Note on Posted Slides

- These are the slides that I intended to show in class on Mon. Jan. 21, 2013.
- They contain important ideas and questions from your reading.
- Due to time constraints, I was probably not able to show all the slides during class.
- They are all posted here for completeness.

PHY205H1S
Physics of Everyday Life
Class 5

- Momentum
- Impulse
- Impulse Changes Momentum
- Bouncing
- Conservation of Momentum
- Collisions

[image from http://en.wikipedia.org/wiki/File:Airbag2.jpg]

Chapter 6 Pre-Class Reading Question

- What is the **law of conservation of momentum?**

A. Every object continues in a state of rest or uniform speed in a straight line unless acted on by a nonzero net force.
B. In the absence of an external force, the momentum of a system remains unchanged.
C. There exists in nature a stabilizing tendency for momentum to be restored within a closed system.
D. When an external force is applied to an object, its momentum is preserved.

Chapter 6 Pre-Class Reading Question

- What is **impulse**?

A. Any influence that tends to accelerate an object.
B. The product of the mass and the velocity of an object.
C. The product of the force acting on an object and the time during which it acts.
D. That which can change the condition of matter.
E. A spontaneous act, such as a kiss.

Chapters 6 and 7: The Big Idea

Introduce the ideas of ***momentum*** and ***energy***. These concepts give us new useful ways of analyzing motion.

In life, some quantities stay the same while other things around them change.

For example, when a bomb explodes, if you add up the mass of all the products, it will be the **same** as the mass of the original bomb. This is "Conservation of Mass": $M_f = M_i$.

Similarly, we have "Conservation of Momentum" ($\vec{p}_f = \vec{p}_i$) and "Conservation of Energy" ($E_f = E_i$) : two new and useful principles which are introduced in chapters 6 and 7.

Last Wednesday I asked…

Imagine you are trapped in a canoe in the middle of a still lake with no paddles. There is a large pile of heavy rocks in the canoe. If you start throwing rocks, can you propel the canoe this way?

Answer: Yes! This is a result of **conservation of momentum.**

If so, and you want to get to shore, which way should you throw the rocks?

Answer: Away from shore!

[image downloaded Jan.16 2013 from http://campbellpost.wordpress.com/2012/01/26/canoe/]

Momentum

- a property of moving things
- means inertia in motion
- more specifically, mass of an object multiplied by its velocity
- in equation form:

  Momentum = mass × velocity

Momentum

Examples:

- A moving boulder has more momentum than a stone rolling at the same speed.
- A fast boulder has more momentum than a slow boulder.
- A boulder at rest has no momentum.

Examples

- A 1000 kg car travels west at 25 m/s. What is its momentum?

- A 0.01 kg bullet is fired straight up, and leaves the gun with a muzzle speed of 1000 m/s. What is its momentum?

Discussion Question. Can you do the math?

A 10 kg cart is moving to the left at 2 m/s. Define positive as "towards the right", so its initial velocity is –2 m/s.
The cart suddenly stops. What is the change in momentum of the cart?
A. –20 kg m/s
B. –10 kg m/s
C. 0 kg m/s
D. 10 kg m/s
E. 20 kg m/s

Impulse

- Product of force and time (force × time)
- In equation form: Impulse = *Ft*

  Example:
  - A brief force applied over a short time interval produces a smaller change in momentum than the same force applied over a longer time interval.

or
  - If you push with the same force for twice the time, you impart twice the impulse and produce twice the change in momentum.

Impulse Momentum Theorem

The impulse on an object equals its change in momentum.

- In equation form: $Ft = \Delta(mv)$

Baseball Example

- A 0.15 kg baseball flies to the left with an initial velocity of -30 m/s.
- José Bautista hits it, and provides an average force during the hit of 12,000 N to the right (+12,000 N). The duration of the hit is one millisecond.
- What is the impulse delivered to the ball by the bat?
- What is the velocity of the ball immediately after the hit?

[Image of José Bautista of the Toronto Blue Jays downloaded Jan.21 2013 from http://bigstory.ap.org/content/encarnacion-johnson-lead-blue-jays-over-orioles]

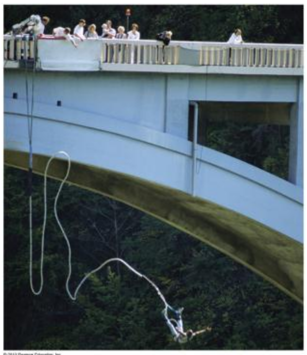
Impulse Changes Momentum

- Case 1: increasing momentum
  - Apply the greatest force for as long as possible and you extend the time of contact.
  - Force can vary throughout the duration of contact.

  Examples:
  - Golfer swings a club and follows through.
  - Baseball player hits a ball and follows through.

Impulse Changes Momentum

- Case 2: decreasing momentum over a long time
  - extend the time during which momentum is reduced



Impulse Changes Momentum
CHECK YOUR NEIGHBOR

A fast-moving car hitting a haystack or a cement wall produces vastly different results.

1. Do both experience the same change in momentum?
2. Do both experience the same impulse?
3. Do both experience the same force?

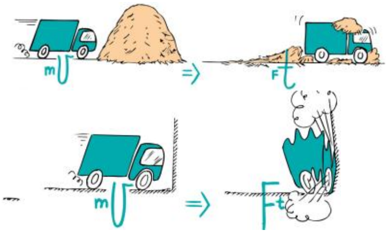
A. Yes for all three
B. Yes for 1 and 2
C. No for all three
D. No for 1 and 2

Impulse Changes Momentum

Examples:

When a car is out of control, it is better to hit a haystack than a concrete wall.

Physics reason: Same impulse either way, but extension of hitting time reduces the force.

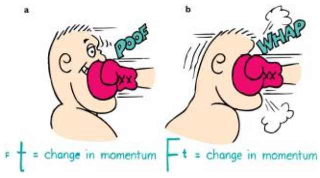


Impulse Changes Momentum

Example (continued):

In jumping, bend your knees when your feet make contact with the ground because the extension of time during your momentum decrease reduces the force on you.

In boxing, ride with the punch.



Airbags

- When you crash, your momentum must be reduced by a fixed amount.
- This means the impulse is fixed..
- The force needed (which can cause injury) can be reduced if the time of the collision is increased.
- Airbags "soften" the impact by increasing the time of the collision.

[image from http://en.wikipedia.org/wiki/File:Airbag2.jpg]

Impulse Changes Momentum

- Case 3: decreasing momentum over a short time
  – short time interval produces large force.

Example: Karate expert splits a stack of bricks by bringing her arm and hand swiftly against the bricks with considerable momentum. Time of contact is brief and force of impact is huge.

Demonstration Prediction

- Two balls of the same mass and the same speed collide with a block of wood.
- One ball is made of putty, and stops when it hits the block of wood.
- One ball is made of rubber, and bounces backward when it hits the block of wood.
  Which ball delivers the larger impulse to the block of wood?

  A. They exert equal impulses.
  B. The putty ball exerts a larger impulse.
  C. The rubber ball exerts a larger impulse.

Bouncing

Impulses are generally greater when objects bounce.

Example:

Catching a falling flower pot from a shelf with your hands. You provide the impulse to reduce its momentum to zero. If you throw the flower pot up again, you provide an additional impulse. This "double impulse" occurs when something bounces.

Bouncing

Pelton wheel designed to "bounce" water when it makes a U-turn on impact with the curved paddle

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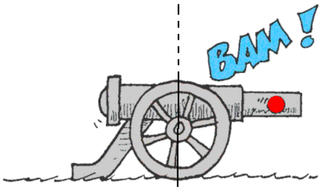
Law of conservation of momentum:

In the absence of an external force, the momentum of a system remains unchanged.

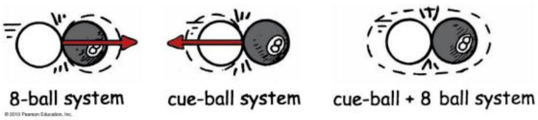


- When a cannon is fired, the force on the cannonball inside the cannon barrel is equal and opposite to the force of the cannonball on the cannon.
- The cannonball gains momentum, while the cannon gains an equal amount of momentum in the opposite direction—the cannon recoils.

Conservation of Momentum

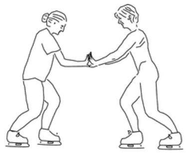
Examples:

- Internal molecular forces within a baseball come in pairs, cancel one another out, and have no effect on the momentum of the ball.
- Molecular forces within a baseball have no effect on its momentum.
- Pushing against a car's dashboard has no effect on its momentum.



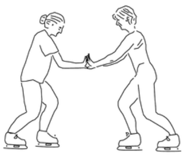
- Two ice skaters, Paula and Ricardo, push off from each other. They were both initially at rest. Ricardo has a greater mass than Paula. Which skater has the greater magnitude of momentum after the push-off?

A. Ricardo
B. Paula
C. neither



- Two ice skaters, Paula and Ricardo, push off from each other. They were both initially at rest. Ricardo has a greater mass than Paula. Which skater has the greater speed after the push-off?

A. Ricardo
B. Paula
C. neither



Collisions

- For most collisions, the forces involved in the collision itself are much greater than any external forces, such as friction.
- Therefore, the net momentum before collision equals net momentum after collision.
- in equation form:

$$(\text{net } mv)_{\text{before}} = (\text{net } mv)_{\text{after}}$$

[image downloaded Jan.21 2013 from http://findcheaperinsurance.ca/blog/7-common-car-accident-causes-part-2/]

Example

- Laura, whose mass is 35 kg, is stranded without a paddle in a 65 kg canoe in a still lake, 5 m from shore.
- She has 10 kg of rocks on board the canoe.
- If she throws all these rocks away from shore, and can throw rocks at 10 m/s, what is the maximum speed she can give herself and the canoe toward the shore?

[image downloaded Jan.16 2013 from http://campbellpost.wordpress.com/2012/01/26/canoe/]

- Two particles collide, one of which was initially moving, and the other initially at rest. Is it possible for *both* particles to be at rest after the collision? [Assume no outside forces act on the particles.]

A. Yes
B. No

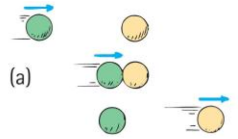
- Two particles collide, one of which was initially moving, and the other initially at rest. Is it possible for *one* particle to be at rest after the collision? [Assume no outside forces act on the particles.]

A. Yes

B. No

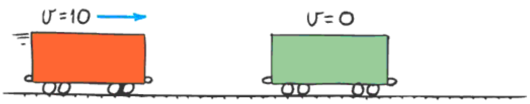
Elastic collision

– occurs when colliding objects rebound without lasting deformation or any generation of heat.



Inelastic collision

– occurs when colliding objects result in deformation and/or the generation of heat.



Single car moving at 10 m/s collides with another car of the same mass, *m*, at rest.

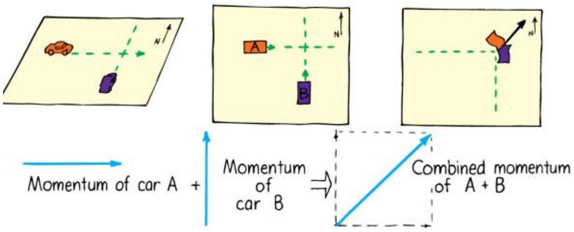
From the conservation of momentum,

$(\text{net } mv)_{\text{before}} = (\text{net } mv)_{\text{after}}$

$(m \times 10)_{\text{before}} = (2m \times V)_{\text{after}}$

$V = 5$ m/s

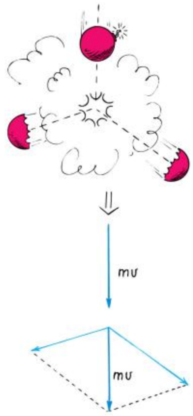
- Sometimes the colliding objects are not moving in the same straight line.
- In this case you create a parallelogram of the vectors describing each initial momentum to find the combined momentum.
- Example: collision of two cars at a corner



Explosions

Another example:

A firecracker exploding; the total momentum of the pieces after the explosion can be added vectorially to get the initial momentum of the firecracker before it exploded.



[animated gif downloaded Jan.21 2013 from http://bestanimations.com/Holidays/Fireworks/Fireworks.html]

Before Class 6 on Wednesday

- Please read Chapter 7, or at least watch the 10-minute pre-class video for class 6
- Something to think about:

- There are two seemingly identical mouse traps sitting on the floor. They have the same mass, size, colour, shape and smell.
- One has been set by bending the spring back and hooking it.
- The other is not set.
- What is the physical difference between the two traps? Why is one so much scarier than the other?

[image retrieved Jan.20 2013 from http://money.msn.com/credit-cards/3-nasty-credit-card-marketing-traps]