- worksheet: `positron.hep.upenn.edu/p8/files/ws18.pdf`
- 5 problems + 2 XC. Two are edits of ch11 lecture problems. Three are very quick torque problems.
- Second ch12 video due **Friday,** and third ch12 video due **Monday.**
- 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: $I = \frac{2}{5} mR^2$.

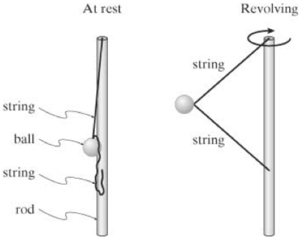
parallel-axis theorem: $I_{\mathrm{displaced}} = I_{\mathrm{about\ CoM}} + md^2$

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

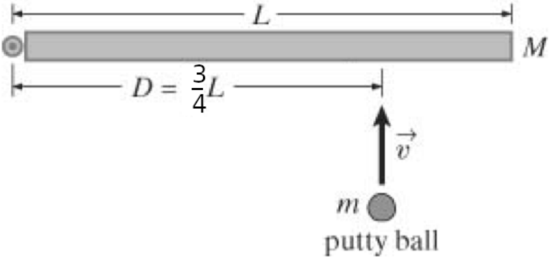
torque (lever arm $\times$ force): $\tau = r_{\mathrm{perp}}\ F$

For an object spinning as it sails through the air, the relevant rotation axis passes through the object's CoM.

1*. A ball is attached to a vertical rod by two strings of equal length. The strings are very light and do not stretch. I hit the ball, as if I am playing a modified version of tetherball, so that the ball rotates around the rod at constant rotational velocity $\omega = 5.0$ radians per second. Assume that friction and other dissipative effects are negligible (at least for long enough for you to analyze the motion) and that somehow the strings are attached such that their lengths and points of attachment to the rod do not change. The ball has mass $m = 1.0\,\mathrm{kg}$. Each string has length $\ell = 1.0\,\mathrm{m}$, and the ball's orbit is a horizontal distance $r = 0.8\,\mathrm{m}$ from the rod axis. (a) Draw a free-body diagram for the ball. (b) Use your FBD to write Newton's second law in the vertical and horizontal directions. (c) Find the tension in the top string and the tension in the bottom string.



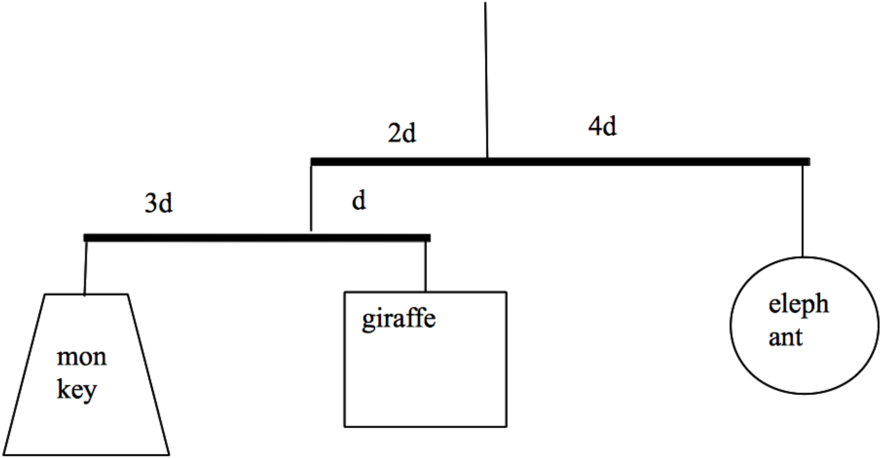
2*. An open door of mass M and width ℓ is at rest when it is struck by a thrown putty ball of mass m that is moving at linear speed v at the instant it strikes the door. The impact point is a distance $D = \frac{3}{4}\ell$ from the rotation axis through the hinges. The putty ball strikes at a right angle to the door face and sticks after it hits. What is the rotational velocity ω_f of the door (with putty stuck to it)? Do not ignore the mass m. (Hint: angular momentum.) Note: drawing is a plan view, not an elevation view.



3*. 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?

4*. A baton-twirler tosses a spinning baton in the air. While the baton is in the air, is its linear momentum constant? Is its angular momentum constant? (For evaluating angular momentum, use the center of mass of the baton as your pivot. That is the relevant pivot to use for an object that is spinning freely in the air.) Explain.

5*. In the mobile shown below, what are the masses of the giraffe and of the elephant, if the monkey's mass is 1.0 kg? (The mobile is stationary, so all torques must balance.)



6XC*. Your aunt owns an amusement park, and she wants you to add a circular loop to an exiting roller coaster ride to make it more fun. The first hill for the existing roller coaster is 25 m tall, and your aunt wants you to build right after this hill the tallest loop possible without having the cars fall out of the track or the passengers fall out of the cars. You think for a minute and realize what the minimum speed at the top of the loop has to be, and this gives you what you need to design the loop. (Usually a roller-coaster is moving very slowly just before it passes over the top of its first hill.)

7XC*. (a) Calculate the rotational inertia of a flat sheet of plywood, of width w and height h, about an axis that passes through the center of the sheet and is perpendicular to the plane of the sheet. Since it's easy to look this answer up, you need to compute it using calculus and to show your work. (b) Calculate the rotational inertia of this same sheet about an axis that passes through the center of the sheet and is parallel to the long edge of the sheet. (c) Calculate the rotational inertia of this same sheet about an axis that passes through the center of the sheet and is parallel to the short edge of the sheet. (d) Verify that your answer for part (a) is the sum of your answers for parts (b) and (c). (The sum in part (d) is true for any object that is so thin that, to a good approximation, all of its mass lies in a single plane. Such an object is called a "lamina.")