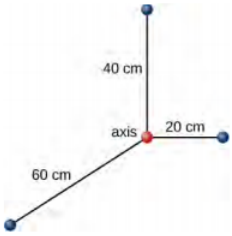
11.E: Fixed-Axis Rotation Introduction (Exercises)

Conceptual Questions

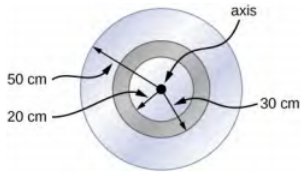
1. A baseball bat is swung. Do all points on the bat have the same angular velocity? The same tangential speed?
2. What if another planet the same size as Earth were put into orbit around the Sun along with Earth. Would the moment of inertia of the system increase, decrease, or stay the same?
3. A solid sphere is rotating about an axis through its center at a constant rotation rate. Another hollow sphere of the same mass and radius is rotating about its axis through the center at the same rotation rate. Which sphere has a greater rotational kinetic energy?
4. What three factors affect the torque created by a force relative to a specific pivot point?
5. Give an example in which a small force exerts a large torque. Give another example in which a large force exerts a small torque.
6. When 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?
7. Can a single force produce a zero torque?
8. Can a set of forces have a net torque that is zero and a net force that is not zero?
9. Can a set of forces have a net force that is zero and a net torque that is not zero?
10. In the expression $\vec{r} \times \vec{F}$ can $|\vec{r}|$ ever be less than the lever arm? Can it be equal to the lever arm?

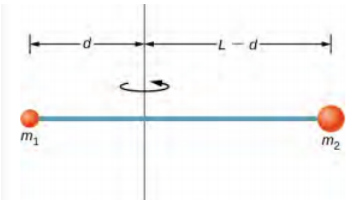
Problems

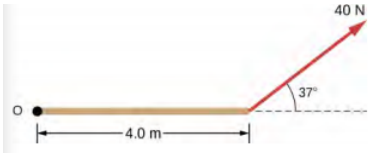
11. At its peak, a tornado is 60.0 m in diameter and carries 500 km/h winds. What is its angular velocity in revolutions per second?
12. A man stands on a merry-go-round that is rotating at 2.5 rad/s. If the coefficient of static friction between the man's shoes and the merry-go-round is μS = 0.5, how far from the axis of rotation can he stand without sliding?
13. An ultracentrifuge accelerates from rest to 100,000 rpm in 2.00 min. (a) What is the average angular acceleration in rad/s^2? (b) What is the tangential acceleration of a point 9.50 cm from the axis of rotation? (c) What is the centripetal acceleration in m/s^2 and multiples of g of this point at full rpm? (d) What is the total distance traveled by a point 9.5 cm from the axis of rotation of the ultracentrifuge?
14. A wind turbine is rotating counterclockwise at 0.5 rev/s and slows to a stop in 10 s. Its blades are 20 m in length. (a) What is the angular acceleration of the turbine? (b) What is the centripetal acceleration of the tip of the blades at t = 0 s? (c) What is the magnitude and direction of the total linear acceleration of the tip of the blades at t = 0 s?
15. What is (a) the angular speed and (b) the linear speed of a point on Earth's surface at latitude 30° N. Take the radius of the Earth to be 6309 km. (c) At what latitude would your linear speed be 10 m/s?
16. A child with mass 30 kg sits on the edge of a merrygo-round at a distance of 3.0 m from its axis of rotation. The merry-go-round accelerates from rest up to 0.4 rev/s in 10 s. If the coefficient of static friction between the child and the surface of the merry-go-round is 0.6, does the child fall off before 5 s?
17. A bicycle wheel with radius 0.3m rotates from rest to 3 rev/s in 5 s. What is the magnitude and direction of the total acceleration vector at the edge of the wheel at 1.0 s?
18. The angular velocity of a flywheel with radius 1.0 m varies according to $\omega(t) = 2.0t$. Plot $a_c(t)$ and $a_t(t)$ from t = 0 to 3.0 s for r = 1.0 m. Analyze these results to explain when $a_c >> a_t$ and when $a_c << a_t$ for a point on the flywheel at a radius of 1.0 m.
19. A system of point particles is shown in the following figure. Each particle has mass 0.3 kg and they all lie in the same plane. (a) What is the moment of inertia of the system about the given axis? (b) If the system rotates at 5 rev/s, what is its rotational kinetic energy?



20. (a) Calculate the rotational kinetic energy of Earth on its axis. (b) What is the rotational kinetic energy of Earth in its orbit around the Sun? (We will assume that Earth is a uniform sphere, which isn't quite right.)
21. A tire (15-kg) with a 0.3m radius comes off of a car traveling at 30 m/s and is rolling down the road straight at you. What is the magnitude and direction of the angular velocity? What is the tire's rotational kinetic energy? What is the tire's total kinetic energy (rotational and translational)? (Treat the tire as a disk.)
22. Calculate the rotational kinetic energy of a 12-kg motorcycle wheel if its angular velocity is 120 rad/s and its inner radius is 0.280 m and outer radius 0.330 m.
23. A baseball pitcher throws the ball in a motion where there is rotation of the forearm about the elbow joint as well as other movements. If the linear velocity of the ball relative to the elbow joint is 20.0 m/s at a distance of 0.480 m from the joint and the moment of inertia of the forearm is 0.500 kg-m^2, what is the rotational kinetic energy of the forearm?
24. A diver goes into a somersault during a dive by tucking her limbs. If her rotational kinetic energy is 100 J and her moment of inertia in the tuck is 9.0 kg • m^2, what is her rotational rate during the somersault?
25. An aircraft is coming in for a landing at 300 meters height when the propeller falls off. The aircraft is flying at 40.0 m/s horizontally. The propeller has a rotation rate of 20 rev/s, a moment of inertia of 70.0 kg • m^2, and a mass of 200 kg. Neglect air resistance. (a) With what translational velocity does the propeller hit the ground? (b) What is the rotation rate of the propeller at impact?
26. A 30kg snowman rolls down an 11m high hill. (Assume snowman starts from rest at the top of the hill.) How fast is the snowman going at the bottom? Assume the snowman is a cylinder with radius 0.5m
27. How fast does a 300g, r=4cm yo-yo need to be spinning so that it can make it back up to your hand if the string is 1.0m long?
28. If air resistance is present in the preceding problem and reduces the propeller's rotational kinetic energy at impact by 30%, what is the propeller's rotation rate at impact?
29. A neutron star of mass 2 x 10^{30} kg and radius 10 km rotates with a period of 0.02 seconds. What is its rotational kinetic energy?
30. An electric sander consisting of a rotating disk of mass 0.7 kg and radius 10 cm rotates at 15 rev/s. When applied to a rough wooden wall the rotation rate decreases by 20%. (a) What is the final rotational kinetic energy of the rotating disk? (b) How much has its rotational kinetic energy decreased?
31. A system consists of a disk of mass 2.0 kg and radius 50 cm upon which is mounted an annular cylinder of mass 1.0 kg with inner radius 20 cm and outer radius 30 cm (see below). The system rotates about an axis through the center of the disk and annular cylinder at 10 rev/s. (a) What is the moment of inertia of the system? (b) What is its rotational kinetic energy?







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