Phys 102 – Lecture 18

Spherical mirrors
Today we will...

• Learn about spherical mirrors
  
  Concave mirrors

  Convex mirrors

• Learn how spherical mirrors produce images
  
  Ray diagrams – principal rays

  Mirror & magnification equations
Curved mirrors

Spherical mirror – section of a sphere

“Concave” – inside surface of sphere

“Convex” – outside surface of sphere

“Center of curvature”

How does light reflect off spherical mirrors?

“Principal axis”

Line through $C$ and center of mirror

$C$ behind mirror

Phys. 102, Lecture 18, Slide 3
**Concave mirror reflection**

Concave mirror – rays $||$ to p.a. reflect through focal point $f$ in *front* of mirror

\[ f = \frac{R}{2} \]
Convex mirror reflection

Convex mirror – rays || to p.a. reflect as if they originated from focal point f behind mirror

Since f is behind mirror, focal length < 0

\[ f = -\frac{R}{2} \]
ACT: CheckPoint 1.1 & 1.2

What kind of mirror can be used to start a fire?

A. Concave
B. Convex
C. Plane

How far from the object to be ignited should the mirror be held?

A. farther than the focal length
B. closer than the focal length
C. at the focal length

Phys. 102, Lecture 18, Slide 6
Lighting a match

Rays traveling through focus before hitting mirror are reflected parallel to Principal Axis.

Rays traveling parallel to Principal Axis before hitting mirror are reflected through focus.
Images & spherical mirrors

Like plane mirrors, spherical mirrors produce images of objects

Key approaches:
• Ray diagrams
• Mirror & magnification equations

Phys. 102, Lecture 18, Slide 8
**Principal rays – concave mirror**

Ray from object traveling:

1) parallel to principal axis, reflects through $f$
2) through $f$, reflects parallel to principal axis
3) through $C$, reflects through $C$

Image is:
Real (light rays cross)
Inverted (opposite direction as object)
Reduced (smaller than object)
**Principal rays – convex mirror**

Ray from object traveling:

1) parallel to principal axis, reflects through $f$
2) through $f$, reflects parallel to principal axis
3) through $C$, reflects through $C$

Image is:

- Virtual (light rays don’t really cross)
- Upright (same direction as object)
- Reduced (smaller than object)
The diagram below shows the object and image, and one ray from the object.

Which arrow most accurately represents how the ray is reflected?

A. 1  
B. 2  
C. 3  

Phys. 102, Lecture 18, Slide 11
In the ray diagram below, which ray is NOT correct?

A. 1
B. 2
C. 3
Optical illusion

Two identical concave mirrors
Each mirror is positioned at the focal point of the other
Mirror & magnification equations

**Mirror equation**

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

**Magnification**

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

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

So, \[ \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} \]

Phys. 102, Lecture 18, Slide 14
**Distance & magnification conventions**

- $d_o = \text{distance object is from mirror:}$
  - $> 0$: object **in front** of mirror
  - $< 0$: object **behind** mirror

- $d_i = \text{distance image is from mirror:}$
  - $> 0$: **real image** (in front of mirror)
  - $< 0$: **virtual image** (behind mirror)

- $h_o = \text{height of object:}$
  - $> 0$: **always**

- $h_i = \text{height of image:}$
  - $> 0$: image is **upright**
  - $< 0$: image is **inverted**

- $f = \text{focal length mirror:}$
  - $> 0$: concave mirror $+R/2$
  - $< 0$: convex mirror $-R/2$

- $|m| = \text{magnification:}$
  - $< 1$: image is **reduced**
  - $> 1$: image is **enlarged**

**Notes:**

- $|m| = \frac{h_i}{h_o}$
- $d_o = f \cdot \frac{h_o}{h_i}$
- $d_i = f \cdot \frac{h_i}{h_o}$

*Phys. 102, Lecture 18, Slide 15*
Calculation: concave mirror

A 6-cm tall candle is placed 24 cm in front of a concave mirror with a focal length $f = +8$ cm. Determine the image location, size, and whether it is upright or inverted.

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

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

\[
h_i = mh_o
\]
**ACT: Plane mirror**

Concave mirrors have $f > 0$ and convex mirrors have $f < 0$

What is the focal length $f$ of a plane mirror?

A. $f = 0$
B. $f = \infty$
C. $f$ is imaginary
Checkpoint 3.1

The image produced by a concave mirror of a real object is:

A. Always Real
B. Always Virtual
C. Sometimes Real, Sometimes Virtual
ACT: Concave Mirror

Where in front of a concave mirror should you place an object so that the image is *virtual*?

A. Closer than the focal length  
B. Farther than the focal length  
C. Either close or far  
D. Not Possible
3 cases for concave mirrors

Object is:      Image is:

Inside $f$:    Upright: $h_i > 0$
$d_o < f$      Enlarged: $m > 1$

Virtual: $d_i < 0$

Between $C$ & $f$: Inverted: $h_i < 0$
$f < d_o < R$    Enlarged: $m > 1$

Real: $d_i > 0$

Past $C$: Inverted: $h_i < 0$
$R < d_o$      Reduced: $m < 1$

Real: $d_i > 0$

DEMO

Phys. 102, Lecture 18, Slide 20
Calculation: convex mirror

A 6-cm tall candle is placed 12 cm in front of a convex mirror with a focal length \( f = -6 \text{ cm} \). Determine the image location, size, and whether it is upright or inverted.

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

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

\[
h_i = mh_o
\]

Diagram should agree!
Checkpoint 3.2

The image produced by a convex mirror of a real object is

A. always real
B. always virtual
C. sometimes real and sometimes virtual
ACT: Convex mirror image

An object placed in front of a convex mirror will __________ produce an upright image

A. Always
B. Sometimes
C. Never
Summary of today’s lecture

- Curved mirrors

- Principal rays – method for images
  - Parallel to p.a. → reflects through $f$
  - Through $f$ → reflects parallel to p.a.
  - Through $C$ → reflects back through $C$

- Mirror & magnification equations
  - Numerical answer consistent with ray diagram
    \[
    \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \quad m \equiv \frac{h_i}{h_o} = -\frac{d_i}{d_o}
    \]