- worksheet: `positron.hep.upenn.edu/p8/files/ws15.pdf`
- 4 problems, all ch11, topics from day15 video
- 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.

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

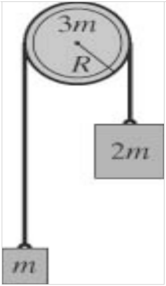
An extended object has both translational and rotational KE:

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

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

1*. You have a pail of water with a rope tied to the handle. If you whirl it fast enough in a vertical circle (i.e. a circle whose central axis is horizontal), none of the water spills out of the bucket, even when the bucket is upside down. (a) Explain how this works. (b) If the bucket rotates at constant speed v on the end of a rope of length ℓ, what minimum speed is required to keep the water from falling out of the pail? (c) If you plug in $\ell = 1.0\,\mathrm{m}$, what number of **revolutions per second** (that's $\omega/(2\pi)$, or $v/(2\pi\ell)$) does this speed correspond to? (You may remember that I spun the bucket about two or three times faster than this in the lecture demo. For simplicity, assume that my arm contrives to keep the motion at constant speed, in spite of the change in height between top and bottom.) (d) Assuming that my arm somehow manages to twirl the bucket in a circle at constant angular velocity (thus constant speed), without the water spilling, draw FBD for water at 12:00, (e) 6:00, (f) 9:00. After figuring out how big $\vec{a}$ needs to be for (d), make $\vec{a}$ the same length in (e) and (f). Be sure to indicate $\vec{a}$ (or probably $m\vec{a}$ is more helpful for scale) on your FBDs.

2*. A block of mass m is attached to a block of mass $2m$ by a very light string hung over a uniform disk of mass $3m$ 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 mass m after it has risen a distance h? Ignore any friction between disk and axle. [Hint: since we consider dissipative forces to be negligible here, you can use the fact that total mechanical energy (translational kinetic, rotational kinetic, plus gravitational potential) is constant during the motion. For solid disk of mass M and radius R, $I = \frac{1}{2}MR^2$.]



3*. The spacecraft in the movie 2001: A Space Odyssey has a rotating cylinder to create the illusion of gravity, inside of which the crew walks and exercises. (a) If the radius of the cylinder is 8.0 meters, what should the rate of revolution of the cylinder be in order to replicate Earth's gravity at this radius? (b) For a person, of height 1.65 meters, standing in this cylinder, how does the "gravitational" acceleration at the top of her head compare with the "gravitational" acceleration at her feet? (Might this be uncomfortable?)

4. Assume that Earth's orbit around the Sun is a perfect circle (it's really an ellipse, but to a good approximation it's a circle). 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. (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.