- before 4th class meeting : topic is **momentum**
- Watch 'day04' video or/and skim Mazur chapter 4.
- I think the video is pretty comprehensive, so if you prefer lectures rather than reading, you can just watch the video and then just quickly look over the checkpoints for the concepts half of Mazur's ch04.
- If you do decide to **skim** Mazur chapter 4, you should focus on the concepts half of the chapter. Try to do the checkpoints, but you can gloss over most of the equations.

- Course www: `http://positron.hep.upenn.edu/physics8`
- Question: momentum is what times what?

Chapter 4: momentum

- An object's momentum is $\vec{p} = m\vec{v}$ $p_x = mv_x$
- m is for "mass" a.k.a. "inertia." Mass plays two roles in physics: how strongly an object is attracted by gravity, and how difficult it is to change an object's velocity. We say "inertia" for now to focus on this latter aspect of mass. Inertia equals mass.
- Momentum is *conserved*: it can be transferred between interacting objects, but it cannot be created or destroyed.
- If the objects within a system have no interactions with the outside world ("isolated system"), then the momentum of that system is constant (cannot change).
- Imagine how it feels to throw a very heavy ball.
- Now imagine that you are standing on a sheet of ice!
- The difference is the *impulse* you get from the interaction between your shoes and the non-slippery floor.

For two carts colliding on a frictionless track, I can define "the system" to include just the two carts. Then $\boxed{\Delta\vec{p}_{\rm system} = \vec{0}}$ because the system is isolated (i.e. interactions with the outside are negligible).

Here are 7 different ways of saying the exact same thing:

$$\Delta\vec{p}_1 + \Delta\vec{p}_2 = \vec{0} \quad \text{(isolated system)}$$

$$\vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f}$$

$$p_{1x,i} + p_{2x,i} = p_{1x,f} + p_{2x,f}$$

$$m_1\ \Delta v_{1x}\ +\ m_2\ \Delta v_{2x}\ =\ 0$$

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

$$m_1\ \Delta v_{1x}\ +\ m_2\ \Delta v_{2x}\ =\ 0$$

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

The boxed equation is most useful for problem solving. The last equation is most useful for visual observation of collisions.

(For an isolated system of two objects)

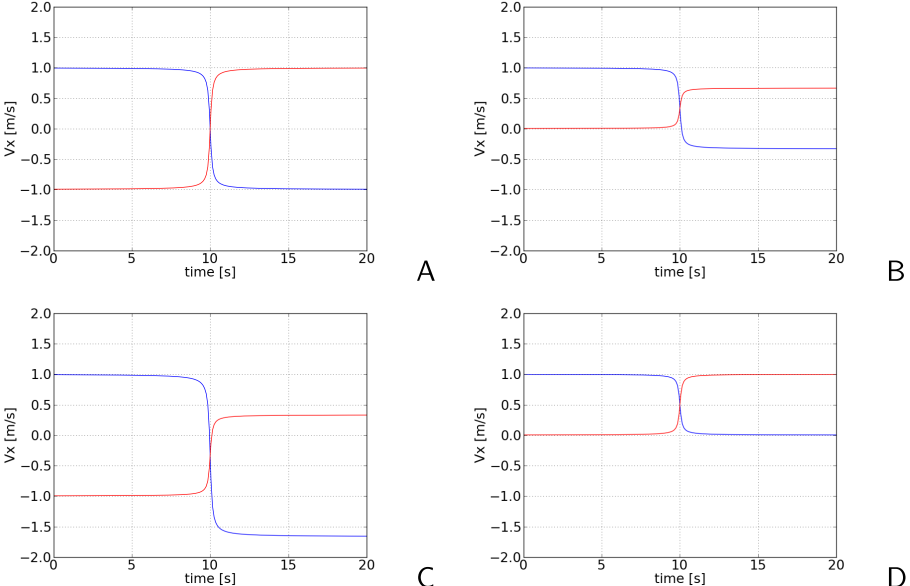
$$m_1 v_{1x,i} + m_2 v_{2x,i} = m_1 v_{1x,f} + m_2 v_{2x,f}$$

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

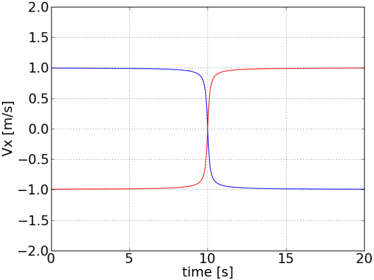
Let's watch the collision between a cart of mass m and a cart of mass $3m$ that you considered after last Tuesday night's reading.

Then let's watch the case where $m_1 = m_2$.

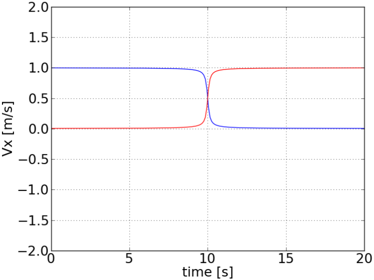
What are the expected shapes of $v_{1,x}(t)$ [blue] and $v_{2,x}(t)$ [red] when $m_2 = m_1$, and initially cart 1 is moving to the right and cart 2 is stationary?



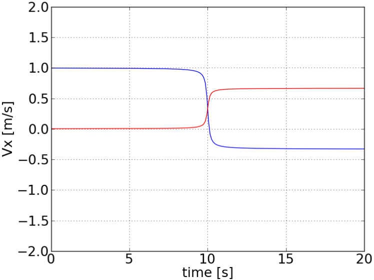
What are the expected shapes of $v_{1,x}(t)$ [blue] and $v_{2,x}(t)$ [red] when $m_2 = m_1$, and initially cart 1 is moving to the right and cart 2 is moving to the left?



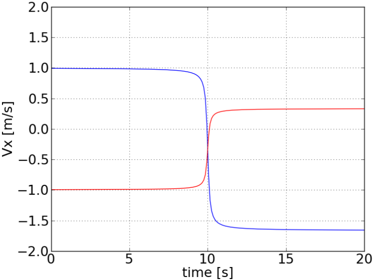
A



B

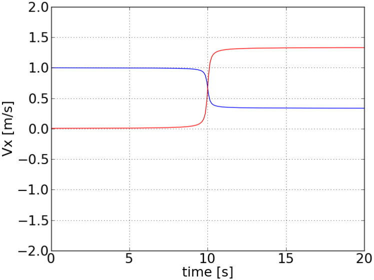


C

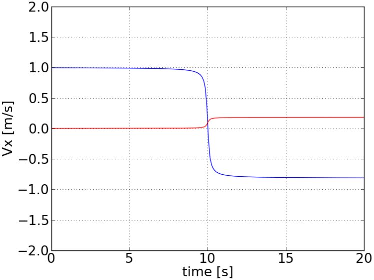


D

What are the expected shapes of $v_{1,x}(t)$ [blue] and $v_{2,x}(t)$ [red] when $m_2 = 2m_1$, and initially cart 1 is moving to the right and cart 2 is stationary?



A



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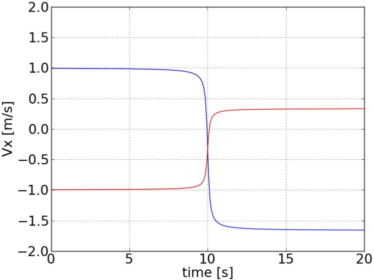
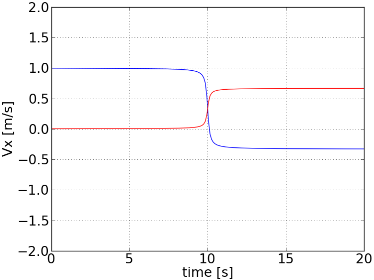


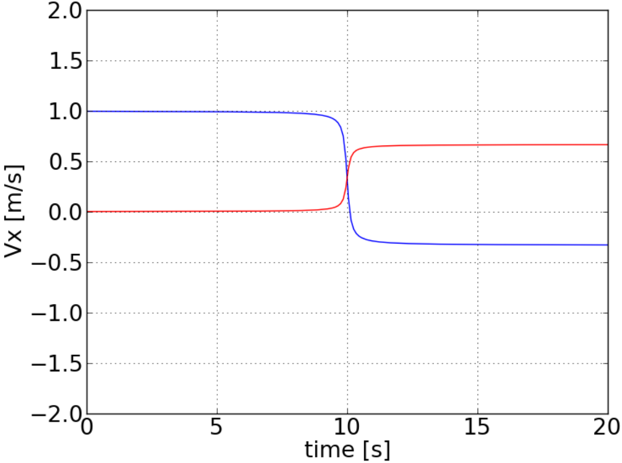
C



D

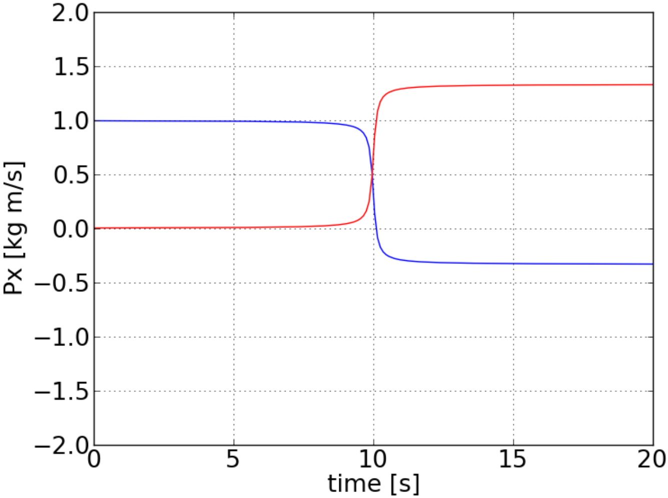
By the way: how would this graph look if we were to graph **momentum** instead of velocity for each cart? (This graph shows velocities. Graph on next page will show momenta.)

(. . . when $m_2 = 2m_1$, and initially cart 1 is moving to the right and cart 2 is stationary?)

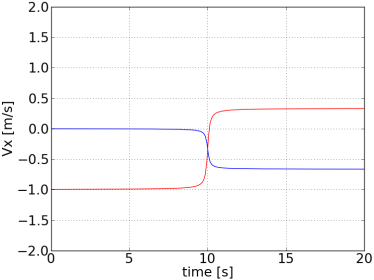


Let's look at momentum p_x instead of velocity v_x:

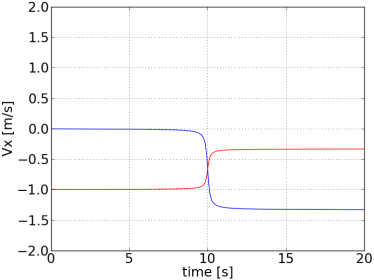
(... when $m_2 = 2m_1$, and initially cart 1 is moving to the right and cart 2 is stationary?)



What are the expected shapes of $v_{1,x}(t)$ [blue] and $v_{2,x}(t)$ [red] when $m_2 = 2m_1$, and initially cart 1 is stationary and cart 2 is moving to the left?



A



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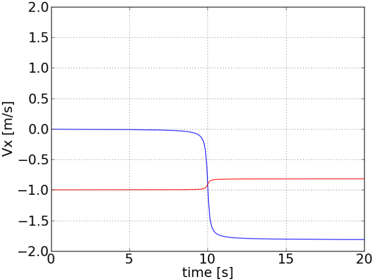

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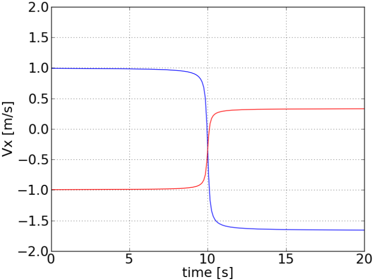
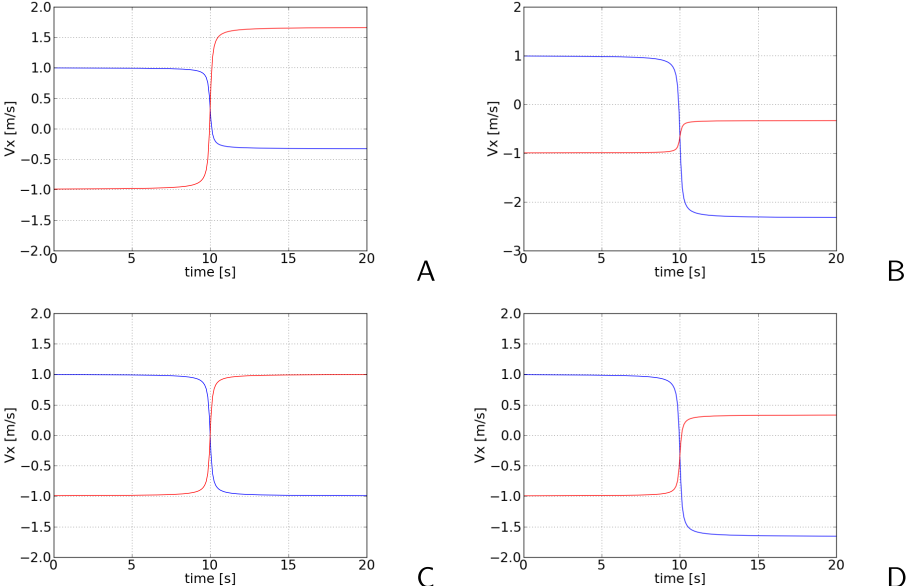


D

What are the expected shapes of $v_{1,x}(t)$ [blue] and $v_{2,x}(t)$ [red] when $m_2 = 2m_1$, and initially cart 1 is moving to the right and cart 2 is moving to the left?



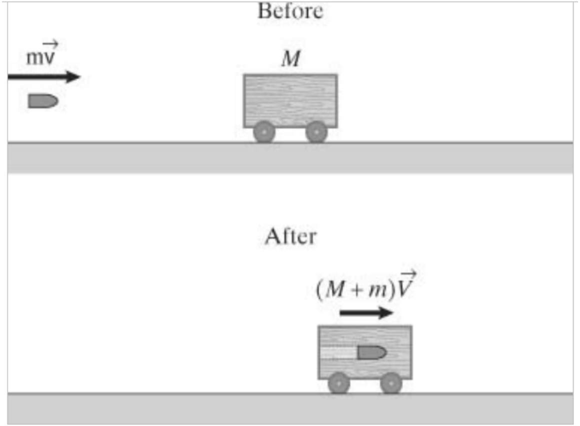
Which has more momentum —
a 0.50 kg baseball pitched at 40 m/s or
a 0.010 kg bullet fired at 400 m/s?

(A) Magnitude of baseball's momentum is larger.

(B) Magnitude of bullet's momentum is larger.

(C) The two momenta are equal in magnitude.

The speed of a bullet can be measured by firing it at a wooden cart initially at rest and measuring the speed of the cart with the bullet embedded in it. The figure shows a 0.0100 kg bullet fired at a 4.00 kg cart. After the collision, the cart rolls at 2.00 m/s. What is the bullet's speed before it strikes the cart? (Once you write down the right expression, the math works out pretty easily without a calculator.)



(A) 4.00 m/s
(B) 798 m/s
(C) 800 m/s
(D) 802 m/s

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?

(Segue: low-tech carts rolling on track.)

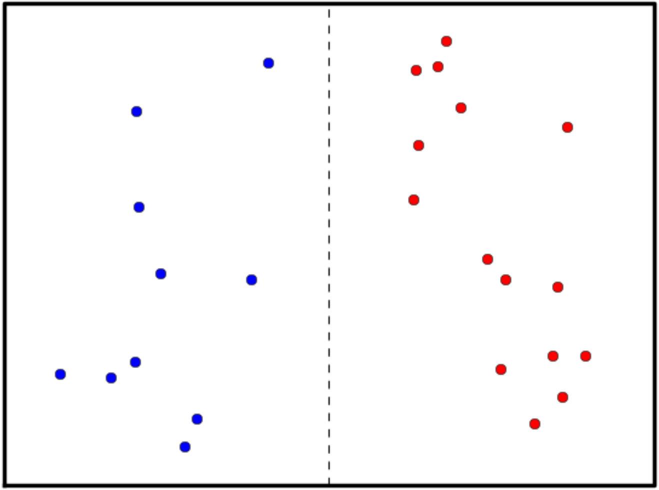
Q about chapter 4: “extensive” quantities

- A quantity Q describing a system is **extensive** if when you divide up the system into two parts,

$$Q(\text{part1}) + Q(\text{part2}) = Q(\text{combined})$$

- Typical examples are volume, money, mass, number of atoms
- Some counterexamples (*not* extensive) are humidity, density, color, temperature.
- Some (just a few) extensive quantities are **conserved**, meaning they can be transferred but can never be created or destroyed. **Momentum** and **energy** are examples of conserved quantities in physics.
- All conserved quantities are extensive, but only a few extensive quantities are conserved.

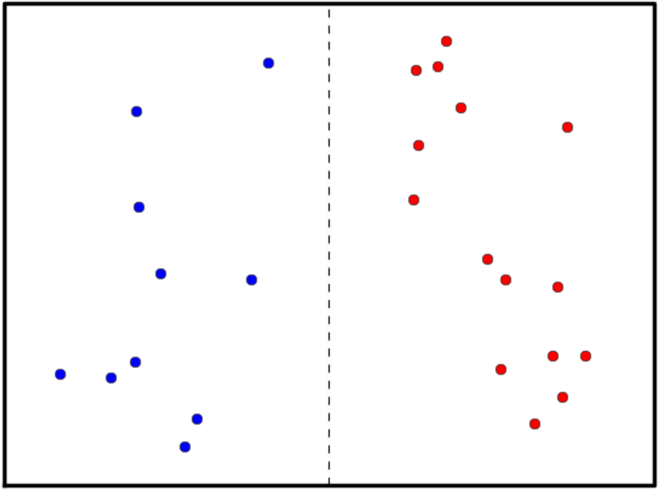
Is **number of dots** an extensive quantity?



(A) Yes.

(B) No.

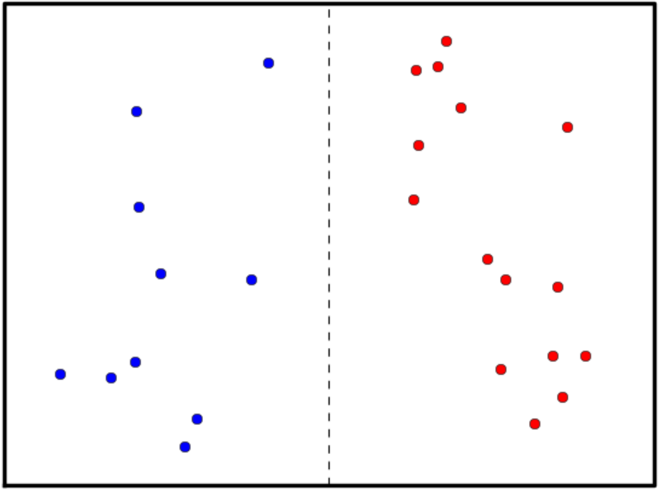
Is **dot diameter** an extensive quantity?



(A) No.

(B) Yes.

Is **total area covered by dots** an extensive quantity?



(A) No.

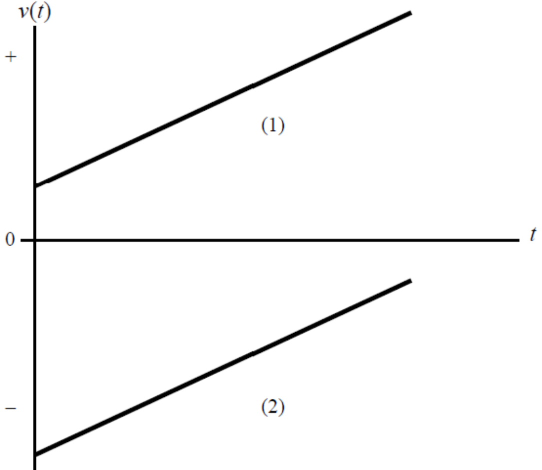
(B) Yes.

(C) Yes, as long as the dots can't overlap.

This may help with one part of one worksheet question:

(The issue is what non-negligible friction would look like on a velocity-vs-time graph.)

The velocity-vs-time graph below shows the motion of two different objects moving across a horizontal surface. Could the change in velocity with time be attributed to friction in each case?



(a) Yes for the top curve, no for the bottom curve.

(b) No for the top curve, yes for the bottom curve.

(c) Yes for both curves.

(d) No for both curves.

(e) I have no idea how friction would affect a velocity-vs-time graph!

Here once again are the key results from 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

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

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, then we *cannot* write $\vec{p}_f - \vec{p}_i = 0$. Instead, we give the momentum imbalance caused by the external influence a name ("impulse") and a symbol ($\vec{J}$). Then we can write $\vec{p}_f - \vec{p}_i = \vec{J}$. You will rarely use $\vec{J}$, other than to consider whether or not it is nonzero.

Do you remember the key results from Ch 3 (acceleration)?

- We are going pretty quickly through the early chapters of the textbook. We will slow down for the more difficult topics in Ch10,11,12. The faster pace now lets us make time for the fun applications to structures later. I hope you'll be glad we did.