Announcements

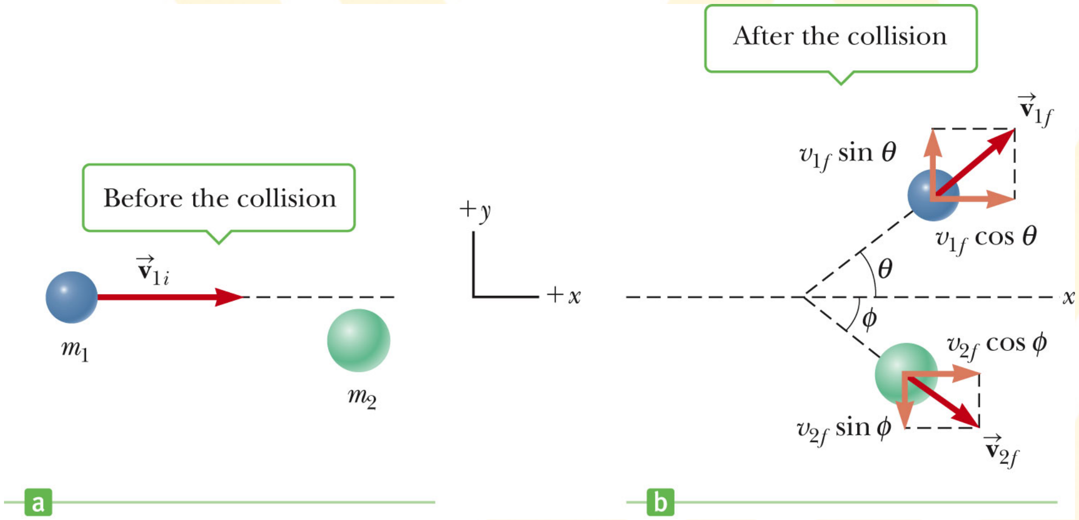
- The second midterm exam is March 8, 5-7 PM in White B51 (this room).
- The makeup exam is March 5, 5-7 PM in Clark 317.
- All exam info, including this, is at the class webpage, http://community.wvu.edu/~stmcwilliams/Sean_McWilliams/SP19_PHYS_101.html
- The exam will cover what we covered in class and was listed in the syllabus, from chapters 5 - 6, including all material through Monday's class.
- The questions will be multiple choice.
- Formula sheets will again be provided.

Example problem: Conservation of momentum

The head of a 200 g golf club is traveling at 55 m/s just before it strikes a 46 g golf ball at rest on a tee. After the collision, the club head travels (in the same direction) at 40 m/s.

Find the speed of the golf ball just after impact.

Conservation of momentum in 2d



If the objects can move in 2 dimensions and external forces can be neglected, the equation for momentum conservation will become a vector equation:

$$m_1\vec{v}_{1i} + m_2\vec{v}_{2i} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}$$

The momentum is then conserved for every component separately. In this case:

x-component: $$m_1 v_{1i} + 0 = m_1 v_{1f}\cos(\theta) + m_2 v_{2f}\cos(\phi)$$

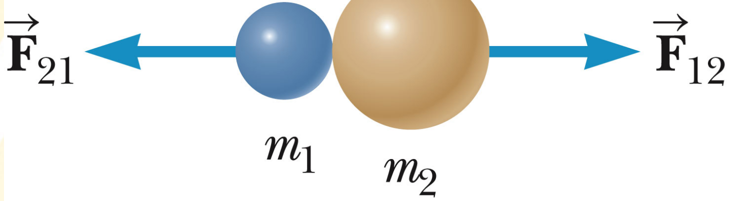
y-component: $$0 + 0 = m_1 v_{1f}\sin(\theta) + m_2 v_{2f}\sin(\phi)$$

Conservation laws

1. Conservation of linear momentum:

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

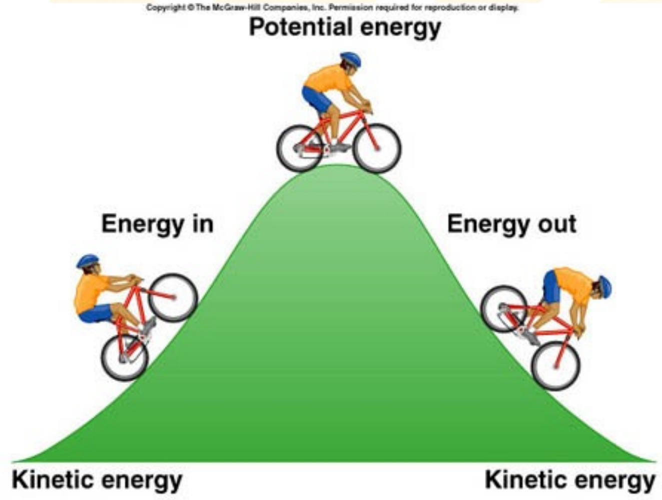
This will be valid, if no effective external force acts on the system (collision process).



2. Conservation of energy:

$$\boxed{(KE + PE_g + PE_s)_i = (KE + PE_g + PE_s)_f}$$

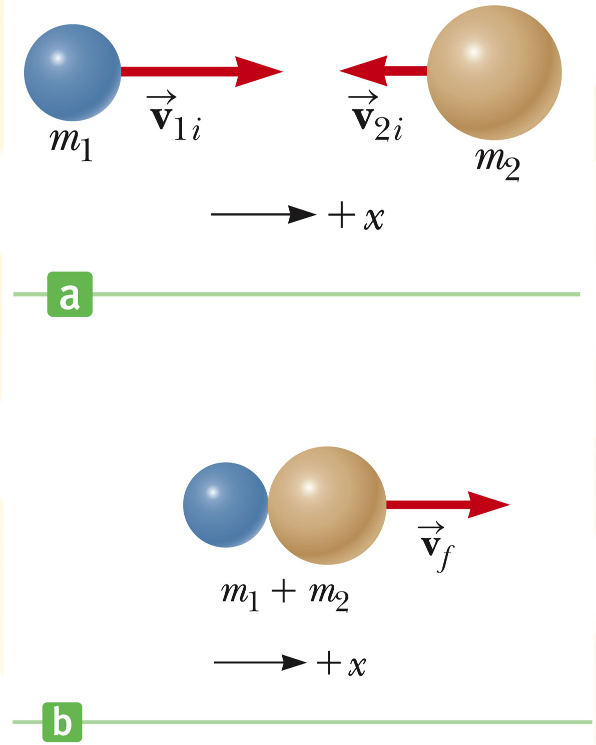
This will be valid, if work due to non-conservative forces can be neglected.



Is energy conserved in collision processes (no external forces)?

Let' see…

Car crash



Both cars of masses m_1 and m_2 have initial velocities (v_{1i}, v_{2i}). After they collided, they stick together and move with the same final velocity (v_f).

We can calculate v_f from momentum conservation:

$$m_1 v_{1i} + m_2 v_{2i} = (m_1 + m_2) v_f \quad \rightarrow \quad \boxed{v_f = \frac{m_1 v_{1i} + m_2 v_{2i}}{m_1 + m_2}}$$

Clicker question

How do you expect the total (kinetic) energy to change in this collision process (one partner initially at rest, partners stick together after collision)?

A. It increases

B. It decreases

C. It doesn't change (energy is conserved)

Does the total energy change?

Initial kinetic energy: $$KE_i = \frac{m_1}{2} v_{1i}^2 + \frac{m_2}{2} v_{2i}^2$$

Momentum conservation: $$v_f = \frac{m_1 v_{1i} + m_2 v_{2i}}{m_1 + m_2} \xrightarrow[v_{2i} = 0\text{ m/s}]{} v_f = \frac{m_1 v_{1i}}{m_1 + m_2}$$

$$\rightarrow KE_f = \frac{m_1 + m_2}{2} v_f^2 = \frac{m_1 + m_2}{2} \frac{m_1^2 v_{1i}^2}{(m_1 + m_2)^2} = \frac{m_1}{2} v_{1i}^2 \cdot \frac{m_1}{m_1 + m_2} < KE_1$$

The total (kinetic) energy of the system decreases!

It is consumed by the deformation of the objects, heat, sound, etc.

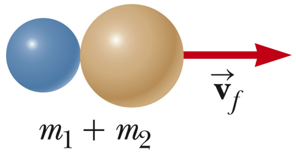
Different types of collisions

There are three types of collision processes:

1. Inelastic collisions:

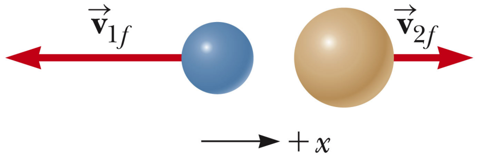
- Momentum conservation is valid.
- Energy conservation is invalid (kin. energy is lost)

If the colliding objects stick together, the collision is called *perfectly inelastic*.



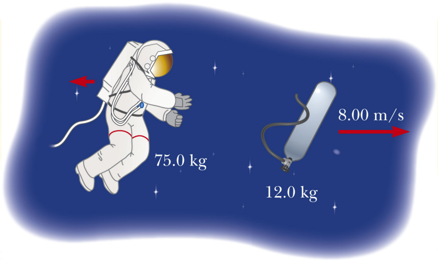
2. Elastic collisions:

- Momentum and energy are conserved.



3. Superelastic collisions:

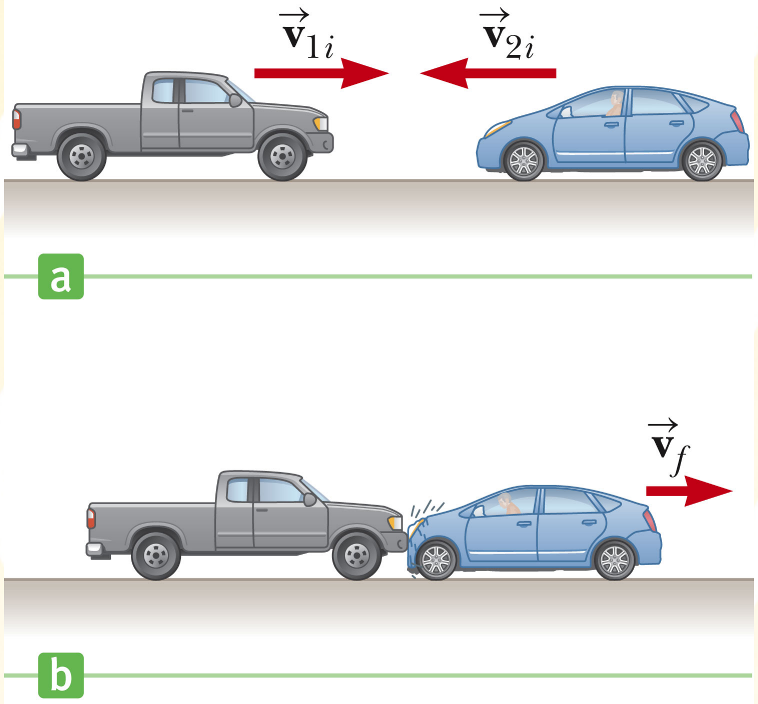
- Momentum conservation is valid.
- Energy conservation is invalid (kin. energy is gained)



Example problem: Perfectly Inelastic Collision

A pickup truck with mass 1800 kg is traveling eastbound at 15 m/s, while a compact car (900 kg) is traveling westbound with -15 m/s. The vehicles collide head-on, becoming entangled.

Find the speed of the entangled vehicles after the collision.



Clicker question

An object of mass m moves to the right with a speed v. It collides head-on with an object of mass 3m moving with speed v/3 in the opposite direction.

If the two objects stick together, what is the speed of the combined object of mass 4m after the collision?

A. 0 m/s

B. v/2

C. v

D. 2v

Elastic collisions

Momentum and energy are conserved:

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

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

Typically, the objects' masses and initial velocities are known and the final velocities must be found. This can be done by combining both equations.

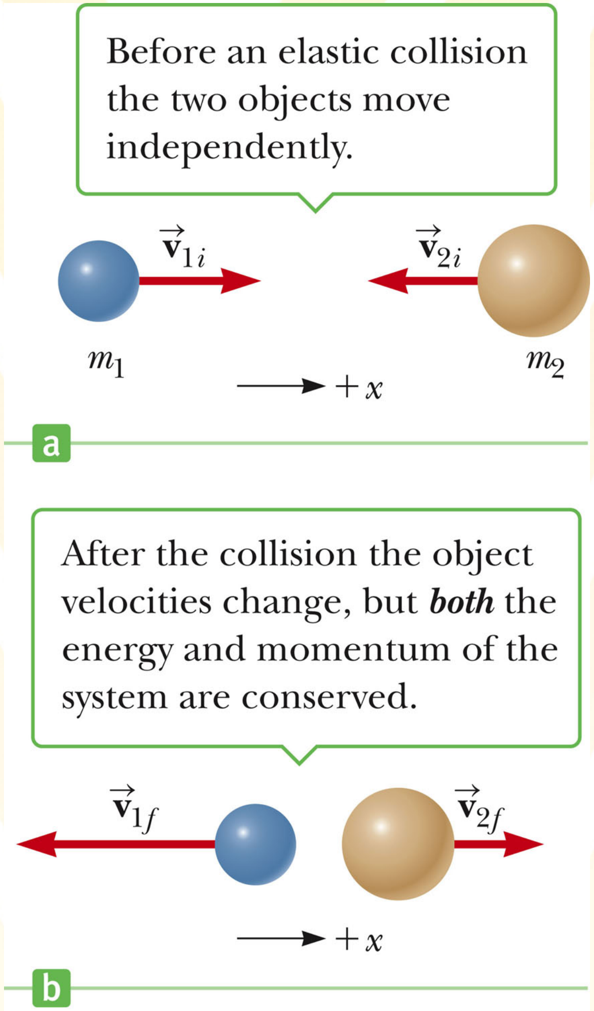
Momentum balance: $m_1(v_{1i} - v_{1f}) = m_2(v_{2f} - v_{2i})$

En. bal.: $m_1(v_{1i} - v_{1f})(v_{1i} + v_{1f}) = m_2(v_{2f} - v_{2i})(v_{2i} + v_{2f})$

Dividing these 2 equations yields:

$$v_{1i} + v_{1f} = v_{2i} + v_{2f} \quad \rightarrow \quad \boxed{v_{1i} - v_{2i} = -(v_{1f} - v_{2f})}$$

The marked equations are usually used to solve problems related to elastic collisions.

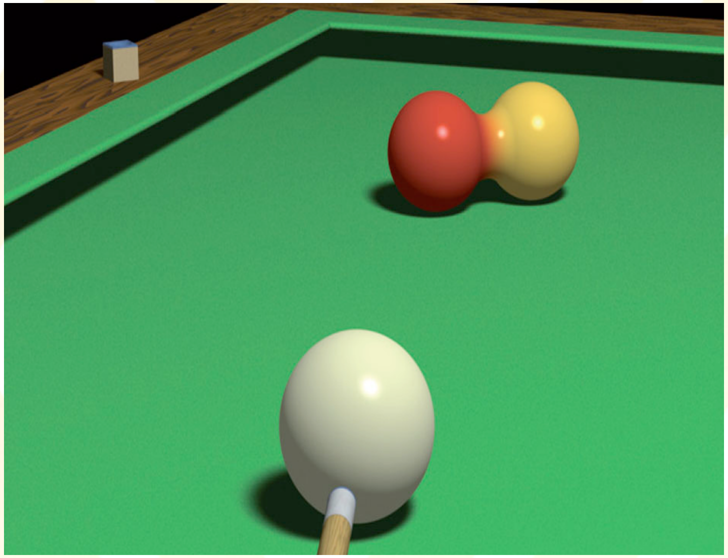


Example problem: Elastic collisions

Two billard balls of identical mass move toward each other. Assume that the collision between them is perfectly elastic.

If the initial velocities of the balls are 30 cm/s and -20 cm/s, what are the velocities of the balls after the collision?

Assume friction and rotation are unimportant.

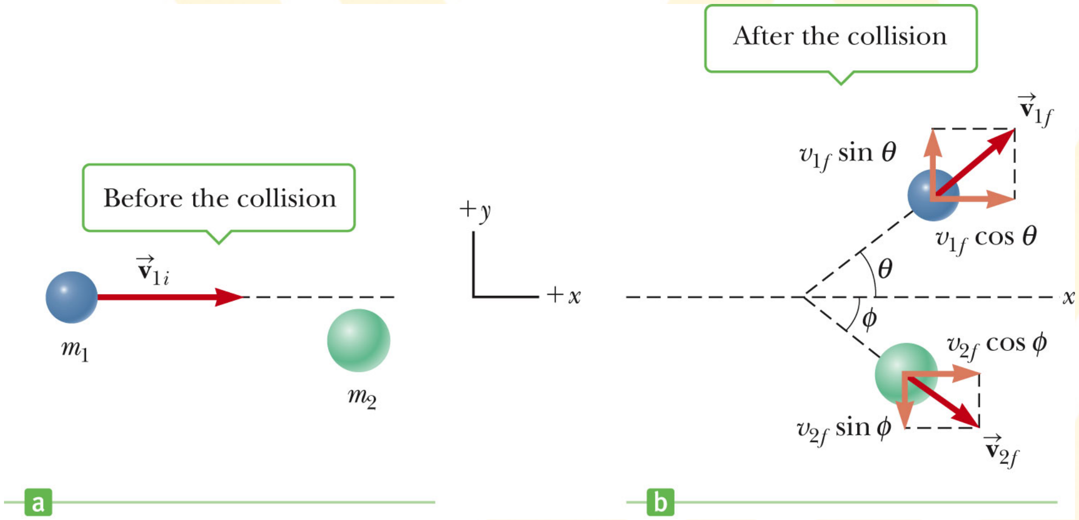


Example problem: Elastic collisions

A rigid object with mass m_1 is moving east with a speed of v_{1i}. It collides head-on with another rigid object having a mass of 6 kg that is initially at rest. After the collision, the speed of m_1 is 2 m/s west and the speed of the 6-kg mass is 4 m/s east.

Assuming a perfectly elastic collision, what are m_1 and v_{1i}?

Glancing collisions



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