Gravitational Fields MS1

Question Number	Answer	Mark
1(a)(i)	Use of $\omega=2\pi/T$ (1) ω = 2.66 × 10^{-6} (rad s^{-1}) (1) Example of calculation $\omega = \frac{2\pi}{T} = \frac{2\pi}{27.3 \times 24 \times 3600\text{s}} = 2.66 \times 10^{-6}\,(\text{rad})\text{s}^{-1}$	**2**
1(a)(ii)	See $(F =)\frac{Gm_1m_2}{r^2}$ (1) Evidence that gravitational force equated to centripetal force (1) Correct substitution [e.c.f.] (1) r = 3.92 × 10^8 m (1) If show that value is used, r = 3.62 × 10^8 m Example of calculation $\frac{GMm}{r^2} = m\omega^2 r$ $r^3 = \frac{GM}{\omega^2}$ $\therefore r = \sqrt[3]{\frac{6.67\times10^{-11}\,\text{Nm}^2\text{kg}^{-2}\times6.4\times10^{24}\,\text{kg}}{(2.66\times10^{-6}\,\text{s}^{-1})^2}} = 3.92\times10^8$ m	**4**
1(b)(i)	Max **two** from: ♦ Gravitational force on moon is reduced (1) ♦ (Therefore) ω or v is decreased (1) ♦ (Hence) the orbital time increases (1) ♦ Valid reference to Kepler's law: $T^2 \propto r^3$ (1)	**Max 2**
1(b)(ii)	Rate of increase = 4 (cm per year) (1) Example of calculation Rate of increase = 800 cm / 200 yr = 4 cm yr^{-1}	**1**
1(b)(iii)*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Answers based on expanding universe/galaxies/stars do not gain credit Idea that in the past the moon was closer OR the gravitational pull would have been larger (1) In the past the tidal effects would have been greater/stronger (1) The rate of change of orbital radius would have been greater (1)	**3**
	Total for question 1	**12**

Question Number	Answer		Mark
2(a)	See $F = mg$ and $F = (-)GmM/r^2$ Equate and cancel m on either side	**(1)** **(1)**	**2**
2(b)	Substitute into $g = GM/r^2$ to obtain g = 9.78 N kg^{-1} [condone m s^{-2}] <u>Example of calculation</u> $g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 5.97 \times 10^{24}\ \text{kg}}{(6.38 \times 10^6\ \text{m})^2} = 9.783\ \text{N kg}^{-1}$	**(1)**	**1**
	Total for question 2		**3**

Question Number	Answer		Mark
3	See $g = \frac{GM}{r^2}$ Correct substitution into $g = \frac{GM}{r^2}$ $r_E/r_m = 3.7$ (Correct inverse ratio i.e. $r_m/r_E = 0.27$, scores full marks) <u>Example of calculation</u> $g_E = \frac{GM_E}{r_E^2} \qquad g_m = \frac{GM_m}{r_m^2}$ $\therefore \frac{g_E}{g_m} = \frac{GM_E/r_E^2}{GM_m/r_m^2} = \frac{M_E}{M_m} \times \frac{r_m^2}{r_E^2}$ $\therefore 6 = 81 \times \frac{r_m^2}{r_E^2}$ $\therefore \frac{r_E}{r_m} = \sqrt{\frac{81}{6}} = 3.67 \approx 3.7$	**(1)** **(1)** **(1)**	**3**
	Total for question 3		**3**

Question Number	Answer		Mark
4(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
4(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
4(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
4(c)	Use of $T = \sqrt{\frac{4\pi^2 r^3}{GM}}$ T = 5530 s [92 minutes] Example of calculation $T = \sqrt{\frac{4\pi^2 r^3}{GM}} = \sqrt{\frac{4\pi^2 (6360000\,\text{m} + 400000\,\text{m})^3}{6.67\times10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 5.98\times10^{24}\ \text{kg}}} = 5530\,\text{s}$	(1) (1)	2
4(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
	Total for question 4		12

Question Number	Answer	Mark
5(a)	Use of $F = \frac{G m_1 m_2}{r^2}$ (1) G = 6.6 × 10^{-11} (N m^2 kg^{-2}) [must see 6.6 × 10^{-11} when rounded to 2 sf] (1) <u>Example of calculation</u> $G = \frac{1.5\times10^{-7}\ \text{N}\times(0.23\ \text{m})^2}{160\ \text{kg}\times0.75\ \text{kg}} = 6.61\times10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$	**2**

Question Number	Answer	Mark
6(a)	See (unbalanced force), $F = \frac{Gm_1m_2}{r^2}$ **(1)** Apply N2 with $a = v^2/r$ **Or** Equate F with mv^2/r **Or** Equate F with $m\omega^2 r$ **(1)** Use of $T = 2\pi r/v$ **Or** $T = 2\pi/\omega$ **(1)** T = 43000 (s) **(1)** **Or** At height of satellite orbit, use $g = GM/r^2$ **(1)** Use $g = a = \omega^2 r$ **Or** $g = a = v^2/r$ **(1)** Use of $T = 2\pi r/v$ **Or** $T = 2\pi/\omega$ **(1)** T = 43000 (s) **(1)** [First 3 marks can be obtained from use of $T = 2\pi\sqrt{\frac{r^3}{GM}}$] [If reverse show that to calculate h = 18 900 km, then max 3 marks] <u>Example of calculation:</u> $\frac{GMm}{r^2} = \frac{mv^2}{r}$ $v = \sqrt{\frac{GM}{r}}$ r = (20200 + 6400) km = 2.66 × 10^7 m $v = \sqrt{\frac{6.67\times10^{-11}\ \text{N m}^2\ \text{kg}^{-2}\times6.0\times10^{24}\ \text{kg}}{2.66\times10^7\ \text{m}}} = 3.88\times10^3\ \text{m s}^{-1}$ $T = \frac{2\pi\times2.66\times10^7\ \text{m}}{3.88\times10^3\ \text{m s}^{-1}} = 43100\ \text{s}$	**4**

6(b)	Communications satellites must be in the same position in sky at all times **Or** communications satellites must be in a geostationary orbit **(1)** (So) communications satellites must rotate at the same rate as the Earth **Or** communications satellites must have same angular velocity as the Earth **Or** communications satellites must have same period as the Earth **Or** communications satellites must be in geosynchronous orbits **(1)**	**2**
6(c)	The radius of the GPS satellite orbit is smaller **(1)** The orbit of the communications satellite must be in an equatorial plane **(1)** [Converse accepted for both marks. Do not credit references to velocity or period]	**2**
	Total for question 6	**8**