- worksheet: `positron.hep.upenn.edu/p8/files/ws17.pdf`
- 4 problems + 2 XC, all ch11, mostly edits of problems I worked out in lecture videos. (Try not to peek until you've tried it yourself.)
- First ch12 video (about 60 minutes long) due Wednesday.
- Email **in advance** & file a CAR if you need to miss class.

Centripetal acceleration:

$$a_c = v^2/R = \omega^2 R \qquad v = \omega R$$

An extended object has both translational and rotational KE:

$$K = \frac{1}{2} m v_{\mathrm{cm}}^2 + \frac{1}{2} I \omega^2$$

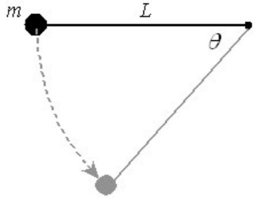
hoop: $I = mR^2$. disk: $I = \frac{1}{2} mR^2$. rod about CoM: $I = \frac{1}{12} m\ell^2$.
rod about end: $I = \frac{1}{3} m\ell^2$. solid sphere: $I = \frac{2}{5} mR^2$.

parallel-axis theorem: $I_{\mathrm{displaced}} = I_{\mathrm{about\ CoM}} + md^2$

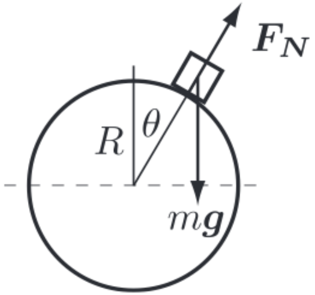
angular momentum: $L = I\omega \qquad L = mv\ r_\perp$

1*. One type of wagon wheel consists of a 5.00 kg hoop plus four 1.00 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?

2*. You attach one end of a string of length ℓ to a small ball of mass m. You attach the string's other end to a pivot that allows free revolution. You hold the ball out to the side with the string taut along a horizontal line, as the in figure. (a) If you release the ball from rest, what is the tension in the string as a function of angle ϑ swept through? To do this, first use the radial component of $m\vec{a} = \sum \vec{F}$ to relate the speed v, the centripetal acceleration, the gravitational force, the string tension, and the angle ϑ. Then use energy conservation to relate v to ϑ. Then eliminate v in favor of ϑ. (b) At what angle, in the range $0 \leq \vartheta \leq \pi$, is the string tension largest? (c) What is the largest value of the string tension, throughout the motion? [**For full credit, your solution should include a FBD for the ball when θ has some nonzero value.** I usually draw $\theta \approx 30^\circ$ so that it is easier to tell which is sine and which is cosine.]



3*. A small block of mass m slides down a sphere of radius R, starting from rest at the top (with perhaps a tiny push to start it sliding). The sphere is immobile, and friction between the block and the sphere is negligible. In terms of m, g, R, and θ, determine (a) the kinetic energy of the block, (b) the centripetal acceleration of the block, and (c) the normal force exerted by the sphere on the block. (d) At what value of θ does the block lose contact with the sphere? (Be proud of yourself once you've solved this problem: students in Physics 150 find it challenging!) **[For full credit, include a FBD for the block when it has slid to an angle θ w.r.t. its initial vertical position.]**



4*. A long, thin rod is pivoted from a hinge such that it hangs vertically from one end. (The hinge is at the top.) The length of the rod is 1.0 m. You want to hit the lower end of the rod just hard enough to get the rod to swing all the way up and over the pivot (i.e. to swing more than 180°). How fast do you have to make the end go? (Hint: consider gravitational potential energy and rotational kinetic energy. For rotational inertia, remember that the rod rotates about its end here, not about its center, so you'll need to use the parallel-axis theorem to get I about the end.)

5XC*. A marble that has a radius of $r = 10\,\mathrm{mm}$ (that's 0.010 m) is placed at the very top of a (stationary) globe of radius $R = 1.00\,\mathrm{m}$. When released, the marble rolls without slipping down the globe. Find the angle θ from the top of the globe to the point where the marble flies off the globe (where the top of the globe is $\theta = 0°$, the equator is $\theta = 90°$, etc).

6XC*. Imagine that an asteroid 2 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 **increase** in the length of a day? Earth's mass is $5.97 \times 10^{24}\,\mathrm{kg}$, the radius of its orbit is $1.50 \times 10^{11}\,\mathrm{m}$, and its orbital period is 365.26 days. Earth's radius is $6.4 \times 10^{6}\,\mathrm{m}$.

7XC++*. I assign this problem, which I borrowed from Prof Charlie Johnson, when I teach Phys 3351 to physics majors. (It is an extra-credit problem even in that course!) If you manage to solve it, be sure to email your solution directly to me! A ring of mass M hangs from a thread, and two beads of mass m slide on it without friction, as shown in the figure below. The beads are released simultaneously from rest (given an infinitesimal kick) at the top of the ring and slide down opposite sides. Show that the ring will start to rise if $m > \frac{3}{2}M$, and find the angle θ at which this occurs. [Hint: If $M = 0$, then $\cos\theta = \frac{2}{3}$.] You will receive partial extra-credit if you do the problem assuming $M = 0$, but for full credit, you must account for the mass M of the ring.