Exercise walk-through

Newton's Second Law in Rotational Form ▪ 5.6

eXercise

You must be able to

- apply the rotational second law: $\tau_{net} = I\alpha$
- recognise it as the analogue of $F = ma$ (torque   force, I mass, α acceleration)
- find any one of τ, I, α given the other two
- explain why a larger rotational inertia gives a smaller angular acceleration

Method — The rotational second law

$$\tau_{net} = I\alpha.$$

A net torque of 8 N m on a wheel with $I = 2$ kg m^2 gives

$$\alpha = \frac{\tau}{I} = \frac{8}{2} = 4 \text{ rad s}^{-2}.$$

Method — The analogy with $F = ma$

Torque plays the role of force, rotational inertia the role of mass, and angular acceleration the role of acceleration.

Method — Bigger inertia, gentler response

For a fixed torque, a larger I gives a smaller α – a heavy flywheel is hard to spin up.

Practice 2.1 ▪ 2 marks

A torque of 12 N m acts on a body with $I = 3$ kg m^2. Find the angular acceleration.

Solution 2.1

Method: The analogy with F = ma

Worked steps

$\alpha = \tau / I = 12/3 = 4$ rad s^{-2} M1 A1.

Practice 2.2 ▪ 1 mark

State the rotational analogue of mass.

Solution 2.2

Method: The analogy with $F = ma$

Worked steps

Rotational inertia I B1.

Practice 2.3 ▪ 2 marks

What net torque gives a 5 kg m^2 wheel an angular acceleration of 2 rad s^{-2}?

Solution 2.3

Method: The rotational second law

Worked steps

$\tau = I\alpha = 5 \times 2 = 10$ N m M1 A1.

Practice 2.4 ▪ 1 mark

For a fixed torque, how does a larger rotational inertia affect α?

Solution 2.4

Method: Bigger inertia, gentler response

Worked steps

It makes α smaller **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** $W = \tau\theta$

Solution 3.1

Method: The rotational second law

A $F = ma$

B $\tau = I\alpha$ ✓

C $p = mv$

D $W = \tau\theta$

Worked steps

B — $\tau = I\alpha$.

Exam-style 3.2 ▪ 1 mark

A 6 N m torque acts on a wheel with $I = 2$ kg m^2. Its angular acceleration is

A 3 rad s^{-2}

B 12 rad s^{-2}

C 0.33 rad s^{-2}

D 8 rad s^{-2}

Solution 3.2

A 3 rad s^{-2} ✓

B 12 rad s^{-2}

C 0.33 rad s^{-2}

D 8 rad s^{-2}

Worked steps

A — $\alpha = 6/2 = 3$ rad s^{-2}.

Exam-style 3.3 ▪ 2 marks

A grindstone with $I = 0.5$ kg m^2 is driven by a net torque of 4 N m.

(a) Find its angular acceleration.

(b) State what happens to α if the torque is doubled.

Solution 3.3

Worked steps

(a) $\alpha = 4/0.5 = 8$ rad s^{-2} **M1** **A1**. (b) It doubles **B1**.

Exam-style 3.4 ▪ 2 marks

A wheel with $I = 4$ kg m^2 speeds up from rest to 6 rad s^{-1} in 3 s.
(a) Find the angular acceleration.
(b) Find the net torque needed.

Solution 3.4

Worked steps

(a) $\alpha = 6/3 = 2$ rad s^{-2} **M1** **A1**. (b) $\tau = I\alpha = 4 \times 2 = 8$ N m **M1** **A1**.