Thin lens equation

Select LEARNING OBJECTIVES:

- Be able to apply the thin lens equation for converging and diverging thin lenses, as well as spherical mirrors.
- Use correct sign conventions for the thin lens equation based off of the optical element type and location of objects and images.

TEXTBOOK CHAPTERS:

Boxsand :: Thin lens equation

WARM UP: An object very far away from a convex mirror is moved toward the mirror at a constant speed. Does the image move faster, slower, or at the same speed?

Ray tracing is often combined under the umbrella term of geometric optics. The term geometric optics suggests that if you are careful enough and construct scaled drawing of the scenario you are analyzing, you can bypass any mathematical models and solve for desired variables via a physical representation (ray tracing diagram). It is great news, you can always default back to drawing a scaled ray diagram to help solve these optical elements problems. However, the mathematical model is often the quick route to an answer so we will spend this lecture discussing the mathematical model for thin lenses and spherical mirrors.

Mathematical model for thin lens (and spherical mirrors)

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_I}$$

f: FOCAL LENGTH; d_o: OBJECT DISTANCE; d_I: IMAGE DISTANCE

* SIGN CONVENTIONS

FOCAL LENGTH
- CONVERGING/CONCAVE (+)
- DIVERGING/CONVEX (−)

IMAGE DISTANCE
- IF d_I IS (+), THEN IT IS ON FAR SIDE OF ELEMENT "RIGHT SIDE"…. REAL IMAGE
- IF d_I IS (−), THEN IT IS ON NEAR SIDE OF ELEMENT "LEFT SIDE"…. VIRTUAL IMAGE

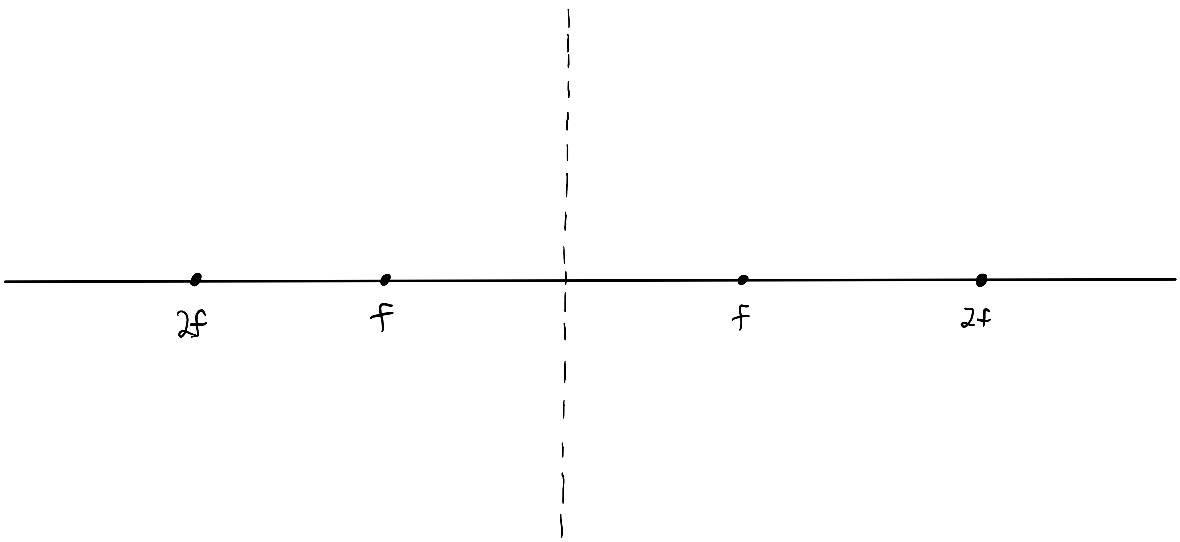
MAGNIFICATION

$$m = \frac{h_I}{h_o} = -\frac{d_I}{d_o}$$

- IF $|m| > 1$ IMAGE LARGER
- IF $|m| < 1$ IMAGE SMALLER
- IF m IS (+) …. SAME ORIENTATION AS OBJ
- IF m IS (−) …. INVERTED ORIENTATION W.R.T. OBJ

Good news everybody! The thin lens equation has the same functional form for all 4 optical elements we talked about, thin lenses and spherical mirrors. Bad news everybody! There are some tricky sign conventions you must pay attention to when using the thin lens equation. We will do some practice problems below to help clarify some of the sign conventions.

PRACTICE: A 10-cm-tall object is located 50.0 cm to the left of a converging lens whose focal length is 30.0 cm. Estimate the height of the image by using a carefully constructed ray diagram? Answer in centimeters



Calculate the location of the image.

PRACTICE: An object in placed a distance d_o from a converging lens of focal length f. Circle the expression that correctly solves for the distance to the image?

$$d_i = f - d_o$$

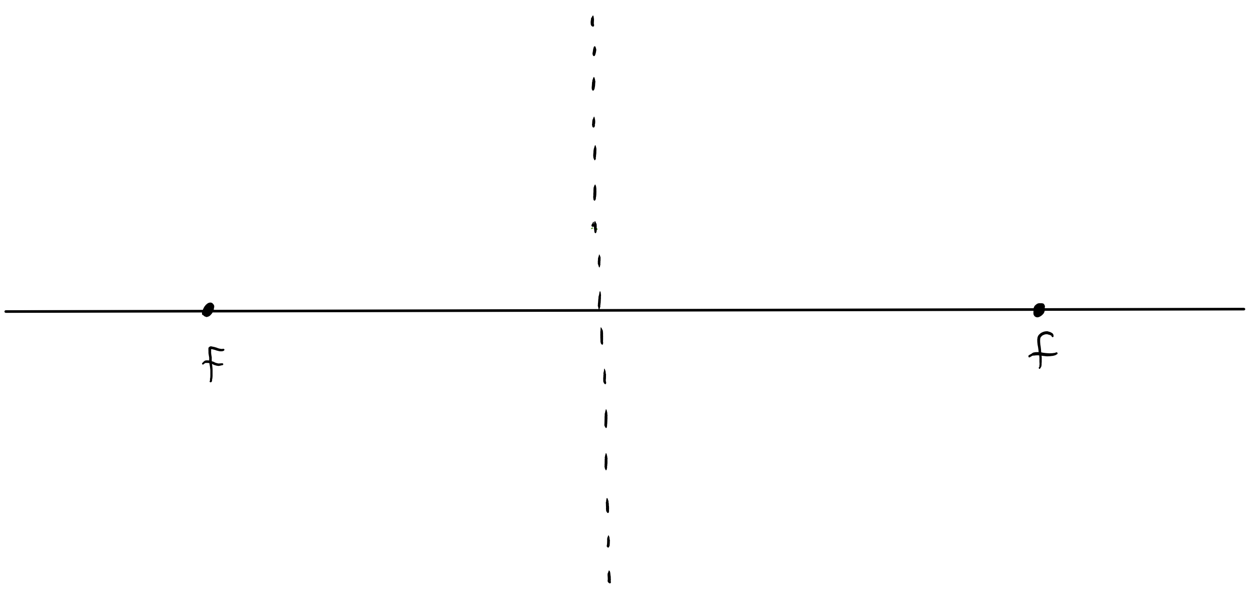
$$d_i = \frac{1-f}{d_o}$$

$$d_i = (f - d_o)^{-1}$$

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

$$d_i = \left(\frac{1}{f} - \frac{1}{d_o}\right)^{-1}$$

PRACTICE: If an object is placed at the focal point of a diverging lens, estimate the magnification of the image using a carefully drawn ray diagram



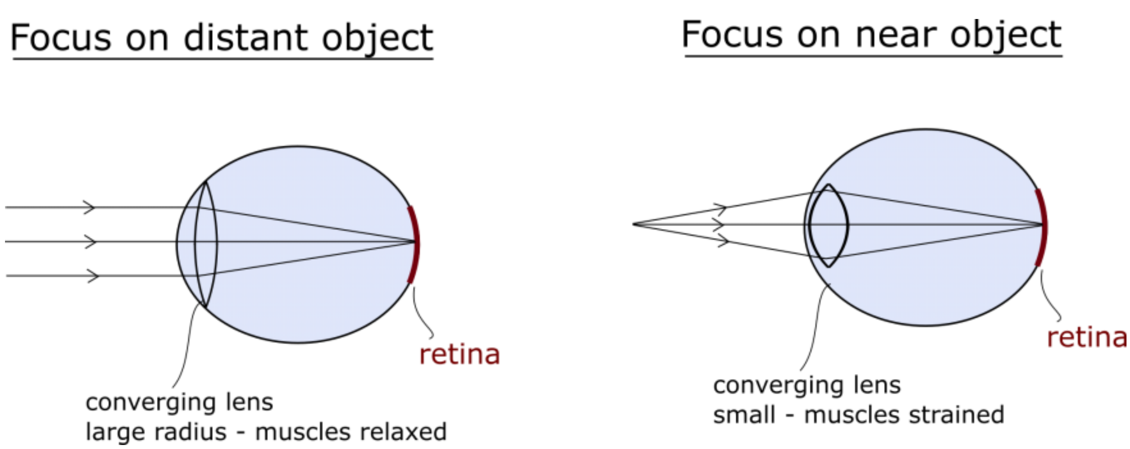
What is the image distance, in terms of f the focal length?

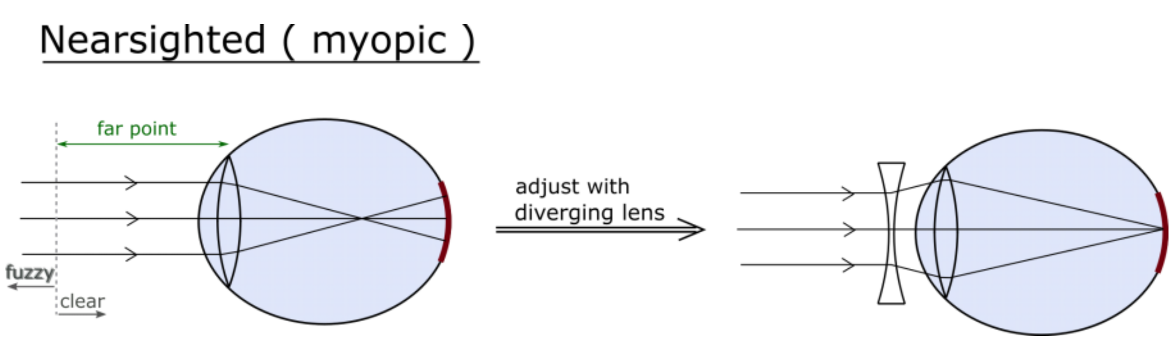
PRACTICE: A gigantic funhouse mirror has a 20 ft radius of curvature and you are standing 6 ft in front of it. Calculate the image distance and magnification.

The eye as an optical element

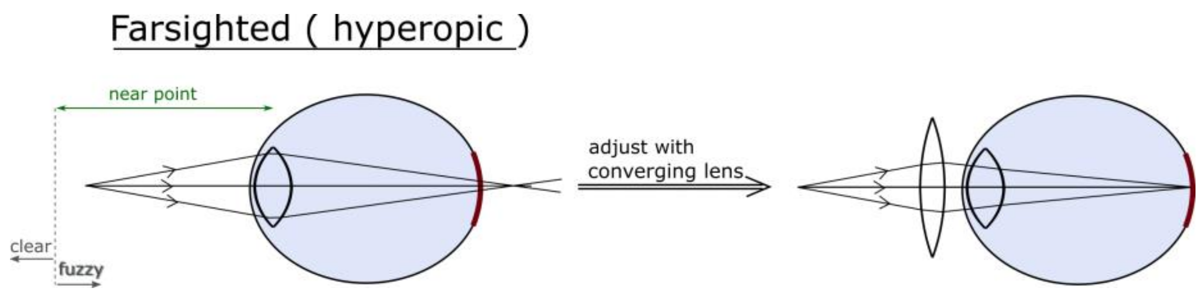
Refractive power ≡ **p** = (1 / focal-length)

- Corrective lens prescribed by power, not focal length
    - Unit is "diopter"





Far point :: furthest distance (measured from eye lens) at which an object can be clearly seen



near point :: closest distance (measured from eye lens) at which an object can be clearly seen. For the average human eye, the near point is about 25 cm.

QUESTIONS FOR DISCUSSION:

1. When you place a straw in a glass of water at an angle, it looks as though the straw bends. Explain this observation with the concepts covered in this lecture.