A Level OCR Physics

Chapter 18 Gravitational fields

Question	Answers	Extra information	Mark	AO Spec reference
1(a)	A 1 kg mass experiences a force of 3.7 N		1	5.4.1 AO1
(b)	$\rho = M/V \quad V = 4/3\ \pi r^3$ $g = g = \frac{GM}{r^2} = \frac{G\rho V}{r^2} = \frac{4G\pi\rho r^3}{3r^2} = \frac{4G\pi\rho r}{3}$ If density constant then $g \propto r$ If g less then r must be less	simple statement radius is less 1 mark only	1 1 1	3.2.4 5.4.2 AO2
(c)	Area under the existing curve shaded in This represents the work done bringing a 1 kg mass from infinity to that point		1 1	5.4.4 AO1
(d)	Either by estimating area under curve: 220 squares ± 5 Each square = 0.1 × 0.4×10^6 J kg^{-1} V_g = 220 × 0.1 × 0.4×10^6 J kg^{-1} = 8.8×10^6 J kg^{-1} OR use of surface data to gain *GM* $g = GM/r^2$ and $gr^2 = GM$ $V_g = GM/r = gr^2/r = gr = 3.7 \times 2.4\times10^6 = 8.9\times10^6$ (J kg^{-1})		 1 1	5.4.4 AO2
(e)	$GMm/r = ½\ mv^2$ $2GM/r = v^2$ $v^2 = 2 \times (9 \times 10^6)$ $v = 4200$ m s^{-1}	All values of V_g yield 4200 m s^{-1} to 2sf	1 1	5.4.4 AO2
2(a)	$g = GM/r^2 \qquad V_g = GM/r$ $V_g = (GM/R^2)R = gR$		1	5.4.2 5.4.4 AO1

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(b)	$GMm/r = ½\, mv^2$ $GM/r = ½\, v^2$ $gR = ½\, v^2$ $v = \sqrt{2gR}$		1	5.4.4 AO2
(c)	$v = \sqrt{2gR}$ $v = \sqrt{2 \times 9.81 \times 6.37 \times 10^6}$ = 11 000 m s^{-1} (11 200)		1	5.4.4 AO1
(d)	Mass of hydrogen = (2 × 0.002)/ 6.02×10^{23} = 6.645×10^{-27} kg $½\, m\, (c_{rms})^2 = 3/2\, kT$ $(m/3k)\,(c_{rms})^2 = T$ T = (6.645 × 10^{-27} kg/3 × 1.38 × 10^{-23}) × 11 000^2 T = 20137 K		1 1 1	5.1.4 AO3
(e)	Value used in **2(d)** uses the mean speed of the molecules. At 650 K there will be a range of molecular speeds and some will have enough speed to escape the atmosphere.		1 1	5.1.4 AO3
3(a)	Gravitational potential V_g at a point is defined as the work done/energy required to bring 1 kg/unit mass from infinity to that point in space.		1	5.4.4 AO1
(b)	If $V \propto 1/r$ Then Vr should equal a constant Take pairs of data, at least 2, and see if this is correct.	Allow plot a graph of V vs 1/r graph should be a straight line through the origin	1 1	5.4.4 AO2
(c)	Tangent drawn at 14×10^6 m Gradient calculated e.g. 58 × 10^6/27 × 10^6 g = 2.1 ± 0.2 Or		1 1	5.4.2 5.4.4 AO2

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	Use of $g = GM/r^2 = V_g/r$ $g = 30 \times 10^6/14 \times 10^6$ m $g = 2.1 \pm 0.2$			
(d)	Graph rising as it moves towards the Moon and then decreasing closer to the Moon. Starts at −63 at Earth's surface, ends at a value smaller at Moon's surface. Does not go to zero		1 1 1	5.4.4 AO3
4(a)	The potential difference between the lines is constant but the distance is not / lines are not equally spaced		1	5.4.1 AO2
(b)	Lines drawn towards the centre of the Earth perpendicular to surface (by eye) Arrow pointing to the centre	Should stop at the surface	1 1	5.4.1 AO1
(c)	$V_g = GM/r$ and $g = GM/r^2$ so $GM = 9.81 \times r^2$ $r = GM/V_g$ $r = 9.81 \times (6.37 \times 10^6)^2 / 4.0 \times 10^7 = 1 \times 10^7$ m (9.95 × 10^6)		1 1	5.4.2 5.4.4 AO2
(d)	Since $V_g = GM/r$ and the mass of the Earth is constant and the height of orbit is constant, the gravitational potential remains the same.		1 1	5.4.4 AO1
5(a)	Arrow down labelled $W = mg$ Arrow along string labelled tension (pointing away from bob) Arrow to the left labelled Force/gravitational force of attraction		1 1 1	3.2.1 AO1
(b)	The force of attraction between two masses is proportional to the product of the masses and inversely proportional to the distance between them squared.	Allow equation but terms must be defined	1	5.4.2 AO1
(c)	$T \cos \theta = mg = GmM_E/R^2$ or $T \sin \theta = GMm/d^2$		1 1	2.3.1 AO2

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	Divide one equation by the other (or substitute for T) $T \sin\theta / T \cos\theta = GMm/d^2 \div GmM_E/R^2$ $\tan\theta = MR^2/M_E d^2$		1	
(d)	% difference = (actual – measured)/actual = ((5510 – 4560)/5510) × 100% = 17%		1	2.2.1 AO2
6(a)	A line segment joining a planet and the Sun sweeps out equal areas in equal intervals of time.		1	5.4.3 AO1
(b)	$F = GMm/r^2$ and $F = mv^2/r$ or $g = GM/r^2$ and $a = v^2/r$ $GMm/r^2 = mv^2/r$ $GM/r = v^2$ $v = 2\pi r/T$ $GM/r = 4\pi^2 r^2/T^2$ $T^2 = 4\pi^2 r^3/GM$ Since others constant $T^2 \propto r^3$		1 1 1	5.4.3 AO1
(c)	Appropriate test proposed T^2/r^3 = constant Data tested at least three times e.g. $(1.769)^2/(422)^3 = 4.2\times10^{-8}$ Relationship holds for the moons		1 1 1	5.4.3 AO2
(d)	$T^2/r^3 = 4\pi^2/GM$ use of constant in appropriate units or pair of data from the table $T^2/r^3 = 3.1\times10^{-16}$ $M = 4\pi^2/G \times 3.1\times10^{-16} = 1.9\times10^{27}$ kg		1 1	5.4.3 AO3
(e)	$T^2 \propto r^3$ $2 \log T \propto 3 \log r$		1	1.1.3 AO3

Question	Answers	Extra information	Mark	AO Spec reference
	log $T \propto \frac{3}{2}$ log r straight line graph with gradient = 3/2		1	
7(a)	Arrow pointing towards centre of Earth (judged by eye)		1	5.4.1 AO1
(b)	To remain in orbit there must be a force perpendicular to direction of motion This satellite could not maintain this orbit without an engine.		1 1	5.2.2 AO2
(c)	Use of r = (3.6 × 10^7 + 6.37 × 10^6) [3.6×10^7 = 36 × 10^6] $GMm/r^2 = mv^2/r$ $GM/r = v^2$ GM = 9.81 × r^2 $v = \sqrt{\frac{GM}{r}}$ $v = \sqrt{\frac{9.81 \times (6.37 \times 10^6)^2}{36 \times 10^6 + 6.37 \times 10^6}}$ v = 3100 m s^{-1} or 3.1 km s^{-1} OR use of $v = 2\pi r/T$ where T = 24 × 60 × 60		1 1 1	5.4.4 AO2
(d)	Use of E = KE + GPE KE = ½ mv^2 = 1.355×10^9 J GPE = $-GMm/r$ = –(6.67×10^{-11} × 6×10^{24} × 282)/(3.6×10^7 + 6.37×10^6) = – 2.664×10^9 J E = −1.31×10^9 J	Students may also have combined equations to yield the same answer Do not award final mark if minus sign not included.	1 1 1	5.4.4 AO2

Question	Answers	Extra information	Mark	AO Spec reference
8(a)	Arrow drawn pointing to centre of the space station		1	5.2.2 AO1
(b)	$a = \omega^2 r$ $9.81/25 = \omega^2$ $\omega = 0.63$ rad s^{-1} $\omega = 2\pi/T$ $T = 2\pi/\omega = 10$ s		1 1	5.2.1 5.2.2 5.2.1 AO2
(c)	Suggested height is –1.8 m (allow between 1.5 m and 2.0 m) $r = 25 - 1.8 = 23.2$ m $a = \omega^2 r$ $a = 0.63^2 \times 23.2 = 9.2$ m s^{-2}		1 1	2.1.1 AO3
(d)	Larger radius the height of astronaut is a smaller fraction of the radius – so difference over body marginal (wtte) Difficulty/expense of taking such large amounts of material into space		1 1	2.2.1 AO3