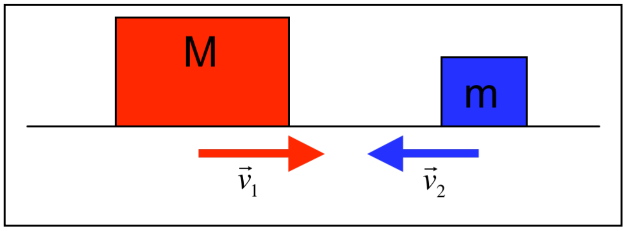
Collisions and Conservation of Momentum



M > m, carts collide.

How does the force on m_2 due to M_1 (F_{21}) compare to the force on M_1 due to m_2 (F_{12})?

➔ Newton's 3rd Law ➔ $\vec{F}_{12} = -\vec{F}_{21}$ ➔ same magnitude, opposite direction

After the collision, each cart will experience a different change in velocity $(\Delta\vec{v})$, the smaller mass will experience a greater acceleration due to the force of the collision.

$$\Delta\vec{v} = \vec{a}\Delta t = \frac{\vec{F}}{m}\Delta t$$

Mass 1: $\Delta\vec{v}_1 = \vec{a}_1\Delta t = \dfrac{\vec{F}_{12}}{M_1}\Delta t \quad \rightarrow \quad M_1\Delta\vec{v}_1 = \vec{F}_{12}\Delta t$

Mass 2: $\Delta\vec{v}_2 = \vec{a}_2\Delta t = \dfrac{\vec{F}_{21}}{m_2}\Delta t \quad \rightarrow \quad m_2\Delta\vec{v}_2 = \underbrace{\vec{F}_{21}}_{=-\vec{F}_{12}}\Delta t = -\vec{F}_{12}\Delta t \quad \rightarrow \quad \vec{F}_{12}\Delta t = -m_2\Delta\vec{v}_2$

➔ $\vec{F}_{12}\Delta t = M_1\Delta\vec{v}_1 = -m_2\Delta\vec{v}_2$ where Δt is the time that the force is applied (duration of collision)

Linear Momentum: $\vec{p} = m\vec{v}$

Change in linear momentum: $\Delta\vec{p} = m\Delta\vec{v}$

➔ $M_1\Delta\vec{v}_1 = -m_2\Delta\vec{v}_2 \quad \rightarrow \quad \Delta\vec{p}_1 = -\Delta\vec{p}_2$ ➔ change in momentum of M_1 = - change in momentum of m_2

➔ momentum was transferred from one mass to the other

Change in total momentum of the system (system = M_1 + m_2): $\Delta\vec{p}_1 + \Delta\vec{p}_2 = 0$

➔ Total momentum of the system is conserved (if $\vec{F}_{net} = 0$).

When $\vec{F}_{net} = 0$, then $\Delta\vec{p}_{system} = 0$ ➔ Momentum is conserved.

$$\Delta\vec{p}_{system} = 0$$

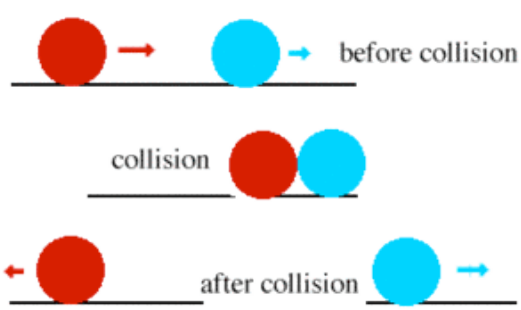
$$\Delta\vec{p}_1 + \Delta\vec{p}_2 = 0$$

$$\left(\vec{p}_{1,f} - \vec{p}_{1,i}\right) + \left(\vec{p}_{2,f} - \vec{p}_{2,i}\right) = 0$$

$$\underbrace{\vec{p}_{1,f} + \vec{p}_{2,f}}_{\substack{\text{momentum of system} \\ \text{after collision or explosion}}} = \underbrace{\vec{p}_{1,i} + \vec{p}_{2,i}}_{\substack{\text{momentum of system} \\ \text{before collision or explosion}}}$$

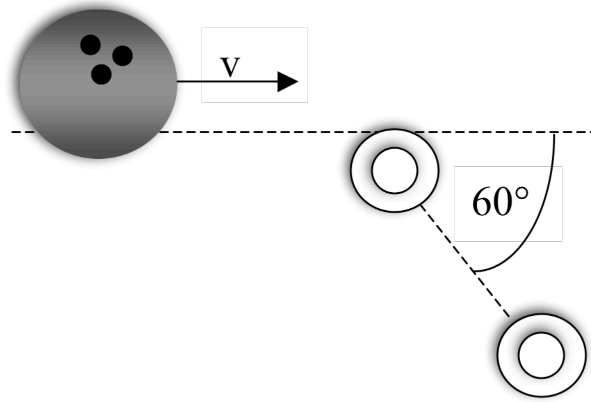
Two astronauts are warming up for a zero-g basketball game, floating in the middle of their space station's gym, tossing a basketball back and forth. Does either astronaut's momentum change while they are doing this? How about the momentum of the basketball? How about the momentum of the system comprising the astronauts and the ball?

Suppose the astronaut working on the Hubble telescope got himself completely loose of the shuttle and threw away a 2-kg hammer at 2 m/s. Could the astronaut remain at rest? If not, what would determine how fast he would be moving? (What would you need to know in order to estimate or determine his speed?) Is there any way he could stop himself from drifting away?



The red ball in the diagram is chasing after the blue ball; they have the same mass. The speed of the red ball is 3 m/s the speed of the blue ball is 2 m/s. After the collision the red ball rebounds at 2 m/s and the blue ball speeds away at 3 m/s. What was the change in velocity experienced by the red ball during the collision? What was the change in velocity experienced by the blue ball during the collision? Normally, momentum is conserved during a collision. However if a huge external force acts during the collision, it may not be. Was momentum conserved during this collision or not?

A bowler has two pins left standing (each having mass = 1 kg). In order to knock down both pins, the bowler must throw the ball (mass = 10 kg) such that the first pin moves towards the second pin with a speed of 40 m/s, making an angle of 60° with the horizontal. How fast does the bowler need to throw the bowling ball in order to create a glancing collision that will knock down both pins?



Assume: 1.) the ball keeps a constant speed from the point where it is thrown to where it hits the pin, 2.) there is no deformation of the pins or the ball after the collision, and 3.) after the collision the ball deflects upward, making an angle of 30° with the horizontal.