Your questions/comments

IMPORTANT ANNOUNCEMENT:
I will be out of town Monday-Tuesday, so no office hour (go to TAs office hour)
EXAM 2 results: mean = 65%, scaled = 75%

"I love the way this class is set up with pre-lectures and checkpoints, but I hate how the exams are set up because we basically lose those 2 weeks of material that is not on the exam, but taught before the exam. Now I have to go back and review everything :("

"Please review how, as distance decreases, what happens to the image (real, virtual, upright, inverted) for convex and concave (and if each one changes or not through all distances)."

"im confused on all things inverted/upright/virtual etc."

"The different ray diagrams were a little confusing."

"I hate mirrors."

Phys 102 – Lecture 18

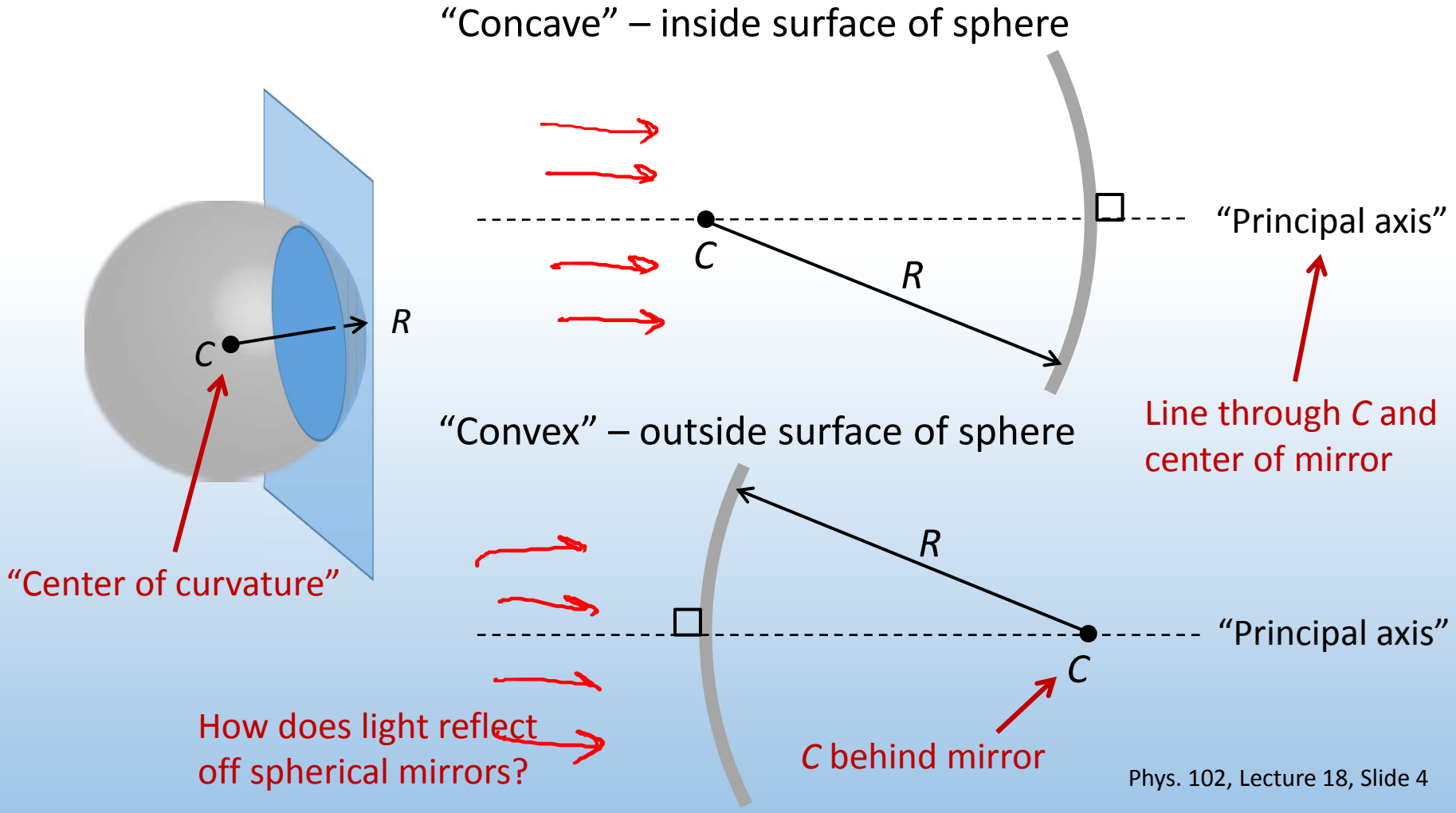
Spherical mirrors

Today we will...

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

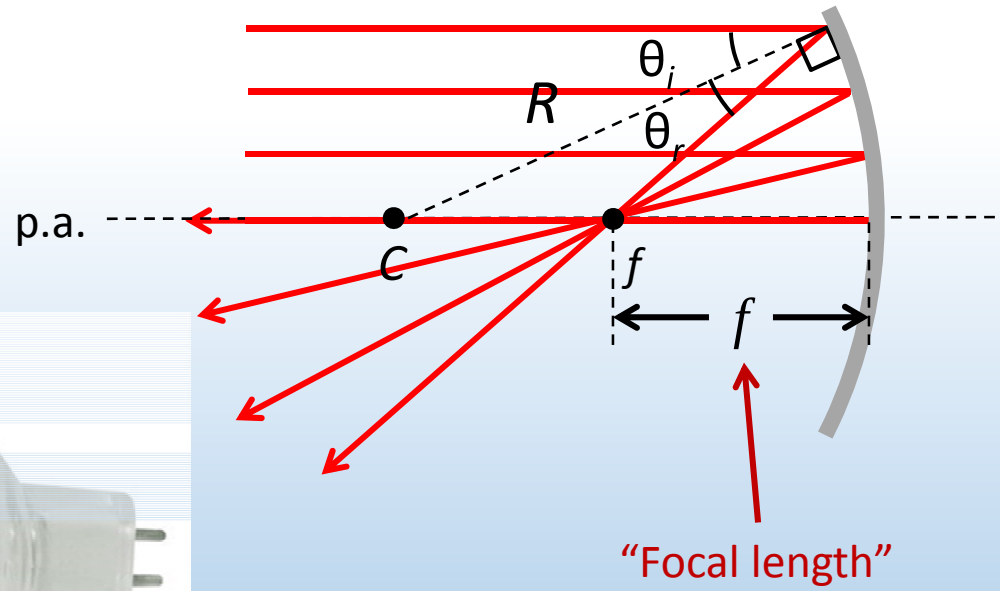
Curved mirrors

Spherical mirror – section of a sphere



Concave mirror reflection

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

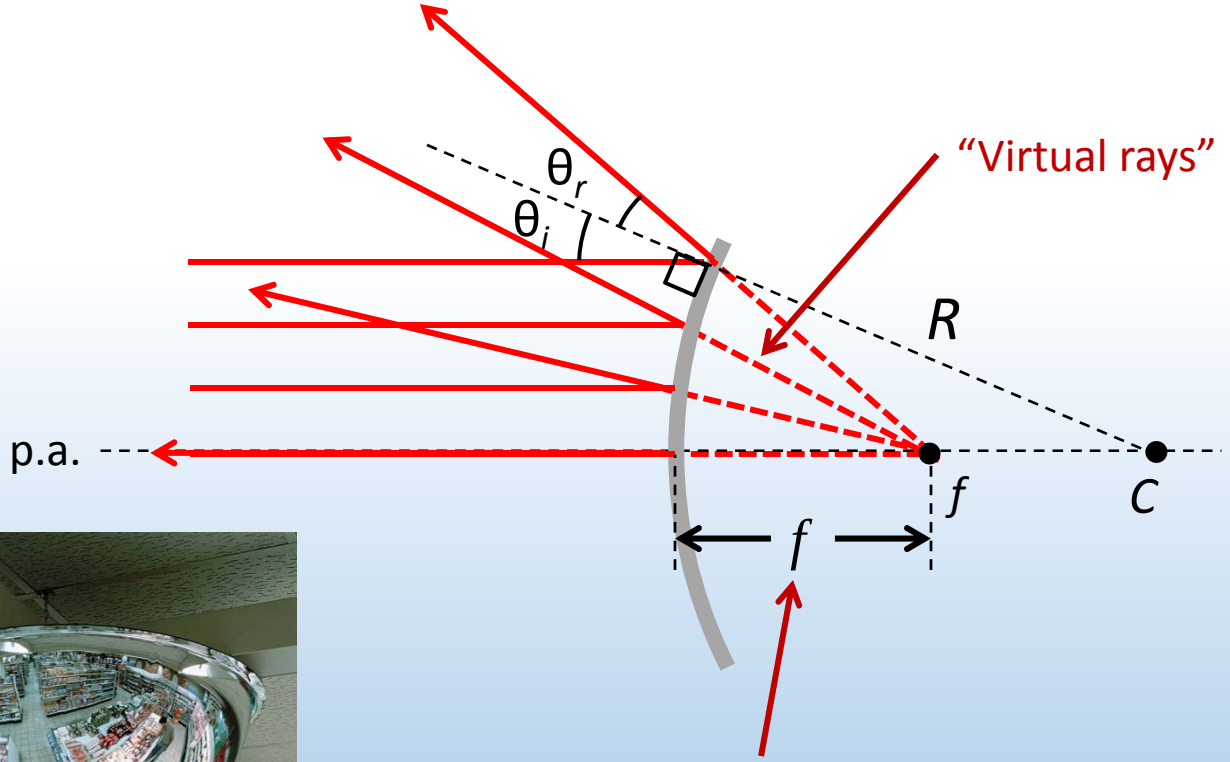


$$f = \frac{R}{2}$$

DEMO

Convex mirror reflection

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



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

Since *f* is behind mirror, focal length < 0

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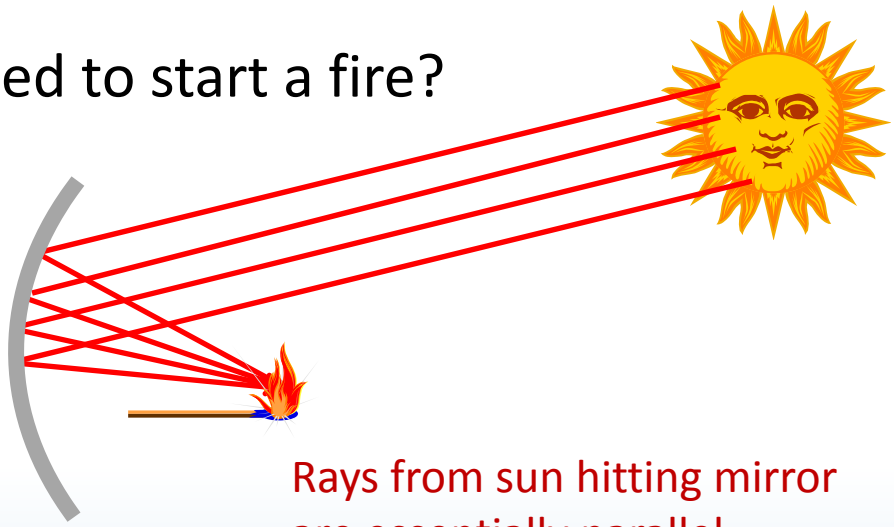
ACT: CheckPoint 1.1 & 1.2

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

70% A. Concave

28% B. Convex

2% C. Plane



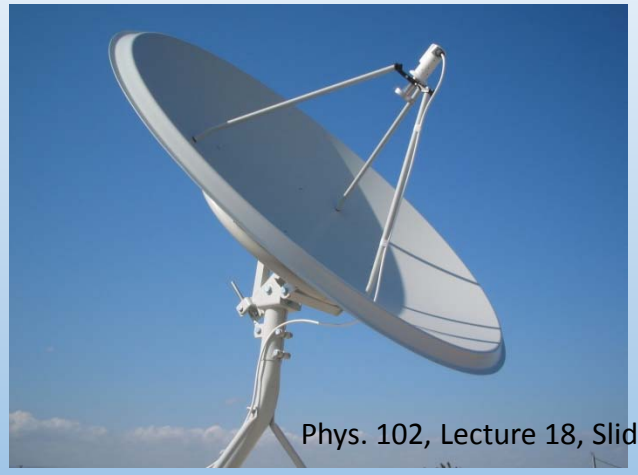
Rays from sun hitting mirror are essentially parallel

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

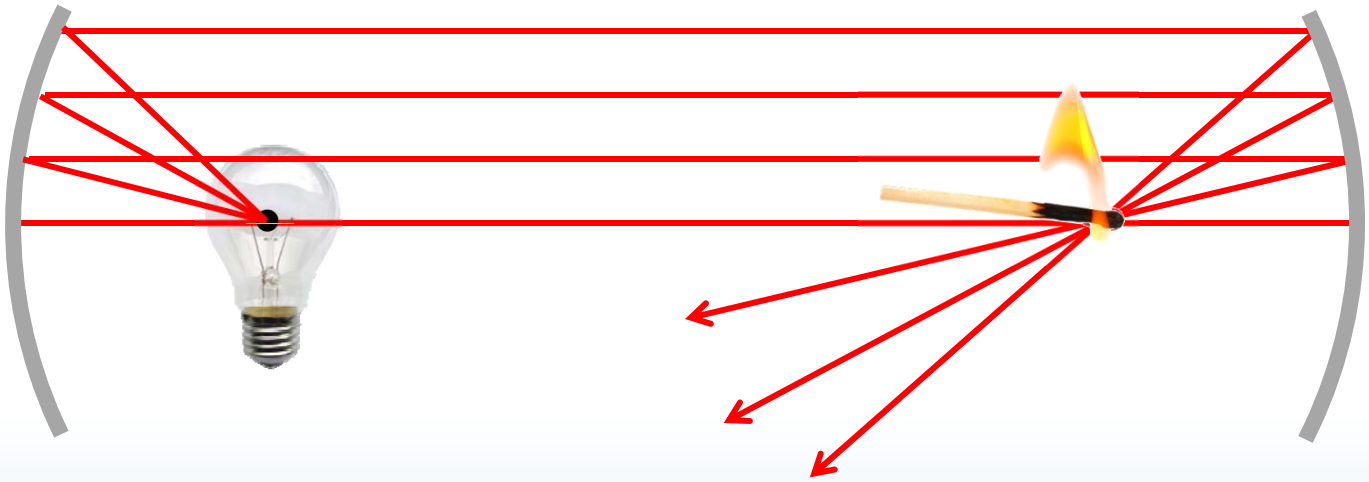
18% A. farther than the focal length

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*

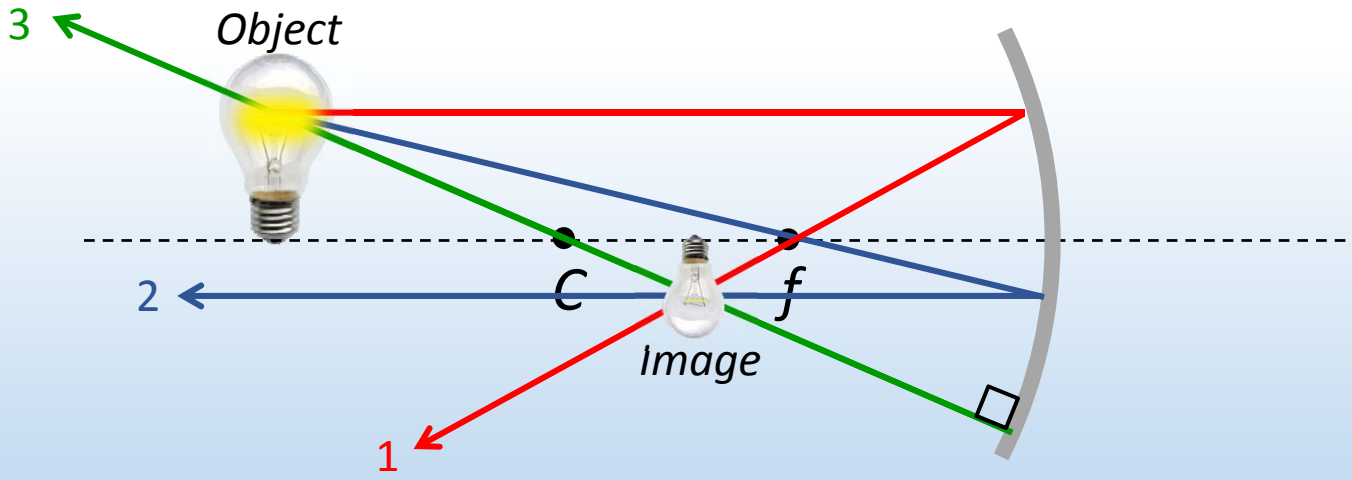


Image is:

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*

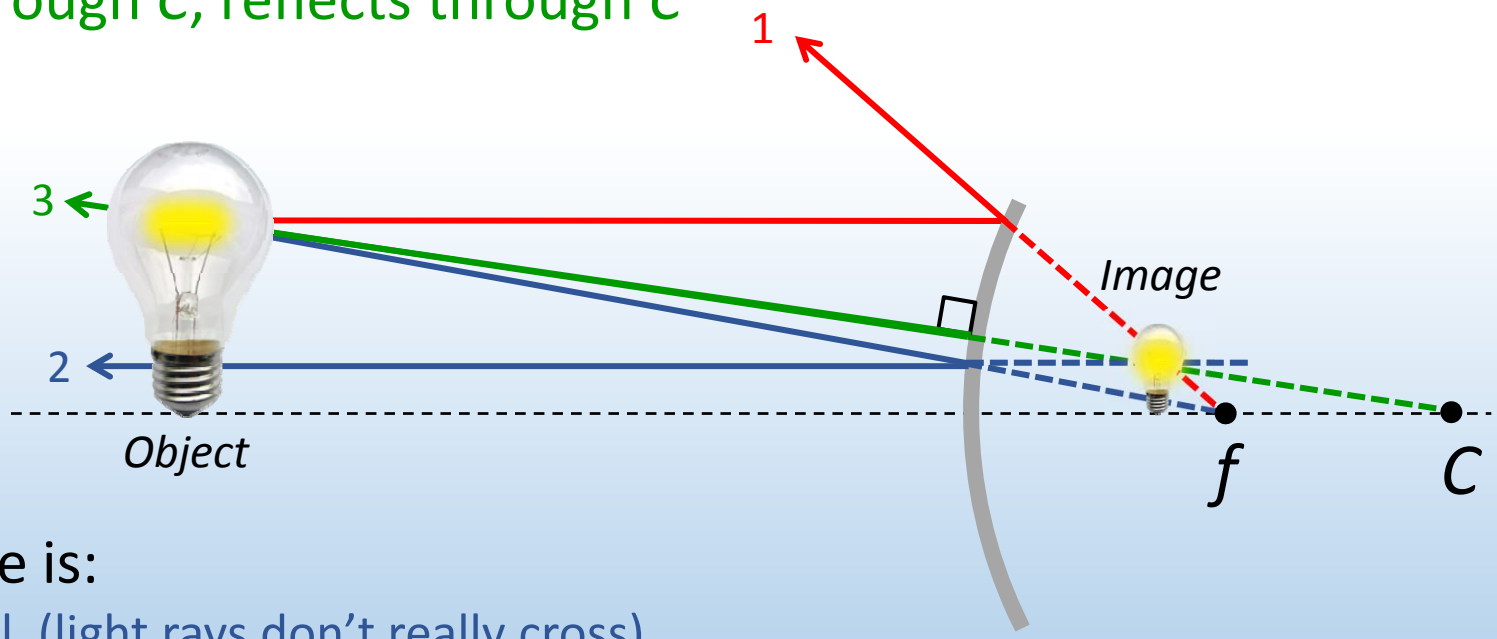
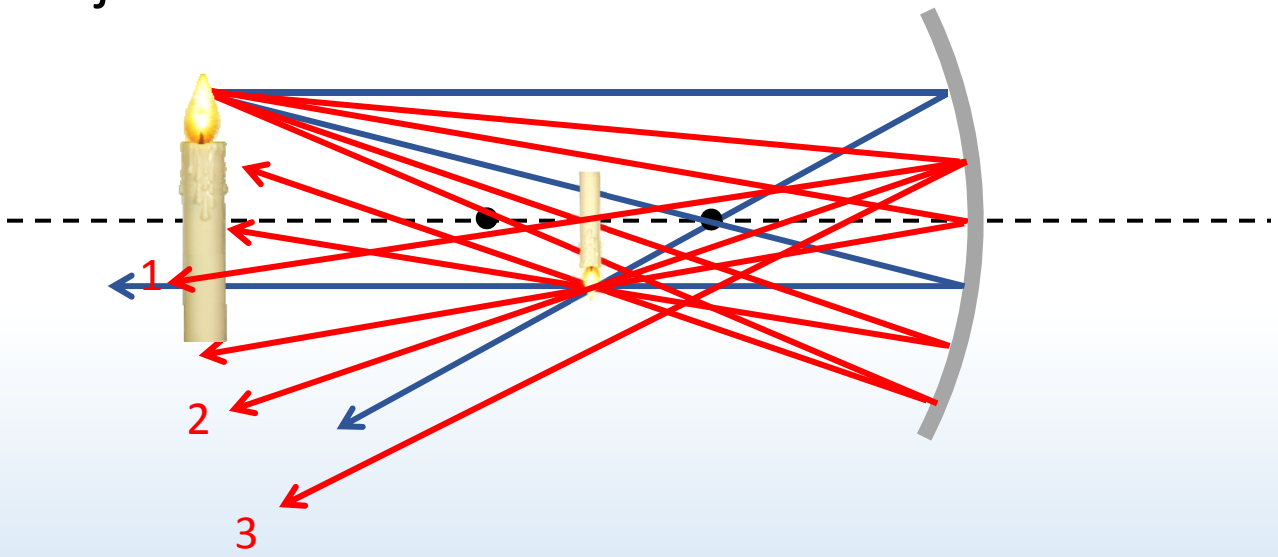


Image is:

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

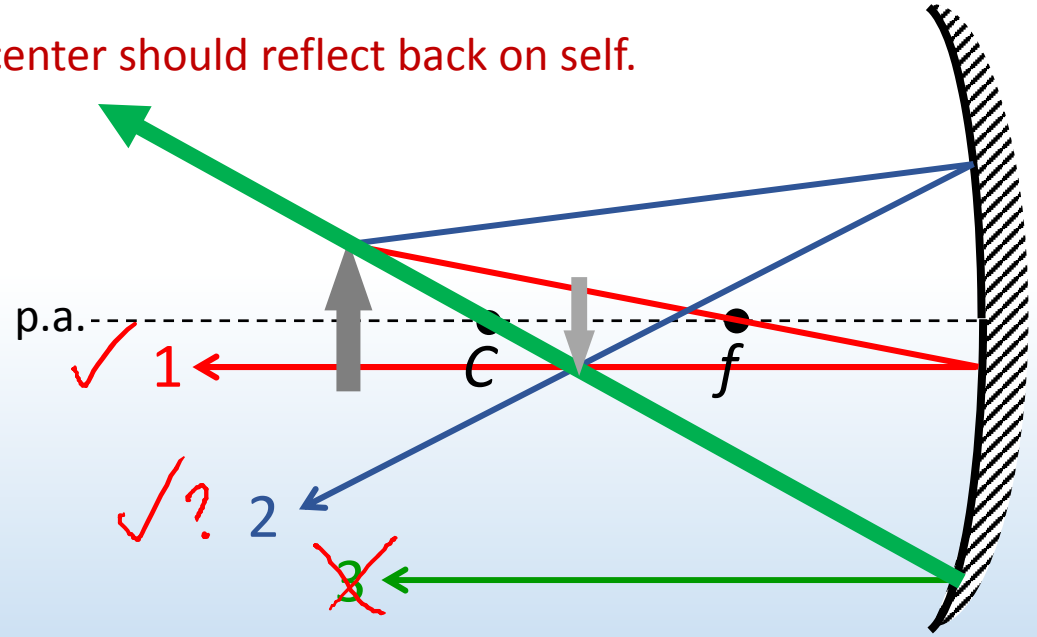
Every ray from *every* point on object is reflected onto corresponding point on image

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

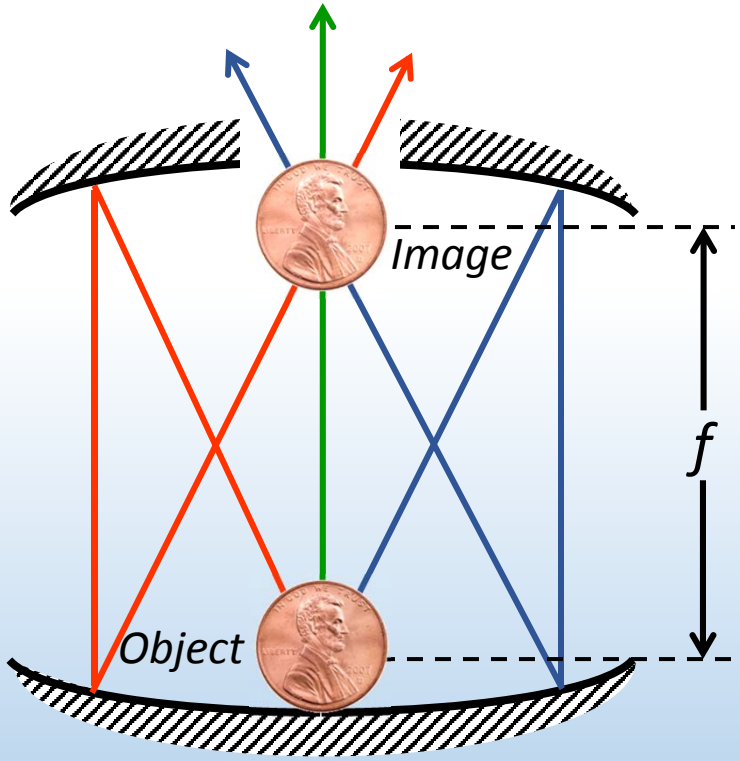
36% C. 3

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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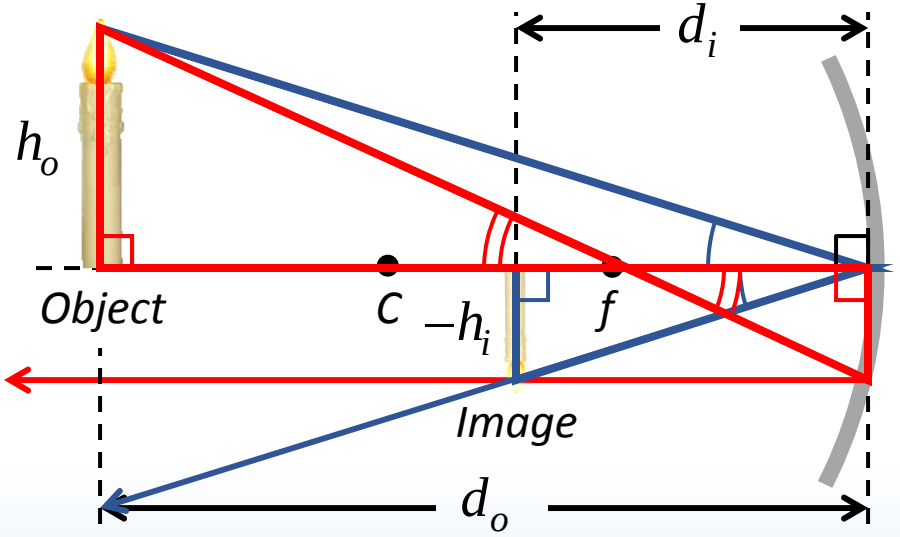
Mirror & magnification equations



Mirror equation

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

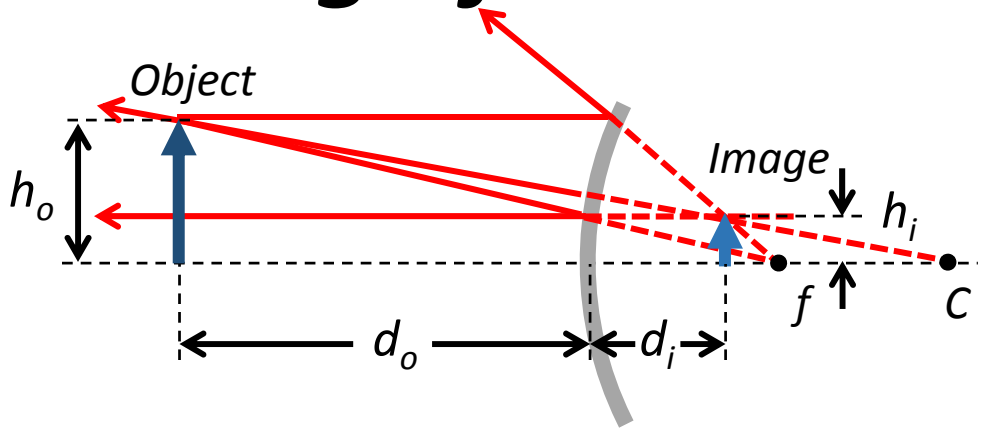
Magnification

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

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

- h_o = height of object:
  - > 0: always

- d_i = distance image is from mirror:
  - > 0: real image (in front of mirror)
  - < 0: virtual image (behind mirror)

- h_i = height of image:
  - > 0: image is upright
  - < 0: image is inverted

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

- $|m|$ = magnification: $= \frac{h_i}{h_o}$
  - < 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

in front of mirror → "real"

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

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

Real image, in front of mirror

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

Reduced image

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

Inverted image

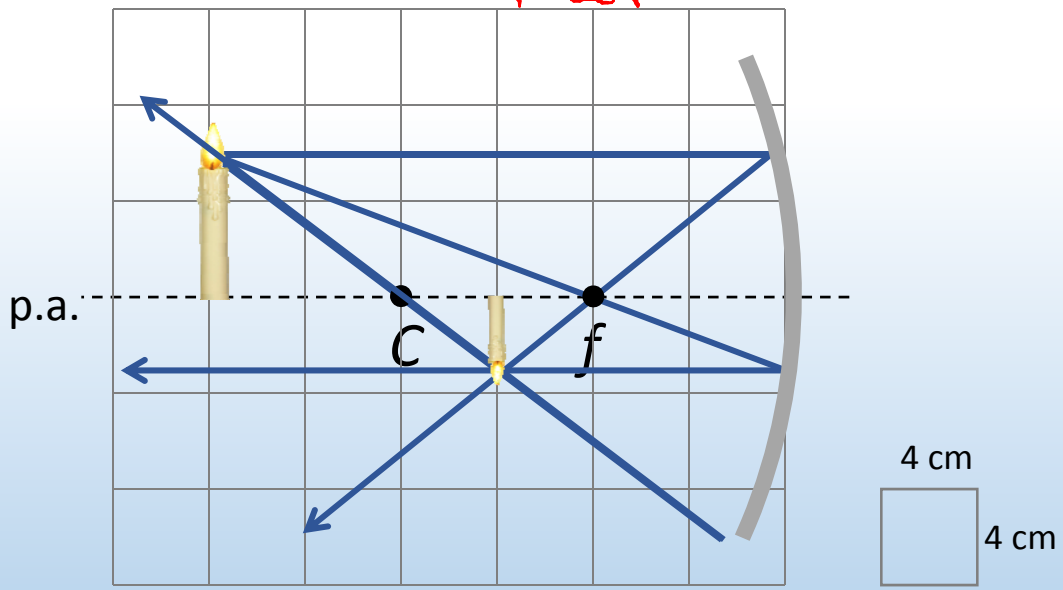
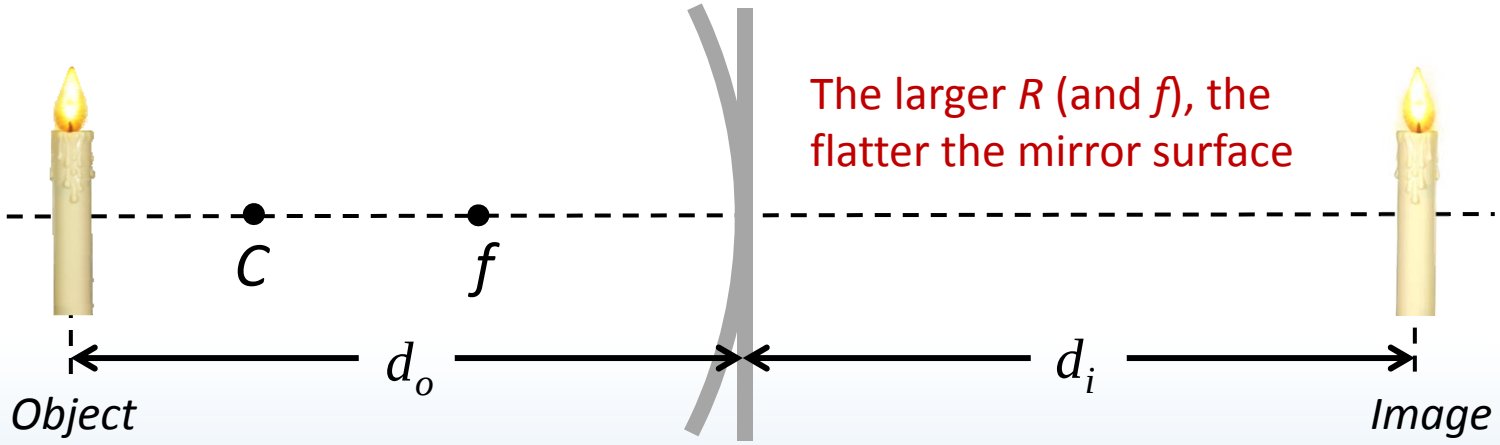


Diagram should agree!

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:

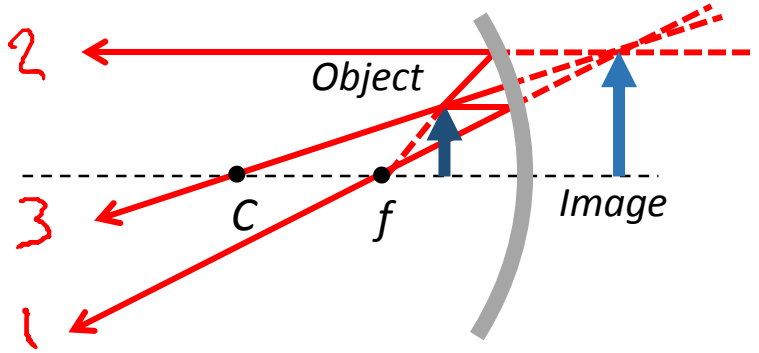
Inside *f*:

$d_o < f$

Upright: $h_i > 0$

Enlarged: $m > 1$

Virtual: $d_i < 0$



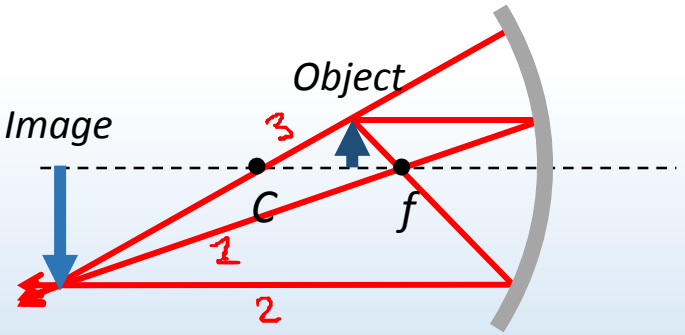
Between *C* & *f*:

$f < d_o < R$

Inverted: $h_i < 0$

Enlarged: $m > 1$

Real: $d_i > 0$



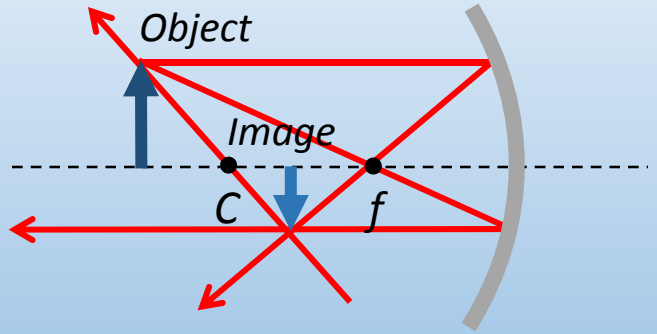
Past *C*:

$R < d_o$

Inverted: $h_i < 0$

Reduced: $m < 1$

Real: $d_i > 0$



DEMO

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

behind mirror "virtual"

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

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

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

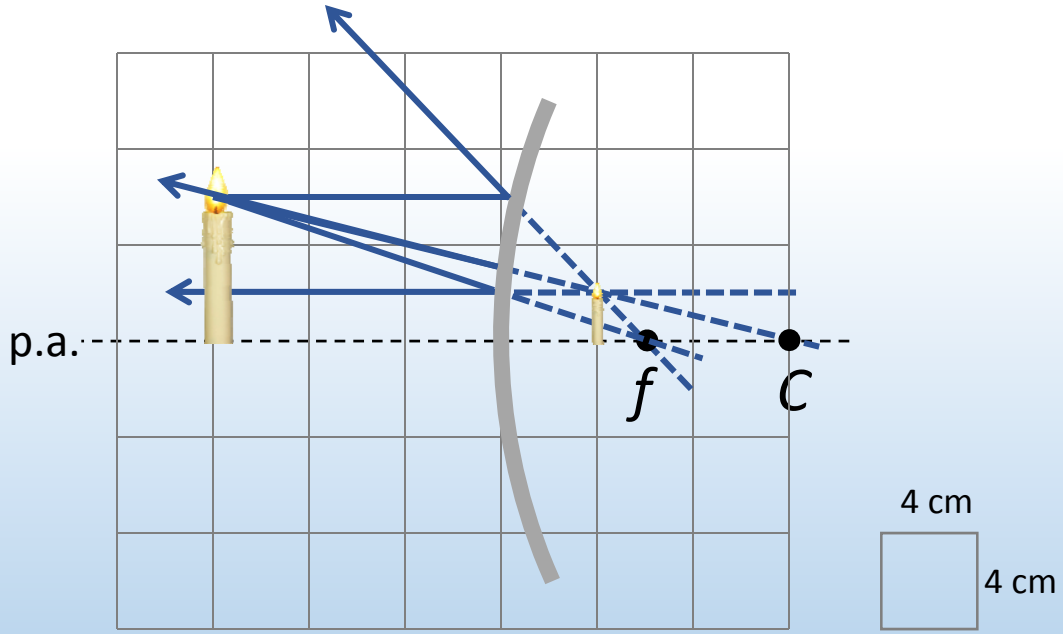


Diagram should agree!

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: $d_o > 0$

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

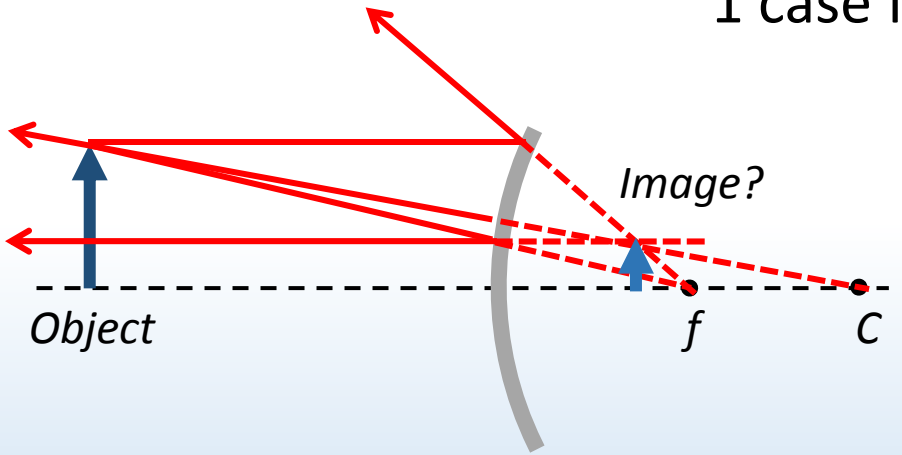
$d_i < 0$ (virtual image) always!

$f < 0$ 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

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