University Physics 1A

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Impulse

$$W_{net} = \int \overrightarrow{F_{net}} \cdot \, \mathrm{d}\vec{x} = \frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2$$

$$\begin{aligned}
\int \overrightarrow{F_{net}} \, \mathrm{d}t &= \int m\vec{a} \, \mathrm{d}t \\
&= \int m\frac{\mathrm{d}\vec{v}}{\mathrm{d}t} \, \mathrm{d}t \\
&= \int m \, \mathrm{d}\vec{v} \\
&= m\int \, \mathrm{d}v \\
&= m\vec{v_f} - m\vec{v_i} \\
\text{impulse} &= \text{change in momentum}
\end{aligned}$$

This is known as the impulse-momentum theorem.

$$\int F \, \mathrm{d}t = F_{avg}\Delta t$$

This applies to systems as well as individual objects. Suppose we have the system:

The internal forces cancel out and the net impulse is only due to the external forces.

$$0 = m_1 v_{1f} + m_2 v_{2f} - (m_1 v_{1i} + m_2 v_{2i})$$
$$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$$

This is known as the conservation of momentum, and is true when the net external force is zero.

Example

A superball of mass $m = 0.0300$ kg heads towards the right with velocity $v = 20.0$ m/s west (?). It hits a wall and then bounces back with the same speed in the opposite direction. The ball is in contact with the wall for $t = 0.0300$ s. What is the average *vector* force **on the ball** during the collision?

$$\begin{aligned} F_{avg}\Delta t &= m\vec{v_f} - m\vec{v_i} \\ F_{avg} &= \frac{m\vec{v_f} - m\vec{v_i}}{\Delta t} \\ &= \frac{(0.03)(20) - (0.03)(-20)}{0.03} \\ &= 40N \end{aligned}$$

Example

A tennis ball of mass $m = 0.0300$ kg is thrown towards the right with velocity $v = 20.0$ m/s west. It hits a wall with a speed of $v = 20.0$ m/s, and the angle between the vertical wall and the initial velocity is 70.0°. It bounces off the wall, still headed upwards with a speed of 10.0 m/s, again making an angle of 70.0° with the vertical wall. The ball is in contact with the wall for $t = 0.0300$ s. What is the average *vector* force **on the ball** during the collision written in component form?

$$\begin{aligned}
v_{xi} &= 20\sin(70) \\
v_{xf} &= -10\sin(70) \\
v_{yi} &= 20\cos(70) \\
v_{yf} &= 10\cos(70) \\
F_{net\ x} &= \frac{mv_{xf} - mv_{xi}}{\Delta t} \\
&= \frac{(0.03)(-10\sin(70)) - (0.03)(20\sin(70))}{0.03} \\
&= -28.2N \\
F_{net\ y} &= \frac{mv_{yf} - mv_{yi}}{\Delta t} \\
&= \frac{(0.03)(10\cos(70)) - (0.03)(20\cos(70))}{0.03} \\
&= -3.42N \\
F_{net} &= \langle -28.2, -3.42 \rangle N
\end{aligned}$$

You can find all my notes at `http://omgimanerd.tech/notes`. If you have any questions, comments, or concerns, please contact me at alvin@omgimanerd.tech