Rigid body mechanics

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

This handout covers selected HL topics for the course first assessed in 2025; it is not the whole syllabus.

Prerequisites: read the stated quantities and units, and use arithmetic and the model conditions below.

The examples are original and fictional: they are not real measurements or real student investigations.

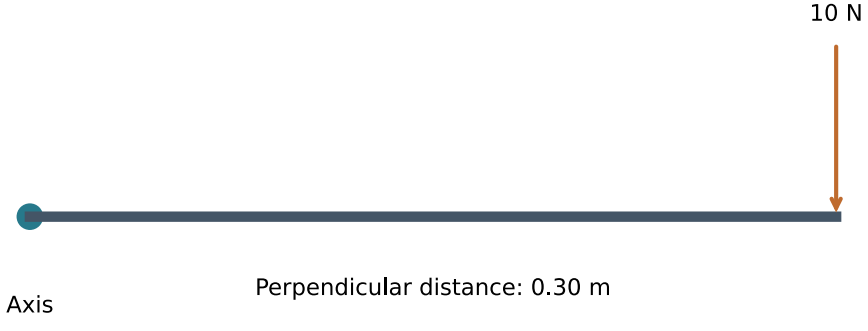
Rigid bodies and rotational dynamics

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.



$$\textit{Torque} = \textit{force} \times \textit{perpendicular distance} = 10\ N \times 0.30\ m = 3.0\ N\ m$$

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. With negligible external torque, a skater spins faster when the arms are pulled inward because the smaller moment of inertia must accompany a larger angular speed.

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.

Write from a conserved angular momentum

- A skater spins with inertia 4.0 kg m^2 at 3.0 rad s^{-1} and pulls her arms in, halving the inertia to 2.0 kg m^2.
- $L = I\omega$ is conserved: $4.0 \times 3.0 = 2.0 \times \omega$, so $\omega = 6.0$ rad s^{-1} – half the inertia, twice the rate.

Write from a balanced seesaw

- A 300 N child sits 2.0 m left of the pivot; a 600 N adult sits on the right.
- Balancing torques: $300 \times 2.0 = 600 \times d$, so $d = 1.0$ m – equal and opposite moments, not equal forces.