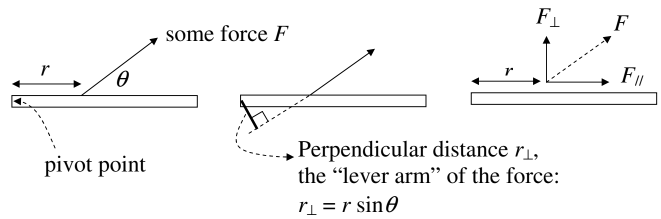
Announcements

1. You can pick up your exams, same spot as last time (N357, ESC)
2. Solutions will be posted same place as last time (near N361, ESC)
3. Look over your exam and the solutions, before talking to me.
   a. If you can't figure something out after that point, I'm happy to discuss it with you.
4. We threw out exam problem 8 (gave everyone full credit). That's the one with the weightlifter; it was a bit ambiguous that he was **holding** the weights at the start of the problem (weights could have been resting on scale).
5. Video: solving physics problems

Review of Torques

Definition of torque: (about a point)

$$\tau = r_{\perp} F = rF_{\perp} = rF \sin\theta$$



Positive/negative:
Produces a **clockwise** rotation = **negative**
Produces a **counter-clockwise** rotation = **positive**

Equilibrium:

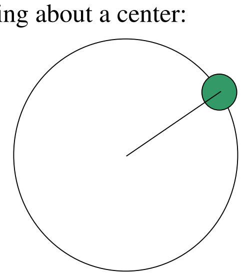
$$\sum F = 0$$
$$\sum \tau = 0$$

Translation:
- if an object is not accelerating, the sum of the forces on it must be equal to zero
- if an object is not speeding up or slowing down its *rotation*, then the sum of the *torques* on it must be equal to zero

Rotational kinetic energy

Demo: Rolling object

Kinetic energy of a **"point object"** rotating about a center:



Write in terms of ω:

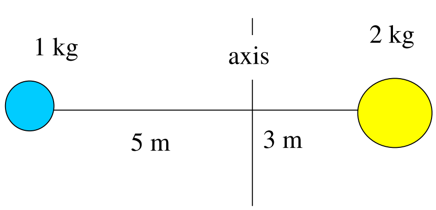
Moment of inertia:

$$I_{pt\ mass} = mr^2$$

Kinetic energy in terms of I and ω:

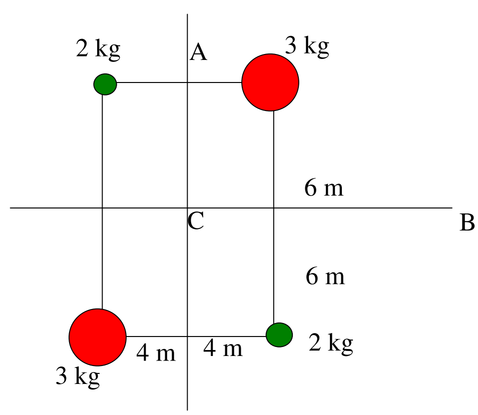
$$KE_{rot} = \frac{1}{2} I\omega^2$$

I for two masses on a rod?



$$I = I_1 + I_2 + \ldots$$

Demo: rod with masses, different points for axis



Calculate I about axis A

Q4. Which has the largest I: rotating about axis A, B or C? (C is into the page)

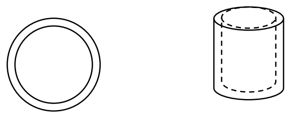
Extended objects

Must add up mr^2 *for each bit of mass* in the object

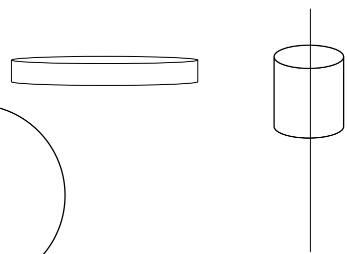
Which bits of mass contribute the most to I?

Which objects have the largest I?

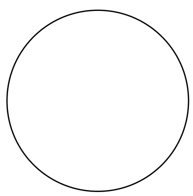
Hoop/cylindrical shell

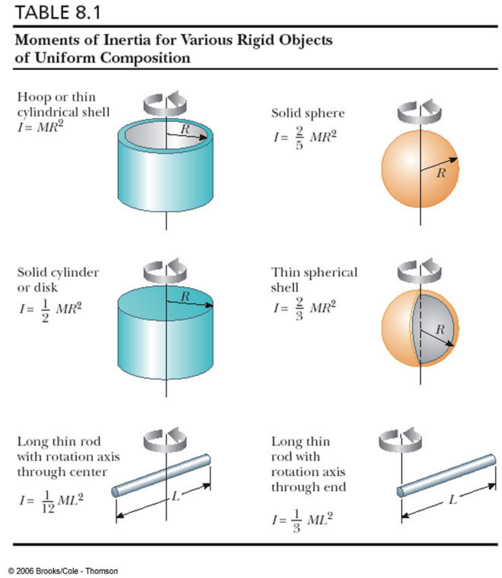


Solid disk/cylinder



Solid sphere





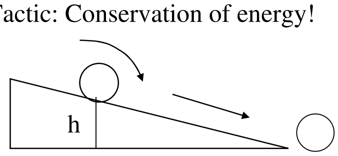
Which kind of rolling object is moving the **fastest** at bottom of an incline? Which got there first?

Sphere, disk or hoop, or all the same? __________

Does it depend on M, R? ____________

Demo: racing objects down incline

Worked Problem: An object with moment of inertia I rolls down a height h without slipping. Find the speed at bottom. Tactic: Conservation of energy!



Without rolling:

Q5. If they continue on, which would go the farthest up a hill on the other side?

a. hoop
b. solid disk
c. solid sphere
d. all the same height at the end

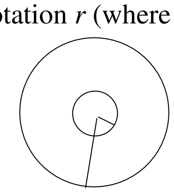
Newton's second law for rotation

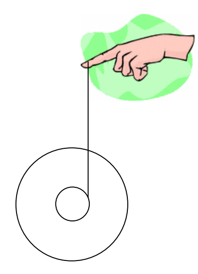
$$\sum \tau = I\alpha$$

still also have $\sum \vec{F} = m\vec{a}$

(but accel. of what?)

Example: **Find downward acceleration of yo-yo** as it unrolls.
Given mass m, radius of yo-yo R, *different radius* of rotation r (where string is)

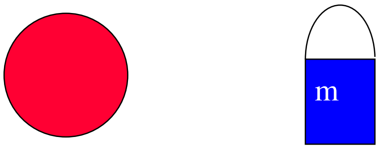


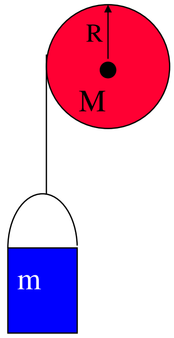


Moment of inertia, assuming **cylindrical** yo-yo (neglect the small gap): ____________

Example: Falling mass and solid disc flywheel

Draw FBDs:

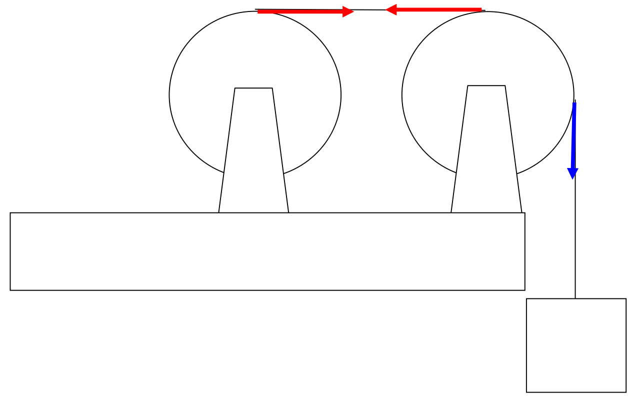




Write $\sum \tau = I\alpha$ for the flywheel

Write $\sum \vec{F} = m\vec{a}_{cm}$ for the bucket.

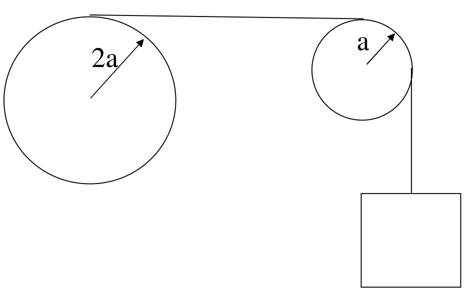
Find α and a



Q6. The left disk has a rope wrapped around its edge and the rope passes over a second disk. The two disks are identical and their **mass is significant**. As the system accelerates there is **no slipping of the rope on either wheel and both wheels accelerate the same**. The tension in the rope is

a. Largest between the disks
b. Largest above the mass
c. The same in both places.

The large disk has a rope wrapped around its edge. The rope passes over a second disk, and turns it with no slipping. The disks both have the <u>same mass</u>, but one has twice the radius.



Q7. As the mass falls, the disk with the largest ω is:

a. the large disk
b. the small disk
c. neither; same

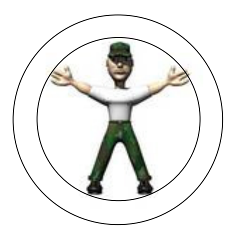
Q8. The disk with the largest rotational kinetic energy is:

a. the large disk
b. the small disk
c. neither; same

(hint: look at how I and ω may vary)

Q9. Mary and Fred are rolling a large tire down a hill. Mary says it will go faster if Fred gets inside the tire as shown and rolls down with it. Fred's not sure. What do you think?

a. It will go faster
b. It will go slower
c. It will take the same time



Q10. Did you discuss at least half of the discussion quiz questions today with a neighbor?

a. Yes b. No