5.6 Newton's Second Law in Rotational Form

Name: _____ Class: _____ Date: _____ **Total: 15 marks**

Objective

Build the skills to answer exam questions on **Newton's second law in rotational form**.

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

1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

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

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

The analogy with F = ma

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

Bigger inertia, gentler response

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

2 Practice

Now apply the methods above.

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

2.2 State the rotational analogue of mass. [1]

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

2.4 For a fixed torque, how does a larger rotational inertia affect α? [1]

3 Exam-style questions

3.1 The rotational form of Newton's second law is [1]

- **A** $F = ma$
- **B** $\tau = I\alpha$
- **C** $p = mv$
- **D** $W = \tau\theta$

3.2 A 6 N m torque acts on a wheel with $I = 2$ kg m^2. Its angular acceleration is [1]

- **A** 3 rad s^{-2}
- **B** 12 rad s^{-2}
- **C** 0.33 rad s^{-2}
- **D** 8 rad s^{-2}

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

(a) Find its angular acceleration. [2]

(b) State what happens to α if the torque is doubled. [1]

3.4 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. [2]

(b) Find the net torque needed. [2]

4 Go further

You are ready for more on this subtopic:

- work through the interactive **5.6 Newton's Second Law in Rotational Form** lesson on the **Learn** page;
- read the **Torque and Rotational Dynamics** section of the AP Physics C: Mechanics handout on the **Know** page for the full explanation and worked diagrams.

Solutions

2.1 $\alpha = \tau / I = 12/3 = 4$ rad s^{-2}.

2.2 Rotational inertia I.

2.3 $\tau = I\alpha = 5 \times 2 = 10$ N m.

2.4 It makes α smaller.

3.1 **B** —$\tau = I\alpha$.

3.2 **A** —$\alpha = 6/2 = 3$ rad s^{-2}.

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

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