Momentum

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- Momentum is defined as the mass of an object times its velocity.

$$p = mv$$

Newton's Second Law (again)

- To change the momentum of an object, we need a force.
- Newton's second law of motion applies
- Newton originally said "The rate of change of momentum of a body is equal to the net force applied to it."

$$F = \frac{\Delta p}{\Delta t}$$

$$\sum F = \frac{\Delta p}{\Delta t}$$

$$\sum F = \frac{mv_2 - mv_1}{\Delta t}$$

$$= \frac{m(v_2 - v_1)}{\Delta t}$$

$$= m\frac{\Delta v}{\Delta t} \qquad a = \frac{\Delta v}{\Delta t}$$

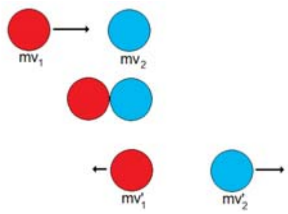
$$F = ma$$

Example

- Water leaves a hose at a rate of 1.5 kgs^{-1} with a speed of 20 ms^{-1} and is aimed at the side of a car which stops it. What is the force of the water exerted on the car?
  - If the water splashes back, will the force be greater or less?

Conservation of Momentum

- The concept of momentum is particularly important because, under normal circumstances, momentum is a conserved quantity.
- Shortly before Newton's time it had been observed that the vector sum of the momentum of two colliding objects remains constant.



Before

$$mv_1 + mv_2$$

After

$$mv_1' + mv_2'$$

$$mv_1 + mv_2 = mv_1' + mv_2'$$

Proof

$$\Delta p = F\Delta t$$

We apply this to ball 2…

$$\Delta p_2 = m_2 v_2' - m_2 v_2 = F_{21}\Delta t$$

And to ball 1…

$$\Delta p_1 = m_1 v_1' - m_1 v_1 = F_{12}\Delta t$$

By Newton's third law, F_{12} is equal and opposite to F_{21}

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

So…

$$m_1 v_1' - m_1 v_1 = -(m_2 v_2' - m_2 v_2)$$

or

$$m_1 v_1 + m_2 v_2 = m_1 v_1' + m_2 v_2'$$

Law of Conservation of Momentum

- The total momentum of an isolated system of bodies remains constant.
  - System: objects interacting with each other
  - Isolated system: the only forces present are those between the objects of the system