- ws16: 1 hands-on activity + 4 problems, all ch11, mostly edits of problems I worked out in lecture videos. (Try not to peek until you've tried it yourself.)
- Email **in advance** & file a CAN if you need to miss class.

Moving in a circle at constant speed requires a **centripetal** (toward center) acceleration $\vec{a}_c$. Velocity $\vec{v}$ is tangential.

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

An extended object has both translational and rotational KE:

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

For a hoop or cylindrical shell, $I = mR^2$.
For a solid disk or solid cylinder, $I = \frac{1}{2} mR^2$.

If α is constant, then

$$\omega_f = \omega_i + \alpha t$$

$$\theta_f = \theta_i + \omega_i t + \frac{1}{2}\alpha t^2$$

$$\omega_f^2 = \omega_i^2 + 2\alpha \Delta\theta$$

1. Hands-on activity! Materials: string, rubber bob, plastic sleeve, all pre-threaded for you. Try not to let the knotted end of the string pull out of the sleeve, or we'll have to re-thread it. Also please be careful not to hit anyone's head or eye with the twirling bob.

(a) First grab the string between the sleeve and the rubber bob, so that the sleeve stays out of the way. Twirl the bob in a circle about your thumb, as you saw me do with a tennis ball. (The plane of motion can be either horizontal or vertical for this part, as you prefer.) Feel the tension as you vary ω from slow to fast to faster.

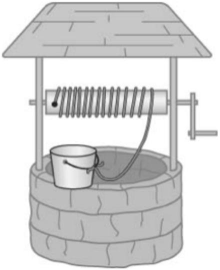
(b) Using a vertical plane of motion, try to go just fast enough to keep the string always taut. Then go a little bit less quickly. Get a feel for the string's going slack near the top of the motion. Why does the string go slack near the top rather than near the bottom?

(continued)

(c) Holding the plastic sleeve in one hand and the knotted tip of the string in the other hand, twirl the bob in a horizontal plane of motion, at a pretty large radius from the top of the sleeve. Then gently pull the knotted tip of the string down so that the bob is twirling at a significantly smaller radius than it was initially. (This is like figure skaters' pulling in their arms.) When the length of the string decreases, what happens to ω? Can you explain this (qualitatively) in terms of angular momentum and rotational inertia? Assuming that angular momentum stayed roughly constant, did the kinetic energy of the bob change? And if so, where did that energy come from or go to? Hint: when you displace the bottom of the string downward, thus decreasing the bob's radius of rotation, how does the direction of the force you exert compare with the direction in which you displace the point where you are applying that force?

2. An automobile accelerates from rest starting at t = 0 such that its tires undergo a constant rotational acceleration $\alpha = 6.28\,\mathrm{s}^{-2}$. The radius of each tire is 0.50 m. At t = 10 s after the acceleration begins, find (a) the instantaneous rotational speed ω of the tires, (b) the total rotational displacement $\Delta\vartheta$ of each tire, (c) the linear speed *v* of the automobile (assuming the tires stay perfectly round and the tires roll without slipping), and (d) the total distance the car travels in the 10 s.

3*. You accidentally knock a full bucket of water off the side of the well shown in the figure. The bucket plunges 10 m to the bottom of the well. Attached to the bucket is a light rope that is wrapped around the crank cylinder. (a) How fast is the handle turning (rotational speed ω) when the bucket hits bottom? (b) How fast is the bucket moving (linear speed v) when it hits the bottom? The mass of the bucket plus water is 10 kg. The crank cylinder is a solid cylinder of radius 0.50 m and mass 4.0 kg. (Assume the small handle's mass is negligible in comparison with the crank cylinder.)



4*. The Ferris wheel shown in the figure is rotating at constant speed. Suppose that each of the pentagonal carriages is attached to the wheel by its own metal rod (where the little circle is drawn at the top of the pentagon). Draw and label free-body diagrams showing the two forces exerted on the carriage at the following six clock-numbered postions: 12:00, 3:00, 6:00, 9:00, 10:00, 4:00. (Consider the tops of the carriages to be at the respective positions on the face of a clock.) In each case, there is a gravitational force, whose magntitude never changes and whose direction is always downward; and there is a contact force exerted by the rod on the carriage. Since the top of each carriage moves at constant speed in a circle of constant radius, the acceleration vector for each carriage always points directly toward the center of the Ferris wheel and always has the same magnitude. For scale, please draw $m\vec{a}$ on your FBD instead of the usual $\vec{a}$. Then you have two vectors, $\vec{F}^{\mathrm{gravitational}}$ and $\vec{F}^{\mathrm{contact}}$, whose vector sum must equal $m\vec{a}$. Try to get the relative lengths of the vector arrows about right. For a realistic Ferris wheel, ma will be much smaller than mg, but to make a drawing that really shows the physics, please make ma be about half the size of mg.

5*. You have a weekend job selecting speed-limit signs to put at road curves. The speed limit is determined by the radius of the curve and the bank angle of the road with respect to horizontal. Your first assignment today is a turn of radius 100 m at a bank angle of 5.7°. (a) What speed limit sign should you choose for that curve such that a car traveling at the speed limit negotiates the turn successfully even when the road is wet and slick? (So at this speed, the car stays on the road even when friction is negligible.) (b) Draw a free-body diagram showing all of the forces acting on the car when it is moving at this maximum speed. (Your diagram should also indicate the direction of the car's acceleration vector.)