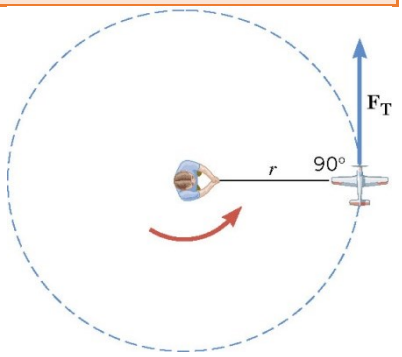
Physics 03-05 Moment of Inertia — *Name:* _____

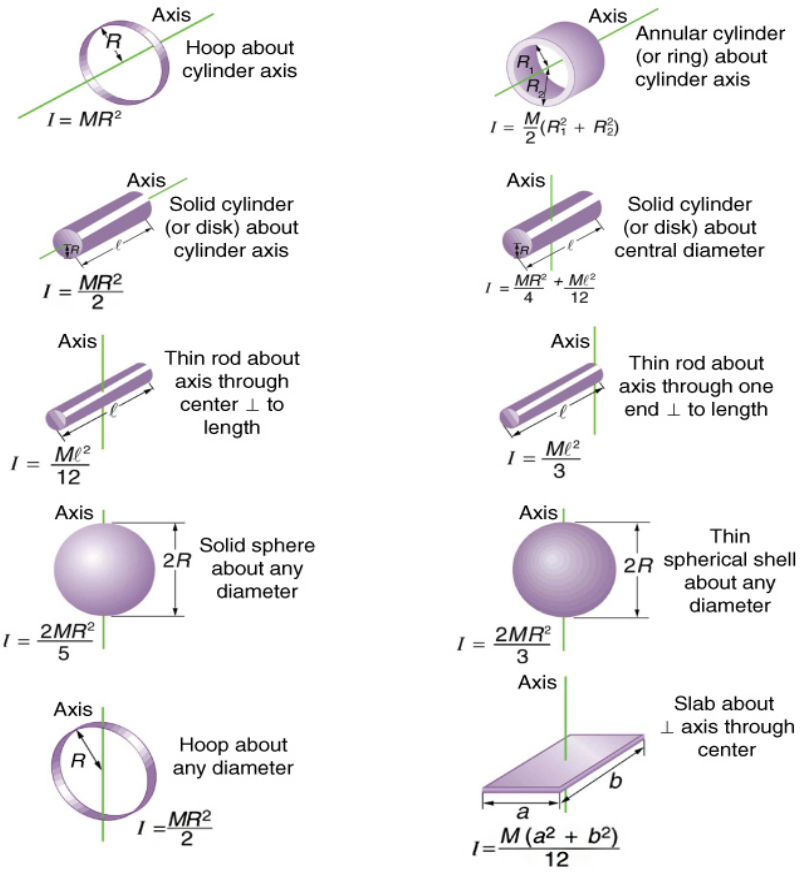
Dynamics of Rotational Motion



Newton's Second Law for Rotation

- _____
  - α is in _____
- $I = mr^2$ → Moment of _____ of a _____
- Moment of Inertia (I) measures how much an _____ wants to keep _____ (or not start _____)
  - Use _____ to find $I = \sum mr^2$
  - Unit: _____

The St. Joseph River Swing Bridge in St. Joseph, Michigan has a mass of 300 tons (2.72×10^5 kg) and is 231 ft (70.4 m) long. If the motor produces 563 kNm of torque and takes 10 s to accelerate the bridge to 0.05 rad/s, what is the bridge's moment of inertia?



A spinning ride at a carnival is accelerating at 4 rad/s^2. If the ride is shaped like a hoop, and the motor is exerting 128000 Nm of torque, what is the radius of the 500 kg ride?

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Practice Work

1. The moment of inertia of a long rod spun around an axis through one end perpendicular to its length is $\frac{ML^2}{3}$. Why is this moment of inertia greater than it would be if you spun a point mass *M* at the location of the center of mass of the rod (at $\frac{L}{2}$)? (That would be $\frac{ML^2}{4}$.)
2. Why is the moment of inertia of a hoop that has a mass *M* and a radius *R* greater than the moment of inertia of a disk that has the same mass and radius? Why is the moment of inertia of a spherical shell that has a mass *M* and a radius *R* greater than that of a solid sphere that has the same mass and radius?
3. Give an example in which a small force exerts a large torque. Give another example in which a large force exerts a small torque.
4. While reducing the mass of a racing bike, the greatest benefit is realized from reducing the mass of the tires and wheel rims. Why does this allow a racer to achieve greater accelerations than would an identical reduction in the mass of the bicycle's frame?
5. Calculate the moment of inertia of a skater given the following information. (a) The 60.0-kg skater is approximated as a cylinder that has a 0.110-m radius. (b) The skater with arms extended is approximately a cylinder that is 52.5 kg, has a 0.110-m radius, and has two 0.900-m-long arms which are 3.75 kg each and extend straight out from the cylinder like rods rotated about their ends. (OpenStax 10.11) $\mathbf{0.363\ kg \cdot m^2}$, $\mathbf{2.34\ kg \cdot m^2}$
6. The triceps muscle in the back of the upper arm extends the forearm. This muscle in a professional boxer exerts a force of 2.00×10^3 N with an effective perpendicular lever arm of 3.00 cm, producing an angular acceleration of the forearm of 120 rad/s^2. What is the moment of inertia of the boxer's forearm? (OpenStax 10.12) $\mathbf{0.500\ kg \cdot m^2}$
7. A soccer player extends her lower leg in a kicking motion by exerting a force with the muscle above the knee in the front of her leg. She produces an angular acceleration of 30.00 rad/s^2 and her lower leg has a moment of inertia of 0.750 kg · m^2. What is the force exerted by the muscle if its effective perpendicular lever arm is 1.90 cm? (OpenStax 10.13) $\mathbf{1.18 \times 10^3\ N}$
8. Suppose you exert a force of 180 N tangential to a 0.280-m-radius 75.0-kg grindstone (a solid disk). (a) What torque is exerted? (b) What is the angular acceleration assuming negligible opposing friction? (c) What is the angular acceleration if there is an opposing frictional force of 20.0 N exerted 1.50 cm from the axis? (OpenStax 10.14) $\mathbf{50.4\ N \cdot m}$, $\mathbf{17.1\ rad/s^2}$, $\mathbf{17.0\ rad/s^2}$
9. Consider the 12.0 kg motorcycle wheel shown in Figure 1. Assume it to be approximately an annular ring with an inner radius of 0.280 m and an outer radius of 0.330 m. The motorcycle is on its center stand, so that the wheel can spin freely. (a) If the drive chain exerts a force of 2200 N at a radius of 5.00 cm, what is the angular acceleration of the wheel? (b) What is the tangential acceleration of a point on the outer edge of the tire? (c) How long, starting from rest, does it take to reach an angular velocity of 80.0 rad/s? (OpenStax 10.15) $\mathbf{97.9\ \frac{rad}{s^2}}$, $\mathbf{32.3\ \frac{m}{s^2}}$, $\mathbf{0.817\ s}$
10. A child rolls a full can of cream of mushroom soup by applying a 2.00 N force tangential to the edge of the can. The can's diameter is 8.25 cm and its height is 10.8 cm. Its mass is 298 grams. What is the angular acceleration of the can? (RW) $\mathbf{325\ rad/s^2}$

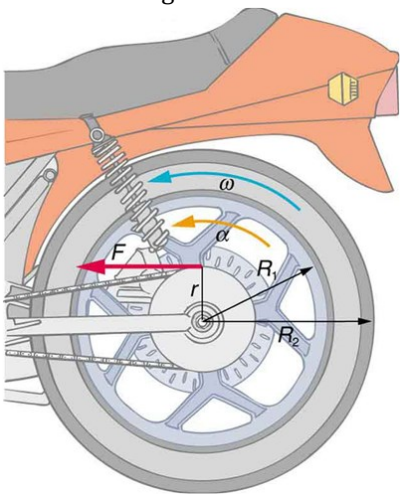

Figure 1