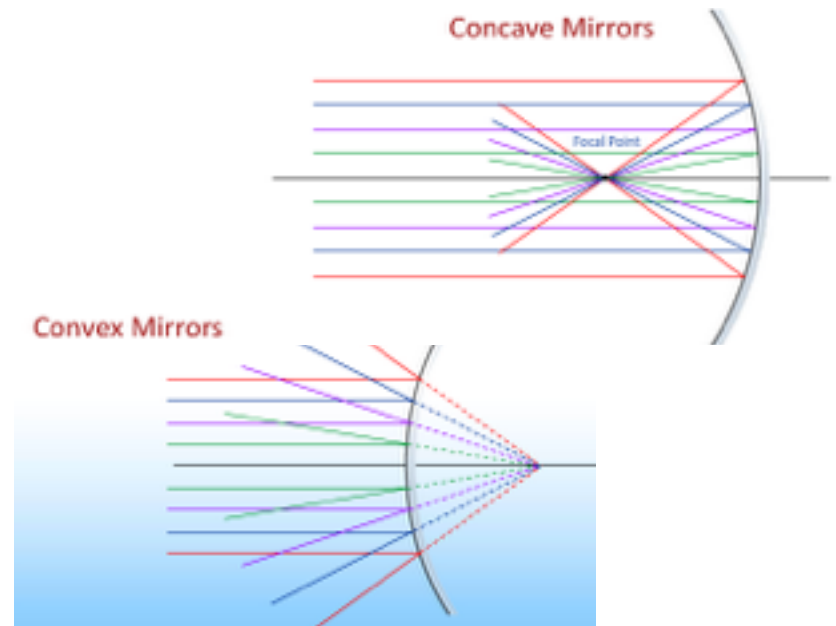


# Physics 121

## Lecture 27

Today's Concept:

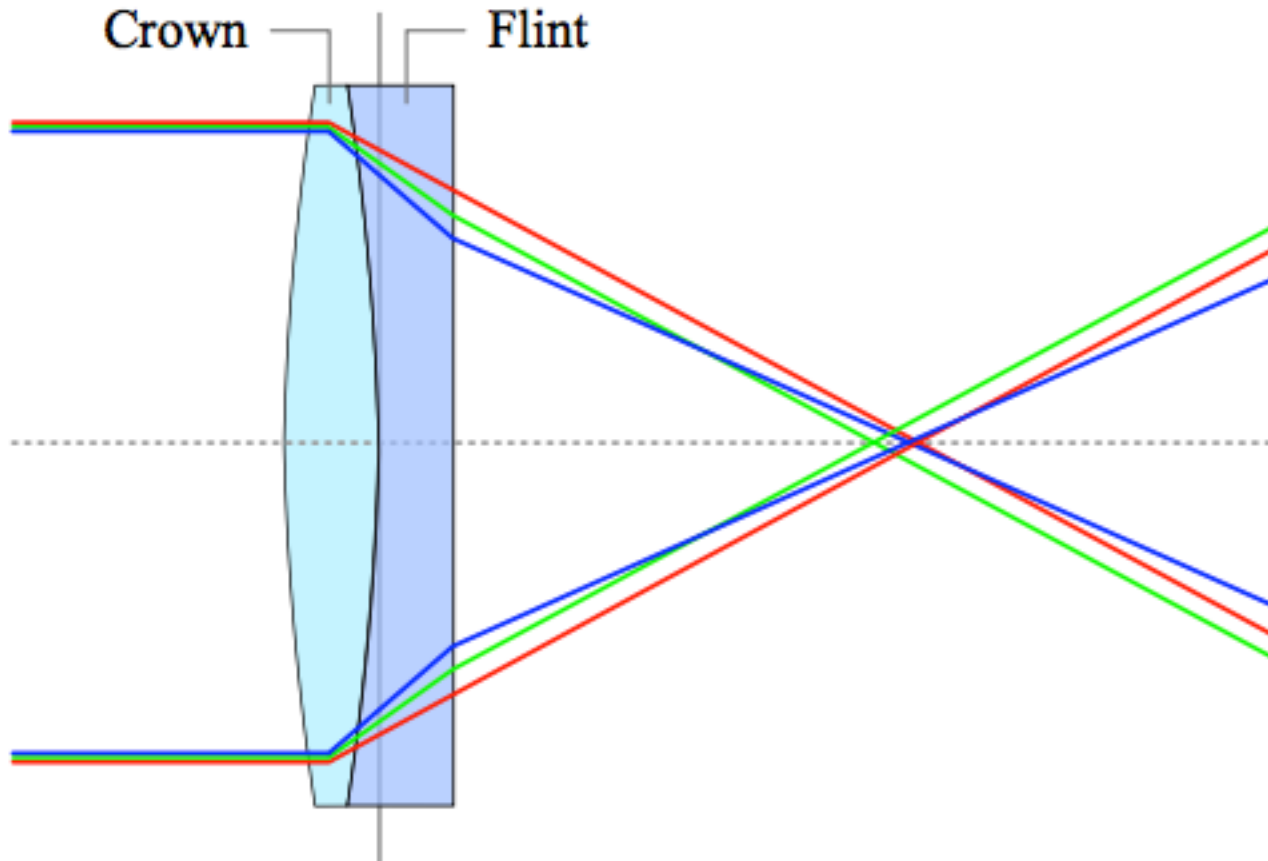
A) Mirrors



# *Your Question*

If white light refracts into a spectrum through a lens, then how can a camera take a colour picture properly, preserving the position of different coloured pixels as they are focused?

Achromatic doublet



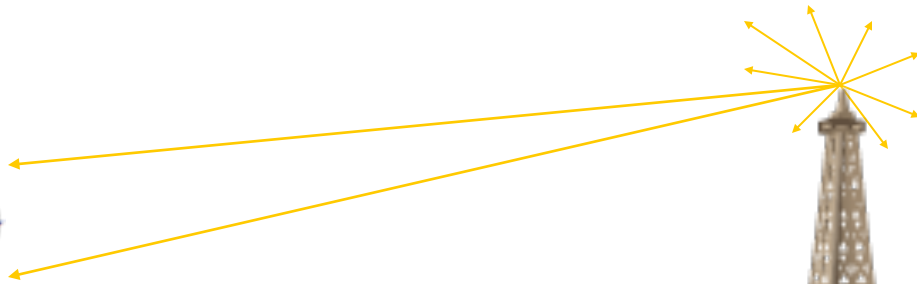
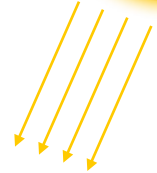
# Object Location

Light rays from sun bounce off object and go in all directions

- Some hits your eyes



We know object's location by where rays come from.



We will discuss eyes in lecture 28...

Since we're in the optics unit, can you please explain the phenomenon of crescent shaped shadows during the total solar eclipse? I held up a strainer when it happened, and instead of getting circle shaped shadows, I got weird crescents. It was pretty creepy.

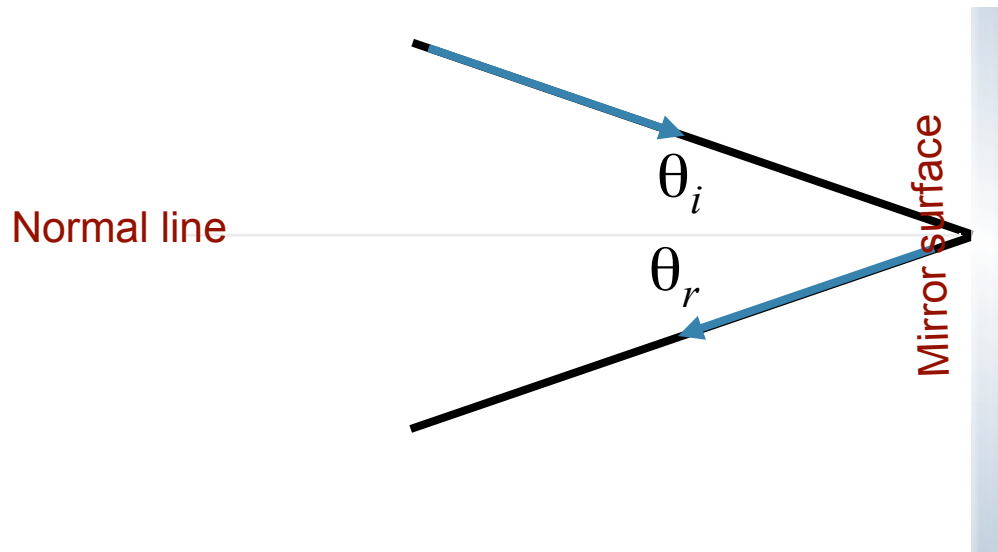
- [Bob Miller's Light Walk](#)



# Reflection

Angle of incidence = Angle of reflection

$$\theta_i = \theta_r$$

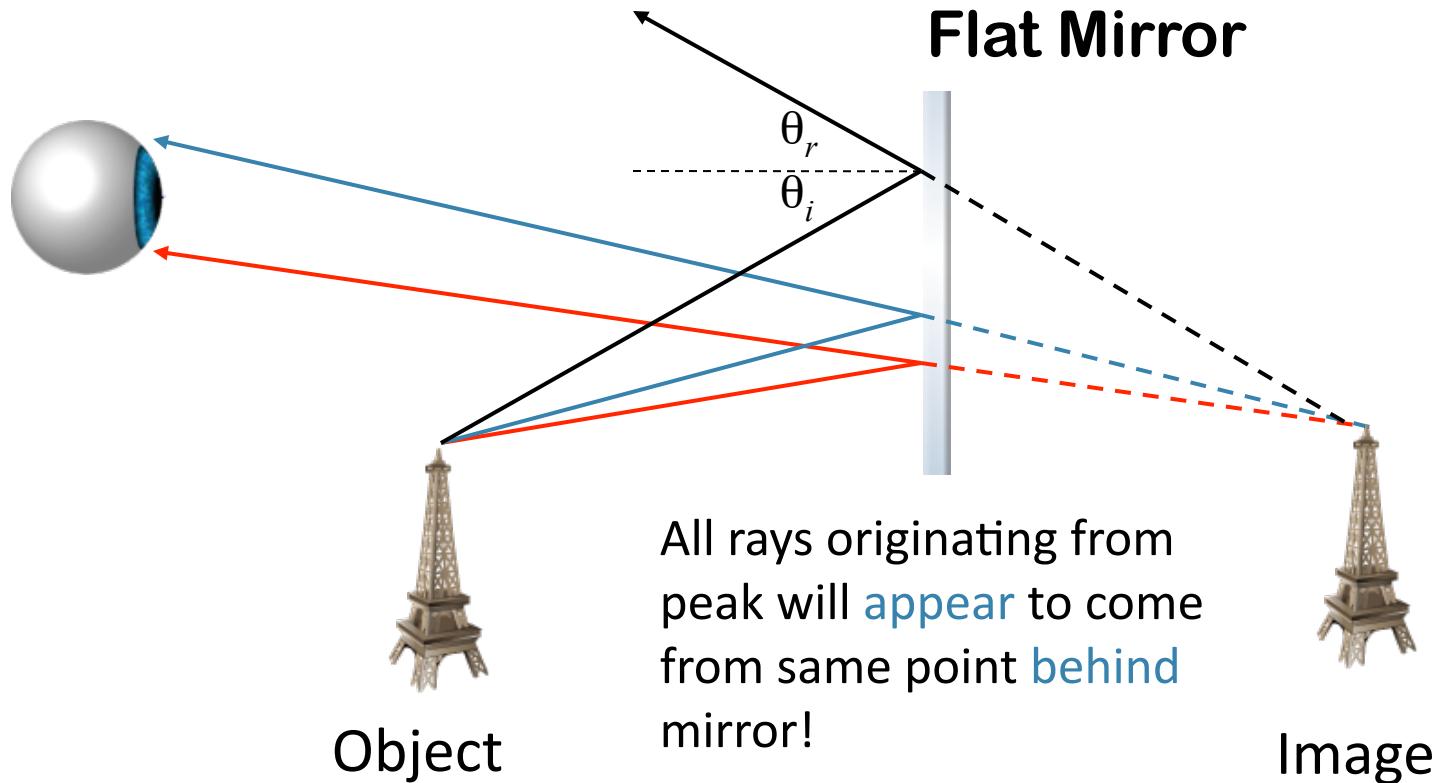


That's all of the physics – everything else is just geometry!

# Flat Mirror

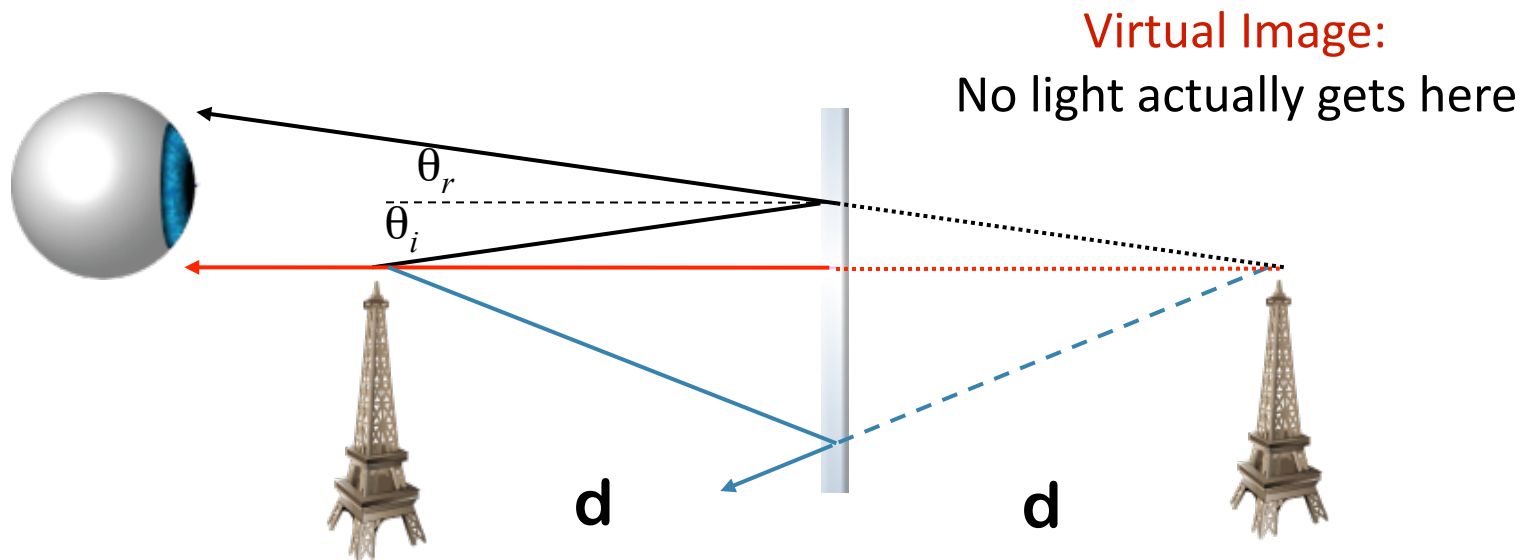
All you see is what reaches your eyes

You think object's location is where rays **appear** to come from.



# Flat Mirror

- 1) Draw first ray perpendicular to mirror  $0 = \theta_i = \theta_r$
- 2) Draw second ray at angle.  $\theta_i = \theta_r$
- 3) Lines appear to intersect a distance  $d$  behind mirror. This is the image location.



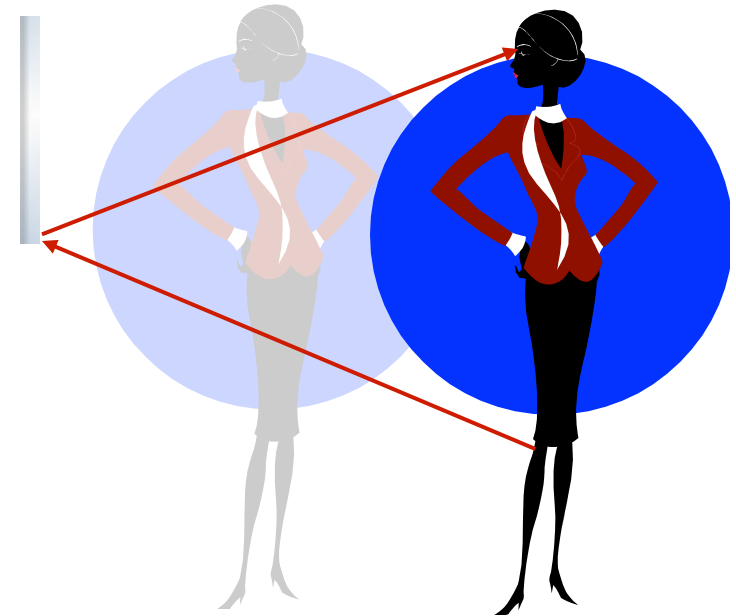
# Clicker Question



A woman is looking at her reflection in a flat vertical mirror.  
The lowest part of her body she can see is her knee.

If she stands **closer to the mirror**, what will be the lowest part of her reflection she can see in the mirror.

- A) Above her knee
- B) Her knee
- C) Below her knee



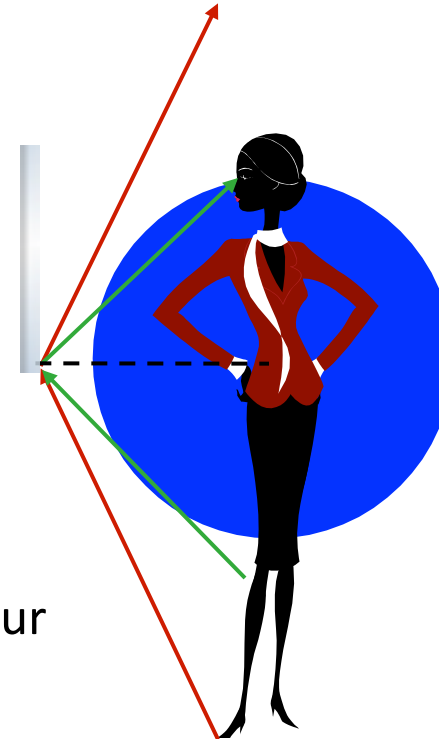


# Clicker Question



A woman is looking at her reflection in a flat vertical mirror. The lowest part of her body she can see is her knee. If she stands **closer to the mirror**, what will be the lowest part of her reflection she can see in the mirror.

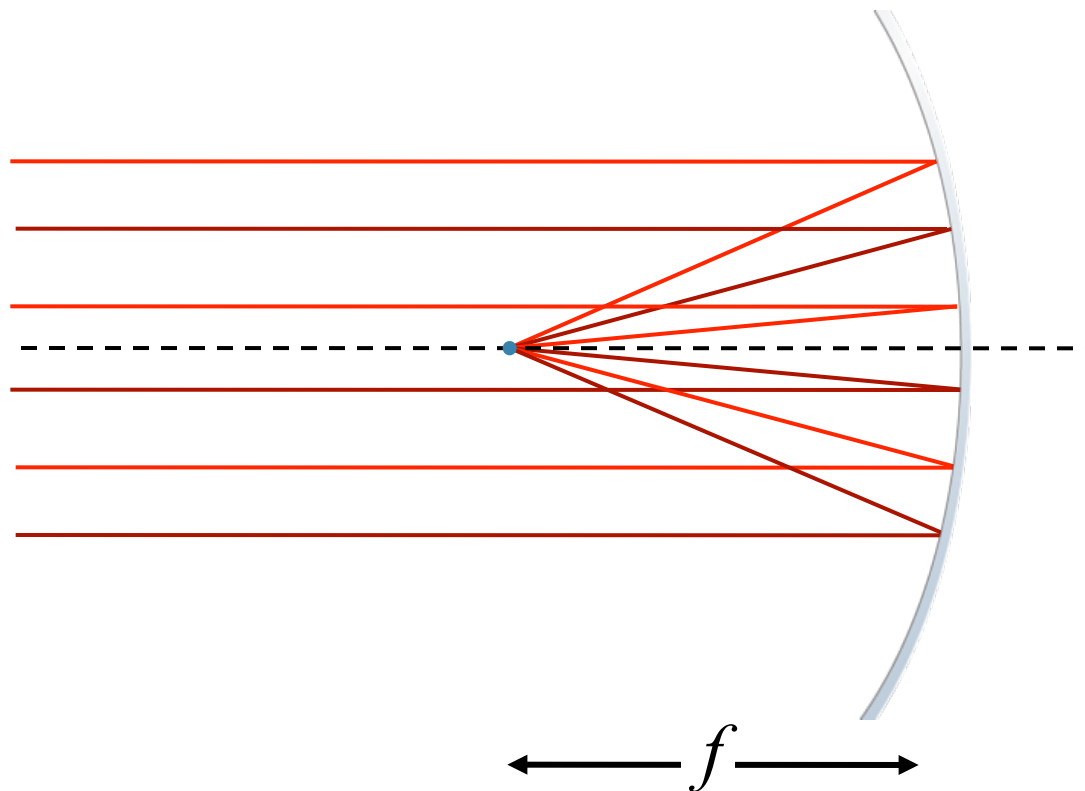
- A) Above her knee
- ☒ B) Her knee
- C) Below her knee



If the light doesn't get to your eye then you can't see it

**Concave:** Consider the case where the shape of the mirror is such that light rays parallel to the axis of the mirror are all “focused” to a common spot a distance  $f$  in front of the mirror:

Note: analogous to “converging lens”  
Real object can produce real image

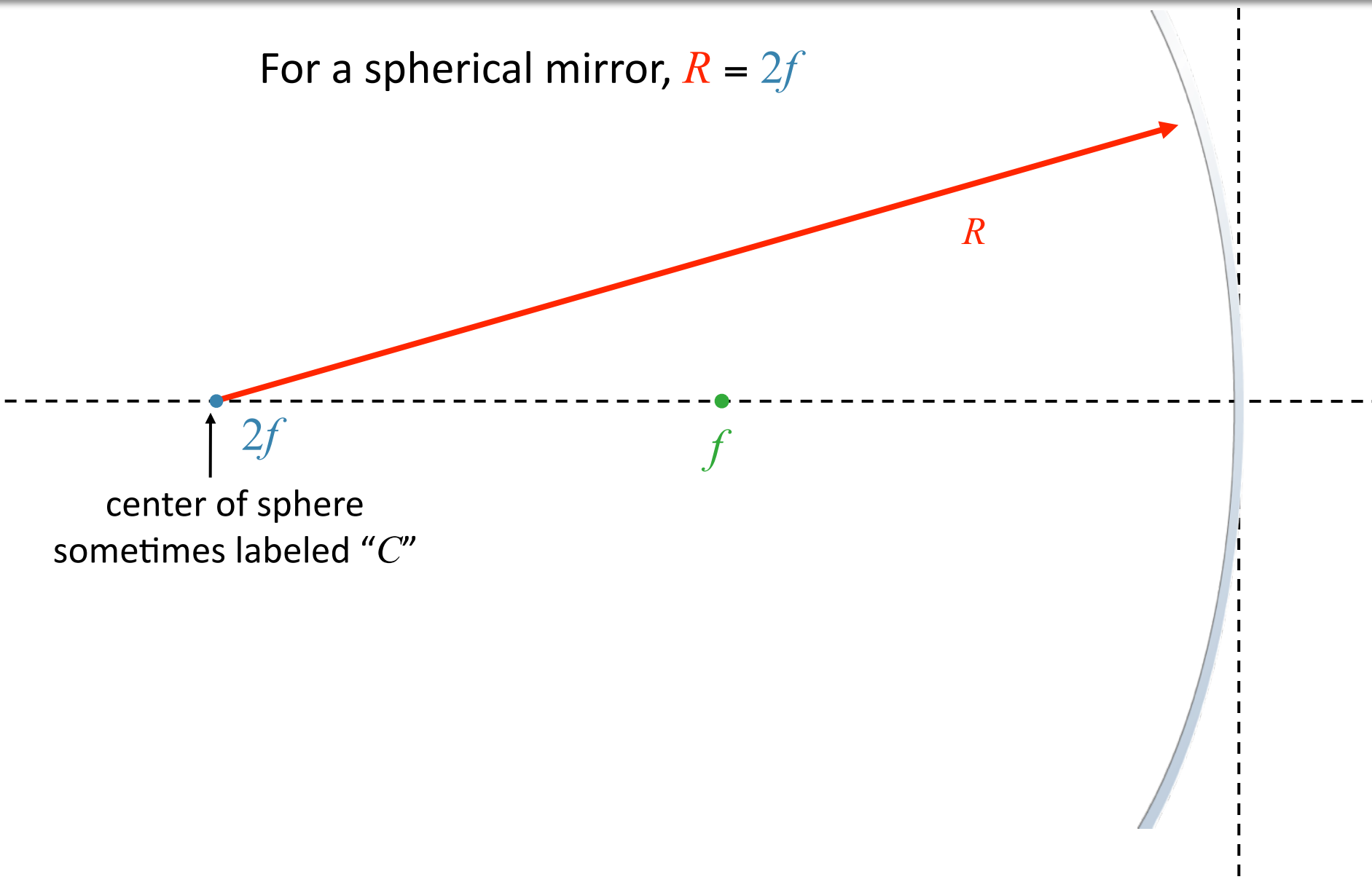


These mirrors are often sections of spheres (assumed in this class).

For such “spherical” mirrors, we assume all angles are small even though we draw them big to make it easy to see...

## Aside:

For a spherical mirror,  $R = 2f$

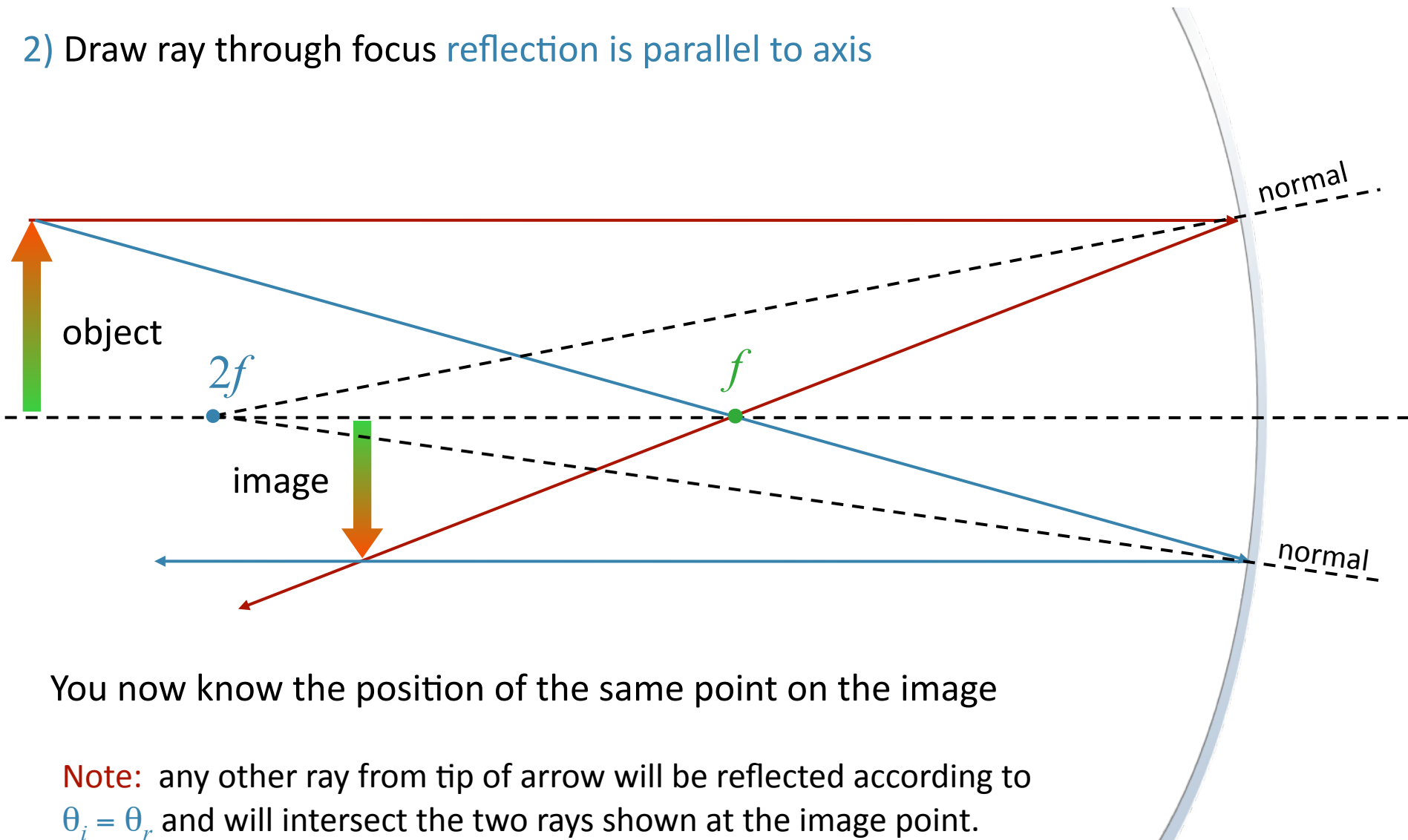


The diagram illustrates the geometry of a spherical mirror. A horizontal dashed line represents the principal axis. A blue dot on this axis is labeled  $2f$  with an upward arrow. Below it, text reads "center of sphere sometimes labeled 'C'". A green dot further to the right is labeled  $f$ . A red arrow, labeled  $R$ , originates from the blue dot and points to the mirror's surface. The mirror is a concave arc on the right, with a vertical dashed line tangent to its vertex.

center of sphere  
sometimes labeled "C"

# Recipe for Finding Image:

- 1) Draw ray parallel to axis reflection goes through focus
- 2) Draw ray through focus reflection is parallel to axis



You now know the position of the same point on the image

**Note:** any other ray from tip of arrow will be reflected according to  $\theta_i = \theta_r$  and will intersect the two rays shown at the image point.

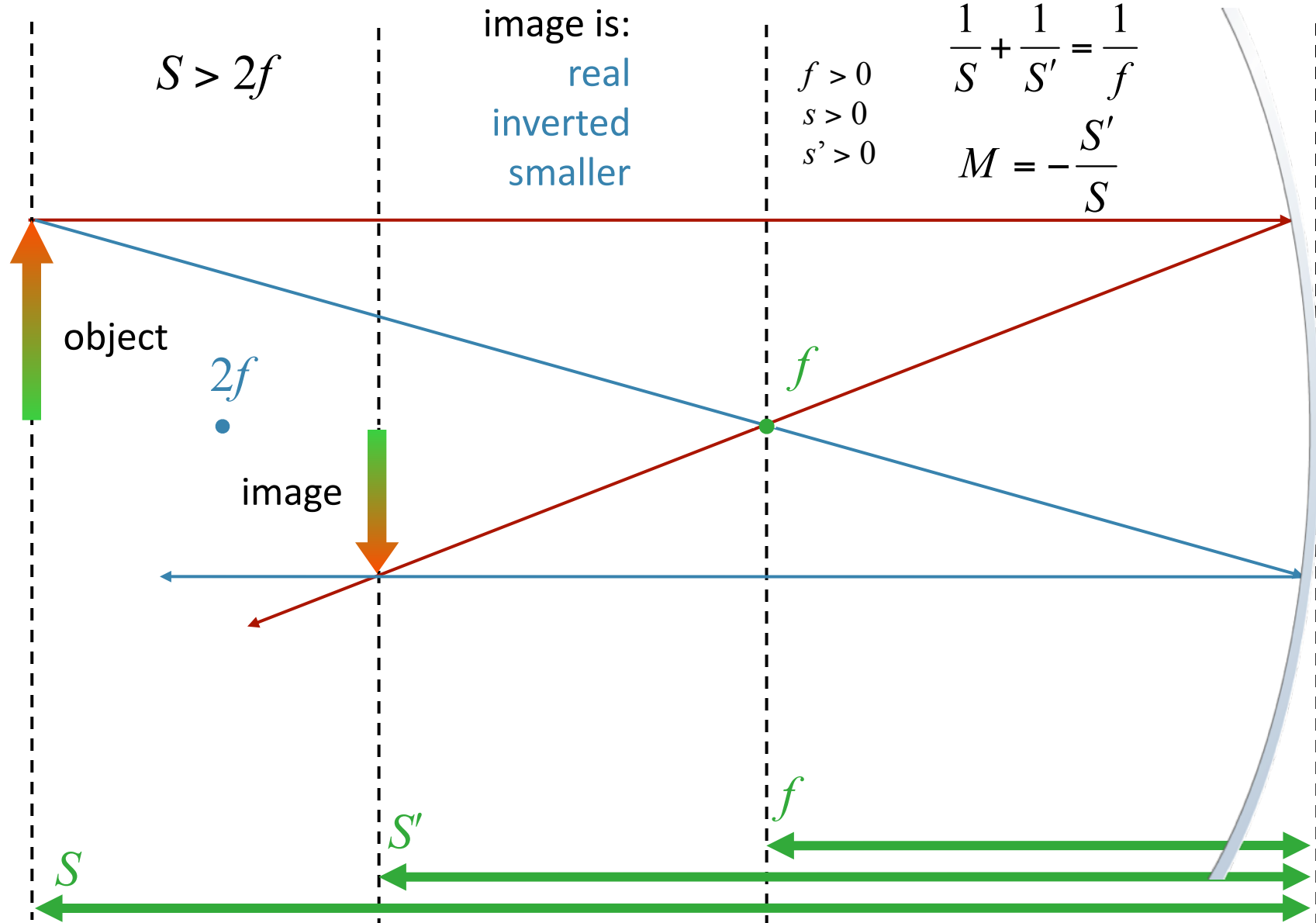
$$S > 2f$$

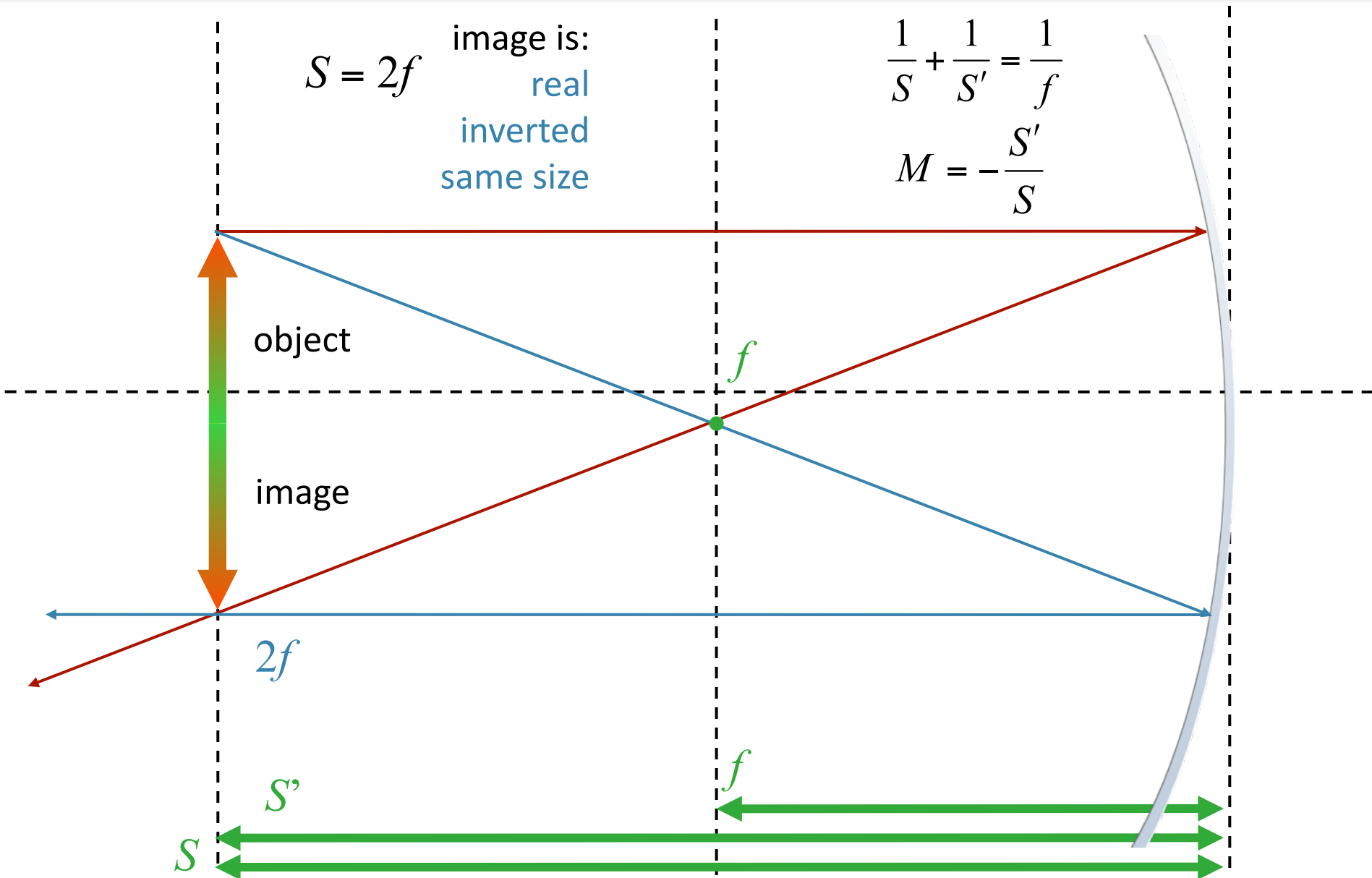
image is:  
real  
inverted  
smaller

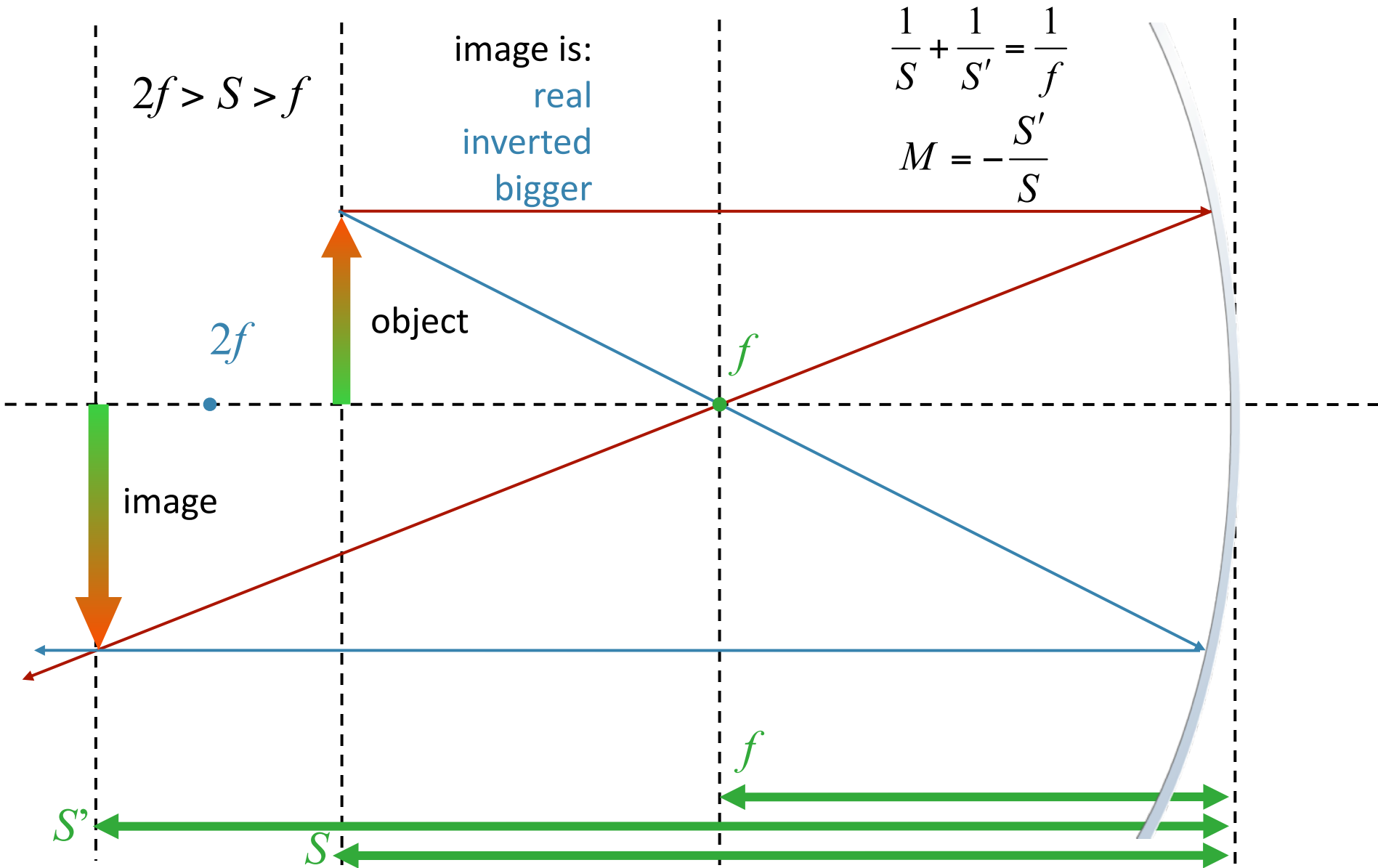
$$\begin{aligned} f &> 0 \\ s &> 0 \\ s' &> 0 \end{aligned}$$

$$\frac{1}{S} + \frac{1}{S'} = \frac{1}{f}$$

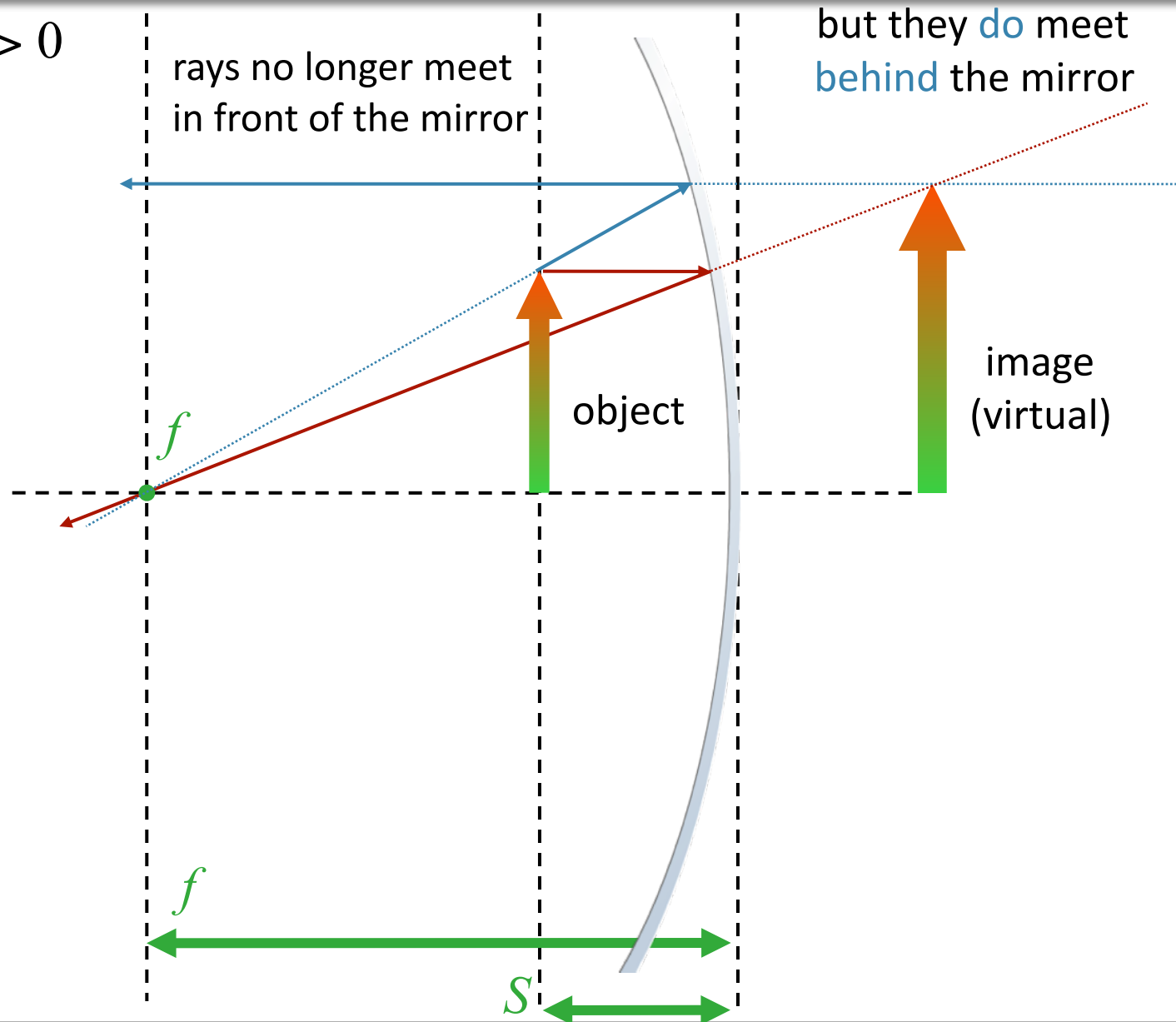
$$M = -\frac{S'}{S}$$







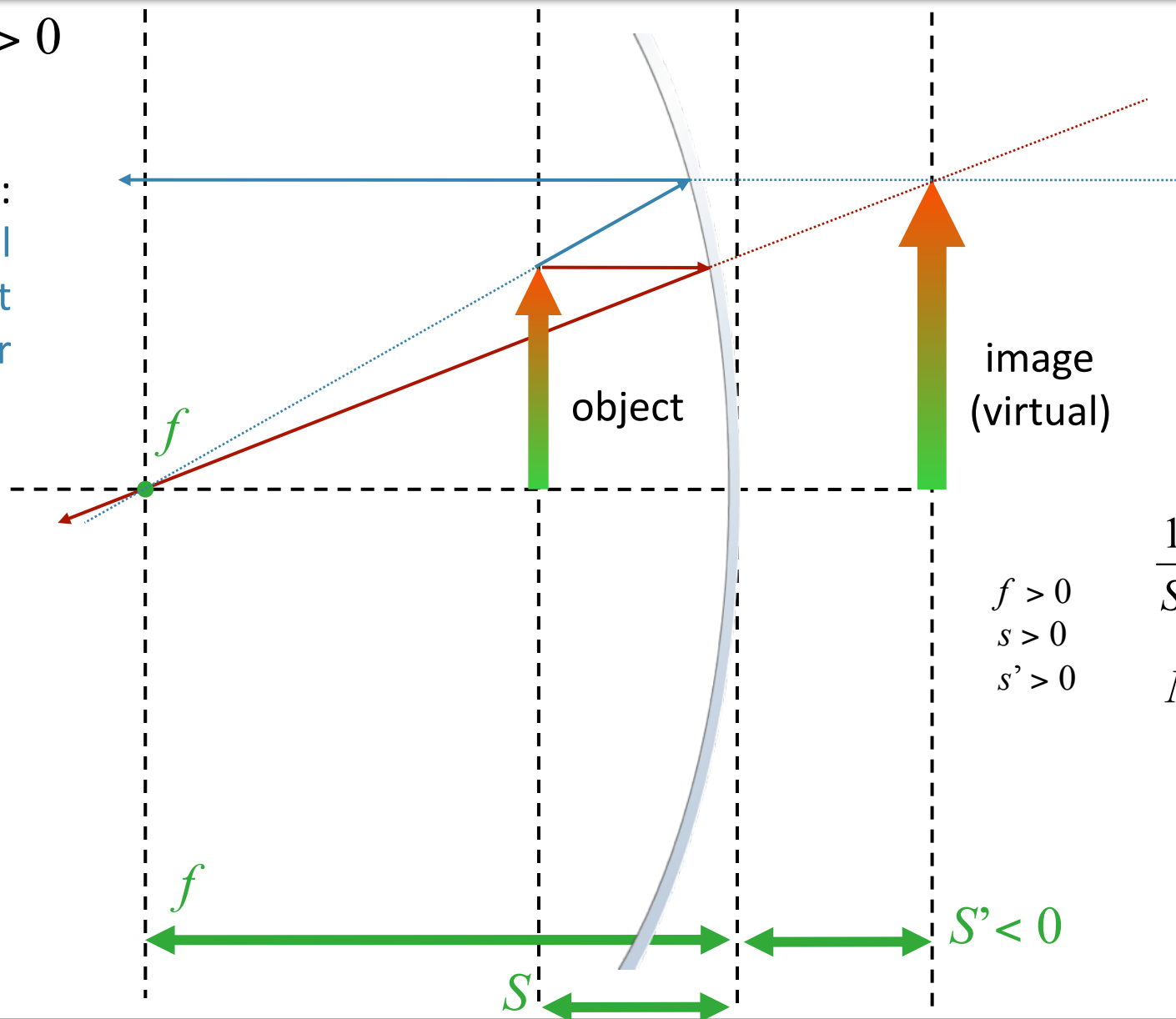
$$f > S > 0$$





$$f > S > 0$$

image is:  
virtual  
upright  
bigger



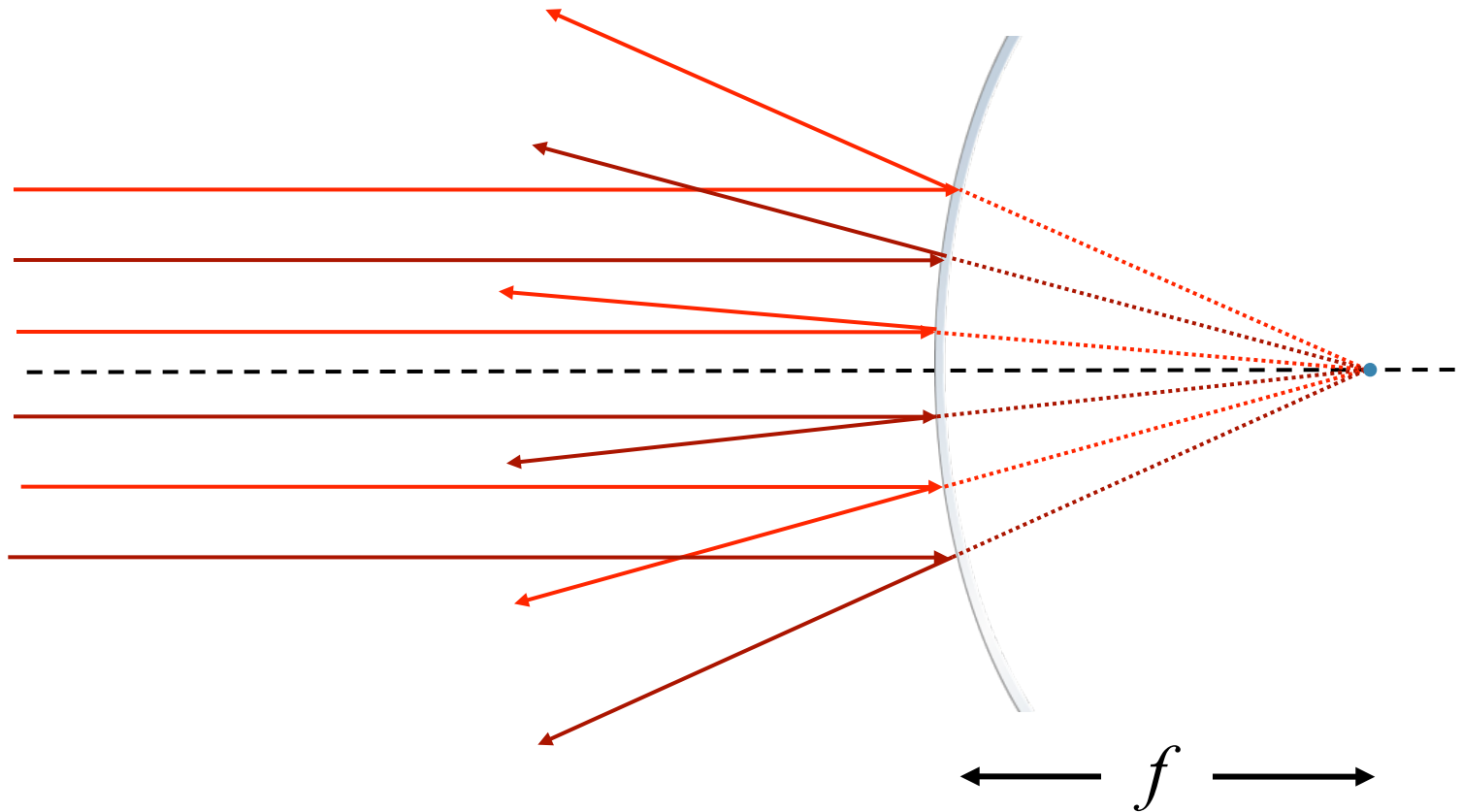
$$\frac{1}{S} + \frac{1}{S'} = \frac{1}{f}$$

$$M = -\frac{S'}{S}$$

$f > 0$   
 $s > 0$   
 $s' > 0$

**Convex:** Consider the case where the shape of the mirror is such that light rays parallel to the axis of the mirror are all “focused” to a common spot a distance  $f$  behind the mirror:

**Note:** analogous to “diverging lens”  
Real object will produce virtual image



*You will also get Images from Curved Mirrors:*



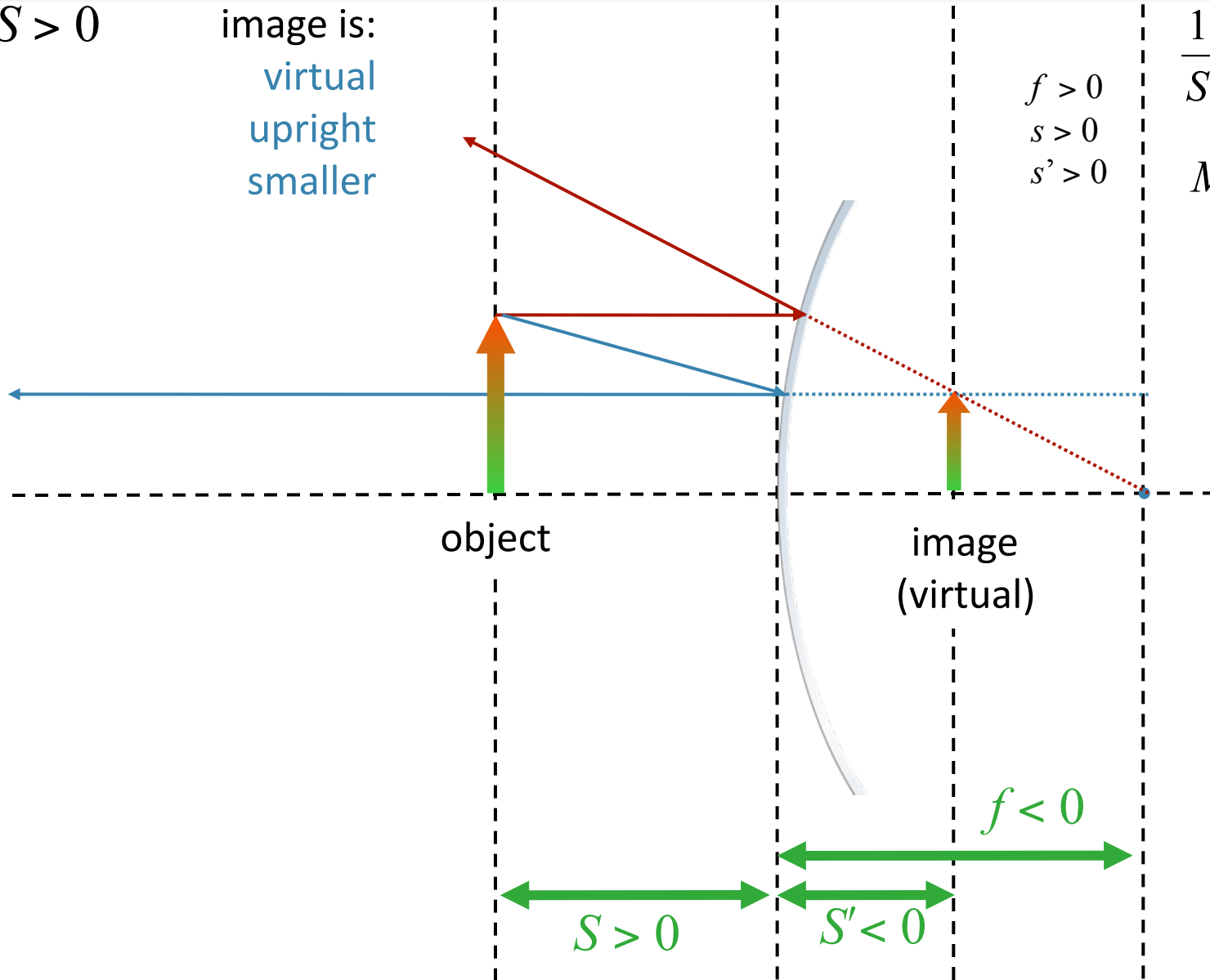
$$S > 0$$

image is:  
virtual  
upright  
smaller

$$\begin{aligned} f &> 0 \\ s &> 0 \\ s' &> 0 \end{aligned}$$

$$\frac{1}{S} + \frac{1}{S'} = \frac{1}{f}$$

$$M = -\frac{S'}{S}$$



# Executive Summary - Mirrors & Lenses:

$$S > 2f$$

real  
inverted  
smaller

$$2f > S > f$$

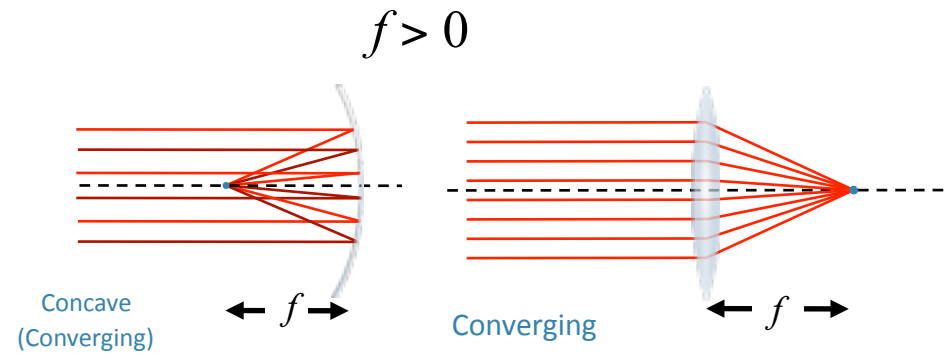
real  
inverted  
bigger

$$f > S > 0$$

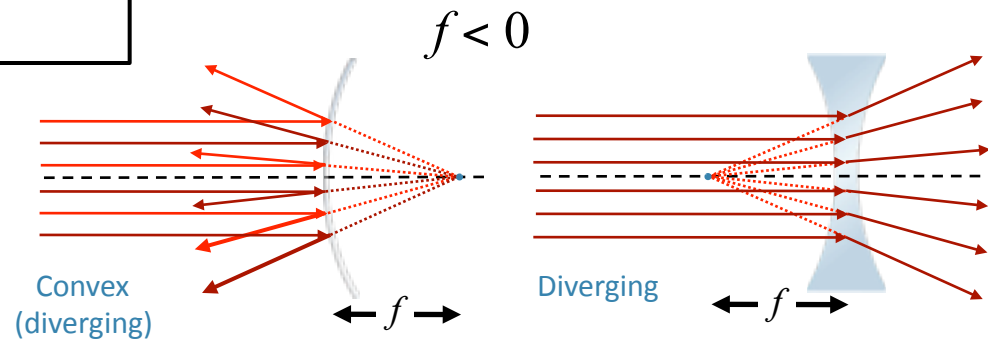
virtual  
upright  
bigger

$$S > 0$$

virtual  
upright  
smaller



$$\frac{1}{S} + \frac{1}{S'} = \frac{1}{f} \quad \text{---} \quad M = -\frac{S'}{S}$$



# It's Always the Same:

$$\frac{1}{S} + \frac{1}{S'} = \frac{1}{f}$$

$$M = -\frac{S'}{S}$$

You just have to keep the signs straight:

$s'$  is positive for a real image

$f$  is positive when it can produce a real image

## Lens sign conventions

$S$ : positive if object is “upstream” of lens

$S'$ : positive if image is “downstream” of lens

$f$ : positive if converging lens

## Mirrors sign conventions

$S$ : positive if object is “upstream” of mirror

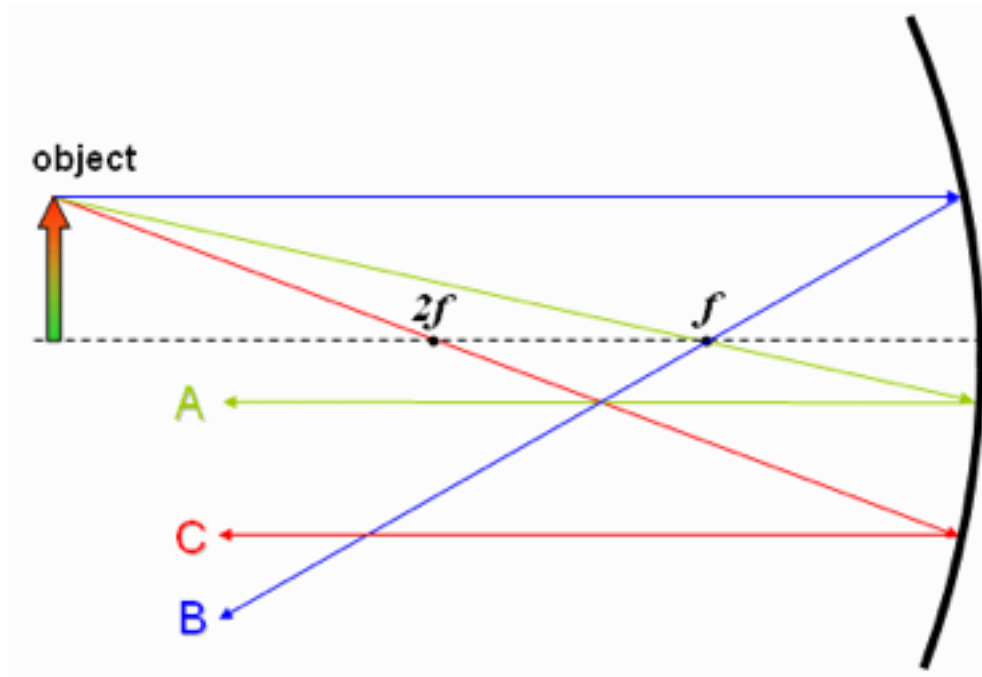
$S'$ : positive if image is “upstream” of mirror

$f$ : positive if converging mirror (concave)

# CheckPoint 2



The diagram below shows three light rays reflected off of a concave mirror. Which ray is NOT correct?

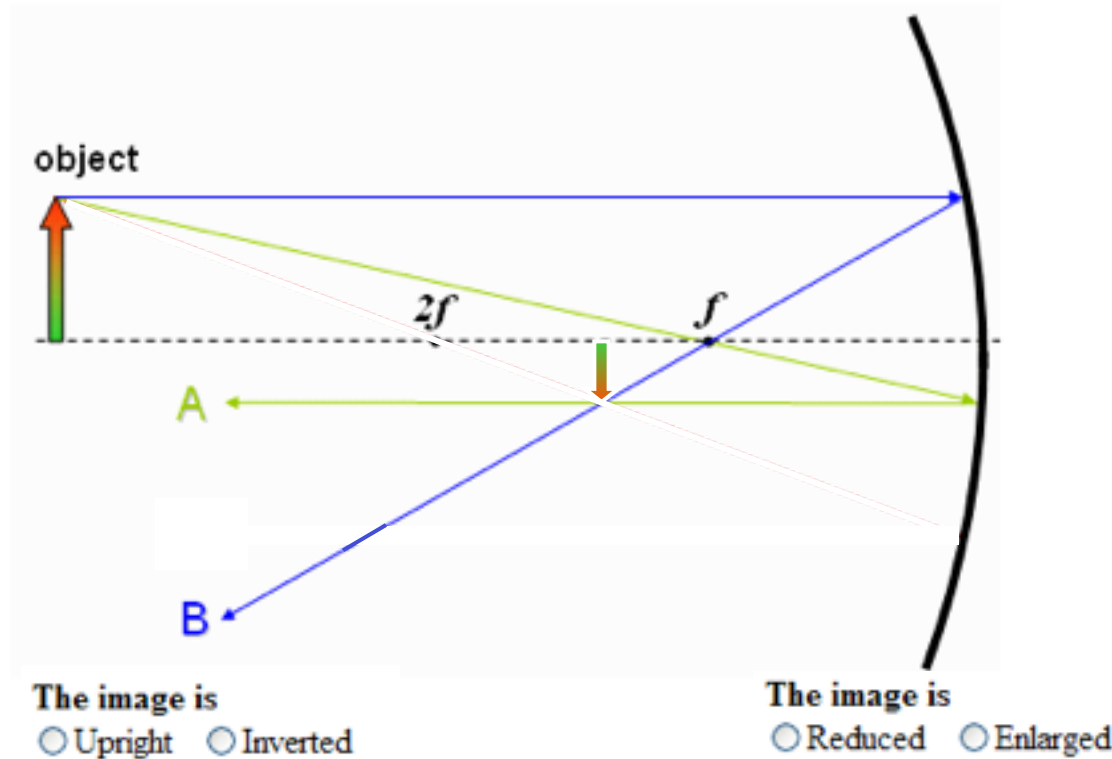


☐ A ☐ B ☒ C

C is not correct as it does not go through the focal point.

# CheckPoints 4 & 5

The diagram below shows three light rays reflected off of a concave mirror. Which ray is NOT correct?



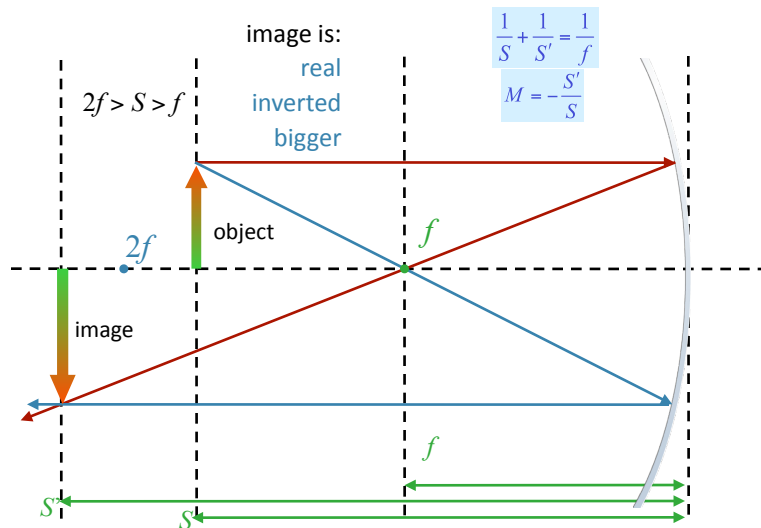


# CheckPoint 7

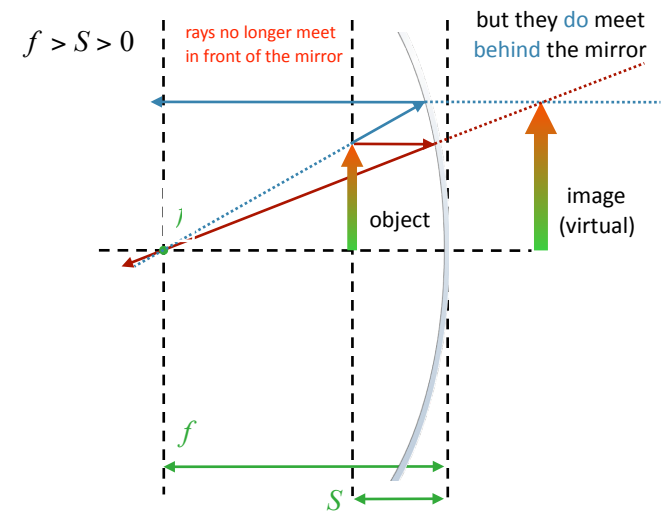


The image produced by a concave mirror of a real object is

- ☐ always upright.
- ☐ always inverted.
- ☒ sometimes upright and sometimes inverted.



If the object is behind the focal length it will reflect an inverted image.



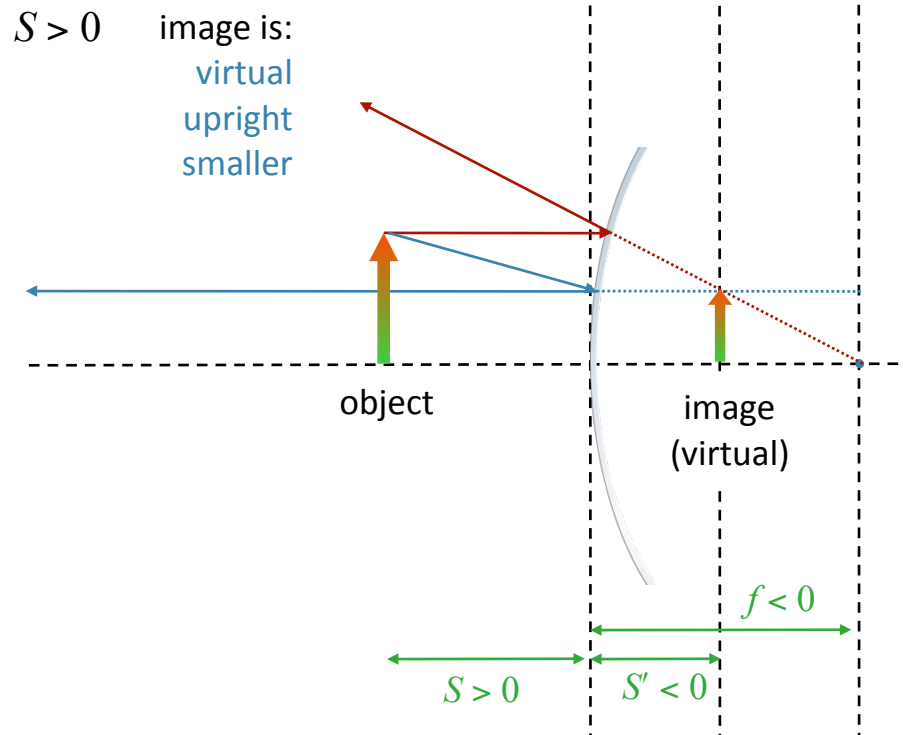
If the object is in front of the focal length it will produce a virtual upright image.

# CheckPoint 9



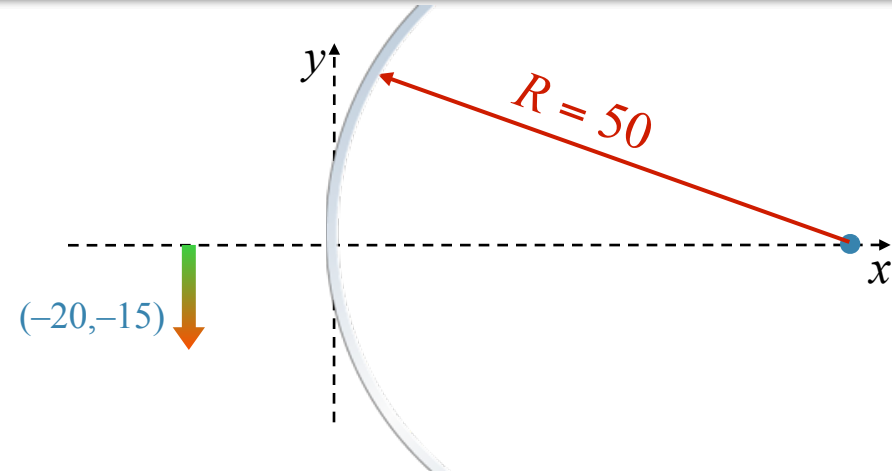
9) The image produced by a convex mirror of a real object is

- ☒ always upright.
- ☐ always inverted.
- ☐ sometimes upright and sometimes inverted.



# Calculation

An arrow is located in front of a convex spherical mirror of radius  $R = 50\text{cm}$ . The tip of the arrow is located at  $(-20\text{cm}, -15\text{cm})$ .



Where is the tip of the arrow's image?

## Conceptual Analysis

Mirror Equation:  $1/s + 1/s' = 1/f$

Magnification:  $M = -s'/s$

## Strategic Analysis

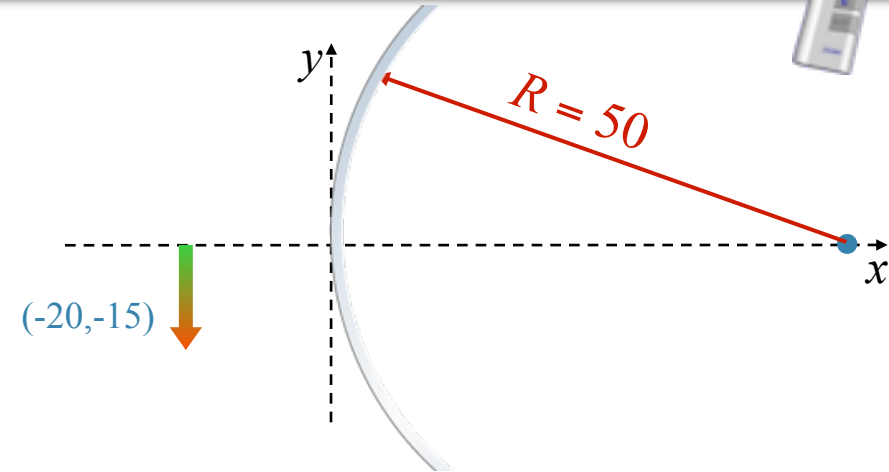
Use mirror equation to figure out the  $x$  coordinate of the image

Use the magnification equation to figure out the  $y$  coordinate of the tip of the image

# Calculation

An arrow is located in front of a convex spherical mirror of radius  $R = 50\text{cm}$ .

The tip of the arrow is located at  $(-20\text{cm}, -15\text{cm})$ .

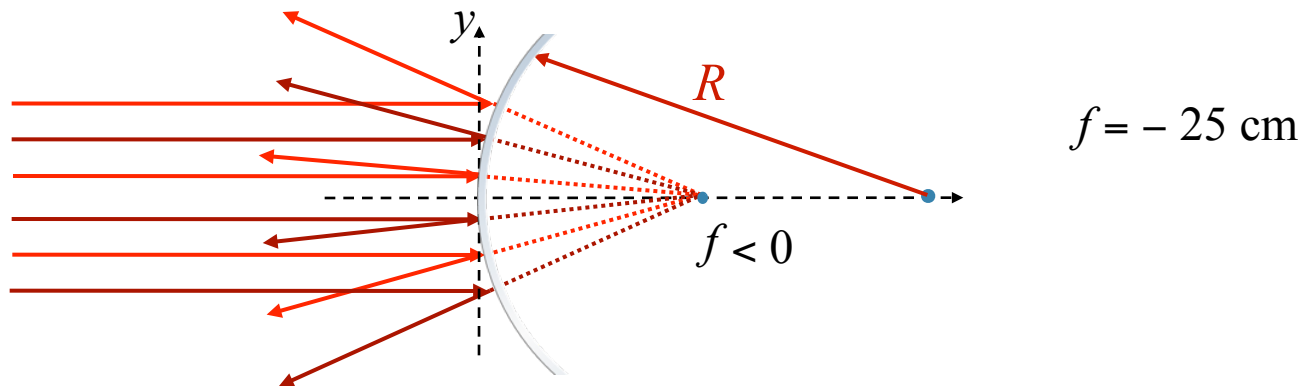


What is the focal length of the mirror?

- A)  $f = 50\text{cm}$     B)  $f = 25\text{cm}$     C)  $f = -50\text{cm}$     **D)  $f = -25\text{cm}$**

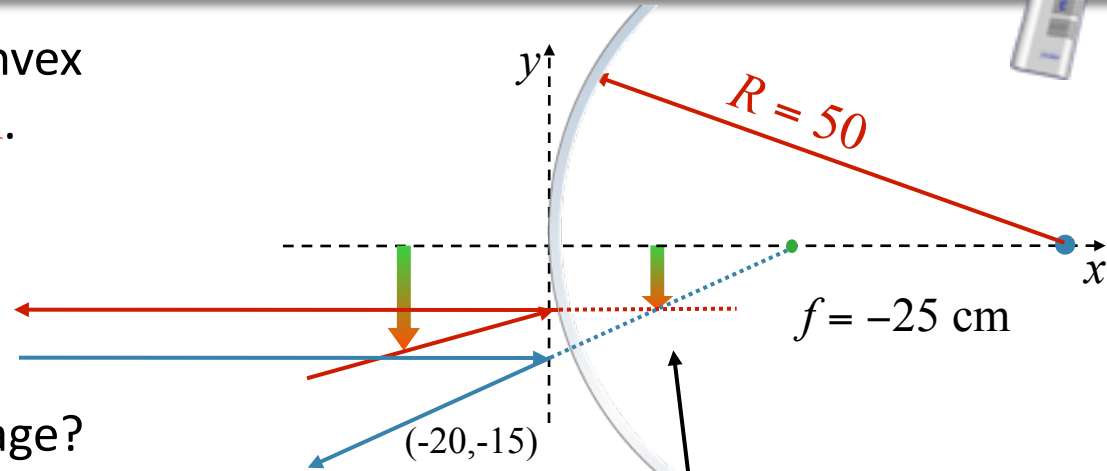
For a spherical mirror  $|f| = R/2 = 25\text{cm}$ .

Rule for sign: Positive on side of mirror where light goes after hitting mirror



# Calculation

An arrow is located in front of a convex spherical mirror of radius  $R = 50\text{cm}$ .  
The tip of the arrow is located at  $(-20\text{cm}, -15\text{cm})$ .



What is the  $x$  coordinate of the image?

A) 11.1 cm

B) 22.5 cm

C) -11.1 cm

D) -22.5 cm

Mirror  
equation

$$\frac{1}{s'} = \frac{1}{f} - \frac{1}{s}$$

$$s' = \frac{fs}{s - f} \quad \begin{array}{l} s = 20\text{ cm} \\ f = -25\text{ cm} \end{array}$$

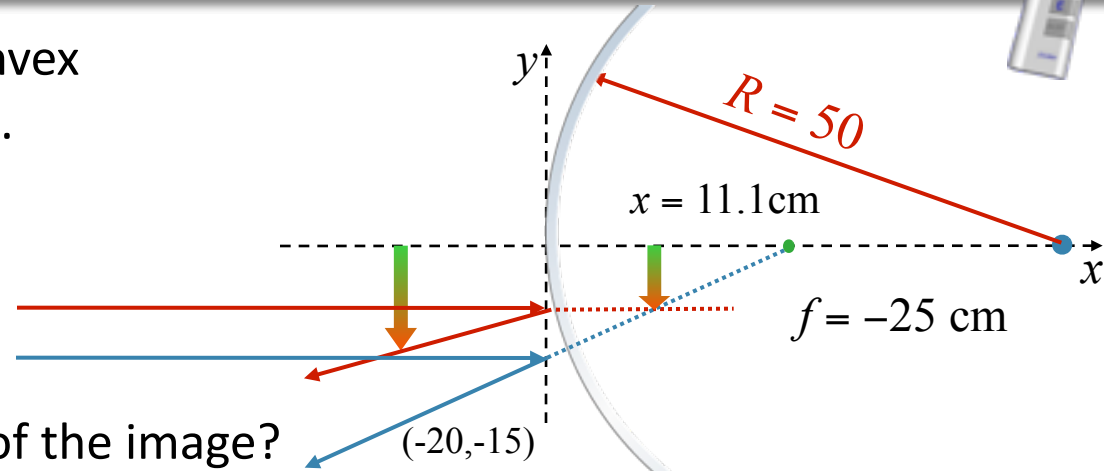
$$s' = \frac{(-25)(20)}{20 + 25} = -11.1\text{ cm}$$

Since  $s' < 0$  the image is virtual (on the “other” side of the mirror)

# Calculation

An arrow is located in front of a convex spherical mirror of radius  $R = 50\text{cm}$ .

The tip of the arrow is located at  $(-20\text{cm}, -15\text{cm})$ .



What is the  $y$  coordinate of the tip of the image?

- A)  $-11.1\text{ cm}$     B)  $-10.7\text{ cm}$     C)  $-9.1\text{ cm}$     **D)  $-8.3\text{ cm}$**

Magnification equation  $\rightarrow M = -\frac{S'}{S}$

$s = 20\text{ cm}$

$s' = -11.1\text{ cm}$

$M = 0.556$

$$y_{\text{image}} = 0.55 y_{\text{object}} = 0.556 \times (-15\text{ cm}) = -8.34\text{ cm}$$