Answers to examination-style questions

Answers	Marks	Examiner's tips
1 (a) Each spring holds its brake pad retainer on the shaft at low speed.	**1**	
If the rotation speed is increased, the brake pad retainer moves away from the shaft and compresses the spring, which acts against the outward movement of the retainer.	**1**	
If the rotation speed is fast enough, the spring is unable to prevent the brake pad coming into contact with the collar.	**1**	
Friction between the brake pad and the collar prevents the shaft rotating any faster.	**1**	max 3 marks for **(a)**
(b) For no braking, the centripetal force < 250 N.	**1**	When the centripetal force exceeds 250 N the spring extends outwards and, as the gap is small, braking occurs.
$\therefore m\omega_0^2 r = 250$ N at the maximum angular speed ω $0.30\ \omega_0^2 \times 0.060 = 250$	**1**	
$\omega_0^2 = \frac{250}{0.30} \times 0.060 = 1.39 \times 10^4$ rad^2 s^{-2}	**1**	
$\omega_0 = 118$ rads^{-1} Maximum frequency of rotation $= \frac{\omega_0}{2\pi}$ $= 19$ Hz	**1**	
(c) If the springs became weaker, the tension in the springs at which the brake pads touched the collar would be less …	**1**	
… so braking would occur at a lower rotation frequency.	**1**	
The lifeboat would descend at a lower speed, or more friction occurs.	**1**	max 2 marks for **(c)**
2 (a) *Relevant points include:* • Speed is the magnitude of velocity (or speed is a scalar but acceleration [*or velocity*] is a vector). • In circular motion at constant speed the direction of motion changes continuously. • Therefore the velocity is changing. • Acceleration is the rate of change of velocity.	**3**	Alternatively, this can be argued as follows: • speed is the magnitude of velocity (or speed is a scalar but acceleration [*or velocity*] is a vector) • force (or acceleration) acts towards the centre of the circle • force (or acceleration) is always perpendicular to the velocity (or has no component in the direction of the velocity) • so the force changes the direction of the velocity but not its magnitude

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(b) Angular speed $\omega = 2\pi f = 2\pi \times \frac{78}{60}$ $= 8.17\ \text{rad s}^{-1}$	**1**	The frequency f is the number of revolutions **per second**, and the angular speed is found by multiplying this by 2π. It is possible (although more tedious) to calculate the answer using $F = \frac{mv^2}{r}$, provided you remember that $\frac{2\pi r}{T}$, and that the period T is $\frac{60}{78}$ s.
Maximum frictional force F = centripetal force	**1**	
$\therefore F = m\,\omega^2\,r$ gives $0.50 = 0.10 \times 8.17^2 \times r$ from which maximum distance $r = 7.5 \times 10^{-2}$ m	**1**	If the distance from the axis were greater than 7.5×10^{-2} m, the centripetal force required to hold the mass on the table would increase; the maximum frictional force of 0.50 N would no longer prevent the mass from being thrown off.
3 (a) Use of $\frac{2\pi r}{T}$, where $T = \frac{60}{45}$ s	**1**	*Alternatively*: Angular speed $\omega = 2\pi f = 2\pi \times \frac{45}{60}$ $= 4.71\ \text{rad s}^{-1}$
gives $v = \frac{2\pi r}{T} = \frac{2\pi \times 0.125}{1.33}$	**1**	
$= 0.59\ \text{m s}^{-1}$	**1**	Linear speed $v = \omega r = 4.71 \times 0.125$ $= 0.59\ \text{m s}^{-1}$
(b) (i) Radial arrow drawn from **D** pointing towards the centre of the disc.	**1**	When the disc rotates at constant speed, the **only** horizontal force acting on the dust particle is the centripetal force. This acts towards the centre of the circle.
(ii) Centripetal acceleration at position **D** $= \frac{v^2}{r} = \frac{0.59^2}{0.125}$	**1**	If you had calculated the angular speed ω in part **(a)**, you might prefer to calculate the centripetal acceleration using $a = \omega^2\,r$.
$= 2.8\ \text{m s}^{-2}$	**1**	
(c) *Relevant points*: • A smaller centripetal force is required for particles that are closer to the centre … • because, when the rate of rotation is constant, force $\propto$ radius r ($F = m\omega^2 r$ and ω is constant). • Friction (or electrostatic attraction) is sufficient to hold the dust particles that are closer to the centre but not those further away.	**3**	When a body rotates at a constant rate, the **angular** speed is constant for the whole of the body, but the **linear** speed of a particle in (or on) the body depends on its radius from the axis of rotation. The argument supporting the answer is less clear if you use $F = \frac{mv^2}{r}$ because both v and r change with radius. However, you can link this approach to ω, as follows: $F = \frac{mv^2}{r} = \frac{m(\omega r)^2}{r} = m\omega^2 r$ Hence, for a given mass, $F \propto r$ when ω is constant.

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4 (a) Angular speed $\omega = 2\pi f = 2\pi \times \frac{9000}{60}$	1	9000 revolutions per minute is the same as 150 revolutions **per second**. This is the frequency of rotation.
$= 2\pi \times 150$	1	
$= 9.42 \times 10^2$ rad s^{-1}		
(b) (i) The centripetal force on the effective mass is applied by the **tension** in the plastic line.	1	The plastic line pulls inwards on the mass all the time it is rotating.
(ii) Centripetal force $F = m\omega^2 r$	1	This calculation needs a little care. In the question the mass is given in g, not kg, and you have to remember to square ω.
$= 0.80 \times 10^{-3} \times (9.42 \times 10^2)^2 \times 0.125$	1	
$= 89$ N	1	
(c) Use of $F\,\Delta t = \Delta(mv)$	1	Part **(c)** is an interesting twist, which revises the work on impulse which is covered in Chapter 1 of *AS Physics A*. The pebble was stationary before being struck by the line, so its change in momentum is (mass) × (velocity acquired).
gives $F \times 0.68 \times 10^{-3} = 1.2 \times 10^{-3} \times 15$	1	
$\therefore$ average force on pebble $F = 26$ N	1	
5 (a) (i) The velocity of the engine changes because the direction of movement changes as it goes round the track.	1	See the more complete answer given (and expected) in Question 1 above. The mark allocation shown alongside each part is a guide to how much you are expected to write. Here it is 2 marks; in Question 1 it is 3 marks.
Acceleration is the rate of change of velocity (or velocity is a vector).	1	
(ii) Arrow drawn towards the centre of the circle on the diagram.	1	A centripetal force is always directed towards the centre of the circular path.
(b) Centripetal force $F = \frac{mv^2}{r} = \frac{0.14 \times 0.17^2}{0.80}$	1	All the necessary data is set out for you to substitute directly into the centripetal force equation. Remember to square v.
$= 5.1 \times 10^{-3}$ N	1	
(c) (i) Centripetal force acts on the **outer** wheel.	1	More insight is required in part **(c)**. The flange of the outer wheel pushes **outwards** against the curved outer rail as the engine attempts to carry on moving in a straight line. The outer rail therefore pushes **inwards** on this same flange, providing the centripetal force.

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(ii) *Relevant points include*: • Stress is $\frac{\text{force } F}{\text{area } A}$ • F depends on the mass of the engine, the speed of the engine, and the radius of the track. • A is the area of contact between the wheel and the rail. • A discussion of how changing a physical quantity would affect the stress, for example increasing the mass of the engine would increase the stress, or an increase in the depth of the flange would decrease the stress.	4	This revises work on materials covered in Unit 2 of *AS Physics A*. Some of the marks would be available if you were to discuss only the vertical forces on the wheel (due to the weight of the engine), but full marks could only be obtained by discussing the effect of the centripetal force. This is because the question requires you to give an answer 'for the toy engine **going round a curved track**'.
6 (a) (i) Use of tension $F = \frac{mv^2}{r}$ gives $0.35 = \frac{30 \times 10^{-3} \times v^2}{0.45}$	1	When substituting values, m must be in kg and r in m. Remember to take the square root of v^2 before writing down your answer.
∴ speed of mass $v = 2.29$ m s^{-1}	1	
(ii) Period $= \frac{2\pi r}{v} = \frac{2\pi \times 0.45}{2.29}$	1	*Alternatively*: angular speed
$= 1.2$ s	1	$\omega = \frac{v}{r} = \frac{2.29}{0.45} = 5.09$ rad s^{-1} period $= \frac{2\pi}{\omega} = \frac{2\pi}{5.09} = 1.2$ s
(b) (i) *Arrows on diagram drawn and labelled as follows*: • **Weight** (or mg), arrow vertically downwards from centre of mass of **M**.	1	The mark would not be given for an arrow labelled 'gravity', and the arrow must be drawn carefully, vertically downwards.
• **Tension**, arrow along thread towards centre of circle.	1	Labelling the arrow 'centripetal force' would not be acceptable, and the arrow must be **on** the thread, not parallel to it.
• **Air resistance** (or drag), arrow along a tangent to the circle in the opposite direction to the rotation arrow.	1	You could easily overlook this force, but it is bound to be present. The mark would not be awarded if you were to label it 'friction'.
(ii) The tension is least when **M** is at the top of the circle and greatest when **M** is at the bottom.	1	In this case the centripetal force is the **resultant** force towards the centre of the circle. At the top, both the weight and the tension act in the same direction (vertically downwards). At the bottom, the weight acts downwards whilst the tension acts upwards, so these forces act in opposite directions.
At the top: centripetal force = weight + tension ∴ tension $= \frac{mv^2}{r} + mg$	1	
At the bottom: centripetal force = tension − weight ∴ tension $= \frac{mv^2}{r} + mg$	1	

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7 (a) Momentum of electron = mv $= 9.1 \times 10^{-31} \times 4.2 \times 10^{7}$ $= 3.8 \times 10^{-23}$ N s (or kg m s^{-1})	1 1	This first part revises work covered in Chapter 1 of *AS Physics A*.
(b) Magnitude of force on electron = centripetal force $F = \frac{mv^2}{r}$ $= \frac{9.1 \times 10^{-31} \times (4.2 \times 10^{7})^2}{0.045} = 3.6 \times 10^{-14}$ N	1 1	In examples such as this, where the object moving in a curved path does not move repeatedly around a circle, it is generally best to use the centripetal force equation in the form $F = \frac{mv^2}{r}$, rather than $F = m\,\omega^2\,r$.
(c) Arrow drawn from **P** towards the centre **O** of the circular path.	1	This is a further test of the fact that the centripetal force acting on an object is directed to the centre of the circle in which it is moving.
8 (a) *Relevant points*: • A force is needed (or there is an acceleration) towards the centre of the bend. • The movement of the pointer is to the left (or away from the centre). • The right hand spring must stretch to provide this force.	3	The mass inside the accelerometer behaves in much the same way as a passenger in a car going round a bend. **Within the accelerometer**, the mass moves outwards (although it is actually attempting to carry on in a straight line) until the pull of the right hand spring is sufficient to provide the required centripetal force.
(b) (i) Centripetal acceleration $a = \frac{v^2}{r}$ $v = 45$ km $h^{-1} = \frac{45 \times 1000}{3600} = 12.5$ m s^{-1} $\therefore a = \frac{12.5^2}{24} = 6.5$ m s^{-2}	1 1	The whole car and its contents experience this same acceleration as it travels round the bend. You are required to convert km h^{-1} (which is the usual unit for the speed of a car) into m s^{-1}, as in Question 8.
(ii) Force on mass = $ma = 0.35 \times 6.5$ $= 2.28$ N Movement of pointer $= \frac{2.28}{0.75} \times 27$ $= 82$ mm	1 1	The force on the mass is the centripetal force, but a has already been calculated in **(b)(i)**. This force will move the pointer $\frac{2.28}{0.75}$ times further than the calibrating force of 0.75 N.