Question Number	Answer		Mark
1(a)	Correct conversion of lb to kg Use of $W = mg$ with $g/6$ $W_{moon} = 26$ N <u>Example of calculation</u> 35 lb = 35 lb × 0.45 = 15.75 kg $g_{moon} = 9.81 \text{N kg}^{-1}/6 = 1.635 \text{ N kg}^{-1}$ $W_{moon} = 15.75 \text{ kg} \times 1.635 \text{ N kg}^{-1}$ $W_{moon} = 25.8$ N	**(1)** **(1)** **(1)**	**3**
1(b)	Divide by six	**(1)**	**1**
1(c)	Spring used on Earth has to be stiffer **Or** have a greater spring/stiffness constant (Accept converse for the spring on the moon) To give the same extension for (the same mass)	**(1)** **(1)**	**2**
	Total for Question		**6**

Question Number	Answer		Mark
2(a)	Use of $g = \frac{GM}{r^2}$ M = 4.5 × 10^{23} kg <u>Example of calculation</u> $M = \frac{gr^2}{G} = \frac{9.81 \text{ N kg}^{-1} \times (1.74 \times 10^6 \text{ m})^2}{6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}} = 4.45 \times 10^{23} \text{ kg}$	**(1)** **(1)**	**2**
2(b)	(the gravitational force on the Moon would be larger), but the centripetal acceleration would be independent of the mass of the Moon **Or** $r\omega^2 = \frac{GM}{r^2} \quad \therefore \omega^2 = \frac{GM}{r^3}$ (angular) velocity and hence T is independent of mass of Moon	**(1)** **(1)**	**2**
2(c)	Gravitational forces on the seas/oceans/Earth would be greater **Or** Tidal variations would be more extreme [accept tides would be bigger, higher, larger, faster; do **not** accept tides would be stronger]	**(1)**	**1**
	Total for Question		**5**

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

3(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**

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

Question Number	Answer	Mark
5(a)	See $F = mg$ and $F = (-)GmM/r^2$ **(1)** Equate and cancel m on either side **(1)**	**2**
5(b)	Substitute into $g = GM/r^2$ to obtain $g = 9.78\ \text{N kg}^{-1}$ [condone m s^{-2}] **(1)** <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**
	Total for question	**3**

Question Number	Answer		Mark
6(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**
6(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**
6(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**
6(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**
6(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		**12**