Topic 032

Dispersion of Light

The speed of light is slower in various materials than it is in a vacuum or outer space. When the light passes into a material at an angle, the light beam is bent or refracted according to Snell's Law and the index of refraction of the material. But also, the speed of light through a material varies slightly with the wavelength or frequency of the light. Thus, each wavelength is refracted at a slightly different angle when passing through a material at an angle. This spreading out of the beam of light is called **dispersion** or chromatic dispersion. This can be seen when sunlight passes through a glass prism. Dispersion can cause problems with camera lenses and must be minimized.

Questions you may have include:

- How does the index of refraction vary with wavelength?
- What is the index of refraction?
- How does light bend?

Index and wavelength

The velocity of light in a material--and thus its index of refraction--depends on the wavelength of the light. In general, the index of refraction is greater for shorter wavelengths. This causes light inside materials to be refracted by different amounts according to the wavelength or color.

The wavelength of visible light is very short and often measured in nanometers (nm), which are 1 billionth of a meter (10^{-9} meter).

Color	Wavelength	Index of Refraction
Blue	434 nm	1.528
Yellow	550 nm	1.517
Red	700 nm	1.510

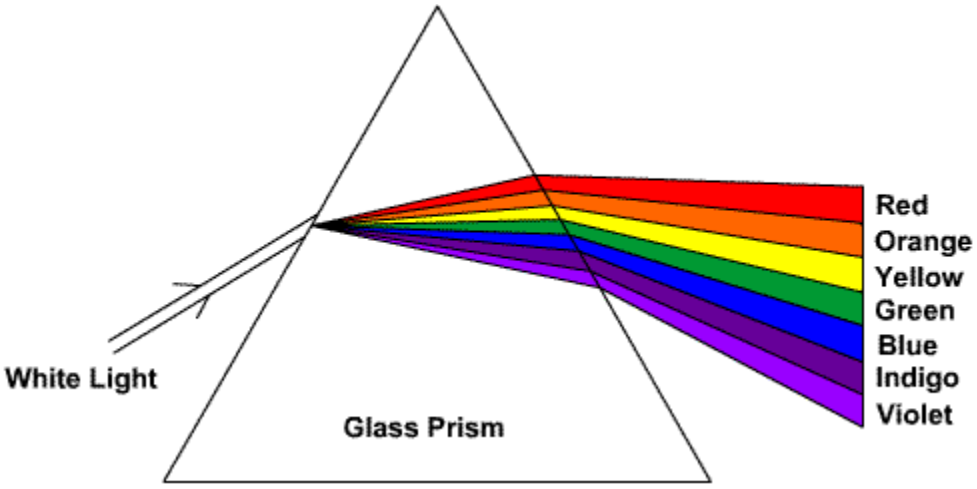
Comparison of wavelength and Index of Refraction

Note: In general shorter wavelengths (i.e. light towards the blue end of the spectrum) have higher indices of refraction and get bent more than light with longer wavelengths (towards the red end).

Spectrum from prism

Sunlight is often called white light, since it is a combination of all the visible colors. Since the index of refraction is different for each color, the angle of refraction will be different for each color when the light passes from air into glass or other transparent material. This is according to Snell's Law. (See *Snell's Law for the Refraction of Light* for more information.)

Now if the piece of glass has parallel sides--such as with a window--the light will return in the same direction that it entered the material. But if the material is shaped like a prism, the angles for each color will be exaggerated, and the colors will be displayed as a spectrum of light.



Prism spreading white light into a spectrum of light

The visible colors are in the order of the spectrum. You can remember the order by the name ROY G. BIV. Note that in the illustration above, the colors are distinctly separated. In realty, they blend into each other, such that there are colors in between. For example, there is red-orange in between red and orange.

Rainbow

Tiny droplets of water refract the white light from the Sun and create a spectrum of colors similar to what happens in a prism. Since the droplets are spheres, the light is reflected internally in the droplets and the spectrum or rainbow returns toward the direction of the light. That is why the Sun will always be behind you when you see a rainbow.

Camera lenses

Chromatic dispersion can be a problem in optical equipment like cameras, microscopes and telescopes. Since a lens is similar to a prism, it will disperse the light into a spectrum. This can be exaggerated when there are several lenses in the system. But you don't want a blurry image where the system focuses different colors of light at different spots. Such blurring is called chromatic aberration.

The solution to that problem is to combine a positive lens that has one index of refraction with a negative lens of a different type of glass and a different index of refraction, such that the dispersion of the two negate each other.

Summary

The speed of light through a material varies slightly with the wavelength or frequency of the light. Each wavelength is refracted at a slightly different angle when passing through a material at an angle. This spreading out of the beam of light is called dispersion. This can be seen in a rainbow or when sunlight passes through a glass prism. Dispersion can cause problems with camera lenses and must be minimized.