- worksheet: `positron.hep.upenn.edu/p8/files/ws07.pdf`
- Only 5 required problems, plus 2 optional/XC.
- Remember to check in with one of us on your way out (if you leave early) or during the last 10 minutes of class (if you stay to the end), so that we can ask how today's work went for you and perhaps offer you some quick feedback on what you've written down.
- Before Wednesday's class meeting, either skim Mazur ch08 or watch my ch08 (part one) video ( youtu.be/QRI1tl5moTs ).
- Chapter 8's topic is **forces**, which we'll spend some serious time on. Richard Farley points out that to understand architectural structures, one first needs to understand three ideas: forces, vectors, and torque.

Two administrative questions to ponder!

- (Think about these today, we'll decide next time.)
- **Do we want occasional quizzes?**
- Three reasons you might say yes are: (a) if you are especially concerned about the "free rider" problem, or (b) if you want a stronger incentive to be sure you understand what you are writing down on your worksheets, or perhaps more cynically (c) if you feel that quizzes give you an advantage.
- **Do we want a traditional final exam?**
- Two reasons you might say yes are: (a) it is simpler to schedule than the alternative, which is small-group chalkboard presentations of problem solving, and (b) if you plan to ace the exam and you want me to be able to quantify in a letter of recommendation how much you distinguished yourself on the final exam.
- Ponder, discuss among yourselves, and we can revisit this on Wednesday.
- Does `pollev.com/billashmanskas261` work for you? (QR code next slide.)

Does `pollev.com/billashmanskas261` work for you?

If $a_x$ is constant, then $v_{xf} = v_{xi} + a_x t$

$$x_f = x_i + v_{xi} t + \frac{1}{2} a_x t^2 \qquad v_{xf}^2 = v_{xi}^2 + 2a_x (x_f - xi)$$

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momentum: $m_1 v_{1xi} + m_2 v_{2xi} = m_1 v_{1xf} + m_2 v_{2xf}$

restitution coeff ($e$): $(v_{1xf} - v_{2xf}) = -e (v_{1xi} - v_{2xi})$

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New results for today:

$$x_{\mathrm{CM}} = \frac{m_1 x_1 + m_2 x_2 + \cdots}{m_1 + m_2 + \cdots}$$

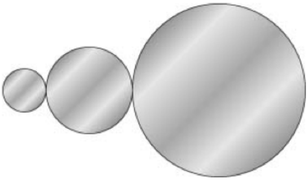
If two objects interact only with one another, then

$$\frac{a_{1x}}{a_{2x}} = -\frac{m_2}{m_1}$$

Lifting an object of mass $m$ from alititude $x_i = 0$ to altitude $x_f = h$ increases the gravitational potential energy of the Earth+objects system by $U^G = mgh$ .

**(Chapter 6 problem.)**

**1.** Let $x = 0$ be the left side of the left circle shown below, and let the $x$ axis point to the right. (a) Find the $x$ coordinate of the center of mass of the system shown below. All three circles are made of sheet metal of the same material, and the diameters are 2.00 m, 4.00 m, and 6.00 m. (b) Repeat the calculation for three solid spheres all made of the same material and having the same diameters as in part a. Hint: to find the CoM, you can replace each circle or sphere with a point mass (of the same mass) at the circle or sphere's own CoM, then find the CoM of those three point masses.



**(Chapter 7 problems.)**

**2.** Two toy cars ($m_1 = 0.350\,\mathrm{kg}$, $m_2 = 0.225\,\mathrm{kg}$) are held together rear to rear with a compressed spring between them. When they are released, the cars are free to roll away from the ends of the spring. If you measure the acceleration of car 1 (the 0.350 kg car) to be $2.75\,\mathrm{m/s^2}$ to the right, what is the acceleration of the other car?

**3*.** Two blocks of inertia (i.e. mass) 3.3 kg each are connected by a string that is draped over the edge of a table, so that one block is on the slippery table and the other is just hanging off the edge. A restraint holds the block on the table in place, and the string is 0.75 m long. After the restraint is released, what speed does each block have at the instant the upper block is pulled off the table? (Think about the two blocks' changes in K.E., and think about the second block's change in G.P.E. Assume that the string stays taut.)

**4.** You drop a rubber ball from a height of 5.00 m. It bounces off a concrete surface to a height of 4.05 m. (a) What is the coefficient of restitution, $e$, for this collision? (b) You want to get the ball to bounce upward (assuming same $e$) to a height of 7.55 m. How fast must you throw it (from the initial height 5.00 m), and in which direction? (Does direction matter?) Use the same restitution coefficient that you found in the first part. Neglect air resistance.

**5.** (a) Show that in an elastic collision between two objects of inertias $m_1$ and $m_2$, with initial velocities $v_{1i} > 0$ and $v_{2i} = 0$, the final velocities are

$$v_{1f} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) v_{1i}, \qquad v_{2f} = \left(\frac{2m_1}{m_1 + m_2}\right) v_{1i}.$$

**Hint:** The easy way to do this is to use Eq 5.4 for elastic collisions, along with momentum conservation. The difficult way is to use the equation for energy conservation instead of Eq 5.4.
(b) Discuss the cases $m_1 \ll m_2$, $m_1 = m_2$, and $m_1 \gg m_2$. Using everyday objects, give an example of each of these three cases.

**6. Optional/XC.** (From Chapter 6.) A golf club of mass $M$ is moving at speed $V_i$ when it strikes (elastically) a stationary golf ball of mass $m$. Show that in the limit $M \gg m$, the golf ball's speed after the collision is $v_f = 2V_i$. (a) First solve this problem by using the result of problem 5, with $m_1 = M$ and $m_2 = m$, and taking the limit $m_1 \gg m_2$. (b) Then re-solve the problem by working in the ZM frame of the collision. Hint 1: in the limit $M \gg m$, the ZM frame is the same as the rest frame of the golf club. Hint 2: for an elastic collision as seen in the ZM frame, each final velocity is just the negative of the corresponding initial velocity. You can see this factor of two at `youtu.be/U3j-o3UXRSI` .

**7. Optional/XC.** (From Chapter 5.) The extinction of the dinosaurs has been attributed to a collision between Earth and an asteroid about 10 km in diameter. Assume that the asteroid had about the same density as Earth. (Earth's mass is $6.0 \times 10^{24}\,\mathrm{kg}$, and its **circumference** is 40,000 km.) Also assume that the asteroid's initial speed with respect to Earth is about the same as Earth's orbital speed around the sun. (This is equivalent to assuming that the moving Earth slams (totally inelastically) into a stationary asteroid.) Estimate the energy released by such an impact. Express your estimate in terms of "megatons of TNT equivalent." (Detonating 1 megaton of TNT releases an energy of $4.2 \times 10^{15}$ joules. Earth's orbital speed around the sun is about 30 km/s.)

Rubric: 4 points per problem: 2 for effort, 2 for correctness.

- 4 points = correct or very nearly correct
- 3 points = minor mistake
- 2 points = major mistake
- 1 point = you haven't convinced us that you put in much effort to try to solve the problem
- 0 points = nothing or very little of substance written down
- For some problems (such as today's hands-on bridge model), it may be unreasonable for us to look for "correctness," so instead all 4 points will be for effort.
- 4 additional overall points for presenting your work clearly, with adequate reasoning. So if $n$ is the number of problems, the total points will usually be $4n + 4$.