Announcements

1. Exam 2 still going on (last day: Monday Oct 1, late fee after 5 pm)
2. Don't forget about HW 9, due Sat night
3. 8 students still not getting credit for clicker quizzes
   a. You <u>must</u> register your clicker via our class website
   b. Email me if you discover you are one of those eight

Where are we now?

Course Objectives (from syllabus):

In this class you will learn about the physics of motion, with an emphasis on

- **mechanical** and
- **thermodynamic** systems.

You will learn and apply

- **mathematical methods**
- **reasoning**
- **general problem solving skills**

These new concepts and skills should

- enhance your **experience** of **the physical world** and
- prepare you to **use physical concepts, devices and instruments**.

Students who successfully complete this course will be able to:

- Solve introductory **physics problems** involving fundamental physics equations and laws
- Answer qualitative questions involving **physics concepts**
- Recognize **physics principles** at work in the world around them

I also hope that as you learn more about the physical laws governing the universe, your appreciation for the order, simplicity and complexity of God's creations will increase.

Where are we now?

Topics (from class schedule):

Kinematics (velocity, acceleration)
Vectors & 2D Motion
Forces & Newton's Laws
Work & Energy
Momentum
Rotations, Torque, and Angular Momentum
Pressure
Fluids & Solids
Temperature, Heat, and Heat Flow
Laws of Thermodynamics
Vibrations & Waves

Collisions

Newton's 3rd Law: the forces in the collision are…

Draw the forces.

$\Delta v_1 = a_1 t$ $\Delta v_2 = a_2 t$

$m_1 \Delta v_1 =$ $m_2 \Delta v_2 =$

$m_1 \Delta v_1 + m_2 \Delta v_2 =$

If we define "momentum" $\boxed{\vec{p} = m\vec{v}}$ then $\Delta \vec{p}_{total} = \_\_$

In other words, $\vec{p}_{total}$ doesn't change in the collision!!
→ This is a **conserved quantity**

Disclaimer: Must have only "internal partner forces" involved, no other forces

Clicker quiz: (from warmup) The total momentum of an isolated system of objects is conserved
(a) only if conservative forces act between the objects
(b) regardless of the nature of the forces between the objects.

Hint: For what kind of forces does Newton's 3rd Law on previous equation apply?

What is momentum?

"impulse equation"

Clicker quiz: A car and a heavier truck are traveling on a highway. To have the same momentum, the car must travel ____ the truck.

a. slower than
b. the same speed as
c. faster than
d. the car can't have the same momentum

Law of Conservation of Momentum:

Define momentum for each object : $\vec{p} = m\vec{v}$

then… $\sum \vec{p}_{before} = \sum \vec{p}_{after}$ (if no external forces)

Compare with law of conservation of energy

$E_{before} = E_{after}$ (if no nonconservative forces)

Strategy for momentum problems

1. Draw initial and final pictures
2. Draw *momentum* vectors on masses in each picture
3. Choose positive direction, 2-D if needed
4. Use $\sum \vec{p}_{before} = \sum \vec{p}_{after}$ as "blueprint equation"
5. Include each momentum from picture in either left-hand or right-hand side of blueprint; be careful with signs!

Demo Problem: A cart moving at 4 m/s runs into a second cart of the same mass and sticks to it. What velocity do the two (stuck together) carts now have?

Demo Problem: A cart moving at 4 m/s runs into a second cart of with *twice* the mass and sticks to it. What velocity do the two (stuck together) carts now have?

Demo Problem: Two carts with the same mass spring apart. If one moves at 4 m/s to the right afterwards, what velocity does the second cart have?

Demos: colliding carts

Clicker question: (from warmup) A ping-pong ball moving forward with a momentum p strikes and bounces off backwards from a heavier tennis ball that is initially at rest and free to move. The tennis ball is set in motion with a momentum:

a. greater than p
b. less than p
c. equal to p

What about if ping-pong ball "thuds" and falls flat?

Demo: Elastic and Inelastic Pendulum—which will cause the wood to be knocked over?

2D Collisions: Momentum is a vector!

Strategy #6: Consider components when needed:

$$\sum p_{x,before} = \sum p_{x,after}$$

$$\sum p_{y,before} = \sum p_{y,after}$$

Problem: In the new sport of "ice football", a 100 kg defensive end running north at 4 m/s tackles a 75 kg quarterback running *east* at 7 m/s. There's no friction. What is their combined velocity right after the tackle?

Problem: An artillery shell of mass 20 kg is moving east at 100 m/s. It explodes into two pieces. One piece (mass 12 kg) is seen moving north at 50 m/s. What is the velocity (magnitude and direction) of the other piece?

Before: After:

Special Case: "Elastic" Collisions

In some special collisions, energy is conserved!

Elastic collisions: "bouncy"—no kinetic energy is lost

Inelastic collisions:

Perfectly inelastic collisions:

Strategy #7: If it's an elastic collision …

$\Sigma KE_{before} = \Sigma KE_{after}$

→ This is in addition to $\sum \vec{p}_{before} = \sum \vec{p}_{after}$

→ Book shows that the two equations can be put together to give you…

$\boxed{(v_1 - v_2)_{bef} = (v_2 - v_1)_{aft}}$ (for elastic collisions)

Careful with signs! "Right = positive, left = negative" still applies

Elastic Collisions, cont.

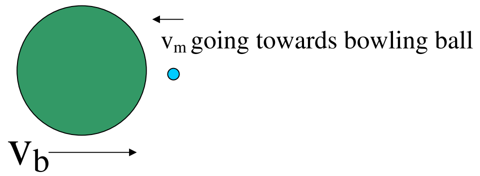
Demo Problem: A cart moving at 4 m/s bounces elastically off of a second cart of twice the mass which is moving at 2 m/s in the same direction. What velocity does each cart now have?

Demo Problem: A cart moving at 4 m/s bounces elastically off of a second cart of the same mass which is stationary. What velocity does each cart now have?

Demos: More carts colliding; Newton's cradle

Demo problem: Elastic collision between very large and very small mass

Bowling ball and a marble! Marble is at rest.



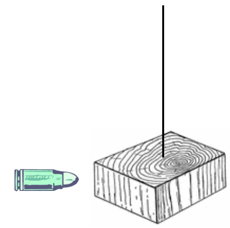
What are final speeds?

Hint: Bowling ball $v_{b\ final} \approx v_{b\ initial}$

Demo: "Velocity amplifier"

Multi-step problems: collision followed by something else

Classic example: "Ballistic pendulum" (very close to HW 11-4) A bullet of mass *m* and speed *v* embeds in a block of wood of mass *M* hanging from a string. How high does the block rise?



How not to do: $\frac{1}{2}mv^2 = (m+M)gh$

How to do:

1. **Collision part: *p* is conserved** (but KE is not!)
   i. This gets you the combined velocity right after the collision
2. **Motion part: Energy is conserved** (but *p* is not!)
   i. This gets you the height based on the "initial" KE

Warmup question

Ralph: He is floating in outer space with no forces acting on him. His momentum is zero. Now, he throws a ball. The ball goes one way, and he goes the other way. Before the collision, there was no momentum… after the collision, there is plenty of momentum! Was momentum conserved?

One key concept: **Momentum is a vector**

Another key concept: **Center of Mass**

What forces can change the motion of the center of mass?

How does the center of mass move?

Demos: Foam object, Rolling double cone, CO_2 rocket

Momentum problems, summary

1. Draw…
2. Draw…
3. Choose…
4. Use…
5. Fill in…
   a. Be careful with…
6. Consider…
7. Special case: