Experiment #4 Nature of Light: Telescope and Microscope and Spectroscope

In this experiment, we are going to learn the basic principles of the telescope and the microscope that make it possible for us to observe very distant objects in the outer space and very tiny organisms that the naked eye is not capable of seeing. We will also explore the visible range of electromagnetic spectrum using a hand held spectroscope and light sources.

Part A: The Telescope

Equipment

-Optics Bench
-75 mm Focal Length Convex Lens
-150 mm Focal Length Convex Lens
-Component Holders (2)

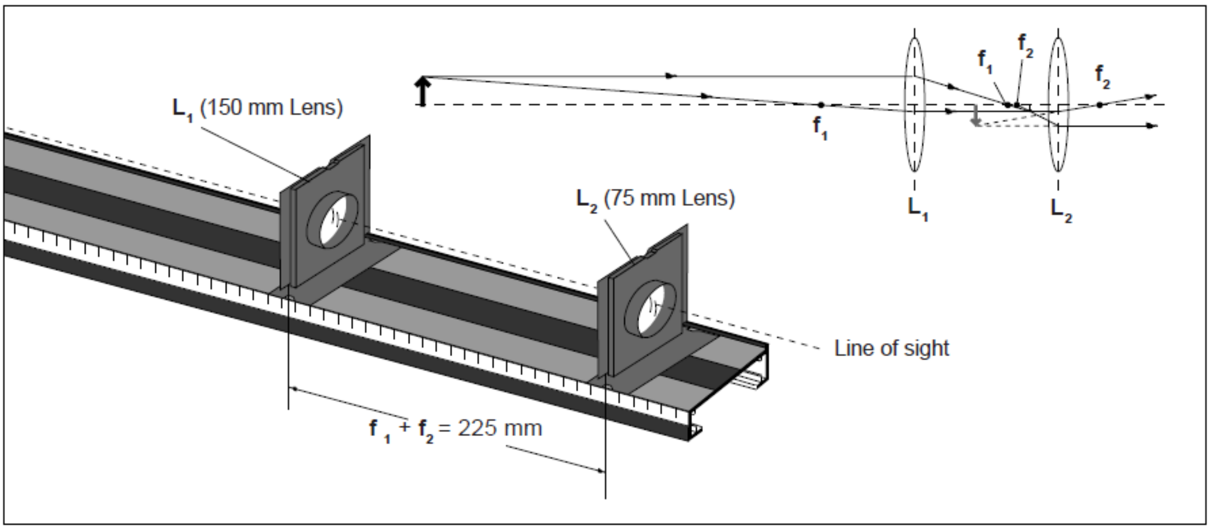

Figure 1: Simple telescope set up

Introduction

Telescopes are used to obtain magnified images of distant objects. The image of a distant object when viewed through a single converging lens will be focused nearly at the focal point of the lens. This image will be real, inverted, and reduced in size. In fact, the greater the distance of the object (with respect to **f**), the smaller the size of the image.

However, this reduced image is useful. By viewing this image through a second converging lens—used as a magnifier—an enlarged image can be seen.

Procedure and Data Analysis

Set up the basic telescope using two lenses as shown in Figure 1. Set up a telescope using the 75 mm and 150 mm focal length lenses as shown in the figure 1. The distance between the lenses should be approximately 225 mm. Using the 75 mm lens as the eyepiece, look at some reasonably distant object. Adjust the distance between the lenses as needed to bring the object into sharp focus.

To measure the magnification, look with one eye through the telescope, and with the other eye look directly at the object. Compare the size of the two images. (If a meter stick is used as the object, fairly accurate measurements of magnification can be made.)

1- What is the magnification of the telescope when using the 75 mm lens as the eyepiece?

Part B: The Compound Microscope

Equipment

-Optics Bench
-75 mm Focal Length Convex Lens
-150 mm Focal Length Convex Lens
-Component Holders (2)
-Viewing Screen

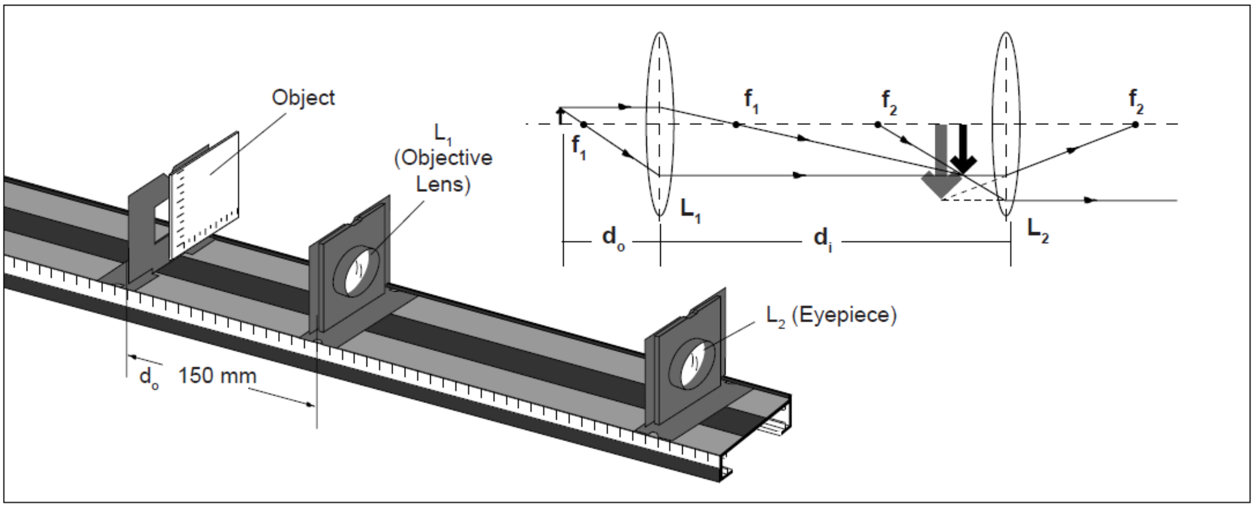

Figure 4: The compound microscope set up

Introduction

A compound microscope uses two lenses to provide greater magnification of near objects than is possible using a single lens as a magnifier. The setup is shown in Figure 4. The objective lens, L_1, functions as a projector. The object is placed just beyond the focal point of L_1 so a real, magnified, inverted image is formed. The eyepiece, L_2, functions as a magnifier. It forms an enlarged virtual image of the real image projected by L_1. The real image that is projected by L_1 is magnified by an amount $m = -d_i / d_o$, as indicated by the Fundamental Lens Equation.

That image is in turn magnified by the eyepiece by a factor of 25/f (in cm). The combined magnification is, therefore: $M = (-\frac{d_i}{d_0})(\frac{25}{f})$.

Procedure and Data Analysis

Set up the microscope as shown in Figure 4. Use the 75 mm focal length lens as the objective lens and the 150 mm focal length lens as the eyepiece. Begin with the objective lens approximately 150 mm away from the object (the Viewing Screen). Adjust the position of the eyepiece until you see a clearly focused image of the Viewing Screen scale.

1- Is the image magnified? How does the magnification compare to using the 75 mm focal length lens alone, as a simple magnifier?
2- Calculate the magnification, M.

Part C: Basic Spectroscope

Equipment

Hand held Spectroscope
Various light sources

Figure 1: Hand held spectroscope qualitatively determines the wavelength of light.

Theory

Light is an electromagnetic wave that travels in small particles like packets called **photons**. Each photon travels at the same speed: 3 x 10^8 m/sec, the speed of light. The energy of a photon is determined by its frequency. The higher the frequency, the more energy it contains. The higher the frequency the bluer is the light, the lower the frequency the redder the light. We have seen rainbow after rain which is made up of a series of colors: **Red**, **Orange**, **Yellow**, **Green**, **Blue**, **Indigo** and **Violet**. These colors are listed in order of increasing energy (decreasing wavelength) and comprise the visible spectrum. The electromagnetic spectrum does not comprise only the visible spectrum, it continues beyond the visible into the higher energies with ultaviolet, x-rays and gamma rays. It also extends below red into lower energies with infrared and radiowaves.

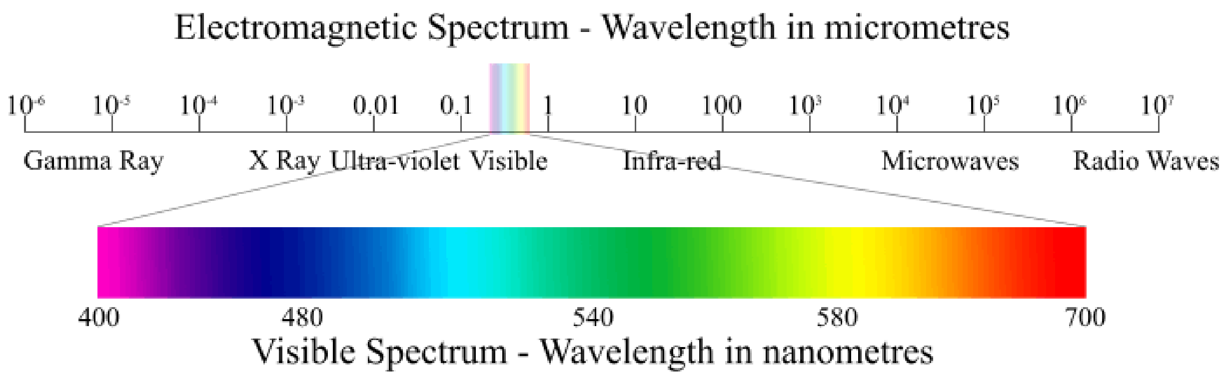

Figure 2: Electromagnetic spectrum spanning from high energy Gamma rays to low energy radio waves.

Electromagnetic radiation is created when an electron inside an atom moves from a higher energy level to lower energy level. The photon of light that is emitted has an energy that corresponds to exactly to the difference in energy between the two energy levels.

Spectroscope

The heart of spectroscope is diffraction grating. This is a thin film of plastic with hundreds or thousands of very closely spaced lines etched in its surface i.e. 600 lines per milimeter. This grating uses a combination of diffraction to bend the light waves as they pass by the lines etched on its surface, and interference to constructively add colors at certain locations and destructively eliminate colors at other locations. What we get after a beam of light is passed through a diffraction grating is a seperation of the colors (wavelenghts) of which the incoming light beam was composed of.

Light is measured by its wavelength (in nanometers = 10^{-9} meters) or frequency (in Hertz). One ***wavelength*** equals the distance between two successive wave crests or troughs. ***Frequency*** (Hertz) equals the number of waves that passes a given point per second.

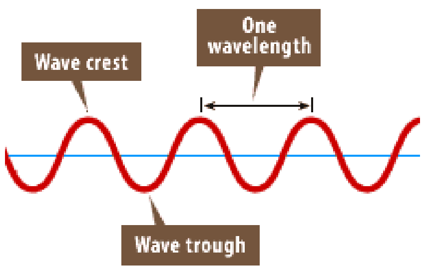

Figure 3: Wavelength of a continuous wave.

Procedure

1. Hold the spectroscope so that the small end with a square hole is towards you.
2. The wider, curved end has a narrow slit which lets light into the spectroscope, and a wide window with a numbered scale representing the wavelength scale.
3. While holding the spectroscope a few centimeters in front of your eyes, look through the eyepiece of your spectroscope and point the slit end at a light source/incandescent light bulbs.

The diffraction grating fitted inside the spectroscope will split light into the constituent colours according to the wavelength.

4. Read the wavelenght of different colors in the color spectrum on the numbered scale of the spectroscope.

Figure 4: Spectroscope scale.

5. Repeat this experiment and note the wavelengths of the colors in the spectrum.

Data Table

Fill in the measured wavelengths of different colors in the spectrum of the light source

Color	**Wavelength**	**Comments**
Red		
Orange		
Yellow		
Green		
Blue		
Violet		

Notes

1. Continuous spectra are usually produced by a luminous liquid or solid. For example a glowing filament of a incandescent lamp.
2. Bright line spectra is produced when source is a glowing gas i.e. fluorescent light bulb.

Questions

1. List the colors in the visible range of electromagntic spectrum in order of decreasing energy.
2. Define wavelength and frequency.
3. What are photons, what is their travelling speed?
4. What information does the spectra gives us about the light source?