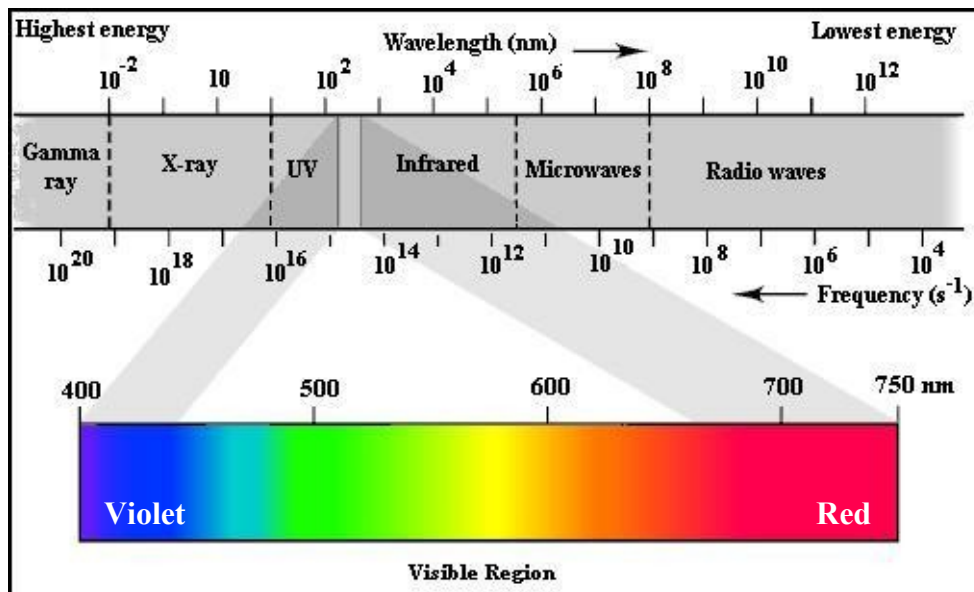


Light and Color

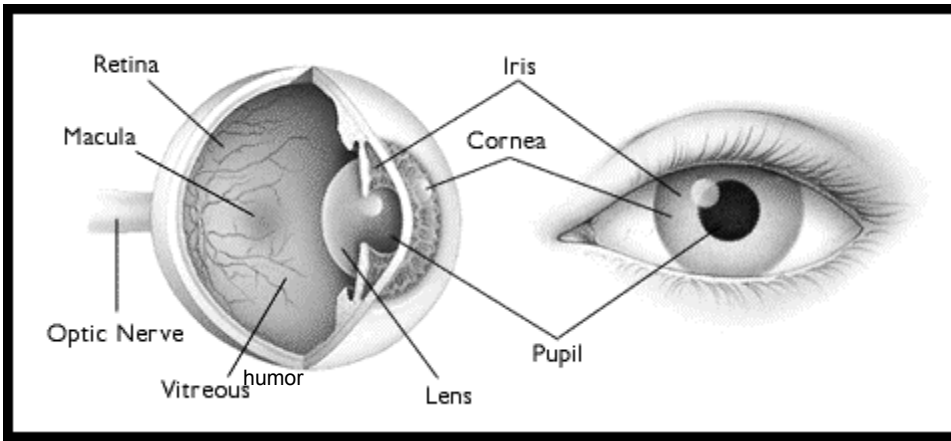
Light is currently considered to be composed of tiny, massless bundles of electromagnetic energy, **photons**, and travels in a transverse wave form. Light exhibits properties and behaviors of both waves and particles. We will mainly concern ourselves with the wave behavior of light in this course. Light is an **electromagnetic wave**: charged particles vibrate causing an electric field. Where there is an electric field there is a magnetic field. These two fields are always perpendicular to each other. As they travel through space a wave pattern results. The photons are basically energy, although this idea is highly simplified here, so the wave is still only “transporting” energy. All electromagnetic waves will travel at 3.0×10^8 m/s in empty space (a vacuum). The electromagnetic spectrum shows all electromagnetic waves as a continuous range of waves with gradually changing frequencies and wavelengths. Major regions of the spectrum have specific names. List some uses of each region based on your experiences. Please note that although the diagrams often show distinct regions, each region blends into the next and there is often overlapping at the boundaries. The following is a common diagram of the electromagnetic spectrum:



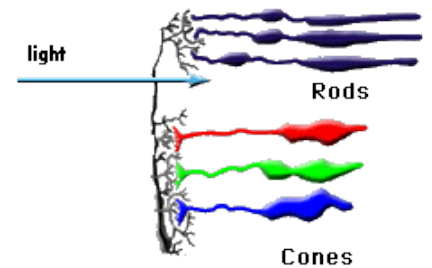
Note the inverse relationship between wavelength and frequency as noted earlier while discussing waves. The diagram also shows the relative energy associated with each type of electromagnetic wave. The more energy a wave has the more change it can cause, such as UV burning human skin and possibly causing cancer. The visible region of the spectrum is a very small part and represents the frequencies that are detected by the nerve cells in the eye.

The Human Eye and Vision

The main parts of the eye are shown in the picture below. The tough, white, outer covering of the eye is called the **sclera**. Light enters the eye at the cornea and passes through until it reaches the retina. The eye is filled with a fluid called the vitreous humor. At the retina the energy of the light causes the stimulation of two main types of nerve cells, the **rods** (light intensity) and the **cones** (color). There are three main cones which detect the three primary colors of light: **red, blue, and green**. The signals from the rods and cones are sent to your brain, which interprets the brightness and color you “see”. The area of the retina with the highest concentration of nerve cells is called the macula.

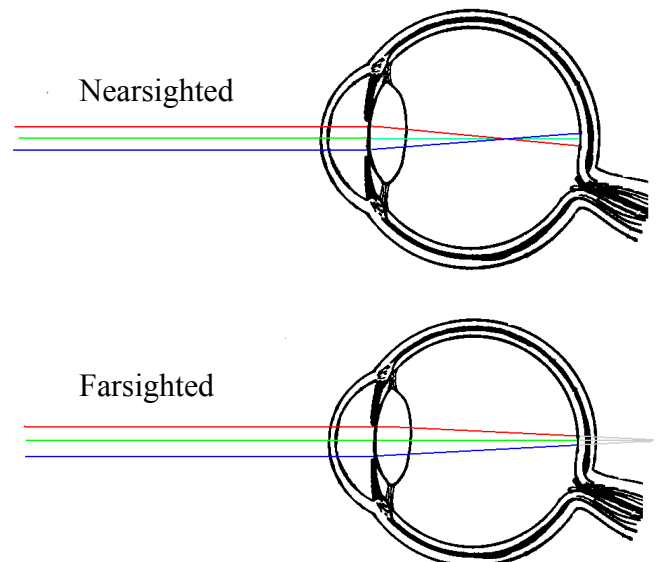


The Retina



An eye with “normal” vision will refract and focus light as it passes through the cornea and the lens and form a focused image on the retina, along the back of the eye. A **nearsighted** eye will focus the light “in front” of the retina producing a blurry image on the retina. A nearsighted eye is able to focus near objects, while distant objects are blurry. A **farsighted** eye will focus the light “behind” the retina producing a blurry image on the retina. A farsighted eye is able to focus distant objects, while near objects are blurry. Many people “become” farsighted as they get older. These people have probably always been farsighted, it’s just that as you age the muscles in your eye that control the fine tuning lens become weaker. As a result you can no longer compensate for the discrepancy in your eye.

Corrective lenses are often used for vision problems. A concave lens for nearsighted vision and a convex lens for farsighted vision. After exploring lenses you should draw the appropriate lens for each eye.



Color Algebra

This is an "algebraic", in the sense that you are using defined variables, approach to mixing colors of light and pigment. The basic principle to remember here is that **you can only see light** given off by or reflected off of an object. You cannot see the object unless light is leaving it and being detected by your eye. **Light**, which is **additive**, is indicated by a (+) in front of the letter. **Pigment**, which is **subtractive**, is indicated by a (-) in front of the letter. The (-) indicates the absorption (or lack) of light.

The following table defines the values for each color of light and pigment to use the color algebra. Note that the light values are represented by adding the colors and the pigment values indicate a subtraction, or what is absorbed by the pigment. For example if you see red light you see red light, if you see a red pigment the only reason you see it is because it absorbs all colors except the red which is reflected. **Try this:** a red pigment is $-B-G$, there is no light here, you can't see a pigment unless there is light to be reflected back to your eye. To keep it simple use normal white light shining on the red pigment, $(+R+G+B) + (-B-G) = +R$, which is red light reflected off the pigment to your eye, so you see red.

The following table lists the primary/secondary colors and their color algebra values:

Primary and Secondary Colors	Light (+)	Primary and Secondary Colors	Pigment (-)
RED	+R	CYAN	-R
GREEN	+G	MAGENTA	-G
BLUE	+B	YELLOW	-B
MAGENTA	+R+B	GREEN	-R-B
CYAN	+B+G	RED	-B-G
YELLOW	+R+G	BLUE	-R-G
WHITE	+R+G+B	BLACK	-R-G-B

In order to determine what you would see as a result of any combination of light/light, pigment/pigment, or light/pigment simply add the values of the desired colors

and you will see only the (+) in the result. One last example: A blue pigment under only red light: $(-R-G) + (+R) = -G$. This result has no light, which is represented by a + in it, so you "see" **BLACK**, which is the absence of light.

Complete the two Venn diagrams showing the relationships of the primary and secondary colors both in light and pigment:

