Physics 140 – Fall 2007
30 October: lecture #16

Ch 9 + 10 topics:

• moment of inertia: parallel axis theorem
• torque
• Newton’s second law of rotation

Midterm exam #2 is this Thursday, 1 Nov, 6-7:30 pm
bring two 3x5 notecards, calculator, #2 pencils
Parallel axis theorem

Given two *parallel* axes (lines), one passing through an object’s center of mass and the other displaced by a distance \( h \), the object’s moment of inertia about the displaced axis is given by

\[
I = I_{\text{com}} + Mh^2
\]

where \( M \) is the object’s mass and \( I_{\text{com}} \) is the moment of inertia measured about the axis that passes through the object’s center of mass.
The three spheres above have the same mass \( M \) and the same radius \( R \). Sphere B is hollow, A and C are solid. Sphere C rotates about an axis adjacent to its edge while spheres A and B rotate about their centers. All rotate at the same angular velocity. Rank the spheres according to their rotational kinetic energy, largest to smallest.

1. A, B, C
2. B, A, C
3. A, C, B
4. C, B, A
Torque

A force acting on an extended object will generally tend to make the object spin. When a force $F$ is applied at some point displaced by $r$ from a rotation axis $O$, the applied torque is

$$\vec{\tau} = r \times \vec{F}$$

A convenient way to compute torque is in the form

$$\tau = F l = F (r \sin \theta)$$

where the distance $l$, known as the **lever arm** (or **moment arm**) is the **perpendicular distance** between the rotation axis and the **line of action**, the continuation of the direction of the applied force $F$. 
Torque (cont’d)

• sign convention of applied torque (use RH rule)
  + for counterclockwise rotation
  – for clockwise rotation

• for a single force $F$, many different torques $\tau$ can result, depending on the location of the rotation axis $O$.

To calculate torque on a body of mass $m$ due to near-Earth gravity, use the fact that the gravitational force acts downward at the body’s center of mass/gravity with magnitude $mg$. 
torque wrench measurements
Which force below produces the largest positive torque about an axis passing through point O?

1. $F_1$
2. $F_2$
3. $F_3$
4. $F_4$
The net torque $\sum \tau$ exerted on an extended object that is able to rotate about an axis $O$ causes angular acceleration $\alpha$ about that axis with magnitude given by

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

where $I$ is the moment of inertia about axis $O$.

Note the similarity to NSL for translation in one dimension,

$$\sum F = ma$$
Can torque due to gravity ever produce a downward linear acceleration with magnitude $>g$?

1. Yes
2. No
3. Maybe?
You are using a wrench to try to loosen a rusty nut. Shown below are possible arrangements for the wrench and your applied force $F$. List the arrangements in order of decreasing torque.

1. $2 > 1 > 3 > 4$
2. $2 > 1 = 4 > 3$
3. $4 > 2 > 1 > 3$
4. $2 > 1 = 3 = 4$