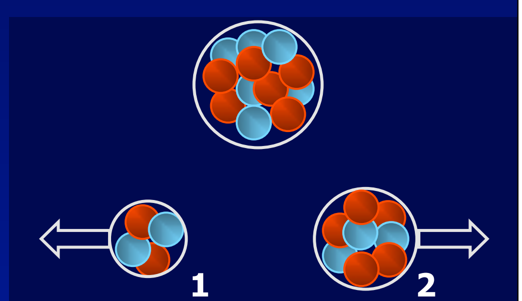
Physics 1021

Spring 2011-9b

ConcepTest 9.1(Post) Nuclear Fission

A uranium nucleus (at rest) undergoes fission and splits into two fragments, one heavy and the other light. Which fragment has the greater speed?

1) the light one
2) the heavy one
3) both have the same speed
4) impossible to say



ConcepTest 9.1 Nuclear Fission

- A uranium nucleus (at rest) undergoes fission and splits into two fragments, one heavy and the other light. Which fragment has the greater speed?

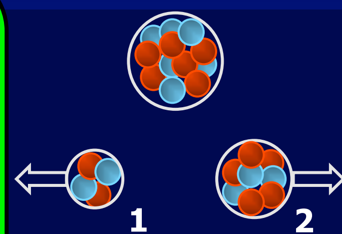
(1) the light one

(2) the heavy one

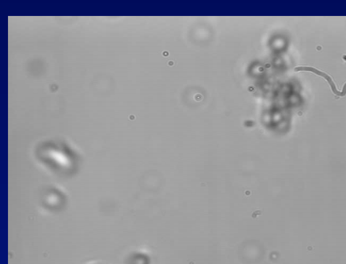
(3) both have the same speed

(4) impossible to say

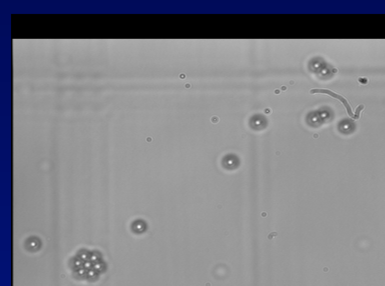
The initial momentum of the uranium was zero, so the final total momentum of the two fragments must also be zero. Thus the individual momenta are equal and opposite. The heavy fragment has the lower speed and the light fragment has the greater speed, in order to keep the magnitude of momentum *mv* the same.



Brownian motion



1 micron beads



3 micron beads

Elastic collisions with water molecules cause this motion. The 1 micron beads are 27 times lighter than the 3 micron beads, so they are much more frenetic in their motion.

Momentum Conservation

$$\Sigma F = \frac{\Delta p}{\Delta t}$$

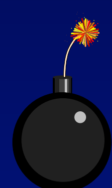
If $\Sigma F = 0$ ➡ $\frac{\Delta p}{\Delta t} = 0$

- If there is no <u>net external force</u> (isolated system), then the total momentum p <u>does not change</u> ($\Delta p = 0$).
  - Total momentum of the system must be constant !!
  - Momentum is conserved !!
- Momentum is always conserved even when energy is not.

Example of momentum conservation: Explosion

- No external forces, so *momentum* is conserved.

Before the explosion:



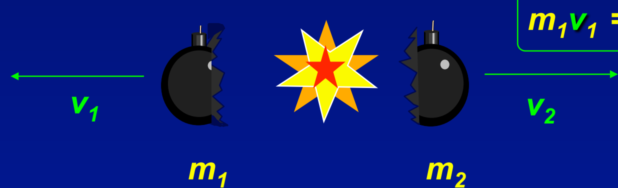
M

Initially: $p = 0$

Finally: $p = m_1 v_1 + m_2 v_2 = 0$

After the explosion:

$$m_1 v_1 = - m_2 v_2$$



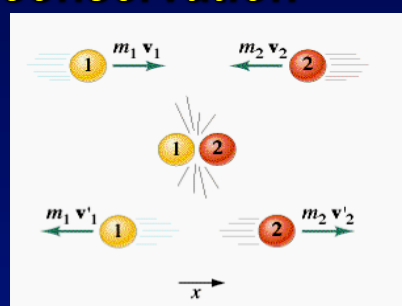
Inelastic Collisions

New Topic

Momentum conservation

Initial: $\mathbf{p}_i = m_1\mathbf{v}_1 + m_2\mathbf{v}_2$

Final: $\mathbf{p}_f = m_1\mathbf{v}_1' + m_2\mathbf{v}_2'$



Momentum conservation: initial momentum = final momentum

Note that this is a vector equation !!

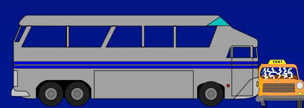
$$m_1\mathbf{v}_1 + m_2\mathbf{v}_2 = m_1\mathbf{v}_1' + m_2\mathbf{v}_2'$$

… p_x and p_y are independently conserved

Elastic vs. Inelastic Collisions

- A collision is said to be ***elastic*** when kinetic energy as well as momentum is conserved before and after the collision: $p_{initial} = p_{final}$ *and* $KE_{initial} = KE_{final}$

- A collision is said to be ***inelastic*** when kinetic energy is ***not*** conserved before and after the collision, but momentum is conserved: $p_{initial} = p_{final}$ *but* $KE_{initial} \neq KE_{final}$



Inelastic Collision...

Use momentum conservation to find $\mathbf{v}$ after the collision.

Before the collision: $\mathbf{P}_i = M\mathbf{V}$

After the collision: $\mathbf{P}_f = (M + m)\mathbf{v}$

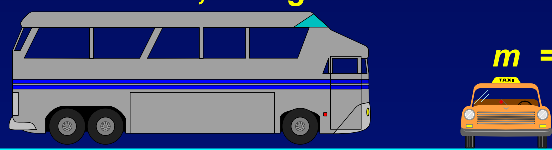
Conservation of momentum: $M\mathbf{V} = (M + m)\mathbf{v}$

$$\mathbf{v} = \frac{M}{(M+m)}\mathbf{V}$$

vector equation

Inelastic Collision: an accident

M = 10,000 kg

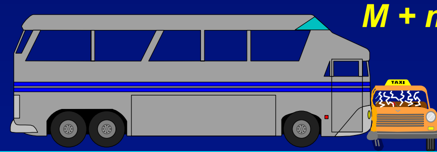


m = 1000 kg

ice
(no friction)

V = 30 m/s → *v = 0*

M + m = 11,000 kg



v_{final} = ?

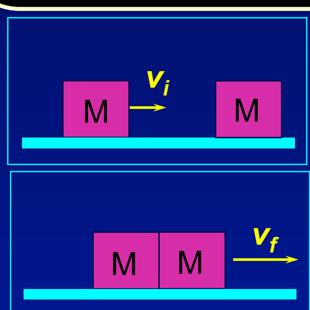
$$v = \frac{M}{(M+m)} V = \frac{10}{11} 30 m/s = 27.3 m/s$$

PHYS 1021: Chap. 9, Pg 11

ConcepTest 9.2-post Inelastic Collisions I

A box slides with initial velocity 10 m/s on a frictionless surface and collides inelastically with an identical box. The boxes stick together after the collision. What is the final velocity?

1) 10 m/s
2) 20 m/s
3) 0 m/s
4) 15 m/s
5) 5 m/s



PHYS 1021: Chap. 9, Pg 12

ConcepTest 9.2 Inelastic Collisions I

A box slides with initial velocity 10 m/s on a frictionless surface and collides inelastically with an identical box. The boxes stick together after the collision. What is the final velocity?

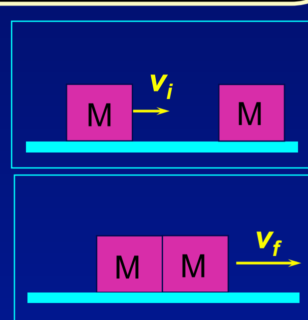
1) 10 m/s
2) 20 m/s
3) 0 m/s
4) 15 m/s
5) 5 m/s

The initial momentum is: $M v_i = (10)\ M$

The final momentum must be the same!!

The final momentum is:

$M_{tot}\ v_f = (2M)\ v_f = (2M)\ (5)$

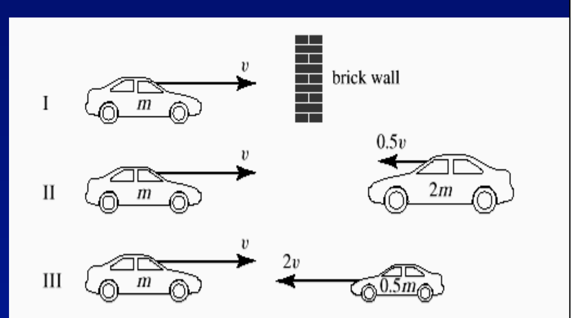


Follow-up: What is the final kinetic energy of the system, compared to the initial KE?

ConcepTest 9.3-post Crash Cars I

If all three collisions below are totally inelastic, which one(s) will bring the car on the left to a complete halt?

1) I
2) II
3) I and II
4) II and III
5) all three



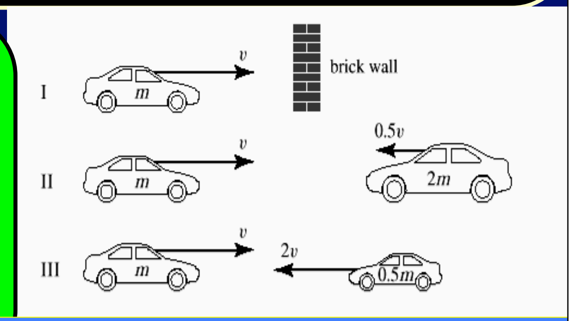
ConcepTest 9.3 Crash Cars I

If all three collisions below are **totally inelastic – that is all parts stick together**, which one(s) will bring the car on the left to a complete halt?

1) I
2) II
3) I and II
4) II and III
5) all three

In case I, the solid wall clearly stops the car.

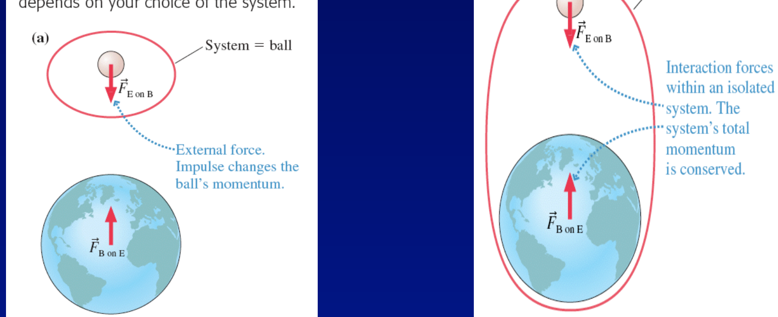
In cases II and III, **since $p_{tot} = 0$ before the collision**, then **p_{tot} must also be zero after the collision**, which means that the car comes to a halt in all three cases.



Follow-up: Which one will cause the most damage (in terms of energy lost)?

Conservation of Momentum Depends on the System

FIGURE 9.17 Whether or not momentum is conserved as a ball falls to earth depends on your choice of the system.



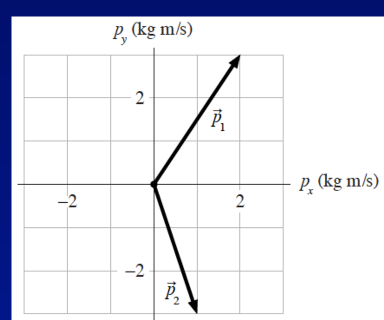
Ponderables on momentum conservation

- The parking brake on a 2000 kg Cadillac has failed, and it is rolling slowly, at 1 mph, toward a group of small innocent children. As you see the situation, you realize there is just time for you to drive your 1000 kg Volkswagen head-on into the Cadillac and thus to save the children. With what speed should you impact the Cadillac to bring it to a halt?

- Dan is gliding on his skateboard at 4 m/s. He suddenly jumps backward off the skateboard, kicking the skateboard forward at 8 m/s. How fast is Dan going as his feet hit the ground? Dan's mass is 50 kg and the skateboard's mass is 5 kg.

Momentum conservation in 2D

- An object initially at rest explodes into three fragments. The momentum vectors of two of the fragments are shown. Draw the momentum vector of the third fragment.



Problem-Solving Strategy: Conservation of Momentum

PROBLEM-SOLVING STRATEGY 9.1 **Conservation of momentum**

MODEL Clearly define *the system.*

- If possible, choose a system that is isolated ($\vec{F}_{net} = \vec{0}$) or within which the interactions are sufficiently short and intense that you can ignore external forces for the duration of the interaction (the impulse approximation). Momentum is conserved.
- If it's not possible to choose an isolated system, try to divide the problem into parts such that momentum is conserved during one segment of the motion. Other segments of the motion can be analyzed using Newton's laws or, as you'll learn in Chapters 10 and 11, conservation of energy.

Problem-Solving Strategy: Conservation of Momentum

VISUALIZE Draw a before-and-after pictorial representation. Define symbols that will be used in the problem, list known values, and identify what you're trying to find.

Problem-Solving Strategy: Conservation of Momentum

SOLVE The mathematical representation is based on the law of conservation of momentum: $\vec{P}_f = \vec{P}_i$. In component form, this is

$$(p_{fx})_1 + (p_{fx})_2 + (p_{fx})_3 + \cdots = (p_{ix})_1 + (p_{ix})_2 + (p_{ix})_3 + \cdots$$

$$(p_{fy})_1 + (p_{fy})_2 + (p_{fy})_3 + \cdots = (p_{iy})_1 + (p_{iy})_2 + (p_{iy})_3 + \cdots$$

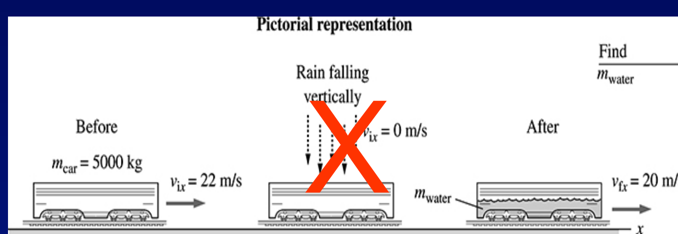
Problem-Solving Strategy: Conservation of Momentum

ASSESS Check that your result has the correct units, is reasonable, and answers the question.

Example

- A 5000 kg open train car is rolling on frictionless rails at a speed of 22 m/s when it starts raining. A few minutes later, the car's speed is 20 m/s.
- **What mass of water has collected in the train car?**
- **G known V_0=22 m/s, V_f = 20 m/s, m_{car} = 5000 kg**
  Unknown: m_{rain} = ??
  Estimate, v changes by 10%, m increases by abou 10%
  … m_{rain} = 500kg

O: System: car + rainwater
There are no *external* horizontal forces on the system, so the horizontal momentum is conserved



A:
$$(m_{car} + m_{water})(20\text{ m/s}) = (m_{car})(22\text{ m/s}) + (m_{water})(0\text{ m/s})$$
$$\Rightarrow (5000\text{ kg} + m_{water})(20\text{ m/s}) = (5000\text{ kg})(22\text{ m/s}) \Rightarrow m_{water} = 5.0\times10^2\text{ kg}$$

L: Units and estimate check. Pretty simple problem

Ponderable: Bullet in wood

- A bullet of mass m is fired into a wood block of mass M, where it lodges. Subsequently, the block slides L m across a floor (μ_k for wood on wood). What was the bullet's speed?

Ponderable

- Bob, whose mass is 75 kg, is standing on very slippery ice, holding a rock of mass 500 g. In order to get off the ice, he intends to throw the rock in one direction, and then he will recoil in the opposite direction.
- **Bob is kind of a wimp, but he throws the rock at 30 m/s, find his recoil speed.**