Technical Aspects of Light

I know you do not want to learn about this stuff. However, in order to become a better photographer, you should understand what light is all about. I will try to keep this chapter in terms that are somewhat easy to understand. This chapter is going to be the most boring one in this book, so let's just get it out of the way.

The subject of light as a form of radiant energy has been theorized upon, experimented with, and studied by many physicists and scientists. Until about three centuries ago, no one had developed a reasonable theory of the nature of light. Then Max Planck, a physicist, published a theory in which light was supposed to consist of a stream of high-speed particles. Planck theorized that any light source sent out an untold number of these particles.

This then was the quantum theory. The quantum of light is called the photon. The quantum theory is used to explain X-ray, radiation, and photo-electricity.

Wavelength, Speed, and Frequency

About the same time, other physicists, Christiann Huygens and Thomas Young, introduced a theory called the wave motion theory. The wave motion theory is used to explain reflection, refraction, diffraction, and polarization. In wave motion theory, light, wavelength, speed, and frequency are important characteristics, and they are interrelated. The wavelengths of light are so small that they are measured in nanometers (nm). A nanometer is equal to one millionth of a millimeter. Wavelengths of light range from about 400nm to 700nm in length, and they travel in a straight line path.

The speed of light varies in different mediums. In air, light travels about 186,000 miles per second. In a denser medium, such as glass, light travels slower. Furthermore, in a denser medium, the speed is different for each color of light.

Wavelength is the distance from the crest of one wave to the crest of the next wave. A wave is similar to an "S" curve on its side. One complete "S" curve is one frequency. Frequency is the number of waves passing a given point in one second. The product of the two is the speed of light. The formula is: Speed = Wavelength x frequency, or Wavelength = Speed / Frequency. Since the speed of light in glass is slower than in air, the wavelength must also be shorter. Only the wavelength changes, the frequency remains constant. Hence, we identify a particular type of radiation (color of light) by its wavelength, bearing in mind that we are speaking of the wavelength in air.

Emission of Light

The photographer considers two important characteristics with the way light travels. First, in a given medium, light always travels in a straight line. Second, in a given medium, it travels at a constant speed.

Once light is produced (emitted), it is no longer dependent on its source, and only its speed is affected by the many mediums through which it can travel. Another example of the independence of light is that when light travels from air into a denser but transparent medium, such as glass, its speed is reduced. However, when it leaves the glass, it returns to its original speed. This changing speed is important in refraction, a behavior of light that allows lenses to form images. Unless light is reflected or focused, it travels or radiates in all directions from the source. As light travels from the source, its energy of light spreads out. The greater the distance it travels, the more it spreads. Therefore, the amount of light reaching a given area at a given distance is less than that reaching the same area closer to the source. In other words, the intensity of illumination on a surface varies when the distance between the light source and the surface, or subject, is changed. This becomes important when exposing film with artificial light.

Color of Light

Look at a bright, red apple on a dark, green tree. It is hard to believe that color is not an inherent property of these objects; in fact, color is not even inherent to light. What you are seeing is a visual perception stimulated by light. The apple and tree are only visible because they reflect light from the sun or other light source, and the apple appears red and the tree appears green because they reflect certain wavelengths of light more than others do. In this case, these particular wavelengths are seen by the human eye as red and green. When we see a color, we are simply seeing light of a particular wavelength reflected back towards us. When a beam of light has a relatively even mixture of light of all visible wavelengths, it appears as white light. When this white light is passed through a prism, its different wavelengths are separated and form the visible spectrum. This visible spectrum is seen as a band of colors: Red, orange, yellow, green, blue, indigo, and violet.

One thing you should realize is that when you are looking at a red apple, you are not seeing a red apple. You are actually seeing all colors of the spectrum aside from red. The apple is absorbing all the colors of the spectrum and reflecting back to you the color red. This is why we say that the apple is all colors aside from red since the apple is absorbing all colors aside from red.

For color slides with fluorescent light, a daylight type of film with the appropriate filter is best. Tungsten film usually produces slides with too much blue or green when made with fluorescent light.

Color Temperature

White light is made up of nearly equal intensities of all wavelengths within the visible spectrum. By passing white light through a prism, scientists have found that light sources have many qualities. They are as follows: Different wavelengths are present in the sources of radiant energy. The frequency and color of wavelengths vary. With each wavelength, there is a variation in the amount of energy. This variation of energy is called spectral energy distribution. The spectral energy of a light source is represented by color temperature. These terms are used in photography to describe and define the sources of light being used. Color temperature describes the color quality of a light source in terms of the amounts of red light and blue light. Color temperature is based on what is called a Planckian radiator, or simply a black body. As the temperature of the metal of the black body is raised, it goes from a dull black through red and orange to blue and finally to white heat. The quality of the light emitted is a function of the temperature of the metal. When the object is red-hot, the color temperature is low since red is at the low end of the scale; and when it is blue-white, the color temperature is high. However, the temperature at which a light source is burned does not control color temperature. For example, a fluorescent tube burns at a low 125°F, yet it has a high color temperature. Color temperature then is raised or lowered relatively by the amount of visible white light radiated from the source.

Be careful not to get too confused. Traditionally reddish light is known as warm and bluish light as cold. In actuality, color temperature is the other way around. The most convenient way to describe the color temperature of a light source is by its Kelvin temperature. From a practical point of view, this term refers to the degree of whiteness of the light. Color temperature is measured on the Kelvin scale and is stated as Kelvin temperature. On the temperature scale, 0 K is the same as –273.16°C. Therefore, degrees Kelvin (K) are always 273.16 degrees higher than the same temperature on the Celsius scale.

The Kelvin temperature scale (K) was developed by Lord Kelvin in the mid 1800s. Lord Kelvin was a British scientist who was born in Belfast, Ireland. He lived from 1824-1907. The zero point of this scale is equivalent to -273.16 °C on the Celsius scale. This zero point is considered the lowest possible temperature of anything in the universe. Therefore, the Kelvin scale is also known as the “absolute temperature scale”. At the freezing point of water, the temperature of the Kelvin scale reads 273 K. At the boiling point of water, it reads 373 K.

Thus, a red-hot piece of iron with an approximate temperature of 2000°C has a color temperature of 2273 K. As the Celsius temperature of an object is raised, it emits a whiter light and produces a relatively higher color (Kelvin) temperature.

Color Relationships

Many ways have been devised to classify the colors we see. Though terminology may differ, it is generally agreed that color can be defined by three qualities: hue, brightness, and saturation.

Hue

Hue is the actual color or wavelength reflected by an object. These are generally the colors of the spectrum. For example, it could be said that the color of an object is blue. Blue identifies the hue. There are seven hues in the visible spectrum, as we have discussed several times. Hue, however, is an inadequate description of a color.

Brightness

To be more specific, we should say that an object is dark blue or light blue. Now we have described the brightness of the color. The brightness of a color is independent of the hue. Two colors may have the same hue but different brightness. Thus, to describe a color or brightness, we say that it is dull, bright, vivid, or brilliant.

Saturation

The saturation of a color is the degree to which the color departs from neutral gray of the same brightness. You can think of it as mixing black, gray, or white paint with a colored paint, thus diluting the color. In other words, saturation is a measure of color purity.

Behavior of Light

Light waves travel in straight lines. When light waves encounter an object or new medium, they act in one or more of the following ways: They may be reflected. They may be absorbed. They may be transmitted.

Reflection

When light is reflected, it acts in a certain way. When the reflecting surface is smooth and polished, the reflection is orderly, or specular. Specular light is reflected at the same angle to the surface as the light incident to the surface. In other words, the path of the light reflected from the surface forms an angle exactly equal to the one formed by its path in reaching the surface. Thus, the angle of reflection is equal to the angle of incidence, which is a characteristic of specular light. However, when the object surface is not smooth and polished but irregular, light is reflected irregularly or diffused; that is, the light is reflected in more than one direction. Practically all surfaces reflect both specular and diffused light; smooth surfaces reflect more specular light, and rough surfaces more diffused light. Since diffused light is more common than specular light, it is of greatest value in photography. Objects that are not light sources are visible and therefore photographic only because they reflect the light that from some luminous source.

Absorption

When light strikes a medium and is neither reflected nor transmitted (passed on), it is said to be absorbed. Black cloth or areas of dark forest, for instance, absorb more light than objects such as a white sheet or a coral sand beach. When light encounters the surface of an object, a certain degree of reflection, and some absorption, always takes place. A medium that does not allow light to pass through it is opaque. An opaque material may also reflect light. When an object is opaque and the light is not reflected, it is absorbed by the object. When light is absorbed, its energy is converted and it no longer exists as light. The color of an object is determined by the way it absorbs light falling upon it (incident light). A woman's dress appears red when it absorbs the blue and green rays of white light and reflects the red waves. A lawn appears green because the grass blades absorb the red and blue rays of light and reflect the green rays. Neutral colors, such as white, black, and the various tones or values of gray, actually absorb almost equal proportions of the colors of light. Varying reflective powers account for their differences. White is highly reflective, while an object of absolute blackness, no matter how much light falls on it, can never be recorded on film except by contrast.

Transmission

In addition to being reflected and absorbed, light rays may be transmitted. They may also pass through some medium they encounter. When objects can be clearly seen through the medium, the medium is transparent**.** A transparent medium transmits light rays in a regular, or uniform, pattern. When the medium transmits light but breaks up the orderliness of the pattern, sending the transmitted rays in many directions, the medium is translucent. In other words, a medium is said to be translucent when light is visible through it, but objects are not clearly distinguishable. Thin fabrics and frosted glass are examples of translucent materials that allow the passage of diffused light. One important form of transmission is termed refraction.

Refraction

Refraction is the change of direction that occurs when a ray of light passes from one transparent substance into another substance of a different density. Refraction enables a lens to form an image. Without refraction, light waves behave as X-rays and pass in straight lines through all suitable substances without any control of direction, and only shadow patterns can be made with them. Refraction occurs because light travels at different speeds in different transparent substances.

The speed of light in each transparent substance is called the index of refraction for that substance. For example, light travels approximately 1½ times as fast in air as it does in glass, so the index of refraction for glass is about 1.5. Refraction, or change of direction, always follows a simple rule. "In passing from one transparent substance into another of greater density, refraction is toward the normal. In passing from one transparent substance into another of lesser density, refraction is away from the normal." In this rule, the normal is defined as a line perpendicular (90°) to the surface between the mediums. All rays striking glass at an angle other than perpendicular are refracted. In the case of a perpendicular ray that enters the glass normal to the surface, no refraction takes place and the ray continues through the glass and into the air in a straight line.

Dispersion

The speed of light in a medium depends on the wavelength of the light. As light enters a denser medium, the short waves, such as blue, are slowed more than the long waves, such as red. Thus, the index of refraction of a medium varies with the wavelength, and the different colors of light are bent different amounts. This changing index of refraction or the breaking up of white light into its component colors is called dispersion. This then ties in with the previous discussion of the colors of light where we saw the way a prism creates a spectrum from white light. The prism is able to create this spectrum because of dispersion.

Diffraction

We have said that light travels in a straight line. Well, that is not always true. An exception to this rule occurs when light travels close to an opaque edge. Because of the wave nature of their travel, light rays passing near an opaque edge are bent ever so slightly. This bending is called diffraction and is evidenced by the formation of a shadow with a fuzzy edge when light passes an opaque object. In this case, the outside edge of the shadow is light and indistinct, but it gradually darkens into the true black of the shadow that indicates that some of the light is scattered into the shadow area. Unlike refraction, in diffraction the long wavelengths of light are bent the most. Diffraction is important to the photographer when the light passes the edges of a lens diaphragm. When the lens diaphragm is opened fully, the amount of diffracted light is quite small. However, when the diaphragm is closed to a small opening, the percentage of diffracted light is quite large and reduces the sharpness of the image formed by the lens. In other words, a small aperture opening interferes with the image-forming light more than a large aperture does. We will discuss this later in several sections.

Polarization

Energy in the form of wave motion radiates from its source and travels through a medium. For example, when a section of line is secured at one end and the free end is held in your hand and given a shake, a wave travels down the length of the line from the end that was shaken to the secured end just like an oscillator. A light source acts as an oscillator. The wave motion in the line, however, does not represent the true wave motion of light because light waves move in all possible directions at right angles to their direction of travel. A much clearer picture of light wave motion can be seen by having a number of parallel lines with each one being shaken in a different direction – one up and down, one sideways, and the others at various angles in between. Ordinarily, light waves vibrate in all directions at right angles to their direction of travel. However, when light waves strike a series of parallel microscopic slots, all the light that passes through vibrates in one direction. This is polarized light. Filters that polarize light, termed polarizing filters have a practical use in photography. Specular reflected light, from a nonmetallic surface at any angle between 32° and 37°, is polarized in such a manner that the light rays vibrate in a direction parallel to the reflecting surface. Light reflected in this manner is said to be plane polarized and is seen as glare. There is no polarization whatsoever produced by reflections from metallic surfaces.