Physics 140 – Fall 2007
1 November: lecture #17

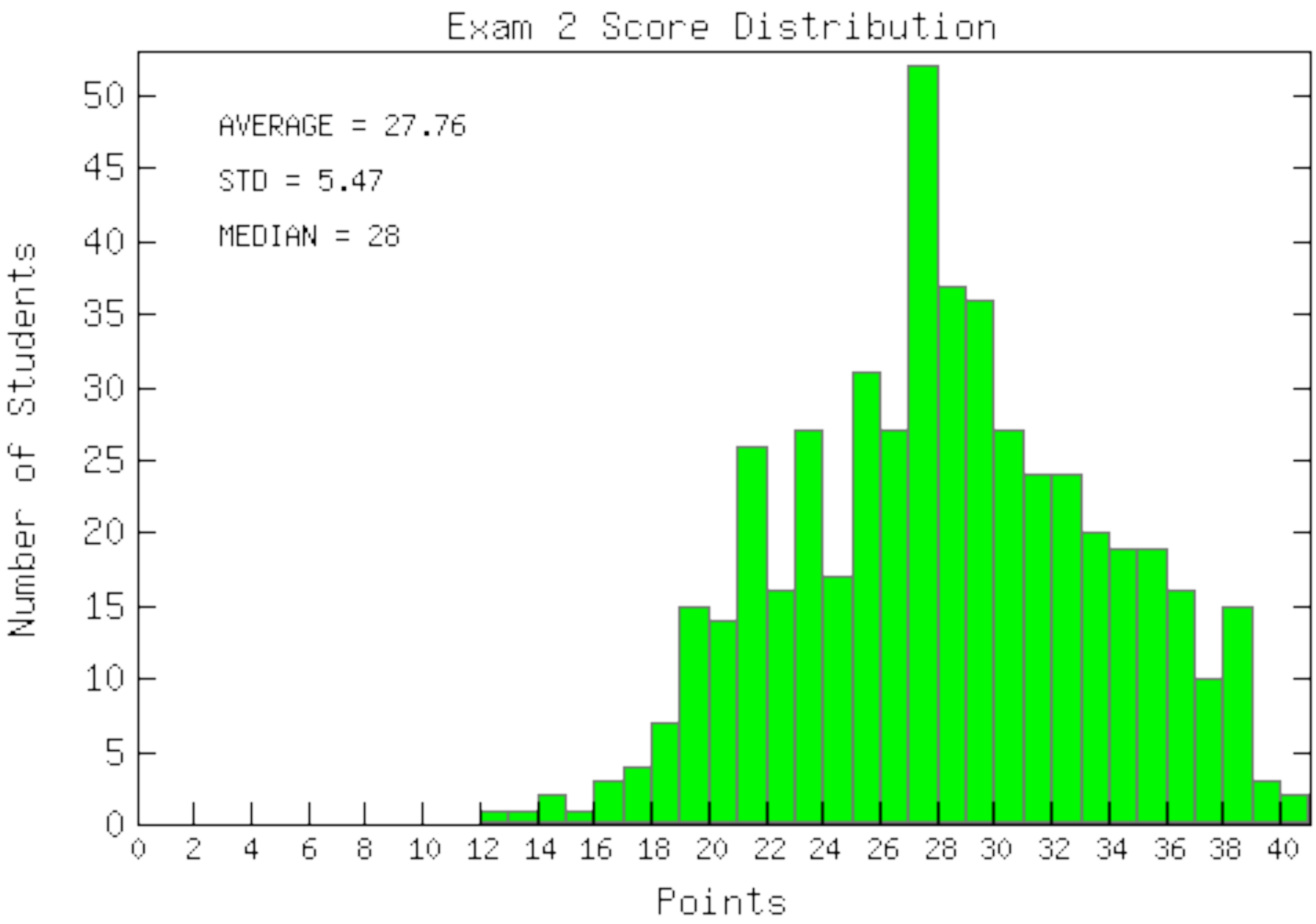
Ch 10 topics:

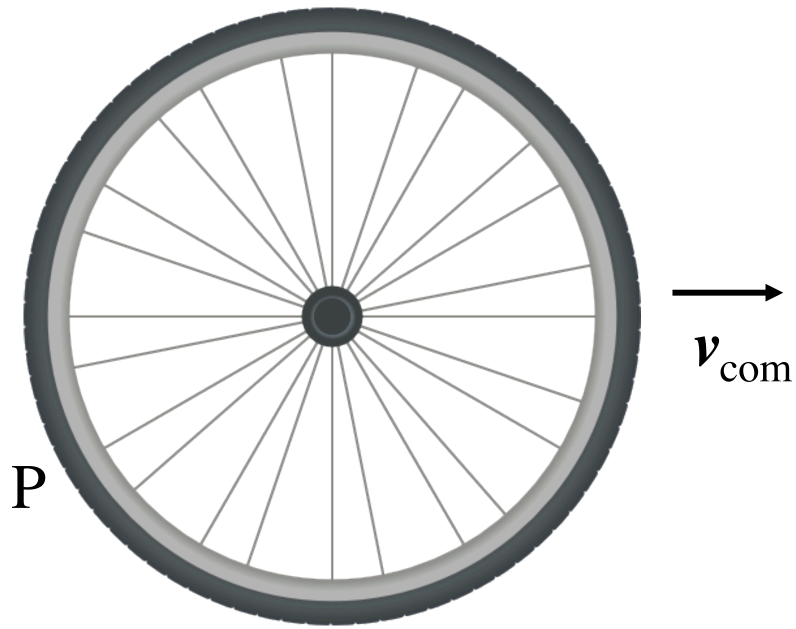
- rolling dynamics
- mechanical energy of rolling

Midterm exam #2 is tonite, 6-7:30 pm

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

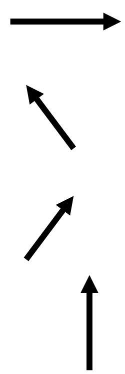
Score distribution of practice exam





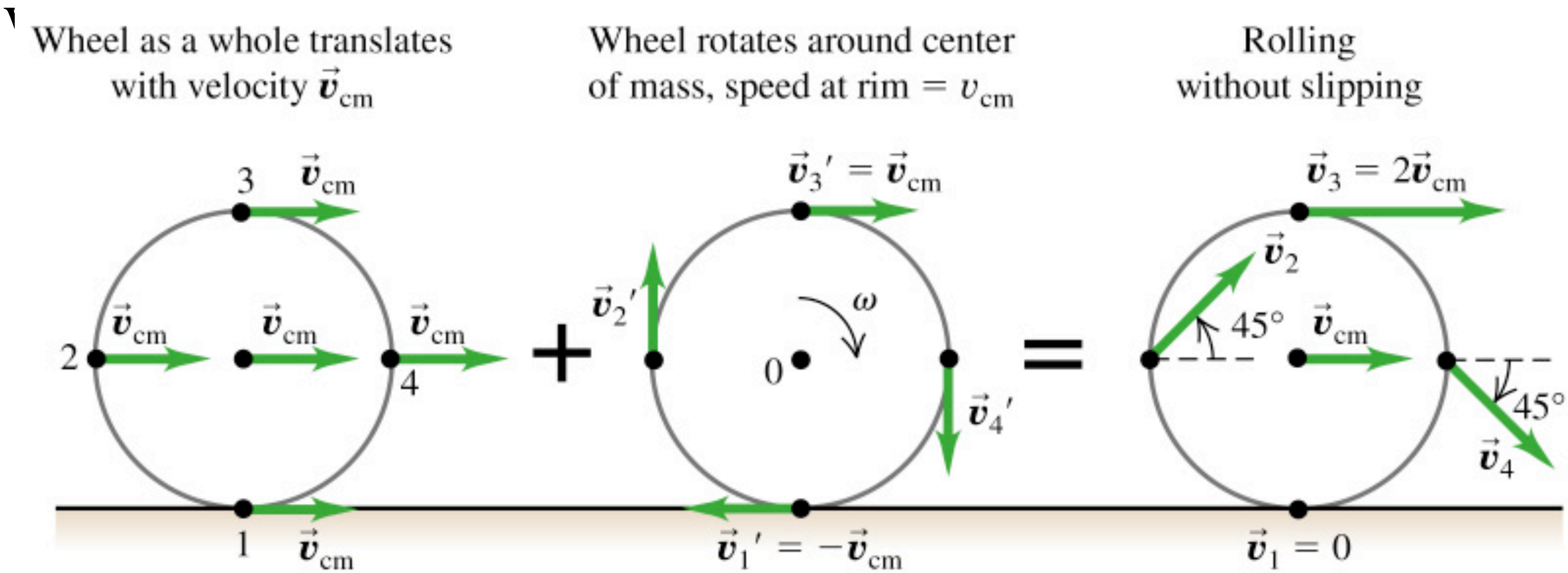
A wheel rolls along without slipping to the right. As viewed from your seat in the lecture hall, what is the velocity of point P?

1.
2.
3.
4.



Rolling

Rolling results from combined actions of linear and angular motion.



The axle traces the center of mass motion

$$v_{axle} = v_{cm}.$$

+

Points on the rim rotate around the (moving axle with angular speed

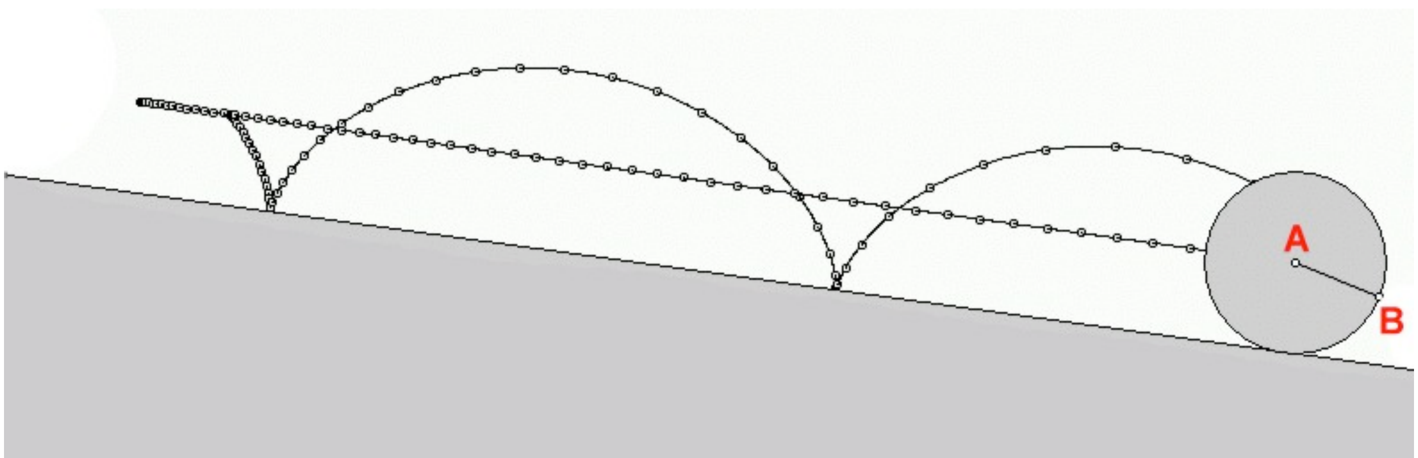
$$\omega = v_{cm} / r.$$

=

The vector sum of these velocity fields is what's seen from the ground.

Rolling is efficient

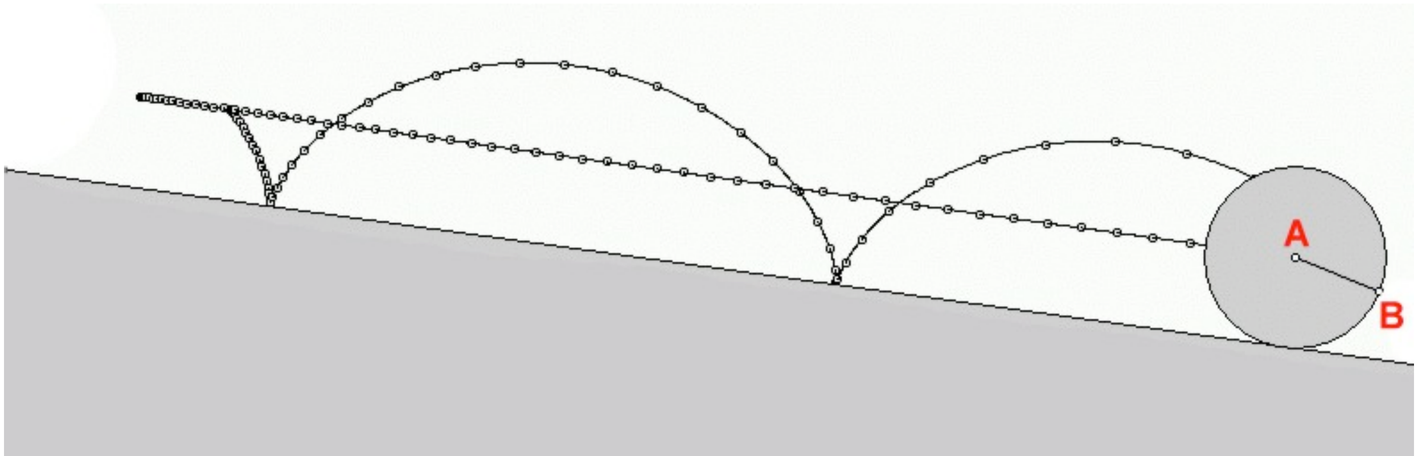
The case of rolling without slipping, starting from rest, along an incline is shown here. Dots are separated by equal time intervals.



Source: Simon Bickerton

http://www.mech.auckland.ac.nz/EngGen121/Pages/CON_WHEEL.html

Kinetic energy of smooth (no slip) rolling



Source: Simon Bickerton

An object rolling has both **translational** and **rotational** kinetic energies. When rolling without slipping, the motions are linked,

$$K_{\text{tot}} = K_{\text{trans}} + K_{\text{rot}}$$

$$= \tfrac{1}{2} m v_{\text{com}}^{2} + \tfrac{1}{2} I \omega^{2}$$

$$= \tfrac{1}{2} m (1 + I / mR^{2}) v_{\text{com}}^{2}$$

and the inertial mass is effectively larger by a factor $(1 + I/mR^2)$.

Mechanical energy of smooth rolling

Any object of circular cross-section that rolls without slipping conserves its **total mechanical energy**

$$E_{\text{mec}} = K_{\text{tot}} + U_{\text{g}}$$

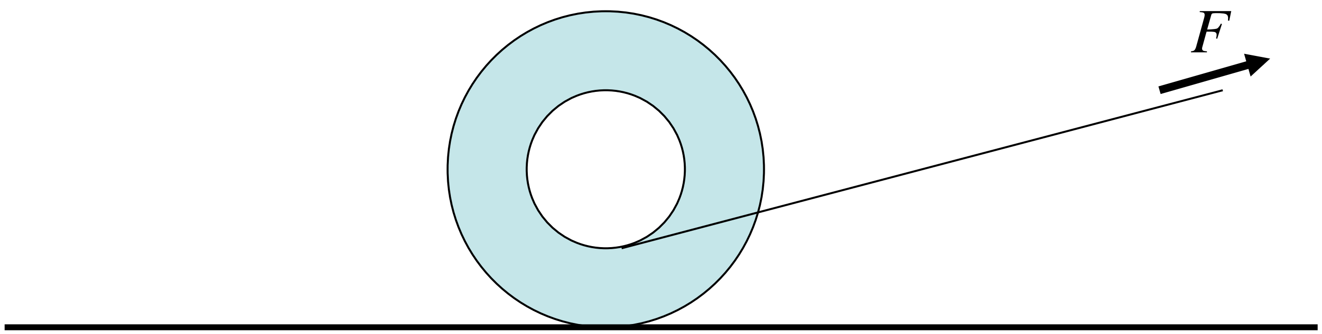
$$= \tfrac{1}{2} m(1 + I/mR^2) v_{\text{com}}{}^2 + mgy$$

Rolling objects (of mass m and cross-sections of radius R) will move at different translational speeds v_{com} after rolling through the same vertical height.

The speed depends on how the mass is distributed, as measured by the dimensionless factor I/mR^2.

A solid disk and a ring roll down an incline. The ring accelerates more slowly down the incline than the disk if:

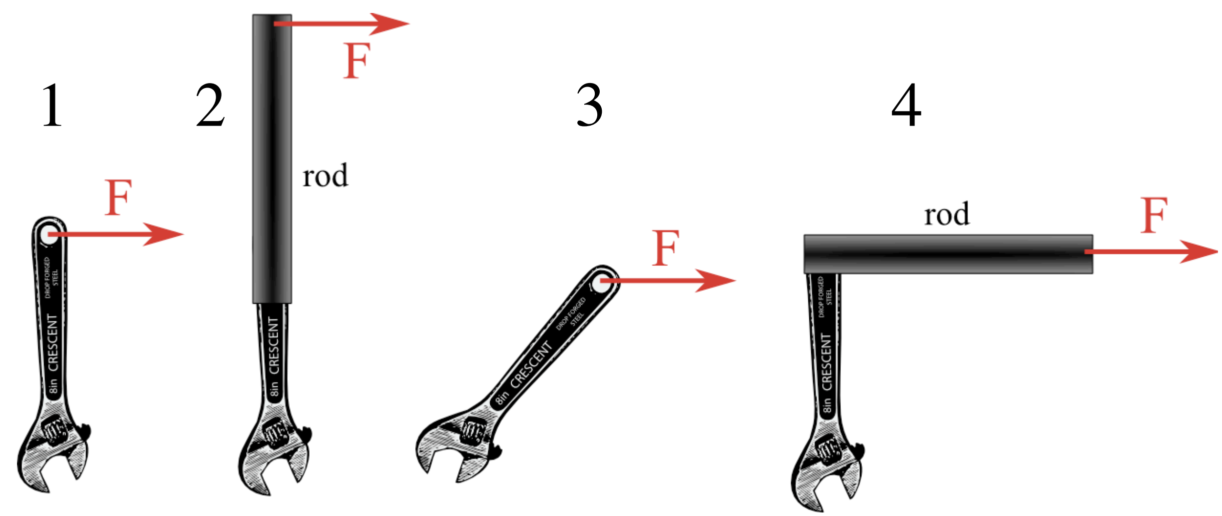
1) $M_{ring} < M_{disk}$, where M is the mass.
2) $R_{ring} > R_{disk}$, where R is the radius.
3) $M_{ring} < M_{disk}$ and $R_{ring} > R_{disk}$.
4) The ring is always slower regardless of the relative values of M and R.



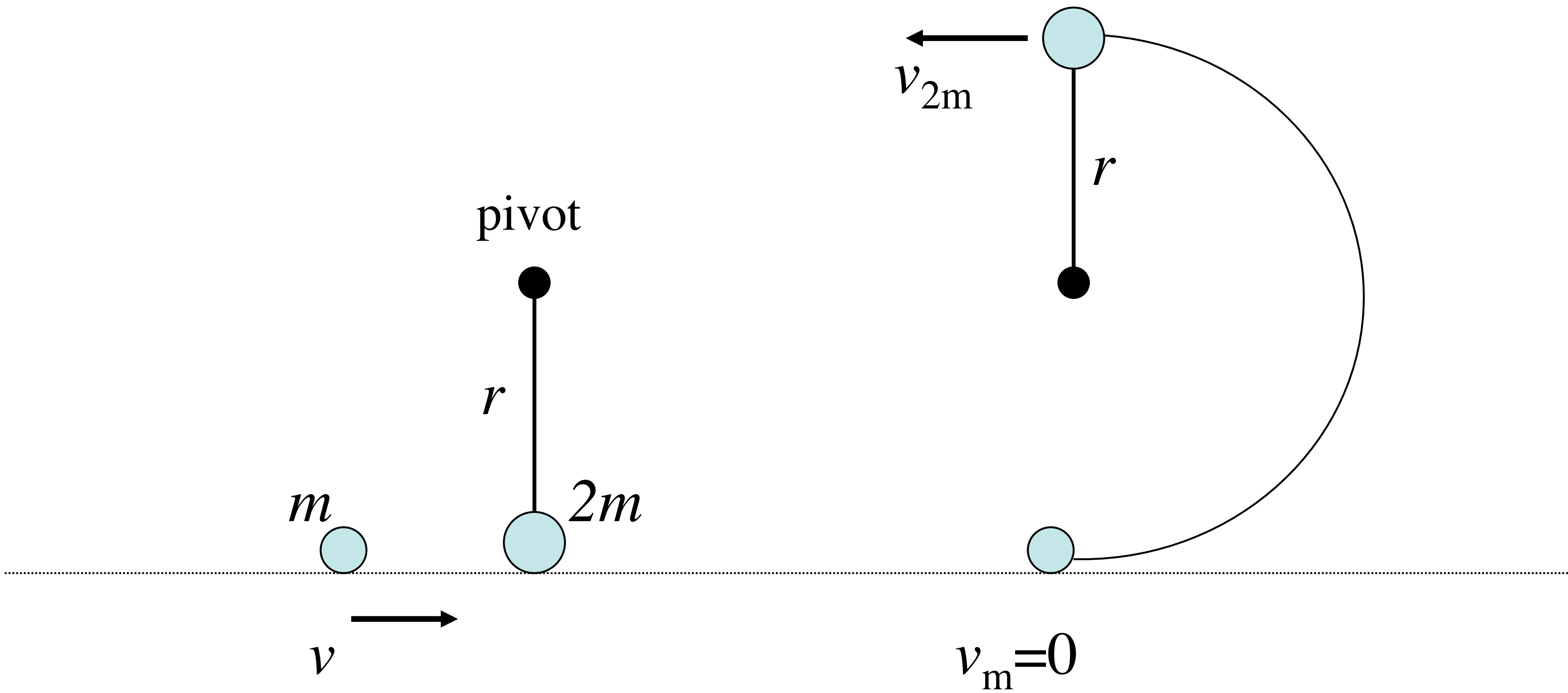
A yo-yo is at rest on a tabletop, with frictional contact between the two. If you pull gently on the string in the direction shown, which way will the yo-yo move?

1. **To the right, toward the applied force.**
2. **To the left, away from the applied force.**
3. **The yo-yo won't move at all.**

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



A ball of mass *m* moving horizontally with speed *v* collides head-on with a stationary ball of mass 2*m* tied to a light string of radius *r*. After the collision, the lighter ball comes to rest. What is the minimum initial speed of the lighter ball such that the heavier one just makes it around the loop?