Name of the Student:_____
Max. Marks : 23 Marks **Time : 23 Minutes**

Mark Schemes

Q1.

(a) C (= $4\pi\varepsilon_O r = 4\pi \times 8.85 \times 10^{-12} \times 0.020$)
= 2.2(2) × 10^{-12} (F) ✔$_1$

✔$_1$ *Mark for substitution or answer. Also it may be seen incorporated into the second mark.*

Substitution of

V (= Q/C) = 52 × 10^{-9}/2.22 × 10^{-12} ✔$_2$

✔$_2$ *Use of r = 0.04 m in the previous mark is treated as an arithmetic error and the substitution 52 × 10^{-9}/4.44 × 10^{-12} is given a CE mark.*

V = 23 000 (V) ✔$_3$ (23 400 V)

✔$_3$

A continuation of the CE gives a mark to the answer 12000 or 11700 (V)

A correct answer gains all 3 marks.

Commonly 23000 V gives 3 marks

11700 V gives 2 marks

Also a power of 10 error in the final answer gives 2 marks.

For any other final answer the only possibility is to get one mark for use of $V = Q/C$ when C is clearly given or $V = \frac{Q}{4\pi\varepsilon_0 r}$ is uses with an incorrect value of r.

3

(b) Labelled arrows on **B**

- Tension or T parallel to thread and upwards
- weight or mg or W starting from sphere centre vertically down
- electrostatic force or repulsion to right and starting from the inside or edge of the sphere ✔✔

2 marks for all 3 arrows and labels
1 mark for 2 arrows and labels
1 mark for 3 arrows, no or incomplete labels

For the electrostatic force label also allow F_{elec} or 'force between charges. F_A etc.

Ignore gravity between spheres.

If a reaction force given – max 1 mark.

2

(c) One mark for stating the problem. ✔$_1$

✔$_1$ *The problem must be explicitly stated but not much detail is needed. EG Anything used between the spheres may disrupt the field.*

One mark for giving a corresponding solution. ✔$_2$

✔$_2$ *The solution must be detailed enough to convey what must happen.*

For example
Metallic or conducting instruments placed between the spheres will affect the separation (because of the movement of charge/electrons within the instrument)
(Inside) callipers made from a non-conduction material in conjunction with a ruler could be used
Or
A travelling telescope on a vernier scale could be used (at a distance)
Other examples of problems
Physically touching the spheres may alter the reading.
Difficulty of measuring distance between curved objects.
A measuring instrument can have a dielectric constant/permittivity, which will affect the separation/disrupt the field.
Reading a ruler behind the spheres will give rise to a parallax error.

Other examples of solutions.

Ruler and set square set up parallel to the line joining the centres of the spheres.

Measure (beforehand) the length of thread y and measure the angle with a protractor and calculate distance x using trig'.

2

(d) Using distance = 80 mm (mark given even in a wrong formula)
Or
Stating that the charge can be considered to be in the centre of each sphere ✔$_1$

$F\left(=\frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}\right)=\frac{\left(52\times10^{-9}\right)^2}{4\pi\varepsilon_0(0.080)^2}$ ✔$_2$

✔$_2$ *Power of 10 errors are condoned and so is the use of the wrong separation (as this was penalized in the previous mark).*

F = 3.8 × 10^{-3} (N) ✔$_3$ (Showing at least 2 sig figs)

✔$_3$ *No ecf for this final mark.*

3

(e) (As each sphere is in equilibrium then tan $\theta = \frac{F_{\text{electrostatic}}}{mg}$ a mark is given for a reference and substitution into this equation in any configuration. The second mark is for an evaluation that is said to be consistent. Use of 4 × 10^{-3} N given in part (d) gains full credit.)

$\theta = \tan^{-1}\left\{\frac{3.8\times10^{-3}}{3.2\times10^{-3}\times9.8}\right\}$ ✔= 6.9° which is consistent ✔

or

$F_{\text{electrostatic}}$ = {3.2 × 10^{-3} × 9.8 × tan 7°} ✔
= 3.8(5) × 10^{-3} (N) which is consistent ✔

or

$m = \left\{\frac{3.8\times10^{-3}}{0.8\cos 7^0}\right\}$ ✔ = 3.1(6) × 10^{-3} (kg) which is consistent ✔

Alternatively

$T = \frac{3.2\times10^{-3}\times9.8}{\cos 7^0}$ = 0.032 ✔1Alt

and $T = \frac{3.8\times10^{-3}}{\sin 7^0}$ = 0.031, the same value so consistent ✔2Alt

using 4 × 10^{-3} N gives 7.3°

More circular routes using Pythagoras are possible but they end in the same calculated results.

using 4 × 10^{-3} N gives 3.3(2) × 10^{-3} kg

✔*1Alt Any equation that results in the calculation of the tension.*

✔*2Alt A second calculation of the tension which is stated to be consistent with the first.*

2

(f) (In the following calculations condone the use of 1 sig fig for all data)

F_{grav} $\left(=\frac{GMm}{r^2}\right)$ = 6.67 × 10^{-11} × $\frac{(3.2\times10^{-8})^2}{0.080^2}$ ✔1a

F_{grav} = 1.1 × 10^{-13} (N) which is small/negligible compared to F_{elect} (≈ 4 × 10^{-3} N) so statement is valid ✔2a

Alternative
(find the ratio between the forces)

$$\left(\frac{F_{elec}}{F_{grav}} = \frac{\frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}}{\frac{GMm}{r^2}}\right)$$

$$\frac{F_{elec}}{F_{grav}} = \left(\frac{Q_1Q_2}{Mm}\right)\frac{1}{G4\pi\varepsilon_o}$$

(mark given for this ratio or the substitution below)

$$\frac{F_{elec}}{F_{grav}} = \left(\frac{(52\times10^{-9})^2}{(3.2\times10^{-3})^2}\right) \times \left(\frac{1}{6.67\times10^{-11}\times4\times\pi\times8.85\times10^{-12}}\right)$$ ✔1b

F_{elec} is 3.6 × 10^{10} times F_{grav}

OR

or F_{grav} is 2.8 × 10^{-11} times F_{elec} ✔2b

✔*1a It is the use of the formula that is important for the mark. Giving the equation in symbols followed by an answer gains the mark.*

✔*2a No ecf for the second mark in order to keep the same level of difficulty as in the alternative.*

2

[14]

Q2.

(a) (Refers to a capacitor that) stores/holds/changes by 370 μC of charge ✔

For every (1) volt/volt change (of pd across its plates) ✔

OR

Reference to charge to pd OR charge to voltage ratio ✔ includes units C or coulomb and V or volt ✔

"Unit of pd" is no substitute for using volt and "unit of charge" is no substitute for coulomb.

However the alternative marking could give a single mark for 370 × 10^{-6} units of charge per unit of pd.

An equation may contribute towards the first mark but only if the symbols are identified. A second mark can be given if the units are identified.

Ignore poor phrasing like 'per unit volt passing through'.

2

(b) (Using time constant = *R C*)

(R = 1.0 / 370 × 10^{-6})

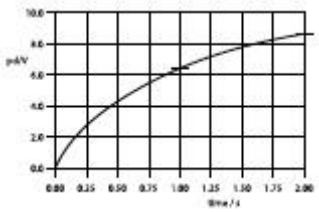
R = 2.7 × 10^{3} (Ω) ✔

Check that the unit on answer line has not been altered.

1

(c) First mark for marking a cross at 2 s and 8.5 V (by eye) ✔

Second mark for graph starting at the origin and having a decreasing gradient ie not reaching horizontal ✔



Cross must be in the bottom half but not on the 8.0 V major grid line or exactly half way up (9.0 V).

If a series of plotting crosses are given only consider the one placed at 2 s for the first mark.

2

(d) (Using $T½ = 0.69\ RC = 0.69 \times 1.0$)

$T½$ = 0.69 (s) ✔

1 sig fig is not acceptable

1

(e) (Use of $Q = Q_o(1 - e^{-\frac{t}{RC}}) = CV_o(1 - e^{-\frac{t}{RC}})$)

Mark for max charge = CV_o which may come from substitution or seeing 3.6(2) × 10^{-3} C ✔

$3.0 \times 10^{-3} = 370 \times 10^{-6} \times 9.8\ (1 - e^{-t})$ ✔

Mark for substitution ($0.8274 = (1 - e^{-t})$ so $e^{t} = 1/0.173 = 5.79$)

t = 1.7 s or 1.8 s ✔

OR

Voltage $V = Q/C = 3 \times 10^{-3} / 370 \times 10^{-6}$
= 8.1(1) V ✔

(Substitute into $V = V_o(1 - e^{-\frac{t}{RC}})$)

$8.1 = 9.8 (1 - e^{-t})$ ✔

t = 1.7 s or 1.8 s ✔

Alternative mark scheme uses the voltage as proportional to the charge.

Do not allow use of the graph for 2nd mark and 3rd mark.

An answer only gains only the last mark.

Evidence of working must be shown which shows substitution into a $(1 - e^{-t})$ form of the equation.

3

[9]