Selected Questions – Set 4 - Answers

1.

a	i	elastic potential energy **and** gravitational potential energy ✓	1	For elastic pe allow "pe due to tension", or "strain energy" etc
a	ii	elastic pe → kinetic energy → gravitational pe → kinetic energy → elastic pe ✓✓ [**or** pe→ke→pe→ke→pe is ✓ only] [**or** elastic pe → kinetic energy → gravitational pe is ✓ only]	2	If kinetic energy is not mentioned, no marks. Types of potential energy must be identified for full credit.
b	i	period = 0.80 s ✓ during one oscillation there are two energy transfer cycles (or elastic pe→ke→gravitational pe→ke→elastic pe in 1 cycle) **or** there are two potential energy maxima per complete oscillation ✓	2	Mark sequentially.
b	ii	sinusoidal curve of period 0.80 s ✓ – cosine curve starting at $t = 0$ continuing to $t = 1.2$s ✓	2	For 1st mark allow ECF from T value given in 3(b)(i).
c	i	use of $T = 2\pi\sqrt{\frac{m}{k}}$ gives $0.80 = 2\pi\sqrt{\frac{0.35}{k}}$ ✓ $\therefore\ k \left(= \frac{4\pi^2 \times 0.35}{0.80^2} \right) = 22\ (21.6)$ ✓ N m^{-1} ✓	3	Unit mark is independent: insist on N m^{-1}. Allow ECF from wrong T value from (b)(i): use of 0.40s gives 86.4 (N m^{-1}).

c	ii	maximum ke = (½ mv_{max}^2) = 2.0 × 10^{-2} gives $v_{max}^2 = \frac{2.0\times10^{-2}}{0.5\times0.35}$ ✓ (= 0.114 m^2s^{-2}) and v_{max} = 0.338 (m s^{-1}) ✓ $v_{max} = 2\pi fA$ gives $A = \frac{0.338}{2\pi\times1.25}$ ✓ and A = 4.3(0) × 10^{-2} m ✓ i.e. about 40 mm [or maximum ke = (½ mv_{max}^2) = ½ m $(2\pi fA)^2$ ✓ ½ × 0.35 × $4\pi^2$ × 1.25^2 × A^2 = 2.0 × 10^{-2} ✓	4	First two schemes include recognition that $f = 1/T$ i.e. f = 1/0.80 = 1.25 (Hz). Allow ECF from wrong T value from (b)(i) – 0.40s gives A = 2.15 × 10^{-2}m but mark to max 3. Allow ECF from wrong k value from (c)(i) –

2.

Question	Answers	Additional Comments/Guidance	Mark
(a)(i)	$\omega\left(=\frac{v}{r}\right)=\frac{8.6}{1.5}$ (= 5.73 rad s^{-1}) ✓ $\theta(=\omega t)$ = 5.73 × 0.40 = 2.3 (2.29) (rad) ✓ $= \frac{2.29}{2\pi}\times 360$ = 130 (131) (degrees) ✓ [**or** $s((=vt)$ = 8.6 × 0.40 (= 3.44 m) ✓ $\theta = \frac{3.44}{2\pi\times1.5}\times360$ ✓ = 130 (131) (degrees) ✓]	Award full marks for any solution which arrives at the correct answer by valid physics.	3
(a)(ii)	tension $F(=m\omega^2 r)$ = 0.25 × 5.73^2 × 1.5 ✓ = 12(.3) (N) ✓ [**or** $F\left(=\frac{mv^2}{r}\right)=\frac{0.25\times8.6^2}{1.5}$ ✓ = 12(.3) (N) ✓]	Estimate because rope is not horizontal.	2
(b)	maximum $\omega\left(=\sqrt{\frac{F}{mr}}\right)=\sqrt{\frac{60}{0.25\times1.5}}$ (= 12.6) (rad s^{-1}) ✓ maximum $f\left(=\frac{\omega}{2\pi}\right)=\frac{12.6}{2\pi}$ = 2.01 (rev s^{-1}) ✓ [**or** maximum $v=\sqrt{\frac{Fr}{m}}=\sqrt{\frac{60\times1.5}{0.25}}$ (= 19.0) (m s^{-1}) ✓ maximum $f\left(=\frac{v}{2\pi r}\right)=\frac{19.0}{2\pi\times1.5}$ = 2.01 (rev s^{-1}) ✓]	Allow 2 (rev s^{-1}) for 2^{nd} mark. Ignore any units given in final answer.	2

(c)	**The student's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The student's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. *The student appreciates that the velocity of the ball is not constant and that this implies that it is accelerating. There is a comprehensive and logical account of how Newton's laws apply to the ball's circular motion: how the first law indicates that an inward force must be acting, the second law shows that this force must cause an acceleration towards the centre and (if referred to) the third law shows that an equal outward force must act on the point of support at the centre. The student also understands that the rope is not horizontal and states that the weight of the ball is supported by the vertical component of the tension.* **Intermediate Level (Modest to adequate): 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. *The student appreciates that the velocity of the ball is not constant. The answer indicates how at least one of Newton's laws applies to the circular motion. The student's understanding of how the weight of the ball is supported is more superficial, the student possibly failing to appreciate that the rope would not be horizontal and omitting any reference to components of the tension.*	A **high level** answer must give a reasonable explanation of the application of at least two of Newton's laws, and an appreciation of why the rope will not be horizontal. An **intermediate level** answer must show a reasonable understanding of how at least one of Newton's laws applies to the swinging ball. A **low level** answer must show familiarity with at least one of Newton's laws, but may not show good understanding of how it applies to this situation. References to the effects of air resistance, and/or the need to keep supplying energy to the system would increase the value of an answer.	max 6

(c)	**Low Level (Poor to limited): 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. *The student has a much weaker knowledge of how Newton's laws apply, but shows some understanding of at least one of them in this situation. The answer coveys little understanding of how the ball is supported vertically.* **The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.** • *First law*: ball does not travel in a straight line, so a force must be acting on it • although ball has constant speed its velocity is not constant because its direction changes constantly • because its velocity is changing it is accelerating • *Second law*: the force on the ball causes the ball to accelerate (or changes the momentum of it) in the direction of the force • the acceleration (or change in momentum) is in the same direction as the force • the force is centripetal: it acts towards the centre of the circle • *Third law*: the ball must pull on the central point of support with a force that is equal and opposite to the force pulling on the ball from the centre • the force acting on the point of support acts outwards • *Support of ball*: the ball is supported because the rope is not horizontal • there is equilibrium (or no resultant force) in the vertical direction • the weight of the ball, mg, is supported by the vertical component of the tension, $F \cos \theta$, where θ is the angle between the rope and the vertical and F is the tension • the horizontal component of the tension, $F \sin \theta$, provides the centripetal force $m \omega^2 r$ **Credit may be given for any of these points which are described by reference to an appropriate labelled diagram.**	A reference to Newton's 3rd law is not essential in an answer considered to be a high level response. 6 marks may be awarded when there is no reference to the 3rd law.	max 6

3.

Question			Answer	Marks	Guidance
	(a)	(i)	$F = \frac{GM_1M_2}{(R_1+R_2)^2}$	B1	Ignore sign
		(ii)	$F_1 = \frac{4\pi^2 M_1 R_1}{T^2}$	B1	Allow $F_1 = \left(\frac{2\pi}{T}\right)^2 M_1R_1$
	(b)		Centripetal forces on both star are same magnitude / $F_1 = F_2$ / answer to a(ii) equated to similar expression for $\mathbf{S}_2$ Correct working starting from <u>correct</u> a(ii) forces $\frac{M_1}{M_2} = \frac{R_2}{R_1}$	M1 A1 A0	Eg $\frac{4\pi^2 M_1R_1}{T^2} = \frac{4\pi^2 M_2R_2}{T^2}$
	(c)		$\frac{R_2}{R_1} = 3 \quad \therefore \quad R_2 = 3R_1 \quad and \quad R_1 + R_2 = 4.8\times10^{12}$ $R_1 = \frac{1}{4}\times 4.8\times10^{12} = 1.2\times10^{12}$ (m) $R_2 = \frac{3}{4}\times 4.8\times10^{12} = 3.6\times10^{12}$ (m)	C1 A1 A1	Allow 2 marks if $R_1 = 3.6 \times 10^{12}$ (m) And $R_2 = 1.2 \times 10^{12}$ (m)
	(d)		$v_1 = \frac{2\pi R_1}{T} = \frac{2\pi\times1.2\times10^{12}}{4\times3.16\times10^7}$ $v_1 = 6.0\times10^4 \; (\text{m s}^{-1})$	C1 A1	Possible ECF Mark is for substitution Max 1 mark if T is not converted to seconds (leads to speed = 1.9×10^{12})

Question			Answer	Marks	Guidance
	(e)		$\frac{M_1 v_1^2}{R_1} = \left(\frac{4\pi^2 R_1 M_1}{T^2}\right) = \frac{GM_1 M_2}{(R_1 + R_2)^2}$ $M_2 = \frac{(6.0\times10^4)^2 \times (4.8\times10^{12})^2}{6.67\times10^{-11}\times1.2\times10^{12}}$ $M_2 = 1.0\times10^{33}$ (kg)	C1 C1 A1	**Allow ECF** from (c) and (d) **only** if method is correct **Allow** this C1 mark if M_1 has been cancelled **Special case** Use of $T^2 \propto R^3$ will lead to 1.73 x 10^{33} (kg) this scores 1 mark. Do not allow any ECF if this method is used.

4.

(a)	(i)	relationship between them is $E_p = mV$ (allow $\Delta E_p = m\Delta V$) [or V is energy per unit mass (or per kg)] ✓	**1**
(a)	(ii)	value of E_p is doubled ✓ value of V is unchanged ✓	**2**
(b)	(i)	use of $V = -\frac{GM}{r}$ gives $r_A = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{12.0 \times 10^6}$ ✓ $= 3.3(2) \times 10^7$ (m) ✓	**2**
(b)	(ii)	since $V \propto (-)\frac{1}{r}$ $\left(or \frac{r_A}{r_B} = \frac{V_B}{V_A} = \frac{36.0}{12.0} = 3\right)$ $r_B = \frac{3.32 \times 10^7 m}{3}$ ✓ (which is ≈ 1.1×10^4 km)	**1**
(b)	(iii)	centripetal acceleration $g_B = \frac{GM}{{r_B}^2} = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(1.11 \times 10^7)^2}$ ✓ [allow use of 1.1×10^7 m from (b)(ii)] $= 3.2$ (m s^{-2}) ✓ [**alternatively**, since $g_B = (-)\frac{V_B}{V_a}$, $g_B = \frac{36.0 \times 10^6}{1.11 \times 10^7}$ ✓ $= 3.2$ (m s^{-2}) ✓]	**2**
(b)	(iv)	use of $\Delta E_p = m\Delta V$ gives $\Delta E_p = 330 \times (-12.0 - (-36.0)) \times 10^6$ ✓ (which is 7.9×10^9 J or ≈ 8 GJ)	**1**
(c)		g is not constant over the distance involved (**or** g decreases as height increases **or** work done per metre decreases as height increases **or** field is radial and/or not uniform) ✓	**1**

5.

	Answer	Marks	Guidance
(a)	The resultant force is zero There is no acceleration	B1 B1	**Not** 'in equilibrium' **Not**: constant velocity; since this is in the question
(b)	(moment of a force =) force × <u>perpendicular</u> distance from point / pivot	B1	**Must use ticks on Scoris to show where the marks are awarded** ✎ '***perpendicular'*** must be spelled correctly to gain the mark.
(c)	Forces are in the same direction / The forces are not opposite / The forces are not equal (in magnitude)	B1	
(d)	(clockwise moments =) (720 × 0.40) + (180 × 0.60) or 396 (N m) sum of clockwise moments = sum of anticlockwise moments 396 = 1.3 *F* *F* = 300 (N)	C1 C1 A1	 **Allow**: 2 marks for '720 × 0.40 = 1.3 × *F*, *F* = 221 (N)' or 180 × 0.60 = 1.3 × *F*, *F* = 83 (N)' **Note**: Answer is 305 (N) to 3 sf and 304.6 (N) to 4 sf
(e)	The force at **X** decreases The force at **Y** increases / greater clockwise moment / $F_X + F_Y = 900$ (N)	B1 B1	 **Allow**: the rider's centre of gravity / mass moves further from **X**