Exercise walk-through

Conservation of Angular Momentum ▪ 6.4

eXercise

You must be able to

- state that **angular momentum 角动量** is conserved when the net external torque is zero
- explain the spinning-skater example (I down, ω up)
- apply conservation of angular momentum to collisions and to a changing rotational inertia

Method — Conservation of angular momentum

When the net external torque is zero, $I_i\omega_i = I_f\omega_f$.

Method — The spinning skater

Pulling the arms in **reduces** I; since $L = I\omega$ stays constant, ω **increases**. Halving I doubles ω.

Method — Adding mass to a turntable

A lump landing on a spinning disc raises I (by mr^2), so ω drops — but L is unchanged.

Practice 2.1 ▪ 1 mark

State the condition for the angular momentum of a system to be conserved.

Solution 2.1

Method: Conservation of angular momentum

Worked steps

the net external torque on the system must be zero **B1**.

Practice 2.2 ▪ 2 marks

A skater with $I = 4.0$ kg m^2 spins at 2.0 rad s^{-1}, then pulls in to $I = 1.0$ kg m^2. Find the new angular velocity.

Solution 2.2

Worked steps

$I_i\omega_i = I_f\omega_f \Rightarrow 4.0(2.0) = 1.0\,\omega_f$, so $\omega_f = 8.0$ rad s^{-1} **M1** **A1**.

Practice 2.3 ▪ 2 marks

Using $L = I\omega$, explain why the skater speeds up.

Solution 2.3

Method: The spinning skater

Worked steps

$L = I\omega$ is conserved; reducing I must raise ω to keep the product constant **B1** **B1**.

Exam-style 3.1 ▪ 1 mark

Angular momentum is conserved when

A kinetic energy is constant

B the net external torque is zero

C the angular velocity is constant

D there is no friction anywhere

Solution 3.1

Method: Conservation of angular momentum

- **A** kinetic energy is constant
- **B** the net external torque is zero ✓
- **C** the angular velocity is constant
- **D** there is no friction anywhere

Worked steps

B.

Exam-style 3.2 ▪ 1 mark

A spinning skater pulls in their arms. Their angular speed

- **A** increases
- **B** decreases
- **C** stays the same
- **D** reverses

Solution 3.2

Method: The spinning skater

A increases ✓

B decreases

C stays the same

D reverses

Worked steps

A.

Exam-style 3.3 ▪ 1 mark

A turntable of $I = 0.10$ kg m^2 spins freely at 6.0 rad s^{-1}. A 0.20 kg lump of clay drops onto it 0.30 m from the axis.

(a) Find the rotational inertia added by the clay ($I = mr^2$).

(b) Find the new angular speed.

Solution 3.3

Method: Adding mass to a turntable

Worked steps

(a) $I_{clay} = mr^2 = 0.20(0.30)^2 = 0.018$ kg m^2 **B1**. (b) $I_i\omega_i = I_f\omega_f \Rightarrow 0.10(6.0) = (0.10 + 0.018)\,\omega_f$, so $\omega_f = \dfrac{0.60}{0.118} = 5.1$ rad s^{-1} **M1** **M1** **A1**.