

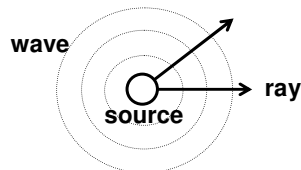
Phy 212: General Physics II

Chapter 34: Images Lecture Notes

Geometrical (Ray) Optics

Geometrical Optics is an approximate treatment of light waves as straight lines (rays) for the description of image formation

1. Light is a radiant, transverse, electromagnetic in nature wave
→ light waves, propagating in a uniform medium, expand equally in all directions
2. The travel of light can be approximated by rays that point normal to the plane of a traveling wavefront



Images

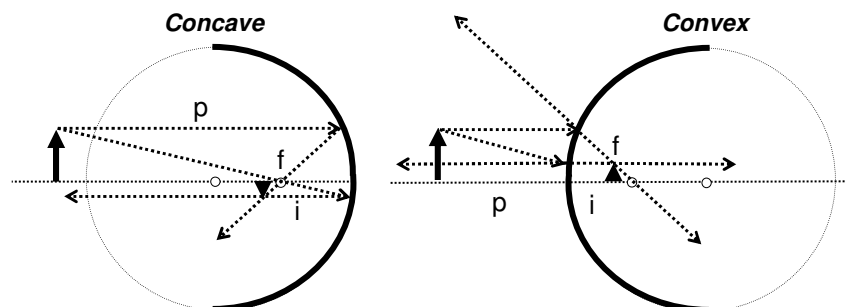
An image is a visual reproduction of an object derived from light. In geometrical optics, images are formed where light rays intersect.

Types of Images:

1. Real: these images actually exist and can be formed and observed on a physical surface
 - The projector image on the drymarker board is a real image
2. Virtual: these images only exist in the mind, a consequence of perception.
 - Your image in a plane mirror is a virtual image

Spherical Mirrors

1. Focal Points: the focal point for a spherical mirror is the location along the “optical axis” where an object at ∞ will form an image
2. Relation between mirror radius (r) & focal point (f): $f = \frac{1}{2}r$
3. Image formation: $\frac{1}{p} + \frac{1}{i} = \frac{1}{f}$



Thin Lenses

- For a lens where the radii of curvature of each face is much greater than the lens thickness, the focal length can be calculated using the Lens maker's formula:

$$\frac{1}{f} = (n - 1) \left(\frac{1}{r_1} + \frac{1}{r_2} \right)$$

Where:

- n is the index of refraction of the lens
- r_1 is the inner radius of curvature
- r_2 is the outer radius of curvature

- The focal length can also be calculated from the locations of an object and its formed image using the thin lens equation:

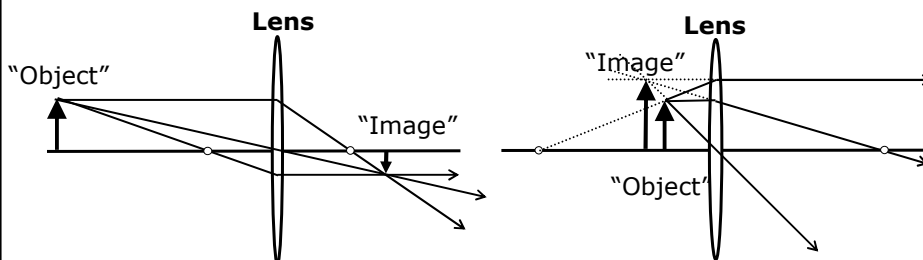
$$\frac{1}{f} = \frac{1}{p} + \frac{1}{i}$$

- Characteristics of thin lens image formation:

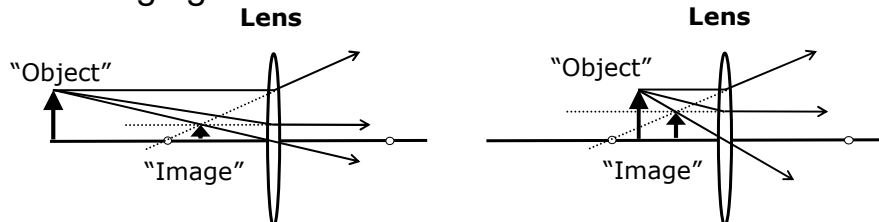
- Converging lenses (+f):
 - Image is real & inverted when $p > f$
 - Image is virtual & upright when $p < f$
- Diverging lenses (-f):
 - Image is always virtual & upright

Ray Diagrams for Lens Systems

- Converging Lenses:

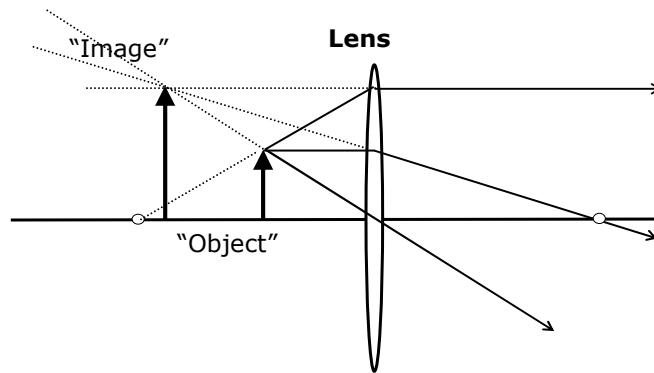


- Diverging Lenses:



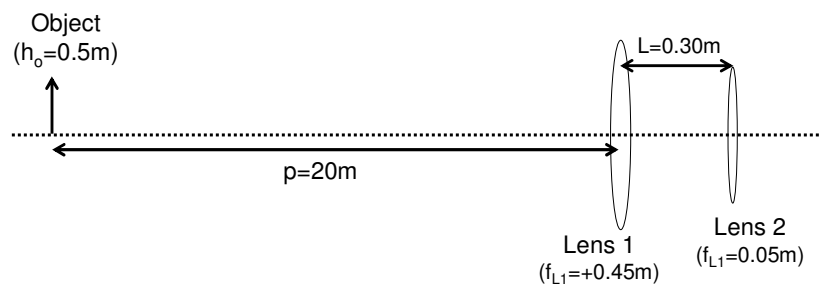
Optical Instruments: Simple Magnifying Glass

1. Consists of a single converging lens
2. The object is located inside focal point
3. The final image is virtual & upright
4. Magnification:



Example: A 2 Lens System

Consider the following 2 lens system:

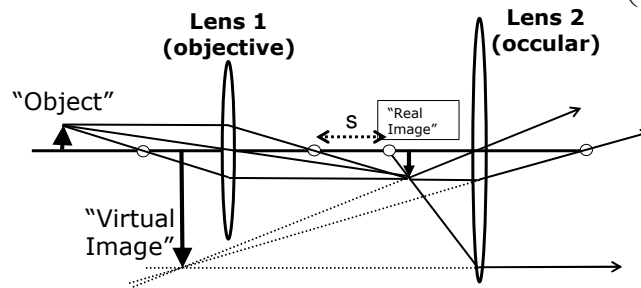


1. What is the image position due to lens 1 w/r to lens 1?
2. What is the final image position w/r to lens 2?
3. What is the final image orientation and size?
4. What is the angular magnification of the final image?

Optical Instruments: Compound Microscope

1. The object is located outside the 1st (objective) lens
2. The converging (objective) lens forms a magnified real image inside the focal point of a 2nd converging (ocular) lens
3. The ocular lens forms a further magnified virtual image

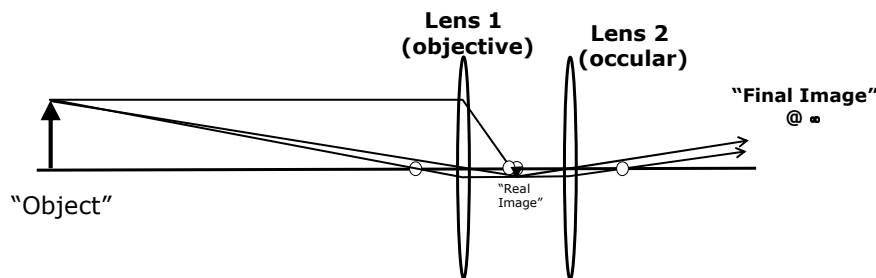
Observed Magnification: $m_{\text{net}} = m_{\text{lateral}} m_{\theta} = - \left(\frac{s}{f_{\text{objective}}} \right) \left(\frac{x_{\text{nearpoint}}}{f_{\text{ocular}}} \right)$



Optical Instruments: Telescope

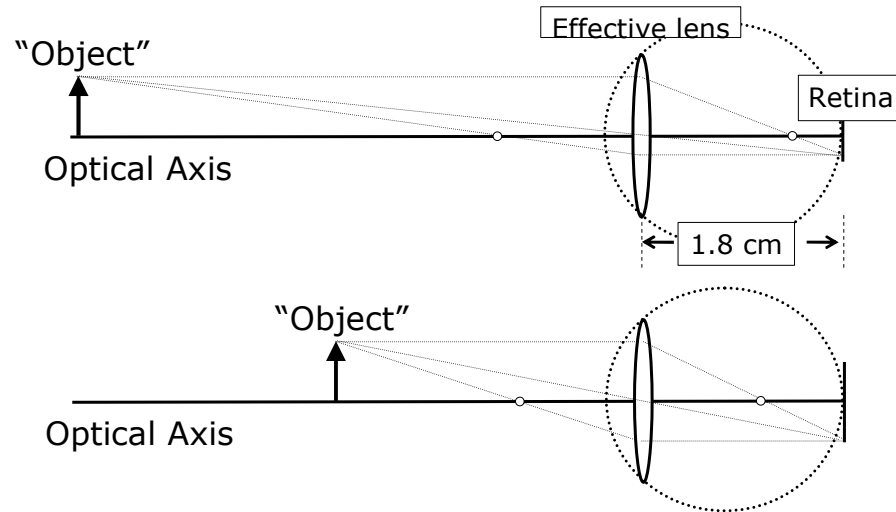
1. Useful for observing an object located at "infinity"
2. A converging (objective) lens gathers light & forms a smaller real image at the focal point of a 2nd (ocular) lens
3. The smaller final image formed by the converging (ocular) lens is also located at "infinity" but appears enlarged

Angular Magnification: $m_{\theta} = - \frac{f_{\text{objective}}}{f_{\text{ocular}}}$



The Human Eye

The human eye is a dynamic optical device that adjusts its focal length to keep the image location positioned at the retina:



Optics of the Eye

1. The "normal" eye can be modeled as a simple lens system with an effective focal length (& optical power) and a fixed image distance, i:

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{0.018\text{m}}$$

2. The job of the eye is to focus images on the retina. The image distance is therefore fixed at 1.8 cm (or 0.018 m).
3. When the eye cannot adequately focus an image on the retina, correction may be needed
4. The 4 common vision problems:
 - a. Myopia (near sightedness, short far & near point)
 - b. Hypermetropia (far sightedness, long far & near point)
 - c. Astigmatism (warped lens optics, focal length not uniform on all axes in the eye)
 - d. Presbyopia (normal distance vision but inability to accommodate for close objects)

Distance Vision Optics

1. When viewing distant objects, the lens power of the eye (& focal length) of the eye is given by:

$$\frac{1}{f} = \frac{1}{\infty} + \frac{1}{0.018 \text{ m}} = \frac{1}{0.018 \text{ m}} = 55.6 \text{ m}^{-1}$$

2. The lens power is 55.6 diopters & the focal length is: $f = 0.018 \text{ m}$
3. When a person is near sighted (myopic), he/she cannot see objects at infinity ("infinity" is the "far point" for a normal eye)
 - Myopic far point < Normal far point

Example: A person with -2.0 diopter distance correction.

- a. This person has a lens power of 57.6 & needs this "minus" correction to lower the effective lens power to a "normal" 55.6:

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{0.018 \text{ m}} = 57.6 \text{ diopters} \Rightarrow p = 0.49 \text{ m}$$

- b. The far point for this person is: $p = 0.49 \text{ m}$ {any object beyond this distance is not in focus}

Near Vision Optics

1. When viewing close-in objects, the lens power of the eye (& focal length) of the eye is given by: $\frac{1}{f} = \frac{1}{0.25 \text{ m}} + \frac{1}{0.018 \text{ m}} = 59.6 \text{ m}^{-1}$
2. The lens power is 59.6 diopters & the focal length is: $f = 0.0168 \text{ m}$
3. A far sighted (hypermetropic) person cannot see objects at close distances even though the eye is accomodating normally
 - Hypermetropic near point > Normal near point (0.25 m)

Example: A person with +2.0 diopter vision correction.

- a. This person has a (near) lens power of 57.6 & needs this "plus" correction to raise the effective lens power to a "normal" close distance power of 59.6:

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{0.018 \text{ m}} = 57.6 \text{ diopters} \Rightarrow p = 0.49 \text{ m}$$

- b. The near point for this person is: $p = 0.49 \text{ m}$ {any object closer is not in focus}
- c. People w/ presbyopia have normal distance lens power but are unable to adjust for closer objects, thus needing "reader" glasses