The Optics of Cameras - Student

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Description

This lab will illustrate how aperture size and focal length affect camera images.

Objectives

- Students will relate aperture size to image sharpness.
- Students will measure the focal length of a lens.
- Students will construct a telephoto lens.
- Students will relate focal length to magnification.

North Dakota State Standards

9-10.1.1 Explain how models can be used to illustrate scientific principles
11-12.1.1 Explain how scientists create and use models to address scientific knowledge
8.2.3 Use basic mathematics and statistics to interpret quantitative data
9-10.2.8 Analyze data found in tables, charts, and graphs to formulate conclusions

Schedule

11:00-11:30 Brief introduction/Cultural introduction
11:30-12:00 Powerpoint
12:00-12:30 Lunch
12:30-1:30 Activity 1: F-Stop Pinhole Camera
1:30-2:30 Activity 2: Focal Length
2:30-3:00 Activity 3: Telescope

Activity 1: F-Stop

F-stop is a measure of the diameter of the aperture in a camera lens. Confusingly, the smaller numbers refer to a larger aperture and the larger numbers refer to a smaller aperture. In other words, an F-stop of 1.4 is larger than an F-stop of 22.

INSERT PICTURE of F-STOPS

Demonstration of Scattering

The light that reaches our eyes comes in at many different angles. You will need a single bright light source and your finger. Make a shadow with your finger on the wall.

- Does the shadow have sharp edges or blurry, poorly defined edges?
- What happens to the edges of the shadow as you get closer to the wall or further from the wall?
- Do you think all the light comes to your finger at the exact same angle or does it come at different angles?

The Pinhole Viewer

In this activity we will look at one of the earliest types of cameras: a pinhole camera. Although constructing a full camera is outside the time we have today, instructions can be found easily on the internet for making a pinhole camera out of ordinary objects such as mind containers or oatmeal cans.

You will need a large box (approximately the size of a box of copy paper) and a smaller box to inside the larger box. You will also need a piece of either wax paper or fairly translucent parchment paper, aluminum foil, a pin, masking tape, and an index card. The tools you will need include a cutting implement, scissors, a 100 W light bulb, a marker, and a light fixture.

Cut a square in the center of an index card and use masking tape to hold a piece of aluminum foil over the square. Tape it only around the edges, not in the middle. Use the smallest pin you can find to very carefully punch a hole through the center of the aluminum foil. Cut a hole in the front of the box and tape your pinhole over that hole. Secure it with masking tape to prevent light leakage. Make an opening for viewing at the other end of the box.

Cut a large opening in your smaller box. Tape the translucent (wax or parchment) paper over this opening to use it as a viewing screen. Put this inside your larger box so that the image through the pinhole is projected onto the wax paper and you can view the image through the other end. Put the cover on your box and your viewer should be ready.

Draw a shape such as a letter F on your frosted 100W bulb. You need to be able to distinguish up, down, right, and left on this shape. Then, in a dark room, position the wax paper screen inside your pinhole box, close the box, and place the box about 1 foot from the lit bulb. Align the pinhole and viewer until you can see a faint image of the bulb appearing on the center of the wax paper screen. The image will be very dim, so you may need to spend some time in the dark to accustom your eyes.

Sketch both the image and the original shape as it appears on the bulb in the space below:

Now enlarge the pinhole slightly and try again.

- What happens to the sharpness of the image?
- What happens to the brightness of the image?

Enlarge the pinhole even more and look again.

- What happens to the sharpness of the image?
- What happens to the brightness of the image?
- In your own words, state the relationship between the size of a pinhole and the sharpness of an image.

- In your own words, state the relationship between the size of a pinhole and the brightness of an image.

- In your own words, state the relationship between the brightness of an image and the sharpness of an image.

Activity 2: Finding the Focal Length

For this activity, you will need two lenses of different sizes, a meter stick, a light source such as a tea candle or an incandescent bulb, a screen (sheet of paper or cardstock), and optics bench supplies to support the lenses.

Part 1: Estimation

Turn off the lights in the room, but leave the windows open. You should be able to hold your lens between the window and a blank surface such as a wall or sheet of poster board. Adjust the distance between the lens and the wall until the image you project is in focus. This method works because the original object is a large distance away

Measure the distance (in centimeters) between the lens and screen. This is your focal length. Record the focal length of 2 different lenses.

What happens to the image when projected through a lens?

Part 2: How a Lens Works

We can picture the behavior of light as it passes through a lens by means of a ray diagram.

INSERT PICTURE HERE

The ray diagram illustrates how a lens bends light to focus the image at different distances from the lens. You may find that, in some photographs, there is a purple fringe around objects. This chromatic aberration occurs because different colors are bent slightly differently, much like the way a rainbow is formed.

Part 3: Measuring the Focal Length

In this lab, we will look at another way to measure the focal length of a lens. Lay a meter stick on your table. At the 0cm end, place a light source such as a tea candle or flashlight bulb. At the 100cm end, support a white screen. The author found that a tissue box turned on its side with white paper taped to its bottom made an effective screen. You will be moving your lens around between the screen and the light source.

We will call the distance between the projected image and the lens the image distance, i. The distance between the light source and the lens will be called the object distance, o. Prepare a 3-column tableto record i, o, and any notes about the image (inverted, magnified, etc.). Then, measure and record all positions at which the lens projects a clear, focused image on the screen. (There should be 2.)

Now, move the screen 10cm closer to the light source and find and record all positions that create images. Continue moving the screen closer in 10cm increments until there are no more sharp images on the screen.

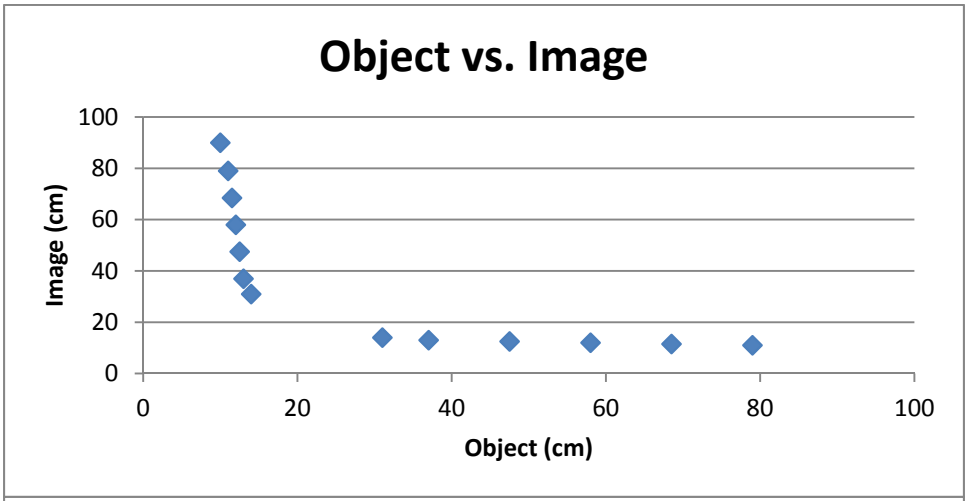
Use the data from your table to create a scatterplot of o vs. I on linear paper and draw a smooth curve through the points.

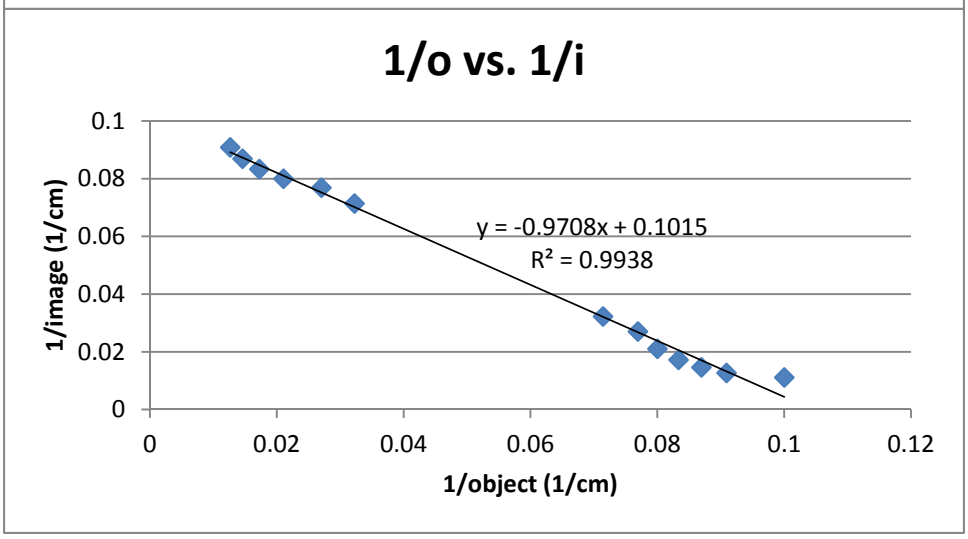
- From the graph, if o becomes very large, what happens to i?
- Also, if i becomes very large, what happens to o?

Now make a scatterplot of 1/o vs. 1/i. You might find it convenient to calculate these values before creating the graph. The graph should create a line of slope -1 and the y-intercept is 1/f, where f is the focal length of the lens. The graph is of the thin lens equation, $1/o + 1/i = 1/f$.

- Use the second graph above to estimate the focal length of the lens.
- For the lens, what is the closest that the image and object can come to each other?
- How do you know?

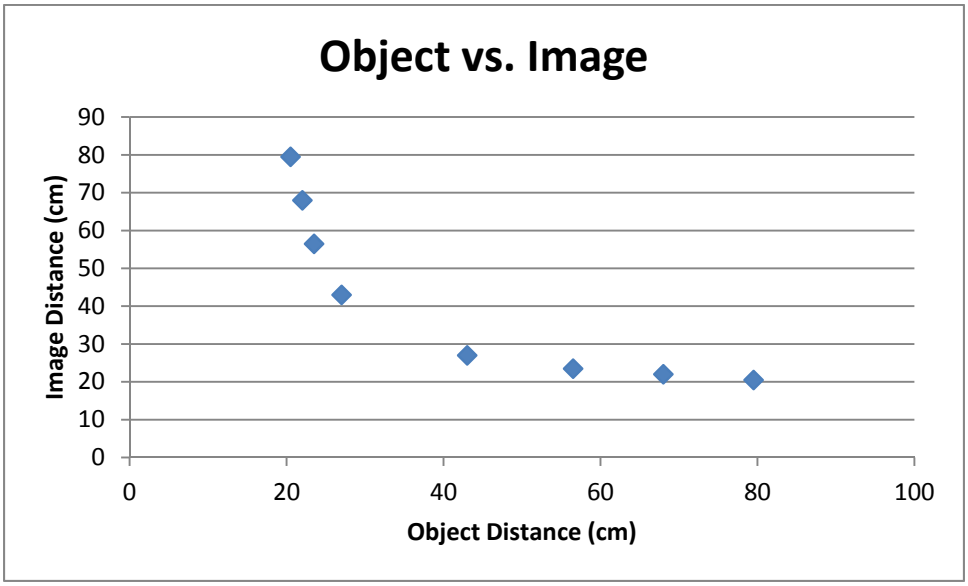
For the 10cm lens:

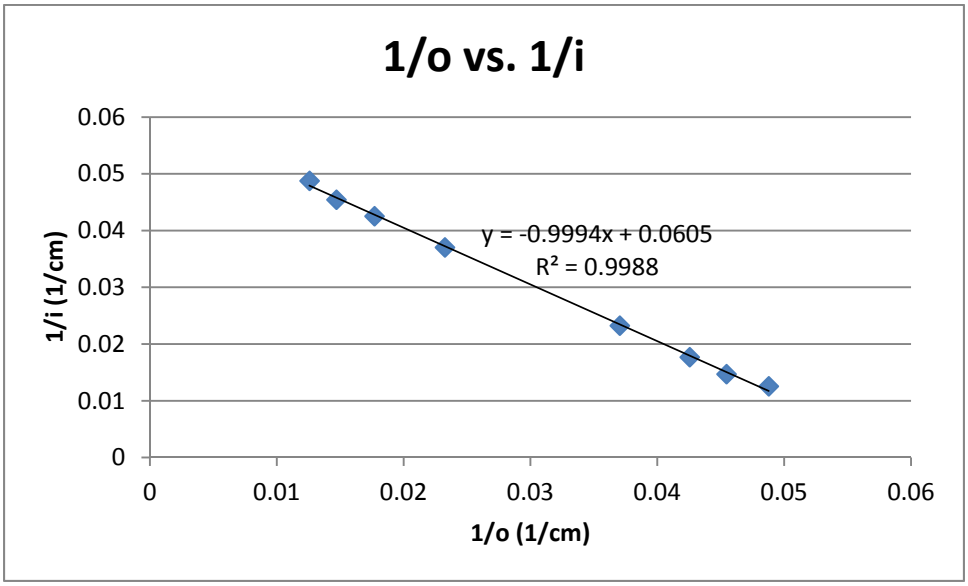




object (cm)	image (cm)
10	90
11	79
79	11
68.5	11.5
11.5	68.5
58	12
12	58
12.5	47.5
47.5	12.5
13	37
37	13
14	31
31	14

For the 17cm Lens





object (cm)	image (cm)
20.5	79.5
79.5	20.5
22	68
68	22
23.5	56.5
56.5	23.5
27	43
43	27

Focal Length and Cameras

When you look at camera lenses, you will see measurements such as 50mm and 85mm. There are also zoom lenses, but these are also beyond the scope of this lab (although the basis is here). These measurements are the focal length of the lens: the distance between the lens and the screen when focused on an object at infinity. The measurement should be approximately the length of the camera lens. However, camera lenses actually consist of a number of lenses put together as you will see in the next activity. This means that the actual length of the camera lens is unrelated to its focal length. A larger focal length will provide greater magnification of an image. Thus, to get a wide image, you might use an 18mm lens, to photograph a bird far away, you might use a 400mm lens, and you might use a 50mm lens at a basketball game.

Activity 3: Making a Telescope

Most camera lenses are made out of several lenses put together. In this activity, we will put two lenses together to provide some magnification. We may continue with the same lenses we have been using.

In a telescope, the objective lens, the one looking at the object, is always a lens with a long focal length. The objective lens produces a real image at its focal point. This image is magnified with the eyepiece lens. In this case, the eyepiece is usually adjusted so that the virtual image is at infinity, in this case something across the room, but it may be adjusted to be closer.

You can construct a telescope on a meter stick. Attach the lens with the smaller focal length to the 0cm end to act as an eyepiece. Attach the lens with the larger focal length to the other end. This will be your objective lens. Then move this lens until the distance between the two lenses is equal to the sum of their focal lengths. Find an object and focus on it. You may need to adjust the position of the objective lens slightly until your object comes into focus.

- What happens to the orientation of the image?
- What happens to the size of the image?
- How do multiple lenses seem to affect the focal length?