Chapter 23 Quiz

Which of the following is \textit{not} a principal ray?

- (1) 1
- (2) 2
- (3) 3
- (4) 4
- (5) All are principal rays

Real image
Concave and Convex Mirrors

\begin{align*}
R > 0 & \quad \text{Real image} \\
R < 0 & \quad \text{Virtual image}
\end{align*}

\[ f = \frac{R}{2} \]
Images from Mirrors

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

Size
\[ M \equiv \frac{h'}{h} = -\frac{q}{p} \]

q > 0 along reflected ray
Mirror Example

- 2 cm tall object ($h = 2$), 80 cm from mirror ($p = 80$)
- Mirror: 100 cm radius of curvature concave towards object ($R = +100$)

\[
\frac{1}{80} + \frac{1}{q} = \frac{1}{50} \Rightarrow q = 133.3
\]

\[
M = -\frac{q}{p} = -\frac{133.3}{80} = -1.67
\]

\[
h' = (-1.67)h = -3.33
\]

Roughly agrees with ray diagram (good to check it)
Images Formed by Refraction

\[ \frac{n_1}{p} + \frac{n_2}{q} = \frac{n_2 - n_1}{R} \]

\[ M = \frac{h'}{h} = -\frac{n_1 q}{n_2 p} \]
Image from Flat Refractive Surface

$n_1 > n_2$

$R = \infty$

\[
\frac{n_1}{p} + \frac{n_2}{q} = 0 \Rightarrow q = -\frac{n_2}{n_1}p
\]

$M = -\frac{n_1q}{n_2p} = +1$

Same size virtual image!
Example: Image in Pool

\[ n_1 = 1.333 \]
\[ n_2 = 1.0 \]

\[ q = -\frac{n_2}{n_1} p \]
\[ q = -\frac{1}{1.333} p \approx -0.75 p \]

So depth of image is about 3/4 depth of object
Atmospheric Refraction

- Refraction in atmosphere makes sun always appear higher in sky
- Can see the sun even when it is below the horizon!
Atmospheric Refraction Causes Various Mirages
Approaching Car on Hot Road
Floating Iceberg! Cold Air, Warm Water
“Squashed” Sun Setting Over Ocean

Fig. 2.22A Distortions of the low sun.

Fig. 2.22B Distortions of the low sun.

Fig. 2.22C Distortions of the low sun.
Thin Lenses

- Biconvex
- Convex–concave (a)
- Plano-convex
- Biconcave
- Convex–concave (b)
- Plano-concave
Thin Lenses

Converging Lens
Rays parallel to axis refract and pass through focal point
\[ f > 0 \]

Diverging Lens
Rays parallel to axis refract and appear to emerge from focal point
\[ f < 0 \]
Location and Size of Image (Recall Mirror)

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

\[ M \equiv \frac{h'}{h} = -\frac{q}{p} \]
Finding Image from Lens: Example

- \( f = 10 \text{ cm} \)
- \( p = 30 \text{ cm} \)
- \( h = 4 \text{ cm} \)

\[
\frac{1}{30} + \frac{1}{q} = \frac{1}{10} \Rightarrow q = +15 \text{ cm}
\]

\[
M = -\frac{q}{p} = -\frac{15}{30} = -0.5
\]

\( h' = -2 \text{ cm} \)
Principal Ray Diagrams for Lenses

$q > 0$
Principal Ray Diagrams for Lenses (cont)

$q < 0$
Principal Ray Diagrams for Lenses (cont)

$q < 0$
Calculating Focal Length for Thin Lenses

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

Lensmaker’s equation

Sign convention:

- \( R > 0 \)
- \( R < 0 \)
Calculating Focal Length Example

Let \( n = 1.5, \ R = 10 \)

\[
\frac{1}{f} = 0.5 \left( \frac{1}{10} - \frac{1}{-10} \right) = 0.1
\]

So \( f_1 = f_2/2 \)

1 has twice the “power” of 2
Quiz on Lenses

All the lenses below have either flat sides or radius of curvature $R$. Rank in descending order the value of $1/f$ (lens power), i.e. from most positive to most negative

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

Each term adds to lens power

- (1) A, C, B, E, D
- (2) C, A, D, B, E
- (3) B, A, C, E, D
- (4) D, E, B, C, A
- (5) C, A, E, D, B
Quiz on Mirrors

An upright object is located in front of a convex mirror a distance greater than the focal length. The image formed by the mirror is:

- (1) real, inverted, and smaller than the object
- (2) virtual, inverted, and larger than the object
- (3) real, inverted, and larger than the object
- (4) real, erect, and larger than the object
- (5) virtual, erect, and smaller than the object

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

\( f < 0, \text{ so } q < 0 \)
\( M = -\frac{q}{p} < +1 \)