Geometrical Optics

Physics 126L   Spring 2025

Lab report due **Tuesday, April 29, at 11:55 P.M.**

Introduction

In this lab we will use the basic equations of geometrical optics to predict the behavior of lens images and a paraboloidal mirror combination called the "Mirage Toy."

You should have the following equipment:

1. Mirage toy. This has four pieces: a stand, two paraboloidal mirrors (one with a hole in the center), and a small plastic frog.
2. Aluminum breadboard and hardware
3. 3-axis 25 mm translation stage (Thorlabs PT3/M)
4. 3D-printed lens holder
5. Set of 50 mm diameter lenses
6. Halogen incandescent bulb light source, mount, power supply, and cable
7. Raspberry Pi (RPi) high quality camera with holder
8. Plastic digital calipers for measuring distances <= 150 mm
9. Fiberglass measuring tape
10. Spherometer
11. Index card and holder

Preparing the equipment

Be certain that you are using a 12 V cable to power the light bulb. **The rheostat controlling the bulb current gets much hotter than you might expect.** Tie it down using screws and don't touch it unless absolutely necessary.

Measuring images formed by the mirage toy

1. The lower mirror is the one without a hole in the center. Place the lower mirror on the stand with the reflector side up. Place the frog facing away from you at the center of the lower mirror. Then place the top mirror facing down toward the bottom mirror. You should see a striking real image at the center of the hole in the top mirror. If you slowly raise the top mirror, you should see additional images.

2. Find at least two images of the frog. Analyze the optical system of the mirage toy using paraxial ray matricies, and compare your measurements of the positions and magnifications of the images with your calculations.

Measuring lens curvatures to find focal length

1. Select a lens from the kit to use for your experiments. You will need a positive focal length (converging lens). The shorter the focal length, the easier the experiments will be to set up.

2. Using the spherometer, measure the curvatures of the two sides of your lens. You can put a piece of paper between the center metal pin and the glass, but you will need to remove the resulting extra thickness from your calculations.

3. Use the lensmaker's equation to find the focal length of the lens. Be sure to include an uncertainty. You will compare this with your results in the next section. The lenses in the kit are made of glass with index of refraction $n = 1.52$.

Measuring object and image distances

To use the Raspberry Pi camera in video preview mode, open a terminal and type

```
rpicam-hello -t 0
```

To take a still photo,

```
rpicam-jpeg -o filename.jpg --immediate
```

For either command, you can see the full list of options by typing, for example,

```
rpicam-hello -h
```

More documentation can be found here:

https://www.raspberrypi.com/documentation/computers/camera_software.html

1. For two different object and image distance configurations, use a single 50 mm diameter lens to project an image of the bulb filament on the camera sensor or index card screen.

2. Measure the object and image distances. Use the thin lens equation to compare the calculated focal length with what you found using the spherometer.

Measuring bulb filament size with the camera

1. For each configuration, capture an image of the filament with the RPi camera sensor (no additional lens) and use Gimp or another program to measure the size of the image in camera pixels.

2. Using the pixel pitch from the camera sensor datasheet, calculate the actual size of each filament image. From the object and image distances, compute the linear magnification and determine the actual size of the filament. Compare results from the two configurations quantitativelty.

Report suggestions

See the Lab Notebook and Report Guidelines handout on the course web page. Answer all questions in this handout, and make sure to include error estimates with all of your measurements and calculated values.