Physics 8, Fall 2015, Homework #7.
Due at start of class on Friday, October 30, 2015

Problems marked with (*) must include your own drawing or graph representing the problem and at least one complete sentence describing your reasoning.

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(Chapter 11 problems.)

1*. A block of inertia $m$ is attached to a block of inertia $2m$ by a very light string hung over a uniform disk of inertia $3m$ and radius $R$ that can rotate on a horizontal axle, as shown below (left). The disk’s outer surface is rough, so the string and the outer surface of the disk move together without slipping. The lower block is held so that the string is taut, and then the blocks are released from rest. What is the speed of the block of inertia $m$ after it has risen a distance $h$? Ignore any friction between disk and axle.

2*. The Ferris wheel shown above (right) is turning at constant speed. Draw and label free-body diagrams showing the forces on a passenger at each of the four numbered positions. Try to get the relative lengths of the vector arrows about right.

3*. One type of wagon wheel consists of a 6.00 kg hoop plus four 3.00 kg thin rods placed along diameters of the hoop so as to make eight evenly spaced spokes. For a hoop of radius 1.00 m (diameter 2.00 m), what is the rotational inertia of the wheel about an axis perpendicular to the plane of the wheel and through the center?
(Chapter 12 problems.)

4*. Draw an extended free-body diagram for a stepladder resting on the floor, which you are standing on after having climbed halfway to the top.

5*. A seesaw consists of a 5.0 kg plastic plank balanced at its center on a very narrow support. A 44 kg child sits 1.0 m away from the center toward one end of the board, and a 33 kg child sits toward the opposite end so the see-saw is balanced. (a) What is the magnitude of the upward force exerted by the support? (Don’t forget the factor $g = 9.8 \text{ m/s}^2$.) (b) Where should the smaller child sit?

6. In the mobile shown below, what are the inertias of the giraffe and of the elephant, if the monkey’s inertia is 0.15 kg?

7*. Suppose a single force (that is not cancelled by any other forces) acts on an object. (a) Is it possible for this single force to change both the object’s linear momentum and its angular momentum (about its CoM)? Explain. (b) Is it possible for this single force to change the object’s linear momentum without changing its angular momentum (about its CoM)? Explain.

8. A baton-twirler tosses her spinning baton in the air. While the baton is in the air, is its linear momentum constant? Is its angular momentum constant? Explain.

9. When the wrench you are working with does not loosen a nut, you can sometimes succeed by slipping a length of pipe over the end of the wrench and pushing at the end of the pipe. Why does this work?

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XC1*. Optional / extra-credit. Assume that Earth’s orbit around the Sun is a perfect circle (it’s really an ellipse). Earth’s inertia is $5.97 \times 10^{24}$ kg, the radius of its orbit is $1.50 \times 10^{11}$ m, and its orbital period is 365.26 days. (a) What is the magnitude of Earth’s centripetal acceleration as it revolves about the Sun? (b) What are the magnitude and direction of the force necessary to cause this acceleration.

XC2*. Optional/extra-credit. Imagine that an asteroid 1 km in diameter collides with Earth. Estimate the maximum fractional change in length of the day due to this collision. Take the density of the asteroid to be somewhere between the density of concrete and the density of steel, both of which are structural materials whose approximate densities you should know. For purposes of estimation, assume that the relative speed of Earth and the asteroid is just the speed at which Earth travels around the Sun (as if Earth ran into a stationary asteroid). Where (and from what direction) should the asteroid hit Earth to cause the biggest change in the length of a day? Use Problem XC1 for Earth’s mass and the radius of its orbit around the Sun. Earth’s radius is $6.4 \times 10^6$ m.

XC3*. Optional/extra-credit. A 5.0 kg bowling ball is thrown down the alley with a speed of 10.0 m/s. At first the ball slides with no rotation. The coefficient of friction between the ball and the alley surface is 0.10. (a) How much time does it take for the ball to achieve pure rolling motion? (b) What is its translational speed at this time?

XC4*. Optional/extra-credit. A marble that has a radius of 10 mm (that’s 0.010 m) is placed at the very top of a (stationary) globe of radius 1.00 m. When released, the marble rolls without slipping down the globe. Find the angle from the top of the globe to the point where the marble flies off the globe (where the top of the globe is $\theta = 0^\circ$, the equator is $\theta = 90^\circ$, etc.).

(one more on next page)
XC5*. Optional/extra-credit. A small ball is put into a cone and made to move at constant speed $v$ in a horizontal circle of constant radius $r$. (See figure below.)

(a) What is the ball’s centripetal acceleration? (b) What is its tangential acceleration? (c) What force can counteract the force of gravity so that the ball keeps moving in a horizontal circle? (d) Use these insights to determine the height $h$ the ball is circling above the bottom of the cone. [Hint: This is equivalent to finding the angle the cone makes with its vertical axis.]