Gravitational Fields - Mark Scheme

Q1.

Question Number	Answer	Mark
	B	1

Q2.

Question Number	Answer		Mark
(a)	Equate $F = \frac{GMm}{r^2}$ and $F = mr\omega^2$ **Or** equate $F = \frac{GMm}{r^2}$ and $\frac{mv^2}{r}$ Use of $T = \frac{2\pi}{\omega}$ **Or** $v = 2\pi r/T$ T = 5550 s <u>Example of calculation</u> $mr\omega^2 = \frac{GMm}{r^2} \quad \therefore \ \omega^2 = \frac{GM}{r^3}$ $\omega = \sqrt{\frac{6.67\times10^{-11}\,\text{Nm}^2\text{kg}^{-2}\times5.98\times10^{24}\,\text{kg}}{(6.37\times10^6\,\text{m}+4.1\times10^5\,\text{m})^3}} = 1.13\times10^{-3}\,\text{rad s}^{-1}$ $T = \frac{2\pi}{\omega} = \frac{2\pi\,\text{rad}}{1.13\times10^{-3}\,\text{rad s}^{-1}} = 5550\,\text{s}$	 (1) (1) (1)	3
(b)	Use of $g = \frac{GM}{r^2}$ [may be by using a ratio] **Or** use of $g\,r^2$ = constant **Or** use of $g = r\,\omega^2$ g = 8.7 N kg^{-1} [accept m s^{-2}] <u>Example of calculation</u> $g = \frac{GM}{r^2} = \frac{6.67\times10^{-11}\,\text{Nm}^2\text{kg}^{-2}\times5.98\times10^{24}\,\text{kg}}{(6.37\times10^6\,\text{m}+4.10\times10^5\,\text{m})^2} = 8.68\,\text{Nkg}^{-1}$	(1) (1)	2
(c)	The orbiting astronaut/spacecraft is effectively in free fall towards the Earth **Or** the gravitational force equals/provides the required centripetal force (Hence) there will be no reaction force on the astronauts (and so they will appear to be weightless).	(1) (1)	2
	Total for question		7

Q3.

Question Number	Answer	Mark
	C	1

Q4.

Question Number	Answer		Mark
(a)	Use of $F = \frac{Gm_1m_2}{r^2}$ **Or** Use of $g = \frac{Gm}{r^2}$ with $F = mg$	(1)	
	$\frac{F_{sun}}{F_{moon}} = 180$	(1)	
	[Allow max 1 if only $g = \frac{Gm}{r^2}$ is used to find $\frac{g_S}{g_M} = 183$]		
	Example of calculation: $\frac{F_{\text{sun}}}{F_{\text{moon}}} = \frac{m_{\text{sun}}}{m_{\text{moon}}} \times \left(\frac{r_{\text{moon}}}{r_{\text{sun}}}\right)^2 = \frac{2\times10^{30}\text{kg}}{7\times10^{22}\text{kg}} \times \left(\frac{3.8\times10^{8}\text{m}}{1.5\times10^{11}\text{m}}\right)^2 = 183$		2
(b)(i)	$g = \frac{GM}{x^2}$ and $g = \frac{GM}{(x+D)^2}$ (on either side of the Earth's diameter D)	(1)	1
(b)(ii)	$x \gg D$ **Or** $(x+D) \approx x$	(1)	
	So $\Delta g \approx 0$ [MP2 dependent upon MP1]	(1)	
	Or		
	The distance of the Sun from the Earth is very large compared with the Earth's diameter	(1)	
	Hence the difference in g (at opposite sides of the Earth due to the Sun) is (very) small [MP2 dependent upon MP1]	(1)	
	[Accept g is approximately the same at both positions for MP2]		2
	Total for Question		5

Q5.

Question Number	Answer	Mark
	The only correct answer is **A** B is not correct because an incorrect distance 2r has been used C is not correct because 3r has been used but not squared D is not correct because an incorrect distance 2r has been used and not been squared	1

Q6.

Question Number	Answer	Mark
	The only correct answer is B *A is not correct because* $g = \frac{GM}{r^2}$ *and* $m = \rho V$ *C is not correct because* $g = \frac{GM}{r^2}$ *and* $m = \rho V$ *D is not correct because* $g = \frac{GM}{r^2}$ *and* $m = \rho V$	**1**

Q7.

Question Number	Answer	Mark
	A	**1**

Q8.

Question Number	Answer		Mark
(a)(i)	Use of $F = \frac{GMm}{r^2}$ and $F = m\omega^2 r$	(1)	
	Use of $\omega = \frac{2\pi}{T}$	(1)	
	Algebra to show $T^2 = \frac{4\pi^2 r^3}{GM}$	(1)	
	Or		
	Use of $F = \frac{GMm}{r^2}$ and $F = \frac{mv^2}{r}$	(1)	
	Use of $v = \frac{2\pi r}{T}$	(1)	
	Algebra to show $T^2 = \frac{4\pi^2 r^3}{GM}$	(1)	**3**
(a)(ii)	Use of $T^2 = \frac{4\pi^2}{GM}.r^3$	(1)	
	Uses $N = \frac{24\times3600}{T}$ to calculate number of orbits	(1)	
	N = 2, hence 4 crossings per day	(1)	**3**
	Example of calculation: $T^2 = \frac{4\pi^2}{GM}.r^3$ $= \frac{4\pi^2}{6.67 \times 10^{-11}\text{N m}^2\text{kg}^{-2} \times 6.0 \times 10^{24}\text{kg}} \times (2.66 \times 10^7 \text{ m})^3$ $T = \sqrt{1.857 \times 10^9 s^2} = 4.31\times10^4 \text{s}$ $N = \frac{24 \times 3600 \text{ s}}{4.31\times10^4 \text{s}} = 2$ So 4 crossings per day		
(b)	$g = \frac{GM}{r^2}$ **Or** $g \propto \frac{1}{r^2}$	(1)	
	g decreases as Δh increases, so the actual value of ΔE_{grav} would be less than the calculated value	(1)	**2**
			8

Q9.

Question Number	Answer		Mark
a	Use of $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$	(1)	
	Use of $\omega = \frac{2\pi}{T}$	(1)	
	$r = 5.8 \times 10^{10}$ m	(1)	
	OR		
	Use of $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$	(1)	
	Use of $v = \frac{2\pi r}{T}$	(1)	
	$r = 5.8 \times 10^{10}$ m	(1)	3
	<u>Example of calculation</u> $\omega = \frac{2\pi \text{ rad}}{7.60 \times 10^6 \text{ s}} = 8.27 \times 10^{-7} \text{rad s}^{-1}$ $\frac{GMm}{r^2} = m\omega^2 r$ $\therefore r = \sqrt[3]{\frac{GM}{\omega^2}} = \sqrt[3]{\frac{6.67 \times 10^{-11} \text{N m}^2 \text{ kg}^{-2} \times 1.99 \times 10^{30} \text{ kg}}{(8.27 \times 10^{-7} \text{ s}^{-1})^2}}$ $\therefore r = 5.79 \times 10^{10}$ m		

bi	Use of $F = \frac{GMm}{R^2}$ with $F = mg$	(1)	
	Algebra to show $g = \frac{GM}{R^2}$	(1)	2
	(Ignore use of r instead of R and use of m_1 and m_2)		
bii	Use of $g = \frac{GM}{r^2}$	(1)	
	$g = 3.7 \text{ N kg}^{-1}$	(1)	2
	(accept m s^{-2})		
	<u>Example of calculation</u> $g = \frac{6.67 \times 10^{-11} \text{N m}^{-2} \text{ kg}^{-2} \times 3.30 \times 10^{23} \text{kg}}{(2.44 \times 10^6 \text{ m})^2} = 3.70 \text{ N kg}^{-1}$		
	Total for Question		7