

## 4.1 Rigid bodies and rotational dynamics

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

Total: 10 marks

**KEY WORDS** torque • moment of inertia

### Objective

Rigid bodies and rotational dynamics. Supported HL concept preparation; original classroom practice, not an official IB paper or assessed learner work.

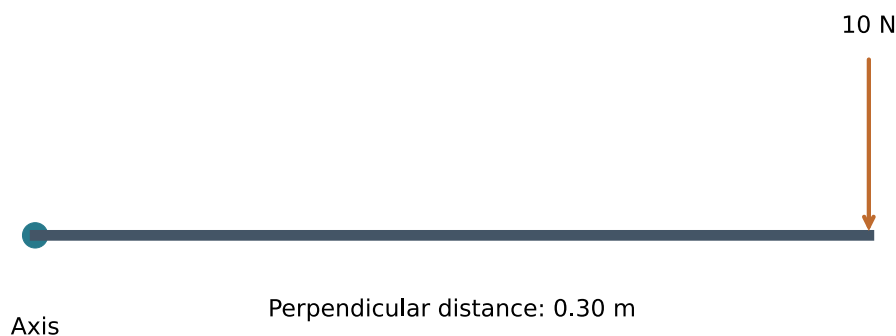
### 1 Key knowledge and worked examples

#### ■ What would explain this observation?

- A door is easier to open when pushed near its outer edge. Force size alone does not determine the turning effect.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

#### ■ Build the model

- **Torque** depends on force and perpendicular distance from the axis. **Moment of inertia** describes resistance to angular acceleration and depends on mass distribution about a stated axis.
- torque: Turning effect about an axis; moment of inertia: Resistance to angular acceleration about a specified axis.



$$\text{Torque} = 3.0 \text{ N m}$$

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### ■ Choose evidence that can test it

- For a rigid body about a fixed axis, net torque equals moment of inertia multiplied by angular acceleration. Rotational kinetic energy depends on angular speed squared. Angular momentum is conserved when net external torque is zero.
- Draw the pivot, force direction and perpendicular lever arm. Do not use the sloping distance from pivot to force point unless it is perpendicular to the force. For experiments, keep rotating parts guarded and loads secure.

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### ■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: a 10 N perpendicular force acts 0.30 m from an axis. Torque = force  $\times$  perpendicular distance =  $10 \times 0.30 = 3.0$  N m. If moment of inertia is 0.60 kg square metres, angular acceleration = torque/inertia =  $3.0/0.60 = 5.0$  radians per second squared.

### Example:

A 12 N force acts perpendicularly 0.25 m from the pivot. Find torque. Use the same sequence: known quantities  $\rightarrow$  model  $\rightarrow$  relation  $\rightarrow$  substitution  $\rightarrow$  unit and interpretation.

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### ■ Check the conclusion and its limits

- Torque has unit N m but is a turning effect, not an energy store. Moment of inertia changes if the same mass moves farther from the axis.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

### Warn:

Moment of inertia depends only on total mass, never its distribution. This claim is false: Torque has unit N m but is a turning effect, not an energy store. Moment of inertia changes if the same mass moves farther from the axis.

### Key:

Rigid bodies and rotational dynamics: For a rigid body about a fixed axis, net torque equals moment of inertia multiplied by angular acceleration. Rotational kinetic energy depends on angular speed squared. Angular momentum is conserved when net external torque is zero.

## 2 Practice

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**2.1** What increases torque for the same perpendicular force? Choose one answer.

- **A** A larger perpendicular lever arm
- **B** A smaller lever arm
- **C** Only changing the colour of the body

[1]

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**2.2** A 12 N force acts perpendicularly 0.25 m from the pivot. Find torque. Show the relation, substitution and units.

[2]

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**2.3** Decide whether this claim is true and justify: Moment of inertia depends only on total mass, never its distribution.

[2]

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**2.4** Turning effect about an axis: write the technical term.

[1]

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### 3 Exam-style questions

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**3.1** A 12 N force acts 0.50 m from a pivot at  $30^\circ$  to the lever. Find torque and compare a perpendicular force at the same radius. [4]

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## Solutions

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**2.1 A** For a rigid body about a fixed axis, net torque equals moment of inertia multiplied by angular acceleration. Rotational kinetic energy depends on angular speed squared. Angular momentum is conserved when net external torque is zero.

**2.2** Torque=force $\times$ perpendicular distance= $12\times 0.25=3.0$  N m.

**2.3** False. Torque has unit N m but is a turning effect, not an energy store. Moment of inertia changes if the same mass moves farther from the axis.

**2.4** torque. torque means Turning effect about an axis.

**3.1** Torque= $rF \sin 30^\circ=3.0$  N m; perpendicular torque= $6.0$  N m. Use the perpendicular moment arm and state the rotation sign convention.