Physics 201 Examples 9

Feb 27, 2013

1. During a tennis serve, a racket is given an angular acceleration of magnitude 160 rad/s^2. At the top of the serve, the racket has an angular speed of 14 rad/s. If the distance between the top of the racket and the shoulder is 1.5 m, find the magnitude of the total acceleration of the top of the racket.

380 m/s^2

2. Two disks are rotating about the same axis. Disk A has a moment of inertia of 3.4 kg-m^2 and an angular velocity of +7.2 rad/s. Disk B is rotating with an angular velocity of -9.8 rad/s. The two disks are then linked together without the aid of any external torques, so that they rotate as a single unit with an angular velocity of -2.4 rad/s. The axis of rotation for this unit is the same as that for the separate disks. What is the moment of inertia of disk B?

4.4 kg-m^2

3. In 9.5 seconds a fisherman winds 2.6 meters of fishing line onto a reel whose radius is 3.0 cm (assumed to be constant as an approximation). The line is being reeled in at a constant speed. Determine the angular speed of the reel.

9.12 rad/s

4. In a large centrifuge used for training pilots and astonauts, a small chamber is fixed at the end of a rigid arm that rotates in a horizontal circle. A trainee riding in the chamber of a centrifuge rotating with a constant angular speed of 2.5 rad/s experiences a centripetal acceleration of 3.2 times the acceleration due to gravity. In a second training exercise, the centrifuge speeds up from rest with a constant angular acceleration. When the centrifuge reaches an angular speed of 2.5 rad/s, the trainee experiences a total acceleration equal to 4.8 times the acceleration due to gravity. (a) How long is the arm of the centrifuge? (b) What is the angular acceleration of the centrifuge in the second training exercise?

(a) 5.0 meters
(b) 7.0 rad/s^2

5. The differential gear of a car axle allows the wheel on the left side of a car to rotate at a different angular speed than the wheel on the right side. A car is driving at a constant speed around a circular track on level ground, completing each lap in 19.5 seconds. The distance between the tires on the left and right sides of the car is 1.60 meters, and the radius of each wheel is 0.350 meters. What is the difference between the angular speeds of the wheels on the left and the right sides of the car?

1.47 rad/s

6. A 15.0-meter length of hose is wound around a reel, which is initially at rest. The moment of inertia of the reel is 0.44 kg-m^2, and its radius is 0.160 meters. When the reel is turning, friction at the axle exerts a torque of magnitude 3.40 newton-meters on the reel. If the hose is pulled so that the tension in it remains a constant 25.0 netwtons, how long does it take to completely unwind the hose from the reel? Neglect the mass of the hose, and assume that the hose unwinds without slipping.

12 seconds

7. Starting from rest, a basketball rolls from the top of a hill to the bottom, reaching a translational speed of 6.6 m/s. Ignore frictional losses. (a) What is the height of the hill? (b) Released from rest at the same height, a can of frozen juice rolls to the bottom of the same hill. What is the translational speed of the frozen juice can when it reaches the bottom?

(a) 3.7 meters
(b) 7.0 m/s

8. A tennis ball, starting from rest, rolls down the hill in Figure 1. At the end of the hill the ball becomes airborne, leaving at an angle of 35° with respect to the ground. Treat the ball as a thin-walled spherical shell, and determine the range x.

2.0 meters

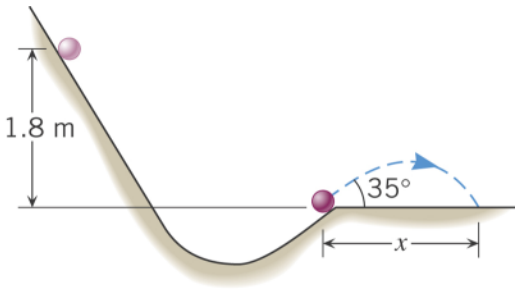

Figure 1: Problem 9.58

9. As seen from above, a playground carousel is rotating counterclockwise about its center on frictionless bearings. A person standing still on the ground grabs onto one of the bars on the carousel very close to its outer edge and climbs aboard. Thus, this person begins with an angular speed of zero and ends up with a nonzero angular speed, which means that he underwent a counterclockwise angular acceleration. The carousel has a radius of 1.50 meters, an initial angular speed of 3.14 rad/s, and a moment of inertia of 125 kg-m^2. The mass of the person is 40.0 kilograms. Find the final angular speed of the carousel after the person climbs aboard.

1.83 rad/s

10. Figure 2 shows a model for the motion of the human forearm in throwing a dart. Because of the force $\vec{M}$ applied by the triceps muscle, the forearm can rotate about an axis at the elbow joint. Assume that the forearm has the dimensions shown in the drawing and a moment of inertia of 0.065 kg-m^2 (including the effect of the dart) relative to the axis at the elbow. Assume also that the force $\vec{M}$ acts perpendicular to the forearm. Ignoring the effect of gravity and any frictional forces, determine the magnitude of the force $\vec{M}$ needed to give the dart a tangential speed of 5.0 m/s in 0.10 seconds, starting from rest.

460 newtons

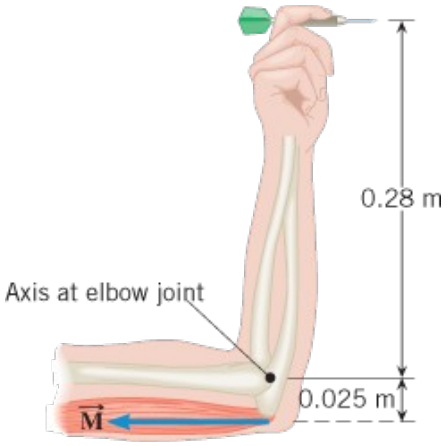

Figure 2: Problem 9.40

11. The crane shown in Figure 3 is lifting a 180 kilogram crate upward with an acceleration of 1.2 m/s^2. The cable from the crate passes over a solid cylindrical pulley at the top of the boom. The pulley has a mass of 130 kilograms. The cable is then wound onto a hollow cylindrical drum that is mounted on the deck of the crane. The mass of the drum is 150 kilograms, and its radius is 0.76 meters. The engine applies a counterclockwise torque to the drum in order to wind up the cable. What is the magnitude of this torque? Ignore the mass of the cable.

1700 newton-meters

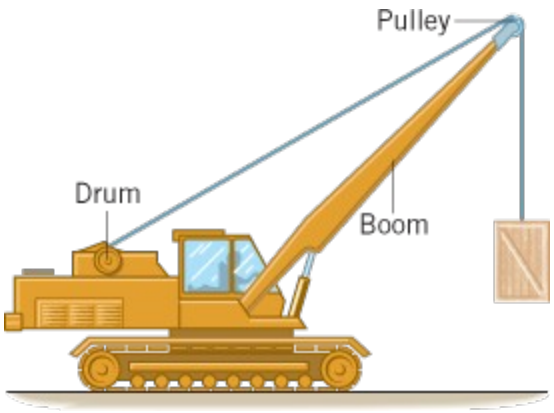

Figure 3: Problem 9.47

12. Calculate the kinetic energy that the earth has because of (a) its rotation about its own axis and (b) its motion around the sun. Assume the earth is a uniform sphere and that its path around the sun is circular. For comparison, the total energy used in the United States in one year is about 1.1×10^{20} joules.

(a) 2.57×10^{29} joules
(b) 2.67×10^{33} joules

13. A flywheel is a solid disk that rotates about an axis that is perpendicular to the disk at its center. Rotating flywheels provide a means for storing energy in the form of rotational kinetic energy and are being considered as a possible alternative to batteries in electric cars. The gasoline burned in a 300 mile trip in a typical midsize car produces about 1.2×10^9 joules of energy. How fast would a 13 kilogram flywheel with a radius of 0.30 meters have to rotate to store this much energy? Give your answer in rev/min.

610,000 rpm

14. When some stars use up their fuel, they undergo a catastrophic explosion called a **supernova**. This explosion blows much or all of the star's mass outward, in the form of a rapidly expanding spherical shell. As a simple model of the supernova process, assume that the star is a solid sphere that is initially rotating at 2.0 revolutions per day. After the star explodes, find the angular velocity, in revolutions per day, of the expanding supernova shell when its radius is 4.0 times the original radius. Assume that all of the star's original mass is contained in the shell.

0.075 revolutions per day

15. A cylindrically shaped space station is rotating about the axis of the cylinder to create artificial gravity. The radius of the cylinder is 82.5 meters. The moment of inertia of the station without people is 3.00×10^9 kg-m^2. Suppose that 500 people, with an average mass of 70.0 kilograms each, live on this station. As they move radially from the outer surface of the cylinder toward the axis, the angular speed of the station changes. What is the maximum possible percentage change in the station's angular speed due to the radial movement of the people?

8%

16. A thin, uniform rod is hinged at its midpoint. To begin with, one-half of the rod is bent upward and is perpendicular to the other half. This bent object is rotating at an angular velocity of 9.0 rad/s about an axis that is perpendicular to the left end of the rod and parallel to the rod's upward half (see Figure 4). Without the aid of external torques, the rod suddenly assumes its straight shape. What is the angular velocity of the straight rod?

4.5 rad/s

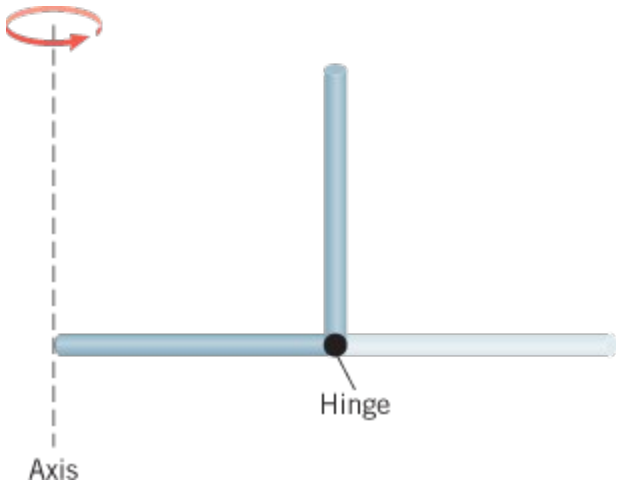

Figure 4: Problem 9.66

17. A small 0.500 kilogram object moves on a frictionless horizontal table in a circular path of radius 1.00 meters. The angular speed is 6.28 rad/s. The object is attached to a string of negligible mass that passes through a small hole in the table at the center of the circle. Someone under the table begins to pull the string downward to make the circle smaller. If the string will tolerate a tension of no more than 105 newtons, what is the radius of the smallest possible circle on which the object can move?

0.573 meters

18. A solid disk rotates in the horizontal plane at an angular velocity of 0.067 rad/s with respect to an axis perpendicular to the disk at its center. The moment of inertia of the disk is 0.10 kg-m^2. From above, sand is dropped straight down onto this rotating disk, so that a thin uniform ring of sand is formed at a distance of 0.40 meters from the axis. The sand in the ring has a mass of 0.50 kilograms. After all the sand is in place, what is the angular velocity of the disk?

0.037 rad/s

19. A thin, rigid, uniform rod has a mass of 2.00 kilograms and a length of 2.00 meters. (a) Find the moment of inertia of the rod relative to an axis that is perpendicular to the rod at one end. (b) Suppose all the mass of the rod were located at a single point. Determine the perpendicular distance of this point from the axis in part (a), such that this point particle has the same moment of inertia as the rod does. This distance is called the **radius of gyration** of the rod.

(a) 2.67 kg-m^2
(b) 1.16 meters

20. By means of a rope whose mass is negligible, two blocks are suspended over a pulley as Figure 5 shows. The pulley can be treated as a uniform solid cylindrical disk. The downward acceleration of the 44.0 kilogram block is observed to be exactly one-half the acceleration due to gravity. Noting that the tension in the rope is not the same on each side of the pulley, find the mass of the pulley.

22.0 kilograms

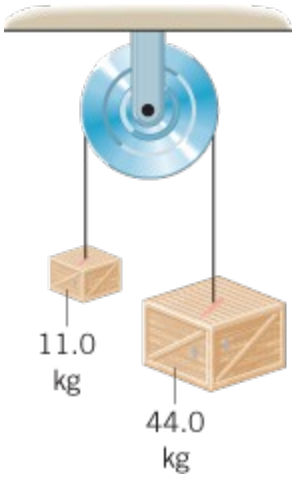

Figure 5: Problem 9.80

21. A horizontal disk with mass 2.0 kg has a radius of 0.10 m. Around the circumference is a string that runs over a pulley supporting a 0.25 kg mass. From rest, how long does it take the mass to fall 1.0 m?

1.0 s

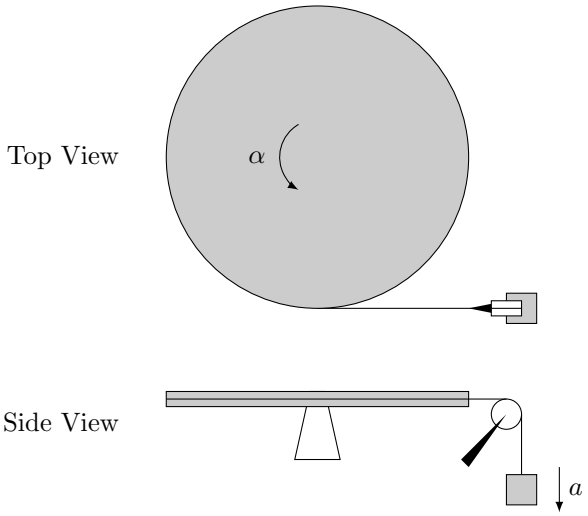

Figure 6: Flywheel and pulley

22. A 5.0-kilogram wheel with radius of gyration 0.20 meters is to be given an angular speed of 10 rev/s in 25 revolutions from rest. Find the constant unbalanced torque required.

2.5 newton-meters