Chapter 9 Review

- By 1900, many physicists believed that the major work of understanding the laws of physics was done. All that was left was details.
- Einstein's theories did not destroy the work of Newton or Maxwell, they just allowed scientific progress in areas where those theories do not apply (*e.g.*, systems with speed near that of light and systems with very large mass).
- The "special" theory of relativity only describes what happens to objects which are not accelerating.
- The principle of relativity is not new, it was developed by Galileo and reinforced by Newton.
  - The principle of relativity is basically that the laws of physics hold equally in any valid reference frame.
  - A reference frame is defined as a coordinate system which is not accelerating.
  - The coordinate system contains three axes. The origin and orientation of these axes is important along with their motion relative to any other coordinate system. Think of a set of three rulers put together at right angles representing the x, y and z axes.
  - A reference frame also needs a time so a clock must be included. The time when the clock reads zero is part of what makes a reference frame unique.
  - In Einstein's world, the reference-frame clock must be at rest relative to the coordinate system (it did not matter in Galileo's or in Newton's versions of relativity).
- Einstein's version of relativity extended Galileo's to all realms of physics including electromagnetism.
- Einstein long had doubts about the speed of light being relative like everything else because the act of catching up with a light wave would violate Maxwell's laws of electromagnetism.
- Einstein's solution was to declare that light must always have the same speed no matter how fast the observer of that light is traveling.
- Einstein's principle of the constant speed of light caused him to rethink the notion of how we know when things happened.
- Depending on the motion of an observer, the timing of events can change.
- There is no "correct" version of when events happened.
- There are limits on how separate events can be interpreted. The speed of light sets the limit.
- Because of the finite, constant speed of light, the notion of time itself is also affected by motion.
- A moving clock will move more slowly than a stationary one.
- Two observers moving relative to each other will observe the *other observer's* clock to be running slow!

- The relationship between the time interval between two events measured in one reference frame, s (considered at rest) and the time interval as measured by an observer in motion relative to that reference frame (reference frame m).

$$\Delta t_m = \frac{\Delta t_s}{\sqrt{1 - \frac{v^2}{c^2}}}$$

  where Δt_s is the time interval measured measured by the "at rest" observer and Δt_m is the time interval measured by the moving observer. v is the relative speed between the two observers and c is the speed of light.

- Because the time interval between events is different in refreference frames which are moving relative to each other, events which may be simultaneous in one reference frame may occur at different times in another.

- In addition to time, the notion of distance also must be changed. To an observer who is moving relative to another object, that object looks shorter in the direction in which the observer is moving.

- The relationship between the length of an object at rest and the length seen by an observer in motion relative to that object is:

$$l_m = l_s\sqrt{1 - \frac{v^2}{c^2}}$$

  where l_s is the length of the object as measured at rest and l_m is the length measured by the moving observer. v is the relative speed between the two observers and c is the speed of light.

- Because the measurement of time and distance varies with reference frame, the usual addition of velocities must be modified. At slow speeds ($v/c \ll 1$), the velocity of an object in one reference frame can be added to the relative velocities between two reference frames to get the velocity of the object in the other reference frame (*e.g.*, when you throw a ball forwards at 5 m/s from a car moving at 10 m/s, the ball looks like it is moving at 15 m/s to someone standing by the road).