Phys 102 – Lecture 18

Spherical mirrors

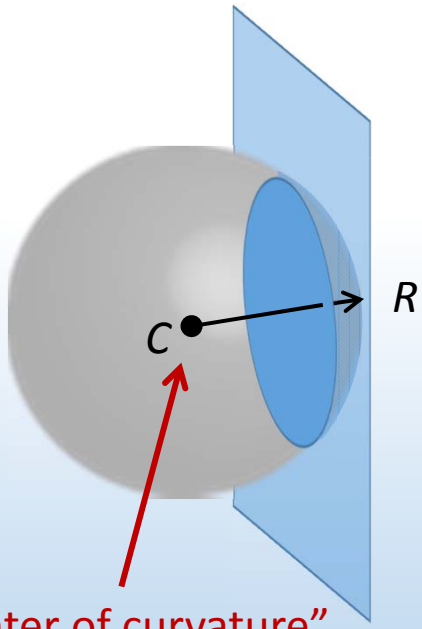
IMPORTANT ANNOUNCEMENT:
Prof. Chemla out of town Monday-Wednesday, so no office hour
EXAM 2 results: mean = 62%, scaled = 75%

Today we will...

- Learn about spherical mirrors
  - Concave mirrors
  - Convex mirrors
- Learn how spherical mirrors produce images
  - Ray diagrams – principal rays
  - Mirror & magnification equations

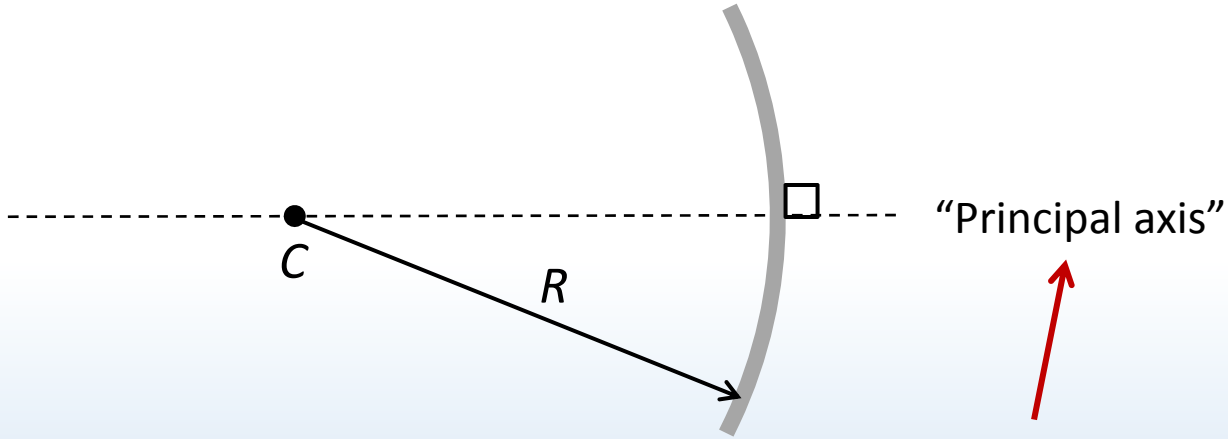
Curved mirrors

Spherical mirror – section of a sphere



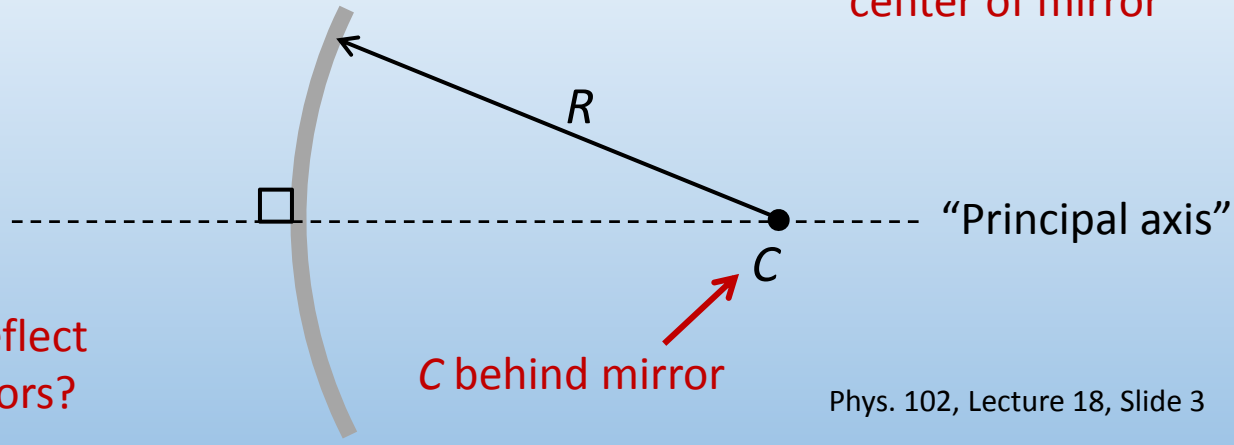
"Center of curvature"

"Concave" – inside surface of sphere



Line through *C* and center of mirror

"Convex" – outside surface of sphere

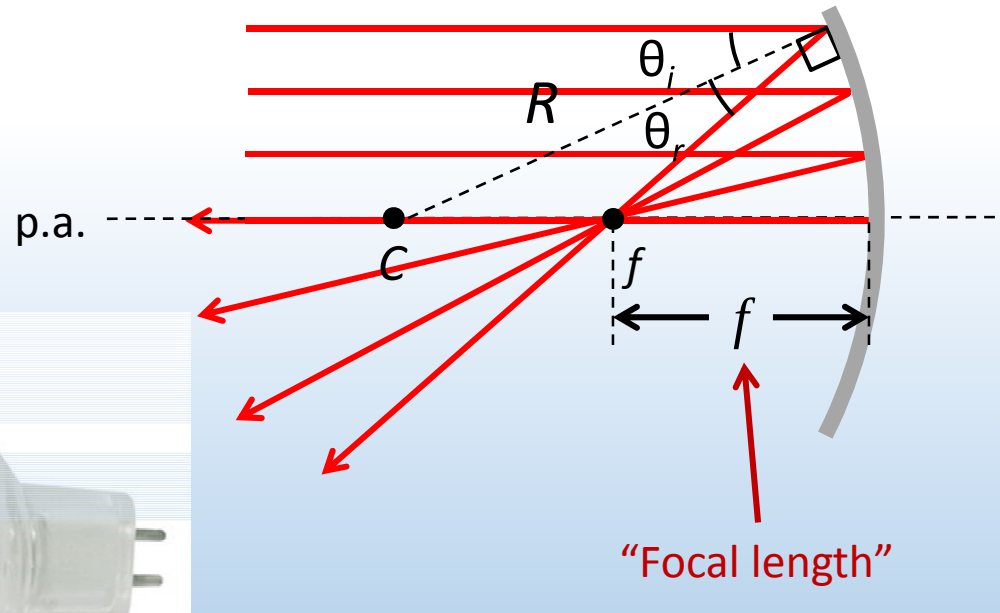


C behind mirror

How does light reflect off spherical mirrors?

Concave mirror reflection

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



$$f = \frac{R}{2}$$

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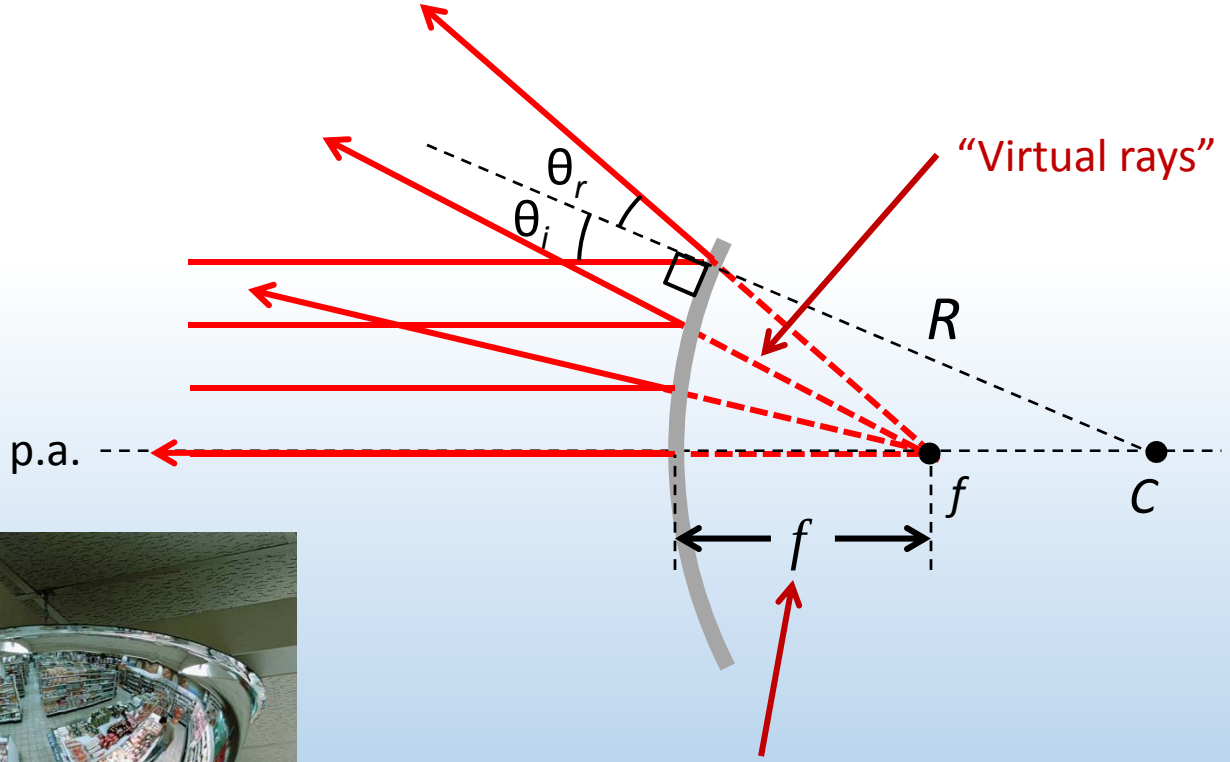
Convex mirror reflection

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



$$f = -\frac{R}{2}$$

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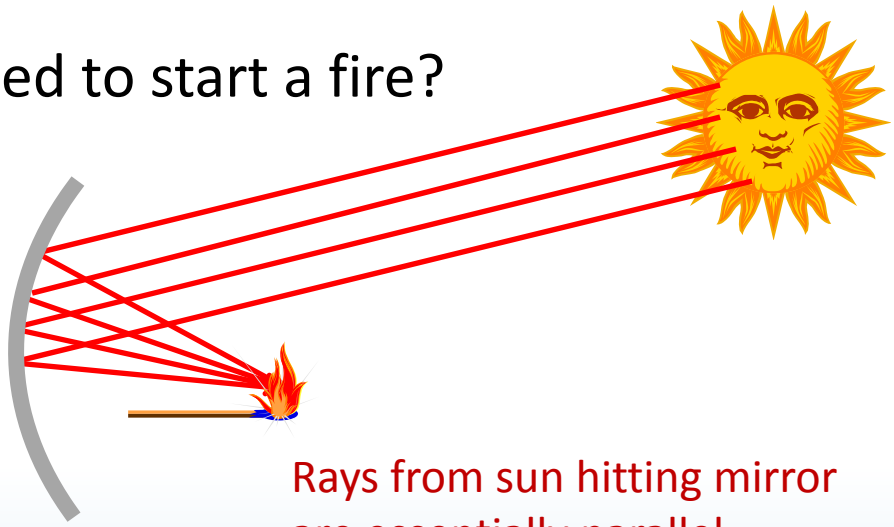
ACT: CheckPoint 1.1 & 1.2

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

70% A. Concave

28% B. Convex

2% C. Plane



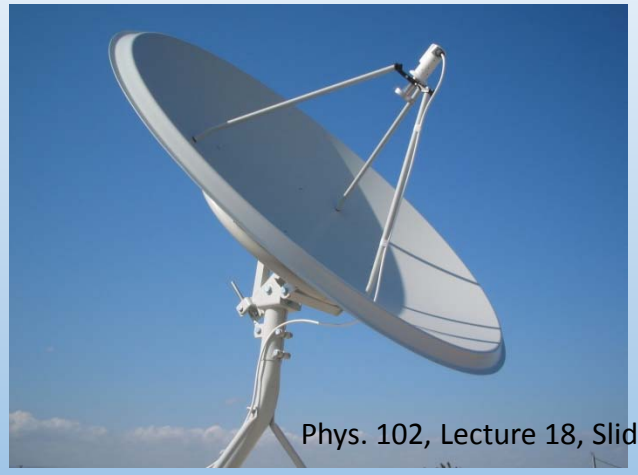
Rays from sun hitting mirror are essentially parallel

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

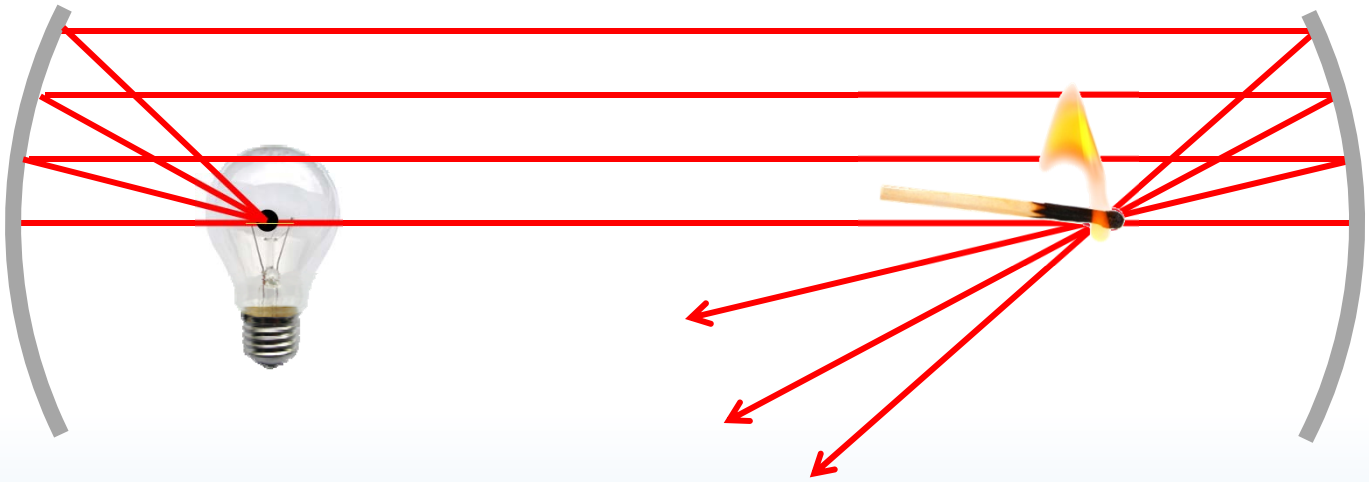
18% A. farther than the focal length

23% B. closer than the focal length

59% C. at the focal length



Lighting a match



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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

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*

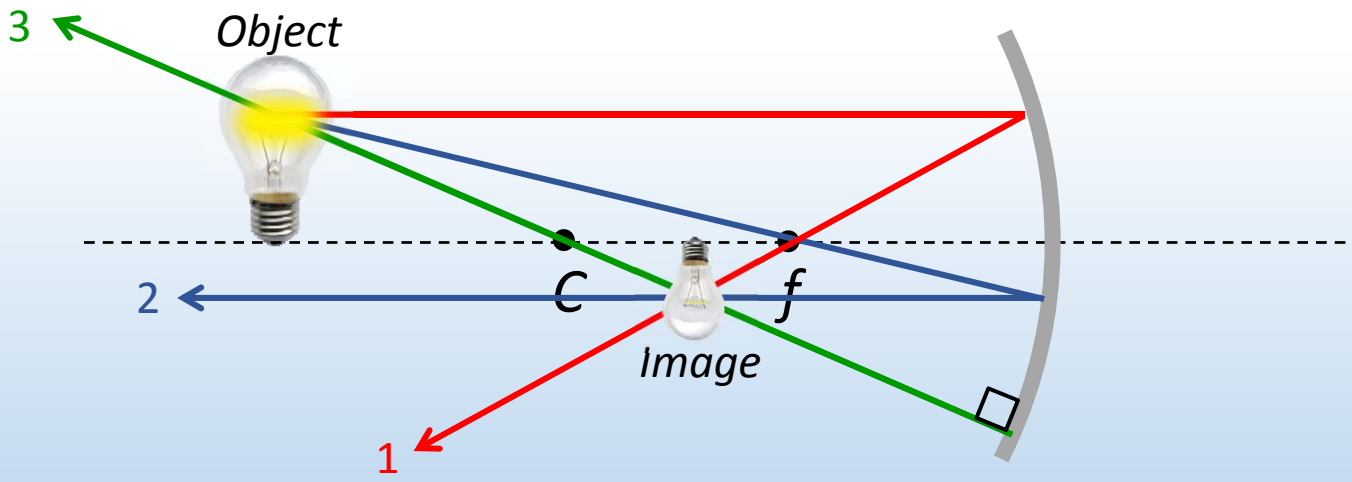


Image is:

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*

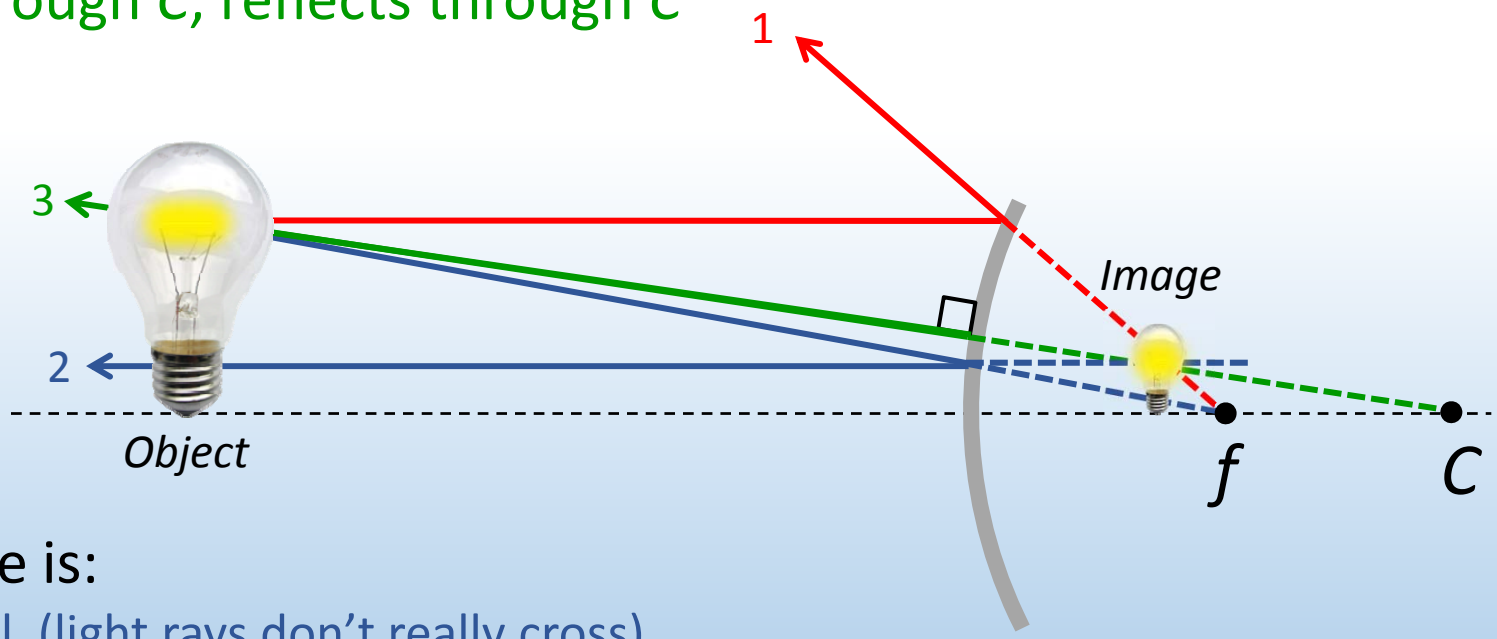
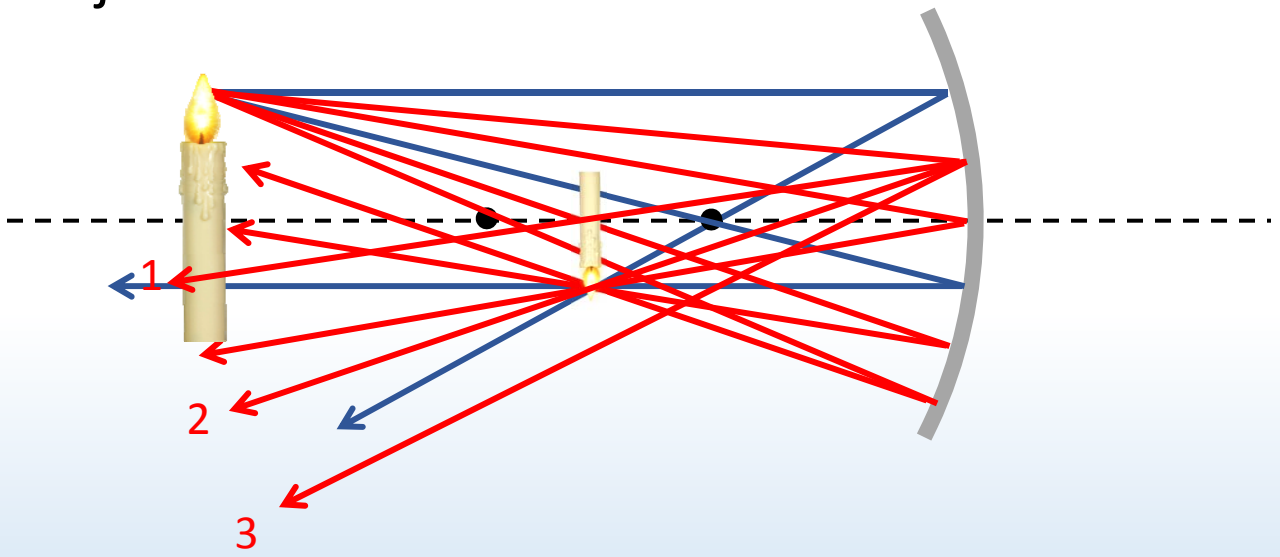


Image is:

Virtual (light rays don't really cross)
Upright (same direction as object)
Reduced (smaller than object)

ACT: Image formation

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

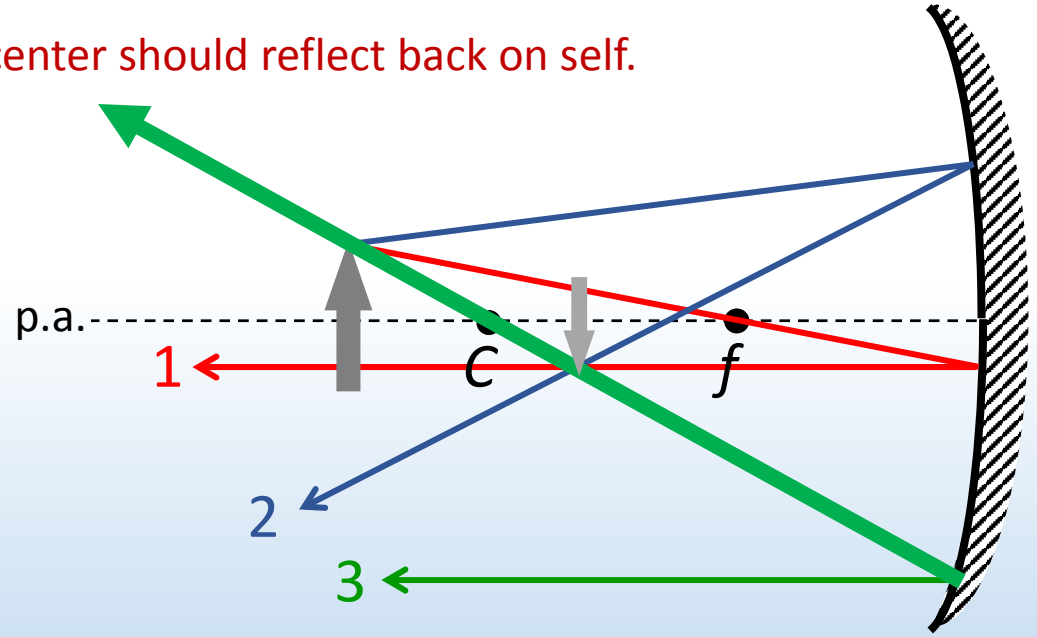
Every ray from *every* point on object is reflected onto corresponding point on image

Principal rays are just the easy ones to draw

ACT: CheckPoint 2.1

In the ray diagram below, which ray is NOT correct?

Ray through center should reflect back on self.



17% A. 1

47% B. 2

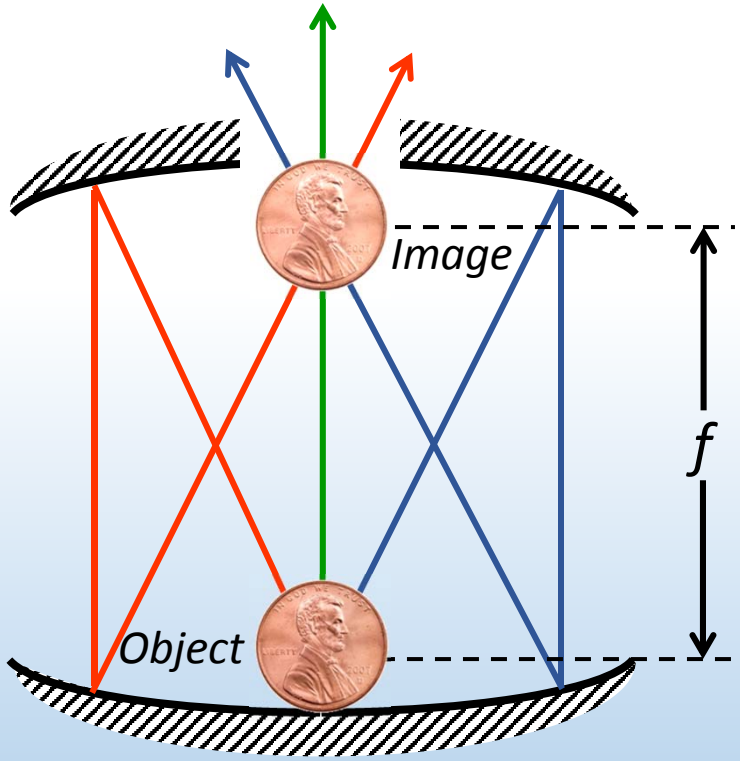
36% C. 3

CheckPoint 2.2: Image is reduced compared to object

Optical illusion

Two identical concave mirrors

Each mirror is positioned at the focal point of the other



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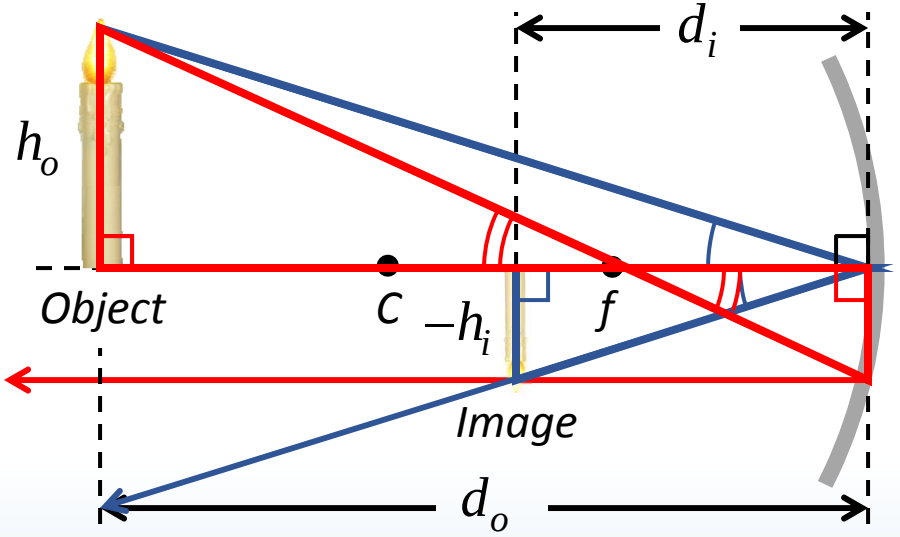
Mirror & magnification equations



Mirror equation

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

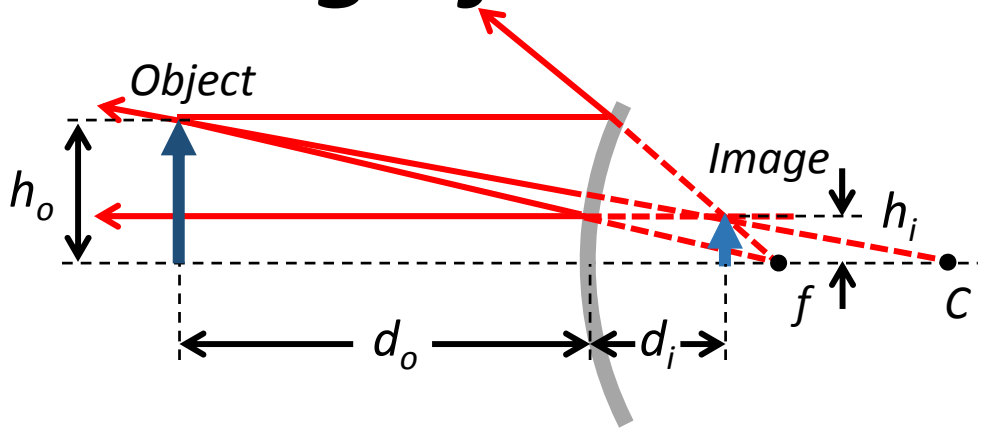
Magnification

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

h_o h_o f d_o $d_o - f$ $-h_i$ d_i $-h_i$

$$\frac{h_o}{d_o - f} = -\frac{h_i}{f} = \frac{d_i}{d_o} \qquad \text{So, } \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$

Distance & magnification conventions



- d_o = distance object is from mirror:
  - > 0: object in front of mirror
  - < 0: object behind mirror
- d_i = distance image is from mirror:
  - > 0: real image (in front of mirror)
  - < 0: virtual image (behind mirror)
- f = focal length mirror:
  - > 0: concave mirror $+R/2$
  - < 0: convex mirror $-R/2$
- h_o = height of object:
  - > 0: always
- h_i = height of image:
  - > 0: image is upright
  - < 0: image is inverted
- $|m|$ = magnification:
  - < 1: image is reduced
  - > 1: image is enlarged

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

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{8} - \frac{1}{24} = \frac{1}{12}$$

$$d_i = +12\,\text{cm}$$

Real image, in front of mirror

$$m = -\frac{d_i}{d_o} = -\frac{12}{24} = -\frac{1}{2}$$

Reduced image

$$h_i = m h_o = -3\,\text{cm}$$

Inverted image

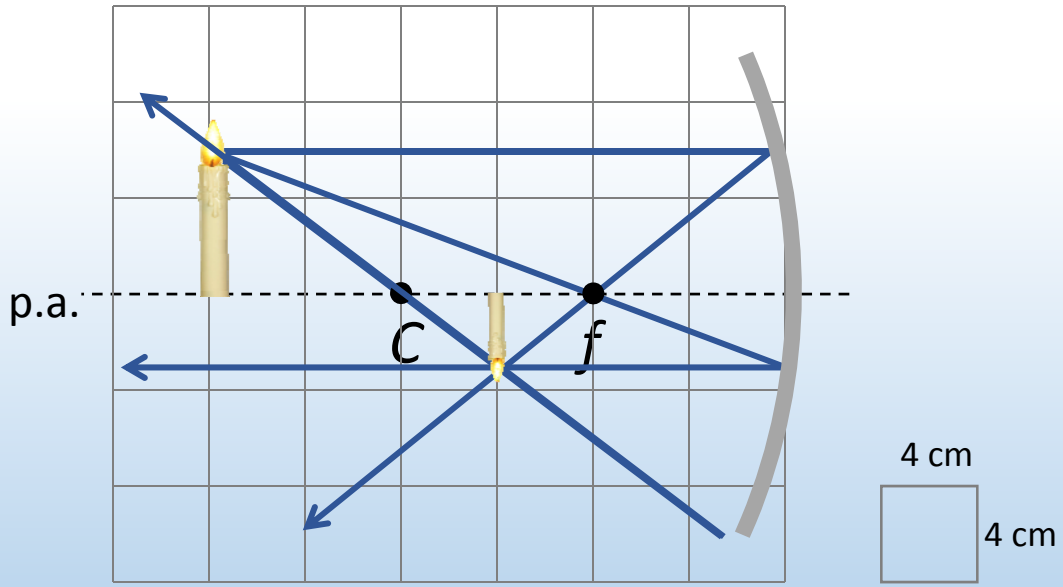
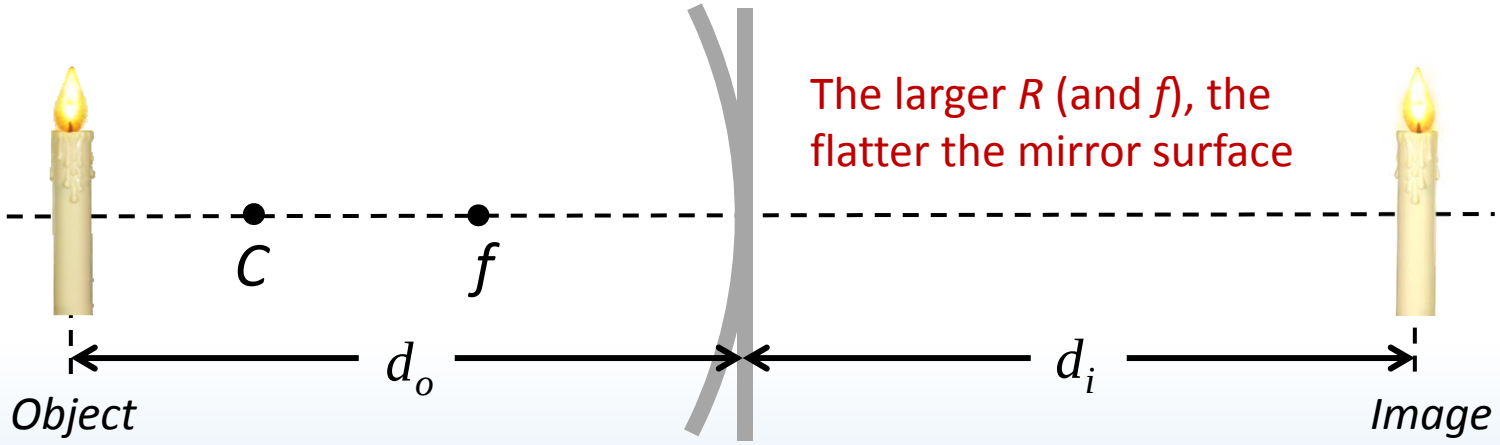


Diagram should agree!

ACT: Plane mirror

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



$$\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f} \qquad d_i=-d_o \qquad m\equiv\frac{h_i}{h_o}=-\frac{d_i}{d_o}=1$$

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:

35% A. Always Real

21% B. Always Virtual

43% C. Sometimes Real, Sometimes Virtual

Concave mirror: $f > 0$

Real object means in front of mirror: $d_o > 0$

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$

$f > 0$ for concave

$d_o > 0$

$d_i > 0$ (real image)

$d_i < 0$ (virtual image)

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

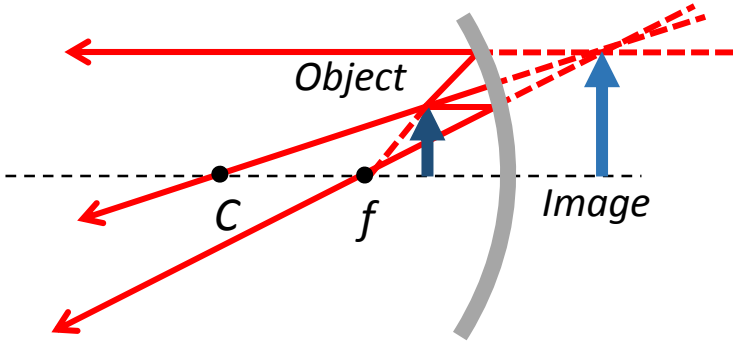
Concave mirror: $f > 0$
Real object means in front of mirror: $d_o > 0$

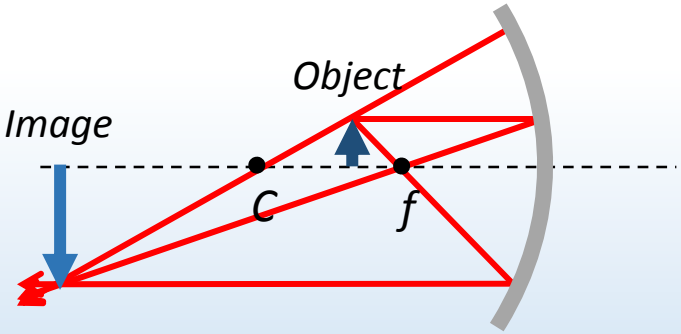
$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$

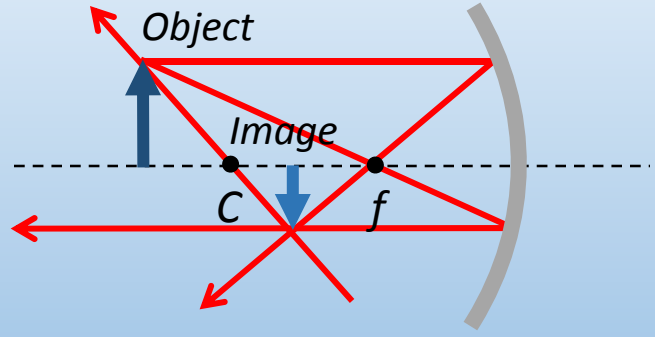
$d_i < 0$ (virtual image) when $1/f < 1/d_o$
OR: $d_o < f$

3 cases for concave mirrors

Object is:	Image is:
Inside *f*: $d_o < f$	Upright: $h_i > 0$ Enlarged: $m > 1$ Virtual: $d_i < 0$
Between *C* & *f*: $f < d_o < R$	Inverted: $h_i < 0$ Enlarged: $m > 1$ Real: $d_i > 0$
Past *C*: $R < d_o$	Inverted: $h_i < 0$ Reduced: $m < 1$ Real: $d_i > 0$







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Calculation: convex mirror

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

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{-6} - \frac{1}{12} = -\frac{1}{4}$$

$$d_i = -4\,\text{cm}$$

Virtual image, behind mirror

$$m = -\frac{d_i}{d_o} = -\frac{-4}{12} = +\frac{1}{3}$$

Reduced image

$$h_i = m h_o = +2\,\text{cm}$$

Upright image

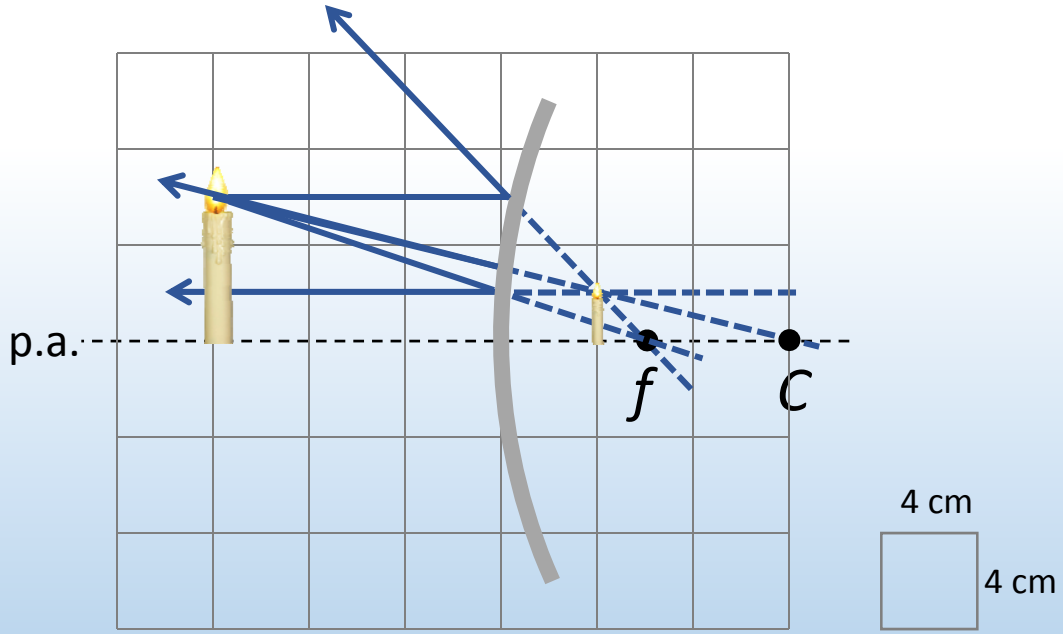


Diagram should agree!

Checkpoint 3.2

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

24% A. always real

50% B. always virtual

26% C. sometimes real and sometimes virtual

Convex mirror: $f < 0$

Real object means in front of mirror: $d_o > 0$

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$

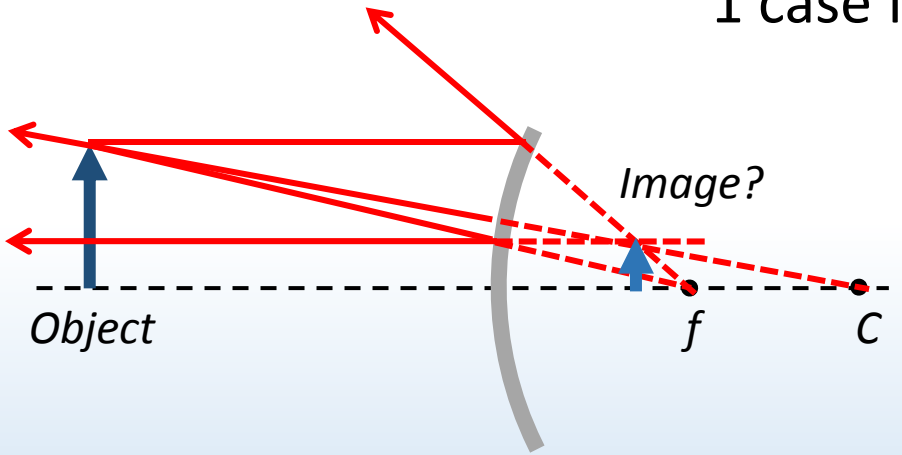
$d_i < 0$ (virtual image) always!

$f < 0$ for convex

$d_o > 0$

ACT: Convex mirror image

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



1 case for convex mirrors!

Image is:

Upright: $h_i > 0$

Reduced: $m < 1$

Virtual: $d_i < 0$

A. Always

B. Sometimes

C. Never

Object in front of mirror: $d_o > 0$

Convex mirror, image always virtual: $d_i < 0$

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

So, $m > 0$ and $h_i > 0$, always!

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

$$\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f} \qquad m \equiv \frac{h_i}{h_o}=-\frac{d_i}{d_o}$$