Tutorial Physics 1 Week 6

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Rotational Motion

1 Figure 10-19 is a graph of the angular velocity versus time for a disk rotating like a merry-go-round. For a point on the disk rim, rank the instants a, b, c, and d according to the magnitude of the (a) tangential and (b) radial acceleration, greatest first.

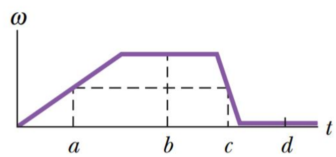

Fig. 10-19 Question 1.

6 In the overhead view of Fig. 10-23, five forces of the same magnitude act on a strange merry-go-round; it is a square that can rotate about point P, at midlength along one of the edges. Rank the forces according to the magnitude of the torque they create about point P, greatest first.

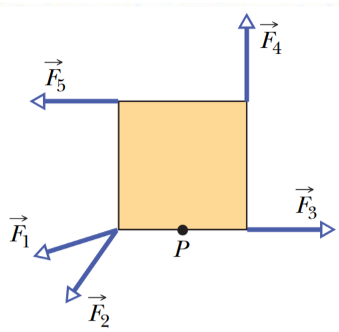

Fig. 10-23 Question 6.

10 Figure 10-26 shows three flat disks (of the same radius) that can rotate about their centers like merry-go-rounds. Each disk consists of the same two materials, one denser than the other (density is mass per unit volume). In disks 1 and 3, the denser material forms the outer half of the disk area. In disk 2, it forms the inner half of the disk area. Forces with identical magnitudes are applied tangentially to the disk, either at the outer edge or at the interface of the two materials, as shown. Rank the disks according to (a) the torque about the disk center, (b) the rotational inertia about the disk center, and (c) the angular acceleration of the disk, greatest first.

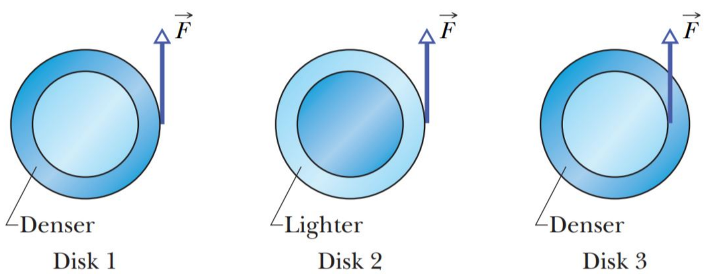

Fig. 10-26 Question 10.

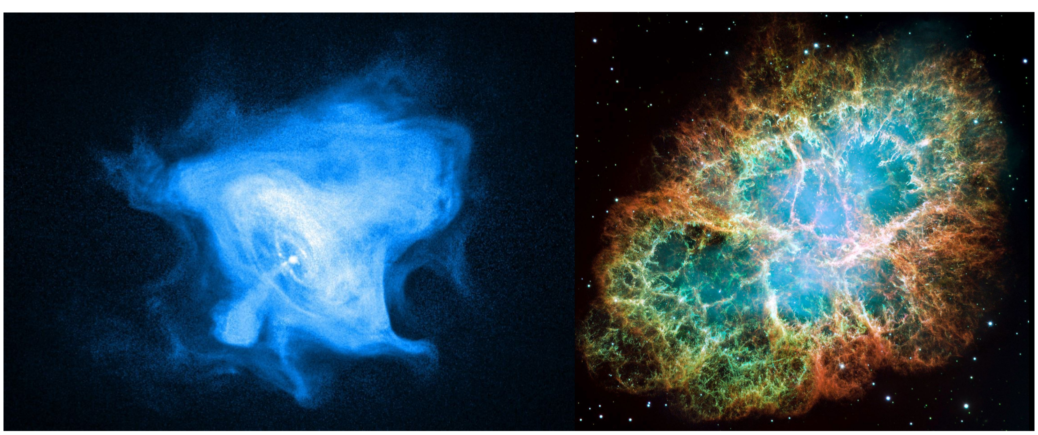

Figure 1: The crab pulsar (left) viewed in x-rays, sits in the centre of (and is much smaller than) the crab nebula (right) seen here in optical. The supernova explosion which created the crab nebula and pulsar shone bright enough to be visible during the day. It is recorded in contemporary Chinese, Japanese, and Islamic literature, fading after about 2 years.

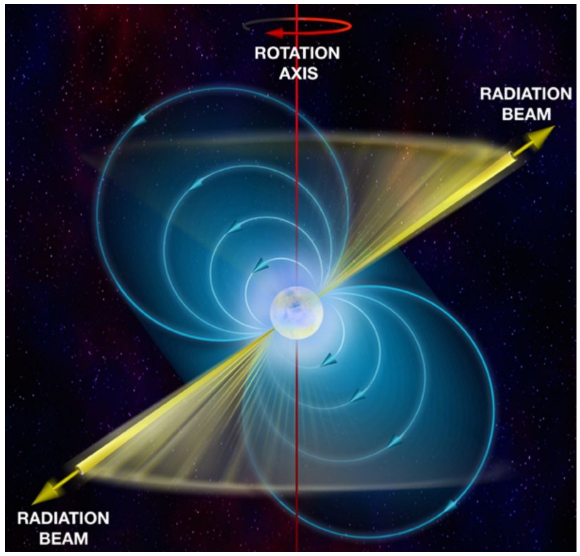

Figure 2: **Adapted from HRW 10.32**. A neutron star is a type of stellar remnant left behind after a large star dies. We will explore this concept over the next couple of weeks. A pulsar is a rapidly rotating neutron star that emits a beam of radio emission from its magnetic pole. Similar to Earth, the rotational poles do not exactly match the magnetic poles. The result for the neutron star is that the radio emission beam flashes an observer once every rotation period, just like a lighthouse. The period of rotation of the star is found by measuring the time between pulses.

(a) A neutron star is roughly the mass of the sun, but a diameter of just 20km!! How does this compare to the diameter of the sun?

  i) The crab pulsar has a rotation period of $T = 0.033$ s. What is the rotation frequency?

  ii) What is the equatorial velocity at the surface of the crab pulsar? Is this fast? Express your answer in terms of c.

  iii) What is the rotational kinetic energy of the star?

(b) Astronomers have determined that the crab's rotation period is increasing by $\dot{T} = 1.26 \times 10^{-5}$ seconds per year. Units!!

  i) What is the pulsar's angular acceleration, α?

  ii) If α is constant, how many years from now will the pulsar stop rotating?

  iii) The pulsar was created during the supernova explosion seen in the year 1054, assuming constant α, find the initial rotation period T_0.

(c) Repeat part a) with your new orbital period T_0.

  i) How much rotational energy has been lost? Where did it go?

(d) What assumptions have you made (either implicitly or explicitly) in solving parts a) - c)?

Moments of Inertia

••41 GO In Fig. 10-37, two particles, each with mass $m = 0.85$ kg, are fastened to each other, and to a rotation axis at O, by two thin rods, each with length $d = 5.6$ cm and mass $M = 1.2$ kg. The combination rotates around the rotation axis with the angular speed $\omega = 0.30$ rad/s. Measured about O, what are the combination's (a) rotational inertia and (b) kinetic energy?

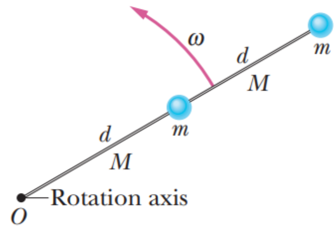

Figure 10-37 Problem 41.

Rolling Motion

•3 SSM A 140 kg hoop rolls along a horizontal floor so that the hoop's center of mass has a speed of 0.150 m/s. How much work must be done on the hoop to stop it?

Additional Problems

••4 The angular position of a point on a rotating wheel is given by $\theta = 2.0 + 4.0t^2 + 2.0t^3$, where θ is in radians and t is in seconds. At $t = 0$, what are (a) the point's angular position and (b) its angular velocity? (c) What is its angular velocity at $t = 4.0$ s? (d) Calculate its angular acceleration at $t = 2.0$ s. (e) Is its angular acceleration constant?

••25 SSM (a) What is the angular speed ω about the polar axis of a point on Earth's surface at latitude 40° N? (Earth rotates about that axis.) (b) What is the linear speed v of the point? What are (c) ω and (d) v for a point at the equator?

•••7 The wheel in Fig. 10-27 has eight equally spaced spokes and a radius of 30 cm. It is mounted on a fixed axle and is spinning at 2.5 rev/s. You want to shoot a 20-cm-long arrow parallel to this axle and through the wheel without hitting any of the spokes. Assume that the arrow and the spokes are very thin. (a) What minimum speed must the arrow have? (b) Does it matter where between the axle and rim of the wheel you aim? If so, what is the best location?

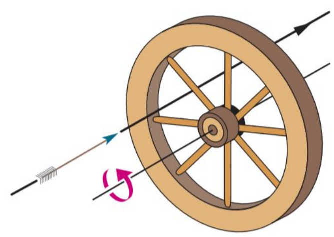

Fig. 10-27 Problem 7.

•••66 A uniform spherical shell of mass $M = 4.5$ kg and radius $R = 8.5$ cm can rotate about a vertical axis on frictionless bearings (Fig. 10-47). A massless cord passes around the equator of the shell, over a pulley of rotational inertia $I = 3.0 \times 10^{-3}\ \mathrm{kg \cdot m^2}$ and radius $r = 5.0$ cm, and is attached to a small object of mass $m = 0.60$ kg. There is no friction on the pulley's axle; the cord does not slip on the pulley. What is the speed of the object when it has fallen 82 cm after being released from rest? Use energy considerations.

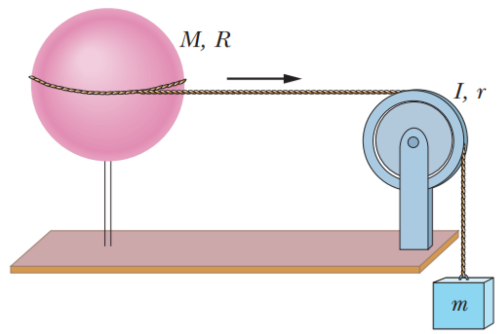

Figure 10-47 Problem 66.

•38 Figure 10-35 shows three 0.0100 kg particles that have been glued to a rod of length $L = 6.00$ cm and negligible mass. The assembly can rotate around a perpendicular axis through point O at the left end. If we remove one particle (that is, 33% of the mass), by what percentage does the rotational inertia of the assembly around the rotation axis decrease when that removed particle is (a) the innermost one and (b) the outermost one?

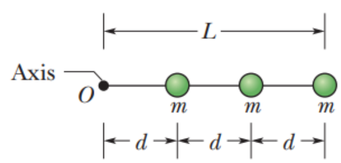

Figure 10-35 Problems 38 and 62.

•4 A uniform solid sphere rolls down an incline. (a) What must be the incline angle if the linear acceleration of the center of the sphere is to have a magnitude of $0.10g$? (b) If a frictionless block were to slide down the incline at that angle, would its acceleration magnitude be more than, less than, or equal to $0.10g$? Why?

••11 In Fig. 11-34, a constant horizontal force $\vec{F}_{app}$ of magnitude 10 N is applied to a wheel of mass 10 kg and radius 0.30 m. The wheel rolls smoothly on the horizontal surface, and the acceleration of its center of mass has magnitude 0.60 m/s^2. (a) In unit-vector notation, what is the frictional force on the wheel? (b) What is the rotational inertia of the wheel about the rotation axis through its center of mass?

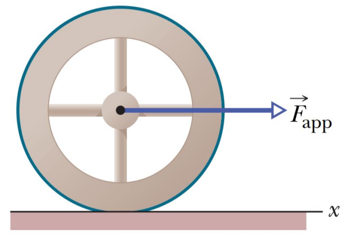

Fig. 11-34 Problem 11.

•••13 *Nonuniform ball.* In Fig. 11-36, a ball of mass M and radius R rolls smoothly from rest down a ramp and onto a circular loop of radius 0.48 m. The initial height of the ball is $h = 0.36$ m. At the loop bottom, the magnitude of the normal force on the ball is $2.00Mg$. The ball consists of an outer spherical shell (of a certain uniform density) that is glued to a central sphere (of a different uniform density). The rotational inertia of the ball can be expressed in the general form $I = \beta MR^2$, but β is not 0.4 as it is for a ball of uniform density. Determine β.

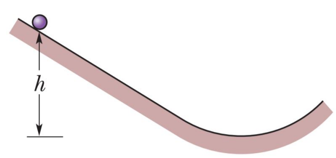

Fig. 11-36 Problem 13.