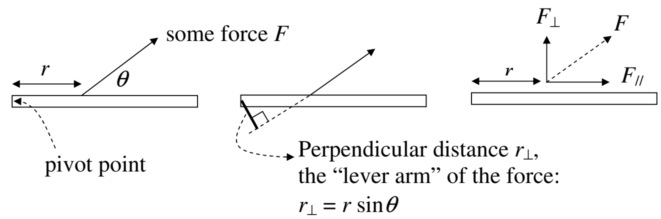
Lecture 16 Announcements

1. Next week: exam 3 starts on Thursday
   a. Thursday will be review session
   b. No HW a week from Saturday
2. More survey stuff

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**

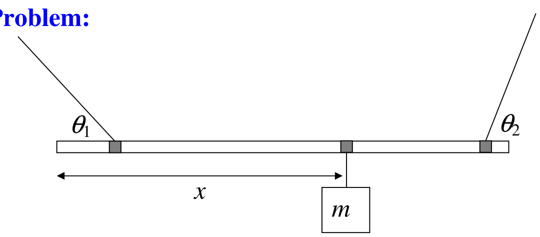
Equilibrium

$$\sum F = 0$$

$$\sum \tau = 0$$

Translation:
- if an object is not speeding up or slowing down, there is no net force on it
- if an object is not speeding up or slowing down its *rotation*, there is no net *torque* on it.

Problem:



A 0.4 kg meterstick is suspended from support pillars (not shown) via two strings at θ_1 =41.4° and θ_2 = 60°, with tensions of 2 N and 3N. The strings are attached at 10 cm and 5 cm from the two ends of the meterstick. The stick is *not* in equilibrium until an additional mass is hung from a point in the middle. Find the unknown *x* and *m*.

Answers: 0.171 kg, 38.2 cm

Rotational kinetic energy

Demo: Race—Cart vs. ball. Who wins? (Like warmup)

Review:

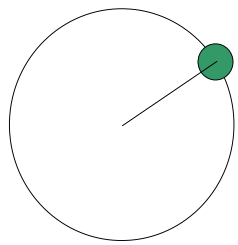
How fast is cart going at bottom? (Energy)

How long did it take to get there? (Kinematics)

→ What's different about the ball?

Kinetic energy of a **"point object"** rotating in a circle:

Write in terms of ω:



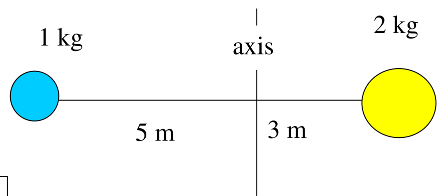
"Moment of inertia"

$$I_{pt\ mass} = mr^2$$ (rotating in a circle)

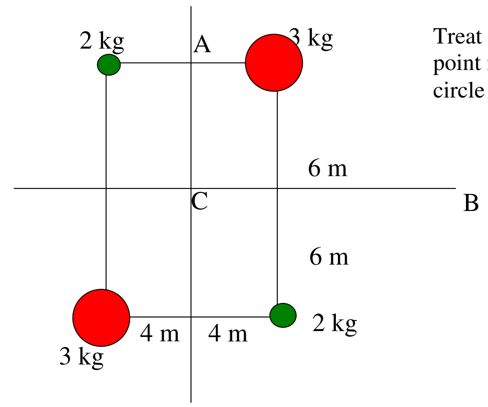
Kinetic energy in terms of I and ω:

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

Moment of inertia for two mass? (connected with a rod)



$$I=I_1+I_2+\dots$$



Treat each mass as a point if its rotating circle > size of object

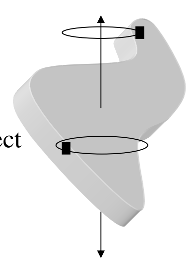
Clicker quiz: Does *I* change when you rotate about axis A vs. axis B?

a. About axis A has larger *I*
b. About axis B has larger *I*
c. They have the same *I*

What about axis C? (C is into the page)

Demo: variable "I-rotator"

Rotating "extended" objects



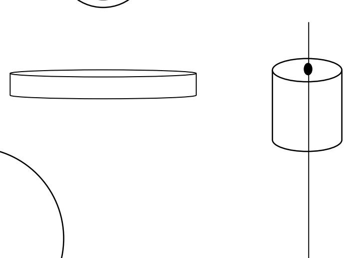
Must add up mr² *for each bit of mass* in the object

Which bits of mass contribute the most to *I*?

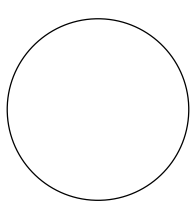
Which objects have the largest I?

Hoop/cylindrical shell

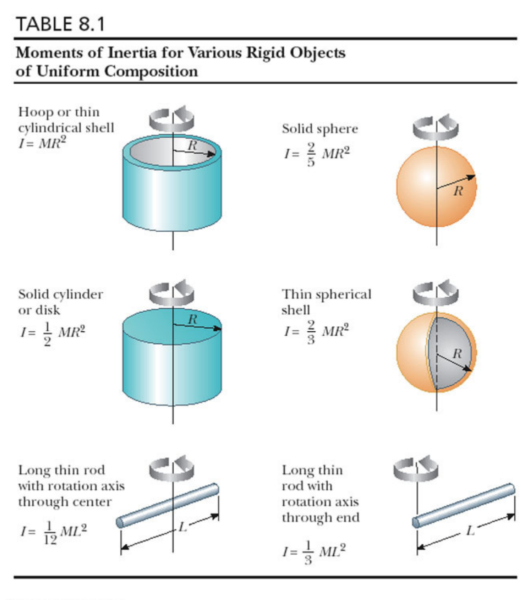
Solid disk/cylinder



Solid sphere



Demo: Long & short "I-bars"

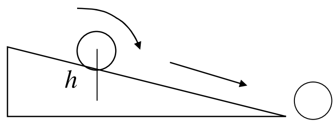


Clicker quiz: Which kind of rolling object will be moving the **fastest** at bottom of an incline? (Which will get there first?)

a. Hoop
b. Solid disk
c. Sphere
d. It depends on size

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.



Answer: $v=\sqrt{\frac{2gh}{1+I/mR^2}}$

Clicker quiz: If they continue on, which would go the farthest up a hill on the other side?

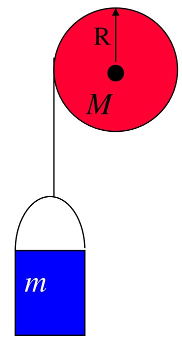
a. Hoop
b. Solid disk
c. Sphere
d. All the same height at the end

Newton's second law for rotation

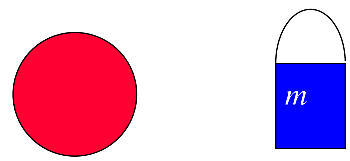
$\sum \tau = I\alpha$ still also have $\sum \vec{F} = m\vec{a}$

(but accel. of what?)

Worked problem: A falling mass starts a cylinder rotating (<u>not</u> a "massless pulley"). What is the acceleration of m?

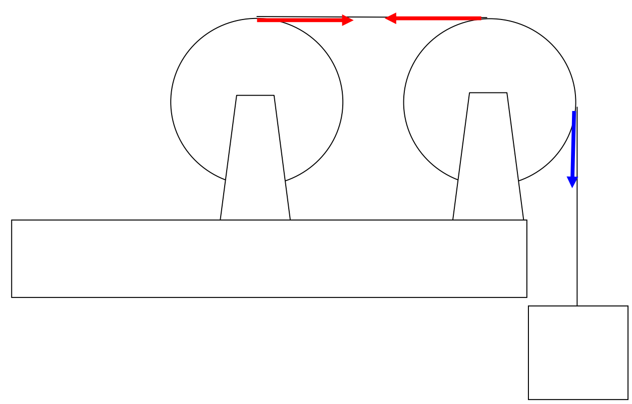


Start with FBDs:



Write equations…

Make a connection between α and a:

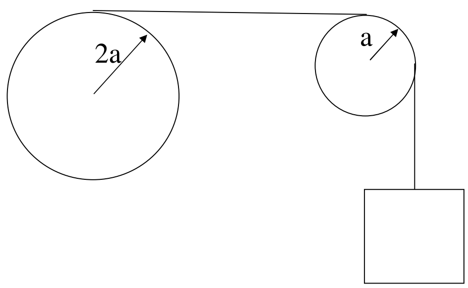


Clicker quiz: The left disk has a rope wrapped around its edge and the rope passes over a second disk. The two disks are identical and their **mass is significant**. As the system accelerates there is **no slipping of the rope on either wheel and both wheels accelerate the same**. The tension in the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

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

What's the difference with our old "massless pulleys"?

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 same mass, but one has twice the radius.



Clicker quiz: As the mass falls, the disk with the largest ω is:

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

Question: The disk with the largest rotational kinetic energy is:

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

Hint: how do I and ω vary?

Clicker quiz: 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