Physics 8 — Friday, September 13, 2019

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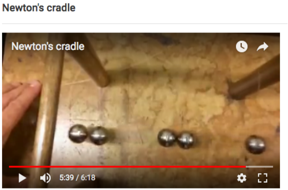
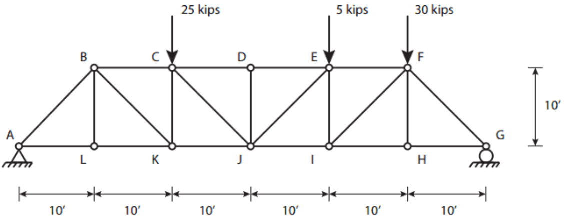
- Pick up HW#3 handout in back of room.
- Next week, you will read Ch7 (interactions) [for Monday] and Ch8 (force) [for Wednesday]. Ch6 and Ch7 take some time to read, but they don't add many new equations ("quantitative results") to learn how to work with. Ch5 (energy) and Ch8 (force) will get more class time than Ch6 and Ch7. So there is really one **substantive** chapter this week and one next week.
- We are going quickly through the early chapters & will slow down for the more difficult topics in Ch10,11,12. The faster pace now lets us make time for "structures" applications later.



https://youtu.be/rrrs81pl_DU

Where are we (going)?

3) Find the forces in members BK and CJ. State whether they are in tension or compression.



To analyze structures, you need a thorough understanding of **forces**, **torques** (a.k.a. "moments" of forces), and **vectors**.

Where are we (going)?

(Richard Wesley: "A course should tell a story.")

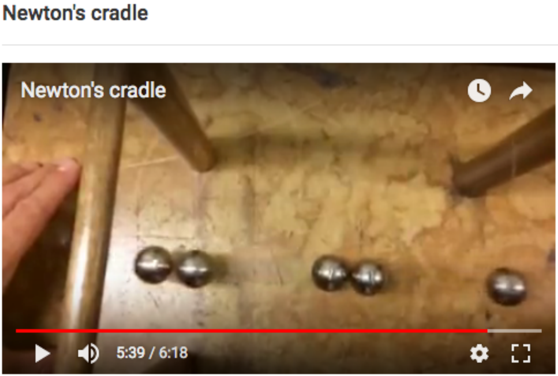
- To analyze structures, you need a thorough understanding of **forces**, **torques** (a.k.a. "moments" of forces), and **vectors**.
- To understand forces well, you need a solid grasp of
  - How forces affect motion.
  - How different forces relate to one another.
  - How objects interact with one another via forces.
- In ch2–3, we studied the key concepts of motion: position, velocity, acceleration, etc.
- In ch4–5, we studied two key conservation laws (momentum, energy) and some of the restrictions they place on how colliding objects can interact with one another.
- Finally in ch8 we'll discuss forces! We're preparing your mind for forces in ch6–7 by learning a few more of the restrictions imposed, as a consequence of momentum & energy conservation, on how objects can interact with one another.

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

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

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

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



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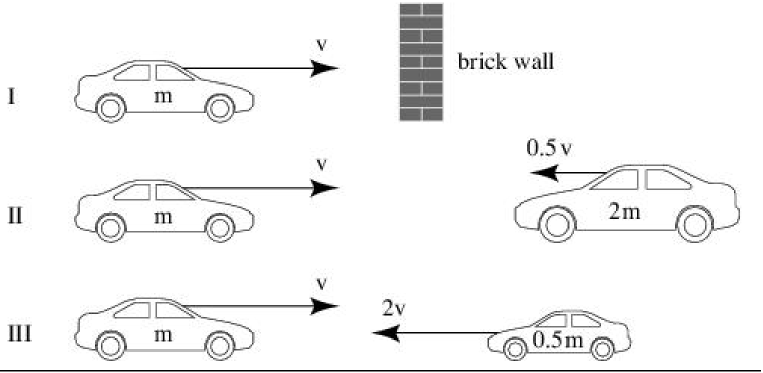
If all three collisions in the figure shown here are totally inelastic, which bring(s) the car on the left to a halt?



(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) + (2) + (3) + (4) + (5)+ (6)
(D) (1) + (2) + (3) + (4) + (6)
(E) (1) + (3) + (6)

We've now spent a week watching two 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:

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

Let's try using these results.

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?

(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?

```
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
```

Digression: notice what happens if I change the 1:9 ratio of masses into a 1:14 ratio, as in HW2 problem 12 (which you only needed to sketch, not solve with equations).

```
ClearAll["Global`*"];
m1 = 1; m2 = 14; v1xi = +1; v2xi = 0;
Reduce[{
  m1 v1xi + m2 v2xi == m1 v1xf + m2 v2xf,
  (v1xf - v2xf) == -(v1xi - v2xi)
 }]
```

$$v2xf == \frac{2}{15} \;\&\&\; v1xf == -\frac{13}{15}$$

```
N[%]
```

v2xf == 0.133333 && v1xf == -0.866667

(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?

(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 $m_1 = 1.0\ \mathrm{kg}$ and $m_2 = 1.0\ \mathrm{kg}$, 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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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?

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 4.00 joules. What are the two carts' final velocities?

(Keep writing with your neighbor(s).)

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```
ClearAll["Global`*"];
m1 = 1.00; m2 = 1.00; v1xi = 0.0; v2xi = 0.0;
Eispring = 4.00; Efspring = 0.00;
Reduce[{
  m1 v1xi + m2 v2xi == m1 v1xf + m2 v2xf,
  1/2 m1 v1xi^2 + 1/2 m2 v1xi^2 + Eispring == 1/2 m1 v1xf^2 + 1/2 m2 v2xf^2 + Efspring,
  v2xf > 0
 }]

v2xf == 2. && v1xf == -2.
```

HW3 problem 8

Two carts, of inertias m_1 and m_2, collide head-on on a low-friction track. Before the collision, which is elastic, cart 1 is moving to the right at 6.0 m/s and cart 2 is at rest. After the collision, cart 1 is moving to the left at 2.0 m/s. What are the speed and direction of motion of cart 2 after the collision? If $m_2 = 6.0\ \mathrm{kg}$, what is the value of m_1?

Since the two-cart system is isolated, what equation can we write down?

Since we are told that the collision is elastic, what second equation can we write down?

HW3 problem 10

A system consists of a 2.00 kg cart and a 1.00 kg cart attached to each other by a compressed spring. Initially, the system is at rest on a low-friction track. When the spring is released, an explosive separation occurs at the expense of the internal energy of the compressed spring. If the decrease in the spring's internal energy during the separation is 10.0 J, what is the speed of each cart right after the separation?

Since the two-cart system is isolated, what equation can we write down?

Since the spring's internal energy is converted into the carts' kinetic energies, we can account for the initial and final energies of the cart + spring + cart system and can see that this system is closed. (No energy goes in or out of the system.) What second equation can we write down?

A compact car and a large truck collide head on and stick together. (Neither driver is applying the brakes.) Which undergoes the larger momentum change?

(a) car
(b) truck
(c) The momentum change is the same (in magnitude) for both vehicles.
(d) Can't tell without knowing the final velocity of combined mass.

A compact car and a large truck collide head on and stick together. (Neither driver is applying the brakes.) Which undergoes the larger velocity change?

(a) car
(b) truck
(c) The velocity change is the same (in magnitude) for both vehicles.
(d) Can't tell without knowing the final velocity of combined mass.

A compact car and a large truck collide head on and stick together. (Neither driver is applying the brakes.) Defining the system as the car plus the truck, which of the following are unchanged (to a very good approximation), from the instant immediately before the collision to the instant immediately after the collision?

(a) kinetic energy
(b) total momentum
(c) total energy
(d) (b) and (c)
(e) (a), (b), and (c)

(Your answer may be different if you compare the situation several minutes after the collision with that just before the collision.)

Two 1-kg carts are about to collide on a frictionless surface; one is initially at rest, the other comes in at a speed of 4 m/s. From the information given, you

(a) can

(b) cannot

determine the final velocities of the two carts.

A sandwich is placed in a sealed metal container filled with oxygen gas. The metal container is immersed in a large vat of water. The vat of water is thermally insulated on all sides so that no heat can escape. A tiny spark ignites the oxygen, with the result that the sandwich is fully combusted. You measure the temperature of the known quantity of water before and after combusting the sandwich. Which of the following is a closed system? (And what would be the purpose of this sort of a set-up?)

(A) Sandwich alone.

(B) All contents of metal container.

(C) Metal container + its contents.

(D) Water alone.

(E) Sandwich + water.

(F) Sandwich + oxygen.

(G) Vat of water + metal container + all of its contents.

(H) None of the above.

A battery-powered car, with bald tires, sits on a sheet of ice. Friction between the bald tires and the ice is negligible. The driver steps on the accelerator, but the wheels just spin (frictionlessly) on the ice without moving the car. Is the car an isolated system (considering only the coordinate along the car's axis) — i.e. does nothing outside the system push/pull on anything inside the system? Is it a closed system (i.e. negligible energy is transferred in/out of the system)?

(A) Closed but not isolated.

(B) Isolated but not closed.

(C) Both closed and isolated.

(D) Isolated: yes. Closed: very nearly so, yes.

(E) Neither closed nor isolated.

A battery-powered Aston Martin car, with James-Bond-like spiked tires, sits on a sheet of ice. Agent 007 (or maybe it is really Austin Powers?) steps on the pedal, and the car accelerates forward. Is the car an isolated system (considering only the coordinate along the car's axis), i.e. nothing outside the system pushes/pulls on anything inside the system? Is it a closed system (i.e. negligible energy is transferred in/out of the system)?

(A) Closed but not isolated.

(B) Isolated: no. Closed: very nearly so, yes.

(C) Isolated but not closed.

(D) Both closed and isolated.

(E) Neither closed nor isolated.

A battery-powered Aston Martin car, with James-Bond-like spiked tires, sits on a sheet of ice. Agent 007 steps on the accelerator, and the car accelerates forward. All the while, a high-tech solar panel on the car's roof rapidly charges the car's battery. Is the car an isolated system (considering only the coordinate along the car's axis), i.e. nothing outside the system pushes/pulls on anything inside the system? Is it a closed system (i.e. negligible energy is transferred in/out of the system)?

(A) Closed but not isolated.

(B) Isolated but not closed.

(C) Both closed and isolated.

(D) Neither closed nor isolated.

A battery-powered Aston Martin, with James-Bond-like spiked tires, sits atop an iceberg that floats in the North Sea. Agent 007 steps on the accelerator, and the car accelerates forward. (What happens to the iceberg?) All the while, a high-tech solar panel on the car's roof rapidly charges the car's battery. Ignore any friction (or viscosity, drag, etc.) between the water and the iceberg. Which statement is true?

(A) "Car alone" system is isolated but not closed.

(B) "Car + iceberg" system is isolated but not closed.

(C) "Iceberg alone" system is isolated but not closed.

(D) "Car alone" system is isolated and closed.

(E) "Car + iceberg" system is isolated and closed.

(F) "Iceberg alone" system is isolated and closed.

(G) None of the above.

- An **isolated** system has no mechanism for momentum to get in/out of the system from/to outside of the system. This means nothing outside of the system can push/pull on anything inside of the system. (Next week, we'll say: "no external forces act on the system.")
- This will make more sense when we discuss *forces*, next week.
- A hugely important idea in physics is that if the parts of a system interact only with each other (do not push/pull on anything outside of the system), then the total momemtum of that system does not change.
- A **closed** system has no mechanism for energy to get in/out of the system. Examples so far are contrived, but soon we will learn to calculate energy stored in springs, energy stored in Earth's gravitational field, etc. The concept of closed system is much more useful once we learn how to account for the many ways energy can be stored.
- Accounting for movement of energy in/out of a system will make more sense when we discuss *work*, just after forces.

I put two carts on a low-friction track, with a compressed spring between them. I release the spring by remote control, which sets the carts moving apart. What system is isolated?

(A) One cart.

(B) One cart plus the spring.

(C) Cart + spring + other cart.

(D) None of the above.

I put two carts on a low-friction track, with a compressed spring between them. I release the spring by remote control, which sets the carts moving apart. Is the cart + spring + other cart system closed?

(A) Yes, for all practical purposes, because the system's total energy $K_1 + K_2 + E_{\mathrm{spring}}$ is the same before and after releasing the spring, and other tiny transfers of energy (escaping sound, etc.) are negligible by comparison.

(B) No.

I put two carts on a low-friction track, with a compressed spring between them. I release the spring by remote control, which sets the carts moving apart. Is the spring alone a closed system?

(A) Yes.

(B) No, because it transferred energy to the carts, which are outside of what you're now calling "the system."

I put two carts on a low-friction track, with a lighted firecracker between them. The firecracker explodes, which sets the carts moving apart. Is the cart + firecracker + other cart system closed?

(A) Yes, by analogy with the cart + spring + cart system.

(B) Yes, for some other reason.

(C) No, because realistically, some of the firecracker's energy will escape in the form of heat, flying debris, etc. So really energy conservation only provides an upper limit on $K_1 + K_2$ after the explosion, because accounting for where the energy goes is more difficult here than for a simple spring.

(D) No, for some other reason.

(E) I still don't understand what "closed" means.

If "inertial reference frames" baffled you:

- Imagine yourself trying to pour a cup of coffee while standing up on an airplane that is cruising smoothly at constant velocity. No problem.
- Now imagine trying to pour coffee while the airplane is taking off, landing, turning sharply, or experiencing turbulence. Your eye and hand are working from the perspective of a non-inertial reference frame — a set of coordinate axes that is accelerating w.r.t. "the fixed stars." The usual rules of physics don't work. To use the usual rules of physics, you have to analyze the situation from the perspective of an inertial frame.
- If you want more detail on frames of reference, watch this 30-minute educational video from 1960. Email me a few sentences detailing what you learned for extra credit.

Physics: Frames of Reference 1960 PSSC Physical Science Study Committee; Reference & Relativity

https://youtu.be/PhVy1WG_1KQ

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