Module 8 – Refraction

REFRACTION

In the early 1600s, Galileo[1] turned a small telescope to the sky and observed the mountains of the Moon, the phases of Venus, the rings of Saturn, and the rotation of the Sun. The result of his observations was to provide indisputable evidence that the geocentric model of the universe described by Aristotle and later Ptolemy could not be correct. Copernicus's heliocentric model, supported by Galileo's observations, eventually prevailed, and modern astronomy was born. Since that time, larger and more complicated telescopes have been built, providing us with a greater understanding of our place in the universe.

Galileo's observations were made possible by one simple physical principle related to the wave nature of light—refraction[2]. Refraction is the bending of light as it moves from one medium to another. This bending is due to a change in speed that occurs as the light moves between regions of greater or lesser optical density.

Optical density is not the same as mass or weight density; instead, optical density is a measure of a substance's ability to transmit electromagnetic radiation. The more optically dense a material, the slower the electromagnetic wave will be transmitted.

One indicator of optical density is the index of refraction[3], n, which is defined as the ratio of the speed of light in a vacuum to the speed of light in a particular medium.

$$n = \frac{c}{v} \tag{1}$$

DISPERSION

For all intents and purposes, all information about the composition and characteristics of stars is provided by electromagnetic radiation. For example, light leaving the Sun's surface passes through its cooler, more rarefied atmosphere, and when it does, some frequencies are absorbed.

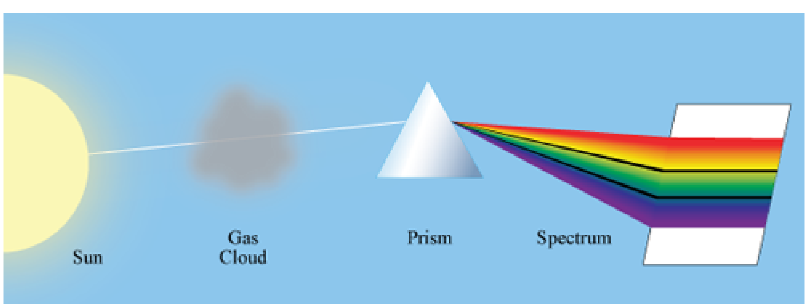

Figure 1

[1]http://outreach.atnf.csiro.au/education/senior/astrophysics/galileo.html
[2]http://www.physicsclassroom.com/Class/refrn/u14l1a.cfm
[3]http://www.physicsclassroom.com/Class/refrn/u14l1d.cfm

When sunlight is passed through a prism, the colors are separated and a spectrum of colors is displayed. Superimposed on this spectrum are dark lines. In the next module, you will study the mechanics of these dark lines, but for now simply remember that they provide information on the elements present in the Sun's outer regions.

SPECTRAL COLORS:

Colors that can be produced by visible light of a single wavelength (monochromatic light) are referred to as the pure spectral colors. Although the spectrum is continuous, and, therefore, there are no clear boundaries between one color and the next, the ranges may be used as an approximation.

Approximate ranges of wavelength and frequency for selected colors are provided in the following table. Note that wavelengths are given in nanometers.

Color	**Wavelength** (nm)	**Frequency** (THz)
Red	630–750	400–476
Orange	590–630	476–508
Yellow	560–590	508–536
Green	490–560	536–612
Blue	450–490	612–667
Violet	400–450	667–750

Nanometers can be converted to meters, as in the example below.

$$\begin{aligned}\lambda &= 380 \text{ nm} \\ &= (380 \text{ nm})\left(\frac{1 \times 10^{-9} \text{ m}}{1 \text{ nm}}\right) \\ &= 380 \times 10^{-9} \text{ m} \\ &= 3.80 \times 10^{-7} \text{ m}\end{aligned}$$

The frequency can then be calculated.

$$\begin{aligned} f &= \frac{c}{\lambda} \\ &= \frac{3.0 \times 10^{8} \text{ m/s}}{3.8 \times 10^{-7} \text{ m}} \\ &= 0.789 \times 10^{15} \text{ Hz} \\ &= 789 \times 10^{12} \text{ Hz} \\ &= 789 \text{ THz} \end{aligned}$$

NOTE:

As the wavelength increases, the frequency decreases, and vice versa.

REFLECTION

The ability of a telescope to gather light and show detail depends on its size; the larger the telescope, the brighter and sharper the image. Large refracting telescopes[4] are heavy and expensive to build; in addition, they suffer from chromatic aberration, a consequence of the dispersion of light. So while Galileo used a telescope based on the principle of refraction, modern telescopes[5] rely on the physical phenomena of the reflection[6] of light.

TOTAL INTERNAL REFLECTION

An interesting phenomenon that relates reflection to refraction is the phenomenon of total internal reflection[7]. Total internal reflection only occurs when light is passing into an optically less dense material at a high angle of incidence. Optical fibers rely on total internal reflection.

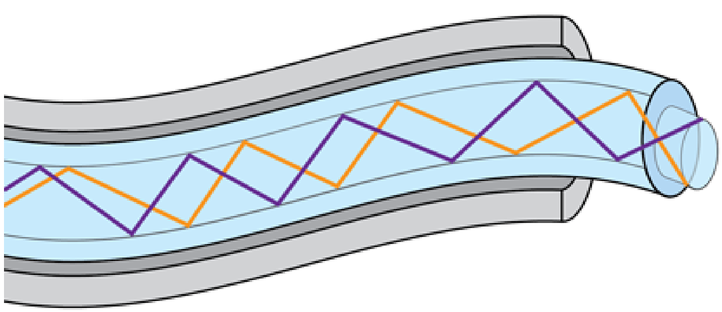

Figure 2: Light traveling along an optical fiber

In this experiment, you will study reflection, refraction, and dispersion.

[4]http://astro.uchicago.edu/vtour/defn.html
[5]http://hubblesite.org/
[6]http://www.physicsclassroom.com/Class/refln/u13l1c.cfm
[7]http://www.physicsclassroom.com/Class/refrn/u14l3b.cfm

PROCEDURE

You will observe the experiment performed and fill in your data sheets.

1 Open the experiment instructions and worksheet.

- Refraction Experiment Instructions (HTML[8] or PDF[9])
- Refraction Experiment Worksheet[10]

2 After you have opened the instructions and worksheet, select and watch the Experiment Video (the Experiment Video is available in your course LMS).

3 Record your data in the worksheet. (You will need it for the lab report assignment in WebAssign.)

[8] ../lab_8_2_procedure/manual.html
[9] ../lab_8_2_procedure/manual.pdf
[10] ../lab_8_2_procedure/worksheet.pdf