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# Physics 140 – Fall 2007

1 November: lecture #17

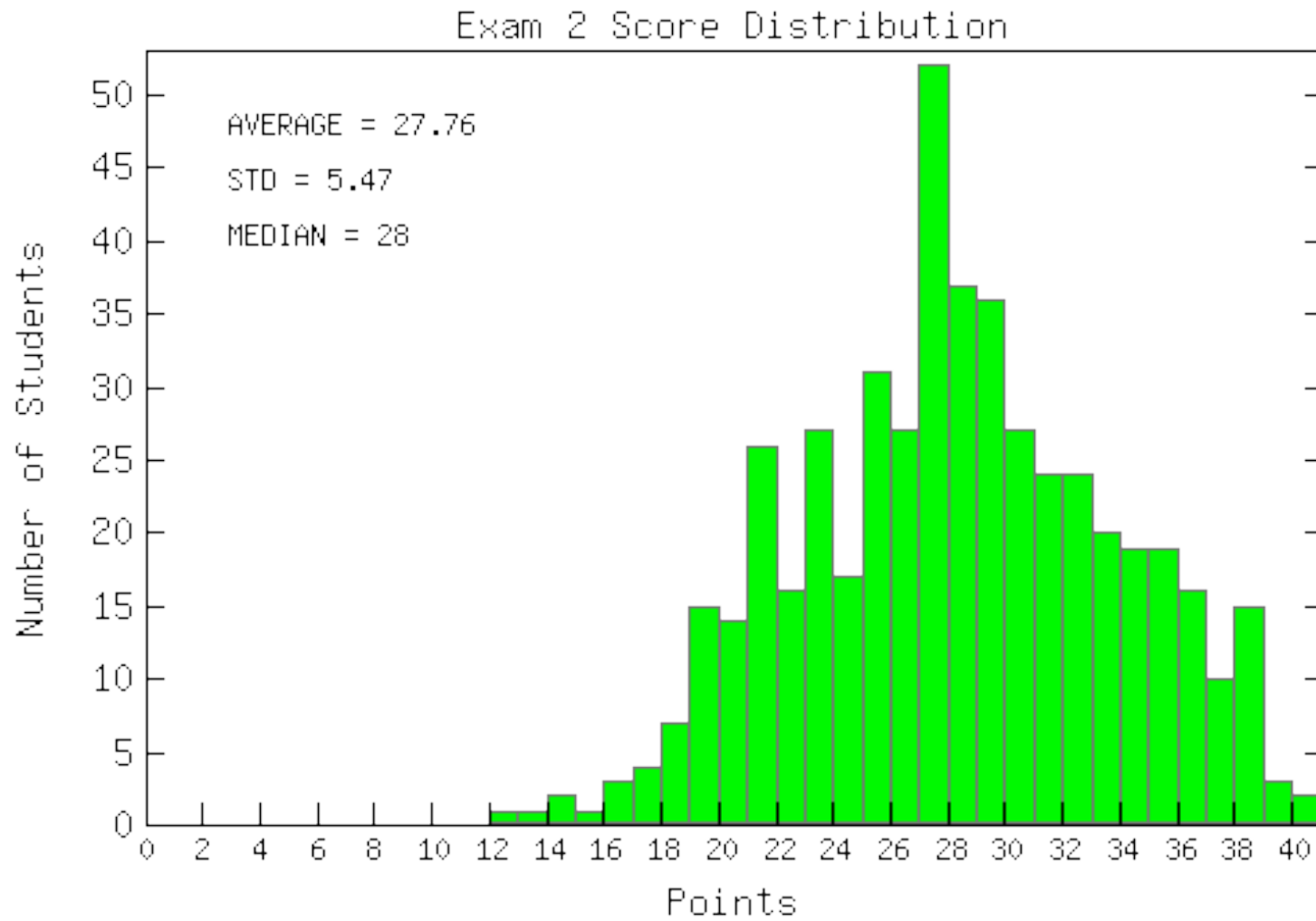
## Ch 10 topics:

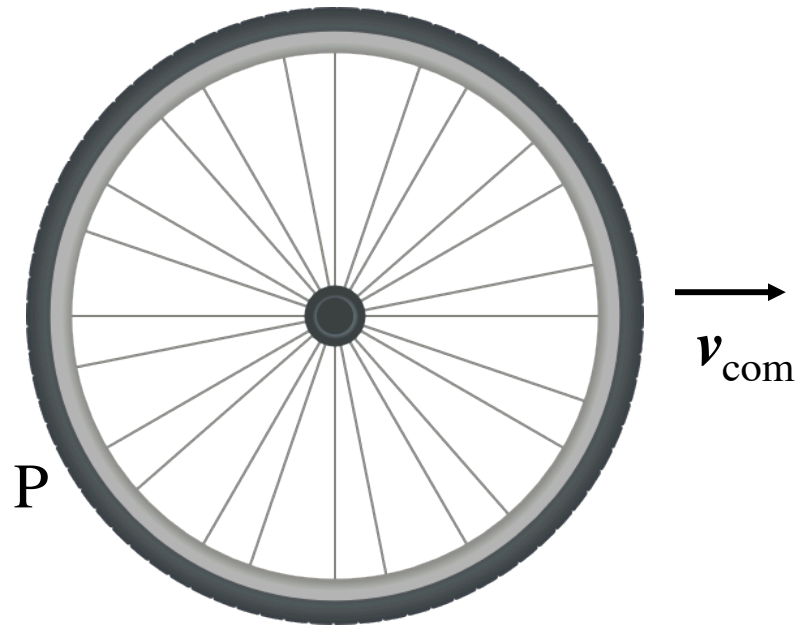
- rolling dynamics
- mechanical energy of rolling

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






bring two 3x5 notecards, calculator, #2 pencils

## Score distribution of practice exam



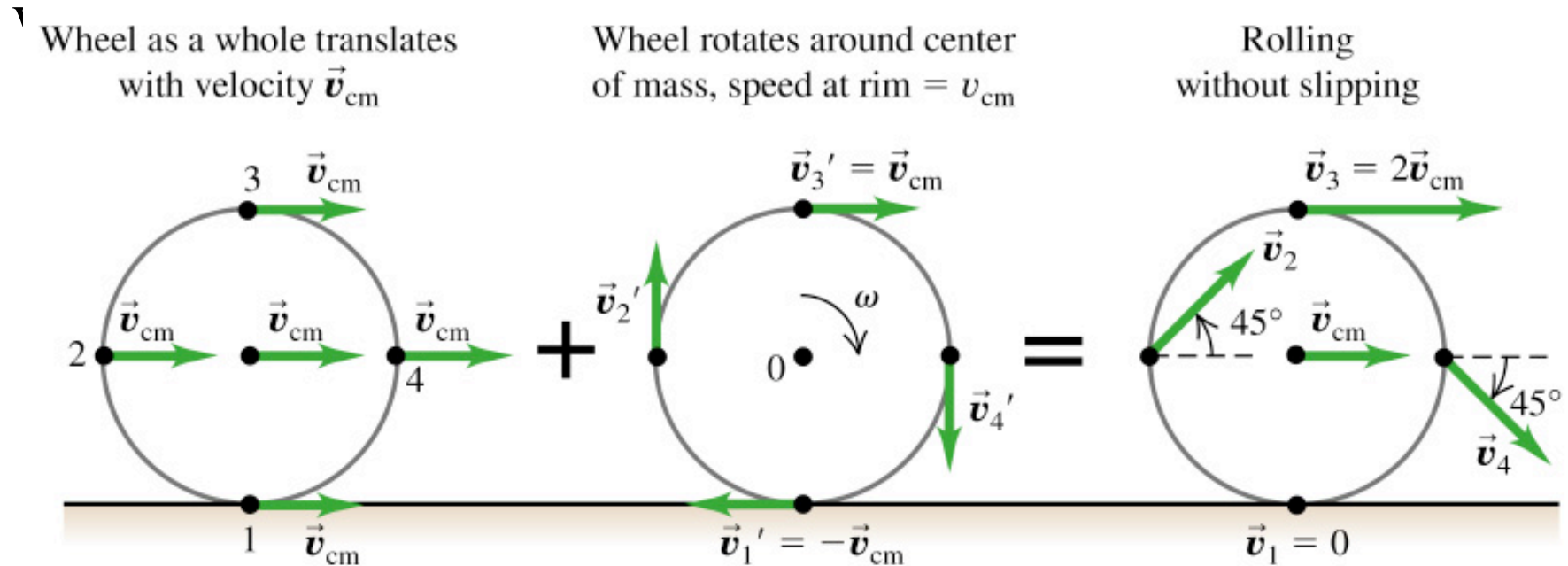


A wheel rolls along without slipping to the right. As viewed from your seat in the lecture hall, what is the velocity of point P?

- 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

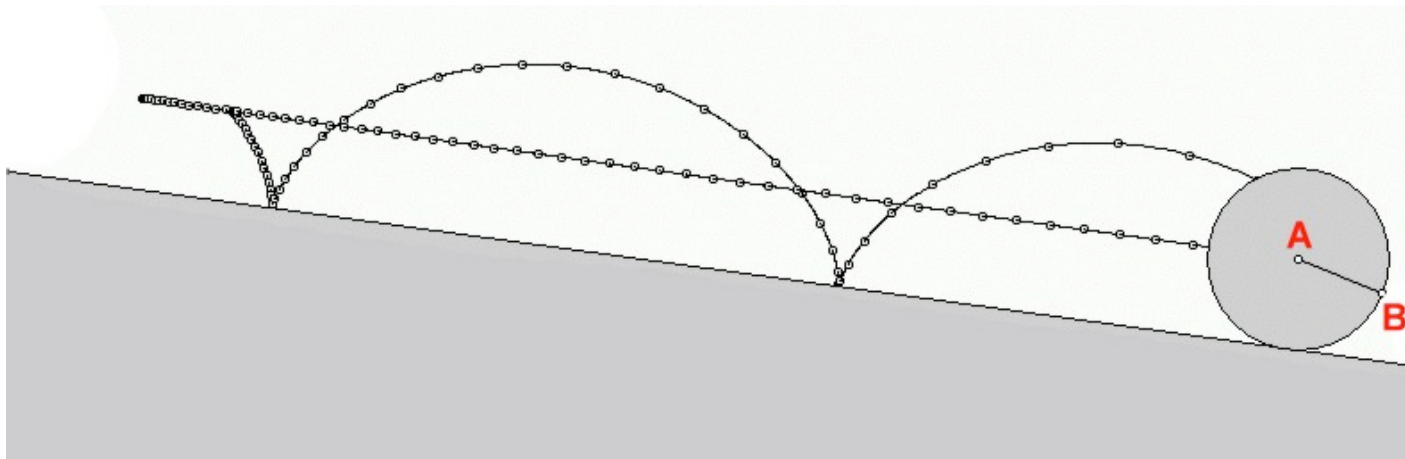
$$\omega = v_{cm} / r$$

=

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

## Rolling is efficient

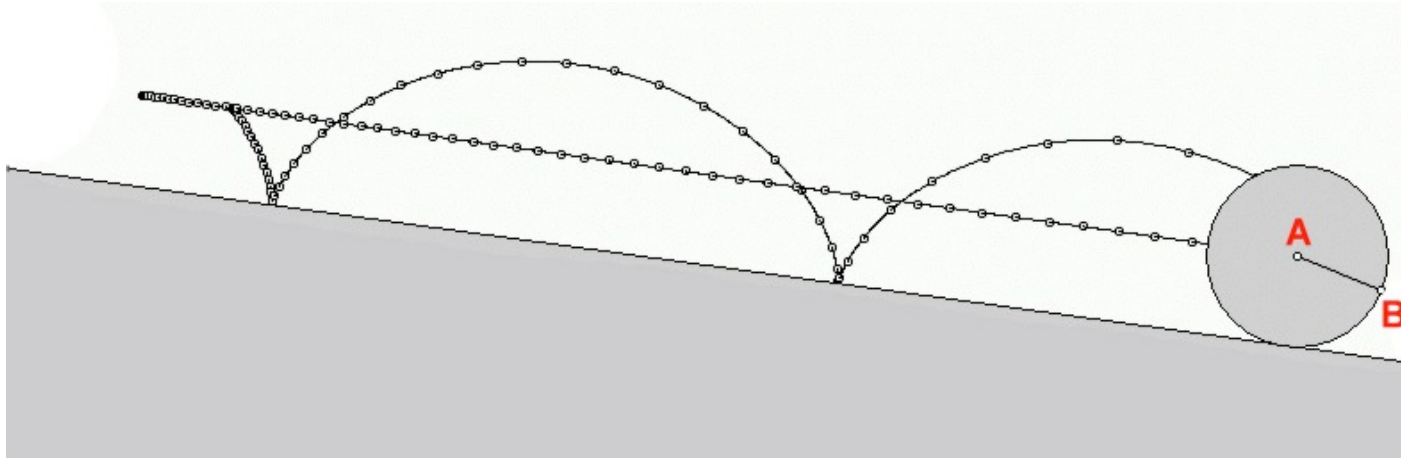
The case of rolling without slipping, starting from rest, along an incline is shown here. Dots are separated by equal time intervals.



Source: Simon Bickerton

[http://www.mech.auckland.ac.nz/EngGen121/Pages/CON\\_WHEEL.html](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,

$$\begin{aligned} K_{\text{tot}} &= K_{\text{trans}} + K_{\text{rot}} \\ &= \frac{1}{2} m v_{\text{com}}^2 + \frac{1}{2} I \omega^2 \\ &= \frac{1}{2} m (1 + I/mR^2) v_{\text{com}}^2 \end{aligned}$$

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**

$$\begin{aligned} E_{\text{mec}} &= K_{\text{tot}} + U_{\text{g}} \\ &= \frac{1}{2} m(1 + I/mR^2) v_{\text{com}}^2 + mgy \end{aligned}$$

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

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



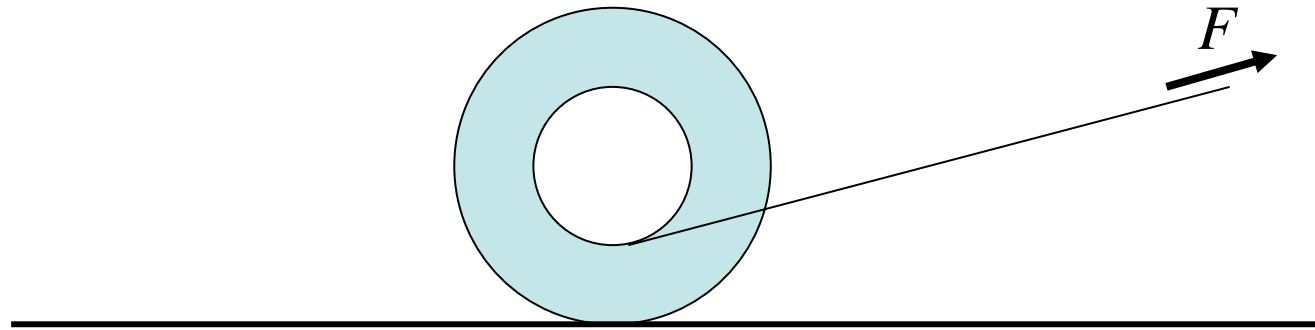
A solid disk and a ring roll down an incline. The ring accelerates more slowly down the incline than the disk if:

1)  $M_{\text{ring}} < M_{\text{disk}}$ , where  $M$  is the mass.

2)  $R_{\text{ring}} > R_{\text{disk}}$ , where  $R$  is the radius.

3)  $M_{\text{ring}} < M_{\text{disk}}$  and  $R_{\text{ring}} > R_{\text{disk}}$ .

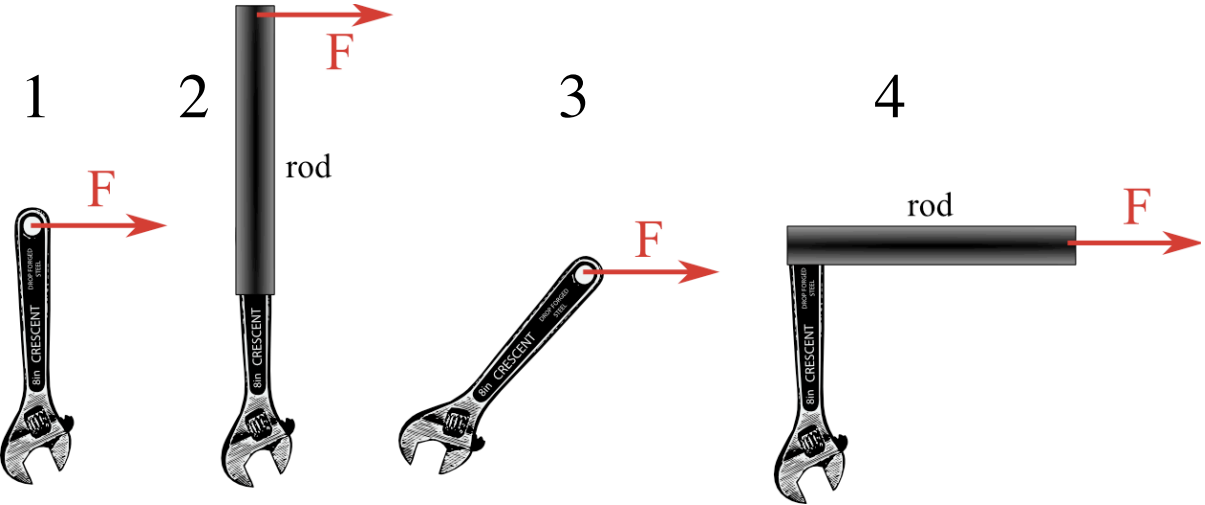
 4) The ring is always slower regardless of the relative values of  $M$  and  $R$ .



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?

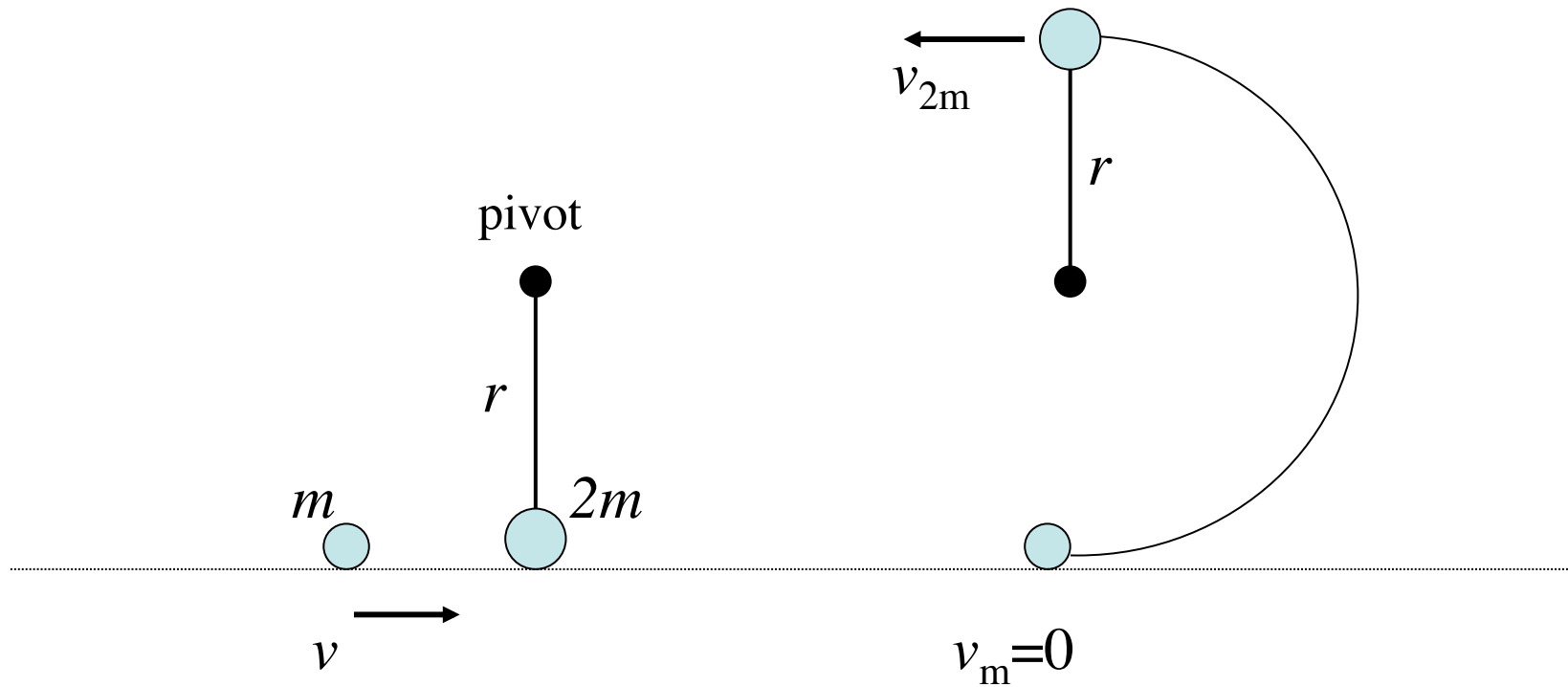
- 
1. To the right, toward the applied force.
  2. To the left, away from the applied force.
  3. The yo-yo won't move at all.

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 decreasing 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  $2m$  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?