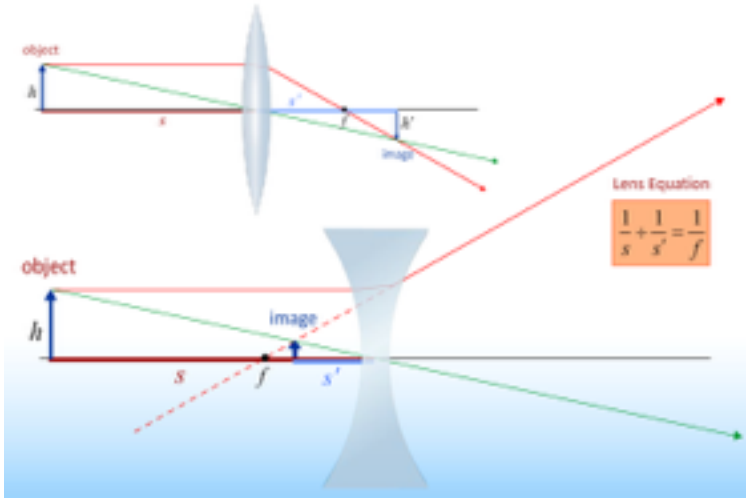
Physics 121
Lecture 26

Today's Concept:

A) Lenses

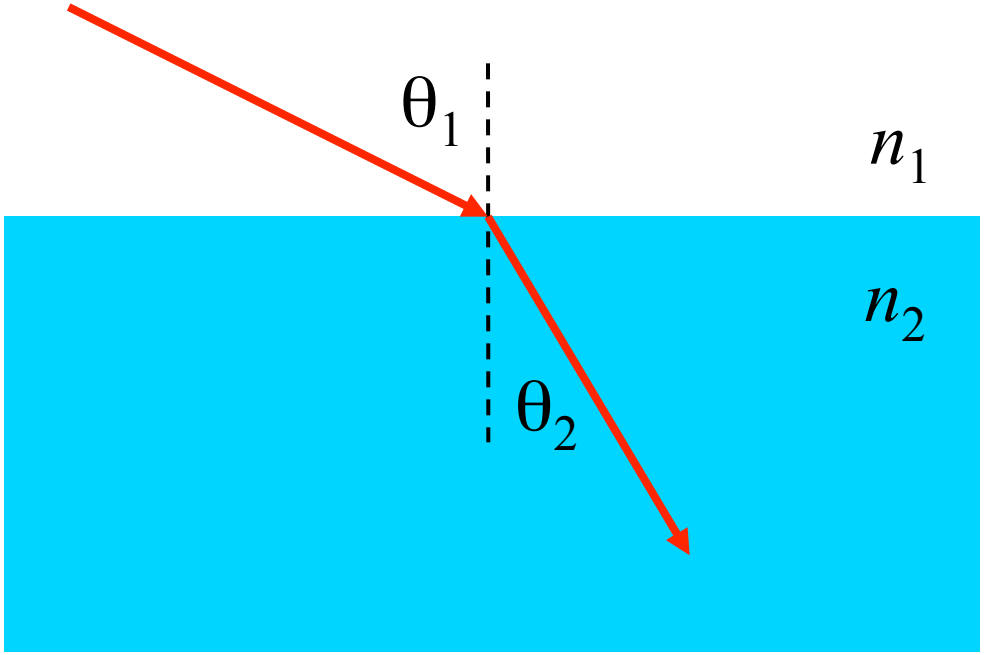
B) Mirrors



Refraction

Snell's Law

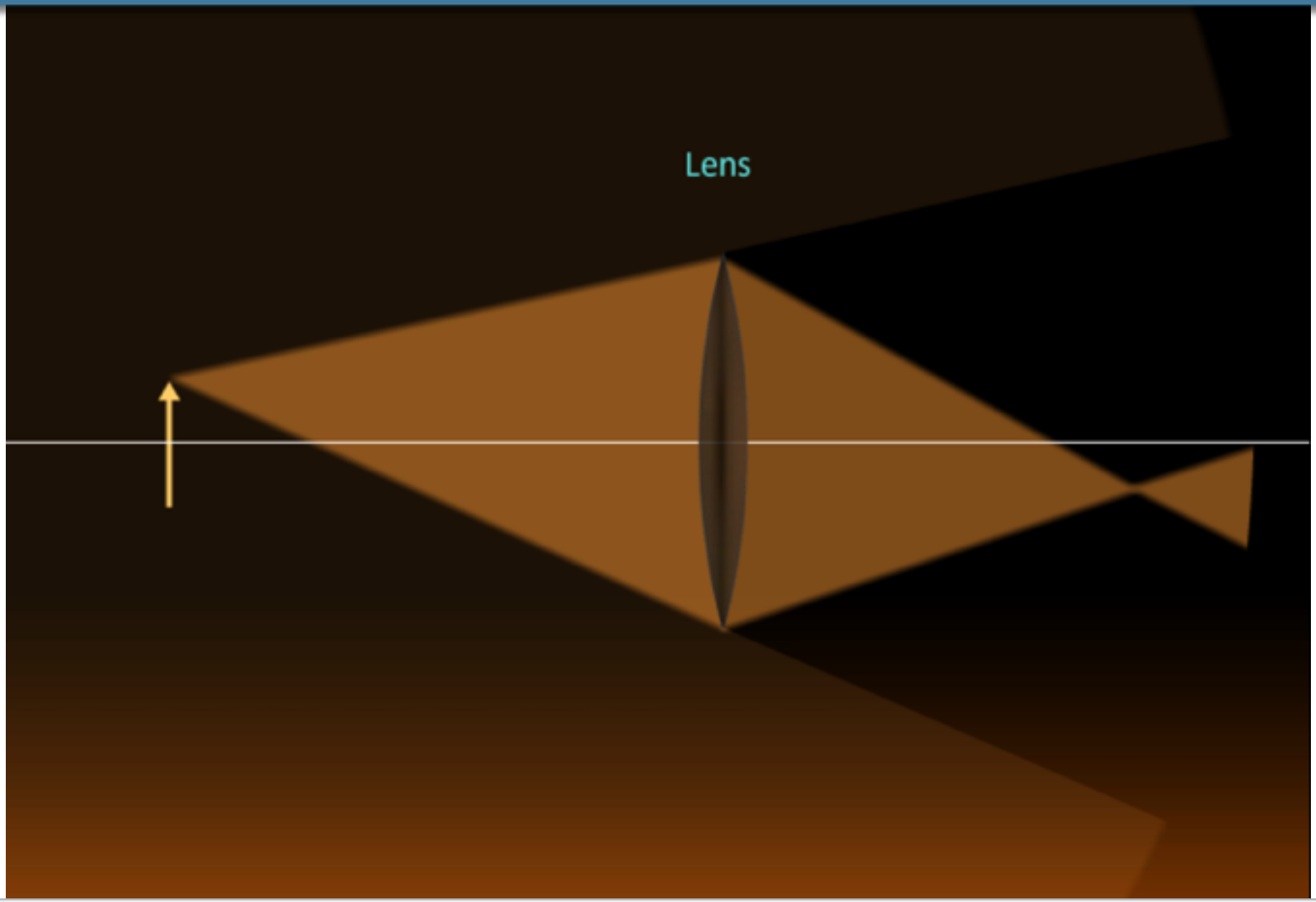
$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$$



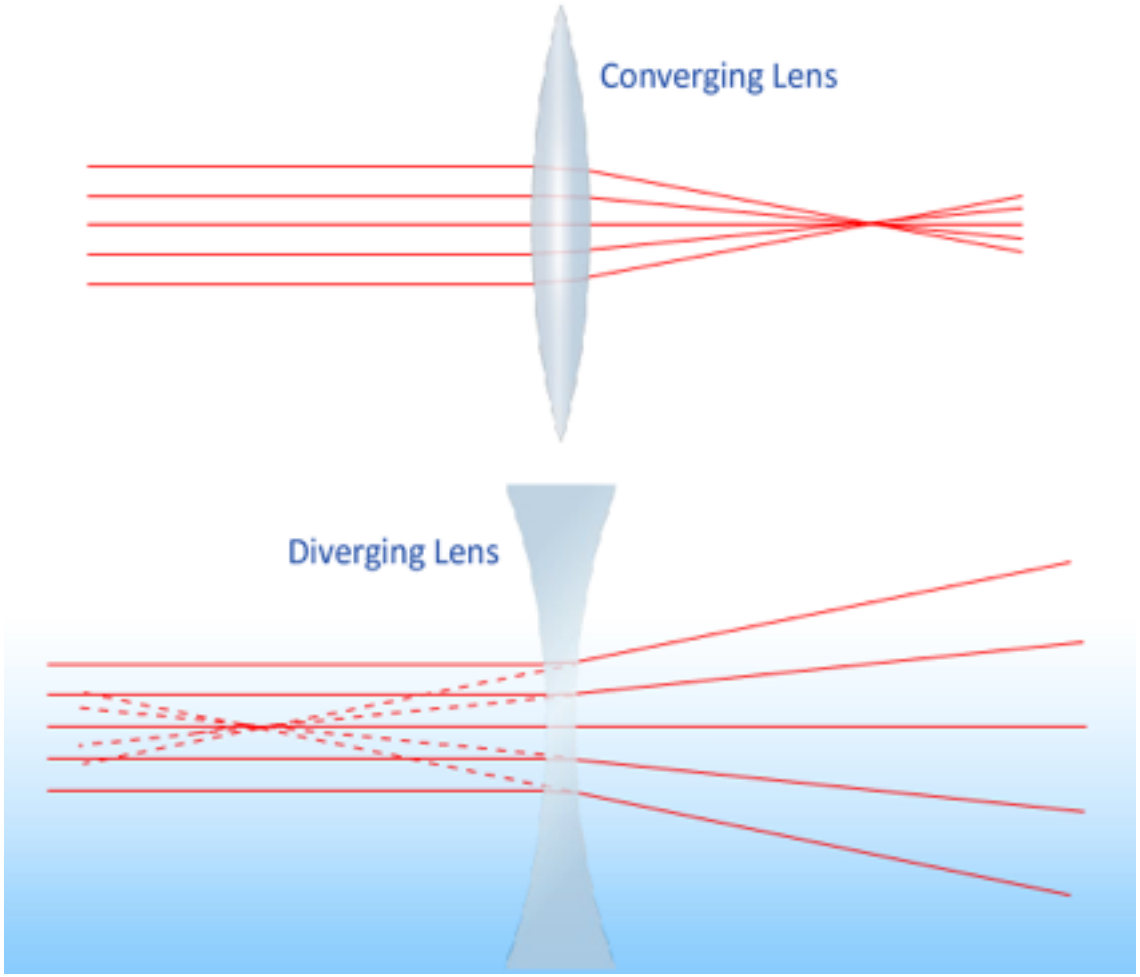
That's all of the physics –

everything else is just geometry!

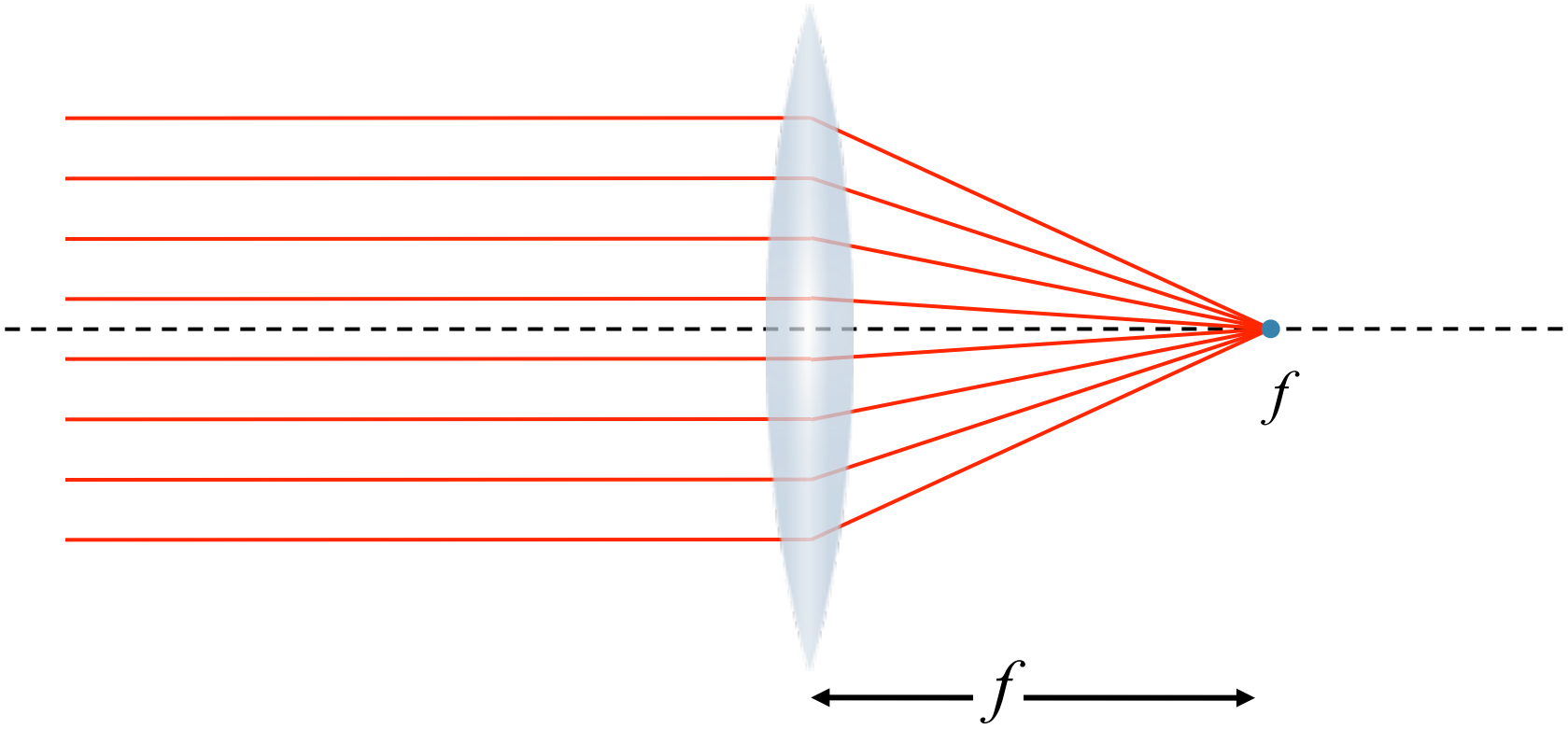
Waves from Objects are Focused by Lens



Two Different Types of Lenses



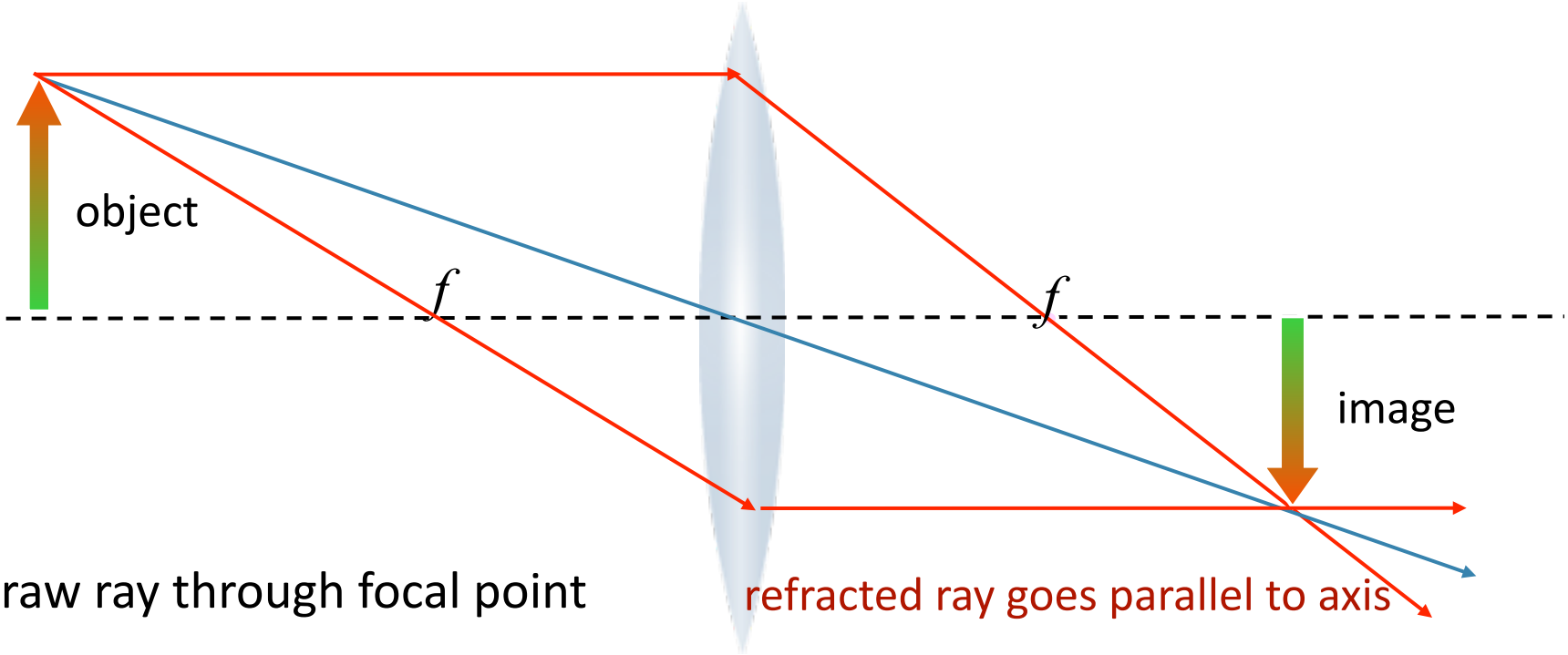
Converging Lens: Consider the case where the shape of the lens is such that light rays parallel to the axis of the mirror are all "focused" to a common spot a distance f behind the lens:



Recipe for Finding Image:

1) Draw ray parallel to axis — refracted ray goes through focal point

2) Draw ray through center — refracted ray is symmetric

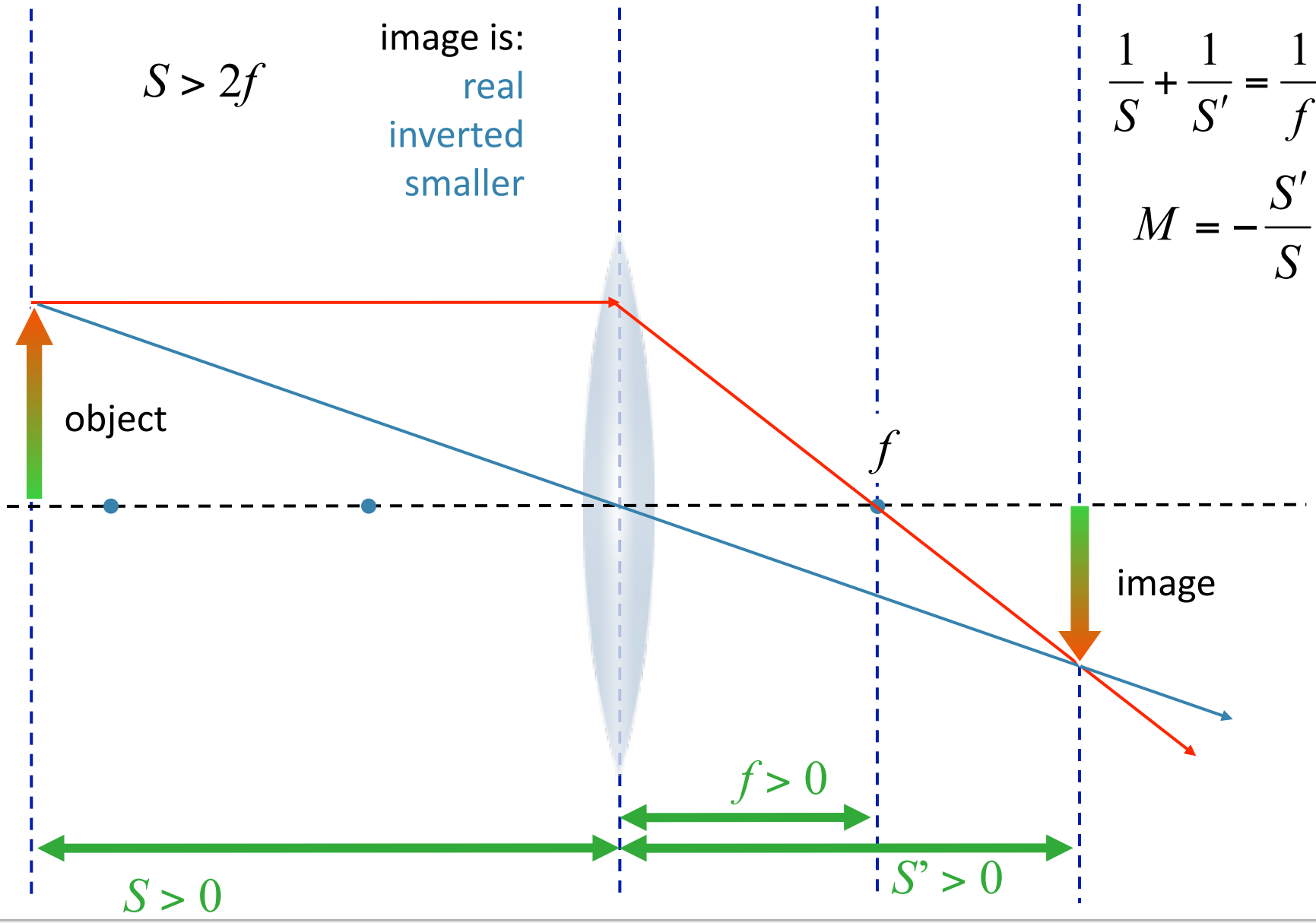


3) Draw ray through focal point — refracted ray goes parallel to axis

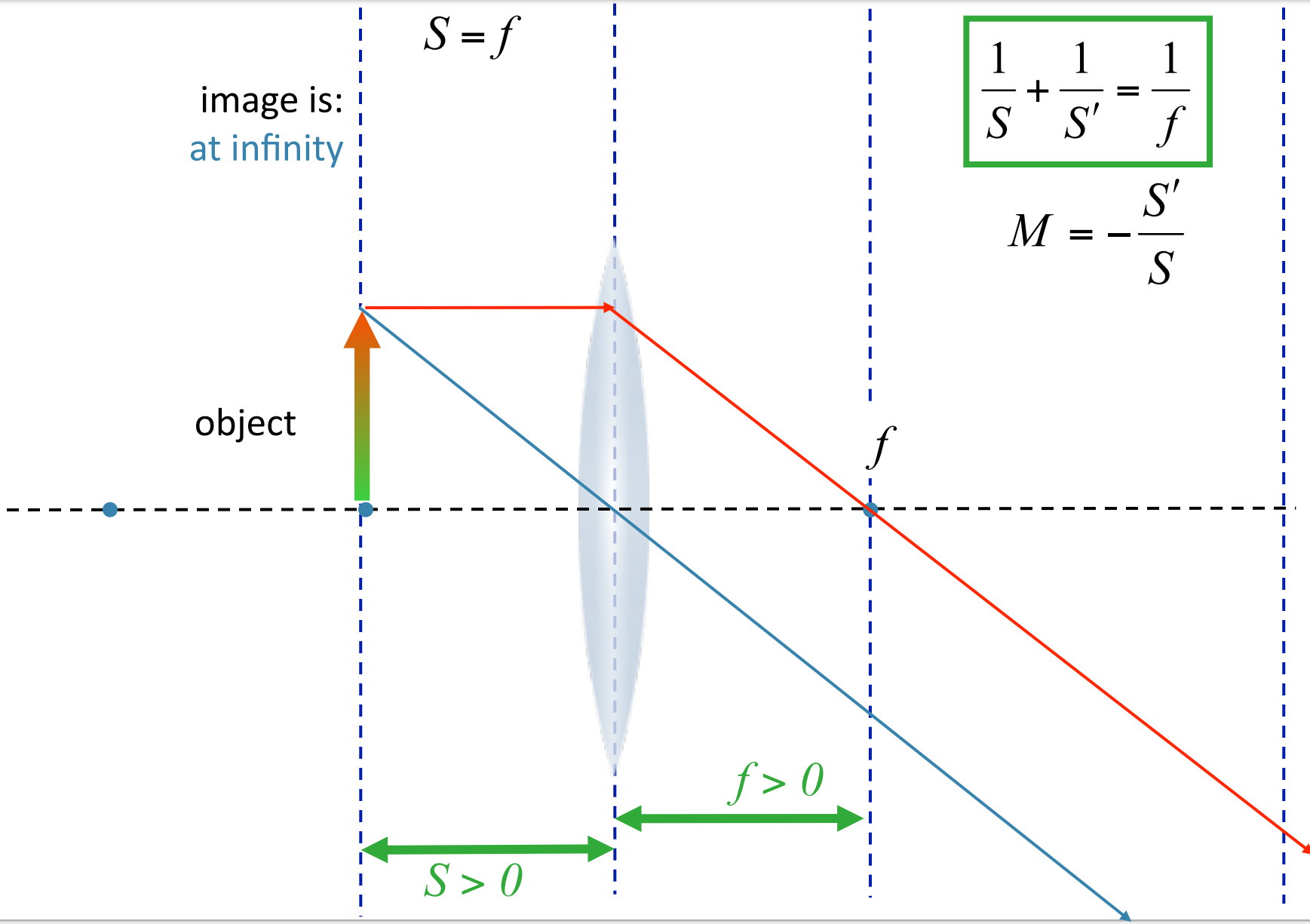
alternate or check

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

Example


$S > 2f$
image is:
real
inverted
smaller
$\frac{1}{S} + \frac{1}{S'} = \frac{1}{f}$
$M = -\frac{S'}{S}$
object
f
image
$f > 0$
$S > 0$
$S' > 0$

Example


$S = f$
image is:
at infinity
$\frac{1}{S} + \frac{1}{S'} = \frac{1}{f}$
$M = -\frac{S'}{S}$
object
f
$f > 0$
$S > 0$

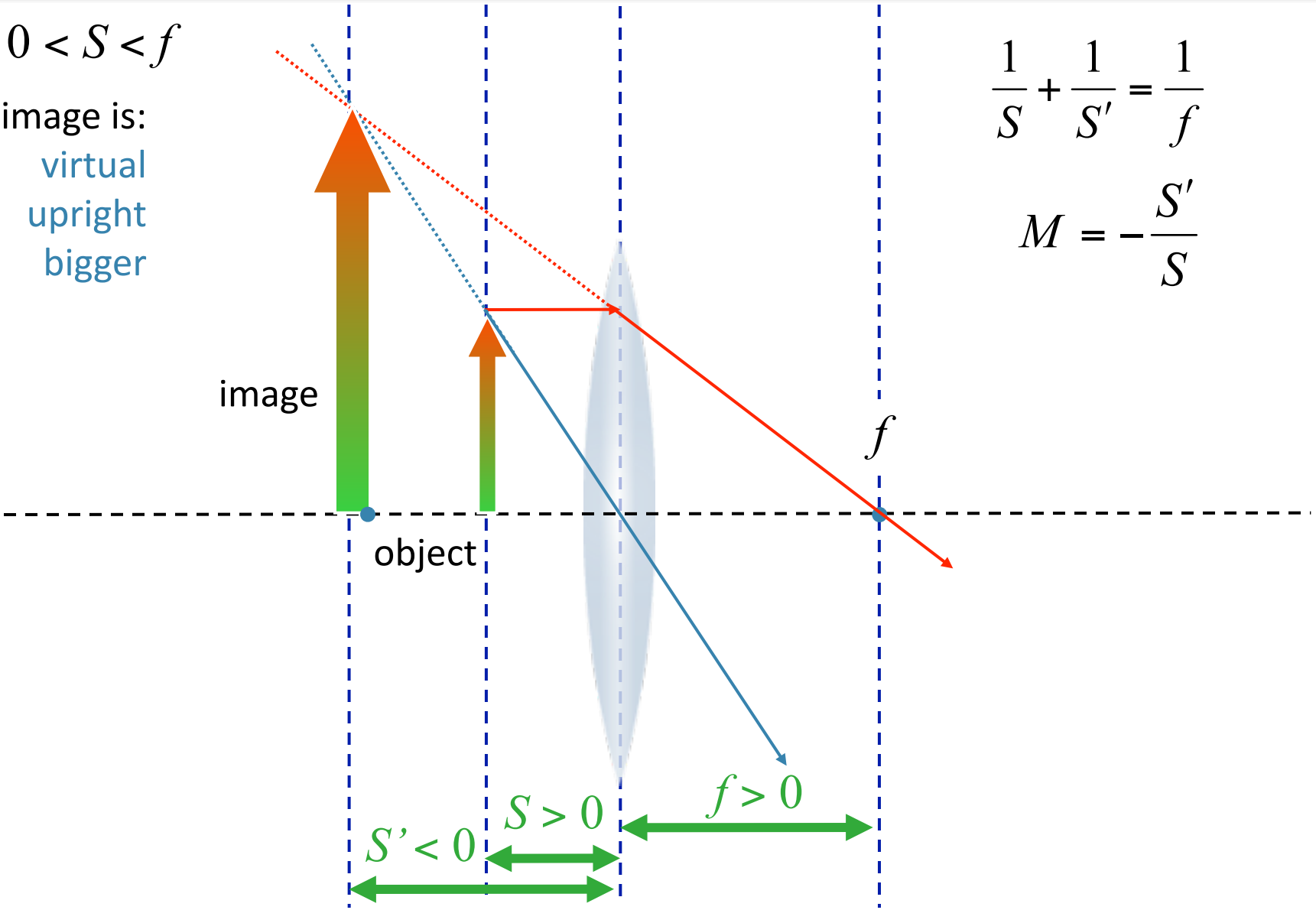
Example

$0 < S < f$

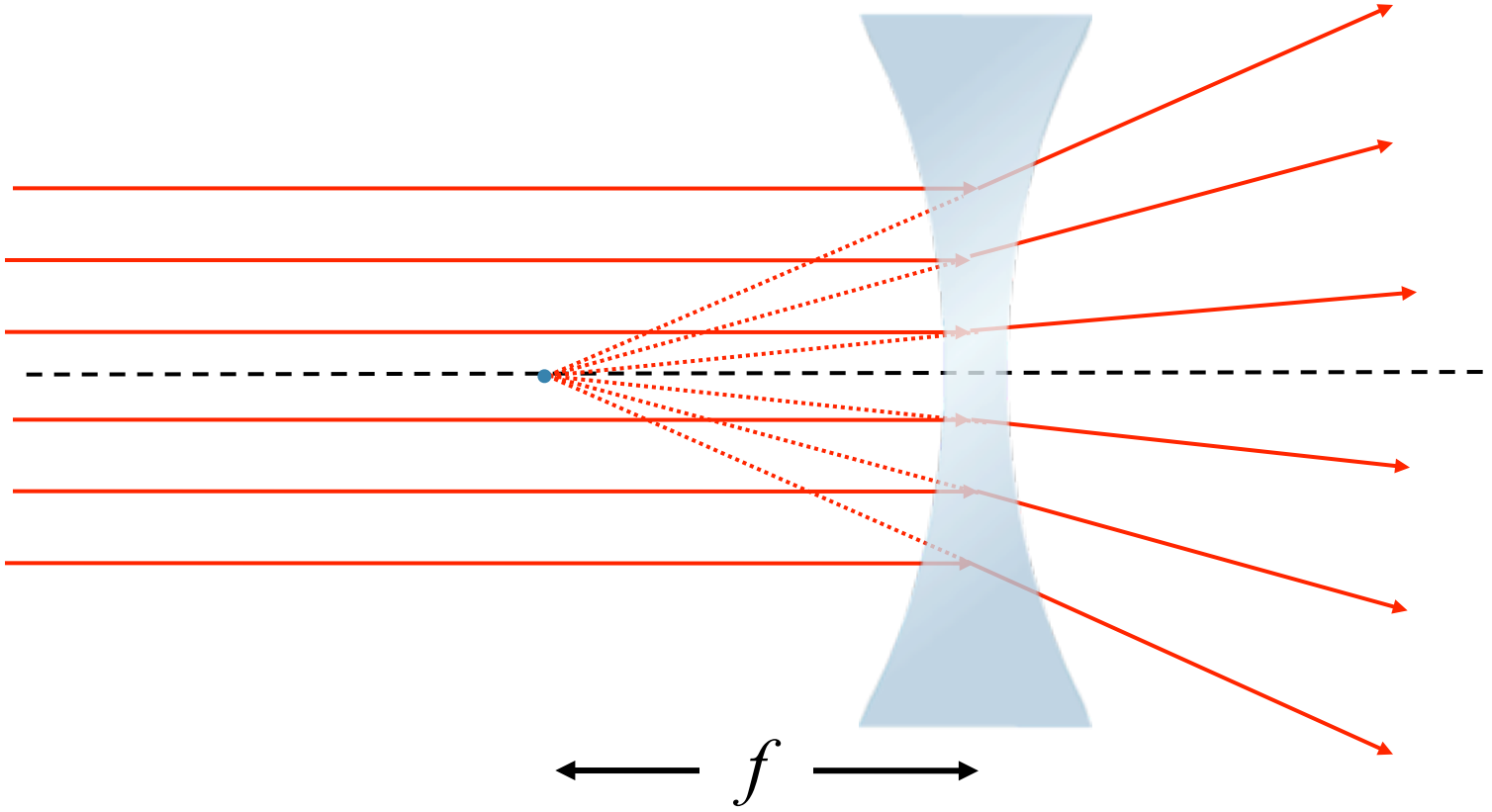
image is:
virtual
upright
bigger

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

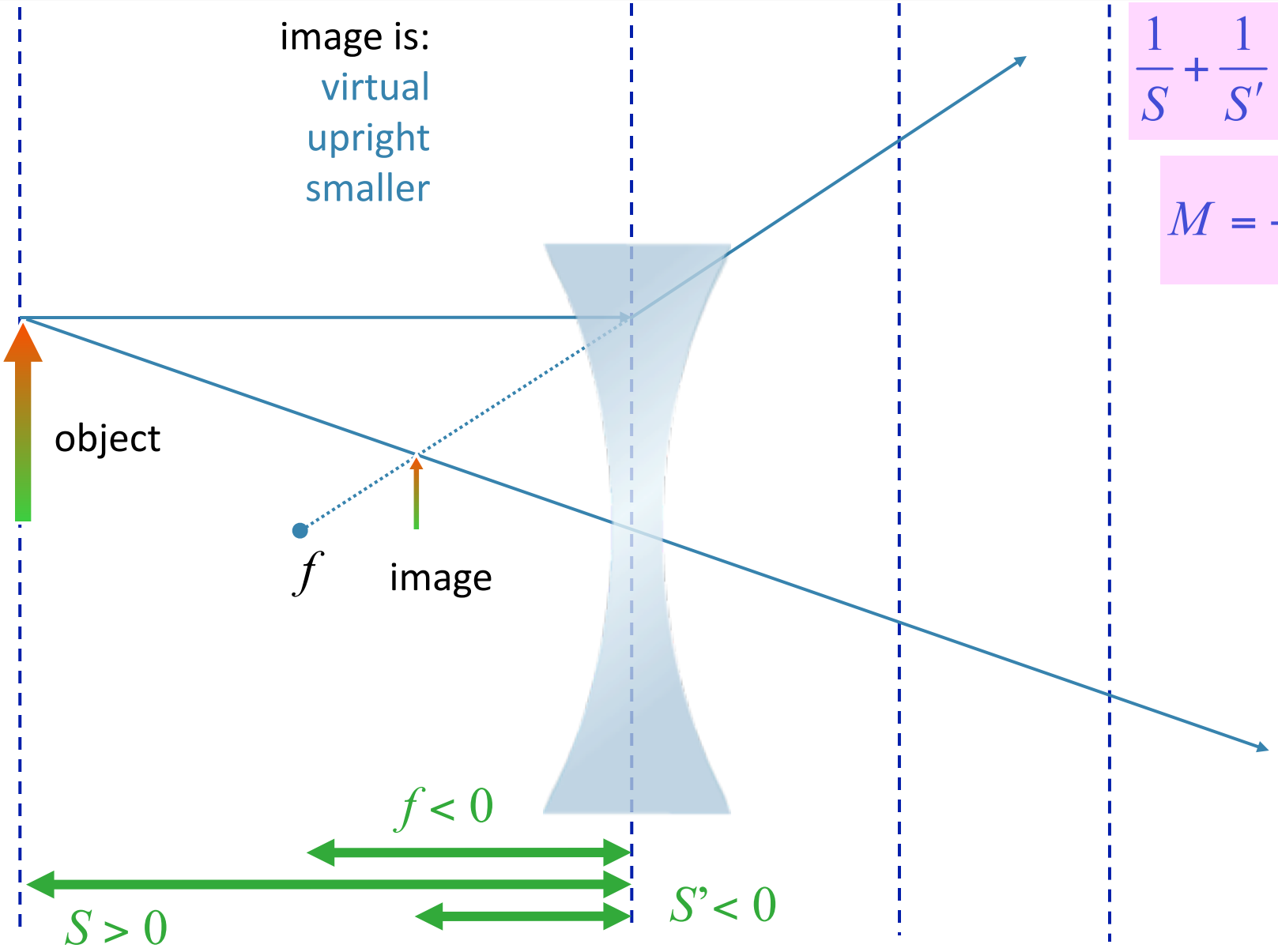
$$M = -\frac{S'}{S}$$



Diverging Lens: Consider the case where the shape of the lens is such that light rays parallel to the axis of the lens all diverge but appear to come from a common spot a distance f in front of the lens:



Example



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

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

Executive Summary - Lenses

$S > 2f$

real
inverted
smaller

$2f > S > f$

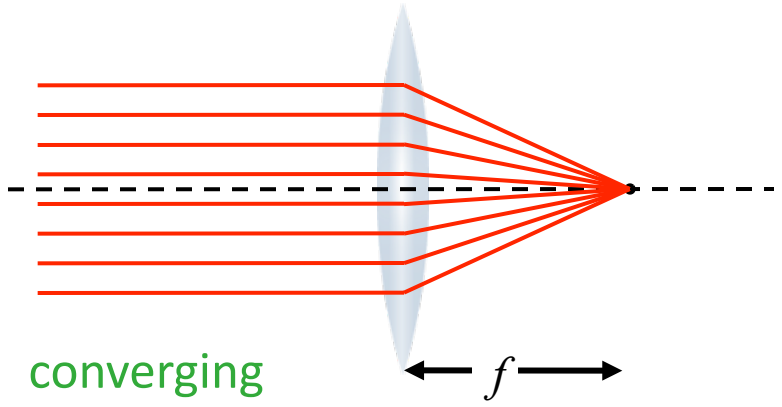
real
inverted
bigger

$f > S > 0$

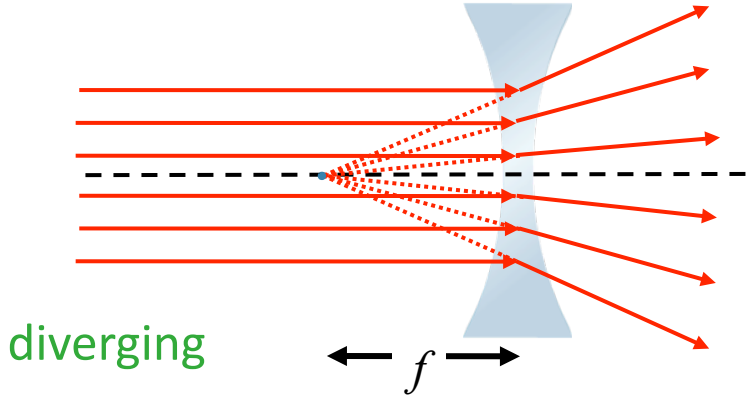
virtual
upright
bigger

$S > 0$

virtual
upright
smaller



$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \qquad M = -\frac{s'}{s}$$



It's Always the Same:

$$\frac{1}{s}+\frac{1}{s'}=\frac{1}{f} \qquad M=-\frac{s'}{s}$$

You just have to keep the signs straight:

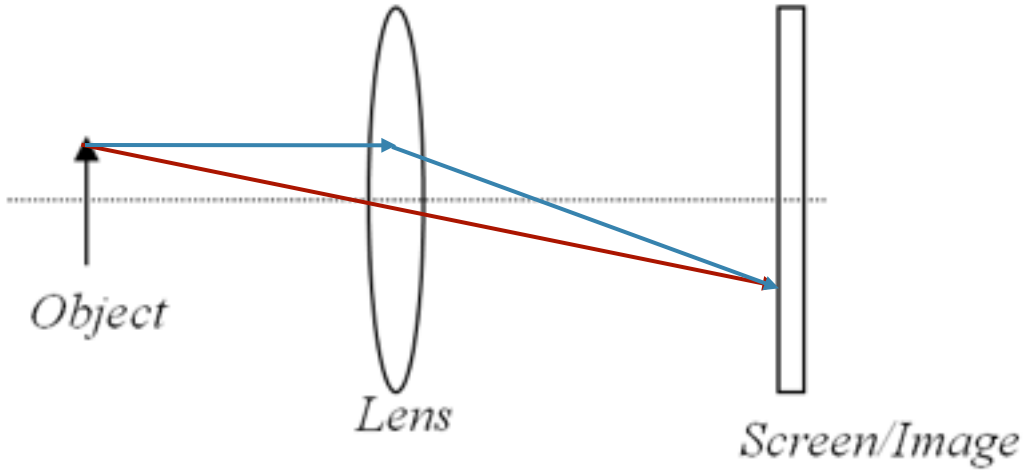
The sign conventions

S: positive if object is "upstream" of lens

S': positive if image is "downstream" of lens

f: positive if converging lens

CheckPoints 2 & 3



A converging lens is used to project the image of an arrow onto a screen as shown above.

The image is
- real
- virtual

The image is
- inverted
- upright

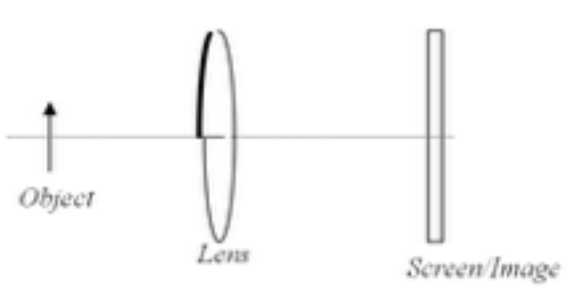
Image on screen

MUST BE REAL

$\rightarrow$ $s' > 0$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \qquad M = -\frac{s'}{s}$$

Checkpoint



A converging lens is used to project the image of an arrow onto a screen as shown above. A piece of black tape is now placed over the upper half of the lens. Which of the following will be seen

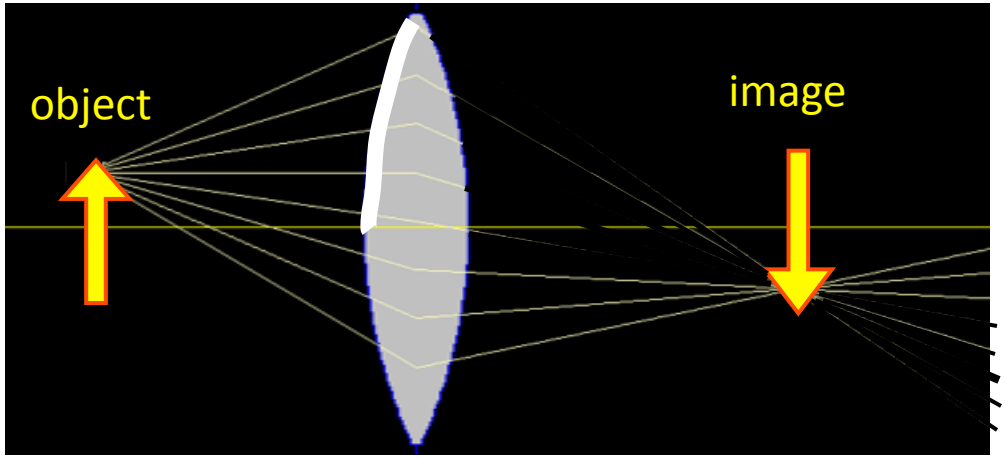
A) Only the lower half of the object

B) Only the upper half of the object

C) The whole object will still show on the screen.

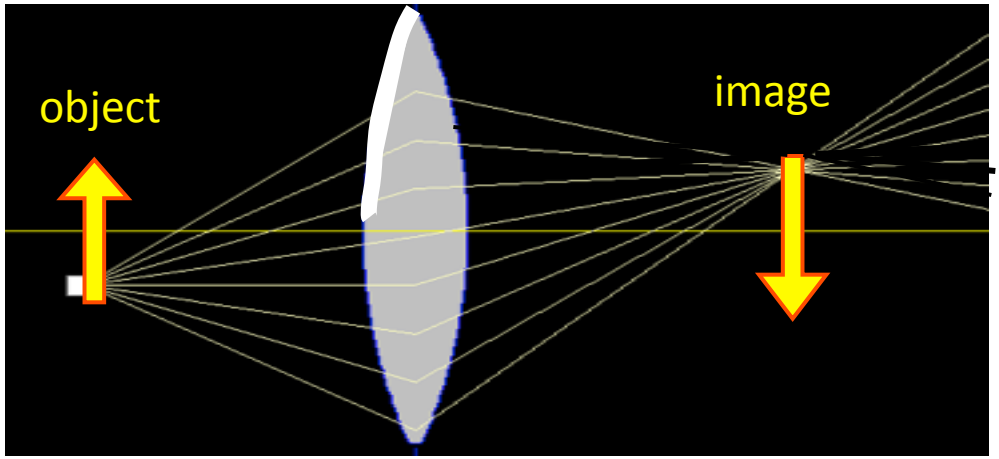
Cover top half of lens

Light from top of object



Cover top half of lens

Light from bottom of object

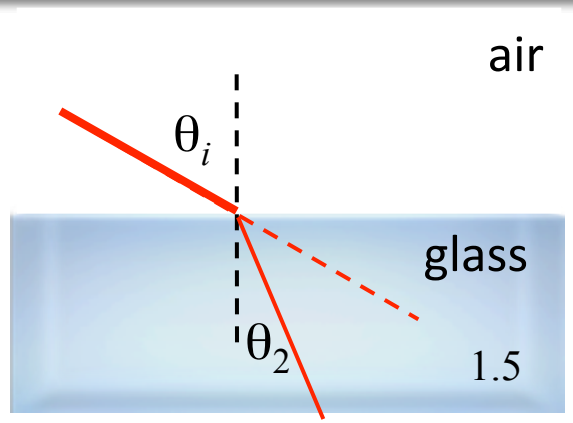


What's the Point?

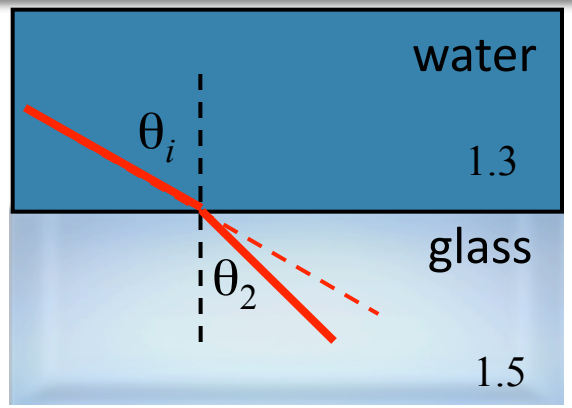
The rays from the bottom half still focus
The image is there, but it will be dimmer!

3) A piece of black tape is now placed over the upper half of the lens. Which of the follow is true.

- ○ Only the lower half of the object (i.e. the arrow tail) will show on the screen.
- ○ Only the upper half of the object (i.e. the arrow head) will show on the screen.
- ○ The whole object will still show on the screen.



Case A



Case B

In Case A light in air heads toward a piece of glass with incident angle θ_i

In Case B, light in water heads toward a piece of glass at the same angle.

In which case is the light bent most as it enters the glass?

A) Case A

B) Case B

C) Same

The angle of refraction in bigger for the water – glass interface:

$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2) \quad \rightarrow \quad \sin(\theta_2)/\sin(\theta_1) = n_1/n_2$$

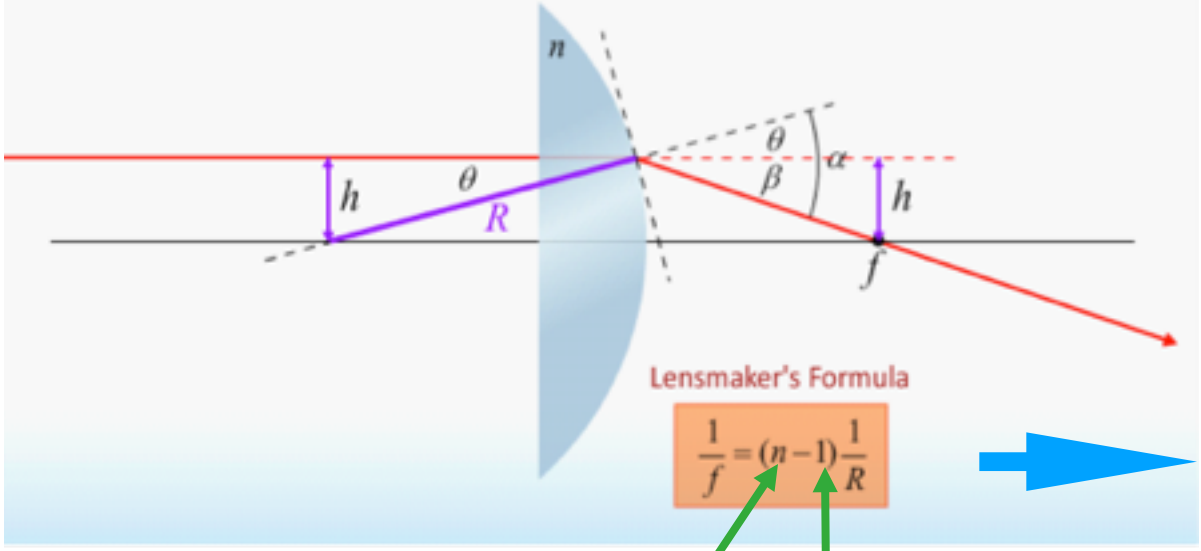
Therefore the BEND ANGLE $(\theta_1 - \theta_2)$ is BIGGER for air – glass interface

CheckPoint 7

What happens to the focal length of a converging lens when it is placed under water?

- increases
- decreases
- stays the same

We can see this also from Lensmaker's Formula



$$\frac{1}{f} = (n_{\text{lens}} - 1.33)\frac{1}{R}$$

n_{water}

Air Bubble in water

A Converging

B Diverging

C not a lens

Ray Optics Simulation

https://ricktu288.github.io/ray-optics/simulator/