Oxford Cambridge and RSA

## GCE

## Physics A

Unit G484: The Newtonian World
Advanced GCE

## Mark Scheme for June 2017

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

## Annotations

| Annotation | Meaning |
| :---: | :---: |
| BOD | Benefit of doubt given |
| BP | Blank Page |
| CON | Contradiction |
| $\cdots$ | Incorrect Response |
| ECF | Error carried forward |
| FT] | Follow through |
| (NAQ | Not answered question |
| NBOD | Benefit of doubt not given |
| POT | Power of 10 error |
| A | Omission mark |
| RE | Rounding error |
| SF | Error in number of significant figures |
| $\checkmark$ | Correct Response |
| AE | Arithmetic error |
| 2 | Wrong physics or equation |


| Annotation | Meaning |
| :---: | :--- |
| $\boldsymbol{I}$ | alternative and acceptable answers for the same marking point |
| $(1)$ | Separates marking points |
| reject | Answers which are not worthy of credit |
| not | Answers which are not worthy of credit |
| IGNORE | Statements which are irrelevant |
| ALLOW | Answers that can be accepted |
| ( ) | Words which are not essential to gain credit |
| - | Underlined words must be present in answer to score a mark |
| ecf | Error carried forward |
| AW | Alternative wording |
| ORA | Or reverse argument |

## Subject-specific Marking Instructions

All questions should be annotated with ticks where marks are allocated; One tick per mark.

| Question |  |  | Answer | Marks | Guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | a |  | $\begin{aligned} & \text { Energy of } \alpha=5.2 \times 10^{6} \times 1.6 \times 10^{-19} \quad\left(=8.32 \times 10^{-13}(\mathrm{~J})\right) \\ & \begin{aligned} E & =1 / 2 \mathrm{mv}^{2} \text { so } \\ \mathrm{v} & =\sqrt{\frac{2 \times 8.32 \times 10^{-13}}{6.6 \times 10^{-27}}} \\ & =1.6 \times 10^{7} \quad\left(\mathrm{~m} \mathrm{~s}^{-1}\right) \end{aligned} \end{aligned}$ | C1 <br> A1 <br> A0 | Must see some working <br> Allow: Max 1 mark for $4 \times 10^{16}$ (not converting to J ) or $1.6 \times 10^{4}$ (not converting MeV to eV) <br> $5.1 \times 10^{5}$ (using keV rather than MeV ) |
|  | b |  | Any three from <br> - Total momentum of system / particles is conserved (as there are no external forces) / Increase in momentum of Sr nucleus equals decrease in momentum of alphaparticle <br> - (Electrostatic) force (of repulsion) acts on (Sr) nucleus <br> - (By Newton's $2^{\text {nd }}$ law Sr ) nucleus accelerates (away from alpha particle) <br> - Sr acceleration increases and then decreases (to zero) <br> - Force on Sr nucleus $\propto$ rate of change of momentum of alpha particle. (AW) | B1 $\times 3$ | momentum / accelerate(s) / acceleration must be spelled correctly to score corresponding mark |
|  | C |  | (Momentum is conserved) $6.6 \times 10^{-27} \times 1.6 \times 10^{7}=1.3 \times 10^{-25} \times V$ $V=8.1 \times 10^{5} \quad\left(\mathrm{~m} \mathrm{~s}^{-1}\right)$ | C1 A1 | Possible ECF from (a) <br> Allow full marks for use of $2 \times 10^{7}$ for speed of alpha particle giving $V=1.0 \times 10^{6}\left(\mathrm{~m} \mathrm{~s}^{-1}\right)$ |
|  | d |  | $\begin{aligned} & \Delta(m v)=2 \times 6.6 \times 10^{-27} \times 1.6 \times 10^{7}\left(=2.11 \times 10^{-19}\right) \\ & F \Delta t=4.8 \times \Delta t=2.11 \times 10^{-19} \\ & \Delta t=4.4 \times 10^{-20}(\mathrm{~s}) \end{aligned}$ | $\mathbf{C 1}$ A1 | Possible ECF from (a) <br> Allow full marks for use of $2 \times 10^{7}$ for speed of alpha particle giving $\Delta t=5.5 \times 10^{-20}$ (s) |
|  |  |  | Total | 9 |  |


| 2 | a |  | (Fig. 2.1 shows) $a$ and $x$ are in opposite directions <br> (Fig. 2.2 shows that magnitude of) $a$ is proportional to $x$ because graph is a straight line through the origin | B1 <br> B1 | Allow $a$ is towards the equilibrium position <br> Reason must be given |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | b |  | $\begin{align*} & \text { gradient }=\omega^{2}=\frac{40}{50 \times 10^{-3}}=800 \\ & T=\frac{2 \pi}{\omega}=\frac{2 \pi}{\sqrt{800}}=0.22 \quad \text { (s) } \tag{s} \end{align*}$ | C1 <br> A1 | Allow : use of equation and one point from graph <br> Allow: Max 1 mark for $T=7$ (s) (not converting mm to m ) |
|  | c | i | $\begin{aligned} & {[k]=\left[\frac{m a}{x}\right]=\frac{\mathrm{kg} \times \mathrm{ms}^{-2}}{\mathrm{~m}}} \\ & {[k]=\mathrm{kg} \mathrm{~s}^{-2}} \end{aligned}$ | $\begin{aligned} & \mathrm{C} 1 \\ & \mathrm{~A} 1 \end{aligned}$ | Allow: C1 mark for any subject |
|  |  | ii | $\frac{k}{m}$ is gradient $\frac{k}{m}=800 \quad\left(\mathrm{~s}^{-2}\right)$ | A1 | Possible ECF from (b) <br> Ignore sign |
|  | d |  | - The period / frequency of the oscillations would remain the same <br> - Successive amplitude(s) would decrease in magnitude <br> - energy is dissipated as heat / thermal energy / work is done against friction (AW) | B1 <br> B1 <br> B1 | amplitude must be spelled correctly to score this mark Allow: 1 mark for bald statement that motion would be 'damped harmonic ' or suitable sketch. |


| 2 | e | i | - C continues to move in a straight line as the tube rotates (by $\mathrm{N1}^{\text {st }}$ Law) stretching the spring. <br> - Spring exerts a force on $\mathbf{C}$ which provides the centripetal acceleration (by Newton's $2^{\text {nd }}$ law) to rotate $\mathbf{C}$ (in a circle of appropriate radius). | B1 B1 | No credit for bald statement of laws. They must be applied to the problem. |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | ii | Any four from <br> - Measure natural length of spring OR <br> Measure mass of $\mathbf{C}$ with balance/scale(s). <br> - Rotate at constant speed and video apparatus and ruler <br> - Measure $R$ from video <br> - Find period $T$ from video and speed $v$ from $2 \pi \mathrm{R} / \mathrm{T}$ <br> - Measure extension from video OR calculate extension, $x$, from $R$ and natural length <br> - Use spring constant and $F=k x$ /Hooke's law OR substitute $M, v R$ into $F=M v^{2} / R$ to find force $F$ | $\begin{gathered} \text { B1 } x \\ 4 \end{gathered}$ |  |
|  |  | iii1 | $F R / N m$ | B1 | Must have appropriate unit (ignore any prefix) |
|  |  | iii2 | $\left.m=F R / v^{2} \quad \text { [any subject }\right]$ <br> mass is gradient of graph | $\begin{aligned} & \text { C1 } \\ & \text { A1 } \end{aligned}$ | Possible ecf from (iii)1 |
|  |  |  | Total | 19 |  |


| 3 | a |  | $\begin{aligned} & \mathrm{g}=\frac{\mathrm{GM}}{\mathrm{R}^{2}} \\ & \frac{\mathrm{~g}_{\text {Mars }}}{\mathrm{g}_{\text {Earth }}}=\left(\frac{\mathrm{GM}_{\text {Mars }}}{\mathrm{R}_{\text {Mars }}^{2}}\right)\left(\frac{\mathrm{R}_{\text {Earth }}^{2}}{\mathrm{GM}_{\text {Earth }}}\right)=\left(\frac{1}{(3400)^{2}}\right)\left(\frac{(6400)^{2}}{9.3}\right) \\ & \mathrm{g}_{\text {Mars }}=0.38 \times 9.81 \\ & \mathrm{~g}_{\text {Mars }}=3.74 \approx 3.7 \quad\left(\mathrm{Nkg}^{-1}\right) \end{aligned}$ | C1 <br> A1 | Allow: use of recalled mass of Earth $\left(\sim 6 \times 10^{24} \mathrm{~kg}\right)$ and G from data tables OR calculation of mass of Earth from $g=9.81 \mathrm{~m} \mathrm{~s}^{-1}$ <br> C1 mark is for substitution into appropriate formula OR mass of Mars $=6.45 \times 10^{23}(\mathrm{~kg})$ <br> Possible FT from their mass of Mars |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | b | i | - Vertical acceleration on Mars is less than on Earth (AW) <br> - time of fall on Mars is greater than time of fall on Earth (AW) <br> - horizontal distance travelled will be greater on Mars | B1 <br> B1 <br> AO |  |
|  |  | ii | - Value of max height will be too small <br> - $g$ /a will reduce as height increases $/ g \propto 1 / r^{2} /$ SUVAT equations only apply if $a$ is constant | B1 B1 | Allow 1 out of 2 marks for 'air resistance will reduce the height' |


| C | $i 1$ | - orbit must be over equator / equatorial <br> - period must be one Martian day / $8.9 \times 10^{4} \mathrm{~s}$ <br> - direction of rotation must be the same as that of Mars / must travel in orbit parallel to a point on surface of Mars | B1 <br> B1 <br> B1 | Allow : same angular speed as Mars |
| :---: | :---: | :---: | :---: | :---: |
|  | i2 | $\begin{aligned} & G M_{\text {Mars }}=g R^{2}=3.74 \times\left(3400 \times 10^{3}\right)^{2} \quad\left(=4.3 \times 10^{13}\right) \\ & T^{2}=\frac{4 \pi^{2}}{G M_{\text {Mars }}} r^{3} \\ & r=\sqrt[3]{\frac{4.3 \times 10^{13} \times\left(8.9 \times 10^{4}\right)^{2}}{4 \pi^{2}}} \\ & r=2.1 \times 10^{7} \quad \text { (m) } \end{aligned}$ | C1 A1 | Possible ECF for mass of Mars from (a) <br> Allow: C1 mark for substitution of values into correct equation written with any subject. <br> Allow: $\begin{aligned} & r=\sqrt[3]{\frac{6.67 \times 10^{-11} \times 6.45 \times 10^{23}\left(8.9 \times 10^{4}\right)^{2}}{4 \pi^{2}}} \\ & r=2.1 \times 10^{7} \quad(\mathrm{~m}) \end{aligned}$ |
|  | ii | $\begin{aligned} & T=\sqrt{\frac{4 \pi^{2} r^{3}}{G M_{\text {Mars }}}}=\sqrt{\frac{4 \pi^{2} \times\left((3400+9000) \times 10^{3}\right)^{3}}{4.3 \times 10^{13}}} \\ & T=4.2 \times 10^{4} \end{aligned}$ $\text { number of images }=\frac{4.2 \times 10^{4}}{25}=1700$ | C1 C1 A1 | Possible ECF from their $G M_{\text {Mars }}$ in c(i)2 or mass of Mars from (a) <br> Allow : Alternative method using $T^{2} \propto r^{3}$ eg $T=\left(\sqrt{\frac{\left(12400 \times 10^{3}\right)^{3}}{\left(2.1 \times 10^{7}\right)^{3}}}\right) \times 8.9 \times 10^{4}=4.2 \times 10^{4}(\mathrm{~s})$ <br> Allow: 2 out of 3 marks for $T=2.6 \times 10^{4}(\mathrm{~s})$ leading to approximately 1034 images [uses 9000 km as radius of orbit] Possible FT from their value of $T$ |
|  |  | Total | 14 |  |


| 4 | a |  | $\begin{aligned} & \text { charge flowing }=I \Delta t=45 \times 10^{-3} \times 1.6=\left(72 \times 10^{-3} \mathrm{C}\right) \\ & \text { number of electrons }=\frac{72 \times 10^{-3}}{1.6 \times 10^{-19}}=4.5 \times 10^{17} \end{aligned}$ | A1 |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | b |  | $\begin{aligned} & \lambda=\frac{h c}{e V}=\frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{1.6 \times 10^{-19} \times 130 \times 10^{3}} \\ & \lambda=9.6 \times 10^{-12} \quad(\mathrm{~m}) \end{aligned}$ | $\begin{aligned} & \mathrm{C} 1 \\ & \mathrm{~A} 1 \end{aligned}$ |  |
|  | C |  | $\begin{aligned} & \text { electrical power }=I V=130 \times 10^{3} \times 45 \times 10^{-3}=5850 \mathrm{~W} \\ & \text { rate of heat produced }=0.9 \times 5850=5265 \mathrm{~W} \\ & 5265=m \times 4200 \times 10 \\ & m=0.125\left(\mathrm{~kg} \mathrm{~s}^{-1}\right) \\ & \mathrm{V}=\frac{\mathrm{m}}{\rho}=\frac{0.125}{1000}=1.25 \times 10^{-4} \quad\left(\mathrm{~m}^{3} \mathrm{~s}^{-1}\right) \end{aligned}$ | C1 C1 A1 | $\begin{aligned} & \text { Allow: electrons energy }=4.5 \times 10^{17} \times 130 \times 10^{3} \text { in } 1.6 \mathrm{~s} . \\ & \text { power }=\frac{4.5 \times 10^{17} \times 130 \times 10^{3} \times 1.6 \times 10^{-19}}{1.6}=5850 \mathrm{~W} \end{aligned}$ <br> Allow: Full marks for correct use of $5 \times 10^{17}$ electrons. Giving $V=1.4 \times 10^{-4}\left(\mathrm{~m}^{3} \mathrm{~s}^{-1}\right)$ |
|  |  |  | Total | 6 |  |


| 5 | a | i | Selection of two or more points from the curve and calculation of $p V$ for each point or comparison of values hence $p V$ constant / $p \propto 1 / \mathrm{V} /$ Boyle's law is obeyed | M1 A1 | Ignore units in calculation |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | ii | - mass of gas / number of molecules must be constant/fixed <br> - Temperature must be constant | B1 B1 | Allow: system must be closed |
|  |  | iii | Straight line graph with positive gradient negative intercept on the mass axis (equal to mass of piston) | $\begin{aligned} & \text { B1 } \\ & \text { B1 } \end{aligned}$ |  |
|  | b | i | $\begin{aligned} & n=\frac{p V}{R T}=\frac{1.0 \times 10^{5} \times(4 / 3) \pi \times 1.0^{3}}{8.31 \times(273+17)}=(174) \\ & \text { mass }=4.0 \times 10^{-3} \times 174=0.70 \quad(\mathrm{~kg}) \end{aligned}$ | $\begin{aligned} & \mathrm{C} 1 \\ & \mathrm{~A} 1 \end{aligned}$ | Allow: 1 mark for mass $=5.6 \mathrm{~kg}$ [incorrect radius] <br> Allow: 1 mark for mass $=12 \mathrm{~kg}$ [incorrect $T$ ] |
|  |  | ii | $\begin{aligned} p_{2} & =\frac{p_{1} V_{1} T_{2}}{V_{2} T_{1}} \\ & =\frac{1.0 \times 10^{5} \times 1.0^{3} \times 240}{4.5^{3} \times 290} \\ p_{2} & =9.1 \times 10^{2} \quad \text { (Pa) } \end{aligned}$ | C1 <br> A1 | Allow: Use of $p=\frac{n R T}{V}$ with their $n$ from $\mathbf{b}$ (i) <br> Allow: 1 mark for $p_{2}=2100(\mathrm{~Pa})$ [incorrect $T$ ] |
|  |  | iii | Use of internal energy $\propto T$ $\frac{\text { internal energy at max height }}{\text { internal energy at ground }}=\frac{240}{290}=0.83$ | C1 <br> A1 | Not ratio $=1.9 \quad[$ incorrect $T]$ |
|  |  |  | Total | 12 |  |

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