Chapter 6
Momentum and Collisions

Linear momentum is defined as:
\[ \vec{p} = m \vec{v} \]

Momentum is given by mass times velocity.
The units of momentum are:
\[ [p] = \text{kg m/s} \]

Since \( \vec{p} \) is a vector, we can also consider the components of momentum:
\[ p_x = m v_x \]
\[ p_y = m v_y \]
\[ (p_z = m v_z) \]

Note: momentum is “large” if \( m \) and/or \( v \) is large.

Recall that \( \ddot{a} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t} \)
\[ \Rightarrow m \ddot{a} = m \frac{\Delta \vec{v}}{\Delta t} = m \vec{v}_f - m \vec{v}_i \]
\[ \frac{\vec{p}_f - \vec{p}_i}{\Delta t} = \frac{\Delta \vec{p}}{\Delta t} \]

And \( \vec{F} = m \ddot{a} \)
\[ \Rightarrow \vec{F} = \frac{\Delta \vec{p}}{\Delta t} \]

The total momentum of an isolated system is constant. This is known as:

The Principle of Conservation of Momentum

Impulse

We can rewrite \( \vec{F} = \Delta \vec{p} / \Delta t \) as:
\[ \vec{F} \Delta t = \Delta \vec{p} \]

\( \vec{F} \Delta t \) is known as the impulse.

The impulse of the force acting on an object equals the change in the momentum of that object.

Collisions

In general, a “collision” is an interaction between bodies passing each other.

- Contact
- Fields
- Can involve more than 2 objects
From the conservation of momentum:

\[ m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f} \]

What about conservation of energy?

We said earlier that the total energy of an isolated system is conserved, but the total kinetic energy may change.

- elastic collisions: KE is conserved
- inelastic collisions: KE is not conserved

- perfectly inelastic: objects stick together after colliding

Perfectly Inelastic Collisions

Note that after a perfectly inelastic collision, both objects move with the same velocity:

\[ m_1 v_{1i} + m_2 v_{2i} = (m_1 + m_2) v_f \]

Elastic Collisions

Kinetic energy is conserved in addition to momentum:

\[ m_1 \vec{v}_{1i} + m_2 \vec{v}_{2i} = m_1 \vec{v}_{1f} + m_2 \vec{v}_{2f} \]

\[ \frac{1}{2} m_1 v_{1i}^2 + \frac{1}{2} m_2 v_{2i}^2 = \frac{1}{2} m_1 v_{1f}^2 + \frac{1}{2} m_2 v_{2f}^2 \]