Exercise walk-through

Newton's Second Law in Rotational Form ▪ 5.6

eXercise

You must be able to

- state **Newton's second law for rotation 转动的牛顿第二定律**, $\tau_{net} = I\alpha$
- determine the **angular acceleration** produced by a given net torque
- explain that a larger **rotational inertia** gives a smaller angular acceleration for the same torque
- analyse systems combining translation and rotation, such as a mass on a pulley

Method — Rotational Newton's second law

$\tau_{net} = I\alpha$ — the rotational analogue of $F = ma$ (with $\tau \leftrightarrow F$, $I \leftrightarrow m$, $\alpha \leftrightarrow a$).

Method — Larger inertia, smaller acceleration

For a fixed net torque, a bigger I gives a smaller α.

Method — Example

A net torque of 6.0 N m on a body of $I = 2.0$ kg m^2 gives $\alpha = \dfrac{6.0}{2.0} = 3.0$ rad s^{-2}.

Practice 2.1 ▪ 1 mark

A net torque of 12 N m acts on a wheel of $I = 3.0$ kg m^2. Find its angular acceleration.

Solution 2.1

Worked steps

$$\alpha = \frac{\tau}{I} = \frac{12}{3.0} = 4.0 \text{ rad s}^{-2}$$ B1.

Practice 2.2 ▪ 1 mark

State how the angular acceleration changes if the rotational inertia doubles for the same torque.

Solution 2.2

Method: Larger inertia, smaller acceleration

Worked steps

it halves ($\alpha \propto 1/I$) B1.

Practice 2.3 ▪ 1 mark

A disc of $I = 0.50$ kg m^2 gains an angular acceleration of 8.0 rad s^{-2}. Find the net torque acting on it.

Solution 2.3

Worked steps

$\tau = I\alpha = 0.50 \times 8.0 = 4.0$ N m **B1**.

Exam-style 3.1 ▪ 1 mark

The rotational form of Newton's second law is

A $F = ma$

B $\tau = I\alpha$

C $p = mv$

D $L = I\omega$

Solution 3.1

Method: Rotational Newton's second law

A $F = ma$

B $\tau = I\alpha$ ✓

C $p = mv$

D $L = I\omega$

Worked steps

B.

Exam-style 3.2 ▪ 1 mark

For a fixed net torque, doubling the rotational inertia makes the angular acceleration

A twice as large

B half as large

C unchanged

D four times as large

Solution 3.2

Method: Larger inertia, smaller acceleration

A twice as large

B half as large ✓

C unchanged

D four times as large

Worked steps

B.

Exam-style 3.3 ▪ 2 marks

A torque of 5.0 N m acts on a disc of rotational inertia 0.25 kg m^2, initially at rest.
(a) Find the angular acceleration.
(b) Find the angular velocity after 4.0 s.

Solution 3.3

Method: Larger inertia, smaller acceleration

Worked steps

(a) $\alpha = \dfrac{5.0}{0.25} = 20$ rad s^{-2} M1 A1. (b) $\omega = \omega_0 + \alpha t = 0 + 20(4.0) = 80$ rad s^{-1} M1 A1.