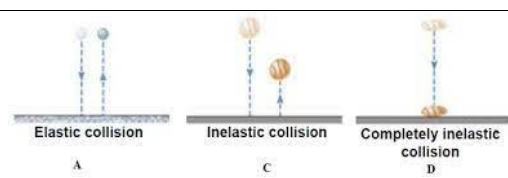
Learning Goals:
Types of Collisions

Objectives

- **Identify** different types of collisions.
- **Determine** the changes in kinetic energy during collisions.
- **Compare** conservation of momentum and conservation of kinetic energy in inelastic and elastic collisions.
- **Find** the final velocity of an object in inelastic and elastic collisions

Types of collisions



Collisions can be classified as either **elastic** or **inelastic**

In an **elastic collision**, both momentum and kinetic energy of the system are conserved

In an **inelastic collision**, momentum is conserved, but kinetic energy is not

A collision where the two objects stick together and move as one is considered **completely (*perfectly*) inelastic**

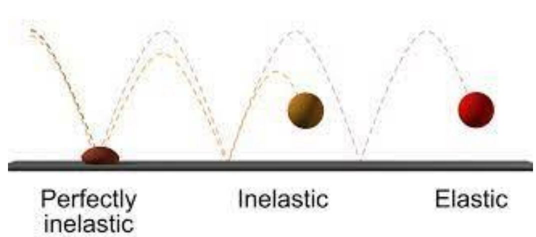
Types of Collisions

The law of conservation of momentum is seen in All collisions.
Net momentum (before collisions) = **Net momentum** (after collisions)

1. **Elastic Collisions**
   - **KE is conserved**
     - $K_f = K_i$
   - **All momentum is conserved**
   - Example: When a Ball hits the ground and bounces to the same height, the collision is elastic
2. **Inelastic Collisions**
   - **KE is converted into other forms of energy: (heat, sound, deformation, etc)**
     - $0 < K_f < K_i$
   - **All momentum is conserved**
   - Example: Cars colliding

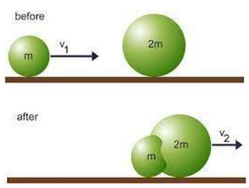
Types of Collisions

3. **Completely (Perfectly) Inelastic Collisions**
   - **Where objects stick together, will result in MAX loss of KE (Kf = minimum) and sticks**
   - **All momentum is conserved**
   - Both objects move with the same velocity afterwards –
     - Example – Firing a bullet that is embedded in a block of wood



KE in Collisions

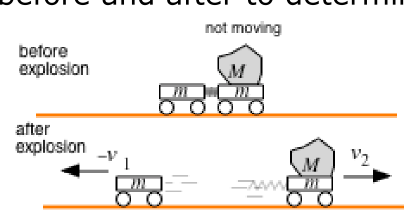
- **Elastic Collisions – KE is conserved**
  - There is no deformation of objects involved in the collision or coupling of objects that stick together
  - $mv_{before} = mv_{after}$ Momentum
  - $\frac{1}{2} mv^2_{before} = \frac{1}{2} mv^2_{after}$ KE



- **Inelastic Collisions – KE is NOT conserved**
  - Some amount of energy is lost as the objects in the collision combine into one object
  - $mv_{before} = mv_{after}$ Momentum
  - $\frac{1}{2} mv^2_{before} \neq \frac{1}{2} mv^2_{after}$ KE

KE in Collisions

Elastic and **Inelastic** collisions "look" the same. You must calculate KE before and after to determine if the collision is Elastic



Explosive Collision - object is initially motionless, has no momentum and no kinetic energy.

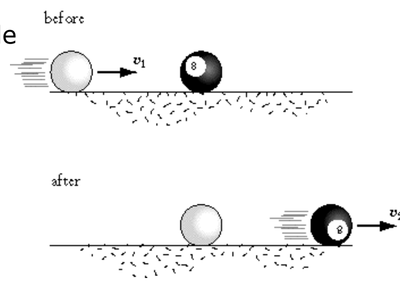
- Some energy is converted from U (spring or chemical) to KE
- $K_f > K_i$
- Example: firecracker, or a bow and arrow, or a rocket rising through the air toward space.

Elastic Collisions

Elastic – 2 objects collide – move separately afterward

- Total momentum and **KE remain constant**
  - No heat generation
  - Objects maintain original shape
- $M_1V_{1i} + M_2V_{2i} = M_1V_{1f} + M_2V_{2f}$

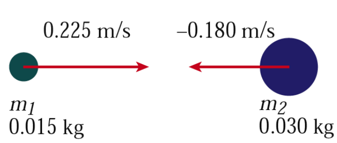
- **Example:** Two billiard balls collide
- Moving billiard ball hits another billiard ball at rest, head on. First ball comes to rest and 2nd ball moves with the initial velocity of second ball.



Elastic Collision - Example

A 0.015 kg marble moving to the right at 0.225 m/s makes an elastic head-on collision with a 0.030 kg shooter marble moving to the left at 0.180 m/s. After the collision, the smaller marble moves to the left at 0.315 m/s. Assume that neither marble rotates before or after the collision and that both marbles are moving on a frictionless surface. What is the velocity of the 0.030 kg marble after the collision?

Diagram:



Given:

m_1 = 0.015 kg
$\mathbf{v_{1i}}$ = 0.225 m/s to the right
$\mathbf{v_{1f}}$ = 0.315 m/s to the left

m_2 = 0.030 kg
$\mathbf{v_{2i}}$ = 0.180 m/s to the left
$\mathbf{v_{2f}}$ = ?

Elastic Collision - Example

Given:

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

?

$$\mathbf{v_{2f}} = (m_1\mathbf{v_{1i}} + m_2\mathbf{v_{2i}} - m_1\mathbf{v_{1f}})/m_2$$

$$v_{2,f} = \frac{(0.015\text{ kg})(0.225\text{ m/s}) + (0.030\text{ kg})(-0.180\text{ m/s}) - (0.015\text{ kg})(-0.315\text{ m/s})}{0.030\text{ kg}}$$

$$v_{2,f} = \frac{(3.4\times10^{-3}\text{ kg}\cdot\text{m/s}) + (-5.4\times10^{-3}\text{ kg}\cdot\text{m/s}) - (-4.7\times10^{-3}\text{ kg}\cdot\text{m/s})}{0.030\text{ kg}}$$

$$v_{2,f} = \frac{2.7\times10^{-3}\text{ kg}\cdot\text{m/s}}{3.0\times10^{-2}\text{ kg}}$$

$$\boxed{\mathbf{v_{2,f}} = 9.0\times10^{-2}\text{ m/s to the right}}$$

Completely Inelastic Collisions

- Two objects collide sticking together
- Become stuck together and travel as a single unit after collision
- Momentum is conserved and **KE is lost**
  - Ignore external forces (heat gain or lost, sound generation)
  - Results the velocity of the 2 colliding objects is the same after they collide

- $M_1V_{1i} + M_2V_{2i} = V_f (M_1 + M_2)$
- $\Delta KE = KE_f - KE_i$

Examples:
- Freight train cars collide (neglect noise)
- Two snowballs collide and stick together

Example Problem: Completely Inelastic Collisions

Two clay balls collide head-on in a perfectly inelastic collision. The first ball has a mass of 0.500 kg and an initial velocity of 4.00 m/s to the right. The second ball has a mass of 0.250 kg and an initial velocity of 3.00 m/s to the left. What is the decrease in kinetic energy during the collision?

Given:

ΔKE = ? (***ΔKE*** = $KE_f - KE_i$)

m_1= 0.500 kg
v_{1i} = 4.00 m/s to the right
$V_{1f}=V_{2f}$
$KE_{1i}= 1/2m_1V_{1i}^2$

m2 = 0.250 kg
v_{2i} = 3.00 m/s to the left
$KE_{2i}=1/2m_2V_{2i}^2$

$KE_f=1/2(m_1+m_2)V_f^2$

Need V_f before you can solve for ***ΔKE***

Example Problem: Completely Inelastic Collisions

Soln: Find V_f 1st

$M_1V_{1i} + M_2V_{2i} = V_f (M_1 + M_2)$

V_f= $M_1V_{1i} + M_2V_{2i}/(M_1+M_2)$

V_f =(.500kg)(4.00 m/s)+(.250kg)(-3.00m/s) / (.500kg+.250kg)

V_f = 1.67 m/s to the right

$KE_i = KE_{1i} + KE_{2i} = ½ m_1V_{1i}^2 + ½m_2V_{2i}^2$

KE_i = ½ (.500kg)(4.00m/s)² + ½ (.250kg)(-3.00 m/s)²

KEi= 5.12 J

$KE_f = ½ (m_1+m_2)V_f^2$

KE_f = ½ (.500 kg +4.00 m/s)(1.67 m/s)²

KE_f = 1.05 J

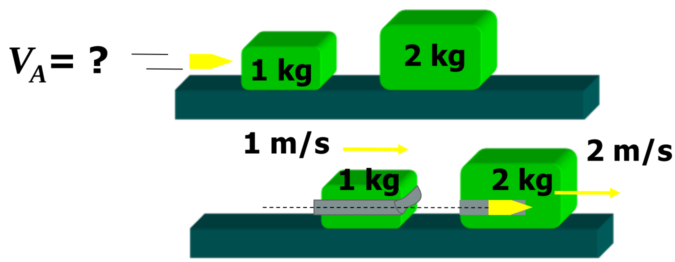
ΔKE = $KE_f - KE_i$

ΔKE = 1.05 J **-** 5.12 J

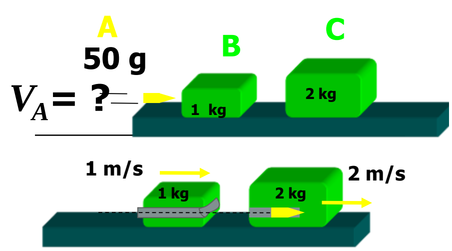
ΔKE = -4.07 J

Example Problem: Completely Inelastic Collisions

A 50 g bullet strikes a 1-kg block, passes all the way through, then lodges into the 2 kg block. Afterward, the 1 kg block moves at 1 m/s and the 2 kg block moves at 2 m/s. What was the entrance velocity of the bullet?



Find entrance velocity of bullet: m_A= 0.05 kg; V_A= ?



Momentum After = Momentum Before

$$m_A V_A + m_B \cancelto{0}{v_B} + m_C \cancelto{0}{v_C} = m_B v_B + (m_A+m_C)\, v_{AC}$$

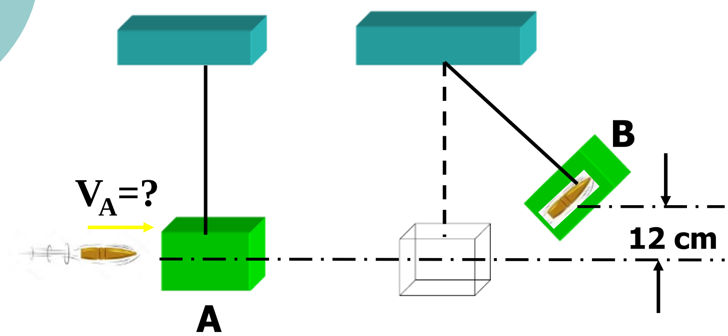
(0.05 kg)V_A =(1 kg)(1 m/s)+(2.05 kg)(2 m/s)

(0.05 kg) V_A =(5.1 kg m/s)

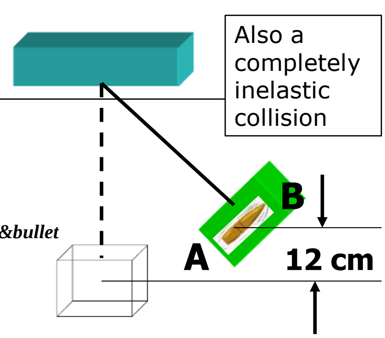
V_A= 102 m/s

Ballistic Pendulum

A 50 g bullet lodges into a 2-kg block of clay hung by a string. The bullet and clay rise together to a height of 12 cm. What was the velocity of the 50-g mass just before entering?



Ballistic Pendulum



Bullet hits Block, move with NEW velocity & momentum

$$\overset{?}{m_A V_A} + \overset{0}{\cancel{m_B V_B}} = (m_A+m_B)\overset{?}{V_{block\ \&bullet}}$$

To find V_A we need $V_{block\ \&bullet}$

After collision, energy is conserved for masses

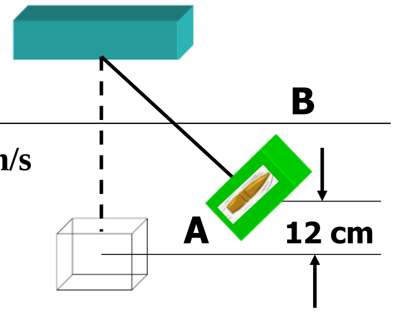
$$KE_i + \overset{0}{\cancel{Ug_i}} = \overset{0}{\cancel{KE_f}} + Ug_f$$

$$\frac{1}{2}\cancel{(m_A+m_B)}v^2_{block\& Bullet} = \cancel{(m_A+m_B)}gh$$

$$V_{block\ \&bullet} = \sqrt{2gh} \qquad V_{block\ \&bullet} = \sqrt{2\left(9.8\frac{m}{s}\right)0.12m}$$

$$V_{block\ \&bullet} = 1.53\ m/s$$

Ballistic Pendulum



$V_{block\ \&bullet} = 1.53$ m/s

Momentum Also Conserved:

$m_A V_A = (m_A + m_B) V_{block\ \&bullet}$

$$V_A = \frac{(m_A + m_B) V_{Block\ \&\ bullet}}{m_A}$$

V_A = **62.9 m/s**

Review: Types of Collisions

- During a collision the momentum of a system is constant.
  - ME is only constant if all the forces exerted on the system are conservative.
  - **Elastic collisions** are ones that only conservative internal forces are exerted
  - **Inelastic collisions** nonconservative internal forces cause the ME to be dissipated.
  - **Explosive collisions** – internal sources provide an increase in KE
  - **Completely inelastic collisions-** Max of ME dissipated. This occurs when the colliding objects stick together, and share the same final velocity