

Angular momentum and rolling motion

AP Physics C (Mechanics and E&M, calculus-based) · Test answers (mark scheme)

The model answers show where each mark is earned. Method marks are awarded even if the final number is wrong, provided the reasoning is correct. Explanations should link cause and effect rather than list facts.

Level: AP Physics C (Mechanics and E&M, calculus-based) · **Curriculum:** AP PC:M Unit 6

Question 1 Rolling relation (2 marks)

a. $\omega = v/R = 6.0 / 0.25 = \mathbf{24 \text{ rad/s}}$.

b. The top moves at $2v = \mathbf{12 \text{ m/s}}$.

Marking: 1 mark each, with unit.

Question 2 Skater (3 marks)

a. $\omega_2 = 2.4 \times 3.0 / 1.2 = \mathbf{6.0 \text{ rad/s}}$.

b. $K_1 = \frac{1}{2}(2.4)(9.0) = 10.8 \text{ J}$; $K_2 = \frac{1}{2}(1.2)(36) = 21.6 \text{ J}$; $\Delta K = \mathbf{+10.8 \text{ J}}$.

c. Her muscles do work pulling the arms inward.

Marking: (a) answer; (b) both energies and difference; (c) work done by her muscles.

Question 3 Hollow against solid (2 marks)

Both lose the same gravitational potential energy mgh . The hollow cylinder has more of its mass at the rim, so it has a larger I and a larger share of its energy goes into rotation. **Less energy is left for translation, so its speed is lower.**

Marking: same energy (1); larger I means more rotational share (1).

Question 4 Rolling up a slope (3 marks)

Total $K = \frac{1}{2} m v^2 + \frac{1}{2} I \omega^2 = \frac{3}{4} m v^2 = 0.75 \times 0.50 \times 9.0 = 3.375 \text{ J}$. Then $m g h = K$, so $h = 3.375 / (0.50 \times 9.81) = \mathbf{0.69 \text{ m}}$.

Marking: $K = \frac{3}{4} m v^2$ (1); equating to mgh (1); answer with unit (1).

Question 5 Friction and work (2 marks)

The contact point is instantaneously at rest relative to the slope, so the friction force acts through zero displacement. **No work is done, but the force still produces a torque about the centre.**

Marking: contact point at rest (1); torque but no work (1).

Question 6 Two discs (3 marks)

a. $0.40 \times 10 = 1.0 \omega$, so $\omega = \mathbf{4.0 \text{ rad/s}}$.

b. $K_1 = \frac{1}{2}(0.40)(100) = 20 \text{ J}$; $K_2 = \frac{1}{2}(1.0)(16) = 8.0 \text{ J}$; lost **12 J**.

Marking: (a) 1; (b) both energies (1), difference (1).

Question 7 Orbiting satellite (2 marks)

Gravity acts along the line to Earth's centre, so the torque about that point is zero and $L = m v r_{\perp}$ is constant. **Smaller r means larger v at perigee.**

Marking: zero torque, L conserved (1); inverse relation of v and r (1).

Question 8 Torque from L(t) (3 marks)

a. $\tau = dL/dt = 12t^2 = 12 \times 4.0 = \mathbf{48 \text{ N m}}$.

b. $L = 4.0 \times 8.0 = 32$; $\omega = 32 / 6.0 = \mathbf{5.3 \text{ rad/s}}$.

c. It increases L, since the torque is positive and equals its rate of change.

Marking: derivative (1); ω (1); statement (1).