Name of the Student:_____
Max. Marks : 20 Marks **Time : 20 Minutes**

Mark Schemes

Q1.

(a) the work done/energy required in bringing 1 kg/unit mass from infinity to the point ✔

A test mass should not be taken to be a unit mass.

Ignore extra comments eg about charge.

1

(b) The potential difference between the lines is constant but the distances are not

Or

$\frac{\Delta V}{\Delta r}$ is changing ✔ (potentials $\frac{\Delta V}{\Delta r}$,inner 0.857, outer = 0.625)

Or

The equipotential surfaces are not straight / not parallel / are curved ✔

The mark is given for the idea that the separation should be uniform or that equipotential lines should not be curved. Owtte Discussions should not imply there is a correct curvature.

Errors can come from references to the moon to first equipotential distance. Or by saying the potential gaps are not uniform or by saying the distance from the centre of the Moon is not proportional to the potential.

1

(c) M = mass of Moon = $= \frac{-V \times r}{G} = \frac{(-1) \times -1.60 \times 10^6 \times 3.06 \times 10^6}{6.67 \times 10^{-11}}$ ✔$_1$

✔$_1$ *The mark is given for use and rearranging the equation so errors may be seen in the data and any equipotential may be used.*

Condone the misuse of a negative sign

M = 7.3 or 7.4 × 10^{22} (kg) ✔$_2$

✔$_2$ *Note All equipotential lines produce the same mass.*

The answer may be seen in the equations that follow.

(Use of $\frac{GMm}{r} = \frac{1}{2}mv^2$)

$v = \sqrt{\frac{2GM}{r}}$ ✔$_3$

✔$_3$ *An attempt to use this re-arranged formula gains this 3rd mark.*

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v = 2.3 or 2.4 × 10^3 (m s^{-1}) ✔4 (2370 m s^{-1})

Alternative

(Use of $V = \frac{-GM}{r}$)

$Vr = -MG$ = constant

Vr = −1.60 × 10^6 × 3.06 × 10^6

= −4.9 × 10^{12} (J Kg^{-1} m) ✔1Alt

✔1Alt *Any attempt to calculate Vr OR to indicate that it is constant gains this mark.*

(at the surface of the Moon)

$V_{surface} = \frac{-4.9 \times 10^{12}}{1.74 \times 10^6}$

$V_{surface}$ = −2.8(2) × 10^6 (J kg^{-1}) ✔2Alt

(Use of mV = $\frac{1}{2}mv^2$)

$\sqrt{2V_{surface}} = \sqrt{2 \times 2.82 \times 10^6}$ ✔3Alt

✔3Alt *An attempt to use this re-arranged formula gains this 3rd mark.*

v = 2.4 × 10^3 (m s^{-1}) ✔

✔4Alt *A correct answer shows the previous work has been done correctly and gains all 4 marks.*

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Q2.

(a) C (= $4\pi\varepsilon_O r$ = 4π × 8.85 × 10^{-12} × 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

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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).

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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 $\theta = \frac{F_{electrostatic}}{mg}$ 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

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

or

$m = \left\{\frac{3.8\times10^{-3}}{9.8\tan 7^{o}}\right\}$ ✔ = 3.1(6) × 10^{-3} (kg) which is consistent ✔

Alternatively

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

and $T = \frac{3.8\times10^{-3}}{\sin 7^{o}}$ = 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)

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

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$\frac{F_{elec}}{F_{grav}} = \left(\frac{Q_1 Q_2}{Mm}\right)\frac{1}{G4\pi\varepsilon}$

(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

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