

Experiment 10

Optical Instruments that use Two Lenses

Preparation

For this week read about microscopes, astronomical telescopes, Galilean telescopes, and angular magnification.

Principles

An image formed by a lens, whether real or virtual, can be used as the object for a second lens. In every case in this experiment a lens, called the objective, will form a real image that a second lens, the eyepiece, will use as an object. The image formed by the eyepiece will be virtual and located at infinity so that the rays which enter the eye are parallel.

The Microscope

A microscope uses an **objective** with a **short focal length** and an **eyepiece** with a **longer focal length**. Both of these are converging lenses. When the object is placed outside the focal point of the objective, the objective will form a real, inverted image. When the eyepiece is placed so that this image is at, or slightly inside the focal point, the eyepiece acts as a simple magnifier and produces an enlarged virtual image. The angular magnification, M , which is the ratio of the angles subtended in the eye by the image and the object, is given by:

$$M = \frac{-25\text{cm}L}{f_o f_e}$$

where f_o is the focal length of the objective, f_e is the focal length of the eyepiece and L is the distance between the two lenses (all in cm). The minus sign indicates that the image is inverted.

The Astronomical Telescope

The astronomical telescope uses a **long focal length objective** and a **short focal length eyepiece**. Again, both are converging lenses. The object will be at infinity and the objective will form a real image near its focal point. The eyepiece is placed so that the image formed by the objective is located at its focal point. Therefore, the length of the telescope will just be the sum of f_o and f_e . The angular magnification is given by:

$$M = \frac{f_o}{f_e}$$

The Galilean Telescope

The Galilean telescope uses a **long focal length objective** and a **diverging eyepiece**. The absolute value of the focal length of the eyepiece must be less than that of the objective. Again the object is infinitely far away from the objective which forms a real image at its focal point. Before these rays converge they pass through the diverging lens which is placed so that its focal point coincides with that of the objective lens. The length of the Galilean telescope is the sum of f_o and f_e , but in this case f_e is negative. The magnification is given by the same equation as the astronomical telescope. Since f_e is negative, the image will be upright and M will be positive.

Equipment

- 1 optical bench*
- 3 optical bench carriages*
- 2 lens holders*
- 1 screen holder*
- 1 short rod*
- 1 10 cm converging lens*
- 1 30 cm converging lens*
- 1 -10 cm diverging lens*

Procedure

Use the values for focal lengths marked on the lens boxes. These values are not exact, but they are close enough. Make sure that the colored spot on the lens matches that on the box.

The Microscope

1. Cut a piece of graph paper and place it in a holder to serve as the object. Build a microscope using a short focal length lens as the objective and a long lens as the eyepiece. Place the object outside the focal point of the objective and move the eyepiece until the image is well focused. The image should be clear in the center of the lens; it will be distorted at the edges because short focal length lenses tend to be very thick.
2. Move your head so that you can see the unmagnified object and the image. Estimate the magnification of the image. This might be easier if you close one eye. Record the positions of the objective and the eyepiece.

The Astronomical Telescope

3. Use the same two lenses to construct a telescope. Get a good image of the concrete blocks on the opposite side of the room. Estimate the angular magnification. Record the positions of the objective and the eyepiece.

The Galilean Telescope

4. Use a long converging lens and a diverging lens to construct a Galilean telescope. The absolute value of the focal length of the diverging lens must be less than the focal length of the converging lens. Estimate the magnification and record the positions of the objective and the eyepiece.

Analysis

1. Compute the theoretical angular magnification for the microscope and find the percent difference between it and your observed magnification.
2. Find the theoretical angular magnification and compare (find the percent difference) it to your observed value for the astronomical telescope. Also compare the distance between the two lenses to the sum of their focal lengths.
3. Repeat the above analysis for the Galilean telescope.