Introduction

Light is an example of an electromagnetic wave. Electromagnetic waves can travel through the vacuum of interstellar space. They do not depend on an external medium—unlike a mechanical wave such as a sound wave which must travel through air, water, or some solid medium. Electromagnetic waves cover a huge range of frequencies, from high-frequency gamma rays and x-rays, to ultraviolet light, visible light, and infrared light, and on into microwaves and radio waves. As the frequency decreases, so does the energy. The wavelength of an electromagnetic wave is inversely proportional to its frequency. So waves with high frequency have short wavelengths, and waves with low frequency have long wavelengths.

We have learned that visible light waves consist of a continuous range of wavelengths or frequencies. When a light wave with a single frequency strikes an object, a number of things could happen. The light wave could be absorbed by the object, in which case its energy is converted to heat. The light wave could be reflected by the object. And the light wave could be transmitted by the object. Rarely however does just a single frequency of light strike an object. While it does happen, it is more usual that visible light of many frequencies or even all frequencies is incident towards the surface of objects. When this occurs, objects have a tendency to selectively absorb, reflect or transmit light certain frequencies. That is, one object might reflect green light while absorbing all other frequencies of visible light. Another object might selectively transmit blue light while absorbing all other frequencies of visible light. The manner in which visible light interacts with an object is dependent upon the frequency of the light and the nature of the atoms of the object. In this section of Lesson 2 we will discuss how and why light of certain frequencies can be selectively absorbed, reflected or transmitted.

We perceive different colors because our visual system has evolved to make use of the spectral information in reflected light. When light interacts with an object, the light can be absorbed by the object, reflected by the object, or transmitted by the object.

For example, when you look at yourself in the mirror, the light that you are seeing has been reflected by the mirror, transmitted through the air, through your cornea, through the lens of your eye, and through two layers of cells in your retina before it is absorbed by light-sensitive pigments in your photoreceptor cells. The energy from the absorbed light starts a cascade of chemical reactions in your photoreceptors that ultimately leads to your perception: seeing yourself in the mirror.

Objects in the world have different colors depending on which parts of the visible spectrum they absorb, and which parts of the visible spectrum they reflect. Red objects reflect long wavelengths of light (and absorb shorter wavelengths), while blue objects reflect short wavelengths of light (and absorb longer wavelengths). Black objects absorb all visible wavelengths about equally, and white objects reflect all visible wavelengths about equally. Light that is absorbed by an object is usually converted into heat energy.

Reflection and transmission of light waves occur because the frequencies of the light waves do not match the natural frequencies of vibration of the objects. When light waves of these frequencies strike an object, the electrons in the atoms of the object begin vibrating. But instead of vibrating in resonance at a large amplitude, the electrons vibrate for brief periods of time with small amplitudes of vibration; then the energy is reemitted as a light wave. If the object is transparent, then the vibrations of the electrons are passed on to neighboring atoms through the bulk of the material and reemitted on the opposite side of the object. Such frequencies of light waves are said to be **transmitted**. If the object is opaque, then the vibrations of the

electrons are not passed from atom to atom through the bulk of the material. Rather the electrons of atoms on the material's surface vibrate for short periods of time and then reemit the energy as a reflected light wave. Such frequencies of light are said to be **reflected**.

The color of the objects that we see is largely due to the way those objects interact with light andultimately reflect or transmit it to our eyes. The color of an object is not actually within the object itself. Rather, the color is in the light that shines upon it and is ultimately reflected or transmitted to our eyes. We know that the visible light spectrum consists of a range of frequencies, each of which corresponds to a specific color. When visible light strikes an object and a specific frequency becomes absorbed, that frequency of light will never make it to our eyes. Any visible light that strikes the object and becomes reflected or transmitted to our eyes will contribute to the color appearance of that object. So the color is not in the object itself, but in the light that strikes the object and ultimately reaches our eye. The only role that the object plays is that it might contain atoms capable of selectively absorbing one or more frequencies of the visible light that shine upon it. So if an object absorbs all of the frequencies of visible light except for the frequency associated with green light, then the object will appear green in the presence of ROYGBIV. And if an object absorbs all of the frequencies of visible light except for the frequency associated with blue light, then the object will appear blue in the presence of ROYGBIV.

Transparent materials are materials that allow one or more of the frequencies of visible light to be transmitted through them; whatever color(s) is/are not transmitted by such objects, are typically absorbed by them. The appearance of a transparent object is dependent upon what color(s) of light is/are incident upon the object and what color(s) of light is/are transmitted through the object.

Materials like air, water, and clear glass are called transparent. When light encounters transparent materials, almost all of it passes directly through them. Glass, for example, is transparent to all visible light. The color of a transparent object depends on the color of light it transmits. If green light passes through a transparent object, the emerging light is green; similarly if red light passes through a transparent object, the emerging light is red.

Materials like frosted glass and some **plastics** are called translucent. When light strikes translucent materials, only some of the light passes through them. The light does not pass directly through the materials. It changes direction many times and is scattered as it passes through. Therefore, we cannot see clearly through them; objects on the other side of a translucent object appear fuzzy and unclear. Because translucent objects are semi-transparent, some ultraviolet rays can go through them. This is why a person behind a translucent object can get a sunburn on a sunny day.

Most materials are opaque. When light strikes an opaque object none of it passes through. Most of the light is either reflected by the object or absorbed and converted to **heat**. Materials such as **wood**, stone, and metals are opaque to visible light.