5	**C is the only correct answer**, as $\Delta E_{grav} = m\Delta V$ and ΔE_{grav} must be negative	1

8	**C is the correct answer**, as $g_{Mars} = \frac{M_{Mars}}{M_{moon}} \times \frac{r_{moon}^2}{r_{Mars}^2} \times g_{moon}$	(1)

Question Number	Answer	Mark
1	**The only correct answer is D (Field strength is inversely proportional to (distance from the centre of each field)^2.)** A is not correct because an electric field only exerts a force on charged particles B is not correct because a gravitational force is always attractive C is not correct because Field strength $\propto 1/x^2$	1

4	**B is the correct answer**, as $\Delta(PE)_{grav} = -\frac{GMm}{r_{final}} - \left(-\frac{GMm}{r_{initial}}\right)$	(1)

10	**A is the only correct answer**, as $g = \frac{GM}{r^2}$	(1)

6	**B is the only correct answer** A is not the correct answer, as gravitational potential increases C is not the correct answer, as gravitational force decreases and gravitational potential increases D is not the correct answer, as gravitational force decreases	(1)

3	**C is the correct answer (both fields can produce repulsive forces)** A is not correct because both fields are radial B is not correct because both fields can exert attractive forces D is not correct because both fields obey an inverse square law for force	1

6	**B is the only correct answer** A is not the correct answer, as speed increases C is not the correct answer, as gravitational potential energy decreases and speed increases D is not the correct answer, as gravitational potential energy decreases	(1)

9	**B is the correct answer (gravitational force between Earth and Moon decreases and gravitational potential energy of Moon increases)** A is not correct because gravitational potential energy (GPE) increases C is not correct because gravitational force decreases and GPE increases D is not correct because gravitational force decreases	1

7	**B is the only correct answer**, as $F = mg$ and $g = (9.81 \text{ m s}^{-2})/4$	(1)

Question Number	Answer		Mark
14(a)	Gravitational force equated to centripetal force	(1)	
	Use of $\omega = \frac{2\pi}{T}$ **Or** Use of $v = \frac{2\pi r}{T}$	(1)	
	$M = 2.0 \times 10^{30}$ (kg)	(1)	3
	Example of calculation $\omega = \frac{2\pi}{365 \times 3.15 \times 10^7 \text{ s}} = 1.99 \times 10^{-7} \text{ rad s}^{-1}$ $m\omega^2 r = \frac{GMm}{r^2}$ $M = \frac{\omega^2 r^3}{G} = \frac{(1.99 \times 10^{-7} \text{ rad s}^{-1})^2 \times (1.49 \times 10^{11} \text{ m})^3}{6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}}$ $\therefore M = 1.96 \times 10^{30}$ kg		

Question Number	Answer		Mark
14(b)	**EITHER**		
	Use of $g = \frac{GM}{r^2}$	(1)	
	Ratio of field strengths = 27.6	(1)	
	Comparison of calculated ratio (of field strengths) with 28 and consistent conclusion (ecf from (a))	(1)	
	OR		
	Use of $g = \frac{GM}{r^2}$	(1)	
	$28 \times g_E = 275 \text{ N kg}^{-1}$	(1)	
	Comparison of calculated field strength values and consistent conclusion (ecf from (a))	(1)	3
	Example of calculation $g_s = \frac{6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2} \times 1.96 \times 10^{30} \text{ kg}}{(1.39 \times 10^9 \text{ m}/2)^2} = 270.7 \text{ N kg}^{-1}$ $\frac{g_s}{g_E} = \frac{271 \text{ N kg}^{-1}}{9.81 \text{ N kg}^{-1}} = 27.6$		
	Total for question 14		**6**

Question Number	Answer		Mark
17(a)	Use of $g = \frac{GM}{r^2}$	(1)	
	$g = 0.40 \text{ N kg}^{-1}$ [allow m s^{-2} for unit] [The correct value is 0.4045 to 4 sig figs, as the value is 0.404459…]	(1)	2
	Example of calculation $g = \frac{6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2} \times 3.1 \times 10^{21} \text{ kg}}{(7.15 \times 10^5 \text{ m})^2} = 0.404 \text{ N kg}^{-1}$		

Question Number	Answer		Mark
17(b)	Equates $F = \frac{GMm}{r^2}$ with $F = m\omega^2 r$	(1)	
	Use of $\omega = \frac{2\pi}{T}$	(1)	
	$T_M = 9.7 \times 10^9$ s	(1)	
	Conversion between seconds and years [Must see a unit for *T*, either in MP3 or MP4]	(1)	
	Calculates ratio of orbital time of Makemake with orbital time of Pluto [Ratio includes a percentage calculation]	(1)	
	Comparison of values **and** consistent conclusion	(1)	
	OR		
	Equates $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$	(1)	
	Use of $v = \frac{2\pi r}{T}$	(1)	
	$T_M = 9.7 \times 10^9$ s	(1)	
	Conversion between seconds and years	(1)	
	Calculates ratio of orbital time of Makemake with orbital time of Pluto [Ratio includes a percentage calculation]	(1)	
	Comparison of values **and** consistent conclusion	(1)	6
	<u>Example of calculation</u> $\frac{GMm}{r^2} = m\omega^2 r$ $\omega = \sqrt{\frac{GM}{r^3}} = \sqrt{\frac{6.67 \times 10^{-1}\ \text{N m}^2\ \text{kg}^{-1} \times 1.99 \times 10^{30}\ \text{kg}}{(6.80 \times 10^{12}\ \text{m})^3}}$ $\therefore \omega = 6.50 \times 10^{-10}\ \text{rad}\ s^{-1}$ $T = \frac{2\pi}{\omega} = \frac{2\pi\ \text{rad}}{6.50 \times 10^{-1}\ \text{rad s}^{-1}} = 9.67 \times 10^9\ \text{s} = \frac{9.67 \times 10^9\ \text{s}}{3.15 \times 10^7\ \text{s year}^{-1}}$ $= 307$ year orbital time ratio $= \frac{307\ \text{year}}{248\ \text{year}} = 1.24$ The orbital time of Makemake is 24% greater than that of Pluto, so website statement is not quite accurate		
	Total for question 17		**8**

Question Number	Answer		Mark
18(a)	Use of $V = \frac{4}{3}\pi r^3$	(1)	
	Use of $\rho = \frac{m}{V}$	(1)	
	Use of $F = \frac{Gm_1m_2}{r^2}$	(1)	
	$F = 7.4 \times 10^5$ N	(1)	4
	<u>Example of calculation</u> $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{5.65\ \text{m}}{2}\right)^3 = 94.437\ \text{m}^3$ $m = \rho V = 1950\ \text{kg m}^{-3} \times 94.437\ \text{m}^3 = 1.842 \times 10^5\ \text{kg}$ $F = \frac{Gm_1m_2}{r^2}$ $= \frac{6.67 \times 10^{-1}\ \text{N m}^2\ \text{kg}^{-3} \times 5.98 \times 10^{24}\ \text{kg} \times 1.842 \times 10^5\ \text{kg}}{(6.38 \times 10^6\ \text{m} + 3.59 \times 10^6\ \text{m})^2}$ $\therefore F = 7.39 \times 10^5$ N		

18(b)	Use of $V_{grav} = (-)\frac{GM}{r}$ Use of $E_{grav} = m \times V_{grav}$ $\therefore \Delta E_{grav} = (-)\ 4.1 \times 10^{12}$ J (Allow ecf for mass from (a)) [Either mass can be used for M in the potential equation, but to award MP2 the multiplier m. must not be the mass used in the potential equation.] <u>Example of calculation</u> $\Delta E_{grav} = -6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 1.842 \times 10^5\ \text{kg} \times 5.98 \times 10^{24}\ \text{kg} \times \left(\frac{1}{6.38 \times 10^6\ \text{m}} - \frac{1}{(6.38 \times 10^6 + 3.59 \times 10^6)\ \text{m}}\right)$ $\therefore \Delta E_{grav} = -4.14 \times 10^{12}$ J [Note the following values, but different degrees of rounding may change these slightly: $V_{final} = (-)\ 6.252 \times 10^7\ \text{J kg}^{-1}$ $V_{initiall} = (-)\ 4.001 \times 10^7\ \text{J kg}^{-1}$ $E_{final} = (-)1.152 \times 10^{13}$ J $E_{initial} = (-)\ 7.296 \times 10^{12}$ J]	(1) (1) (1)	3
18(c)	Work would be done on the asteroid by frictional forces **Or** Drag/friction causes heating (of the asteroid) Asteroid burns up	(1) (1)	2