

Linear momentum

Definition of linear momentum

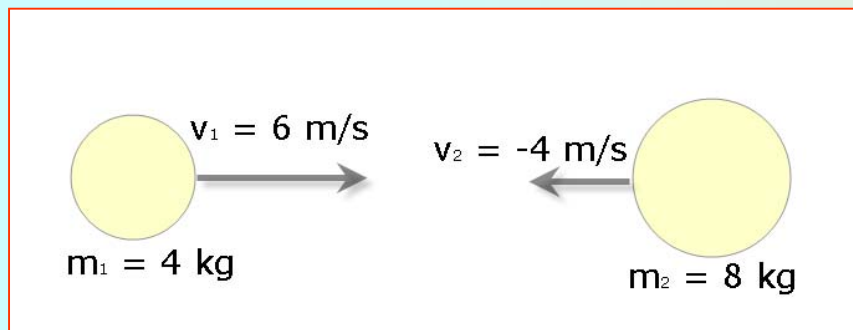
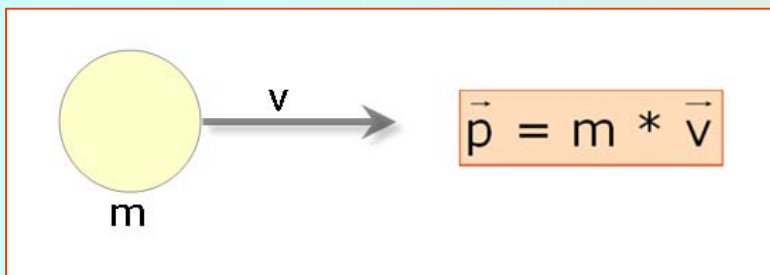
The linear momentum of a body with mass m , travelling with velocity \mathbf{v} is defined to be the product of the mass and the velocity.

Since mass is a scalar quantity and velocity is a vector quantity, momentum (\mathbf{p}) is a vector quantity:

$$\vec{p} = m * \vec{v}$$

In this example, the magnitudes of linear momentum of bodies "1" and "2" are:

$$\begin{aligned} \vec{p}_1 &= m_1 * \vec{v}_1 = (4 \text{ kg}) * (6 \vec{i} \text{ m/s}) = \\ &= 24 \vec{i} \text{ kg*m/s} \\ \vec{p}_2 &= m_2 * \vec{v}_2 = (8 \text{ kg}) * (-4 \vec{i} \text{ m/s}) = \\ &= -32 \vec{i} \text{ kg*m/s} \end{aligned}$$



Linear momentum

Impulse

The quantity $\mathbf{F} \cdot \Delta t$ is called **impulse** (where \mathbf{F} is the net force applied to an object during a time Δt)

The impulse and linear momentum are related:

$$\begin{aligned}\vec{J} &= \vec{F} \cdot \Delta t = (m \cdot \vec{a}) \cdot \Delta t = \\ &= m \cdot (\vec{v} - \vec{v}_0) = \vec{p} - \vec{p}_0 = \Delta \vec{p}\end{aligned}$$

The impulse on an object changes the linear momentum of that object

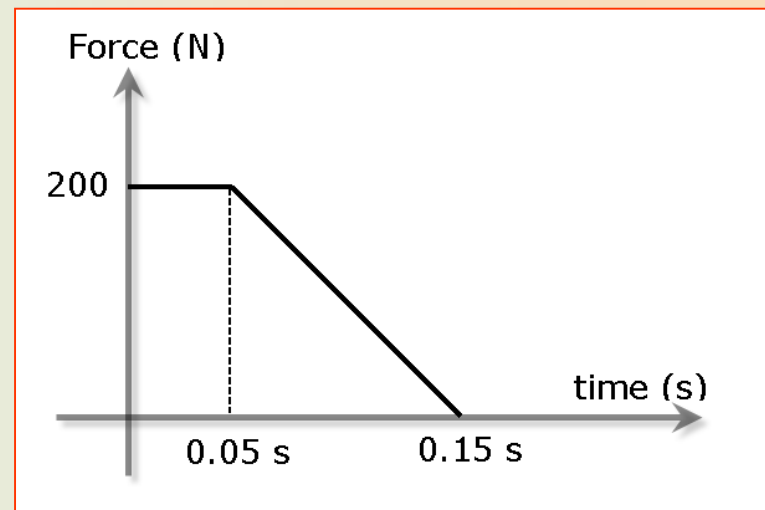
$$\vec{J} = \Delta \vec{p}$$

Problem

A baseball ball has a mass of 0.2 kg and an initial velocity (against the bat) of 30 m/s.

The force done on the ball is represented in the graphic below.

Determine the final velocity



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Solution

The impulse can be calculated graphically

Impulse = Area

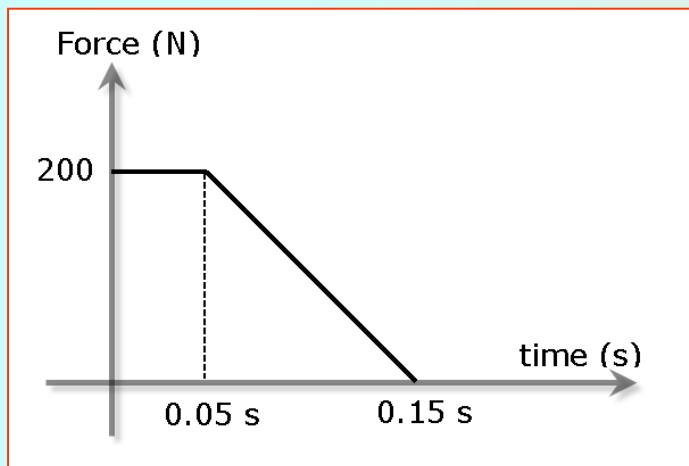
$$J = (200 \text{ N} * 0.05 \text{ s}) + \frac{1}{2} (200 \text{ N} * 0.1 \text{ s}) = 20 \text{ N.s}$$

Impulse = Change in linear momentum

$$\vec{J} = 20 \vec{i} \text{ N.s} = \vec{p} - \vec{p}_0$$

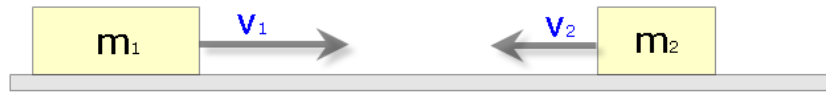
$$\vec{p}_0 = 0.2 \text{ kg} * (-30 \vec{i} \text{ m/s}) = -6 \vec{i} \text{ kg*m/s} = -6 \vec{i} \text{ N.s}$$

$$\vec{p} = 26 \vec{i} \text{ N.s} = 0.2 \text{ kg} * \vec{v} \rightarrow \vec{v} = 130 \text{ m/s } \vec{i}$$

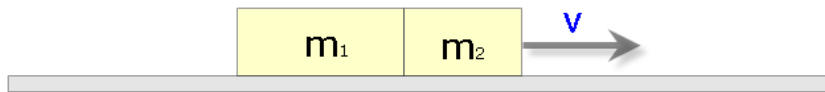


Linear momentum

Before the collision



After the collision



Perfectly inelastic collisions

In that type of collisions, the two objects couple with each and move together at the same velocity.

When two bodies collide (when no external force is applied) the linear momentum remains constant. This rule is called **the conservation of linear momentum** and the expressions we can use are:

$$\vec{p}_{\text{before}} = \vec{p}_{\text{after}}$$

$$m_1 * \vec{v}_1 + m_2 * \vec{v}_2 = (m_1 + m_2) \vec{v}$$

The same expressions can be used when a body is separated into two or more parts.

In our case:

$$\vec{p}_{\text{before}} = \vec{p}_{\text{after}}$$

$$(M + m) \vec{v}_0 = M * \vec{v}_1 + m * \vec{v}_2$$

