Question	Expected Answers	Marks	Additional guidance
1 (a) (i)	Horizontal component of **L** provides the centripetal force (WTTE) Vertical component of **L** balances the weight (WTTE)	B1 B1	
(a) (	$F = mv^2/r$ correct rearranged into $v = \sqrt{(Fr/m)}$ $v = \sqrt{(1.8\text{x}10^6 \text{ x}2000/1.2\text{x}10^5)}$ = **173** m s^{-1} (or 170)	C1 A1	Allow correct substitution of values into $F = mv^2/r$ for C1 mark
(b)	$mv^2/r = GMm/r^2$ $T = 2\pi r/v$ Correct manipulation of equations to give $T^2 = \dfrac{4\pi^2 r^3}{GM}$	B1 M1 A1	Do not allow a bare $v^2 = GM/r$ for the first mark – we need to see where this has come from.
(c)	**Equatorial** orbit (WTTE) (QWC mark) Period is 24h/1day/same as Earth **OR** moves from West to East (WTTE)	B1 B1	QWC equatorial or equator must be spelled correctly
(c) (	Correct rearrangement of $T^2 = (4\pi^2 r^3/GM)$ to give $r^3 = T^2GM/4\pi^2$ correct sub. $r^3 = \{6.67 \text{ x}10^{-11} \text{ x } 6.0 \text{ x } 10^{24} \text{ x } (8.64\text{x}10^4)^2\}/4\pi^2 = 7.57\text{x}10^{22}$ r = **$4.23 \text{ x } 10^7$ m** (or 4.2 or 4.3 x 10^7)	C1 C1 A1	(1 day = 8.64 x10^4s is given on the data sheet). For those who use $g = GM/r^2$ with g = 9.81 award 1 mark for r= 6.4 x 10^6 m.
	Total	12	

Question			Answer	Marks	Guidance
2	(a)	(i)	$g = \frac{v^2}{r}$ or $v^2 = \frac{GM}{r}$ $v = \sqrt{gr}$ $v = \sqrt{7.7 \times 7.2 \times 10^6}$ $v = 7400$ (m s^{-1})	C1 C1 A1	Correct formula in any form **Allow:** use of *a* for *g* Mark is for substitution (**Note** Mass of Earth is 6.0 x 10^{24} kg) **Any use of r = 800 km is WP scores 0/3** **Note:** Answer to 3 sf is 7450 (m s^{-1})
		(ii)	$T = \frac{2\pi r}{v}$ $T = \frac{2\pi \times 7.2 \times 10^6}{7450}$ = 6100 (s) $T^2 = \frac{4\pi^2 r^3}{GM}$ $T^2 = \frac{4\pi^2 (7.2 \times 10^6)^3}{6.67 \times 10^{-11} \times 6 \times 10^{24}}$ T = 6100 (s)	C1 A1	**Allow:** possible ecf for *v* from (a)(i) **No ecf** for use of *r* = 6.4 x 10^6 again or use of r = 800 km Both score 0/2 **Note:** Answer to 3 sf using v = 7400 is 6110 (s) Answer to 3 sf using v = 7450 is 6070 (s)
	(b)	(i)	Number of orbits = $\frac{24 \times 3600}{6080}$ (= 14.2) ≈ 14	B1	**Allow** any correct method **Allow** ora **No ecf** from a(ii)
		(ii)	Circumference = $2\pi r$ $\frac{\text{equatorial circumference}}{\text{width of photograph}} = \frac{2\pi \times 6400}{3000} = 13.4$ (But each orbit crosses the equator twice hence) number of orbits = 6.7 This is fewer than 14 orbits so whole of Earth's surface can be photographed (AW)	C1 C1 A1 A0	**Allow**: Circumference = $2\pi r$ (C1) length of equator covered per orbit = 2π x 6.4 x 10^3/14 (C1) (= 2872) (But each orbit crosses the equator twice hence) min width to be photographed = ½ x 2872 = 1400 km (A1) < 3000 km so all of Earth's surface can be photographed in one day (A0)

Question			Answer	Marks	Guidance
	(c)		suitable example: eg weather / spy / surveying / mapping / GPS	B1	**Ignore** TV / radio / communications
			Total	**10**	

Question			Answer	Marks	Guidance
3	(a)		Force is proportional to the product of the masses and inversely proportional to the square of their separation (AW)	B1	**Allow:** $F = \frac{GmM}{r^2}$ with **all** symbols defined.
	(b)	(i)	$mg = \frac{GmM_J}{r^2}$	C1	**Allow:** formula with m cancelled
			$M_J \left(= \frac{g r^2}{G} \right) = \frac{7.5 \times (1.3 \times 10^8)^2}{6.67 \times 10^{-11}}$	C1	**Allow:** use of $T^2 = \frac{4\pi^2 r^3}{GM_J} \Rightarrow M_J = \frac{4\pi^2 (1.3 \times 10^8)^3}{6.67 \times 10^{-11} \times (7.2 \times 60^2)^2}$ **Note:** mark is for substitution with any subject
			M_J = 1.9 x 10^{27} (kg)	A1	
		(ii)	$\frac{g_M}{g_A} = \frac{r_A^2}{r_M^2}$		**Allow:** use of $g = \frac{GM_J}{r^2}$ with possible ecf for M_J from (b)(i)
			$\frac{g_M}{7.5} = \frac{(1.3 \times 10^8)^2}{(2.4 \times 10^{10})^2}$	C1	$g_M = \frac{(6.67 \times 10^{-11}) \times (1.9 \times 10^{27})}{(2.4 \times 10^{10})^2}$ **Note:** mark is for substitution
			g_M = 2.2 x 10^{-4} (N kg^{-1})	A1	g_M = 2.2 x 10^{-4} (N kg^{-1})
		(iii)	$T^2 \propto r^3$ OR T^2/r^3 = constant (= $4\pi^2/GM_J$)	C1	**Allow:** possible ecf for M_J from b(i) **Allow:** use of other **c**orrect formulae
			$\frac{T_M^2}{7.2^2} = \frac{(2.4 \times 10^{10})^3}{(1.3 \times 10^8)^3}$	C1	**Note:** mark is for substitution
			T_M = 1.8 x10^4 (hours)	A1	**Note** using times in seconds gives T_M = 6.49 x10^7 (s) scores 2 marks
			Total	**9**	

Question			Answer	Marks	Guidance
4	(a)	(	**geostationary** or **synchronous** 🖉**The term geostationary** or **synchronous** **to be included and spelled correctly to gain the B1 mark**	B1	**Must use tick or cross on Scoris to show if the mark is awarded**
		(ii)	So that they stay: above the same point (at all times) at same point in the sky	B1	**Allow**: travel at same (angular) speed / period and same direction as the Earth
		(iii)	<u>Dish</u> can be fixed to point in one (specific) direction/ <u>Dish</u> does not have to track the satellite (across the sky)	B1	**Allow**: Receiver / aerial for dish
		(iv)	Select from data sheet $T^2 = (4\pi^2/GM)r^3$ $r^3 = T^2\ (GM/4\pi^2)$ $r^3 = (8.64 \times 10^4)^2\ (6.67 \times 10^{-11} \times 6.0 \times 10^{24} / 4\pi^2)$ any subject $(= 7.56 \times 10^{22})$ $r = 4.2 \times 10^7$ (m) $r \approx 4 \times 10^7$ (m)	C1 C1 A1 A0	**Allow**: Full credit if candidate assumes $r = 4 \times 10^7$ and shows T is approx 1 day. 1 day = 8.64×10^4 s $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2} Mark for radius can only be awarded if suitable working is shown
	(b)	(i)	The cube of the planets distance (from the Sun) divided by the square of the (orbital) period is the same (for all planets) (WTTE)	B1	**Allow**: radius for distance., **Allow:** $T^2 \propto r^3$ or r^3 / T^2 = constant provided *T* and *r* are <u>identified</u>
		(ii)	$\text{ratio}^3 = \left(\frac{27.3}{1}\right)^2$ $\text{ratio} = (27.3)^{2/3}$ ratio = 9.1	C1 A1	**Allow:** 1 mark for correct value of distance of Moon from Earth's centre 3.8×10^8(m) **Note**: Full credit for 4×10^7 (m) used from (a)(iv)
			Total	**9**	

Question	Expected Answers	Marks	Additional guidance
5(a)(i)	resultant OR net OR overall force acts (on object) perpendicular to the velocity OR towards the centre of the circle	B1	Ignore any reference to "centripetal force"
(a)(ii)	velocity OR direction is always changing acceleration is in direction of force OR is towards the centre/perp. to velocity	B1 B1	Allow a (resultant) force is acting (hence there is an acceleration))
(b)	centripetal force OR $mv^2/r = GMm/r^2$ OR $v^2/r = GM/r^2$ $v^2 = GM/r \Rightarrow r = GM/ v^2$ $r = 6.67 \times 10^{-11} \times 6 \times 10^{24} / 3700^2$ r = **2.92×10^7** m	C1 C1 C1 A1	
(c)(i)	Any mass ejected in the same direction as the satellite (WTTE)	B1	Idea of rocket motor pushing against direction of motion of satellite.
(c)(ii)	v^2r = constant OR $v^2 = GM/r$ OR $v = \sqrt{\{(6.67\times10^{-11}\times6 \times 10^{24})/2\times10^7\}}$ new $v = \sqrt{(3700^2 \times2.94/2)}$ = **4500** m s^{-1} (4473)	C1 A1	
	Total	**10**	