WJEC EDUQAS A-LEVEL PHYSICS · COMPONENT 1

PHYSICS



EXAM QUESTION PACK

1.5 CIRCULAR MOTION

SCORE	PERCENTAGE
/90	%

STEMUP

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#1

2. *(a)* (i) Define the angular velocity, ω, for a body moving in a circle. [1]

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(ii) Two equations giving the acceleration of a body moving at constant speed in a circle are:

$$a = \frac{v^2}{r} \quad \text{and} \quad a = r\omega^2.$$

Show clearly that the equations are equivalent. [2]

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(b) A moon called *Deimos* orbits Mars in a circular path of radius 23 500 km. Astronomers have calculated the mass of Deimos to be 1.48×10^{15} kg, and the force exerted on it by Mars to be 1.15×10^{14} N.

(i) Calculate the speed of Deimos around Mars. [2]

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(ii) Explain whether or not a moon of twice the mass of Deimos, but in a circular orbit of the same radius about Mars, would have the same speed as Deimos. [2]

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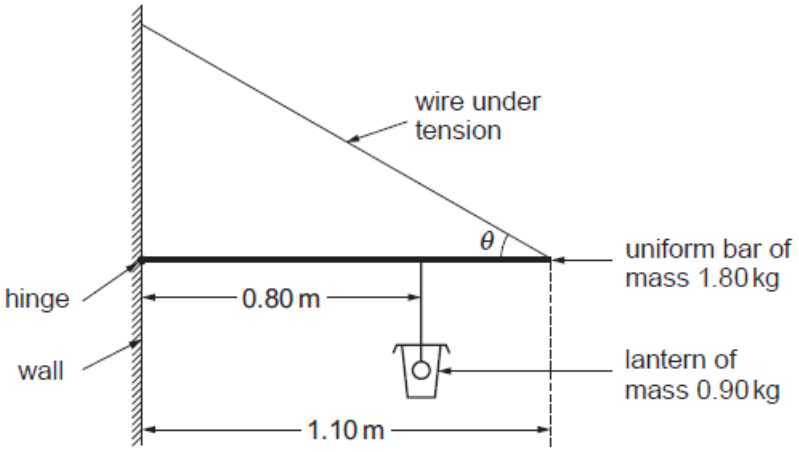
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Question taken from Eduqas examination paper 842101, June 2018

#2

A lantern is suspended from a hinged horizontal metal bar, as shown in the diagram.



(a) (i) Calculate the sum of the clockwise moments about the hinge of the forces acting on the bar. [3]

(ii) For an angle, θ, of 35°, calculate the tension in the wire. [2]

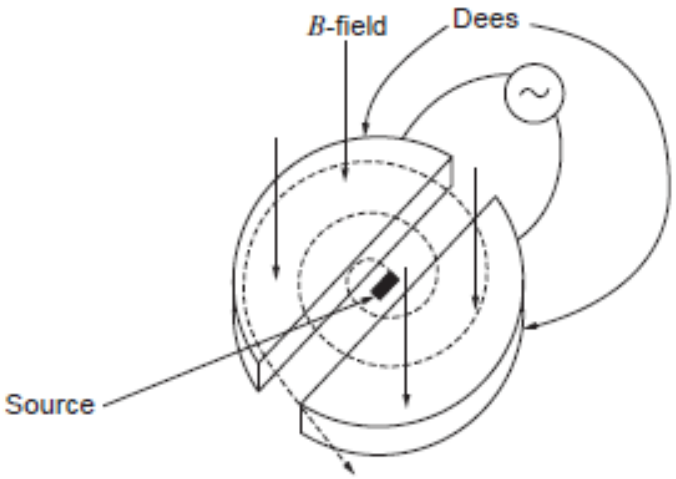
(iii) Discuss the effect, if any, on the tension of making the angle θ smaller (by using a shorter wire and attaching it to a lower point on the wall). [2]

(b) A physics student, Sundeep, calculates that if the wire breaks, then, 0.10 s after it breaks, the angular velocity of the bar about the hinge would be 1.3 rad s^{-1}. Calculate the speed of the tip of the bar (right hand end) when it has this angular velocity. [1]

Question taken from Eduqas examination paper 842101, June 2017

#3

9. A cyclotron is shown and it is used to accelerate helium-4 nuclei from rest. After completing 12 cycles of the cyclotron, a helium nucleus has a kinetic energy of 4.32 MeV.



(a) Calculate the final velocity of a helium-4 nucleus (the mass of a helium-4 nucleus is 4u). [3]

(b) Calculate the pd between the dees. [3]

(c) The uniform magnetic flux density is 0.47 T. Calculate the frequency of the alternating pd applied to the dees. [3]

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Question taken from Eduqas examination paper 842103, June 2018

#4

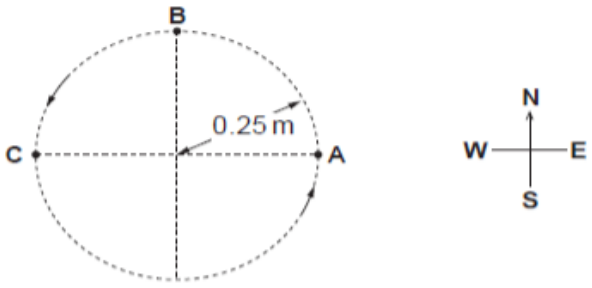
(a) State what is meant by a body's *mean acceleration* over a period of time. [1]

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(b) Protons are 'stored' by being made to go round and round a circular path of radius 0.25 m at constant speed. They perform 5.2×10^6 revolutions per second.



(i) Show clearly that the protons' speed is approximately $8 \times 10^6 \text{ m s}^{-1}$. [2]

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(ii) Determine the magnitude and direction of a proton's acceleration at point **B**. [3]

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(iii) Calculate a proton's mean acceleration over the semicircle **ABC**. [3]

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(c) Two students discuss the mean force on a proton over one revolution **ABCA**. Adam says that the mean force is the same as the force at B, because the force is the same all the way round. Brian says that the mean force is zero. Evaluate these opinions. [2]

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Question taken from Eduqas examination paper 842101, November 2020

#5

(a) The magnitude of the acceleration of a body travelling at speed v in a circle of radius r is given by:

$$a = \frac{v^2}{r}$$

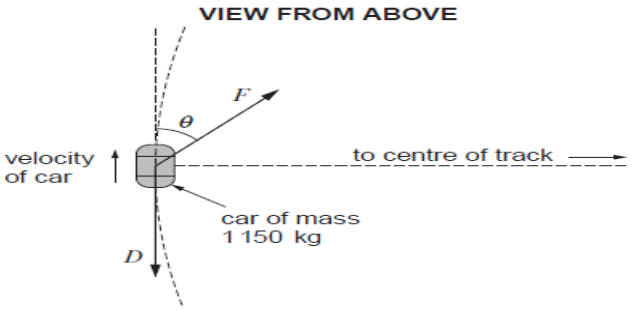
(i) Show clearly that this equation is homogeneous in terms of units. [2]

(ii) A teacher claims that the equation gives a 'sensible' value for the centripetal acceleration as r becomes extremely large. Justify her claim. [2]

(b) A car of mass 1 150 kg moving at constant speed takes 52 s to complete a lap of a flat circular track of radius 200 m.

(i) Show that the magnitude of the centripetal force on the car is approximately 3400 N. [3]

(ii) The diagram shows the car at one point on its journey (clockwise) around the track. D is the force of air resistance on the car, and F is the horizontal component of the force on the car's tyres from the road. F = 5500 N.



I. Calculate the angle, θ, at which F must act in order to provide the centripetal force calculated in *(b)*(i). [2]

II. Calculate D, giving your reasoning. [3]

Question taken from Eduqas examination paper 842101, June 2017

#6

4. *(a)* A fairground ride rotates at a rate of 8.20 revolutions per **minute**.

(i) Calculate:

I. the angular velocity in radians per second; [2]

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II. the time taken to travel an arc of length 10.0 m for a point P on the ride at 3.80 m from the central axis around which the ride is rotating; [2]

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III. the acceleration of point P. [2]

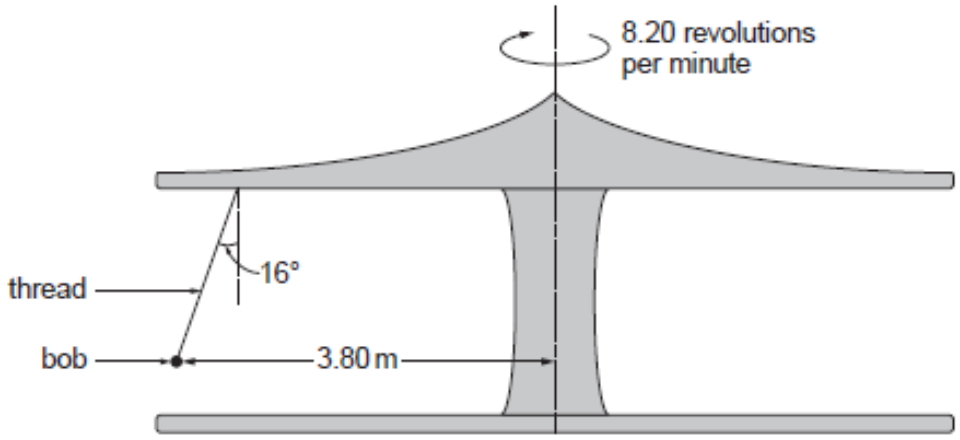
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(ii) Annushka has been given permission to tie a simple pendulum from the ceiling of the rotating ride. She finds that, when the pendulum has stabilised, it hangs at 16° to the vertical, with its bob at 3.80 m from the central axis (see diagram).



I. The mass of the bob is 0.270 kg. By considering the **vertical** force components on the bob, calculate the tension in the thread. [2]

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II. State what provides the centripetal force on the bob and show clearly whether or not this is consistent with the acceleration calculated in *(a)*(i)III. [3]

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(b) Discuss **one** way in which our knowledge of the magnitude of centripetal force has been applied in the design of roads or railways or a domestic appliance. [3]

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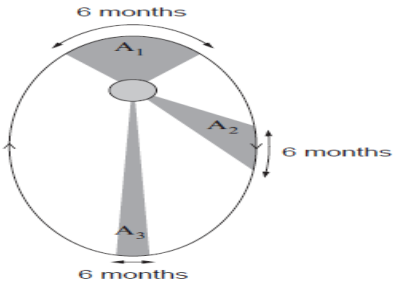
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Question taken from Eduqas examination paper 842101, June 2019

#7

Johannes Kepler devoted much of his life to the study of planetary motion. In the process he discovered three laws which describe the motion of any orbital body.

(a) The diagram is taken from a physics text book. Describe how it is used to explain Kepler's 2nd law. [3]

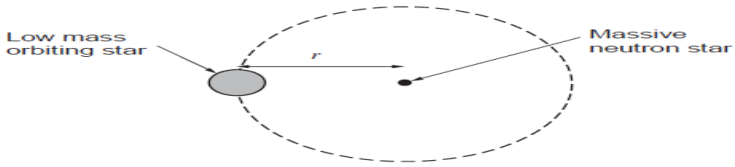


(b) Use a formula for centripetal acceleration and Newton's law of gravitation to show that, for a planet in circular orbit of radius, r, around a star of mass, M:

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

where T is the period of the planet's orbit. [3]

(c) A binary star system consists of a star of low mass orbiting a far more massive neutron star in a circular orbit of radius, r.



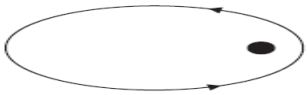
(i) When analysing light from the low mass star, a hydrogen line at $\lambda = 486.140\,\text{nm}$ has a maximum Doppler shift of 0.052 nm. Further experimental measurements show that the orbital period is 1.45 years. Show that the radius of the low mass star's orbit is approximately 2.3×10^{11} m. [4]

(ii) Astronomers believe that the mass of the neutron star is 1.8 times the mass of the Sun. Determine whether or not this is correct, stating any assumption you make.
[Mass of Sun = 2.0×10^{30} kg] [4]

Question taken from Eduqas examination paper 842102, June 2017

#8

(a) The diagram shows the elliptical orbit of a planet around a star. Use the diagram (by adding to it) to explain Kepler's second law of planetary motion. [2]



(b) Starting with Newton's law of gravitation, show that for a circular orbit, the period of orbit, T, of a planet around a star is related to its distance, r, from the centre of the star by the relationship $T^2 \propto r^3$. [Assume the mass of the planet is much less than the mass of the star.] [3]

(c) Mars has two small moons, Phobos and Deimos. The diagram shows their orbital paths around Mars.



(i) Phobos has an orbital period of 7.7 hours and the radius of its orbit is 9400 km. Show that the mass of Mars is approximately 6.4×10^{23} kg. [3]

(ii) It is proposed to send a space-probe to study Phobos and Deimos. The first part of the mission will be to place the probe in orbit around Phobos.

I. Show that the gravitational potential due to Mars at the Phobos orbit is approximately $-4.5\,\text{MJ kg}^{-1}$. [2]

II. The second part of the mission involves manoeuvring the space-probe into a higher orbit to enable it to study Deimos. However, on the journey to Mars the probe used more fuel than was expected. Scientists are now unsure as to whether or not the probe has enough fuel to enable it to reach the orbit of Deimos. The following information is available:

Energy available per kg of space-probe: $4.4\,\text{MJ kg}^{-1}$
Efficiency of fuel-burn process: 60 %
Distance of Deimos from centre of Mars: 23 500 km

Assuming the mass of the fuel is very small compared to the mass of the probe itself, and ignoring the gravitational effects of both moons, determine whether or not the scientists should attempt the manoeuvre. [4]

(iii) Explain why it is not possible to use the equation $\Delta E_p = mg\Delta h$ when determining the change in the gravitational potential energy of the probe as it moves between these orbits. [1]

Question taken from Eduqas examination paper 842102, November 2020

Marking Scheme

#1

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*	(i)	$\omega = \frac{\text{angle swept out}}{\text{time taken}}$ [or in words] Or angle [accept: number of radians] swept out per unit time [or per second]	1			1		
		(ii)	Clear use of $\omega = \frac{v}{r}$ or equivalent (1) Convincing algebra (1)	1	1		2	1	
	(b)	(i)	Substitution into: $F = m\frac{v^2}{r}$ or equivalent either before or after rearrangement (1) v = 1.35 km s^{-1} (1)	1	1		2	1	
		(ii)	$\frac{GMm}{r^2} = \frac{mv^2}{r}$ or equivalent with M and m correctly identified (1) m cancels so speed of moon of twice the mass would be the same as that of Deimos. [Must be supported by argument even if argument not clear enough to give first mark.] (1) or in words, e.g. Equivalence of gravitational and inertial mass however expressed, [e.g. the force would be double and the mass is doubled] (1) Hence speed the same (1) or Another identical moon next to the existing one will orbit at the same speed (1), so the composite moon [of double the mass] will orbit at that speed (1).		2		2		
			Question 2 total	**3**	**4**	**0**	**7**	**2**	**0**

#2

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)	[lantern moment] 0.9 × 9.81 × 0.8 [= 7.06] [N m] or by implication (1) [bar moment] 1.8 × 9.81 × 0.55 [= 9.70] [N m] or by implication (1) Total = 17 N m **UNIT** (1) accept 16.8 and 16.7 Give 1 mark if *g* omitted and answer given as 1.7 with or without any unit.	1 1	1		3	3	
		(ii)	[Anticlockwise] torque due to wire = T × 1.1 m × sin 35° or by implic (1) T = 27 [N] **ecf on (a)(i)** (1)			2	2	2	
		(iii)	Tension must increase (1) Convincing brief explanation e.g. reducing angle decreases [perpendicular] distance **or** reduces component of tension perpendicular to bar (vertical component **or** tension must increase to compensate **or** so that [total] clockwise moment is still balanced (1) **Accept** numerical demonstration using a specific angle smaller than 35° for both marks (First mark for demonstration, second for conclusion)			2	2		
	(b)		1.4 [m s^{-1}]		1		1		
			Question total	**2**	**2**	**4**	**8**	**5**	**0**

#3

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
9	(a)		Conversion $4.32 \times 10^6 \times 1.6 \times 10^{-19}$ i.e. 6.912×10^{-13} [J] (1) Rearrangement for v i.e. $v = \sqrt{\frac{2E}{m}}$ (1) Answer = 1.44×10^7 m s^{-1} (1)		3		3	2	
	(b)		24 total energy 'kicks' (or 2 per revolution) (1) 4.32 MeV divided by 24 (=180 000) (1) Also need to divide by $2e$, Answer = 90 000 V (1) (2 marks for 180 kV, 1 mark for 360 kV, 2.16 MV →1 mark)		3		3	2	
	(c)		Equating: $m\omega^2 r = Bqv$ (1) or $\omega = \frac{Bq}{m}$ Rearrangement: $f = \frac{Bq}{2\pi m}$ (1) By implication can give 2 marks for this Answer = 3.6 MHz (ecf on part (b) i.e. using $1e$ instead of $2e$ 1.8 MHz) (1)		3		3	2	
			Question 9 total	**0**	**9**	**0**	**9**	**6**	**0**

#4

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(a)			$\frac{\text{final velocity - initial velocity}}{\text{time [taken to change]}}$ or equivalent [1]	1			1		
	(b)	(i)		[Distance gone per second] = $2\pi \times 0.25$ [m] $\times$ 5.2×10^6 [s^{-1}] [1] = 8.2×10^6 [m s^{-1}] [1]	1	1		2	2	
		(ii)		acc = $\frac{(8.0\times10^6)^2}{0.25}$ [m s^{-2}] **or** $\frac{(8.17\times10^6)^2}{0.25}$ [m s^{-2}] [1] = 2.6 (or 2.7) $\times$ 10^{14} m s^{-2} **unit mark** [1] South or towards circle centre. Accept downwards. [1]	1 1	1		3	1	
		(iii)		Time for half revolution = $\frac{1}{2} \times \frac{1}{5.2 \times 10^6}$ s [= 9.62×10^{-8} s] [1] Final velocity – initial velocity = 1.63×10^7 [m s^{-1}] [South] [1] Mean acc = 1.7×10^{14} [m s^{-2}] **South** [Accept South for Δv] [1]		3		3	2	
	(c)			Adam is wrong because acc's (or force) *direction* keeps changing [1] Brian is right because final vel – initial vel = 0 or equiv [1]			2	2		
				Question total	**4**	**5**	**2**	**11**	**5**	**0**

#5

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)		Units of a, v, r given as m s^{-2}, m s^{-1}, m (1) Convincing algebra **must see** m^2 s^{-2} (1)	1	1		2	1	
		(ii)		[According to equation] a becomes smaller **or** zero (1) [Sensible because] body's path [almost] straight **or** equivalent (1)			2	2		
	(b)	(i)		$v = \frac{2\pi \times 200}{52}$ [= 24.2 m s^{-1}] or $\omega = 0.121$ [rad s^{-1}](1) $F_{centrip} = 1\,150 \times (\frac{2\pi \times 200}{52})^2 \div 200$ [N] or equivalent or by implic(1) $F_{centrip}$ = 3 360 [N] **or** 3 400 [N] **Accept** 3 358 [N] or 3 300 [N] (1)		3		3	3	
		(ii)	I	$F_{centrip} = F \sin\theta$ **or** 3 360 (or 3 000) = 5 500 sin θ **or** equiv **or** by implic **ecf** on $F_{centrip}$ (1) θ = 37.6°(or 38°) (1)		2		2	2	
			II	Forward component of F must balance D (**or** must be equal and opposite to D) **or** since car is travelling at constant speed (1) $D = F \cos\theta$ or equiv **ecf on** θ (1) D = 4 360 [N] (1)	1	1 1		3	2	
				Question total	**2**	**8**	**2**	**12**	**8**	**0**

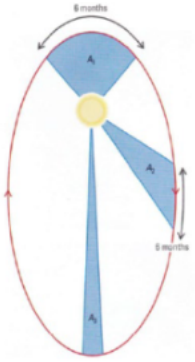
#6

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*	(i)	I	Use of $\omega = 2\pi f$ even if f is still in revs per minute **or by impl** [1] $\omega = 0.859$ [rad s^{-1}] [1]	1	1		2	1	
			II	Use of $v = r\omega$ [= 3.26 m s^{-1}] **or equiv or by impl.** [1] Time = 3.06 [s] [1] **ecf**	1	1		2	1	
			III	Use of $a = \frac{v^2}{r}$ or $a = r\omega^2$ **or by implication** [1] a = 2.80 [m s^{-2}] [1] **ecf**	1	1		2	1	
		(ii)	I	Correct substitutions in $mg = T\cos\theta$ (or after transposition) or by implication [1] 2.76 [N] [1] [2.55 N indicates error of principle]		2		2	1	
			II	[Horizontal component of] tension provides centripetal force [1] T sin 16° evaluated [0.761 N **ecf on** T] or used in calculation [1] Conclusion clearly based on calculation e.g. Either $\frac{2.76\sin 16°}{0.270} = 2.82$ [m s^{-2}] **or** 2.80 **ecf** from (a)(i)III × 0.270 kg = 0.756 [N] **and** agreement noted **ecf** [1]			3	3	2	
	(b)			Example defined e.g. bends in roads or rail lines, spin-drier... [1] One factor affecting centripetal acceleration considered in context e.g. bends in roads or tracks must not be too sharp, or spin speed must be high enough... [1] Another factor considered e.g. vehicle speed warnings, drum size limited or more intricate measures e.g. banking of tracks [1]			3	3		
				Question 4 total	**3**	**5**	**6**	**14**	**6**	**0**

#7

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		Line drawn from Sun to planet..... (1) .....will sweep out equal areas reference to $A_1 = A_2 = A_3$ (1) .....in equal time intervals / 6 months (1)	3			3		
	(b)		$\frac{mv^2}{r} = \frac{GMm}{r^2}$ (1) $v = \frac{2\pi r}{T}$ (1) Substitution and clear algebra step shown (1) **Or:** $mr\omega^2 = \frac{GMm}{r^2}$ (1) $\omega = \frac{2\pi}{T}$ (1) Substitution and clear algebra step shown (1)	1 1	1		3	3	
	(c)	(i)	1.45 years = 4.573×10^7 [s] (1) Substitution into $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ i.e. $\frac{0.052}{486.14} = \frac{v}{3.0 \times 10^8}$ (1) $v = 3.209 \times 10^4$ [m s^{-1}] (1) $r = \frac{vT}{2\pi} = \frac{3.209 \times 10^4 \times 4.573 \times 10^7}{2\pi}$ $= 2.34 \times 10^{11}$ [m] (1) **Alternative** for 4.573×10^7 see $1.45 \times 86\,400 \times 365$	1	1 1 1		4	4	
		(ii)	Assumption CoM at/near centre of neutron star or M_1 much greater than M_2 (1) **Either**: $M = \frac{v^2 r}{G}$ (1) $M = \frac{(3.209 \times 10^{\ })^2 \times 2.34 \times 10^{\ 11}}{6.67 \times 10^{-11}}$ (substitution) (1) **ecf** on v $M = 3.6 \times 10^{30}$ [kg] **and** valid conclusion (1)						
		(ii)	**Alternative:** $M = \frac{4\pi^2 r^3}{GT^2}$ (1) $M = \frac{4\pi^2 \times (2.34 \times 10^{\ })^3}{6.67 \times 10^{-11} \times (4.573 \times 10^{\ })^2}$ (substitution) (1) **ecf** on T $M = 3.6 \times 10^{30}$ [kg] **and** valid conclusion (1)			4	4	4	
			Question total	**6**	**4**	**4**	**14**	**11**	**0**

#8

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(a)			Areas and time periods shown correctly or described [1] $A_1 = A_2 (= A_3)$ indicated [1]  6 months	2			2		
	(b)			$\frac{mv^2}{r} = \frac{GMm}{r^2}$ [1] $v = \frac{2\pi r}{T}$ [1] Substitution and clear algebra step shown [1] **Or** $mr\omega^2 = \frac{GMm}{r^2}$ [1] $\omega = \frac{2\pi}{T}$ [1] Substitution and clear algebra step shown [1]	1	1 1		3	2	
	(c)	(i)		$\omega = \frac{2\pi}{(7.7 \times 3\,600)}$ or $2.26(7) \times 10^{-4}$ rads^{-1} seen [1] $M = \frac{(2.27 \times 10^{-4})^2 \times (9.4 \times 10^6)^3}{6.67 \times 10^{-11}}$ substitution and re-arrangement [1] $M = 6.39[8] \times 10^{23}$ k[g] [1]		3		3	3	
		(ii)	I	Substitution into $V_g = -\frac{GM}{R}$ i.e. $V_g = -\frac{6.67 \times 10^{-11} \times 6.4 \times 10^{23}}{9.4 \times 10^6}$ [1] $V_g = -4.5(4) \times 10^6$ [J kg^{-1}] [1]	1	1		2	2	
			II	V_g at orbit of Deimos = $-\frac{6.67 \times 10^{-11} \times 6.4 \times 10^{23}}{2.35 \times 10^7}$ $= -1.8(2) \times 10^6$ J kg^{-1}[1] $\Delta V = -1.82 + 4.54 = 2.72$ M[J kg^{-1}] [1] Energy available per kg of fuel = $0.6 \times 4.4 = 2.64$ M[J kg^{-1}] [1] Scientists should not attempt manoeuvre [1] [**ecf** based on calculations]			4	4	3	
		(iii)		One of: • g is not constant [over the distance between orbits] • g decreases as height increases • work done per metre decreases as height increases • field is not uniform		1		1		
				Question total	**4**	**7**	**4**	**15**	**10**	**0**