A Level AQA Physics

11 Circular motion – answers

Question	Answers	Extra information	Mark	AO	Spec reference
01.1	There is a force/acceleration directed towards the centre of the circle/at right angles to the velocity		1	1	3.6.1.1
01.2	Angle = 2π radians Time = $225 \times 24 \times 3600 = 1.94 \times 10^7$ s $\omega = \frac{2\pi}{T} = \frac{2\pi}{1.94 \times 10^7} = 3.23 \times 10^{-7}$ rad s^{-1}	 Correct angle and time Answer	 1 1	2	3.6.1.1
01.3	$r = 67.24 \times 10^6 \times 1609$ m $= 1.08 \times 10^{11}$ m Centripetal acceleration = $\omega^2 r$ $= (3.23 \times 10^{-7}$ rad s$^{-1})^2 \times 1.08 \times 10^{11}$ m $= 1.13 \times 10^{-2}$ m s^{-2} Or Speed = $\frac{2\pi r}{T} = \frac{2\pi \times 1.08 \times 10^{11}\text{ m}}{1.94 \times 10^7\text{ s}} = 34\,978$ m s^{-1} Centripetal acceleration = $\frac{v^2}{r} = \frac{34\,978^2}{1.08 \times 10^{11}}$ $= 1.13 \times 10^{-2}$ m s^{-2}	Correct distance Use $\omega^2 r$ or $\frac{v^2}{r}$ Answer	1 1 1	2	3.6.1.1
01.4	$F = ma$ or $m = \frac{F}{a}$ $m = \frac{5.6 \times 10^{22}\text{ N}}{1.13 \times 10^{-2}\text{ m s}^{-2}}$ $= 4.95 \times 10^{24}$ kg		 1	2	3.6.1.1
01.5	$v = \frac{2\pi r}{T} = \frac{2\pi \times 1.05 \times 10^{11}\text{ m}}{365 \times 4 \times 3600} = 29\,885$ m s^{-1} Centripetal acceleration = $\frac{v^2}{r} = \frac{29\,885^2}{1.05 \times 10^{11}}$ $= 5.95 \times 10^{-3}$ m s^{-1} Which is about half the centripetal acceleration of Venus	Calculation of speed Calculation of centripetal acceleration Comment	1 1 1	2 3	3.6.1.1
02.1	Vertical arrow downwards labelled weight/force of Earth on car Vertical arrow upwards of equal length labelled normal force		1 1	1	3.6.1.1

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02.2	TWO OF: If it is stationary, the normal force equals the weight If it is not zero, the normal force is less than the weight At a maximum speed, the weight is not sufficient to keep the car on the road		2	1	3.6.1.1
02.3	Centripetal force = $\frac{mv^2}{r} = \frac{1600 \times 9^2}{22}$ $= 5890\,\text{N}$ Centripetal force = weight – normal force Normal force = weight – centripetal force $= 1600 \times 9.8 - 5890 = 9789\,\text{N} = 9800\,\text{N}$	Calculation of centripetal force Showing equation for normal force Answer	1 1 1	2	3.6.1.1
02.4	The maximum speed happens when the normal force is zero, so the centripetal force = weight. $\frac{mv^2}{r} = mg$ $v = \sqrt{gr} = \sqrt{9.8 \times 22}$ $= 14.7\,\text{m s}^{-1}$	Explanation showing normal force = 0 Answer	1 1	3	3.6.1.1
03.1	Tension		1	1	3.6.1.1
03.2	Example calculation: 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 = $\frac{mv^2}{r} = \frac{0.025 \times 1.88^2}{0.3} = 0.3\,\text{N}$	Correct estimates: 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	2	3.6.1.1

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03.3	At the top of the circle, the tension is smaller than the tension in **03.2** At the bottom of the circle, the tension is bigger than the tension in **03.2**		1 1	2	3.6.1.1
03.4	Minimum speed is when the tension = 0 and/or centripetal force = weight $\frac{mv^2}{r} = mg$ $v = \sqrt{gr} = \sqrt{9.8 \times 0.3} = 1.7\,\text{m s}^{-1}$		1 1	2	3.6.1.1
04.1	$v = \omega r, \omega = \frac{v}{r} = \frac{5.3}{0.6} = 8.8\,\text{rad s}^{-1}$		1	2	3.6.1.1
04.2	Frequency $= \frac{8.8}{2\pi} = \frac{8.8\,\text{rad s}^{-1}}{2\pi} = 1.40\,\text{Hz}$		1	2	3.6.1.1
04.3	Friction (between the bicycle tyre and the road)		1	1	3.6.1.1
04.4	$F_c = N\sin\theta$ $mg = N\cos\theta$ $\frac{F_c}{mg} = \tan\theta$ so $F_c = mg\tan\theta$	reject force triangles methods since vertical and horizontal resolution is asked for in question allow $F_c = \frac{mg\sin\theta}{\cos\theta}$	1 1 1	2	3.6.1.1
04.5	$mg\tan\theta = \frac{mv^2}{r}$ $v = \sqrt{gr\tan\theta} = \sqrt{9.8 \times 50 \times \tan 15} = 11\,\text{m s}^{-1}$		1 1	2	3.6.1.1
04.6	The frequency would increase as speed increases, and so does angular velocity		1	3	3.6.1.1
05.1	Using Newton's first law, each person will continue in a straight line unless a 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	3.6.1.1

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OXFORD Revise

Question	Answers	Extra information	Mark	AO	Spec reference
05.2	The operators remove the floor when there is sufficient frictional force to balance the weight of the person, i.e. 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	3.6.1.1
05.3	56 rpm = $\frac{56 \times 2\pi \text{ radians}}{60\text{ s}}$ = 5.86 rad s^{-1} Frequency = $\frac{\omega}{2\pi} = \frac{5.86\text{ rad s}^{-1}}{2\pi}$ = 0.93 Hz		1 1	2	3.6.1.1
05.4	Centripetal acceleration = $\omega^2 r = 5.86^2 \times 1.9\text{ m} = 0.93\text{ m s}^{-2}$		1	2	3.6.1.1
05.5	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	3.6.1.1
06.1	The pilot experiences ‘apparent’ weight as the normal force between themself and the seat This force changes as the plane loops. At the bottom, the normal force = centripetal force + weight. At the top, the normal force = centripetal force – weight. The centripetal force will change during the loop since the speed of the plane will not be constant		1 1	3	3.6.1.1
06.2	The force of the air on the plane/lift and gravity in the top half of the loop		1	1	3.6.1.1
06.3	The force of the seat is the centripetal force = $\frac{mv^2}{r}$ speed, $v = \frac{2\pi r}{T}$, so $r = \frac{vT}{2\pi} = \frac{70 \times 12.4}{2\pi}$ = 138 m $F_N = \frac{mv^2}{r} = \frac{70 \times 70^2}{138}$ = 2485 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	3.6.1.1

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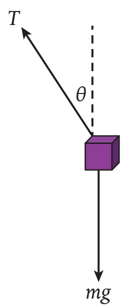
06.4	Height difference between top and bottom of loop = 2 × 138 = 276 m. Energy considerations: $\frac{1}{2}mv^2_{bottom} = mgh + \frac{1}{2}mv^2_A$ $v_A = \sqrt{v^2_{bottom} - 2gh}$ $= \sqrt{70^2 - 2 \times 9.81 \times 138}$ $= 47\ m\ s^{-1}$ The speed is approximately halved The force will be reduced by a factor of about 4 (556 N)	Use of conservation of energy New speed Effect on value above	1 1 1	2	3.6.1.1
06.5	Information needed: Height of plane: to work out the time that the ball takes to hit the ground using $s = ut + \frac{1}{2}at^2$ 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	All 3 factors and explanations: 4 marks 2 factors and explanations: 3 marks 1 factor and explanation: 2 marks Factors without explanation: 1 mark	4	3	3.4.1.3 3.4.1.4
06.6	Correct suggestion/explanation, e.g. The plane higher than expected, time to fall is greater, horizontal distance is greater, ball will overshoot the pool	Suggestion: 1 mark Explanation: 1 mark	2	3	3.4.1.3 3.4.1.4
07.1		Two arrows only Labelled tension, or T and weight, or mg	1 1	2	3.4.1.1

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07.2	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 second toy is bigger	Resolution of forces Elimination of T Conclusion about mass Manipulation to show radius proportional to v Conclusion	1 1 1 1	2	3.4.2.2
07.3	Appropriate method. e.g. Radius: video measurement with horizontal ruler behind the orbit / measure length of string and difference in height and use trig Estimated uncertainty= ±2 cm. Allow 0.5 cm – 4 cm Percentage uncertainty e.g. $= 2 \times \frac{100}{17} = 12\%$ Time: video measurement with stopwatch in view/ time several cycles and divide time by that number Estimated uncertainty = ±0.05 s allow 0.01 s – 1 s Percentage uncertainty $= 0.05 \times \frac{100}{1.3} = 3.8\%$	Appropriate methods (1 × 2) Estimated uncertainties (1 × 2) Calculated percentages (1 × 2)	3 × 2	1	3.1.2

Question	Answers	Extra information	Mark	AO	Spec reference
07.4	No The distance from the centre of the orbit = horizontal speed × time Time depends on height from floor as $s = \frac{1}{2}at^2$ For the first toy, both the speed and time are smaller (slower speed, smaller angle), so the distance will always be smaller than the second toy	Evidence of use of $s = \frac{1}{2}at^2$, explicitly or implied Conclusion	1 1	3	3.6.1.1
08.1	There is a force on the student that is perpendicular to their velocity		1	1	3.6.1.1
08.2	$mg\Delta h = \frac{1}{2}mv^2$ $v = \sqrt{2g\Delta h}$ $= \sqrt{2 \times 9.81 \times (2.7 - 1.4)}$ $= 5.1\ \mathrm{m\,s^{-1}}$	Evidence of conservation of energy	1 1	2	3.4.1.8
08.3	Time to fall to surface of water using $s = \frac{1}{2}at^2$ $t = \sqrt{\frac{2s}{g}}$ $= \sqrt{\frac{2 \times 1.4}{9.81}}$ $= 0.29\ \mathrm{s}$ In that time, the student will travel $s = vt = 5.1\ \mathrm{m\,s^{-1}} \times 0.29\ \mathrm{s}$ $= 1.5\ \mathrm{m}$ yes, they will reach the platform	Calculation of time Time and speed to find distance Answer and conclusion	1 1 1	2	3.4.1.3
08.4	Sensible reasoning. e.g. If the rope stretches, the student will be travelling faster when they reach point **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	3.4.1.3

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OXFORD Revise

Skills box answers

Question	Answer
1	$\omega = \frac{2\pi}{T} = \frac{2\pi}{(30 \times 60)} = 3.5 \times 10^{-3}\ \text{rad s}^{-1}$
2	$\omega = \frac{2\pi}{T} = \frac{2\pi}{1.5 \times 10^{-16}} = 4.2 \times 10^{16}\ \text{rad s}^{-1}$
3	$F = \frac{mv^2}{r} = \frac{4.0\ \text{kg} \times (8.6\ \text{m s}^{-1})^2}{1.1}\ \text{m}$ so $F = 270$ N to 2 significant figures