PHY 203- PHYSICS III

Image Formation

INTRODUCTION

- This chapter is concerned with the images that result when light rays encounter flat and curved surfaces.
- Images can be formed either by reflection or by refraction.
- We continue to use the ray approximation and to assume that light travels in straight lines.

Images Formed by Flat Mirrors

- Rays from light source O come to the eye after being reflected by the mirror.
- The dashed lines are extensions of the diverging rays back to a point of intersection at I.
- Point I is called the image of the object at O.

What are the differences between classical physics and modern physics?

A geometric construction that is used to locate the image of an object placed in front of a flat mirror.

PQR and P’QR congruent triangles

$|p| = |q|$ and $h = h'$.

Magnification:
Image of the object that is in front of the mirror is behind the mirror (virtual image).

There is no magnification.

$$M \equiv \frac{\text{Image height}}{\text{Object height}} = \frac{h'}{h}$$

Image is upright.

Image has an *apparent* left–right reversal.

Example: The Tilting Rearview Mirror

- How does a rearview mirror in cars work?
- In the day setting, the light from an object behind the car strikes the glass wedge at point 1. Most of the light enters the wedge and it re-enters the air as ray *B* (for *bright*). In addition, a small portion of the light is reflected at the front surface of the glass as ray *D* (for*dim*).
- In the night setting, the wedge is rotated so that the path followed by the bright light (ray B) does not lead to the eye. Instead, the dim light reflected from the front surface of the wedge travels to the eye.

- **Focal point**
- • Parallel beams coming from infinity intersect at the focal point after thay reflect from the mirror.
- • Focal point does not depend on the material of the mirror made of, it depends on the curvature of the mirror.
- Why is it different for lenses?

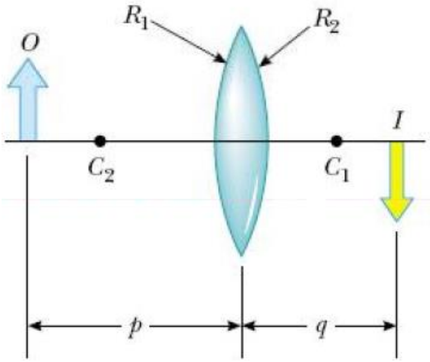
$$f = \frac{R}{2}$$

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

Derivation of Lens Formula

$$\frac{1}{p_1}+\frac{n}{q_1}=\frac{n-1}{R_1}\quad\xrightarrow{\text{the same}}\quad\frac{1}{p_1}+\cancel{\frac{n}{q_1}}=\frac{n-1}{R_1}$$

$$\frac{n}{p_2}+\frac{1}{q_2}=\frac{1-n}{R_2}\quad\xrightarrow{p_2=-q_1}\quad+\quad\underline{-\cancel{\frac{n}{q_1}}+\frac{1}{q_2}=\frac{1-n}{R_2}}$$



$$\frac{1}{p_1}+\frac{1}{q_2}=(n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$$\boxed{\frac{1}{p}+\frac{1}{q}=(n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)}$$

It is valid only for paraxial rays and only when the lens thickness is much less than R1 and R2.

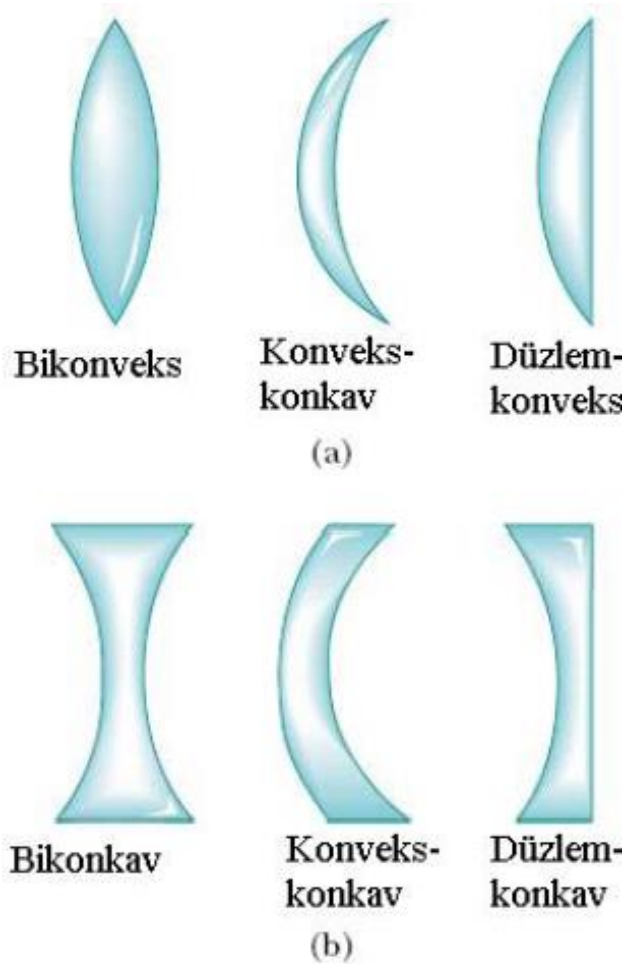
Magnification of Images

$$M = \frac{h'}{h} = -\frac{q}{p}$$

- M > 0 → The image is upright and on
- the same side of the lens as the object.

- M < 0 → The image is inverted and
- on the side of the lens opposite the object.

Lens Types



Convex lenses have positive focal lengths

Concave lenses have negative focal lengths

Example:The Case of a Diverging Lens

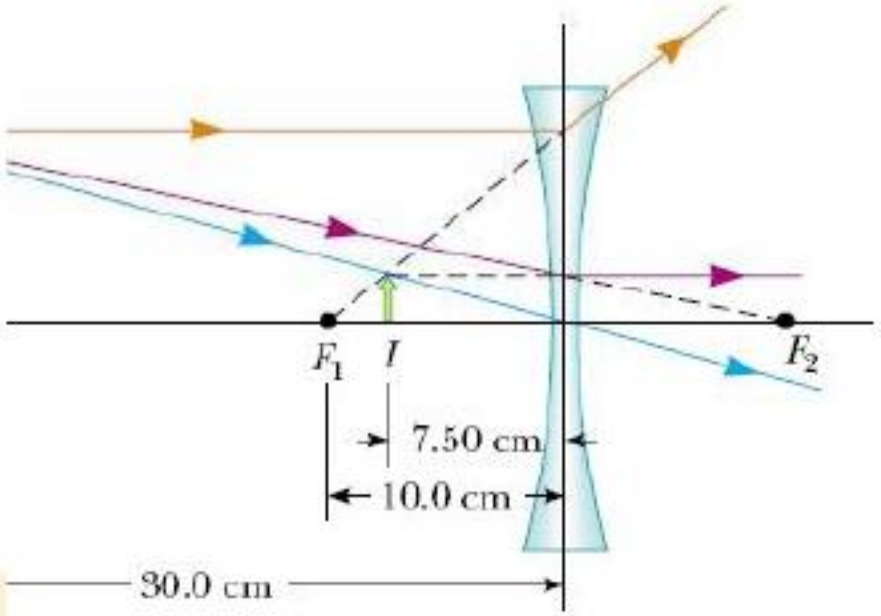
- A diverging lens of focal length 10.0 cm forms images of objects placed (A) 30.0 cm, (B) 10.0 cm, and (C) 5.00 cm from the lens. In each case, construct a ray diagram, find the image distance and describe the image.

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

$$\frac{1}{30.0\text{ cm}} + \frac{1}{q} = \frac{1}{-10.0\text{ cm}}$$

$$q = \boxed{-7.50\text{ cm}}$$

$$M = -\frac{q}{p} = -\left(\frac{-7.50\text{ cm}}{30.0\text{ cm}}\right) = \boxed{+0.250}$$



Lens Aberrations

Aberrations are distortions that occur in images, usually due to imperfections in lenses, some unavoidable, some avoidable.

They include:

Chromatic aberration

Spherical aberration

Astigmatism

Coma

Curvature of field

Pincushion and Barrel distortion

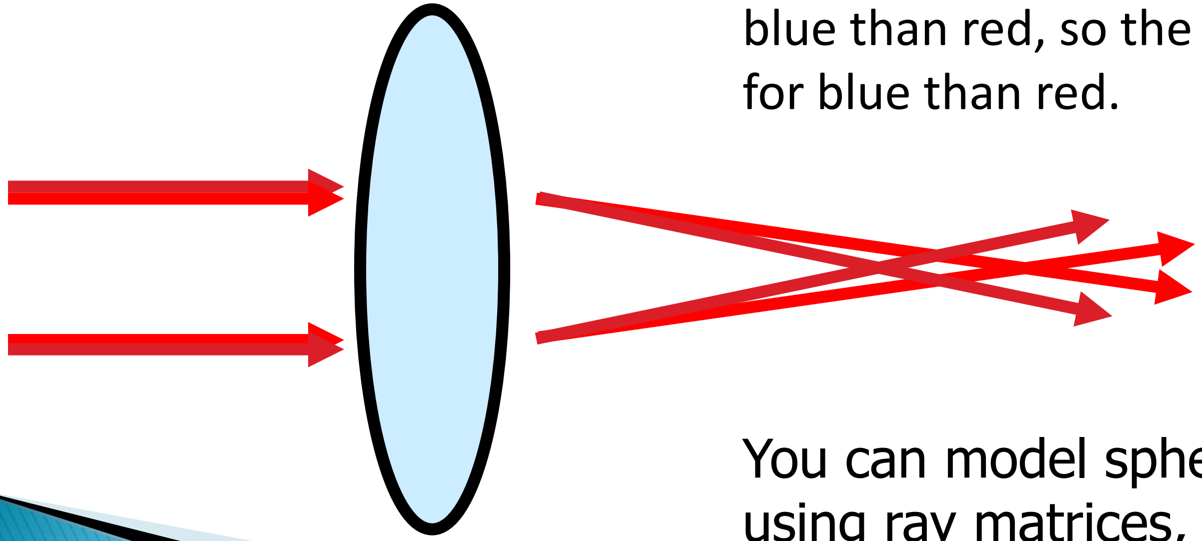
Most aberrations can't be modeled with ray matrices. Designers beat them with lenses of multiple elements, that is, several lenses in a row. Some zoom lenses can have as many as a dozen or more elements.

Chromatic aberration

Because the lens material has a different refractive index for each wavelength, the lens will have a different focal length for each wavelength. Recall the lens-maker's formula:

$$\boxed{1/f(\lambda) = (n(\lambda)-1)(1/R_1 - 1/R_2)}$$

Here, the refractive index is larger for blue than red, so the focal length is less for blue than red.



You can model spherical aberration using ray matrices, but only one color at a time.