Fluids, Thermodynamics, Waves, & Optics
Optics
Lab 8
Optical Instruments

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Overview

- Purpose
- Part 1: Simple convex lenses
- Part 2: The microscope
- Part 3: The telescope

Purpose of the Lab

To build and play with simple optical instruments, while also learning about and calculating magnifications.

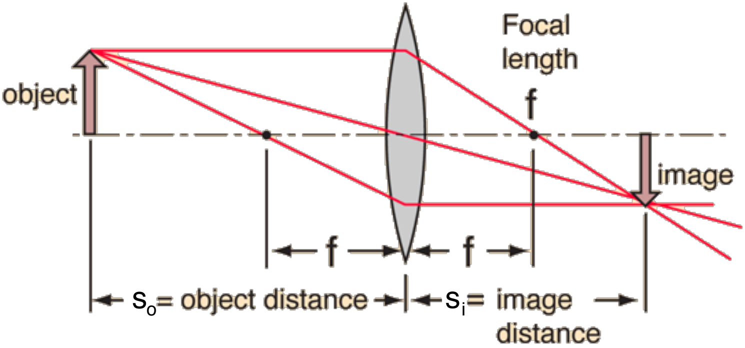
You will use a lamp on an optical bench and screens to study the behavior of convex lenses on their own and in combinations.

You will

1. measure measure the object and image distances for two convex lenses and calculate their focal lengths.
2. build a microscope to observe a virtual image of a nearby object and calculate the magnification.
3. build a telescope to observe a virtual image of a far away object and calculate the magnification.

Equipment

Theory: Thin Lenses



The **thin lens equation**

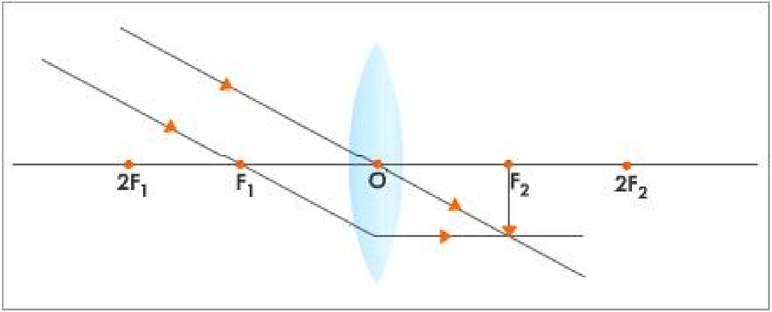
$$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$$

Theory: Thin Lenses

If the object is "at infinity", $s_o \to \infty$, and $\frac{1}{s_o} \to 0$.

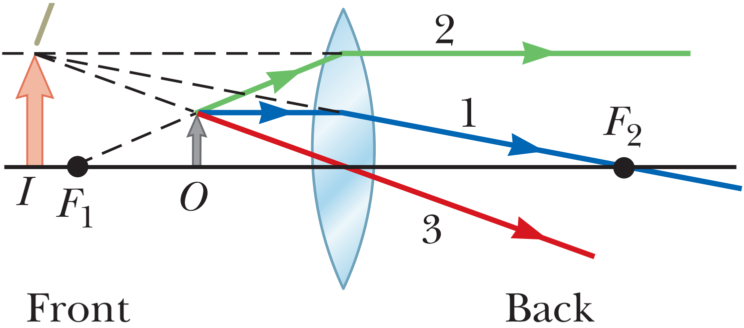
$$\cancelto{0}{\frac{1}{s_o}} + \frac{1}{s_i} = \frac{1}{f}$$

So, $s_i = f$.



Theory: Convex Lenses

For an object placed less than a distance f from the lens ($s_o < f$)

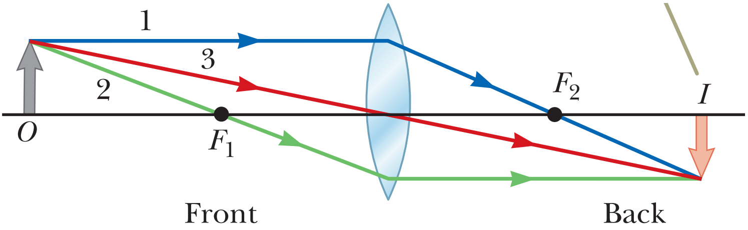


a virtual, upright, and enlarged image is formed.

This is the configuration for a magnifying glass.

Theory: Convex Lenses

For an object placed more than a distance f from the lens ($s_o > f$)



a real, inverted image is formed.

Equipment: Simple Magnifier Setup

Equipment: Lamp with crosshairs

Lab Activity - Part 1: Simple Magnifier

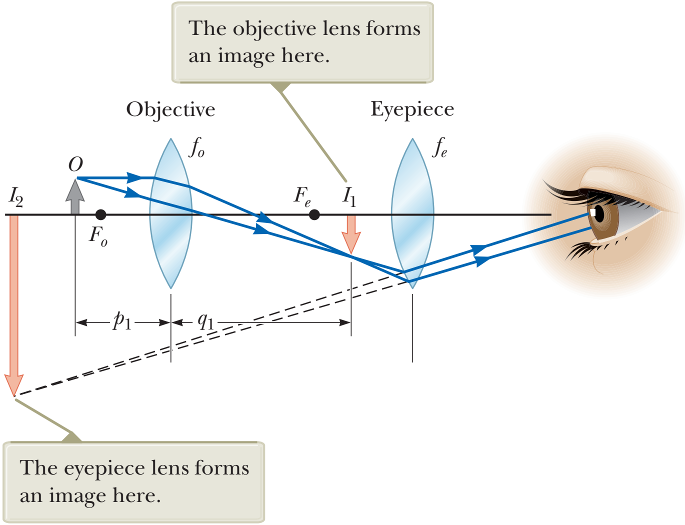
1. Form a real image of an object "at infinity" to find f for the 48mm lens. Bright objects work best, *eg.* the screen, the open door of the classroom, the ceiling lights.

2. Put the lamp with crosshairs target and lens on the optical track and form a real image of the crosshairs. Use s_o and s_i to determine f.

3. Repeat for the 252mm lens.

Theory: Mircroscope

Multiple lenses can be used in sequence to get a larger magnification.



Lab Activity - Part 2: The Microscope

1. On the optical bench, use the 48mm lens as the objective lens.

2. Put the 48mm lens just a bit further than its focal length away from the crosshairs on the lamp (the object). The objective lens needs to be between f_o and $2f_o$ from the object.

3. Form a real image on the screen, record its location and remove the screen.

4. Use the 127mm lens as the eyepiece. Place it one focal length f_e behind where the image is formed.

5. Place a sheet of paper over the crosshairs to dim the source, then you can look through the eyepiece to see the image.

6. Estimate, then calculate, the magnification.

Theory: Mircroscope

The total magnification is the produce of the magnification by each lens: the lateral magnification of the objective, m_0, and the angular magnification of the eyepiece, M_e.

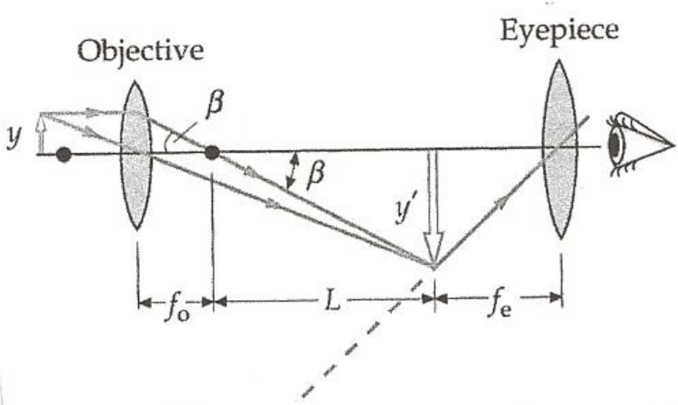
$$m_o = -\frac{y'}{y} = -\frac{s_i}{s_o} = -\frac{L}{f_o}$$

$$M_e = \frac{\theta_e}{\theta_o} = \frac{x_{\text{np}}}{f_e}$$

x_{np} is the near point of the human eye, the closest point the eye can focus comfortably. A typical value is $x_{\text{np}} = 25$ cm.

$$M = -\frac{L}{f_o}\frac{x_{\text{np}}}{f_e}$$

Theory: Mircroscope

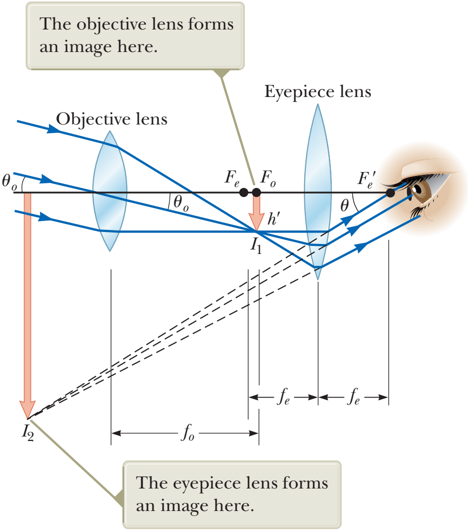


$$m_o = -\frac{y'}{y} = -\frac{s_i}{s_o} = -\frac{L}{f_o} \qquad M_e = \frac{\theta_e}{\theta_o} = \frac{x_{\mathrm{np}}}{f_e}$$

$$M = -\frac{L}{f_o}\frac{x_{\mathrm{np}}}{f_e}$$

Theory: Telescope

Multiple lenses can be used in sequence to get a larger magnification, also for distant objects.



Lab Activity - Part 3: The Telescope

1. Use the 252mm lens as the objective and form an image of a distant object on the screen. Mark the location of the screen and remove it.
2. Use the 48mm lens as the eyepiece, and place it one focal length away from where the screen was.
3. Look through your telescope at the distant object to see it enlarged.
4. Estimate, then calculate, the magnification.

Equipment: Telescope Setup