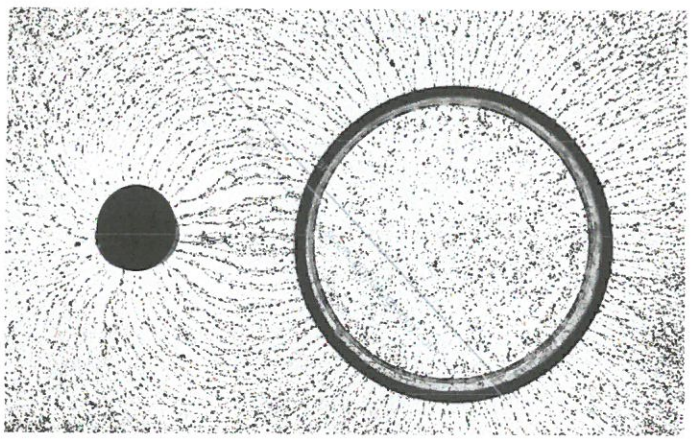
(½) Charges (a) & (b) are the same size but charge (c) (½) has a greater magnitude. The greater the number of E field lines per unit area the stronger the E field & hence the greater the charge. ✓

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

Working diagram	Resultant diagram
	 ✓ direction of arrows ✓ greater density ✓ No E field.

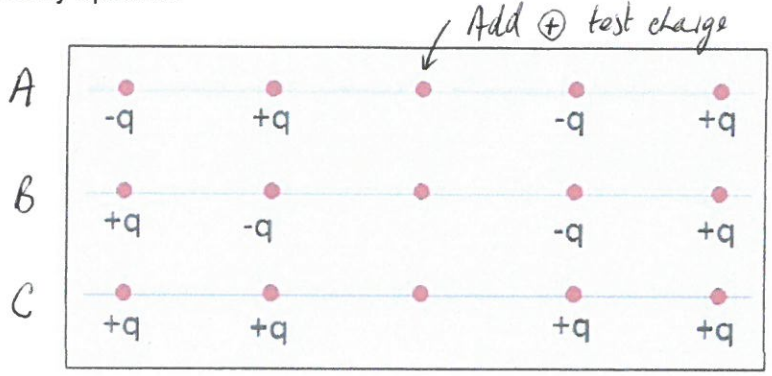
(-1) if lines not ⊥ to surface.

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

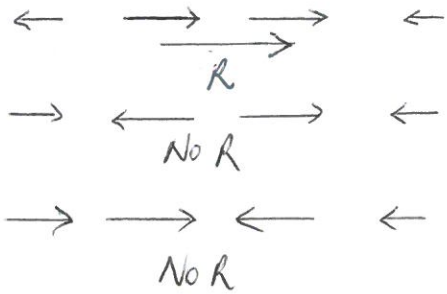


1. Objects are oppositely charged since E field lines extend from one object to the other.
2. Large circle is acting as an E field shield since there is no E field inside since no particles are aligned
3. Objects have static charge since E lines ⊥ to surface.

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



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

Central charge in A has greatest force.

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

To right

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

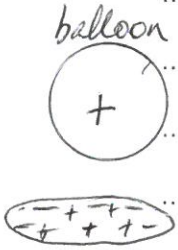
(a) Explain why the balloon can cause the cat's hair to stand up. [3]

The balloon becomes charged by gaining or losing e^- when it is rubbed against jumper. ✓

The balloon attracts the cat fur by induction. ✓

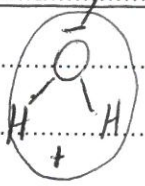
The charged balloon causes charge separation in the fur due to attraction or repulsion of e^- in the fur. ✓ Since opposite charges attract the fur stands up. ✓

[Note: fur spreads out since like charges repel.]



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

The water molecules in the air on a wet day are polar. These are attracted to the charges on the balloon & neutralise the charge on the balloon & so there is less force acting on the fur.



5. A strong lightning bolt strikes a tree and transfers about 25 C to Earth.

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

$1e^- = -1.60 \times 10^{-19}$ C

$x = 25$ C

No of $e^- = \dfrac{25}{1.60 \times 10^{-19}}$ //

$= 1.56 \times 10^{20}$ (3sf)

(b) If the transfer through the tree takes 4.0 ms, what current flows though the tree? [2]

$q = It$ ✓

$25 = I(4 \times 10^{-3})$

$I = 6250$ A !! ✓

Notice the ground flow of current! (∴ do not shelter under trees.)

6. (a) A body having a negative charge of –6.0 μC exerts an attractive force of 65 N on a second charged body that is 5.0 cm away. What is the magnitude and polarity of the second charge? [3]

$F = \dfrac{9 \times 10^9 \, q_1 q_2}{r^2}$

$q_1 = 6 \times 10^{-6}$ C (½) $\quad 65 = \dfrac{9 \times 10^9 (6 \times 10^{-6}) q_2}{(0.05)^2}$

$r = 0.05$ m (½)

$q_2 = \dfrac{+3.01 \times 10^{-6} \text{ C}}{\checkmark \quad \checkmark} = +3.01 \, \mu\text{C}$

(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 electrons will transfer from $-6\,\mu C$ to $+3.01\,\mu C$ until charges are equal

av $q = \frac{(-6\,\mu C + 3.01)}{2} = -1.50\,\mu C$ ✓

$F = \frac{9\times10^{9}\,(1.50\times10^{-6})^{2}}{(0.05)^{2}}$

$= 8.10\ N$ ✓ repulsion ✓

7. Point R is 0.40 m from a -2×10^{-5} C charge. Find the electric field intensity at point R. [3]

$F = Eq_t = \frac{9\times10^{9}\,q\times q_t}{d^{2}}$ ✓

$E = \frac{9\times10^{9}\,(2\times10^{-5})}{(0.40)^{2}} = 1.125\times10^{6}\ NC^{-1}$

$= 1.13\times10^{6}\ NC^{-1}$ ✓ towards the charge.

8. The electric field in a particle accelerator has a magnitude of $4.50 \times 10^{5}\ NC^{-1}$. How much work is done to move a proton 25 cm through that field? [3]

$W = Vq$

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

$4.50\times10^{5} = \frac{V}{0.25}$ ✓

$V = 1.125\times10^{5}\ V$

$W = 1.125\times10^{5}\times1.6\times10^{-19}$ ✓

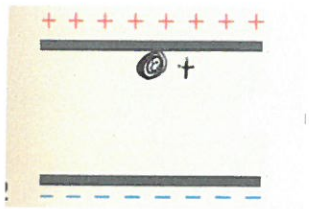
$= 1.80\times10^{-14}\ J$ ✓ $(= 0.113\ MeV)$

OR

$F = Eq = 4.50\times10^{5}\times1.60\times10^{-19} = 7.20\times10^{-14}\ N$

and $W = Fs = 7.20\times10^{-14}\times0.25 = 1.80\times10^{-14}\ J.$

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]



$E = \frac{V}{d}$ ✓

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

$d = \frac{125}{4.25 \times 10^3} = 0.0294\ m = 2.94\ cm$ ✓

(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]

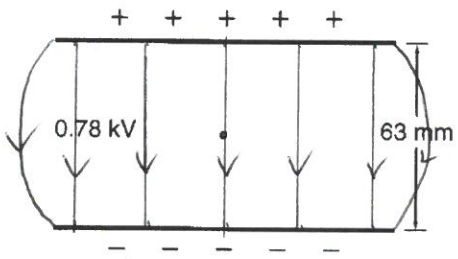
$W \Leftrightarrow E_K$: $W = Vq = \frac{1}{2}mv^2$ ✓ $(\frac{1}{2})(\frac{1}{2})$

$125 \times 1.6 \times 10^{-19} = \frac{1}{2}(1.67 \times 10^{-27})v^2$

$v = \sqrt{2.39 \times 10^{10}}$ ✓

$= 1.55 \times 10^5\ ms^{-1}$ ✓

10. In an oil drop experiment, a drop with a mass of 2.22 x 10^{-15} kg was suspended motionless when the potential difference between the plates that were 63 mm apart was 0.78 kV.



✓ direction
✓ evenly distributed
$(-\frac{1}{2})$ if end effects not shown.

(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]

$V = 0.78\ kV = 780\ V$

$d = 63\ mm = 0.063\ m$ $(\frac{1}{2})$

$F_{up} = F_{down}$ ✓

$F_E = F_g$ $(\frac{1}{2})$

$Eq = mg$

$\frac{V}{d}q = mg$ ✓

$\frac{780}{0.063}q = 2.22 \times 10^{-15} \times 9.8$ ✓

$q = -1.76 \times 10^{-18}\ C$ ✓

} 1 mark for equating $F_{up} = F_{down}$

$(E = \frac{V}{d} = \frac{780}{0.063} = 1.238 \times 10^4\ Vm^{-1})$

$(= 10.98 = 11e^-)$

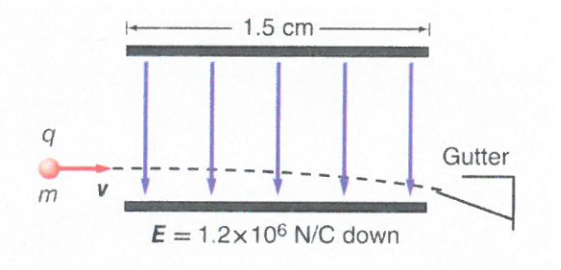
(ii) Does the oil drop have a deficiency or an excess of electrons? Explain briefly [2]

An excess of $\bar{e}$. In order for there to be an upward electrostatic force the oil drop must be repelled by the lower plate. Since this is negative and $\bar{e}$ are negative

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

$\Delta V = 780\,V$ ∴ $V_{top\ plate} = 680\,V$

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 $E = 1.20 \times 10^6$ N/C between them and are 1.5 cm long. Drops with a mass $m = 0.100$ ng and a charge $q = 1.00 \times 10^{-16}$ 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]

$F = Eq$ ✓

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

$= 1.20 \times 10^{-10}$ N ✓ down (3sf)

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

$F = ma$ ✓

$1.20 \times 10^{-10} = (0.1 \times 10^{-9}) \times 10^{-3}\, a$

$a = 1.20 \times 10^{3}\ ms^{-2}$ (3sf) down ✓

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

Horiz: $s = vt$ ✓

$1.5 \times 10^{-2} = 15 \times t$

$t = 1.00 \times 10^{-3}$ sec (3sf) ✓

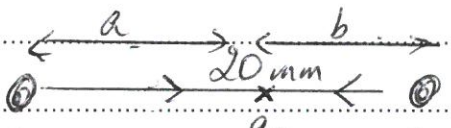
(d) How far are they displaced? [2]

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

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

$= 6.00\times10^{-9}$ m down ✓

12. Two charges of 15 pC and 9.0 pC are separated by a distance of 20 mm. How far from the smaller charge will the electric field intensity be zero? Show your working clearly. [5]



15pC, qt $\quad \frac{9\times10^{9}\, q_1 q_2}{d^2} = \frac{9\times10^{9}\, q_1 q_2}{d^2}$ ✓ $\quad$ 9pC, qt

$\frac{15\times10^{-12}}{a^2} q_t = \frac{9\times10^{-12}}{b^2} \times q_t$

$\frac{a^2}{b^2} = \frac{15}{9} = \frac{5}{3} = 1.67$ ✓

$\frac{a}{b} = \sqrt{1.67} = 1.29$ ✓

$\therefore a = 1.29b$ ... (1)

And $a + b = 20$ ✓

Subst $\therefore a = 1.29(20 - a)$

$= 25.84 - 1.29a$

$\therefore 2.29a = 25.84$

$a = \frac{25.84}{2.29} = 11.29$

$\therefore a = 11.3$ cm. ✓

$\therefore b = 20 - 11.3 = 8.70$ cm from 9pC