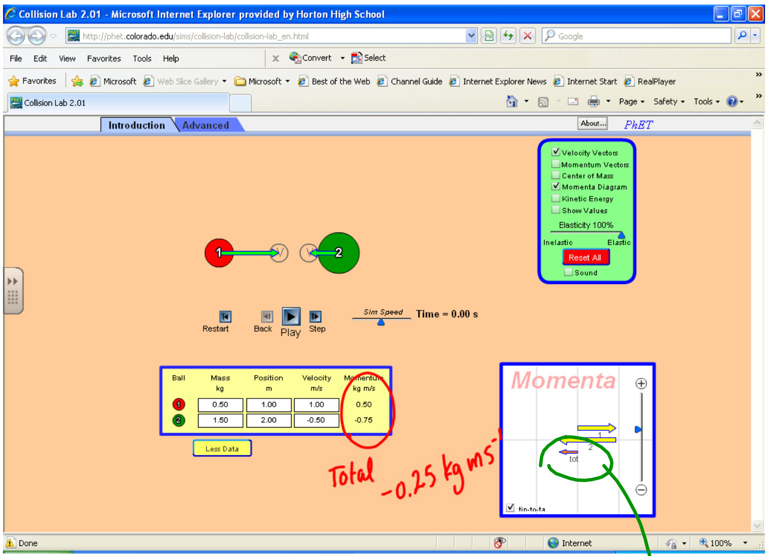
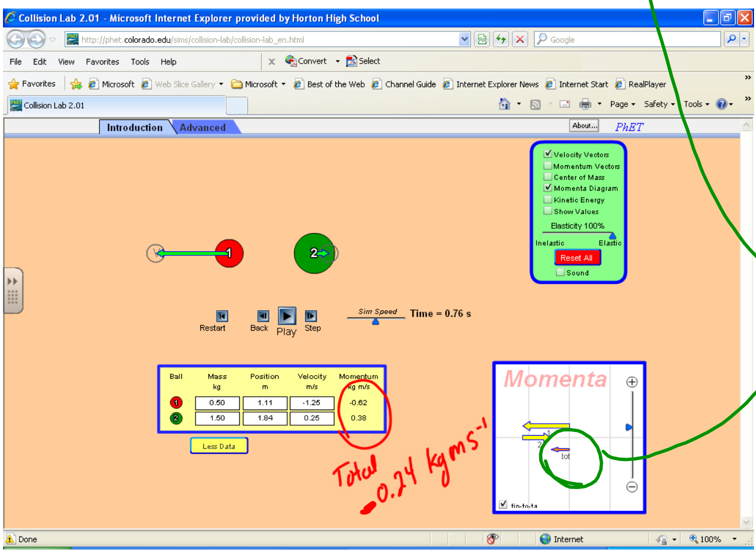


BEFORE collision

p_{total} = -0.25 kg m s^{-1}



AFTER collision

p'_{total} = -0.24 kg m s^{-1}

ALSO note the momenta diagram

the total momentum vector is the same

In all 8 of the collisions you investigated, the total momentum was the same both before and after the collision (true even when the bodies stuck together or even when a 2D collision or even when more than 2 bodies involved)

We can express this mathematically

$$\vec{P}_{total}(\text{before}) = \vec{P}_{total}(\text{after}) \qquad \left(\sum \vec{p}\right)$$

ptotal

$$m_1\vec{u}_1 + m_2\vec{u}_2 = m_1\vec{v}_1 + m_2\vec{v}_2$$

- This a particular case (i.e. two bodies) for the more general form of the Law of Conservation of Momentum.

- This applies only when the collision occurs in an "isolated system".

Conservation laws in Physics

- many types of quantities are conserved in nature.
- these quantities are called "conserved quantities" and their conservation is expressed in "conservation laws"
  - mass
  - energy
  - electric charge
  - linear momentum.

- within a closed system, these quantities can be transferred from one body to another. but the total remains the same.

Closed System (Isolated System)

The conserved quantities are only conserved (constant) provided there are no outside influences.

Law of Conservation of Linear Momentum

In any closed system of interacting bodies (i.e. one in which there are no external forces acting) the total momentum
(like friction/air resistance)
of the bodies is constant in both magnitude and direction regardless of the interaction of its parts.

Example: A 2.0 kg skateboard is rolling across a smooth flat floor when a small girl kicks it, causing it to speed up to 4.5 m s^{-1} in 0.50 s without changing its direction. If the average force exerted by the girl on the skateboard in its direction of motion was 6.0 N, with what initial velocity was it moving?

$m = 2.0\,kg$

$v = 4.5\,ms^{-1}$

$\Delta t = 0.50\,s$

$F_{net} = 6.0\,N$

$u = ?$

$$\vec{F}_{net}\Delta t = m\Delta\vec{v}$$ (impulse-momentum)

$$\vec{F}_{net}\Delta t = m(\vec{v} - \vec{u})$$

$$\vec{v} - \vec{u} = \frac{\vec{F}_{net}\Delta t}{m}$$

$$-\vec{u} = \frac{\vec{F}_{net}\Delta t}{m} - \vec{v}$$

$$\vec{u} = \vec{v} - \frac{\vec{F}_{net}\Delta t}{m}$$

Δv

$$\vec{u} = 4.5\,ms^{-1} - \frac{(6.0\,N)(0.50\,s)}{(2.0\,kg)}$$

$$\vec{u} = 4.5\,ms^{-1} - 1.5\,ms^{-1}$$

$$\vec{u} = 3.0\,ms^{-1}\ [\text{forward}]$$

EXAMPLE: A loaded railway car of mass 6000 kg is rolling to the right at 2.0 m s^{-1} when it collides and couples with an empty freight car of mass 3000 kg, rolling to the left on the same track at 3.0 m s^{-1}. What is the velocity of the pair after the collision?

+

−

railway car:

$m_1 = 6000\,kg$

$u_1 = +2.0\,m/s$

right

freight car:

$m_2 = 3000\,kg$

$u_2 = -3.0\,m\,s^{-1}$

left

$$\vec{P}_{total\,(before)} = \vec{P}_{total\,(after)}$$

$$\vec{P}_1 + \vec{P}_2 = \vec{P}_{12}$$

$$m_1\vec{u}_1 + m_2\vec{u}_2 = m_{12}\vec{v}_{12}$$

$$(6000\,kg)(2.0\,m/s) + (3000\,kg)(-3.0\,m/s) = (9000\,kg)\vec{v}_{12}$$

$$12000\,kg\cdot ms^{-1} - 9000\,kg\cdot ms^{-1} = (9000\,kg)\vec{v}_{12}$$

$$3000\,kg\cdot ms^{-1} = (9000\,kg)\vec{v}_{12}$$

$$\vec{v}_{12} = \frac{3000\,kg\cdot m\,s^{-1}}{9000\,kg}$$

$$\vec{v}_{12} \doteq 0.33\,ms^{-1}\,[R]$$

EXAMPLE: Calculate the recoil velocity of an unconstrained rifle of mass 5.0 kg after it shoots a 50 g bullet at a speed of 300 m s^{-1}, with respect to the Earth

$$\vec{P}_{total(before)} = \vec{P}_{total(after)}$$

$$\vec{P}_{gun+bullet} = \vec{P}_{gun} + \vec{P}_{bullet}$$

$$m_{gb}\vec{V}_{gb} = m_g\vec{V}_g + m_b\vec{V}_b$$

$$0 = (5.0\,kg)\vec{V}_g + (0.050\,kg)(300\,ms^{-1})$$

$$-(5.0\,kg)\vec{V}_g = (0.050\,kg)(300\,ms^{-1})$$

$$\vec{V}_g = \frac{(0.050\,kg)(300\,ms^{-1})}{-5.0\,kg}$$

$$\vec{V}_g = -3.0\,ms^{-1}$$

$$\boxed{\vec{V}_g = 3.0\,ms^{-1}\ \text{[opposite the motion of the bullet]}}$$

EXAMPLE: A 1.0 kg ball moving with a velocity of 2.0 m s^{-1} to the right collides straight-on with a stationary 2.0 kg ball . After the collision, the 2.0 kg ball moves off to the right with a velocity of 1.2 m s^{-1}. What is the velocity of the 1.0 kg ball after the collision?

A

B

+

+ right

- left

$m_A \simeq 1.0 kg$

$m_B = 2.0 kg$

$$\vec{P}_{total(before)} = \vec{P}_{total(after)}$$

$$\vec{P}_{A_1} + \vec{P}_{B_1} = \vec{P}_{A_2} + P_{B2}$$

$$m_A \vec{u}_A + m_B \vec{u}_B = m_A \vec{V}_A + m_B \vec{V}_B$$

$$\frac{m_A \vec{u}_A + \cancel{m_B \vec{u}_B} - m_B \vec{V}_B}{m_A} = \vec{V}_A$$

0

$$\frac{(1.0 kg)(+2.0 ms^{-1}) - (2.0 kg)(+1.2 ms^{-1})}{1.0 kg} = \vec{V}_A$$

$$\frac{2.0 kg \cdot ms^{-1} - 2.4 kg \cdot ms^{-1}}{1.0 kg} = \vec{V}_A$$

$$-0.40 ms^{-1} = \vec{V}_A$$

$$\vec{V}_A = 0.40 ms^{-1} \text{ [left]}$$