- worksheet: `positron.hep.upenn.edu/p8/files/ws04.pdf`
- Bill is away (UT Arlington) today (Wednesday). Helping Ryan & Marija will be two of Phys8 2021's top students: Christina Cunningham & Sydney Goldstein. Same seating as Monday.
- Remember to check in with Ryan or Marija **or Sydney or Christina** 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.
- Please write to Bill **in advance** if you need to miss class.
- End of day (midnight) is fine for worksheet PDF upload to Canvas. We just prefer for you not to have to keep working after class, since you have a lot of out-of-class video/reading work to do to prepare for each class.

- before next Monday's class meeting:
- Watch my day05 video (energy), probably at 1.5× or 2× speed. It's well under 2 hours this time!
- I think if you do that, you will probably **not** need to **skim** Mazur chapter 05 (PDF on Canvas), though you could look over the stuff on energy diagrams and on "internal energy."
- If you like to read and don't like lectures, you can read the book and skip most of my videos. If you prefer lectures, I think you can watch the lecture videos and skip the reading, though I originally wrote the lecture material assuming you did the reading first. My lecture video PDF slides are at `positron.hep.upenn.edu/p8/files` with filenames `phys8_slides_*.pdf` eg `phys8_slides_05.pdf` for the video to watch before our "day05" class and worksheet ws05.
- So I'm pretty sure that you'll be able to choose either video or textbook reading to prepare for each class day.

Reminder of ch03 key results

velocity is rate of change of position: $v_x = \frac{\mathrm{d}x}{\mathrm{d}t}$

acceleration is rate of change of velocity: $a_x = \frac{\mathrm{d}v_x}{\mathrm{d}t}$

If acceleration is **constant**, then:

$$v_{x,f} = v_{x,i} + a_x t$$

$$x_f = x_i + v_{x,i} t + \frac{1}{2} a_x t^2$$

$$v_{x,f}^2 = v_{x,i}^2 + 2a_x \left(x_f - x_i\right)$$

Important cases for which a_x is constant:

free fall: $a_x = -g$
(x axis points up)

inclined plane: $a_x = +g \sin\theta$
(x axis points downhill)

Key results from today's Chapter 4 (momentum):

Momentum $\boxed{\vec{p} = m\vec{v}}$. Constant for *isolated* system: no external pushes or pulls (next week we'll say "forces"). Conservation of momentum in isolated two-body collision implies

$$\boxed{m_1 v_{1x,i} + m_2 v_{2x,i} = m_1 v_{1x,f} + m_2 v_{2x,f}}$$

which then implies (for isolated system, two-body collision)

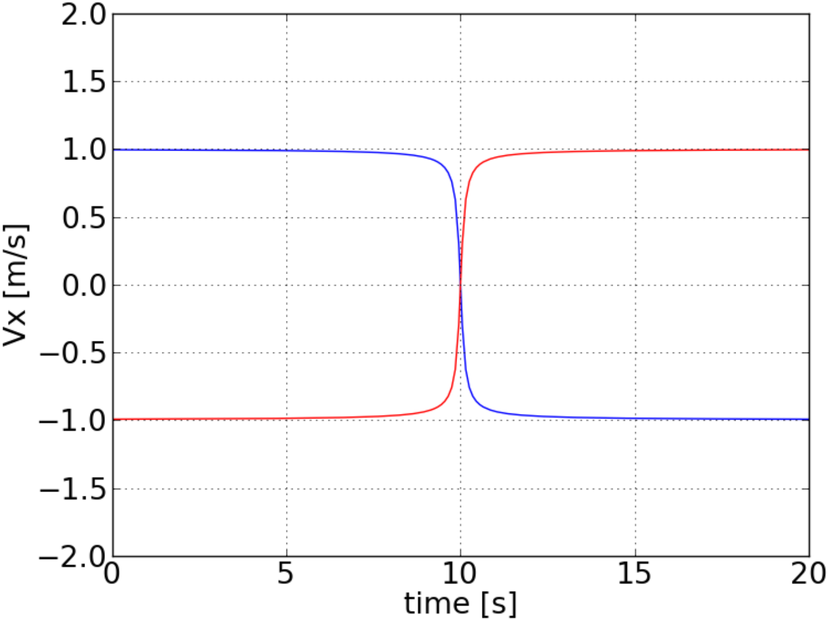
$$\frac{\Delta v_{1x}}{\Delta v_{2x}} = -\frac{m_2}{m_1}$$

If system is not isolated, we introduce a concept called "impulse" meaning the transfer of momentum into a system from outside the system, due to objects inside the system interacting with objects outside the system. You will rarely use impulse, other than to consider whether or not it is nonzero.

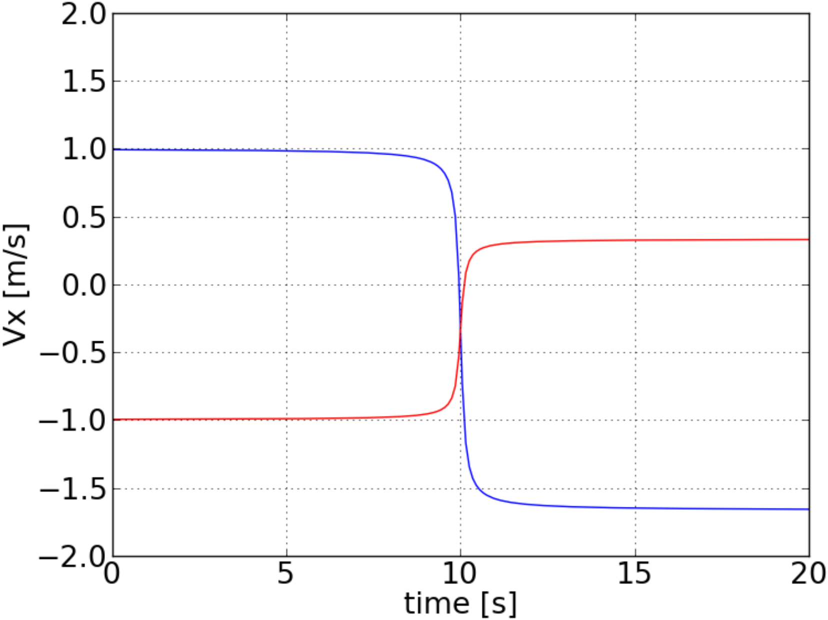
Write this on board before next few slides:

(A) Red mass is 5$\times$ blue mass [“alpha!”]
(B) Blue mass is 5$\times$ red mass [“bravo!”]
(C) The two masses are the same [“charlie!”]
(D) Red mass is 2$\times$ blue mass [“delta!”]
(E) Blue mass is 2$\times$ red mass [“echo!”]

What is the ratio of masses in this collision?



What is the ratio of masses in this collision?



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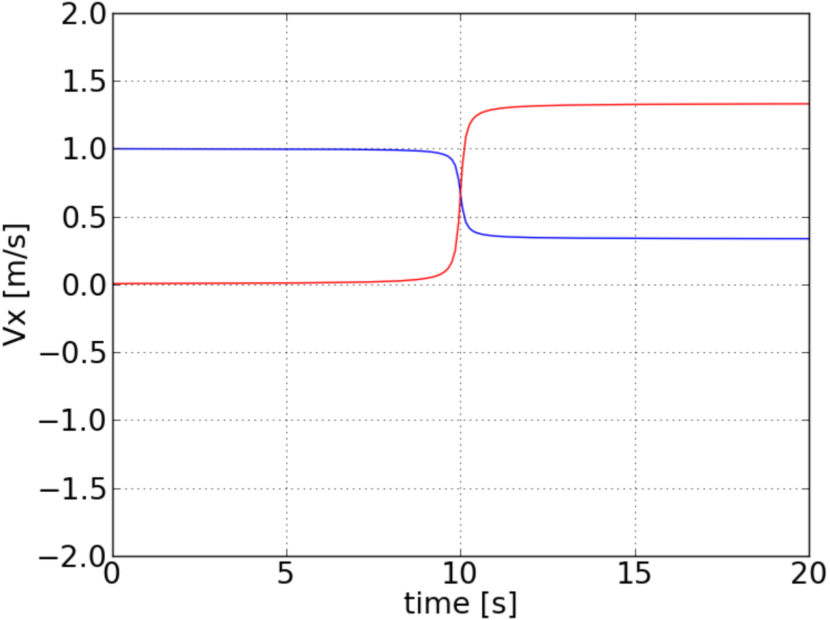
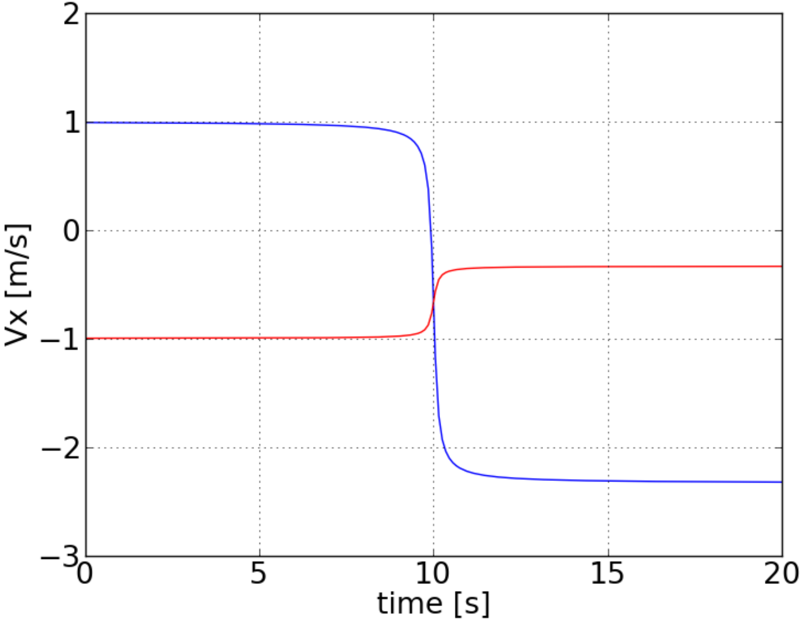


What is the ratio of masses in this collision?



An old exam problem started like this . . .

You have been hired to check the technical correctness of an upcoming made-for-TV murder mystery. The mystery takes place in the space shuttle. In one scene, an astronaut's safety line is sabotaged while she is on a space walk, so she is no longer connected to the space shuttle. She checks and finds that her thruster pack has also been damaged and no longer works. She is 200 meters from the shuttle and moving with it. That is, she is not moving with respect to the shuttle. There she is — drifting in space — with only 4 minutes of air remaining. To get back to the shuttle, she decides to unstrap her 10 kg tool kit and . . .

What do you think the rest of the problem says she does with her 10 kg tool kit?

You've now watched many pairs of carts collide on low-friction tracks. Conservation of momentum lets us write one equation:

$$m_1 v_{1x,i} + m_2 v_{2x,i} = m_1 v_{1x,f} + m_2 v_{2x,f}$$

Often we know both initial velocities, but we don't know either of the two unknown final velocities. So we have two unknowns. Energy adds a second equation, which usually involves **relative speed** $|v_{1x} - v_{2x}|$ of the two carts.

- elastic: $(v_{1x,f} - v_{2x,f}) = -(v_{1x,i} - v_{2x,i})$
- totally inelastic: $(v_{1x,f} - v_{2x,f}) = 0$
- if e is given: $(v_{1x,f} - v_{2x,f}) = -e(v_{1x,i} - v_{2x,i})$
- if change in internal energy is given:

$$K_{1i} + K_{2i} + E_{i,\text{internal}} = K_{1f} + K_{2f} + E_{f,\text{internal}}$$

Video 05 includes many examples of using these results, as well as the very-big-deal result that kinetic energy is

$$K = \frac{1}{2}mv^2$$

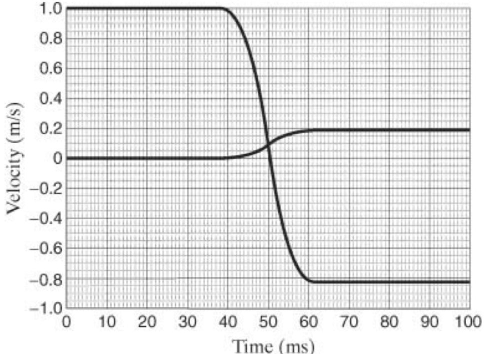
Physics 8, Fall 2023, Worksheet #4.

1*. During a blackout (a non-fire event, advises Prof Farley), you are trapped in a tall building. You want to call rescuers on your cell phone but can't remember which floor you're on. You pry open the doors to the elevator shaft, stoop down to floor level, drop your keys down the shaft, and hear them hit bottom at ground level 3.67 s later. (a) Making a simple calculation and remembering that the ground floor is numbered floor 1 (conventional in the USA), you determine which floor you're on. What floor is that? (Take the distance between flights to be 3.0 m.) (b) Before you make that phone call, however, you realize you've forgotten that the sound of the impact at the bottom travels up the shaft at 343 m/s, and so you redo your calculation. What floor number do you tell the rescuers? (The challenge here is explaining your reasoning for part (b)!)

2*. Two male moose charge head-on at each other with the same speed and meet on an icy patch of tundra. As they collide, their antlers lock together and the two slide together with one-half of their original speed. (a) What is the ratio of their inertias (i.e. the ratio of their masses)? (b) In which direction do they slide after colliding?

3*. A load of coal is dropped vertically from a bunker into a railroad hopper car of inertia $2.7 \times 10^4\,\mathrm{kg}$ coasting at $0.51\,\mathrm{m/s}$ on a level track. The car's speed is $0.23\,\mathrm{m/s}$ after the coal falls. What is the inertia (i.e. the mass) of the load of coal? (Since we are analyzing only the horizontal motion, we can consider the coal+car system to be isolated.)

4. In some collisions, the velocity of one participant changes little while that of the other changes a lot, as the figure below illustrates. (a) In which direction (positive or negative) are the objects moving before the collision? (b) After the collision? (c) What is the ratio of the inertia (ie mass) of the larger object to the inertia (ie mass) of the smaller object? (d) Does friction play an important role in this collision? (Explain what feature of the graph would indicate whether or not friction is negligible here. Hint: non-negligible friction would cause moving objects to slow down, before, during, and after the collision.)



5*. In the process of moving out of your house, you are dropping stuff out a second-floor window to a friend 6.8 m below. You are about to drop a 13 kg stereo speaker when you remember that your friend cannot catch anything that has a momentum greater than 140. kg·m/s. Should you drop the speaker?

6. At an amusement park, a 130 kg bumper car traveling east at 2.5 m/s collides head-on with a 170 kg bumper car traveling at 1.9 m/s in the opposite direction. The bumper cars do not have brakes. You do not know anything about the type of material used in the bumper cars' bumpers, e.g. how well it regains its initial shape after being deformed. So the cars may stick together, may recoil, or something in between. (a) From the given information, is it possible to predict the velocities of the two cars after the collision? Explain your answer. (b) Is it possible to predict the value that any pertinent physical quantity has after the collision? If so, state that quantity and its final value. (Hint: think of a quantity whose units are kg·m/s.)

If you have extra time, you can revisit the ws03 XC problems.

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 $4n + 4$.