A Level OCR Physics

Chapter 16 Circular motion

Question	Answers	Extra information	Mark	AO	Spec reference
1(a)	There is a force/acceleration directed towards the centre of the circle/at right angles to the velocity		1	1	5.2.2
(b)	Angle = 2π radians Time = 165 × 365 × 24 × 3600 = 5.20×10^9 s $\omega = \frac{2\pi}{T} = \frac{2\pi}{5.20 \times 10^9} = 1.20 \times 10^{-9}$ rad / s	Allow 365.25 for days in a year Correct angle and time Answer	 1 1	2	5.2.1
(c)	$r = 2.79\times10^9 \times 1609\text{m} = 4.49\times10^{12}$ m centripetal acceleration = $\omega^2 r$ $= \left(1.20 \times 10^{-9}\ \text{rad s}^{-1}\right)^2 \times 4.49 \times 10^{12}$ m $= 6.47\times10^{-6}$ m s^{-2} Or Speed = $\frac{2\pi r}{T} = \frac{2\pi \times 4.49 \times 10^{12}\text{m}}{5.20 \times 10^9\text{s}} = 5425$ m s^{-1} centripetal acceleration = $\frac{v^2}{r} = \frac{34978^2}{4.49\times10^{12}}$ $= 6.47\times10^{-6}$ m s^{-2}	Correct distance Use $\omega^2 r$ or $\frac{v^2}{r}$ answer	1 1 1	2	5.2.2
(d)	$F = ma$, so $m = \frac{F}{a} = m = \frac{6.71 \times 10^{20}\ \text{N}}{6.46 \times 10^{-6}\ \text{m s}^{-2}}$ $= 1.0\times10^{26}$ kg	ECF	1	2	5.2.2
(e)	Centripetal acceleration = v^2/r	Use of equation/speed to work out relationship between acceleration, r and T	1	2	5.2.2

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	$= \frac{\left(\frac{2\pi r}{T}\right)^2}{r} = \frac{4\pi^2 r^2}{rT^2} = \frac{4\pi^2 r}{T^2}$ So centripetal acceleration is proportional to r/T^2 $= 0.65/(0.5)^2$ = 2.6	Answer	1	3	
2(a)	Vertical arrow downwards labelled weight/force of Earth on car Vertical arrow upwards of equal length labelled normal force		1 1	1	3.2.1
(b)	As speed increases, normal force decreases		1	1	3.2.1
(c)	Centripetal force = $\frac{mv^2}{r} = \frac{1400 \times 8.1^2}{18}$ = 5103 N Centripetal force = weight – normal force Normal force = weight − centripetal force = (1400 × 9.81) – 5103 = 8631 N = 8600 N	Calculation of centripetal force Showing equation for normal force answer	1 1 1	2	5.2.2
(d)	The maximum speed happens when the normal force is zero, so the centripetal force = weight. $\frac{mv^2}{r} = mg$ $v = \sqrt{gr} = \sqrt{9.81 \times 18}$ $= 13.3 \text{ m s}^{-1}$	Explanation showing normal force = 0 e.c.f. form (b) Answer	1 1	3	5.2.2
3(a)	Tension		1	1	3.2.1
(b)	Example calculation:	Correct estimates:		2	5.2.2

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	Mass of cork = 25 g Radius of orbit = 30 cm Time for one orbit = 1 s $v = \frac{2\pi r}{T} = \frac{2\pi \times 0.3}{1} = 1.88 \text{ m s}^{-1}$ Centripetal force = $\frac{mv^2}{r} = \frac{0.025 \times 1.88^2}{0.3} = 0.3 \text{ N}$	Estimate of mass between 10 g and 100 g Estimate of radius between 20 cm and 50 cm Estimate of time between 0.5 s and 2 s Calculation of force commensurate with estimates Values between 2 N and 0.05 N	1 1		
(c)	At the top of the circle the tension is smaller than the tension in part 3(b) At the bottom of the circle the tension is bigger than the tension in part 3(b)		1 1	2	5.2.2
(d)	Minimum speed is when the tension = weight $\frac{mv^2}{r} = mg$ $v = \sqrt{gr} = \sqrt{9.8 \times 0.3} = 1.7$ m/s		1 1	2	5.2.2
4(a)	$v = \omega r$, $\omega = \frac{v}{r} = \frac{4.9}{0.55} = 8.91 \text{ rad s}^{-1}$		1	2	5.2.1
(b)	Frequency = $\frac{8.9}{2\pi} = \frac{8.8 \text{ rad s}^{-1}}{2\pi} = 1.42$ Hz		1	2	5.2.1
(c)	Friction (between the bicycle tyre and the road)		1	1	3.2.1
(d)	$F_c = N \sin\theta$ $mg = N \cos\theta$		1 1 1	2	3.2.1

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	$\frac{F_c}{mg} = \tan\theta$ so $F_c = mg\tan\theta$				
(e)	$mg\tan\theta = \frac{mv^2}{r}$ $v = \sqrt{gr\tan\theta} = \sqrt{9.81 \times 50 \times \tan 18} = 12.6\ \text{m s}^{-1}$		1 1	2	5.2.2
(f)	The frequency would increase, as speed increases, and so does angular velocity		1	3	5.2.1
5(a)	Using Newton's first law, each person will continue in a straight line/constant motion unless a resultant force acts That force is the normal force of the wall of the drum on the person / the wall pushes them in		1 1	1 2	3.5.1
(b)	The operators remove the floor when there is sufficient frictional force to balance the weight of the person – weight = mg The frictional force depends on the normal force, which is the centripetal force, which depends on m, $\frac{mv^2}{r}$ So the mass cancels – the speed required to produce sufficient frictional force does not depend on the mass	Weight = mg, which balances F F depends on N, which depends on m So m cancels	1 1 1	3	5.2.2
(c)	52 rpm = $\frac{52 \times 2\pi \text{ radians}}{60 s} = 5.45 \text{rad } s$ Frequency = $\frac{\omega}{2\pi} = \frac{5.45 \text{ rad} s^{-1}}{2\pi} = 0.87$ Hz		1 1	2	5.2.1
(d)	Centripetal acceleration = $\omega^2 r = 5.45^2 \times 1.9 \text{ m} = 56.4 \text{ ms}^{-2}$		1	2	5.2.2

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(e)	They could fit more people on the ride/make more money They would need to accelerate the drum to a much larger angular velocity in order to operate the drum successfully		1 1	3	5.2.2
6(a)	The pilot experiences 'apparent' weight as the normal force between themselves and the seat This force changes as the plane loops. At the bottom, the normal force = centripetal force + weight. At the top = centripetal force – weight. The centripetal force will change during the loop since the speed of the plane will not be constant.		1 1	3	3.2.1
(b)	The force of the air on the plane/lift, and gravity in the top half of the loop		1	1	3.2.1
(c)	The force of the seat is the centripetal force = $\frac{mv^2}{r}$ speed = $\frac{2\pi r}{T}$; $r = \frac{vT}{2\pi} = \frac{70 \times 12.4}{2\pi}$ = 138 m $F_N = \frac{mv^2}{r} = \frac{70 \times 70^2}{138}$ = 2486 N = 2500 N	Recognition that gravity does not affect the pilot in this position explicit or implied Calculation of radius Calculation of force	1 1 1	2	5.2.2
(d)	Height difference between A and bottom of loop = 138 m. Energy considerations: $\frac{1}{2} mv_{bottom}^2 = mgh + \frac{1}{2} mv_A^2$ $v_A = \sqrt{(v_{bottom})^2 - 2gh}$ $= \sqrt{(70)^2 - 2(9.81 \times 138)}$ = 46.8 m s^{-1}	Use of conservation of energy New speed	1 1	2	3.3.2

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	The force will be reduced by a factor of about 2 (1111 N)	Effect on value above	1		
(e)	**Level 3 (5–6 marks)** Clear description of the information required along with an appropriate suggestion for missing the pool *The student presents relevant information coherently, employing structure, style and SP&G to render meaning clear.* **Level 2 (3–4 marks)** Clear description of the information required but may be lacking appropriate suggestion for missing the pool *The student presents relevant information and in a way which assists the communication of meaning. SP&G are sufficiently accurate not to obscure meaning.* **Level 1 (1–2 marks)** Limited description of the information required *The student presents some relevant information in a simple form. SP&G allow meaning to be derived although errors are sometimes obstructive.* 0 marks No response or no response worthy of credit.	**Indicative scientific points may include:** Information required: - Height of plane – to work out the time that the ball takes to hit the ground using $s = ut + ½ at^2$ - Speed of plane at the bottom of the loop: to work out the horizontal distance using $d = vt$ - The position on the ground above which the plane will release the ball. Suggestions for missing the pool: - The plane higher than expected - time to fall is greater - horizontal distance is greater - ball will overshoot the pool for these suggestions (accept vice versa)	6	3	3.1.3

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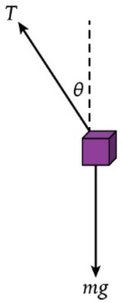
7(a)		Two arrows only Labelled tension and weight, or mg	 1 1	2	3.2.1
(b)	Resolving forces: $T\cos\theta = mg$ $T\sin\theta = \frac{mv^2}{r}$ $\tan\theta = \frac{v^2}{gr}$ The angle/radius is independent of the mass $gr\tan\theta = v^2$, $\tan\theta \approx \sin\theta = \frac{r}{l}$ $\frac{gr^2}{l} = v^2$ $r = v\sqrt{\frac{l}{g}}$ r is proportional to the speed of the object, so the radius for the plane is bigger.	Resolution of forces Elimination of T Conclusion about mass Manipulation to show radius proportional to v Conclusion	1 1 1 1	2	3.2.1
(c)	Appropriate method e.g.:	Estimated uncertainties	1	1	5.2.2

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	Radius –horizontal ruler behind the orbit Estimated uncertainty – ±1 cm Percentage uncertainty = 1/17 × 100 = 5.9% Time –stopwatch Estimated uncertainty – ±0.1 ss Percentage uncertainty = 0.1/1.3 × 100 = 7.7%	Allow a range for the radius uncertainty of 0.5 cm to 4 cm Allow a range for the time uncertainty of 0.05 s to 0.5 s Calculated percentages	1		
(d)	The distance from the centre of the orbit = horizontal speed × time Time depends on height from floor as $s = ½\ at^2$ For toy 1 both the speed and time are smaller (slower speed, smaller angle), so the distance will always be smaller than toy 2.	Evidence of use of $s = ½\ at^2$, explicitly or implied Conclusion	1 1	3	5.2.2 3.1.2
8(a)	There is a force on the student that is perpendicular to their velocity		1	1	5.2.2
(b)	$mg\ \Delta h = ½\ mv^2$ $v = \sqrt{2g\Delta h}$ $= \sqrt{2 \times 9.81 \times (2.7 - 1.4)}$ = 5.05 m/s	Evidence of conservation of energy	1 1	2	3.3.2
(c)	Time to fall to surface of water using $s = ½\ at^2$ $t = \sqrt{2s/g}$ $= \sqrt{(2 \times 1.4)/9.81}$ = 0.534 s In that time the student will travel $s = vt$ = 5.05 m/s × 0.534 s = 2.70 m Yes, they will reach the platform	Calculation of time Time and speed to find distance Answer and conclusion	1 1 1	2	3.1.2

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(d)	Sensible reasoning e.g. If the rope stretches the student will be travelling faster when they reach part b as the change in height is bigger The time before they hit the water will be smaller, so they will travel about the same distance		2	3	3.1.3