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. Original classroom practice for IB HL; not an official IB paper.

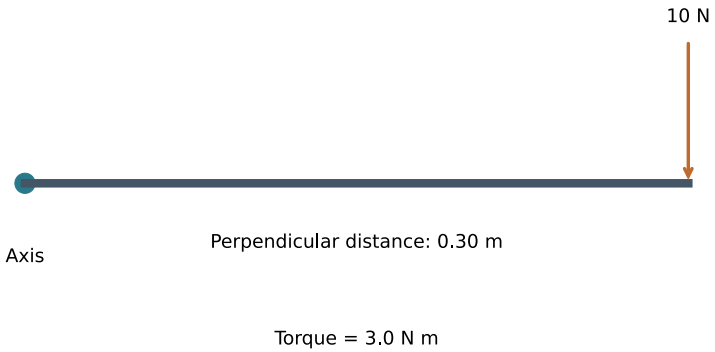
1 Key knowledge and worked examples

■ 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.

■ 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.



■ 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.

In the lab: 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.

■ Work from known quantities

- Known: a 10 N perpendicular force acts 0.30 m from an axis.
- Torque = force × perpendicular distance = 10×0.30 = 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.

Your turn: A 12 N force acts perpendicularly 0.25 m from the pivot. Find torque.

■ 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.

Not true: Moment of inertia depends only on total mass, never its distribution. Moment of inertia depends on how mass is distributed relative to the axis: the same total mass farther from the axis gives a larger moment of inertia. That is why a skater spinning with arms extended slows when the arms are pulled in.

Key:

- Torque depends on force and perpendicular distance from the axis.
- For a rigid body about a fixed axis, net torque equals moment of inertia multiplied by angular acceleration.
- Watch for: torque has unit N m but is a turning effect, not an energy store.

■ Write from a torque of 8 newton metres

- A 20 N force acts perpendicularly 0.40 m from the pivot.
- Find the torque. Moment of inertia depends on how mass is distributed.

2 Practice

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]

2.2 A 12 N force acts perpendicularly 0.25 m from the pivot. Find torque. Show the relation, substitution and units. [2]

2.3 Decide whether this claim is true and justify: Moment of inertia depends on how mass is distributed relative to the axis: the same total mass farther from the axis gives a larger moment of inertia. [2]

2.4 Turning effect about an axis: write the technical term. [1]

3 Exam-style questions

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

Solutions

2.1 A Torque = force x perpendicular distance from the axis, so for the same force a larger perpendicular lever arm gives a larger torque. This is why a longer spanner loosens a tight nut more easily.

2.2 Torque=force×perpendicular distance=12×0.25=3.0 N m.

2.3 True. True. Moment of inertia depends on how mass is distributed relative to the axis: the same total mass farther from the axis gives a larger moment of inertia. That is why a skater spinning with arms extended slows when the arms are pulled in.

2.4 torque. torque means Turning effect about an axis.

3.1 Torque=rF sin30°=3.0 N m; perpendicular torque=6.0 N m. Use the perpendicular moment arm and state the rotation sign convention.