Physics 202  Spring 2010
Lecture 25

Today’s topics:
reflection and mirrors
refraction and lenses
Two types of reflection

Specular reflection: reflection off a smooth surface

Diffuse reflection: reflection off a rough surface
Specular Reflection

$\theta_i = \text{angle of incidence}$

$\theta_r = \text{angle of reflection}$

$\theta_i = \theta_r$
Reflection from a mirror
Reflection from a mirror

image

object
Reflection from a mirror

The image is virtual, not real.
Reflection from a mirror

$O =$ object $ I =$ image

- reflected rays seem to come from $I$
- Point $I$ is located behind the mirror at the same distance ($h$) as $O$ from the mirror
- Point $O$ and point $I$ are on a line perpendicular to the plane of the mirror

The image is *virtual*, not real
Reflection from a mirror

\[ O = \text{object} \quad I = \text{image} \]

- reflected rays seem to come from \( I \)
- Point \( I \) is located behind the mirror at the same distance (\( h \)) as \( O \) from the mirror
- Point \( O \) and point \( I \) are on a line perpendicular to the plane of the mirror

The image is \textit{virtual}, not real
Plane (flat) mirror

- Image produced is upright
- Image is same size as the object
- Distance between the mirror and the image is the same as between the mirror and the object
- Image is a virtual image -- light rays do not pass through the image (so that image cannot be focused on a screen placed at image location)
Ray diagram for plane mirror

Rays are drawn from object to mirror, along with rays that reflect off the mirror.

Image is where the reflected rays intersect.

Since reflected rays diverge, image is behind the mirror.
Reflection from a sphere
Convex spherical mirror

- Convex mirror bulges in the center towards the object and viewer

  \[ C = \text{center of sphere} \]
  \[ F = \text{focal point (apparent origin of light rays after reflection)} \]

Image of convex spherical mirror is virtual.
Convex mirrors are useful because they have a larger field of view than plane mirrors

- **Uses:**
  - Car side-view mirrors
    - “Objects may be closer than they appear” because convex mirrors distort the scene and throw off distance perception
  - Stores and libraries
    - large field of view allows surveillance of many aisles by one person
Concave spherical mirror

- Concave mirror curves away from the object and viewer

C = center of sphere
F = focal point (apparent origin of light rays after reflection)

Image of far-away object in convex spherical mirror is **real** (light rays actually intersect at focal point).
Concave mirrors can yield both real and virtual images, depending on how far away object is

- far away object: real image
- nearby object: virtual image

http://micro.magnet.fsu.edu/primer/java/mirrors/concave.html
Physics 202, Lecture 25

- Refraction and Lenses
Refraction: Snell’s law

\[ \frac{\sin \theta_{\text{air}}}{\sin \theta_{\text{water}}} = \frac{n_{\text{water}}}{n_{\text{air}}} \]

- \( \theta_{\text{air}} \) = angle of incidence
- \( \theta_{\text{water}} \) = angle of refraction
- \( n \) = index of refraction

Light ray is closer to normal in material with higher refractive index.
Refraction: Snell’s law

\[
\frac{\sin \theta_{\text{air}}}{\sin \theta_{\text{water}}} = \frac{n_{\text{water}}}{n_{\text{air}}}
\]

\(\theta_{\text{air}}\) = angle of incidence
\(\theta_{\text{water}}\) = angle of refraction
\(n\) = index of refraction

Inverted ray: water-air case

Light ray is closer to normal in material with higher refractive index
Image Formed by Refraction

\[ \frac{n_1}{i} + \frac{n_2}{o} = \frac{n_2 - n_1}{R} \]

\[ M = \frac{h_i}{h_o} = -\frac{i}{o} \]

Example: looking at a fish

\[ R = \infty \]
\[ i = -\frac{o(n_2/n_1)}{R} \]
\[ M = -\frac{i}{o} \]
\[ = n_2/n_1 < 1 \]

Closer, not-inverted, reduced, virtual...

\( o = \) distance from glass surface to object
\( i = \) distance from surface to image
Refraction: non parallel surfaces

3D view of a prism

front view of the same prism

demo: white board
Refraction: nonparallel edges

double prism

region in which the rays cross
Lens: shape for which light rays that are different distances from the axis all focus at the same point.

**double prism**

apex 1

apex 2

region in which the rays cross

**lens**
converging lens
converging lens
converging lens
converging lens
converging lens
A converging lens causes parallel rays to come to a focal point. The distance from the lens to the focal point is the focal length, denoted as $f$. These principles are fundamental in the study of optics and the behavior of light through lenses.
Thin Lenses

Lenses are refractive optical devices with two spherical sides.

![Thin Lenses Diagram](image)

**Focal Points**

- $F_1, F_2$: Focal points
- $f = f_1 = f_2$: Focal length

**Lens Maker's Equation**

$$\frac{1}{f} = (n - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

- $f > 0$: converging
- $f < 0$: diverging
converging lens: 3 easy rays

Horizontal ray goes through focal point behind lens

Ray through center of lens is undeflected

Ray that goes through focal point in front of lens is deflected to be horizontal behind lens
image of an object in a converging lens
image of an object in a converging lens

optical axis
converging lens

\[ \frac{1}{o} + \frac{1}{i} = \frac{1}{f} \]

lens formula
Derivation of lens equation (1)

$h_o = \text{height of object}$

$h_i = \text{height of image}$

From similar triangles,

$$\frac{h_o}{h_i} = \frac{o-f}{f}$$
Derivation of lens equation (2)

$h_o = \text{height of object}$

$h_i = \text{height of image}$

from similar triangles,

$$\frac{i}{h_i} = \frac{o}{h_o} \Rightarrow \frac{h_o}{h_i} = \frac{o}{i}$$
Derivation of lens equation (3)

\[
\frac{h_o}{h_i} = \frac{o - f}{f} \quad \text{and} \quad \frac{o}{i} = \frac{h_o}{h_i}
\]

So,

\[
\frac{o}{i} = \frac{o - f}{f} = \frac{o}{f} - 1
\]

\[
\frac{1}{i} + \frac{1}{f} = \frac{1}{o}
\]