Chapter 7 – Light

As usual, read the chapter carefully. This chapter is full of interesting things!

Visible light is just a small part of the broad spectrum of **electromagnetic radiation** that spans from below the frequencies of AM radio waves up to gamma rays. The only difference between these is their frequency. AM radio waves are about 1 MHz and gamma rays have frequencies up to 10^{20}Hz.

Electromagnetic waves are composed of individual particles called **photons**, each with an energy proportional to frequency. The energy of a single photon is $E=hf$ where $h=6.63\times10^{-34}\text{J}\cdot\text{s}$ is a fundamental constant of nature. A 1 MHz radio wave photon has an energy of $6.63\times10^{-28}\text{J}$ while the energy of a gamma ray photon is 10^{14} times greater. A typical radio wave might have 10^{22} photons all acting in a **coherent** (coordinated) manner to move produce a significant signal in an antenna, but photons of visible light and higher frequencies can be detected one at a time.

Light moves at the "speed of light" only in a vacuum. In air it is a bit slower and in glass it travels 30% less than in a vacuum. The **index of refraction** n is the ratio of the speed of light in a vacuum c to that in a material v, $n=c/v$. How light bends when entering a material depends on the index of refraction, and different colors (frequencies) of light can have different indexes of refraction. That is how a prism splits colors.

Fermat's principle states that light will take the quickest path between two points although in special cases might take the slowest. I'll explain this in lecture.

When photons pass through openings of a size comparable to their wavelength, patterns of **interference** such as shown in Figure 7.19 will appear. We will see this demonstrations with a laser in the lab. These **diffraction** effects limit the resolution of microscopes and telescopes.

The electric field of photons is perpendicular to the direction of motion of the photon which can cause it to reflect and refract differently depending on how it strikes a surface. The direction of the electric field is called the **polarization** direction of the photon. See the handout showing photos taken with different polarizations.

Einstein's **Special Theory of Relativity** adds corrections to Newton's laws that become serious when objects approach speeds near the speed of light. Time and space are found to be mixed up:

> **The length of an object is shorter when it is moving.**
> **Moving clocks run more slowly.**
> **Moving objects have a momentum greater than *mv*.**

Einstein's **General Theory of Relativity** shows how space and time are distorted by the presence of mass leading to the illusion of gravity. **Black holes** are an extreme case of this.

These conclusions of Einstein's theories have been confirmed by numerous experiments. They just seem strange because we do not travel near the speed of light and do not live near a black hole.