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

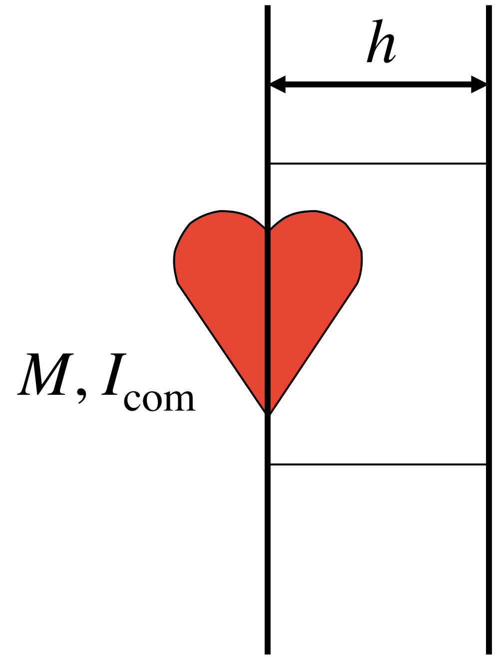
Midterm exam #2 is this Thursday, 1 Nov, 6-7:30 pm

bring **two** 3x5 notecards, calculator, #2 pencils

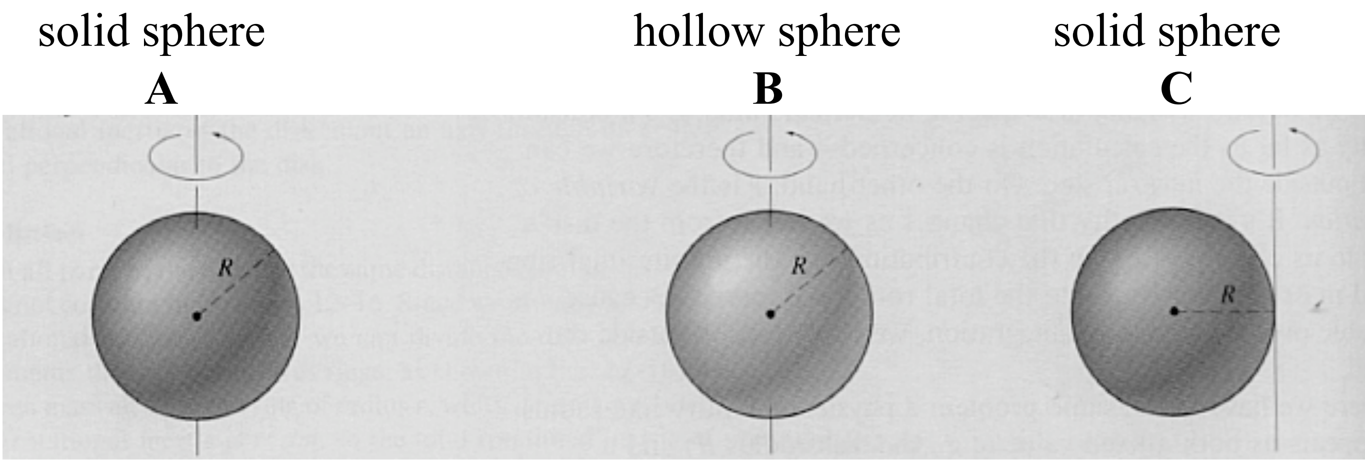
Parallel axis theorem

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_{com} is the moment of inertia measured about the axis that passes through the object's center of mass.



Source: Undetermined

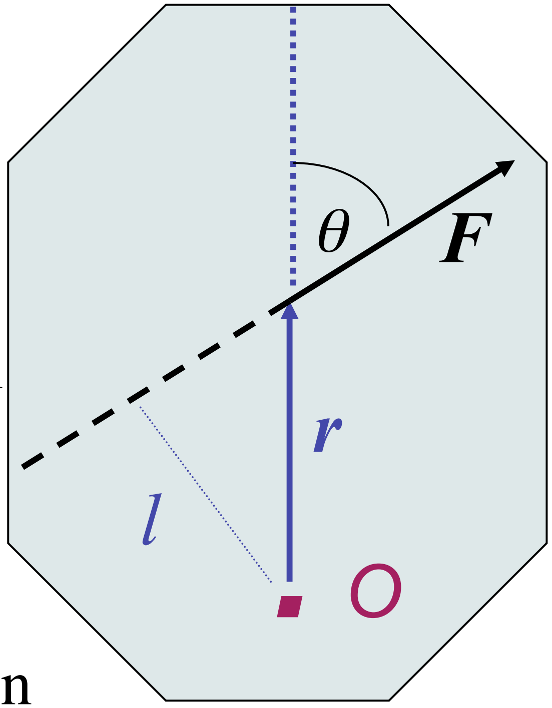
The three spheres above have the same mass M and the same radius R. Sphere B is hollow, A and C are solid. Sphere C rotates about an axis adjacent to its edge while spheres A and B rotate about their centers. All rotate at the same angular velocity. Rank the spheres according to their rotational kinetic 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

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



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***.

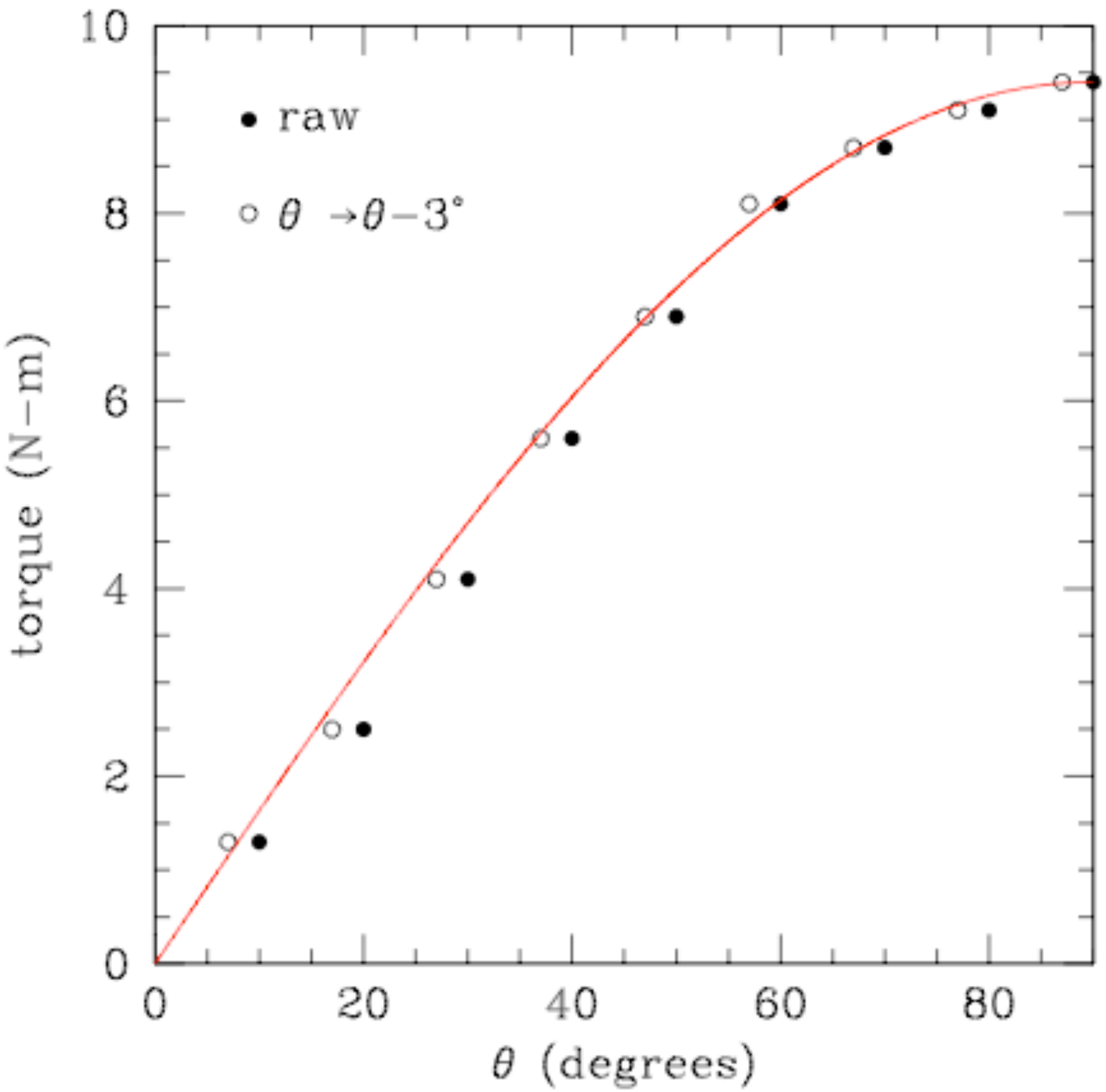
Torque (cont'd)

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

- for a single force $\boldsymbol{F}$, many different torques τ can result, depending on the location of the rotation axis O.

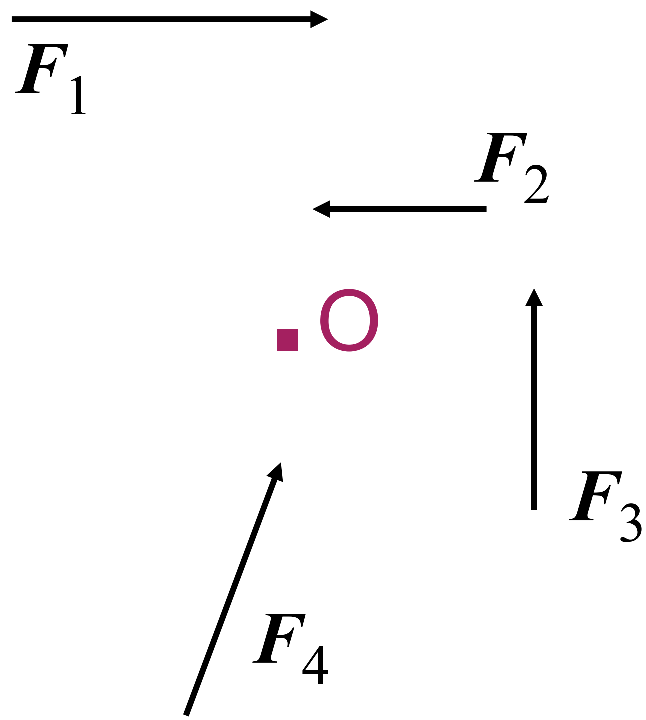
> To calculate torque on a body of mass m due to near-Earth gravity, use the fact that the gravitational force acts downward <u>at the body's center of mass/gravity</u> with magnitude mg.

torque wrench measurements



Which force below produces the largest positive torque about an axis passing through point O?

1. $\boldsymbol{F}_1$
2. $\boldsymbol{F}_2$
3. $\boldsymbol{F}_3$
4. $\boldsymbol{F}_4$



Newton's Second Law for rotation

The net torque $\Sigma\tau$ exerted on an extended object that is able to rotate about an axis O causes angular acceleration α about that axis with magnitude given by

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

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

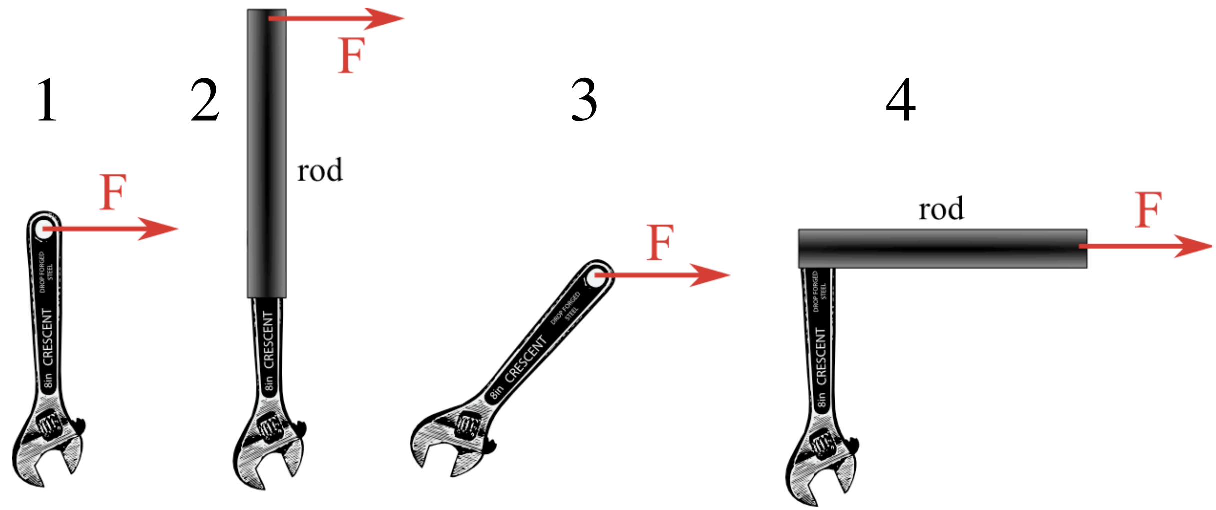
Note the similarity to NSL for translation in one dimension,

$$\sum F = ma$$

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 <u>decreasing</u> torque.



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