Physics 8 — Wednesday, September 11, 2019

- Course www: `http://positron.hep.upenn.edu/physics8`
- Today's focus will be ch5 (energy), which you read for Monday. For today you read ch6 (relative motion).
- Next week, you will read Ch7 (interactions) [for Monday] and Ch8 (force) [for Wednesday]. Ch6 and Ch7 take some time to read, but they don't add many new equations ("quantitative results") to learn how to work with. Ch5 (energy) and Ch8 (force) will get more class time than Ch6 and Ch7. So there is really one **substantive** chapter this week and one next week.
- 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. You'll be glad we did.
- Remember homework #2 due this Friday, at the start of class. It covers Chapters 3 (acceleration) and 4 (momentum).
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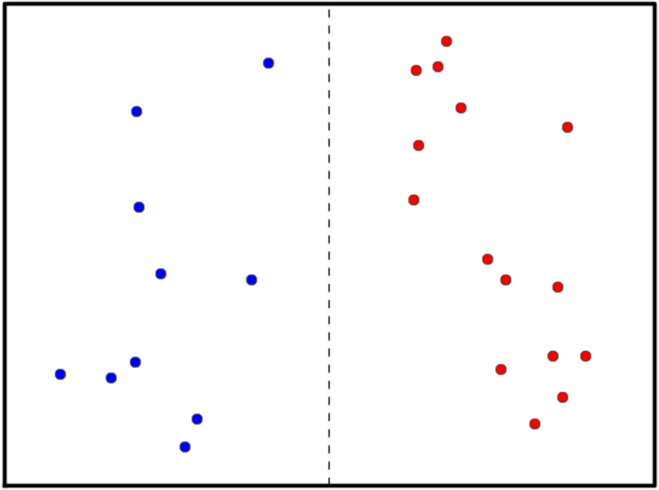
Q about chapter 4: "extensive" quantities

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

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

- 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.

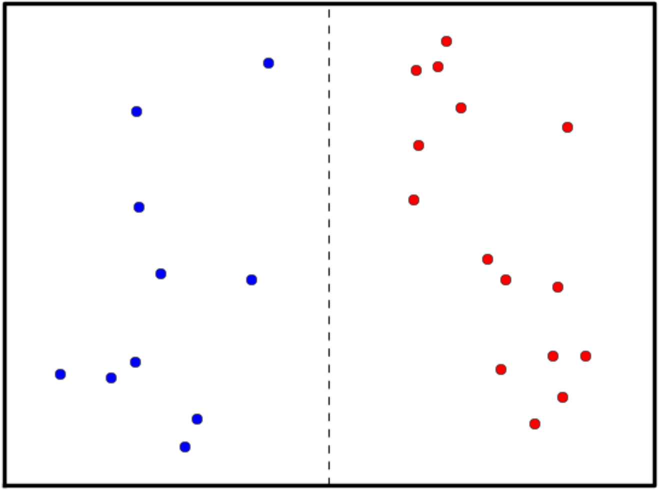
Is **number of dots** an extensive quantity?



(A) Yes.

(B) No.

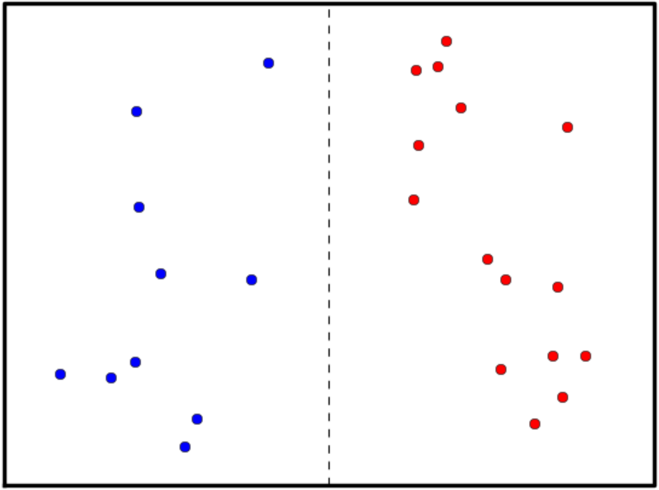
Is **dot diameter** an extensive quantity?



(A) No.

(B) Yes.

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



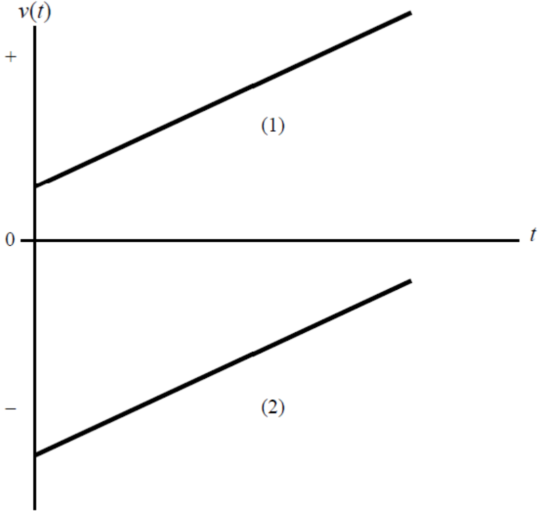
(A) No.

(B) Yes.

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

This may help you with HW2 #11(d)

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!

Checkpoint 5.13 typo (in PDF: printed book is good)

5.13 Yes; cart 1 gets twice as much energy as cart 2: $K_{1f} = \frac{1}{2} m_1 v_{1f}^2 = \frac{1}{2}(0.25 \text{ kg})(2.0 \text{ m/s})^2 = 0.50 \text{ J}$, $K_{2f} = \frac{1}{2} m_2 v_{2f}^2 = \frac{1}{2}(0.50 \text{ kg})(1.0 \text{ m/s})^2 = 0.25 \text{ J}$. The reason is that the system's final momentum needs to be zero, and so v_{1f} must be $2v_{2f}$. Because $m_2 = 2m_1$, you have $K_{2f} = \frac{1}{2}m_2 v_{2f}^2 = \frac{1}{2}(2m_1)(\frac{1}{2}v_{1f})^2 = \frac{1}{4}m_1 v_{1f}^2 = \frac{1}{2}K_{1f}$.

He means "no" here.

Most of this answer is fine, but when he writes, "Yes" at the beginning, he really means to write, "No." (Even Harvard professors make mistakes once in a while!)

HW2 covers acceleration (Ch 3) and momentum (Ch 4). So 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)?

Chapter 5: Energy

What is the expression for the kinetic energy of an object of mass m that is moving at speed v ?

(Assume the object is not rotating — we'll deal with that later.)

Kinetic energy

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

- is the energy of *motion*.
- is unchanged (in total) in an *elastic* collision.

e.g.

$$\frac{1}{2}m_1 v_{1i}^2 + \frac{1}{2}m_2 v_{2i}^2 = \frac{1}{2}m_1 v_{1f}^2 + \frac{1}{2}m_2 v_{2f}^2$$

but it's much easier in practice to write (equivalently)

$$|v_{12,i}| = |v_{12,f}|$$

i.e. relative *speed* is the same before and after an elastic collision

$$(v_{1x,f} - v_{2x,f}) = -(v_{1x,i} - v_{2x,i}) \qquad \text{[Eqn. 5.4]}$$

What are 4 types of collision? What distinguishes them?

Types of collisions

- Elastic collision: objects recoil with same *relative speed* as before they collided. Kinetic energy $K_i = K_f$.

$$(v_{1x,f} - v_{2x,f}) = -(v_{1x,i} - v_{2x,i}) \qquad \text{[Eqn. 5.4]}$$

- Totally inelastic collision: objects stick together.

$$(v_{1x,f} - v_{2x,f}) = 0$$

- Inelastic collision: objects recoil, but with a reduction in relative speed

$$(v_{1x,f} - v_{2x,f}) = -e(v_{1x,i} - v_{2x,i}) \qquad \text{with } 0 < e < 1$$

- Explosive separation: imagine T.I.C. movie played in reverse.

$$(v_{1x,i} - v_{2x,i}) = 0$$

$$(v_{1x,f} - v_{2x,f}) \neq 0$$

Q (tricky): what value of e describes an explosive separation?!

If I play in reverse a movie of an elastic collision, what sort of collision would I appear to see?

(a) elastic
(b) inelastic
(c) totally inelastic
(d) explosive separation
(e) it depends!

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We have one equation, but two unknowns. Knowing something about energy gives us a second equation. Relative speed = key.

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- if change in internal energy is given:

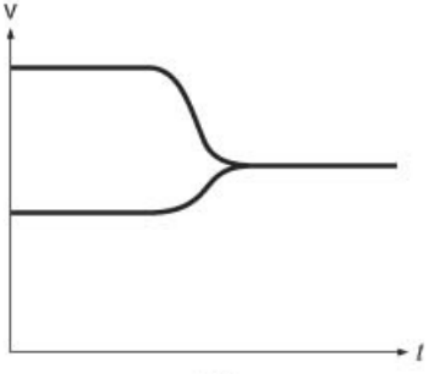
$$\frac{1}{2}m_1 v_{1i}^2 + \frac{1}{2}m_2 v_{2i}^2 = \frac{1}{2}m_1 v_{1f}^2 + \frac{1}{2}m_2 v_{2f}^2 + \Delta E_{\text{internal}}$$

  (or equivalently)

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

(We'll work some HW-like examples on Friday or Monday.)

What sort of collision is illustrated by this velocity-vs-time graph?



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(By the way, can you infer the ratio of masses?)

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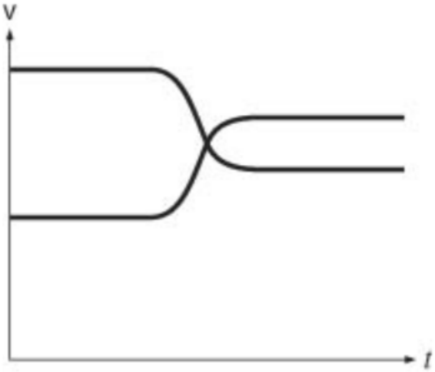

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(By the way, can you infer the ratio of masses?)

Suppose you find an isolated system in which two objects about to collide have equal and opposite momenta. If the collision is totally inelastic, what can you say about the motion after the collision?

(Discuss with your neighbor, and then I'll call on a few people to see what you think. If some of us disagree on the answer, it's not a problem: we will all learn by discussing.)

Imagine making two springy devices, each made up of a dozen or so metal blocks loosely connected by springs, and then colliding the two head-on. Do you expect the collision to be elastic, inelastic, or totally inelastic? (Think about what happens to the kinetic energy.)

(A) elastic

(B) inelastic

(C) totally inelastic

`http://youtu.be/SJIKCmg2Uzg`

"Newton's cradle:" what do you expect to happen if I pull back two of the spheres and release them?

- Discuss with your neighbor!

"Newton's cradle:" what do you expect to happen if I pull back two of the spheres and release them?

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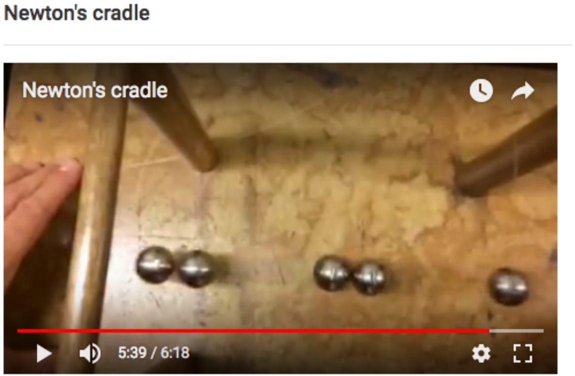
What do you expect to happen if I put a piece of play dough between two of the spheres?

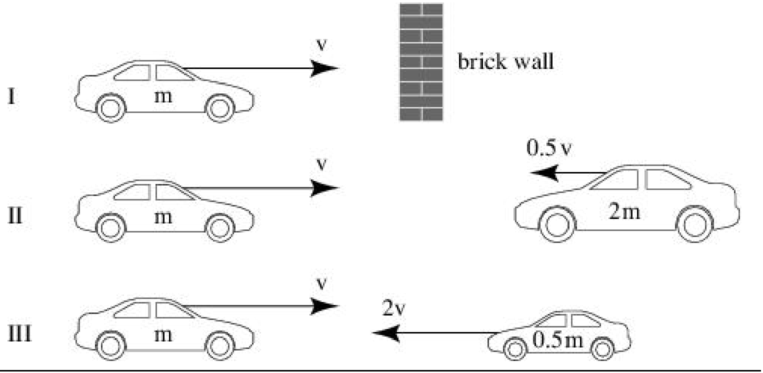
- Discuss! (No clicking required.)

Newton's cradle (slow motion video from my smartphone)



https://youtu.be/rrrs81pl_DU

If all three collisions in the figure shown here are totally inelastic, which bring(s) the car on the left to a halt?



(A) I

(B) II

(C) II,III

(D) all three

(E) III

Which of these systems are isolated?

(1) While slipping on ice, a car collides totally inelastically with another car. System: both cars (ignore friction)
(2) Same situation as in (a). System: slipping car
(3) A single car slips on a patch of ice. System: car
(4) A car brakes to a stop on a road. System: car
(5) A ball drops to Earth. System: ball
(6) A billiard ball collides elastically with another billiard ball on a pool table. System: both balls (ignore friction)

(A) (1) only
(B) (6) only
(C) (1) + (3) + (6)
(D) (1) + (2) + (3) + (4) + (6)
(E) (1) + (2) + (3) + (4) + (5)+ (6)

Write this up with your neighbor(s) and turn it in at the end of class. If you miss class today or if you forget to hand it in on your way out, you can scan & email it to me later if you wish. Remember that in-class work like this is re-scaled so that 80% gets full credit at the end of the term, so missing a couple is OK.

Two carts, of inertias (masses) $m_1 = 1.0\ \mathrm{kg}$ and $m_2 = 1.0\ \mathrm{kg}$, collide head-on on a low-friction track. Before the collision, which is elastic, cart 1 is moving to the right at 1.0 m/s and cart 2 is at rest. What are the two carts' final velocities?

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```
In[88]:= ClearAll["Global`*"];
         m1 = 1.0; m2 = 1.0; v1xi = +1.0; v2xi = 0.0;
         Reduce[{
           m1 v1xi + m2 v2xi == m1 v1xf + m2 v2xf,
           (v1xf - v2xf) == -(v1xi - v2xi)
          }]

Out[90]= v2xf == 1. && v1xf == 0.
```

(Keep writing with your neighbor(s).)

Two carts, of inertias $m_1 = 1.0\ \mathrm{kg}$ and $\boxed{m_2 = 9.0\ \mathrm{kg}}$, collide head-on on a low-friction track. Before the collision, which is elastic, cart 1 is moving to the right at 1.0 m/s and cart 2 is at rest. What are the two carts' final velocities?

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```
In[91]:= ClearAll["Global`*"];
m1 = 1.0; m2 = 9.0; v1xi = +1.0; v2xi = 0.0;
Reduce[{
  m1 v1xi + m2 v2xi == m1 v1xf + m2 v2xf,
  (v1xf - v2xf) == -(v1xi - v2xi)
 }]

Out[93]= v2xf == 0.2 && v1xf == -0.8
```

(Keep writing with your neighbor(s).)

Two carts, of inertias $m_1 = 1.0 \text{ kg}$ and $m_2 = 9.0 \text{ kg}$, collide head-on on a low-friction track. Before the collision, which is **totally inelastic**, cart 1 is moving to the right at 1.0 m/s and cart 2 is at rest. What are the two carts' final velocities?

(Keep writing with your neighbor(s).)

Two carts, of inertias $m_1 = 1.0\ \mathrm{kg}$ and $m_2 = 9.0\ \mathrm{kg}$, collide head-on on a low-friction track. Before the collision, which is **totally inelastic**, cart 1 is moving to the right at 1.0 m/s and cart 2 is at rest. What are the two carts' final velocities?

```
In[94]:= ClearAll["Global`*"];
m1 = 1.0; m2 = 9.0; v1xi = +1.0; v2xi = 0.0;
Reduce[{
   m1 v1xi + m2 v2xi == m1 v1xf + m2 v2xf,
   (v1xf - v2xf) == 0
  }]

Out[96]= v2xf == 0.1 && v1xf == 0.1
```

(Keep writing with your neighbor(s).)

Two carts, of inertias $m_1 = 1.0 \text{ kg}$ and $m_2 = 1.0 \text{ kg}$, collide head-on on a low-friction track. Before the collision, cart 1 is moving to the right at 2.0 m/s and cart 2 is moving to the left at 2.0 m/s. After the collision, cart 1 is moving to the left at 1.0 m/s and cart 2 is moving to the right at 1.0 m/s.

Let "the system" be cart 1 + cart 2. With the given values, is the system's total momentum the same before and after the collision?

What is the coefficient of restitution, e, for this collision?

(Keep writing with your neighbor(s).)

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What is the coefficient of restitution, e, for this collision?

Initial and final momentum are both zero, as you can verify. The relative speed of the two objects is reduced by a factor $e = 0.5$.

(Keep writing with your neighbor(s).)

A system consists of two 1.00 kg carts attached to each other by a compressed spring. Initially, the system is at rest on a low-friction track. When the spring is released, internal energy that was initially stored in the spring is converted into kinetic energy of the carts. The change in the spring's internal energy during the separation is 2.00 joules. What are the two carts' final velocities?

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```
In[101]:= ClearAll["Global`*"];
          m1 = 1.00; m2 = 1.00; v1xi = 0.0; v2xi = 0.0;
          Eispring = 2.00; Efspring = 0.00;
          Reduce[{
            m1 v1xi + m2 v2xi == m1 v1xf + m2 v2xf,
            0.5 m1 v1xi^2 + 0.5 m2 v2xi^2 + Eispring ==
             0.5 m1 v1xf^2 + 0.5 m2 v2xf^2 + Efspring,
            v2xf > 0
           }]

Out[104]= v2xf == 1.41421 && v1xf == -1.41421
```

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