Physics 202, Lecture 24

Today’s Topics

- Image Formation
- Real Image, Virtual Image, and No Image
- Ray Diagram
- Images Formed by:
  - Mirrors (reflection)
    - Concave and Convex
  - Lenses (refraction)
    - Converging and Diverging
Imaging

- Imaging: visible object $\rightarrow$ optical device $\rightarrow$ image

Note: If image can be formed, only two rays per point are necessary.

No Image: No point to point correspondence

Image Aberration: Poorly focused imaged points
Image Properties

- Image properties to be concerned include
  - location, real/virtual, reduced/enlarged, upright/inverted, similar/distorted,…

Real and Virtual Images

- **Real Image:**
  - image lights actually pass through image

- **Virtual Image:**
  - image lights appear to have come from the image

- Real images can be formed on a screen.
Ray Diagrams

- If image can be formed, only two rays are necessary to determine an image point.

- Useful rays:
  - Object ray pointing to the center (C)
    - image ray inline with the object ray
  - Object ray parallel to principal axis
    - image ray “pointing to” a focal point (F)
  - Object ray passing through a focal point
    - image ray parallel to principal axis.
Image Formation Equation and Magnification

Parameters
- \( p \): object distance
- \( q \): image distance
- \( h \): object height
- \( h' \): image height
- \( M \): magnification
- \( f \): focal length

\[
\frac{1}{p} + \frac{1}{q} = \frac{1}{f}
\]

\[
q = \frac{fp}{p - f}
\]

If \(|M| < 1\) \(\rightarrow\) Image < Object
If \(|M| > 1\) \(\rightarrow\) Image > Object
If \(M < 0\) \(\rightarrow\) Image \(\downarrow\uparrow\) Object
If \(M > 0\) \(\rightarrow\) Image \(\uparrow\uparrow\) Object
Image Formed by Flat Mirrors

Properties:
- Image is virtual and behind the mirror.
- Object distance = image distance (|p|=|q|)
- Lateral magnification M=1
- Image is upright (for upright object)
- Image has front/back reversal.

Parameters:
- p: object distance
- q: image distance
- h: object height
- h’: image height
- M: magnification

\[ p > 0, q < 0 \]
\[ M = \frac{h'}{h} = -\frac{q}{p} = 1 \]
Quiz 1: Is there another convenient ray to use?

Quiz 2:
1. Real or virtual?
2. Upright or inverted?
3. Enlarged or reduced?

Answer: Virtual, upright ($M>0$), reduced ($|M|<1$)
Object (O) in between F and Mirror:
virtual, upright, enlarged

Object in front of Mirror:
real, inverted. Enlarged or reduced, depending on p.

\[ f = \frac{R}{2} \]
\[ \frac{1}{p} + \frac{1}{q} = \frac{1}{f} \]
\[ M = \frac{h'}{h} = -\frac{q}{p} \]
Image Formed by Refraction

Example: looking at a fish

\[ R = \infty \]
\[ q = -p \left( \frac{n_2}{n_1} \right) \]
\[ M = -\frac{q}{p} = \frac{n_2}{n_1} < 1 \]

Closer, not-inverted, reduced, virtual…
Thin Lenses

- Lenses are refractive optical devices with two spherical sides.

Lens maker’s equation:

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

Focal length:

- \( f > 0 \): converging
- \( f < 0 \): diverging

\( F_1, F_2 \): Focal points

\( f = f_1 = f_2 \): Focal length
Converging and Diverging Lenses

sign convention:

\[ f < 0 \]

sign convention:

\[ f > 0 \]
**Images Formed by Converging Lens**

- **Object (O) is in front of F₁**: real, inverted, enlarged or reduced

- **Object (O) in between F₁ and lens**: virtual, upright, enlarged.

Mathematical equations:

1. \( \frac{1}{p} + \frac{1}{q} = \frac{1}{f} \)
2. \( M = \frac{h'}{h} = -\frac{q}{p} \)

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Images formed by diverging lenses are always virtual, upright, and reduced.

\[ f < 0 \]
\[ \frac{1}{p} + \frac{1}{q} = \frac{1}{f} \]
\[ M = \frac{h'}{h} = -\frac{q}{p} \]

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## Sign Conventions

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<th></th>
<th>&gt;0</th>
<th>&lt;0</th>
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<tr>
<td>( f )</td>
<td>concave mirrors</td>
<td>convex mirrors</td>
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<tr>
<td></td>
<td>converging lens</td>
<td>diverging lens</td>
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<tr>
<td>( p )</td>
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<td>the other side</td>
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<tr>
<td>( q )</td>
<td>real</td>
<td>virtual</td>
</tr>
<tr>
<td>( M=-\frac{q}{p} )</td>
<td>upright</td>
<td>inverted</td>
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