Name: ____

Edexcel_Gravity_Old

Mark Scheme

Date:

Time:

Total marks available:

Total marks achieved: ______

Mark Scheme

Q1.

Question Number	Answer	Mark
	A	**1**

Q2.

Question Number	Answer	Mark
	B	**1**

Q3.

Question Number	Answer	Mark
	B	**1**

Q4.

Question Number	Answer	Mark
	B	**(1)**

Q5.

Question Number	Answer	Mark
	D Electric fields: $F_E = \frac{kQq}{r^2}$, $E = \frac{kQ}{r^2}$. **Gravitational fields:** $F_G = \frac{GMm}{r^2}$, $g = \frac{GM}{r^2}$	**1**
	Incorrect Answers: (all due to incorrect variables selected from information given) A – field strength is inversely proportional to distance squared B – electric fields can have a zero field strength anywhere C – Gravitational forces can only be attractive	

Q6.

Question Number	Answer	Mark
	A	1

Q7.

Question Number	Answer	Mark
	C	**1**

Q8.

Question Number	Answer	Mark
	C	**1**

Q9.

Question Number	Answer		Mark
	Use of $F = \frac{Gm_1 m_2}{r^2}$ $F = 8.2 \times 10^{16}$ N <u>Example of calculation:</u> $F = \frac{Gm_1 m_2}{r^2} = \frac{6.67 \times 10^{-11}\ \mathrm{N\,m^2\,kg^{-2}} \times 6.4 \times 10^{23}\ \mathrm{kg} \times 6.0 \times 10^{24}\ \mathrm{kg}}{(5.6 \times 10^{10}\ \mathrm{m})^2}$ $F = 8.17 \times 10^{16}$ N	(1) (1)	2
			2

Q10.

Question Number	Answer		Mark
(a)	See $F = mg$ and $F = (-)GmM/r^2$ Equate and cancel m on either side	(1) (1)	**2**
(b)	Substitute into $g = GM/r^2$ to obtain $g = 9.78\ \text{N kg}^{-1}$ [condone m s^{-2}] <u>Example of calculation</u> $g = \frac{GM}{r^2} = \frac{6.67\times10^{-11}\ \text{N m}^2\ \text{kg}^{-2}\times5.97\times10^{24}\ \text{kg}}{(6.38\times10^6\ \text{m})^2} = 9.783\ \text{N kg}^{-1}$	(1)	**1**
	Total for question		**3**

Q11.

Question Number	Answer		Mark
	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**

Q12.

Question Number	Answer		Mark
	Use of $T = \frac{2\pi}{\omega}$	(1)	
	Use of $F = \frac{GMm}{r^2}$	(1)	
	Use of $F = mr\omega^2$	(1)	
	$h = 3.59 \times 10^7$ m	(1)	
	Or		
	Use of $T = \frac{2\pi r}{v}$	(1)	
	Use of $F = \frac{GMm}{r^2}$	(1)	
	Use of $F = \frac{mv^2}{r}$	(1)	
	$h = 3.59 \times 10^7$ m	(1)	4
	<u>Example of calculation</u> $\omega = \frac{2\pi\,\text{rad}}{24 \times 3600\text{ s}} = 7.27 \times 10^{-5}\text{ rad s}^{-1}$ $mr\omega^2 = \frac{GMm}{r^2} \quad \therefore \omega^2 = \frac{GM}{r^3}$ $r = \sqrt[3]{\frac{6.67 \times 10^{-11}\text{ Nm}^2\text{kg}^{-2} \times 5.98 \times 10^{24}\text{ kg}}{(7.27 \times 10^{-5}\text{ rad s}^{-1})^2}} = 4.226 \times 10^7\text{ m}$ $h = 4.226 \times 10^7\text{ m} - 6.36 \times 10^6\text{ m} = 3.59 \times 10^7\text{ m}$		

Q13.

Question Number	Answer		Mark
(a)	Use of $g = \frac{GM}{r^2}$	(1)	
	$M = 4.5 \times 10^{23}$ kg	(1)	
	<u>Example of calculation</u> $M = \frac{gr^2}{G} = \frac{9.81\text{ N kg}^{-1} \times (1.74 \times 10^6\text{ m})^2}{6.67 \times 10^{-11}\text{ N m}^2\text{ kg}^{-2}} = 4.45 \times 10^{23}\text{ kg}$		2

Question Number	Answer		Mark
(b)	(the gravitational force on the Moon would be larger), but the centripetal acceleration would be independent of the mass of the Moon		
	Or		
	$r\omega^2 = \frac{GM}{r^2} \quad \therefore \omega^2 = \frac{GM}{r^3}$	(1)	
	(angular) velocity and hence T is independent of mass of Moon	(1)	2

Question Number	Answer	Mark
(c)	Gravitational forces on the seas/oceans/Earth would be greater (1) **Or** Tidal variations would be more extreme [accept tides would be bigger, higher, larger, faster; do **not** accept tides would be stronger]	1

Q14.

Question Number	Answer	Mark
*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Gravitational fields are regions in which a mass experiences a force due to its mass (1) Electric fields are regions in which a charge experiences a force due to its charge (1) Both types of field have an infinite range (1) In each type of field the force varies as an inverse square (1) The force between masses is always attractive whereas the force between charges can be attractive or repulsive **Or** electric fields can cancel or reinforce but gravitational fields always reinforce one another (1) The force between (unit) charges at a given separation is much stronger than the force between (unit) masses at the same separation (1)	6
	Total for question	**6**

Q15.

Question Number	Answer		Mark
(a)(i)	Use of $\omega = \frac{2\pi}{T}$	(1)	
	See $F = \frac{GMm}{r^2}$ and $F = m\omega^2 r$	(1)	
	$GM = 4.07 \times 10^{14}$ (m^3 s^{-2})	(1)	
	Or		
	Use of $v = \frac{2\pi r}{T}$	(1)	
	See $F = \frac{GMm}{r^2}$ and $F = \frac{mv^2}{r}$	(1)	
	$GM = 4.07 \times 10^{14}$ (m^3 s^{-2})	(1)	3
	[If reverse "show that" attempted, max 2]		
	Example of calculation: $\omega = \frac{2\pi}{T} = \frac{2\pi \text{ rad}}{2.36 \times 10^6 \text{ s}} = 2.66 \times 10^{-6} \text{ rad s}^{-1}$ $\frac{GMm}{r^2} = m\omega^2 r$ $GM = \omega^2 r^3 = (2.66 \times 10^{-6} \text{ s}^{-1})^2 \times (3.86 \times 10^8 \text{ m})^3 = 4.07 \times 10^{14} \text{ m}^3 \text{ s}^{-2}$		
(a)(ii)	Use of $g = \frac{GM}{R^2}$ 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
	Example of calculation: $R = \sqrt{\frac{GM}{g}} = \sqrt{\frac{4.07 \times 10^{14} \text{ m}^3 \text{ s}^{-2}}{9.81 \text{ N kg}^{-1}}} = 6.44 \times 10^6 \text{ m}$		

(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)	2
	[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]		
	Total for Question		7

Q16.

Question Number	Answer		Mark
(a)(i)	See $F = GMm/r^2$ Equated to mg to give required expression **Or** use of g = F/m	(1) (1)	**2**
(a)(ii)	Use of $g = \omega^2 r$ OR $g = v^2/r$ Use of $\omega = 2\pi/T$ OR $v = 2\pi r/T$ Correct algebra leading to expression given <u>Example of calculation:</u> $\omega^2 r = \frac{GM}{r^2}$ $\left(\frac{2\pi}{T}\right)^2 = \frac{GM}{r^3}$ $r^3 = \frac{GMT^2}{4\pi^2}$	(1) (1) (1)	**3**
(a)(iii)	See T = 24 hours T converted into s $r = 4.2 \times 10^7$ m <u>Example of calculation:</u> $T = 24 \times 60 \times 60$ s = 86 400 s $r^3 = \frac{GMT^2}{4\pi^2} = \frac{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 6.0 \times 10^{24}\ \text{kg} \times (86400\ \text{s})^2}{4\pi^2} = 7.57 \times 10^{22}\ \text{m}^3$ $r = \sqrt[3]{7.57 \times 10^{22}\ \text{m}^3} = 4.23 \times 10^7\ \text{m}$	(1) (1) (1)	**3**
(b)	The satellite must rotate with the Earth **Or** the satellite must be in a geosynchronous orbit **Or** any non-equatorial orbit would cause the satellite to move N-S		**1**
	Total for question		**9**

Q17.

Question Number	Answer	Mark
(a)(i)	Use of $\omega = 2\pi/T$ (1) $\omega = 2.66 \times 10^{-6}$ (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
(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) $r = 3.92 \times 10^8$ m (1) If show that value is used, $r = 3.62 \times 10^8$ m Example of calculation $\frac{GMm}{r^2} = m\omega^2 r$ $r^3 = \frac{GM}{\omega^2}$ $\therefore r = \sqrt[3]{\frac{6.67 \times 10^{-11}\,\text{Nm}^2\text{kg}^{-2} \times 6.4 \times 10^{24}\,\text{kg}}{(2.66 \times 10^{-6}\,\text{s}^{-1})^2}} = 3.92 \times 10^8$ m	4

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

Q18.

Question Number	Answer		Mark
(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
(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
(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
(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
(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

Q19.

Question Number	Answer		Mark
(a)(i)	Gravitation OR gravity OR gravitational attraction / pull / force	(1)	1
(a)(ii)	Use of $F=Gm_1m_2/r^2$ F = 4.2 × 10^{35} (N) (no u.e.) Example of calculation $F = \frac{Gm_1m_2}{r^2}$ $F = \frac{6.67\times10^{-11}\text{ N m}^2\text{kg}^{-2}\ (1.6\times10^{39}\text{kg})(4.0\times10^{37}\text{kg})}{(3.2\times10^{18}\text{ m})^2}$ $F = 4.17\times10^{35}$ N	(1) (1)	2
(a)(iii)	Use of $F = m\omega^2 r$ or $F = mv^2/r$ Use of $T=2\pi/\omega$ or $T=2\pi r/v$ T = 108 (years) [accept 107 – 111 years] (no ue) [If r^3 appears in solution, max 1 mark out of 3. If $\omega = \sqrt{\frac{G(M+m)}{(R+r)^3}}$ used, then full credit may be given. This method leads to T = 109 years] Example of calculation $\omega = \sqrt{\frac{4.2\times10^{35}\text{ N}}{(1.6\times10^{39}\text{ kg})\times7.7\times10^{18}\text{ m}}}$ $\omega = 1.85\times10^{-9}$ rad s^{-1} $T = \frac{2\pi\text{ rad}}{1.85\times10^{-9}\text{ rad s}^{-1}} = 3.40\times10^9$ s $T = \frac{3.40\times10^9\text{ s}}{365\times24\times60\times60\text{ s year}^{-1}} = 108$ years	(1) (1) (1)	3
* (b)(i)	(QWC- Work must be clear and organised in a logical manner using technical wording where appropriate.) Radiation (is received) with a longer/stretched wavelength (compared to that emitted) OR lower/smaller frequency This indicates that distant galaxies are receding / distance between galaxies is increasing/galaxies are moving apart (Hence) the universe is expanding / provides evidence for Big Bang	(1) (1) (1)	3
(b)(ii)	The rotational motion (of the black holes) is small compared with that due to the overall recession (So) both black holes are still moving away OR (hence) the overall effect when the black hole is approaching is to cause a small reduction in the observed red (rather than a blue) shift ALTERNATIVE APPROACH: Reference to plane of orbit being perpendicular to line of sight from the Earth Therefore there is no change in wavelength due to rotation of black holes	(1) (1) (1) (1)	2
(b)(iii)	Use of $z = v/c$ Use of $v = H_0 d$ $d = 7.1\times10^{25}$ m Example of calculation $v = Zc = 0.38\times3\times10^8\text{ m s}^{-1} = 1.14\times10^8\text{ m s}^{-1}$ $d = \frac{1.14\times10^8\text{ m s}^{-1}}{1.6\times10^{-18}\text{ s}^{-1}} = 7.13\times10^{25}$ m	(1) (1) (1)	3
	Total for question		14

Q20.

Question Number	Answer	Mark
(a)(i)	Calculation of time period (1) Use of $v = \frac{\Delta s}{\Delta t}$ or $\omega = \frac{2\pi}{T}$ (1) Use of $a = \frac{v^2}{r}$ or $a = r\omega^2$ (1) Correct answer (1) **Example of calculation:** $T = \frac{24 \times 60 \times 60\, s}{15} = 5760\, s$ $v = \frac{2\pi r}{T} = \frac{2\pi \times 6.94 \times 10^6\, m}{5760\, s} = 7.57 \times 10^3\, ms^{-1}$ $a = \frac{v^2}{r} = \frac{(7.6 \times 10^3\, ms^{-1})^2}{6.94 \times 10^6\, m} = 8.26\, ms^{-2}$ OR $\omega = \frac{2\pi}{T} = \frac{2\pi}{5760\, s} = 1.09 \times 10^{-3}\, ms^{-1}$ $a = r\omega^2 = 6.94 \times 10^6 \times (1.09 \times 10^{-3})^2 = 8.26\, ms^{-2}$	**(4)**

Question Number	Answer	Mark
(a)(ii)	mg equated to gravitational force expression (1) g (= a) = 8.3 ms^{-2} substituted (1) Correct answer (1) **Example of calculation:** $mg = \frac{GMm}{r^2}$ $\therefore 8.3\, ms^{-2} = \frac{6.67 \times 10^{-11}\, N\, m^2\, kg^{-2} M}{(6.94 \times 10^6\, m)^2}$ $\therefore M = \frac{8.3\, ms^{-1} \times (6.94 \times 10^6\, m)^2}{6.67 \times 10^{-11}\, Nm^2 kg^{-2}} = 6.0 \times 10^{24}\, kg$	**(3)**
(b)	The observed wavelength is longer than the actual wavelength / the wavelength is stretched out (1) One from: The universe is expanding (1) (All distant) <u>galaxies</u> are moving apart (1) The (recessional) velocity of <u>galaxies</u> is proportional to distance (1) The furthest out <u>galaxies</u> move fastest (1)	**(max 2)**

(c)(i)	A light year is the distance travelled (in a vacuum) in 1 year by light / em-radiation (1) The idea that light has only been able to travel to us for a time equal to the age of the universe. (1)	**(2)**
(c)(ii)	(Use of v = H_o d to show) $H_o = \frac{1}{t}$ (1) Correct answer (1) **Example of calculation:** $H_o = \frac{1}{t} = \frac{1}{12 \times 3.15 \times 10^{16}\, s} = 2.65 \times 10^{-18}\, s^{-1}$	**(2)**
(c)(iii) **QWC**	The answer must be clear and be organised in a logical sequence There is considerable uncertainty in the value of the Hubble constant (1) Any sensible reason for uncertainty (1) Idea that a guess implies a value obtained with little supporting evidence OR the errors are so large that our value is little better than a guess (1)	**(3)**
	Total for question	**(16)**