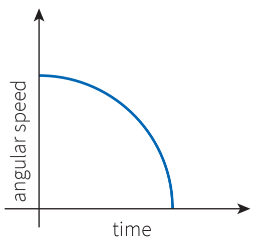
A Level AQA Physics

25 Rotational mechanics – answers

Question	Answers	Extra information	Mark	AO	Spec reference
01.1	100 revolutions per minute $= 100 \times \frac{2\pi}{60}$ $= 10.5\ \text{rad s}^{-1}$ $\Delta t = \frac{\Delta\omega}{a} = \frac{10.5}{2.00} = 5.24\ \text{s}$	Conversion to rad s^{-1} Answer	1 1	2	3.11.1.3
01.2	Find the moment of inertia of the wheel Use torque = moment of inertial × angular acceleration to find torque Use torque = force × distance (radius of wheel) to find force	Use of $T = I a$ Use of $T = F r$	1 1	3	3.11.1.4
01.3	$\omega_2^2 = \omega_1^2 + 2a\theta$ $\theta = \frac{\omega_2^2 - \omega_1^2}{2a}$ $= \frac{0 - 10.5^2}{2 \times 2.00}$ $= 27.4\ \text{rad}$ $= \frac{27.4}{2\pi}$ $= 4.36$ revolutions	Substitution Answer Conversion to revolutions	1 1 1	2	3.11.1.3
01.4		Does not start at zero Gradient increases	1 1	3	3.11.1.3
01.5	The graph in part **01.1** would be linear The deceleration is constant		1 1	3	3.11.1.3
02.1	Correct suggestion, e.g., Engineers may apply torques by firing engines, and they need the moment of inertia to work out the angular acceleration		1	3	3.11.1.4

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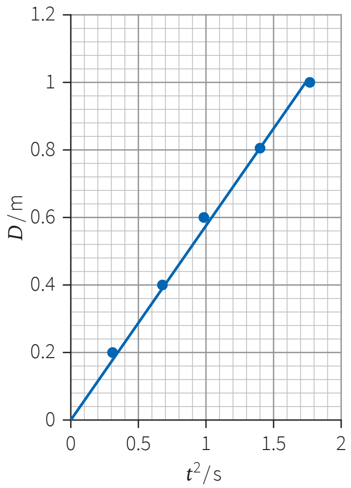
<tr><th>Question</th><th>Answers</th><th>Extra information</th><th>Mark</th><th>AO</th><th>Spec reference</th></tr>
<tr><td>02.2</td><td>

A column with t^2

D / m	t^2 / s^2
0.2	0.3025
0.4	0.6724
0.6	0.9801
0.8	1.3924
1.0	1.7689

Graph



$D = \frac{1}{2}at^2$, so the gradient $= \frac{1}{2}a$

Gradient $= \frac{0.8\,\text{m}}{1.4\,\text{s}^2} = 5.7\,\text{m}\,\text{s}^{-2}$

</td><td>Either use of t^2 or $\sqrt{D}$
Values calculated
Points plotted, straight line of best fit
Axes correct and labelled with units

Correct use of equation

Answer</td><td>1

1
1

1

1

1</td><td>2</td><td>3.11.1.3</td></tr>
</table>

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02.3	$I = mR^2\left(\frac{g}{a} - 1\right)$ $I = 0.1 \times 0.032^2\left(\frac{9.8}{5.7} - 1\right)$ $= 7.3\times10^{-5}\,\text{kg m}^2$	Substitution Answer	1 1	2	3.11.1.1
02.4	Correct suggestion and explanation, e.g., The moment of inertia of the pulley is not taken into account This means the calculated value is larger than it should be		2	3	3.11.1.3
03.1	To smooth out the torque produced by the crankshaft, to ensure that a constant torque/speed is produced		1	1	3.11.1.2
03.2	No external torque is exerted on the system		1	1	3.11.1.5
03.3	$I_1\omega_{1i} + I_2\,\omega_{2i} = (I_1 + I_2)\omega_f$ $0.21 \times 530 + 0.15 \times 240 = (0.21 + 0.15)w$ $\omega = 409\,\text{rad s}^{-1}$ (409.2)	Use of conservation of angular moment (explicit or implied) Answer	1 1	2	3.11.1.5
03.4	Impulse = change in angular momentum $= I\Delta\omega$ $= 0.36 \times 0.1 \times 410$ $= 14.8\,\text{kg m}^2\,\text{rad s}^{-1}$ Assuming torque is constant	Substitution Answer Unit Assumption	1 1 1 1	2 2 1	3.11.1.5
04.1	Angular velocity = $\frac{\text{linear velocity}}{r}$ Or linear velocity = angular velocity $\times r$		1	1	3.11.1.4
04.2	2200 revolution per minute $= 2200 \times \frac{2\pi}{60}$ $= 1.38 \times 10^4\,\text{rad s}^{-1}$ Linear velocity $v = \omega r$ $= 1.38\times10^4 \times 0.125\,\text{m}$ $= 1.73\times10^3\,\text{m s}^{-1}$	Substitution Answer	1 1	2	3.11.1.4

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Question	Answers	Extra information	Mark	AO	Spec reference
04.3	Kinetic energy $= \frac{1}{2}mv^2$ Power $= \frac{\text{energy}}{\text{time}}$ $= \frac{\frac{1}{2} \times 1.3 \times 10^{-3} \times (1.73 \times 10^3)^2}{0.25}$ $= 7.76 \times 10^3$ W	Use of data from diagram Answer	1 1	3	3.11.1.2
04.4	Moment of inertia $= \frac{1}{2}mR^2$ $= \frac{1}{2} \times 1.3 \times 10^{-3} \times (0.125)^2$ $= 1.02 \times 10^{-5}$ kg m^2 $= 1.0 \times 10^{-5}$ kg m^2	Substitution Answer	1 1	2	3.11.1
04.5	Torque exerted on mass $= F \times d$ $= 6.50 \times 0.125 = 0.813$ N m Power $= T \times \omega$ ω is reduced by $\frac{1}{0.813} = 1.23$ rad s^{-1}	Substitution Answer	1 1	3	3.11.1.5 3.11.1.6
05.1	$I = \frac{1}{2} \times 50$ kg $\times (0.3$ m$)^2$ $= 2.25$ kg m^2 $= 2.3$ kg m^2		1	2	3.11.1.1
05.2	$I_{hand} = mR^2$ $= 4$ kg $\times (0.8$ m$)^2$ $= 2.56$ kg m^2 Total $I = I_{cylinder} + 2 \times I_{hand}$ $= (2.25 + 2.56 + 2.56)$ kg m^2 $= 7.37$ kg m^2 $= 7.4$ kg m^2	Use of equation Calculation for 2 'hands' Total answer Allow 7.5 kg m^2	1 1 1	2	3.11.1.1

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Question	Answers	Extra information	Mark	AO	Spec reference
05.3	$L = I\omega$ $= 7.37\ \text{kgm}^2 \times 2.2\ \text{rad s}^{-}$ $= 16.2\ \text{kg m}^2\ \text{s}^{-1}$ $= 16\ \text{kg m}^2\ \text{s}^{-1}$		1 1	2	3.11.1.5
05.4	moment of inertia decreases Angular momentum stays the same/is conserved The angular speed increases Assuming no external torques act	 Do not accept 'external force'	1 1 1 1	3	3.11.1.5
05.5	$T\Delta t = \Delta(I\omega)$ $T = \frac{\Delta(I\omega)}{\Delta t}$ $= \frac{\{\text{student's answer to } \mathbf{05.3}\}\ \text{kg m}^2\ \text{rad s}^{-1}}{24\ \text{s}}$ = 0.67 N m (if used L = 16) = 0.68 N m (if used L = 16.2)	 Substitution Answer	 1 1	2	3.11.1.5
06.1	Rotational kinetic energy $= \frac{1}{2} I\omega^2$ $= \frac{1}{2} MR^2 \times \omega^2$ $= 0.5 \times 15 \times 0.2^2 \times 1920^2$ $= 1.11 \times 10^6\ \text{J}$	Substitution Answer	1 1	2	3.11.1.2

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Question	Answers	Extra information	Mark	AO	Spec reference
06.2	Change in E_k of the car = gain in rotational E_k of the flywheel Final E_k of the car = initial E_k – rotational E_k gained $= \frac{1}{2}mv_i^2 - 1.11\ldots \times 10^6$ J $= 0.5 \times 660 \times 67^2 - 1.11\ldots \times 10^6$ J $= 0.37137 \times 10^6$ J Final speed of the car = $\sqrt{\frac{2 \times 0.37137 \times 10^6}{660}}$ $= 33.546\ldots$ m s^{-1} Deceleration = $\frac{\Delta v}{\Delta t}$ $= \frac{33.546\ldots - 67}{3.3}$ $= -10$ m s^{-2}	Explicit or implicit Change in energy Final speed ignore minus sign	1 1 1 1	3	3.11.1. 3.4.1.3
06.3	Correct suggestion, e.g. The flywheel axle could be connected to a generator that produces a pd A capacitor connected across the generator would charge up	Link to flywheel Use of generator	1 1	3	3.7.5.4
06.4	Energy stored in a capacitor = $\frac{1}{2}CV^2$ $0.5 \times 1.0 \times V^2 = 1.11 \times 10^6$ J $V = 1490$ V This is a very high voltage	Substitution Answer comment	1 1 1	2	3.7.4.3
06.5	At very high p.d., there is a large field strength/the dielectric can break down The capacitor conducts/a large current flows/risk of wire melting/fire		1 1	3	3.7.4.2
07.1	An ionised gas consists of charged particles If the particles are moving, there is a force on them $F = BIl$ / magnetic field to not effect stationary charges		1 1	3	3.7.5.1

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Question	Answers	Extra information	Mark	AO	Spec reference
07.2	Moment of inertia of each wheel = $I = \frac{1}{2}Mr^2$ = 7 846 875 = 7.85 × 10^6 kg m^2 Energy stored by one wheel when spinning at 24 rad s^{-1} $= \frac{1}{2}I\omega^2$ = 0.5 × 7.85 × 10^6 × 24^2 = 2.259…× 10^9 J Power = $\frac{\text{energy}}{\text{time}} = \frac{2.25\times10^9}{4.2}$ = 538 × 10^6 W So two wheels are need to supply 1000 MW	MoI calculated Energy calculated Power needed related to 2 wheels	1 1 1	3	3.11.1.6
07.3	As the flywheel spins, there is stress in the wheel because it requires a force to continue to keep the material of the wheel moving in a circle The force is provided by the forces between atoms/microstructures, and, if there are imperfections, the force may not be sufficient and the wheel will fly apart	Reference to circular motion and (centripetal force) Reference to forces	1 1	3	3.6.1.1
07.4	Resistance = $\frac{\rho L}{A}$ Energy dissipated = $I^2 Rt = \frac{I^2\rho Lt}{A}$ (ρ = resistivity) thermal energy gained = $mc\Delta\theta = dLAc\Delta\theta$ (d = density) $I^2t\frac{\rho L}{A} = dLAc\Delta\theta = A = \sqrt{\frac{I^2t\rho}{d\Delta\theta}}$ A = 0.226… m^2 diameter = 0.54 m OR $= I^2t\frac{\rho_R l}{A} = (51\times10^6)^2 \times 4.2 \times \frac{1.72\times10^{-8}\times 1\,\text{m}}{A}$ $= \frac{1.87\times10^8}{A}$	Manipulation of equations for resistance, density, and specific heat capacity Use of change of temperature from room temperature Substitution and calculation or algebraic manipulation	1 1 1	3	3.5.1.3 3.4.2.1 3.6.2.1

OXFORD Revise

Question	Answers	Extra information	Mark	AO	Spec reference
	$E = mc\Delta\theta = dALc\Delta\theta$ $= 8960 \times A \times 1 \times 385 \times (1085 - 20)$ $= 3.67 \times 10^9 \times A$ $3.67 \times 10^9 \times A = \frac{1.87 \times 10^8}{A}$ $A^2 = \frac{1.87 \times 10^9}{3.67 \times 10^8}$ $= 0.05095\ \text{m}^2$ $A = 0.226\ldots\ \text{m}^2$ Diameter = 0.54 m This is extremely large, so the coils must be continuously cooled	Answer for area Answer for diameter Comment	1 1 1		
08.1	The centre of mass is the point through which the mass of the object appears to act, but the moment of inertia is a body's tendency to resist angular acceleration	Both needed for mark	1	1	3.4.1.2 3.11.1.
08.2	There is a torque/force acting at a distance from the pivot to the centre of mass, which turns the ruler about the pivot The torque decreases to zero when the ruler is vertical, but continues because it has angular momentum As it moves up from being vertical, the torque opposes the motion, so the angular velocity decreases to zero (momentarily)	Do not accept energy argument	1 1 1	2	3.11.1.4
08.3	Torque is analogous to force, and angle is analogous to distance Area under a force–distance graph is work done, so area under the torque–distance graph is work done		1 1	1	3.11.1.3

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OXFORD Revise

Question	Answers	Extra information	Mark	AO	Spec reference
08.4	$mgh = \frac{1}{2}I\omega^2$ The centre of mass of the ruler is raised through a vertical height of 15 cm Moment of inertia $= \frac{1}{3} \times 0.065 \times 0.3^2$ $= 0.00195\ \text{kg m}^2$ $\omega^2 = \frac{mgh}{\frac{1}{2}I}$ $\therefore\ \omega = 9.9\ \text{rad s}^{-1}$	Conservation of energy Moment of inertia Answer	1 1 1	3	3.4.1.8 3.11.1.2
08.5	Angular momentum before = angular momentum after Angular momentum of ball $= mR^2 \times \frac{v}{R} = mvR$ $0.00195 \times 9.9 = 0.005 \times 2.5 \times 0.3 + 0.00195 \times \omega_f$ $\omega_f = 8.0\ (7.98)\ \text{rad s}^{-1}$	Conservation of angular momentum Use of mR^2 for ball Answer	1 1 1	3	3.11.1.1 3.11.1.5
08.6	Angular kinetic energy has been reduced by $\left(\frac{0.17}{0.34}\right)^2$, so the height would be $\approx$ 65% $\times$ the previous height, so yes the difference in height would be noticeable	Use of energy Answer	1 1	3	3.4.1.8 3.11.1.2

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Skills box answers

Question	Answer
1	In 12 hours the hour hand will rotate through 2π rad. $\omega = \dfrac{2\pi}{(12 \times 60 \times 60)} = 1.5\times10^{-4}\ \text{rad s}^{-1}$
2	Angular displacement in 1 minute = $23\,000 \times 2\pi = 46\,000\pi$ rad. $\omega = \dfrac{46\,000\pi}{60} = 2.4\times10^{3}\ \text{rad s}^{-1}$
3	Linear displacement $s = 200$ m; $r = \dfrac{50}{2\ \text{cm}} = 0.25$ m; $t = 20$ s Angular displacement $= \dfrac{s}{r} = \dfrac{200}{0.25} = 800$ rad $\omega = \dfrac{800}{20} = 40\ \text{rad s}^{-1}$