Types of Light

To understand light you have to know that what we call light is what is visible to us. Visible light is the light that humans can see. Other animals can see different types of light. Dogs can see only shades of gray and some insects can see light from the ultraviolet part of the spectrum. The key thing to remember is that our light is what scientists call visible light.

Scientists also call light electromagnetic radiation. Visible light is only one small portion of a family of waves called electromagnetic (EM) radiation. The entire spectrum of these EM waves includes radio waves, which have very long wavelengths and both gamma rays and cosmic rays, which are at the other end of the spectrum and have very small wavelengths. Visible light is near the middle of the spectrum.

It's all Energy

The key thing to remember is that light and EM radiation carry energy. The quantum theory suggests that light consists of very small bundles of energy/particles; it's just that simple. Scientists call those small particles photons, and the wavelength determines the energy and type of EM radiation, and the number of photons tells you how much radiation there is. A lot of photons give a brighter, more intense type of light. Fewer photons give a very dim and less intense light. When you use the dimmer switch on the wall, you are decreasing the number of photons sent from the light bulb. The type of light is the same while the amount has changed.

Different Speeds of Light?

As far as we know, all types of light move at one speed when in a vacuum. The speed of light in a vacuum is 299,792,458 meters per second. That speed is really fast, but even when you're traveling that fast, it takes a while to get places in space. It takes about seven minutes for light from the Sun to reach Earth. It takes over four years for the light from our Sun to get to the nearest star. It would take a particle of light over 100,000 years to get from one side of our galaxy to the other side. All of those values are light moving through a vacuum. You can slow light down in other substances such as the atmosphere, water, or a diamond. Light moves at about 124,000,000 meters per second (less than half the speed in a vacuum) in a diamond.

Types of Electromagnetic Radiation

There are waves of energy and light moving all around us in the form of TV and audio transmissions, gamma radiation from space, and heat in the atmosphere. Scientists call them all electromagnetic radiation. The waves of energy are called electromagnetic (EM) because they have oscillating electric and magnetic fields. Scientists classify them by their frequency or wavelength, going from high to low frequency (short to long wavelength). For a wave with a high frequency, it has a lot of energy, so it could be a gamma ray or x-ray. If it has low frequency, it has less energy and could be a TV or radio wave.

All EM energy waves travel at the speed of light. No matter what their frequency or wavelength, they always move at the same speed. Some properties of waves, such as diffraction and interference, are also seen in EM radiation. Scientists have figured out that there are tiny particles in these waves; they are called photons. The photons are specific units, or packets, of energy. Sometimes those particles interact with each other and change the way the light originally behaved.

Listening to the Heavens

All types of EM radiation are useful to the world of science. Look at radio waves as an example. Radio stations and ham radio operators of Earth work with radio waves every day. Radio waves are used to carry communications from one point to another. Radio waves are also extremely important to astronomers. Astronomers are constantly listening to the radio waves of other galaxies to learn more about their stars. Stars give off large amounts of EM radiation across the entire spectrum, and we can study that radiation to learn more about the universe.

Radiation Doesn't Scare Us... Much

An important idea you should always remember is that sometimes we use the word radiation. When you think of radiation, you probably think about nuclear power plants, bombs, and X-rays. Sure, those are all types of radiation. Nevertheless, more important to physics is the idea that all light is considered radiation. That means that everything from television and radio waves to gamma rays are all types of radiation. Think about the word LASER. The R stands for radiation, while a laser is just a souped-up flashlight. Think about heat. Most heat is actually infrared light being given off by an object. That heat is also radiation.

Seeing the Light

Let's take a moment to talk about visible light. As you can tell by the name, visible light is the light that humans can see. More specifically, you see the light that is not absorbed by objects. Green plants are green because they absorb all of the colors of the visible spectrum except the green color (you could also say the green wavelengths). A red wall is red to your eyes because it is not absorbing light from the red wavelengths. Mirrors reflect all of the colors of visible light.

Not Seeing the Light

We describe the world the way we see it as humans. Other living things on Earth see the world in different ways. Dogs only see things in black, white and gray. Some insects see colors that none of us can see. When you are learning about visible light you should remember we mean visible to humans. We should also mention that not all humans can see all the colors. There is an eye defect called color-blindness that affects many men. Color-blind men cannot see certain colors of the spectrum. It has to do with a genetic defect in their eyes.

Visible Light Colors

We now introduce you to Mr. Roy G. Biv. Was he a scientist? No. Did he create great optics and telescopes? No. He is not even a he. ROY-G-BIV is the acronym that represents all of the colors in the visible spectrum of light. R (red) - O (orange) - Y (yellow) - G (green) - B (blue) - I (indigo) - V (violet). Not only are those the colors we can see as humans, but they are also in the right order. Red has the longest wavelength and violet has the shortest. You could also say that red is the least energetic and violet is the most energetic of the visible spectrum.

Edges of Visibility

Although we can't see them with our eyes, some wavelengths of light that bookend the visible spectrum are also important. Infrared radiation is next to the red portion of the spectrum. Infrared light is heat. Scientists use infrared light sensing optics when they want to see differences in temperature. Ultraviolet radiation (UV) is just beyond the violet end of the visible spectrum. UV light is given off by the Sun and absorbed by ozone in the atmosphere. Ultraviolet light can also mutate cells in your skin and give you skin cancer.

Particles and Waves

During the early 1900's scientists proved that electromagnetic radiation not only has packs of energy (quanta), but also proved that light moves in a wave pattern. It's like a stream of individual packets.

Looking at the Waves

All types of light move in wave-like patterns. In each wave pattern are high points and low points. The distance between two high points, or low points, is called the wavelength. Scientists use the Greek letter lambda to describe that distance. Depending on what type of light you are talking about, each type has a different lambda, or wavelength. All of the wavelengths of light together are called the EM spectrum.

Looking at the Particles

Light not only moves in waves; it also moves with a flow of little particles. Scientists call these particles of light, photons. The packets contain the energy that makes up the energy of the light. Scientists measure something called the relative energy of different types of light. The energy increases as the wavelength decreases.

Looking at the Energy

Compare different types of light. You will see that as you move up the EM spectrum and the wavelengths get smaller, those types of light have more energy. The big idea to remember is that light consists of both waves, and energy (transmitted with particles). EM radiation, like gamma waves and cosmic waves, has huge amounts of energy compared to a radio wave. When you look at the visible part of the spectrum, you will see that violet light is more energetic than light from the red part of the spectrum.

Reflection Basics

When a light ray hits an object and bounces off, it is called reflection. When you think of reflection, think about mirrors. They reflect all of the light. That is the reason you can see yourself. Even the ocean reflects light, just not all of it. If you are above the ocean, you can't see the reflection that well, but when you are at an angle, look closely; you can see a reflection of the sky. So the ocean only has partial reflectivity.

Refraction Basics

When scientists talk about refraction, they use a formula. "n = c / v" "c" is the speed of light in a vacuum, "v" is the speed of light in that substance and "n" is the index of refraction. According to the formula, the index of refraction is the relation between the speed of light in a vacuum and the speed of light in a substance. But what is refraction? When light moves from one substance to another it changes speed and direction. That change in direction is called refraction. Some indexes of refraction are diamond (2.419), glass (1.523), and water (1.33).

Let's make a jump here. Since our formula says n=c/v and we know that the value for c is a constant, we can figure out that light has different speeds when it is in different substances. It goes at full speed in a vacuum, and slower everywhere else. Using our examples, we can discover that light moves faster in water than it does in a diamond. Light moves at its fastest speeds when it is in a vacuum. Light moves at about 124,000,000 meters per second (less than half the speed in a vacuum) in a diamond compared to 299,792,458 meters per second in a vacuum.

Light is refracted only when it hits a boundary at an angle, so if light goes straight down into a substance it will continue to move straight down. You need to understand that the speed of light changes in different substances. If a light ray slows down when it hits a substance, it bends towards the normal. The normal is the line that is perpendicular to the surface of the substance. If a light ray speeds up when it hits a substance, it moves away from the normal.

Bending Light with Refraction

Lenses are pieces of glass that bend light. The easiest thing to think about is lenses in eyeglasses. People who do not have 20/20 vision might see things a little out of focus. They wear glasses or contact lenses to make their sight clearer. Those glasses have specially ground lenses that bend the rays of light just enough to focus the image for the person to see properly. All lenses bend and refract rays of light.

In the refraction section we said that light changes speeds when it moves from one medium to another. A medium is a substance like water, air, or glass. When light slows down or speeds up it changes direction a little bit. There are three basic shapes that a lens can have: concave, convex, and planar. A concave shape is bowed inward, like looking into a mixing bowl. Convex is just the opposite, bowed outward. Have you ever seen those mirrors in the grocery stores, where everything is reflected in a spherical way? That's convex. Planar is just that, a plane. It's a flat surface. Just think of a planar mirror on your wall.

Using Lenses

Telescopes and microscopes are excellent examples of how lenses are used every day. By using different combinations of lenses, light is focused to create an image we could not see with the naked eye. Telescopes are able to see very distant objects that are very small to our sight and magnify them so we can see the details. The larger telescopes offer a greater ability to see objects that are more distant. Microscopes work with a similar idea but are concerned with size, not distance. Microscopes enlarge very small objects that are close to the viewer.

Using Prisms

Prisms are a very special type of lens. When refraction is at work in a prism it breaks the beam of visible light into its basic colors. In visible light, the magic colors you can see are red, orange, yellow, green, blue, indigo, and violet. Scientists say ROY-G-BIV. A prism is made up of two planar surfaces at an angle. It uses the slower speed of light in glass to its advantage by refracting the light twice. Because of the different wavelengths of light, each color is refracted a different amount. When the light ray leaves the prism, it speeds up again (entering the air) and refracts a second time. That second dispersal creates the colorful spectrum of colors.

Pull out Your Pointers

Finally, high tech stuff! Lasers aren't so high tech anymore. Lasers have been around since the 1960's. You probably even know someone who has one of those laser pointers. A laser is just a really powerful beam of light. Those laser pens aren't big on power. However, some lasers in satellites can focus a beam anywhere on the planet. That's powerful. Lasers are even used for tests in fusion reactions. Laser isn't a word but an acronym. It stands for LIGHT AMPLIFICATION by STIMULATED EMISSION of RADIATION.

Exciting Atoms

The amount of light normally given off by an atom is increased or exaggerated (stimulated). To make the light even stronger, the source atoms are special and are selected to give off only one wavelength of light. That's why it's usually one color. All of these effects work together to make the light well defined and very focused. You'll find lasers every day in medical offices, universities, and construction. How about this acronym: A REALLY STRONG LIGHT CREATED by EXCITED ATOMS? RSLCEA? It doesn't quite flow off your tongue, does it? Better stick with laser.

Lasers don't start with a light bulb and a magnifying glass. It's all about energy levels. We've got a picture of the rough set up. The atoms are excited by a flow of electricity. When the atoms are excited, they increase in energy. When the energy in the atoms drops, photons are released. And bang! Light. Okay, we admit it's not that simple, but it does give you the basic ideas.

Remember the description of the acronym "LASER" and the term "stimulated emission?" The idea is that you pump energy into the laser and push electrons to higher energy levels. Then you stimulate them to change to a lower energy level and release of energy/photons. The released photons are reflected back and forth, and on each pass, more photons are added. That's the whole "amplification" part of the word laser. You start with one photon, pump in energy to excite an atom, and when the atom returns to its original energy level, it releases an additional photon (now there are two photons). Repeat as needed. When you get the desired number of photons, release them all in one burst.