Spring 2013

PHYS-2010

ANNOUNCEMENTS

- **CAPA Set # 9** due Friday, March 15, at 11:59 pm

(reminder: please pick up your printed copies!)

- This week in Section: **Lab 3 “Momentum”**

- Read **Giancoli Chapter 7**.

Collisions and Momentum

Collisions

Before the collision:

After the collision:

v_{1f} = final velocity of mass 1

v_{2f} = final velocity of mass 2

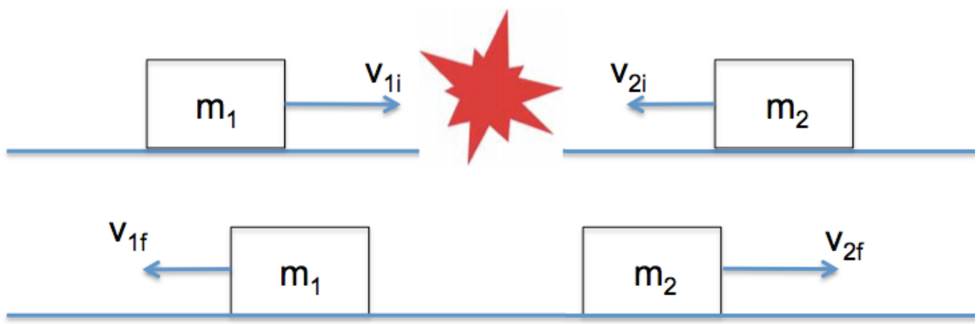
These collisions should obey Newton's Laws

Elastic Collisions

Total kinetic energy remains constant during elastic collisions:

KE is conserved or $\Delta KE = 0$

No energy converted to thermal or potential energy



$$KE_{1i} + KE_{2i} = KE_{1f} + KE_{2f}$$

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

Inelastic Collisions

Real macroscopic objects never have perfectly elastic collisions although it's sometimes a good approximation.

Inelastic Collision: KE is not constant; some is converted to another kind of energy; typically heat or deformation.

Totally Inelastic Collision: KE is not conserved, and the objects stick together after collision.

New Conserved Quantity → **Momentum**

momentum $\vec{p} = m\vec{v}$ (a vector)

(Units: kg m/s)

Total momentum vector is always conserved in collisions (both elastic and inelastic):

$$\vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f}$$

Conservation of Momentum

$$mv_{1i} + mv_{2i} = mv_{1f} + mv_{2f}$$

(in one-dimension)

Momentum conservation greatly facilitates solving collision problems!

Why is Momentum Conserved?

During the collision, Newton's Third Law applies.

$$F_{21} = - F_{12}$$

$$m_2 a_2 = - m_1 a_1$$

Assume a constant acceleration when the objects are in contact for a time Δt

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t}$$

$$m_1\left(\frac{v_{1f} - v_{1i}}{\Delta t}\right) = -m_2\left(\frac{v_{2f} - v_{2i}}{\Delta t}\right)$$

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

Momentum conservation resulting from Newton 2^{nd} + 3^{rd} Law

Clicker Question

Room Frequency BA

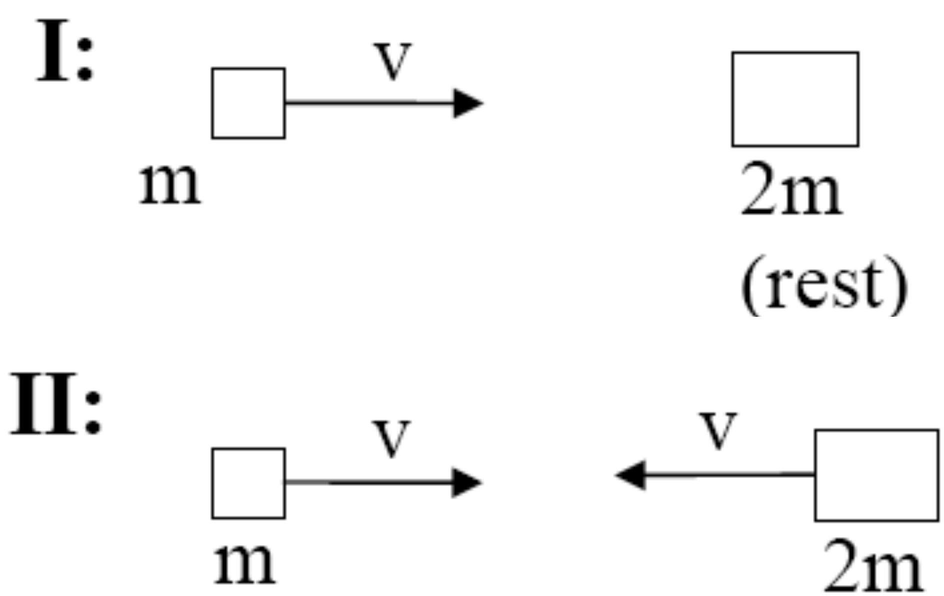
In which situation is the magnitude of the total momentum the largest?

A) Situation I.

B) Situation II.

C) Same in both.

Magnitudes are the same $|p_{total}| = mv$



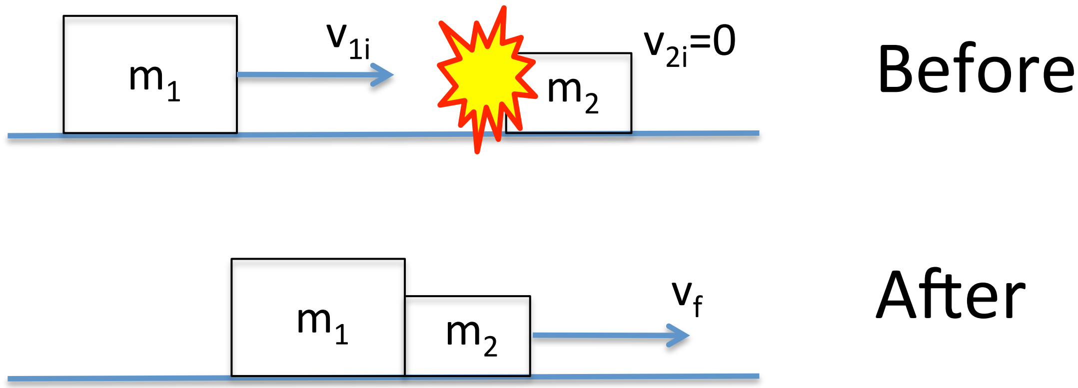
$p_{total} = mv + 0 = mv$

$p_{total} = mv - 2mv = -mv$

Totally Inelastic Collision

An object of mass m_1 initially moving with speed v_{1i} collides with another object of mass m_2 initially at rest.

The objects stick together after the collision.



What is the velocity of the objects after the collision?

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

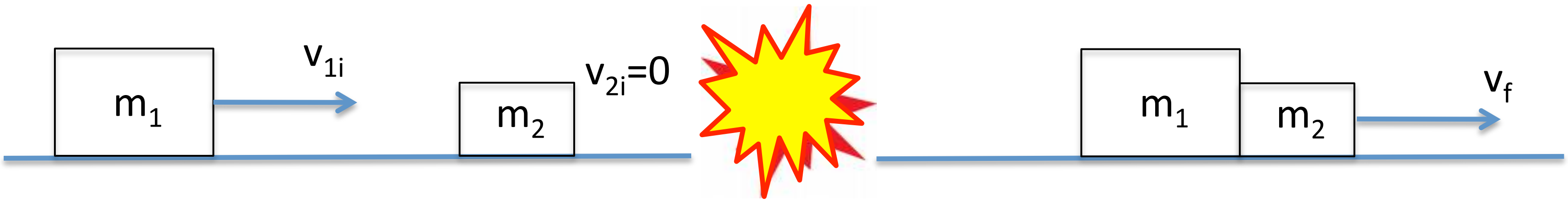
$$m_1 v_{1i} + 0 = (m_1 + m_2) v_f$$

$$v_f = \frac{m_1}{m_1 + m_2} v_{1i}$$

Does that make sense?

Totally Inelastic Collision

Is Kinetic Energy conserved?



Before

$$KE_i = \frac{1}{2} m_1 v_{1i}{}^2 + 0$$

After

$$KE_f = \frac{1}{2}(m_1 + m_2) v_f^2$$

From momentum conservation

$$v_f = \frac{m_1}{m_1 + m_2} v_{1i}$$

$$KE_f = \frac{1}{2}(m_1 + m_2)\left(\frac{m_1}{m_1 + m_2}\right)^2 v_{1i}^2$$

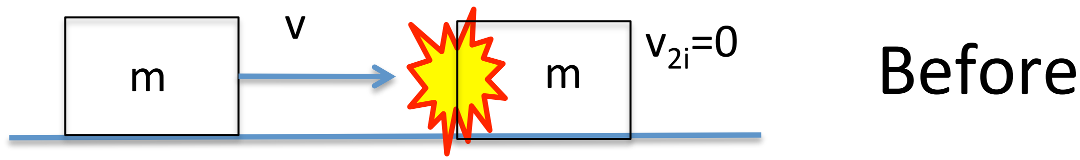
$$KE_f = \frac{1}{2} m_1 v_{1i}^2 \left(\frac{m_1}{m_1 + m_2}\right)$$

Kinetic Energy Decreases (not conserved)

$$KE_f = KE_i \left(\frac{m_1}{m_1 + m_2}\right)$$

Elastic Collision Example

An object of mass **m** initially moving with speed **v** collides with another object of mass **m** initially at rest.



For an elastic collision, what happens afterwards?

Momentum Conserved

$$p_{initial} = p_{final}$$

$$mv + 0 = mv_{1f} + mv_{2f}$$

One equation, two unknowns (v_{1f} & v_{2f})

Kinetic Energy Conserved

$$\frac{1}{2}mv^2 + 0 = \frac{1}{2}mv_{1f}^2 + \frac{1}{2}mv_{2f}^2$$

Now we have two equations, two unknowns (v_{1f} & v_{2f})

Momentum Conserved:

$$mv = mv_{1f} + mv_{2f}$$

$$v = v_{1f} + v_{2f}$$

$$v_{1f} = v - v_{2f}$$

plug in

Kinetic Energy Conserved:

$$\frac{1}{2}mv^2 = \frac{1}{2}mv_{1f}^2 + \frac{1}{2}mv_{2f}^2$$

$$v^2 = v_{1f}^2 + v_{2f}^2$$

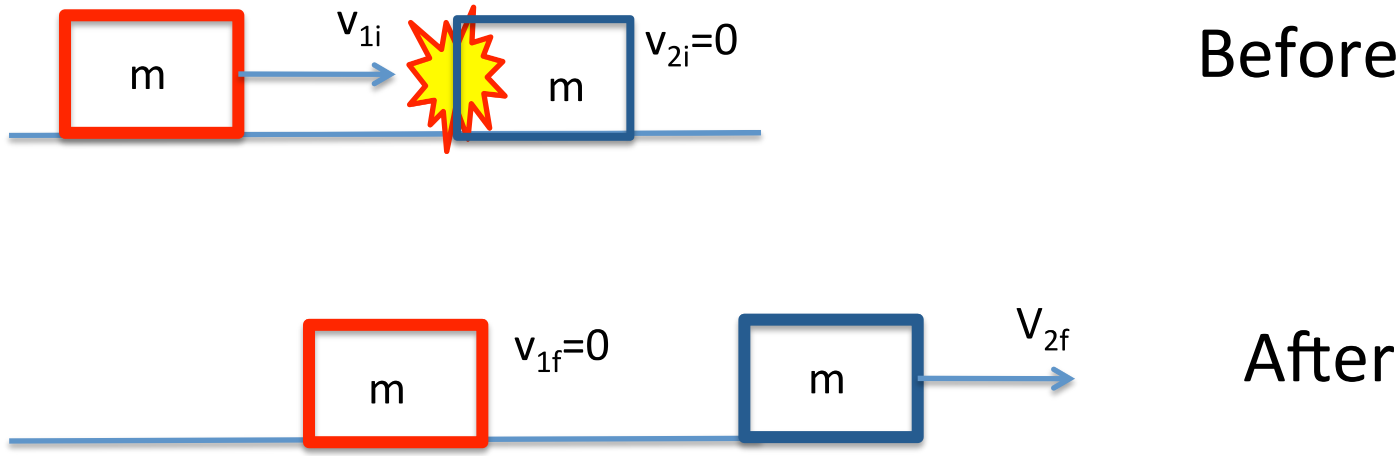
$$v^2 = (v - v_{2f})^2 + v_{2f}^2$$

$$v^2 = v^2 - 2vv_{2f} + v_{2f}^2 + v_{2f}^2$$

$$2vv_{2f} = 2v_{2f}^2$$

$$\boxed{v_{2f} = v}$$

$$v_{1f} = v - v_{2f} \Rightarrow \boxed{v_{1f} = 0}$$



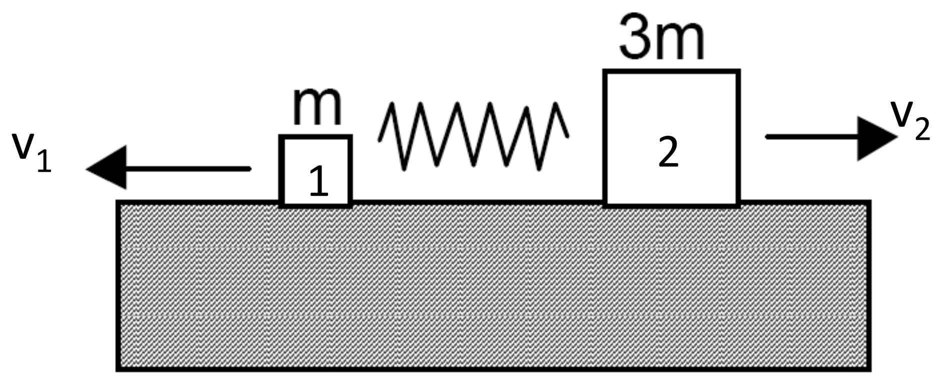
Is that really correct?

Clicker Question

Room Frequency BA

Two masses of size **m** and **3m** are at rest on a frictionless table.

A compressed, massless spring between the masses is suddenly allowed to uncompress, pushing the masses apart.



After the masses separate, the speed of **m** is _______the speed of **3m**.

A) the same as
B) twice
C) 3 times
D) 4 times

$$p_{initial} = p_{final}$$

$$0 = mv_1 + 3mv_2$$

$$v_1 = -3v_2$$

Clicker Question

Room Frequency BA

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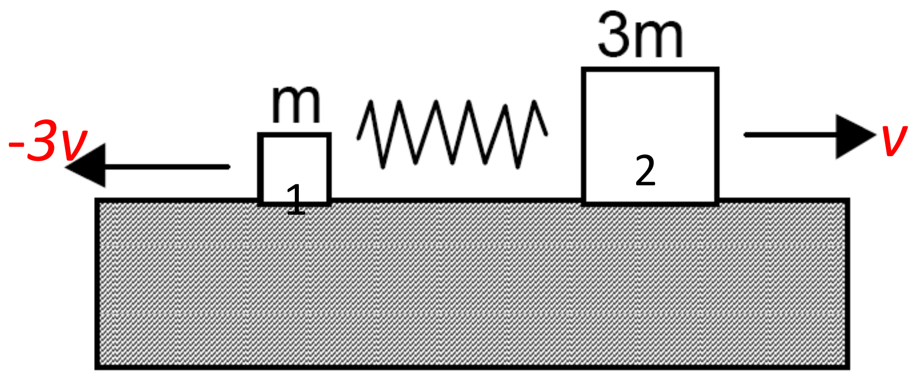

After the masses separate, the KE of **m** is ________ the KE of **3m**.

A) the same as B) twice C) 3 times D) 9 times

$$KE_1 = \frac{1}{2}m(3v)^2 = \frac{9}{2}mv^2 \qquad KE_2 = \frac{1}{2}(3m)v^2 = \frac{3}{2}mv^2$$