PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 12: GRAVITATIONAL FIELDS

SCORE	PERCENTAGE
/155	%

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Mark Scheme

Q1.

Question Number	Answer		Mark
*	**(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)** **Max 6** (marks must be for one earth method and one space method) **Earth (max 3)**: Weight/downwards force (on person). There is an upward force on person (from the floor) **Or** (normal) reaction/contact force No resultant force **Or** person not accelerating (Therefore) the reaction/contact force from the floor upwards = weight **Or** the person feels an upwards force equal to their weight **Or** $R - mg = ma$ Acceleration = 0 $R = mg$ **Space(max 3)**: Must be a resultant /unbalanced force on the person Force (exerted) by floor/box on person/foot Equal to *ma* (accept *mg*) **Or** The idea that an unbalanced force acts $\sum F = ma$ (if seen this scores MP1 and 2) $\sum F = mg$ **Comparison:** In both cases person feels <u>force</u> from floor of *mg* **Or** in both cases the feels the same <u>force</u> from the floor (Accept points when they are shown as annotations to the diagram) (to be awarded all 6 marks, as this is a QWC question, all letters must be defined)	 **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**6**

Q2.

Question Number	Answer	Mark
	The only correct answer is B because $mg = GMm/r^2$ so acceleration of free fall is proportional to mass / diameter^2 = $g(M/9)/(D/2)^2 = \frac{9.81 \times 4}{9}$	**1**

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $v = u + at$ (1) • $a = 0.81\ \text{m s}^{-2}$ (1)	Example of calculation $a = \frac{v-u}{t} = \frac{97\ \text{m s}^{-1}}{120\ s} = 0.808\ \text{m s}^{-2}$	2
(ii)	• Use of $s = ut + \frac{1}{2}at^2$ **Or** $v^2 = u^2 + 2as$ **Or** $s = \left(\frac{(v+u)}{2}\right)t$ (1) • Use of $v_{av} = \frac{s}{t}$ with $t = 320$ s (1) • $v_{av} = 75\ \text{m s}^{-1}$ (1)	Ecf acceleration from (a)(i) Example of calculation $s = ut + \frac{1}{2}at^2 = 0.5 \times 0.808\ \text{m s}^{-2}\ (120\ \text{s})^2 = 5820\ \text{m}$ $s_2 = 29900\ \text{m} - 5820\ \text{m} = 24\,080\ \text{m}$ $t = 440\text{s} - 120\ \text{s} = 320\ \text{s}$ $v_{av} = \frac{24\,080\ \text{m}}{320\ \text{s}} = 75.3\ \text{m s}^{-1}$	3

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	Use of $F = mv^2 / r$ with $F = Gm_1 m_2 / r^2$ (1) Use of $v = 2\pi r / T$ (1) $T = 6.64 \times 10^8$ s (= 21 years) (1) **Or** Use of $F = m\omega^2 r$ with $F = Gm_1 m_2 / r^2$ Use of $\omega = 2\pi / T$ $T = 6.64 \times 10^8$ s (= 21 years)	Example of calculation $F = Gm_1 m_2 / r^2 = m_2 v^2 / r = (2\pi r)^2 m_2 / rT^2$ $T^2 = 4\pi^2 r^3 / G m_1$ $= 4\pi^2 \times (1.9 \times 10^{14}\ \text{m})^3 / (6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 9.2 \times 10^{36}\ \text{kg})$ $T = 6.64 \times 10^8$ s (= 21 years)	3

Q5.

Question Number	Answer		Mark
(a)(i)	Use of $W = mg$ Use of $T\cos30$ **Or** $W/\cos30$ **Or** $T\sin60$ **Or** $W/\sin60$ Factor of 4 seen/used $T = 1.5\times 10^{-3}$ N Example of calculation Weight $=5.4 \times 10^{-4}$ kg $\times$ 9.81 N kg^{-1} $= 5.30 \times 10^{-3}$ N Vertical component of tension $= T \cos 30°$ $4T\cos 30° = 5.30 \times 10^{-3}$ N $T = 1.53 \times 10^{-3}$ N	(1) (1) (1) (1)	4
(a)(ii)	The tension has a horizontal component (as well) **Or** only the vertical component of the tension supports the weight	(1)	1
(b)	When under the twig (the stress/force is) tensile and when on top it is compressive	(1)	1
	Total for question		6

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$ (1) • Correct substitutions to calculate r (1) • $h = 5.4\times10^5$m (1) **OR** • Use of $g = \frac{GM}{r^2}$ to find value of g at orbit height (1) • Use of $a = \frac{v^2}{r}$ with value of g at orbit height (1) • $h = 5.4\times10^5$m (1)	Example of calculation: $\frac{GMm}{r^2} = \frac{mv^2}{r}$ $r = \frac{GM}{v^2}$ $r = \frac{6.67\times10^{-11}\text{N m}^2\text{kg}^{-2}\times5.97\times10^{24}\text{ kg}}{(7.59\times10^3\text{ m s}^{-1})^2}$ $r = 6.91\times10^6$m $\therefore h = (6.91\times10^6 - 6.37\times10^6)$ m $= 5.42\times10^5$m	3
(ii)	• Use of $GPE = \frac{GMm}{r}$ (1) • GPE = 5.7×10^{10} J (ecf from (a)(i)) (1)	Example of calculation: $GPE = GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$ $\therefore$GPE$=6.67\times10^{-11}$Nm^{2}kg^{-2} $\times$ 5.97×10^{24} kg $\times$ 11600 kg $\left(\frac{1}{6.37\times10^6\text{m}} - \frac{1}{6.91\times10^6\text{m}}\right)$ $\therefore$GPE$=5.67\times10^{10}$J	2

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	• This would bring the gravitational potential energy closer to zero (1) • This would mean that the satellite would orbit at a greater height as $GPE \propto \frac{1}{r}$ (1) • To remain in orbit the centripetal acceleration must equal the gravitational field strength at the orbit height **Or** Since gravitational force smaller, $\frac{mv^2}{r}$ would be reduced (1) • (Hence) r is greater so v must be smaller **Or** $v^2 = \frac{GM}{r}$ and satellite would orbit at lower speed (1) **OR** • HST will have more kinetic energy at the original orbit height (1) • The centripetal force will be too small to keep it in this orbit (1) • The satellite would be travelling too fast, so it would move to a higher orbit (1) • (Hence) r is greater so v must be smaller **Or** $v^2 = \frac{GM}{r}$ and satellite would orbit at lower speed (1)		4

Q7.

Question Number	Answer		Mark
(a)	The gravitational field strength [accept "g"] decreases **Or** the (gravitational) force on the satellite/object/mass decreases It is a centripetal force (and not a centrifugal force) The satellite is accelerating and so is not in balance	**(1)** **(1)** **(1)**	**3**
(b)(i)	See $\frac{mv^2}{r} = \frac{GmM_E}{r^2}$ **Or** $m\omega^2 r = \frac{GMm}{r^2}$ $\therefore v^2 = \frac{GM_E}{r}$ **Or** $v = \sqrt{\frac{GM_E}{r}}$ GM_E is constant (and so v decreases as r increases) **Or** $v^2 \propto \frac{1}{r}$ **Or** $v \propto \frac{1}{\sqrt{r}}$	**(1)** **(1)** **(1)**	**3**
(b)(ii)	State $T = \frac{2\pi}{\omega}$ and $\omega = \frac{v}{r}$ **Or** $T = \frac{s}{v}$ and $s = 2\pi r$ Hence $T = \frac{2\pi r}{v}$ (so smaller v leads to a larger value of T) [Accept $T = \frac{2\pi GM_E}{v^3}$ for final mark]	**(1)** **(1)**	**2**
(c)	Use of $T = \sqrt{\frac{4\pi^2 r^3}{GM}}$ T = 5530 s [92 minutes] <u>Example of calculation</u> $T = \sqrt{\frac{4\pi^2 r^3}{GM}} = \sqrt{\frac{4\pi^2 (6360000\,\text{m} + 400000\,\text{m})^3}{6.67 \times 10^{-11}\,\text{N m}^2\,\text{kg}^{-2} \times 5.98 \times 10^{24}\,\text{kg}}} = 5530\,\text{s}$	**(1)** **(1)**	**2**
(d)	**Max 2** As radius decreases: There is a transfer of gravitational potential energy to kinetic energy [Accept kinetic energy increases and gravitational potential energy decreases] Sum of kinetic and gravitational potential energy decreases **Or** satellite does work against frictional forces **Or** transfer of kinetic energy of satellite to thermal energy **Or** heating occurs	 **(1)** **(1)**	**2**

Q8.

Question Number	Answer	Mark
*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Gravitational fields are regions in which a mass experiences a force due to its mass (1) Electric fields are regions in which a charge experiences a force due to its charge (1) Both types of field have an infinite range (1) In each type of field the force varies as an inverse square (1) The force between masses is always attractive whereas the force between charges can be attractive or repulsive **Or** electric fields can cancel or reinforce but gravitational fields always reinforce one another (1) The force between (unit) charges at a given separation is much stronger than the force between (unit) masses at the same separation (1)	6
	Total for question	6

Q9.

Question Number	Acceptable answer	Additional guidance	Mark
	D	The only correct answer is **D**: potential is proportional to $1/x$ A is not correct because electric fields do not cause a force on uncharged particles B is not correct because the force caused by gravitational field has only ever been shown to be attractive C is not correct because field strength is inversely proportional to x^2	1

Q10.

Question Number	Acceptable answer	Additional guidance	Mark
	B	The only correct answer is **B** because the electric field is always positive except at infinity, when it is zero A is not the correct choice because the statement is correct C is not the correct choice because the statement is correct D is not the correct choice because the statement is correct	1

Q11.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• use of $F = Gm_1m_2/r^2$ **and** use of $F = mr\omega^2$ **Or** use of $F = Gm_1m_2/r^2$ **and** use of $F = mv^2/r$	(1)	MP3 and 4 - for force and angular velocity, both approaches required Example of calculation $T^2 = 4\pi^2r^3 / G\,m_1$	4
	• use of $T = 2\pi/\omega$ **Or** use of $T = 2\pi r/v$	(1)	$T^2 = 4\pi^2 \times (2\,430\,000\text{ m} + 7\,690\,000\text{ m})^3 / 6.67 \times 10^{-11}\text{ N m}^2\text{ kg}^{-2} \times 3.30 \times 10^{23}\text{ kg}$	
	• $T = 12$ hours **Or** $F = 120$ N by gravitational approach and centripetal force approach **Or** $\omega = 1.45 \times 10^{-4}$ radians s^{-1} by gravitational approach and circular motion approach **Or** height of orbit = 7700 km	(1)	$T = 43115$ s = 11.98 hours	
	• Comparative statement consistent with their value(s)	(1)		
(ii)	**Max 2** • Allows satellite to get (much) closer to surface	(1)	For each, the second marking point is dependent on the first. Award second marking point for other sensible advantages	2
	• So more detailed photographs/scans possible	(1)		
	OR • Allows satellite to spend time further from the surface	(1)		
	• So prevents exposure to prolonged heat from planet damaging probe	(1)		
	OR • Satellite varies distance from surface	(1)		
	• So it can take wide-angle and close-up pictures of the planet	(1)		

Q12.

Question Number	Answer	Mark
	B	1

Q13.

Question Number	Answer		Mark
(a)(i)	See $F = GMm/r^2$	(1)	
	Equated to mg to give required expression **Or** use of g = F/m	(1)	2
(a)(ii)	Use of $g = \omega^2 r$ OR $g = v^2/r$	(1)	
	Use of $\omega = 2\pi/T$ OR $v = 2\pi r/T$	(1)	
	Correct algebra leading to expression given	(1)	3
	Example of calculation: $\omega^2 r = \frac{GM}{r^2}$ $\left(\frac{2\pi}{T}\right)^2 = \frac{GM}{r^3}$ $r^3 = \frac{GMT^2}{4\pi^2}$		
(a)(iii)	See T = 24 hours	(1)	
	T converted into s	(1)	
	$r = 4.2 \times 10^7$ m	(1)	3
	Example of calculation: $T = 24 \times 60 \times 60$ s = 86 400 s $r^3 = \frac{GMT^2}{4\pi^2} = \frac{6.67\times10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 6.0\times10^{24}\ \text{kg} \times (86400\ \text{s})^2}{4\pi^2} = 7.57\times10^{22}\ \text{m}^3$ $r = \sqrt[3]{7.57\times10^{22}\ \text{m}^3} = 4.23\times10^7\ \text{m}$		
(b)	The satellite must rotate with the Earth **Or** the satellite must be in a geosynchronous orbit **Or** any non-equatorial orbit would cause the satellite to move N-S		1
	Total for question		9

Q14.

Question Number	Answer	Mark
	A	1

Q15.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• use of density = mass / volume	(1)	Example of calculation: $V = 1.0 \times 10^{13}$ kg ÷ 470 kg m^{-3} $= 2.13 \times 10^{10}$ m^3 $= 4/3\ \pi r^3$ $r = \sqrt[3]{(2.13 \times 10^{10}\ \text{m}^3 \times 3) \div 4\pi}$ $= 1720$ m	**(3)**
	• use of $V = 4/3\ \pi r^3$	(1)		
	• $r = 1720$ m	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• use of $g = GM/r^2$	(1)	Example of calculation: $g = 6.67 \times 10^{-11}$ N m^2 kg^{-2} × 1.0×10^{13} kg / (1720 m)^2 $g = 2.25 \times 10^{-4}$ N kg^{-1}	**(2)**
	• $g = 2.3 \times 10^{-4}$ N kg^{-1}	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(c)	• use of $s = ½\ gt^2$	(1)	Example of calculation: $s = 0.5 \times 2.25 \times 10^{-4}$ m s^{-2} × (3300 s)^2 $= 1.2 \times 10^3$ m	**(2)**
	• $s = 1.2 \times 10^3$ m	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(d)	An explanation that makes reference to the following:			**(3)**
	• the calculated height is comparable with the radius (of asteroid)	(1)		
	• the field should be considered as radial rather than parallel, so the gravitational field strength is decreasing significantly for the probe	(1)		
	OR $g = GM/r^2$ the change in r is comparable with the radius, so there will be a significant change in g	(1)		
	• acceleration is less, so the actual height would be less	(1)		

Q16.

Question Number	Answer	Mark
	D Both fields act on all particles.	**1**
	Incorrect Answers: A – this is a similarity B – this is a similarity C – this is a similarity	

Q17.

Question Number	Answer	Mark
(a)(i)	Use of $\omega = \frac{2\pi}{T}$ (1) See $F = \frac{GMm}{r^2}$ **and** $F = m\omega^2 r$ (1) $GM = 4.07 \times 10^{14}$ ($m^3\ s^{-2}$) (1) **Or** Use of $v = \frac{2\pi r}{T}$ (1) See $F = \frac{GMm}{r^2}$ **and** $F = \frac{mv^2}{r}$ (1) $GM = 4.07 \times 10^{14}$ ($m^3\ s^{-2}$) (1) [If reverse "show that" attempted, max 2] Example of calculation: $\omega = \frac{2\pi}{T} = \frac{2\pi\,\text{rad}}{2.36\times10^{6}\,\text{s}} = 2.66\times10^{-6}\ \text{rad s}^{-1}$ $\frac{GMm}{r^2} = m\omega^2 r$ $GM = \omega^2 r^3 = \left(2.66\times10^{-6}\,\text{s}^{-1}\right)^2 \times \left(3.86\times10^{8}\,\text{m}\right)^3 = 4.07\times10^{14}\ \text{m}^3\ \text{s}^{-2}$	**3**
(a)(ii)	Use of $g = \frac{GM}{R^2}$ with $g = 9.81\ \text{N kg}^{-1}$ (1) $R = 6.4 \times 10^{6}$ m [6.5×10^{6} m if show that value used] (1) Example of calculation: $R = \sqrt{\frac{GM}{g}} = \sqrt{\frac{4.07\times10^{14}\,\text{m}^3\,\text{s}^{-2}}{9.81\,\text{N kg}^{-1}}} = 6.44\times10^{6}\,\text{m}$	**2**

(b)	Force varies with distance (from the Earth) according to inverse square law $F \propto \frac{1}{r^2}$ (1) so force (on these asteroids) is (very) small (1) **Or** Gravitational field strength varies with distance (from the Earth) according to inverse square law $g \propto \frac{1}{r^2}$ (1) so gravitational field strength is (very) weak at this distance (1) [Accept idea that since the asteroids are much further from the Earth (than the moon) they are only weakly bound (to the Earth) for max 1 mark]	2
	Total for Question	**7**

Q18.

Question Number	Answer	Mark
	Use of $F = \frac{Gm_1m_2}{r^2}$ (1) $F = 8.2 \times 10^{16}$ N (1) Example of calculation: $F = \frac{Gm_1m_2}{r^2} = \frac{6.67\times10^{-11}\,\text{N m}^2\,\text{kg}^{-2} \times 6.4\times10^{23}\,\text{kg} \times 6.0\times10^{24}\,\text{kg}}{(5.6\times10^{10}\,\text{m})^2}$ $F = 8.17\times10^{16}$ N	2
		2

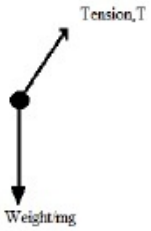
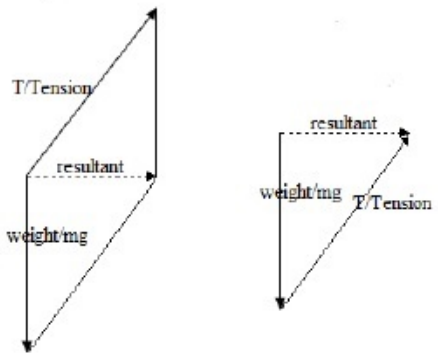
Q19.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of $V = -Gm / r$ • Change in $V = 3.18 \times 10^{13}$ (J kg^{-1})	(1) (1)	Example of calculation $\Delta V = -Gm\,(1/r_2 - 1/r_1)$ $= -6.67 \times 10^{-11}$ N m^2 kg^{-2} $\times$ 9.2×10^{36} kg $\times$ $((1/2.7 \times 10^{14}$ m $- 1/1.8 \times 10^{13}$ m) $= 3.18 \times 10^{13}$ J kg^{-1}	2
(ii)	• Equate change in gravitational potential energy to change in kinetic energy **Or** use of $E_p = mV$ • Use of $E_k = ½\,mv^2$ • $v = 1.4 \times 10^6$ m s^{-1}	(1) (1) (1)	Example of calculation $m \times 3.18 \times 10^{13}$ J kg^{-1} $= (0.5 \times m \times (8.10 \times 10^6$ m s$^{-1})^2) - (0.5 \times m\,v_2^2)$ $v_2 = 1.4 \times 10^6$ m s^{-1}	3

Q20.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $V_{grav} = -\frac{GM}{r}$ • Recognises that $\Delta E_{grav} = m \times \Delta V_{grav}$ • $\Delta E_{grav} =$ $(-)\,3.4 \times 10^7$ J **OR** • Use of $g_{Mars} = -\frac{GM}{r^2}$ with justification that change in g is minimal • Use of $\Delta E_{grav} = m \times g \times \Delta h$ • $\Delta E_{grav} =$ $(-)\,3.4 \times 10^7$ J	(1) (1) (1)	Example of calculation $\Delta V_{grav} = -\frac{GM}{r_2} + \frac{GM}{r_1}$ $\Delta V_{grav} = GM\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$ $\Delta V_{grav} = 6.67 \times 10^{-11}$ N m^2 kg^{-2} $\times$ 6.39×10^{23} kg $\left(\frac{1}{(3.39 \times 10^6 + 11.0 \times 10^3)\text{m}} - \frac{1}{(3.39 \times 10^6 + 2.1 \times 10^3)\text{m}}\right)$ $\therefore \Delta V_{grav} = -3.29 \times 10^4$ J kg^{-1} $\therefore \Delta E_{grav} = -3.29 \times 10^4$ J kg^{-2} $\times$ 1030 kg $= -3.39 \times 10^7$ J	3

Q21.

Question Number		Mark
(a)(i)	Weight (1) (accept *W* or mg or gravitational pull/force) ('gravity' doesn't get the mark) Tension (1) (accept *T*) (Both arrows and labels required for each marking point)  (Arrows must touch mass for marks; ignore any arrows, for correct or incorrect forces, not touching (Minus one from maximum possible mark for each additional force (e.g. resultant, pull) or other arrow (e.g. speed or motion) touching mass)	**2**
(a) (ii)	A triangle or parallelogram with W and T in correct position for vector addition with correct labels and directions. (1) Triangle or parallelogram completed correctly with resultant in correct directions. (1) (Can score 2 marks even if the resultant is not horizontal) e.g. (scores 2 marks)  	**2**

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(a)(iii)	$ma/mg = \tan\theta$ **OR** $T\cos\theta = mg$ **and** $T\sin\theta = ma$ (1) (seen or substituted into) $a = 1.2$ (m s^{-2}) (1) Example of calculation $a = \tan 7° \times g = \tan 7° \times 9.81$ m s^{-2} $= 1.2$ m s^{-2}	**2**
(b)(i)	Straight down (by eye) (1) 	**1**
(b)(ii)	To left, angle between string and roof to be less than 83° but not horizontal (1) 	**1**
(b)(iii)	To right, at any angle except horizontal (1) 	**1**
(c)	Always has weight **Or** gravitational force **Or** force due to gravity (1) so tension needs a vertical component (1) **Or** Use of the equation $ma/mg = \tan\theta$ (1) Leading to the idea of infinite value of $\tan\theta$ requiring infinite acceleration (1)	**2**
(d)	Any correct physics answer that uses the concept of the independence of motion at right angles (1) e.g. (to detect movement) in the x,y,z directions/planes/axes **Or** up-down, left-right and forwards-backwards	**1**
	Total for question	**12**

Q22.

Question Number	Answer	Mark
	B	**1**

Q23.

Question Number	Acceptable Answers	Mark
(a)	**Laminar**: Continuous lines, not crossing, below the wing, with at least 2 continuing beyond the wing **(1)** **Turbulent:** swirls, crossing lines, changes of direction greater than 90° **only** above the wing, not necessarily attached to the lines from the left **(1)**	**2**

Question Number	Acceptable Answers	Mark
(b)(i)	The idea that a (component of) lift = weight **(1)** See L cos 20° or mg / cos 20° **(1)** L = 0.66 or 0.7 (N) **(1)** Example of calculation Vertical component of lift = weight $L\cos 20^{\circ} = 0.063\ \text{kg} \times 9.81\ \text{N kg}^{-1}$ L = 0.66 (N)	**3**

Question Number	Acceptable Answers	Mark
(b)(ii)	Find the horizontal component of lift (drag) using trig or Pythagoras **(1)** (L sin 20°, W tan 20°, $\sqrt{L^2 - W^2}$) Use of $F = ma$ **(1)** Acceleration = (−) 3.6 to 3.7 m s^{-2} (ecf) **(1)** Example of calculation $L_{\text{horizontal}} = -L\sin 20^{\circ} = -0.66\ \text{N} \times \sin 20^{\circ} = -0.226$ (N) $\text{acceleration} = \dfrac{-0.226\ \text{N}}{0.063\ \text{kg}}$ acceleration = −3.57 m s^{-2}	**3**

Question Number	Acceptable Answers		Mark
(c)(i)	Bird/leg exerts force/push (down) on ground	(1)	4
	N3 ground exerts a force (up) on bird	(1)	
	Force ≠ / > weight **Or** there is a resultant/unbalanced force	(1)	
	Due to N2 / N1 bird accelerates	(1)	

Question Number	Acceptable Answers		Mark
(c)(ii)	Maximum force read from graph = 2.00 N to 2.10 N	(1)	3
	resultant force = $F - W$ (1.37 N to 1.43 N)	(1)	
	Answer = 23 m s^{-2}	(1)	
	Example of calculation Maximum force = 2.05 N 2.05 N – (0.063 kg x 9.81 m s^{-2}) = 0.063 kg × a a = 22.7 m s^{-2}		
	Total for question		**15**

Q24.

Question Number	Acceptable answers		Additional guidance	Mark
i	• Use of $\omega = 2\pi/T$	(1)	For MP3, accept correctly rounded answers in range 6.5 × 10^{-6} radian s^{-1} to 6.6 × 10^{-6} radian s^{-1}	3
	• For at least 2 full cycles	(1)	Example of calculation	
	• ω = 6.5 × 10^{-6} (radian s^{-1})	(1)	$\omega = 5 \times 2\pi / (56 \times 24 \times 60 \times 60)$ s = 6.49 × 10^{-6} radian s^{-1}	
ii	• Equates $F = Gm_1m_2/r^2$ and $F = m\omega^2r$ **Or** $F = Gm_1m_2/r^2$ and $F = mv^2/r$ with $v = 2\pi r/T$	(1) (1)	Example of calculation r^3 = 6.67 × 10^{-11} N m^2 kg^{-2} × 0.12 × 1.99 × 10^{30} kg / (6.5 × 10^{-6} radian s^{-1})^2	3
	• Correct rearrangement and substitution (e.g. in $r^3 = Gm_1/\omega^2$)	(1)	r = 7.2 × 10^9 m	
	• r = 7.2 × 10^9 m (ecf from (b)(i))		(r = 7.6 × 10^9 m for 'show that' value)	

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Q25.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $V_{grav} = -GM/R$ (1) • Calculate $\Delta V_{grav} = V_{grav\ Moon} - V_{grav\ Earth}$ (1) • Use of $m\ \Delta V_{grav} = E_k = ½\ mv^2$ (1) • $v = 11\ 000\ m\ s^{-1}$ (1)	Example of calculation $V_{grav} = -6.67 \times 10^{-11}\ N\ m^2\ kg^{-1} \times 5.97 \times 10^{24}\ kg$ / $6\ 370\ 000\ m = -62.5\ MJ\ kg^{-1}$ $\Delta V_{grav} = -62.5\ MJ\ kg^{-1} - -1.28\ MJ\ kg^{-1}$ $= -61.2\ MJ\ kg^{-1}$ $½\ v^2 = 61.2\ MJ\ kg^{-1}$ $v = 11\ 100\ m\ s^{-1}$	4

Q26.

Question Number	Answer	Mark
(a)	Use of $F = \frac{G m_1 m_2}{r^2}$ (1) $G = 6.6 \times 10^{-11}$ (N m^2 kg^{-2}) [must see 6.6×10^{-11} when rounded to 2 sf] (1) Example of calculation $G = \frac{1.5 \times 10^{-7}\,\text{N} \times (0.23\,\text{m})^2}{160\,\text{kg} \times 0.75\,\text{kg}} = 6.61 \times 10^{-11}\,\text{N m}^2\,\text{kg}^{-2}$	**2**
(b)(i)	Read (peak) times from graph for at least 3 cycles (1) T = 6.4 min (±0.2 min) [T = (380 ±12) s] (1) [max 1 mark if correct answer shown without working] Example of calculation $T = \frac{(28.0 - 2.5)\text{min}}{4} = 6.38\text{min}$	**2**
(b)(ii)	Air resistance acts on the sphere [accept frictional forces **Or** (viscous) drag for air resistance] (1) Energy is removed from the oscillation/system (1) **Or** the oscillation/system is damped [For mp 2 do not credit 'energy is lost' but accept 'energy is dissipated'; answer must indicate idea of transfer of energy]	**2**
(b)(iii)	Evidence of values of at least 3 consecutive peaks read from graph (1) [accept values of 3 points separated by equal time intervals] Attempt to obtain amplitudes, by subtracting 0.75 (1) Calculation of two values of A_{n+1}/A_n with corresponding conclusion **Or** Calculation of two values of difference of ln A_{n+1} and ln A_n with corresponding conclusion (1) **Or** Use peaks of graph to sketch curve (1) Use curve to determine "half-life" [accept other ratio] (1) Calculation of two values of "half-life" with corresponding conclusion (1) Example of calculation $A_0 = 1.45\text{-}0.75 = 0.7$, $A_1 = 0.75\text{-}0.25 = 0.5$, $A_2 = 1.1\text{-}0.75 = 0.35$, $A_4 = 0.75 - 0.5 = 0.25$	**3**
	$\frac{A_1}{A_0} = \frac{0.50}{0.70} = 0.71$ $\frac{A_2}{A_1} = \frac{0.35}{0.50} = 0.70$ $\frac{A_3}{A_2} = \frac{0.25}{0.35} = 0.71$	
	Total for question	**9**

Q27.

Question Number	Acceptable answers	Additional guidance	Mark
	D		1

Q28.

Question Number	Answer	Mark
	C	1

Q29.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $F = k\,\Delta x$ **(1)** • $k = 14.4$ N m^{-1} **(1)** • Use of $T = 2\pi\sqrt{\frac{m}{k}}$ **(1)** • Use of $f = 1/T$ **(1)** • $f = 2.4$ Hz **(1)**	Example of calculation: $k = mg/\Delta x = 66\times 10^{-3}$ kg $\times$ 9.81m s^{-2})/4.5 $\times 10^{-2}$ m = 14.4 N m^{-1} $T = 2\pi(0.066/14.4.0)^{1/2} = 0.425$ s $f = 1/T = 1/0.425 = 2.35$ Hz	5

Q30.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Satellite would always be above the same point on the Earth's surface **(1)** • So that contact/communication with the space station would be maintained at all times **(1)**		2

(ii)	Use of $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$	**(1)**		
	Use of $\omega = 2\pi/T$	**(1)**	Example of calculation: $m\omega^2 r = \frac{GMm}{r^2}$	
	$r = 4.23 \times 10^7$ m	**(1)**	$\therefore \left(\frac{2\pi}{T}\right)^2 = \frac{GM}{r^3}$	
	$h = 3.6 \times 10^7$ m	**(1)**	$\therefore r = \sqrt[3]{\frac{GMT^2}{4\pi^2}}$	
	OR		$r = \sqrt[3]{\frac{6.67\times10^{-11}\,\text{N m}^2\,\text{kg}^{-2}\times6.00\times10^{24}\,\text{kg}\times(8.64\times10^4\,\text{s})^2}{4\pi^2}}$	
	Use of $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$	**(1)**		
	Use of $v = 2\pi r/T$	**(1)**	$r = 4.23 \times 10^7$ m	
	$r = 4.23 \times 10^7$ m	**(1)**	$h = r - R_E = 4.23 \times 10^7 - 6.4 \times 10^6$ m $= 3.59 \times 10^7$ m	
	$h = 3.6 \times 10^7$ m	**(1)**		**4**