Week 3 Challenge Homework

Ray Optics

Submission Details | Submit a digital copy (PDF, jpg, etc.) to Canvas. Please use the interface to associate each page of your submission with the corresponding question number! It makes grading much easier. Please clearly indicate which question is being solved. If data is needed to complete a problem, be sure to cite the source you've acquired your data from. See the course website for further details.

Group Submissions | You may submit a group collaboration to Canvas. Add each group member to the submission. Each group member should contribute to the work. Clearly indicate which part of the submission is written by each member (color or labels are preferable).

Sensemaking | You will be asked to apply sensemaking in some problems. More information about sensemaking can be found on the Boxsand Sensemaking page, which is linked on the Canvas homepage. There are many different types of sensemaking. In this course, we will focus on evaluative sensemaking. This is often phrased as checking if your answer is reasonable or not. Usually, the evaluative sensemaking process consists of making a prediction with an explanation, then a comparison. First, make a **prediction** of what you would expect your answer or solution to look like, based on one of the techniques below. Then, provide an **explanation** for the prediction using arguments based in physical reasoning. Finally, make a **comparison** between the answer that you did find and your prediction. Briefly explain why they do or do not match.

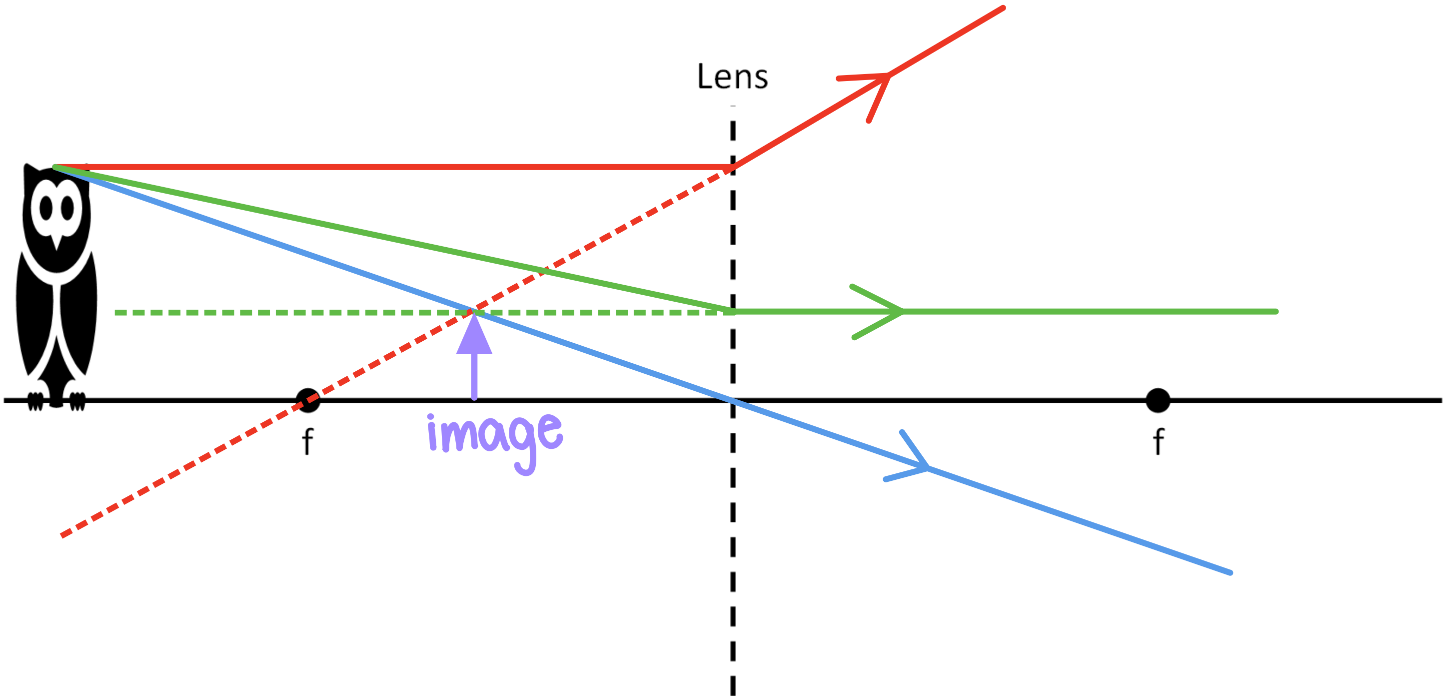
Short explanations of the various sensemaking techniques we will use in this course are included below. Please see the Boxsand sensemaking page for more complete details.

- *Sign:* Explain a prediction for the **sign** of your answer or a quantity in your solution. Compare your prediction with the found quantity.
- *Dimensionality:* Explain a prediction for the **units or dimensions** of your answer or a quantity in your solution. Compare your prediction with the found quantity.
- *Related Quantities:* Explain a prediction for the **relationship between two quantities** within your solution. Compare your prediction with the found relationship.
- *Proportionality,* also known as *Covariation:* Usually using a symbolic solution, explain a prediction for the **behavior of one quantity in your solution when another or others are changed.** Compare your prediction with the found quantity.
- *Order of Magnitude:* Explain a prediction for the **order of magnitude** of your answer or a quantity in your solution. Compare your prediction with the found quantity.
- *Graphical Analysis:* Explain a prediction for your answer or a quantity in your solution based on arguments made from **analysis of a graph**. Compare your prediction with the found quantity or relationship.
- *Special Cases:* Explain a prediction for your answer or a quantity in your solution by examining the behavior as another quantity is taken to a limit or **special case**, such as 0, infinity, 0 degrees, or 90 degrees. Compare your prediction with the found relationship.
- *Self-consistency:* Explain or show that your answer is **self-consistent**. Usually this involves using your found answer within an earlier part of your solution and showing that the result is as expected.
- *Known Values:* Explain a prediction of your answer or a quantity in your solution based on a **known value**, such as the speed of light or the density of water. This can involve research and citing a source. Compare your prediction with the found quantity.

Question 1

Owliver the barn owl is sitting, as shown, in front of a diverging lens with the pictured focal points.

(a) Using the provided optical axis (or a good copy), carefully and precisely draw a ray diagram to find the location of Owliver's image. Use a straight edge! Indicate where the image appears.



(b) Is the image real, or virtual? Explain how you determined this.

(c) Estimate the magnification of the image.

(b) The image is virtual because the light rays do not converge on the location of the image (the rays only converge when you trace back).

(c) The image is upright (same orientation as object) → positive magnification

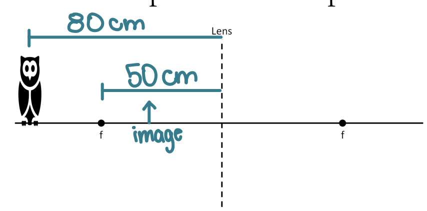
Image is smaller than object → magnification (m) < 1

Visually, the image looks about 30-40% the size of the object

$$m \approx +\frac{1}{3}$$

Question 2

Owliver the barn owl is sitting, as shown, in front of a diverging lens with the pictured focal points.



(a) Owliver is sitting 80 cm from the lens, which has a focal length of 50 cm. Using the math representation, find the location of the image.

(b) Using the math representation find the magnification of his image.

(c) Use the related quantities sensemaking technique to compare your answers to Question 2 parts (a) and (b) with those found when studying the same problem with ray tracing in Question 1. Do this by answering the following prompts:
- Make a prediction for whether or not your answers should agree.
- Explain your prediction. What made you think your answers should or should not agree?
- Finally, compare your answers from parts (a) and (b) with the related answers in Question 1. Are the answers of the same order of magnitude? Does this support your prediction?

(a) knowns:

$d_o = 80\text{ cm}$

$f = -50\text{cm}$ → negative because diverging lens

What we want to solve: d_i

↳ d_i will be negative because the image is virtual

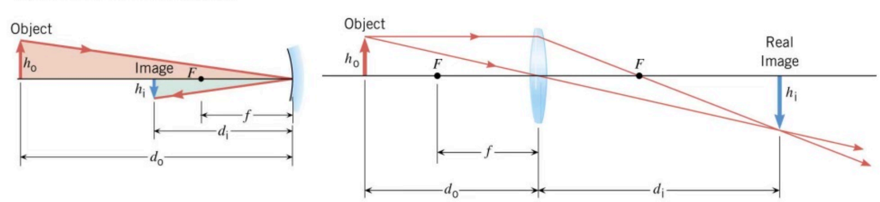
Sign Convention for Spherical Mirrors and Thin Lenses

Applies to: Mirror and Thin Lens Equation: $1/d_o + 1/d_i = 1/f$

Magnification Equation: Image height/Object height = $h_i/h_o = -d_i/d_o$

	Spherical Mirrors	Lenses
Focal Length (f)	+ for concave mirrors	+ for a converging lens
	- for convex mirrors	- for a diverging lens
Object Distance (d_o)	+ if object is in front of the mirror (real object)	+ if the object is to the left of the lens (real object)
	- if object is behind the mirror (virtual object)*	- if the object is to the right of the lens (virtual object)*
Image Distance (d_i)	+ if the image is in front of the mirror (real image)	+ for an image (real) formed to the right of the lens by a real object
	- if the image is behind the mirror (virtual image)	- for an image (virtual) formed to the left of the lens by a real object
Magnification (m)	+ for an image that is upright with respect to the object	+ for an image that is upright with respect to the object
	- for an image that is inverted with respect to the object	-for an image that is inverted with respect to the object.

* Optical system that use multiple mirrors/lenses sometimes use the image formed by the first mirror/lens as the object for the second mirror/lens. When this happens, the object distance is negative and the object is said to be a virtual object.



Mirror | Thin Lens

Rearrange & Solve for d_i

$$-\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \xrightarrow{\text{negative } f} -\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\frac{1}{d_i} = \frac{1}{-f} - \frac{1}{d_o}$$

$$\frac{1}{d_i} = \frac{1}{-50\text{cm}} - \frac{1}{80\text{cm}} = -\frac{8}{400\text{cm}} - \frac{5}{400\text{cm}} = -\frac{13}{400\text{ cm}}$$

$$\frac{1}{d_i} = -\frac{13}{400\text{cm}} \rightarrow d_i = -\frac{400}{13} = -30.8\text{ cm}$$

(b) $m = -\frac{d_i}{d_o} = \frac{-\frac{400}{13}\text{ cm}}{80\text{ cm}} = +\frac{5}{13} = +0.38$

(c) Prediction: The answers to Question 1 should match the answers to Question 2

Explanation: I predict this because through Question 1, we can see that the image created is smaller than the object and the object and image are both upright, meaning magnification should be (+) and <1. Because we are using the same object/image system in Question 2, the relationships between f, d_i, d_o, and m should hold true and mathematically we should get a magnification that matches Question 1.

Compare Answers: My answer to #1c was that m is (+) and <1 and $\approx \frac{1}{3}$. My answer to #2b was $+0.38$, which is on the same order of magnitude and very close to my answer to #1c. Therefore, this supports my prediction that my answers should match.