

Rotational inertia and Newton's second law

AP Physics 1 (algebra-based) · Test answers (mark scheme)

Model answers with the mark scheme. Give credit for a correct equation or substitution even if the arithmetic slips, and apply the unit mark in each calculation.

Level: AP Physics 1 (algebra-based) · **Curriculum:** AP P1 Unit 5

Question 1 Definition (2 marks)

- a. Rotational inertia is a measure of an object's resistance to changes in its rotational motion about a given axis, $I = \Sigma mr^2$.
- b. Any two of: **its mass; the distribution of the mass (distance from the axis); the position of the axis.**

Marking: 1 mark for each part.

Question 2 Three point masses (3 marks)

- a. $I = \Sigma mr^2 = 0.20 \times (0.10)^2 + 0.30 \times (0.20)^2 + 0.50 \times (0.40)^2 = 0.0020 + 0.012 + 0.080 =$
0.094 kg m².
- b. The **0.50 kg mass** contributes most (0.080 kg m²): it is both the heaviest and the farthest from the axis, and r is squared.

Marking: (a) 1 mark for the method, 1 mark for the result; (b) 1 mark.

Question 3 Wheel on an axle (2 marks)

- a. $\tau = rF = 0.30 \times 12 =$ **3.6 N m.**
- b. $\alpha = \tau/I = 3.6 \div 0.25 =$ **14 rad/s² (14.4).**

Marking: 1 mark each, with units.

Question 4 Pulley and hanging mass (3 marks)

- a. $I = \frac{1}{2}MR^2 = 0.0050 \text{ kg m}^2$; $T = Ia/R^2 = \frac{1}{2}Ma = 0.50a$. $mg - T = ma$ gives $0.50 \times 9.81 =$
 $(0.50 + 0.50)a$, so **a = 4.9 m/s².**
- b. $T = 0.50 \times 4.905 =$ **2.5 N.**

Marking: (a) 1 mark for the two equations, 1 mark for the result; (b) 1 mark.

Question 5 Swinging a bat (3 marks)

Holding the bat at the end puts the heavy part far from the axis, so its rotational inertia $I =$

Σmr^2 is large. By $\tau = I\alpha$, the same torque from the hands gives a **smaller angular acceleration**. Holding it nearer the heavy part reduces r , hence I , so the bat speeds up more easily.

Marking: 1 mark for relating I to distance, 1 mark for $\tau = I\alpha$, 1 mark for the conclusion about α .

Question 6 Pushing a door (2 marks)

a. $\tau = rF \sin\theta = 0.80 \times 30 \times \sin 60^\circ$.

b. $\tau = 24 \times 0.866 = \mathbf{21 \text{ N m}}$ (20.8).

Marking: 1 mark each.

Question 7 Accelerating a wheel (3 marks)

a. $\alpha = \Delta\omega/t = 30 \div 5.0 = \mathbf{6.0 \text{ rad/s}^2}$.

b. $I = \tau/\alpha = 0.60 \div 6.0 = \mathbf{0.10 \text{ kg m}^2}$.

c. $\theta = \frac{1}{2}\alpha t^2 = \frac{1}{2} \times 6.0 \times (5.0)^2 = \mathbf{75 \text{ rad}}$.

Marking: 1 mark each.

Question 8 Hoop or disk (2 marks)

The **disk** has the larger angular acceleration. $I_{\text{hoop}} = MR^2$ and $I_{\text{disk}} = \frac{1}{2}MR^2$, so with the same torque $\alpha = \tau/I$ is **2 times** greater for the disk.

Marking: 1 mark for naming the disk with reference to I ; 1 mark for the factor of 2.