

Rotational energy, rolling and angular momentum

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

Model answers with the mark scheme. Award method marks for correct conservation equations even if the arithmetic slips, and apply the unit mark in each calculation.

Level: AP Physics 1 (algebra-based) · **Curriculum:** AP P1 Unit 6

Question 1 Definitions (2 marks)

- a. $L = I\omega$.
- b. The net external torque on the system must be **zero**.

Marking: 1 mark each.

Question 2 Flywheel (2 marks)

- a. $K = \frac{1}{2}I\omega^2 = \frac{1}{2} \times 0.80 \times (25)^2 = \mathbf{2.5 \times 10^2 \text{ J}}$ (250 J).
- b. $L = I\omega = 0.80 \times 25 = \mathbf{20 \text{ kg m}^2/\text{s}}$.

Marking: 1 mark each, with units.

Question 3 Spinning skater (3 marks)

- a. $I_i\omega_i = I_f\omega_f$; $\omega_f = 3.0 \times 2.4 \div 1.2 = \mathbf{6.0 \text{ rad/s}}$.
- b. $K_i = \frac{1}{2} \times 3.0 \times (2.4)^2 = 8.64 \text{ J}$ and $K_f = \frac{1}{2} \times 1.2 \times 36 = 21.6 \text{ J}$, so the **kinetic energy increases**: she does work pulling her arms inwards.

Marking: (a) 1 mark for the conservation equation, 1 mark for the result; (b) 1 mark for the increase with the reason.

Question 4 Rolling cylinder (3 marks)

- a. $K_{\text{trans}} = \frac{1}{2}mv^2 = \frac{1}{2} \times 2.0 \times 16 = \mathbf{16 \text{ J}}$.
- b. $K_{\text{rot}} = \frac{1}{2} \times \frac{1}{2}MR^2 \times (v/R)^2 = \frac{1}{4}Mv^2 = \mathbf{8.0 \text{ J}}$.
- c. $K_{\text{total}} = 16 + 8.0 = \mathbf{24 \text{ J}}$.

Marking: 1 mark each; allow error carried forward in (c).

Question 5 Racing down a ramp (3 marks)

- a. The **solid disk** reaches the bottom first.

b. Both lose the same gravitational potential energy mgh . A hoop has $I = MR^2$, so a larger share of its energy is kept as rotation and its centre moves slower; the disk has $I = \frac{1}{2}MR^2$, so more energy becomes translation and it reaches a higher speed ($\sqrt{(4gh/3)}$ compared with $\sqrt{(gh)}$).

Marking: (a) 1 mark; (b) 1 mark for equal energy available, 1 mark for the greater share of rotational energy in the hoop.

Question 6 Clay lump on a turntable (3 marks)

a. $I_f = 0.20 + 0.050 = 0.25 \text{ kg m}^2$. $\omega_f = 0.20 \times 6.0 \div 0.25 = \mathbf{4.8 \text{ rad/s}}$.

b. $K_i = \frac{1}{2} \times 0.20 \times 36 = 3.6 \text{ J}$; $K_f = \frac{1}{2} \times 0.25 \times (4.8)^2 = 2.88 \text{ J}$. Lost = **0.72 J**.

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

Question 7 Work by a torque (2 marks)

a. $W = \tau\Delta\theta = 3.0 \times 8.0 = \mathbf{24 \text{ J}}$.

b. $\frac{1}{2}I\omega^2 = 24 \text{ J}$, so $\omega = \sqrt{(2 \times 24 \div 0.30)} = \sqrt{160} = \mathbf{13 \text{ rad/s}}$ (12.6).

Marking: 1 mark each.

Question 8 Ball up a slope (2 marks)

$K_{\text{total}} = \frac{1}{2}mv^2 + (1/5)mv^2 = (7/10)mv^2$. Setting this equal to mgh gives $h = 0.70 v^2/g = 0.70 \times 12.25 \div 9.81 = \mathbf{0.87 \text{ m}}$.

Marking: 1 mark for total kinetic energy in terms of v ; 1 mark for the height.