Geometric Optics (Ch 23)

- Ray Model
  - Assume light travels in straight line
  - Uses rays to understand and predict reflection & refraction

Reflection

- Law of reflection
  - The angle of incidence equals angle of reflection
  - Angles measured from normal

Ch 23: Question 1

- What would be the appearance of the Moon if it has
  - (a) a rough surface?
  - (b) a polished surface?
**Plane Mirrors**

Parallel rays striking a concave mirror come together at the focal point. The focal length is given by

\[ f = \frac{r}{2} \]

**Spherical Mirrors**

Image Formation:

1. Ray 1 goes out from F parallel to the axis and reflects through F.
2. Ray 2 goes through F and reflects back parallel to the axis.
3. Ray 3 is drawn perpendicular to mirror and is then reflected through F.

Real Image

Focal Point & Focal Length

- Parallel rays striking a concave mirror come together at the focal point.
Ch 23: Problem 8

- How far from a concave mirror (radius 23.0 cm) must an object be placed if its image is to be at infinity?

Convex Mirrors

- Virtual Image
  - can’t detect on paper or screen
- Sign Conventions
  - object, image, or focal point on reflecting side of mirror has a positive distance
  - Anything behind mirror has negative distance
  - image height is positive if upright, negative if inverted (relative to object)

Refraction

- index of refraction, \( n \)
  - \( n_{\text{air}} = 1 \)
  - \( n_{\text{glass}} = 1.5 \)
- Snell’s Law
  \[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]
Indices of Refraction

<table>
<thead>
<tr>
<th>Medium</th>
<th>n = c/λ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum</td>
<td>1.0000</td>
</tr>
<tr>
<td>Air (at STP)</td>
<td>1.003</td>
</tr>
<tr>
<td>Water</td>
<td>1.33</td>
</tr>
<tr>
<td>Ethyl alcohol</td>
<td>1.36</td>
</tr>
<tr>
<td>Glass</td>
<td></td>
</tr>
<tr>
<td>Fused quartz</td>
<td>1.46</td>
</tr>
<tr>
<td>Crown glass</td>
<td>1.52</td>
</tr>
<tr>
<td>Light flint</td>
<td>1.58</td>
</tr>
<tr>
<td>Lucite or Plexiglas</td>
<td>1.51</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>1.53</td>
</tr>
<tr>
<td>Diamond</td>
<td>2.42</td>
</tr>
</tbody>
</table>

* A = 589 nm.

Total Internal Reflection

- Incident angle where refracted angle (θ₂) is 90° is the critical angle

\[ \sin \theta_C = \frac{n_2}{n_1} \sin 90^\circ = \frac{n_2}{n_1} \]

- At incident angles greater than critical angle, light is totally internally reflected

Ch 23: Problem 31

In searching the bottom of a pool at night, a watchman shines a narrow beam of light from his flashlight, 1.3 m above the water level, onto the surface of the water at a point 2.7 m from the edge of the pool. Where does the spot of light hit the bottom of the pool, measured from the wall beneath his foot, if the pool is 2.1 m deep?

Ch 23: Problem 32

Light is incident on an equilateral glass prism at a 45 degrees to one face. Calculate the angle at which light emerges from the opposite face. Assume n=1.58.
Ch 23: Question 7

- What is the focal length of a plane mirror?
- What is the magnification of a plane mirror?

Thin Lenses

- **Focal Length, Focal Plane and Power**
  - \( f = \) focal length
  - **Power**
    - inverse of focal length
    - \( P = \frac{1}{f} \)
    - measured in diopter (D)
    - \( 1 \text{ D} = 1 \text{ m}^{-1} \)

Ray Tracing
Thin Lens Equation

\[ \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \]

Magnification

\[ m = \frac{h_i}{h_o} = -\frac{d_i}{d_o} \]

Ch 23: Problem 43

A sharp image is located 78.0 mm behind a 65.0-mm focal-length converging lens. Find the object distance (a) using a ray diagram, (b) by calculation.

Ch 23: Problem 44

Sunlight is observed to focus at a point 18.5 cm behind a lens. (a) What kind of lens is it? (b) What is its power in diopters?

Sign Conventions

- **focal length**
  - positive for converging lenses
  - negative for diverging lenses
- **object distance**
  - positive if the object is on the side of the lens from which the light is coming (this is usually not the case)
  - otherwise, it is negative.
- **image distance**
  - positive if the image is on the opposite side of lens from where light is coming
  - positive for real images, negative for virtual images
- **image height**
  - positive if image is upright, negative for inverted images
  - \( h_i \) is always positive
Ch 23: Problem 45

- A certain lens focuses light from an object 2.75 m away as an image 48.3 cm on the other side of the lens. What type of lens is it and what is its focal length? Is the image real or virtual?

Ch 23: Problem 53

- (a) How far from a converging lens with a 50.0-mm-focal-length lens must an object be placed if its image is to be magnified 2.00 times and be real?
- (b) What if the image is to be virtual and magnified 2.00 times?