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) (u =)0.2(0) or 20 or 200 **and** (v =)0.25 or 25 or 250 $_1$✔;

Both *velocities seen / allow seen in* $(a =)\frac{v-u}{t_3}$ */ condone (possible) powers of ten (POT) error for 1st mark and 2nd mark in their v and u*

and any substitution v and u into $(a =)\frac{v-u}{t_3}$

Where t_3 has been substituted must be t_3 = 1.19 (s)

substitution of their u and v in $(a =)\frac{v-u}{t_3}$ ✔

Where t_3 has been substituted must be t_3 = 1.19 (s)

Values for:

u (0.20 (m s^{-1}) or 20 (cm s^{-1})200 (mm s^{-1})) and

v (0.25 (m s^{-1}) or 25 (cm s^{-1}) or 250 (mm s^{-1}))

Correctly combined with t_3 (1.19) will earn 1st and 2nd marks

Where u and v are not correct, they must be identifiable as their u and v (2nd mark is only mark available except where error is POT)

Allow their $\frac{\Delta v}{1.19}$ *(= a) where clear it is their* Δv

a = 4.2 × 10^{-2} (m s^{-2}) $_3$✔

Correct result for a will earn three marks;

Accept 420 mm s^{-2} or 42 cm s^{-2} if m s^{-2} has been replaced on the answer line

2 sf answer only

3

(b) (set **B** because) it has a greater time / takes longer (to travel between gates) (hence distance between gates is larger) $_1$✔

(and) set **B**'s <u>average velocity</u> is greater / set **B**'s <u>velocity</u> at <u>gate 1</u> is greater / Set **B**'s <u>velocity</u> is greater at both gates

Two calculations for gate separation s using either

OR

(and) set **A**'s <u>average velocity</u> is smaller / set **A**'s <u>velocity</u> at <u>gate 1</u> is smaller/ Set **A**'s <u>velocity</u> is smaller at both gates $_2$✔

Alternative Method

values of u and v are calculated (condone POT error) and corresponding values for each s determined; $_1$✔

<u>a comparison of ***their*** distances</u> leading to <u>conclusion</u> that set **B** produced when s is largest

OR

ratio $(t_3 \times \frac{t_1 + t_2}{t_1 \times t_2})$ is <u>proportional to distance</u> s and **B**'s <u>ratio is greater</u> $_2$✔

$(s=)\left(\frac{u+v}{2}\right)\times t_3$ **OR** $(s)=\frac{v^2-u^2}{2a}$; **OR** $(s=)\,t_3\times\frac{t_1+t_2}{t_1\times t_2}$

	u/ms^{-1}	v/ms^{-1}	s/m	$v^2 - u^2$/ m^2s^{-2}
Set A	0.164	0.238	0.356	0.0297
Set B	0.181	0.270	0.476	0.0401

$t_3\times\frac{t_1+t_2}{t_1\times t_2}$

Set A	7.12
Set B	9.54

Allow ecf for acceleration where used to find s

Using a = 0.042: s_A = 0.354 and s_B = 0.478

Treat a larger change in velocity as neutral

2

(c) Continuous, ruled straight best fit line through 1st and last points $_1$✔

n=4 point below and n=7 above, other points cut by line of best fit

Line must not be thicker than half a square grid

Line must have no variation in thickness

Do not accept more than one line drawn, do not accept discontinuities

Gradient from $\frac{y\text{ step}}{x\text{ step}}$ **seen**

and

G = 0.045 range (0.042 to 0.053) $_2$✔

Steps at least half the height and half the width of the grid; (at least 3 squares horizontally and at least 5 squares vertically)

Allow $\frac{\text{change in y}}{\text{change in x}}$ *where points are on line and are at least half drawn line apart ($\Delta x \geq 3$ and $\Delta y \geq 0.175$)*

Ignore any units given for G

Allow 1 sf answers of 0.04 or 0.05 where correct working is shown

2

(d) $\frac{\text{their } G}{4.9}$ ✔

(h = 9.2 × 10^{-3} m)

*Ecf from part **(c)***

***Expect 2 sf normally**. Penalise 3 or more sf*

*Condone 1 sf answers where correct working is shown in part **(d) and** where their G is quoted to 1sf*

In this case, allow use of their rounded G or full carry value

1

(e) idea that the intercept can be found by calculating *a* – *Gn* where *a* and *n* are values read-off (from a point on the line) and *G* is the gradient ; intercept compared to 0, 0 (OWTTE in a general y=mx +c description)

Simply explaining how to find the intercept does not fully answer the question and gets no credit must describe the <u>comparison</u> aspect; do not accept idea of extrapolation off the grid or re-plotting on axes that include (0, 0)

OR

Read-off points (of line of best fit for) x_1 and x_2 compare with corresponding y_1 and y_2 , <u>compares</u> the ratio of the x terms to the ratio of the y terms; if equal then directly proportional

OR

Determine the constant of proportionality for at least two points (on line of best fit) and <u>compare</u>, where constant exists then directly proportional ✔

Idea that a and n will share a common factorial increase

1

[9]