Chapter 28: Special Relativity

Essential Concepts and Summary
Events and Inertial Reference Frames

- **Event**: a physical "happening" that occurs at a certain place and time
- **Reference frame**: a set of x,y,z axes (coordinate system) and a clock
- **Inertial reference frame**: one in which Newton's law of inertia is valid.
- **No such thing as "absolute" reference frame**
- **Any inertial frame is as good as any other for expressing laws of physics**
Postulates of Special Relativity

- **Postulate**: fundamental assumption

1. **Relativity Postulate**: The laws of physics are the same in every inertial reference frame.

2. **Speed of Light Postulate**: The speed of light in a vacuum, measured in any inertial reference frame, always has the value \( c \), regardless of the speed of observer and the source of light.

Called **special** because its applies only to the special case of frames of reference moving at a constant speed relative to each other.
Time Dilation
Time Dilation

- Because speed of light is always constant, and speed is distance over time, some other constant has to change. In special relativity, a phenomenon called **time dilation** occurs.

- In the previous picture, we look at the astronaut from his own reference frame, then an outside, still inertial, reference frame.
Length Contraction

Because of time dilation, relativistic length is less than the **proper length** between two points.

Length contraction only occurs in the direction of motion.

\[ L = L_0 \sqrt{1 - \frac{v^2}{c^2}} \]
Mass Increase

\[ m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} \]
Relativistic Momentum

Like speed and time, relativity modifies our ideas about momentum.

Like normal momentum, however, relativistic momentum in an isolated system is conserved.

\[ p = \frac{m_0 v}{\sqrt{1 - \frac{v^2}{c^2}}} \]
Equivalence of Mass and Energy

One of the most amazing results of special relativity is mass and energy are equivalent.

Rest energy of an object is the special case when its velocity is 0.

\[
m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}
\]

\[
E = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}}
\]

\[
E_0 = m_0c^2
\]

\[
KE = E - E_0
\]

\[
KE = mc^2 - m_0c^2
\]

\[
= (m - m_0)c^2
\]
Relativistic Addition of Velocities

For a general situation, the relative velocities are related by the velocity addition formula.

At speeds much below the speed of light, this is equivalent to our current understanding of addition of velocities.

\[ v_{AB} = \frac{v_{AC} + v_{CB}}{1 + \frac{v_{AC}v_{CB}}{c^2}} \]

\( v_{xy} \) is velocity of object \( X \) relative to object \( Y \)
\[ \Delta t = \frac{\Delta t_0}{\sqrt{1 - \frac{v^2}{c^2}}} \]

\[ L = L_0 \sqrt{1 - \frac{v^2}{c^2}} \]

\[ p = \frac{m_0 v}{\sqrt{1 - \frac{v^2}{c^2}}} \]

\[ v_{AB} = \frac{v_{AC} + v_{CB}}{1 + \frac{v_{AC} v_{CB}}{c^2}} \]

\[ E = \frac{m_0 c^2}{\sqrt{1 - \frac{v^2}{c^2}}} \]

\[ E_0 = m_0 c^2 \]

\[ KE = mc^2 - m_0 c^2 \]