

# Rotational inertia and Newton's second law

## AP Physics 1 (algebra-based) · Worksheet

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

These problems build your skill with rotational inertia, torque and Newton's second law for rotation. You will calculate  $I$  for point masses and standard shapes, solve for angular acceleration, and combine rotation with straight-line motion in pulley problems, as in AP Physics 1 unit 5.

Early problems use a single equation; the last ones include experiments and error spotting. Use  $g = 9.81 \text{ m/s}^2$ , choose counterclockwise as positive and give units in every answer.

**Level:** AP Physics 1 (algebra-based) · **Curriculum:** AP P1 Unit 5

### Problem 1 Units and symbols (easy)

State the SI unit of each quantity.

1. Rotational inertia.
2. Torque.
3. Angular acceleration.
4. Explain in one sentence what rotational inertia measures.

### Problem 2 A single point mass (easy)

A 0.40 kg point mass is on a light rod at a distance of 0.50 m from the axis.

1. Calculate its rotational inertia.
2. Calculate the new rotational inertia if the mass is moved to 1.0 m from the axis, and state the factor of increase.

### Problem 3 Torque from a force (easy)

A 25 N force acts at the end of a 0.40 m spanner.

1. Calculate the torque when the force is perpendicular to the spanner.
2. Calculate the torque when the force makes an angle of  $30^\circ$  with the spanner.

### Problem 4 Angular acceleration (easy)

A net torque of 6.0 N m acts on a wheel of rotational inertia  $0.30 \text{ kg m}^2$ .

1. Calculate the angular acceleration.
2. Calculate the time to reach  $40 \text{ rad/s}$  from rest.

**Problem 5 Finding rotational inertia** (easy)

A net torque of 12 N m gives a flywheel an angular acceleration of  $4.0 \text{ rad/s}^2$ .

1. Calculate the rotational inertia of the flywheel.
2. Calculate the angular acceleration if the same torque acts on a flywheel with twice the rotational inertia.

**Problem 6 Hoop and disk** (easy)

A hoop and a solid disk each have mass 2.0 kg and radius 0.30 m.

1. Calculate the rotational inertia of each about its centre.
2. State which one is easier to spin up and explain why.

**Problem 7 Dumbbell axes** (medium)

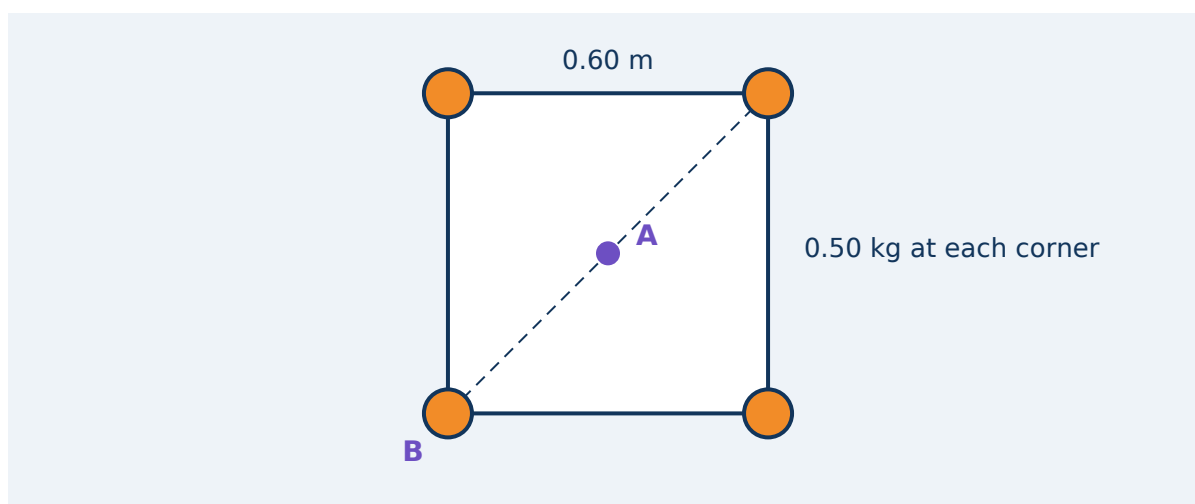
Two 0.80 kg masses are fixed to the ends of a light rod 1.0 m long.

1. Calculate the rotational inertia about an axis through the centre of the rod.
2. Calculate the rotational inertia about an axis through one end.
3. Compare the two values and explain the difference.

**Problem 8 Masses at the corners of a square** (medium)

Four 0.50 kg masses are at the corners of a light square frame of side 0.60 m, as shown.

1. Calculate  $I$  about axis A, through the centre and perpendicular to the frame.
2. Calculate  $I$  about axis B, through a corner and perpendicular to the frame.
3. State which axis would be easier to turn the frame about.



Four equal point masses joined by a light square frame. Axes are perpendicular to the page.

**Problem 9 Pulling a rope on a wheel** (medium)

Bilal in Lahore pulls a rope wound on a wheel of radius 0.25 m with a tangential force of 18 N. The wheel has rotational inertia  $0.50 \text{ kg m}^2$ .

1. Calculate the torque on the wheel.

2. Calculate its angular acceleration.
3. Calculate its angular speed after 3.0 s, starting from rest.

### Problem 10 Slowing a flywheel (medium)

A flywheel of rotational inertia  $0.80 \text{ kg m}^2$  spins at  $60 \text{ rad/s}$  and is brought to rest by a constant friction torque in 12 s.

1. Calculate the angular acceleration.
2. Calculate the friction torque.
3. The friction force acts at a radius of 0.10 m. Calculate its size.

### Problem 11 Solid disk (medium)

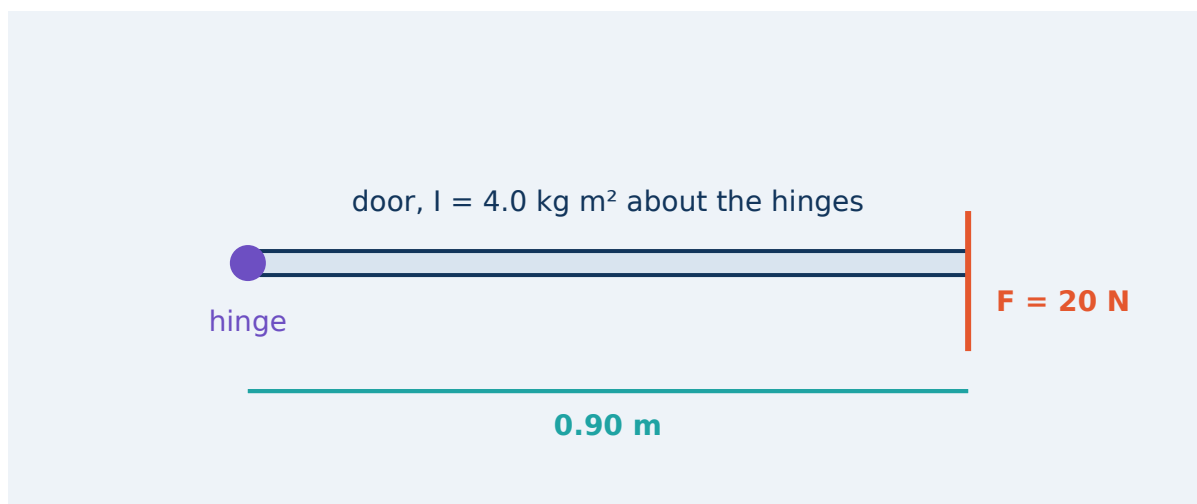
A solid disk has mass 3.0 kg and radius 0.20 m.

1. Calculate its rotational inertia about its centre.
2. Calculate its angular acceleration when a net torque of  $0.30 \text{ N m}$  acts.

### Problem 12 Opening a door (medium)

Mei in Singapore pushes the door shown with a constant  $20 \text{ N}$  force perpendicular to it, at the handle.

1. Calculate the torque about the hinges.
2. Calculate the angular acceleration.
3. Calculate the time to open through  $90^\circ$  ( $\pi/2 \text{ rad}$ ), starting from rest.



*The door starts at rest and turns about the hinges.*

### Problem 13 Choking up on a bat (medium)

A cricketer "chokes up" on the bat by sliding both hands closer to the middle.

1. Explain, using rotational inertia, why the bat is easier to swing.
2. State what happens to the angular acceleration for the same torque.

**Problem 14 Pulley and a hanging mass** (medium)

A 1.5 kg mass hangs from a string wound on a solid disk pulley of mass 2.0 kg and radius 0.050 m.

1. Calculate the rotational inertia of the pulley.
2. Calculate the acceleration of the mass.
3. Calculate the tension and the angular acceleration of the pulley.

**Problem 15 Two masses and a pulley** (hard)

Masses of 3.0 kg and 1.0 kg hang on either side of a solid disk pulley (mass 2.0 kg, radius 0.10 m). The string does not slip.

1. Calculate the acceleration of the masses.
2. Calculate the tension on each side.
3. Show that the difference between the tensions gives the correct torque on the pulley.

**Problem 16 Falling rod** (hard)

A uniform rod of mass 1.2 kg and length 0.80 m is pivoted at one end and released from rest in a horizontal position. Its weight acts at the centre.

1. Calculate the torque of the weight about the pivot.
2. Calculate the initial angular acceleration.
3. Calculate the initial acceleration of the free end and compare it with  $g$ .

**Problem 17 Unwinding from a cylinder** (hard)

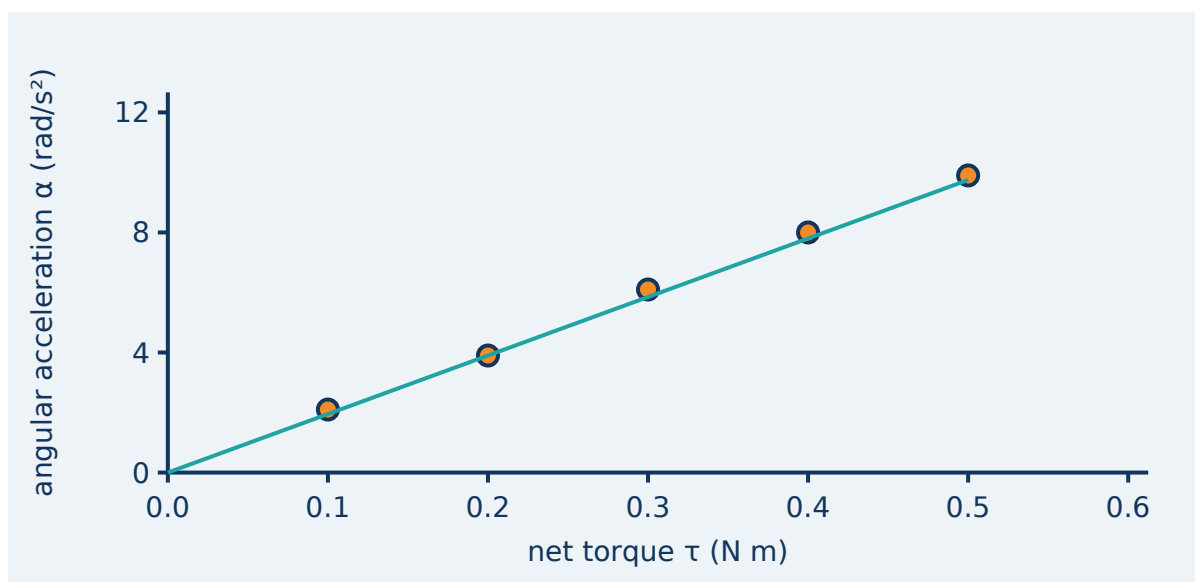
A string is wound around a solid cylinder of mass 0.50 kg and radius 0.040 m. The free end is held fixed, and the cylinder is released so that it falls while the string unwinds.

1. Write the equation for the vertical motion of the cylinder.
2. Write the rotational equation about the centre and use  $a = R\alpha$ .
3. Calculate the acceleration and the string tension.

**Problem 18 Analysing an experiment** (hard)

Kofi in Accra applies five different net torques to a solid disk of mass 0.80 kg and radius 0.36 m and records the angular acceleration. The data are plotted.

1. Use the first and last points to calculate the gradient of the graph.
2. Calculate the rotational inertia from the gradient.
3. Calculate the theoretical rotational inertia and the percentage difference.



Best-fit line drawn through the origin.

### Problem 19 Spot the error (hard)

Emma in Leeds says: "A hoop and a disk have the same mass and radius. With the same torque of 2.0 N m, the hoop spins up faster because it has more of its mass at the edge." The mass is 4.0 kg and the radius is 0.50 m.

1. Identify her error.
2. Calculate the angular acceleration of each.
3. State the ratio of the two angular accelerations.

### Problem 20 Child on a roundabout (hard)

A playground roundabout is a solid disk of rotational inertia 200 kg m<sup>2</sup> and radius 2.0 m. A 30 kg child sits 1.5 m from the axis while an adult pushes tangentially at the rim with 80 N.

1. Calculate the net torque.
2. Calculate the total rotational inertia and the angular acceleration.
3. Calculate the angular acceleration if the child moves to 0.50 m from the axis, and explain the change.