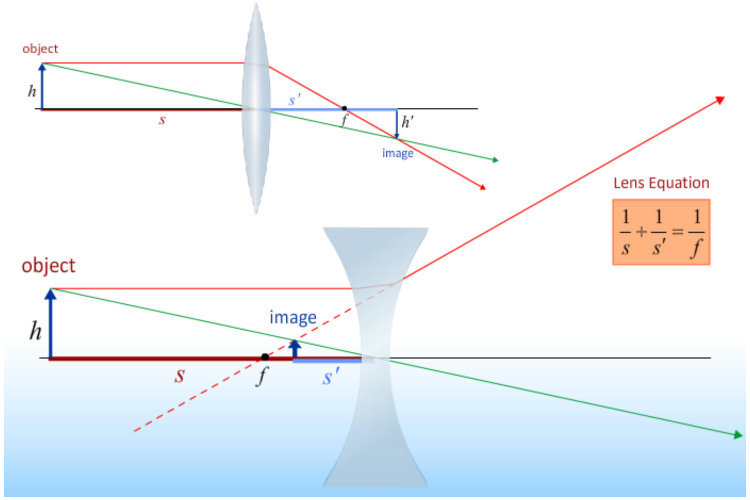
Physics 212
Lecture 26

Today's Concept:

Lenses



Your Comments

To what extent will we need to utilize the lensmaker's formula? I noticed there were no slides of it within our printed lecture packets...

Could you go over virtual/real again? Also, I haven't seen optics before unlike E&M in high school, so this stuff is a little more foreign to me. Any idea of how I can wrap my head around this?

why the beam of light passes the center of the lens is not bent?

Optics is relatively easier than what we learned just before. But the concept of drawing the line between real and virtual images kind of throws me off. I could just do my own research and find out, but I'd prefer to listen to the professor's explanation on this material.

Can a virtual image be of any use?

Are we going to cover thin films? I remember studying that in high school after optics and it was so fun!

In reality, light bounces off and scatters in all random directions. What, conceptually, is represented when we draw the two lines through the lens and horizontally?

End-of-Term and Exam Stuff

*There will be NO CLASS on Tuesday, May 5th

* - **Final Exam dates are scheduled**: 5/12, 1:30-4:30pm (combined) and 5/14, 7:00-10:00pm (conflict). You will be automatically signed up for the combined exam; if you want to instead take the conflict you must sign up in the gradebook. Please email shunk@illinois.edu if you have a double conflict.

Exam 3: Wed. April 29th at 7:00

- Covers material in Lectures 17 – 25 (Today's material)
- Sign up in Gradebook for Conflict Exam at 5:15pm
- Link in Gradebook if you have a double-conflict

Exam Preparation:

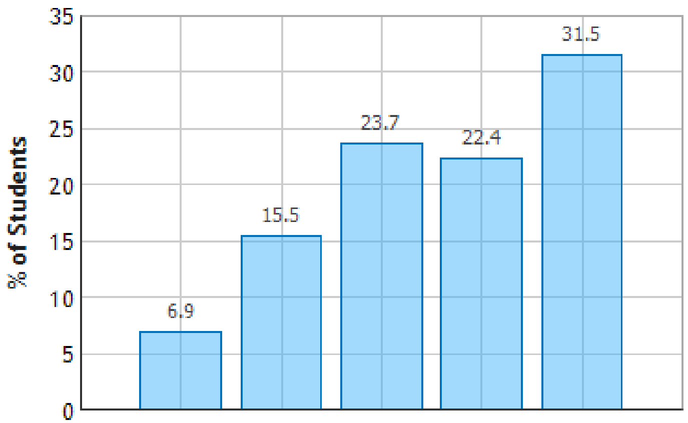
- Study HW, Discussion, Checkpoints
- Old Exams are a good way to assess what you need to know
- Video Solutions of Spring 2013 Hour Exam 3

Extra Office Hours next week:

- (see website for schedule and rooms)

Electronics In Lecture Survey

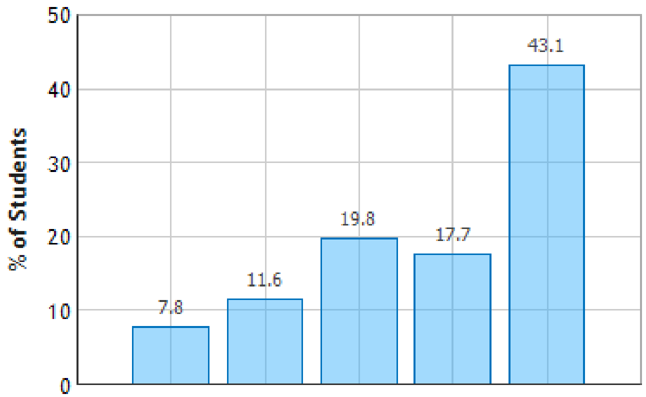
Personally, I use a surface tablet and onenote to take notes in many of my other classes. The screen brightness is low and it lays flat or nearly flat on the desk. I don't see why I can't use it in lecture. Maybe you could designate that if a student wishes to use their laptop, then they have to sit in one of the back x rows in order to avoid the dreaded cone of distraction.



Yes Phones No Phones

People using their phones, laptops, or talking during class is EXTREMELY disruptive and I appreciate the "no electronics and silence rule". If only everyone actually followed that rule.

I get very bothered by the amount of people who chat around me during lecture. If you could make the lecture hall more quiet during the time you are speaking, I would prefer that. I like the discussion during clicker questions, but it becomes very distracting at other times.

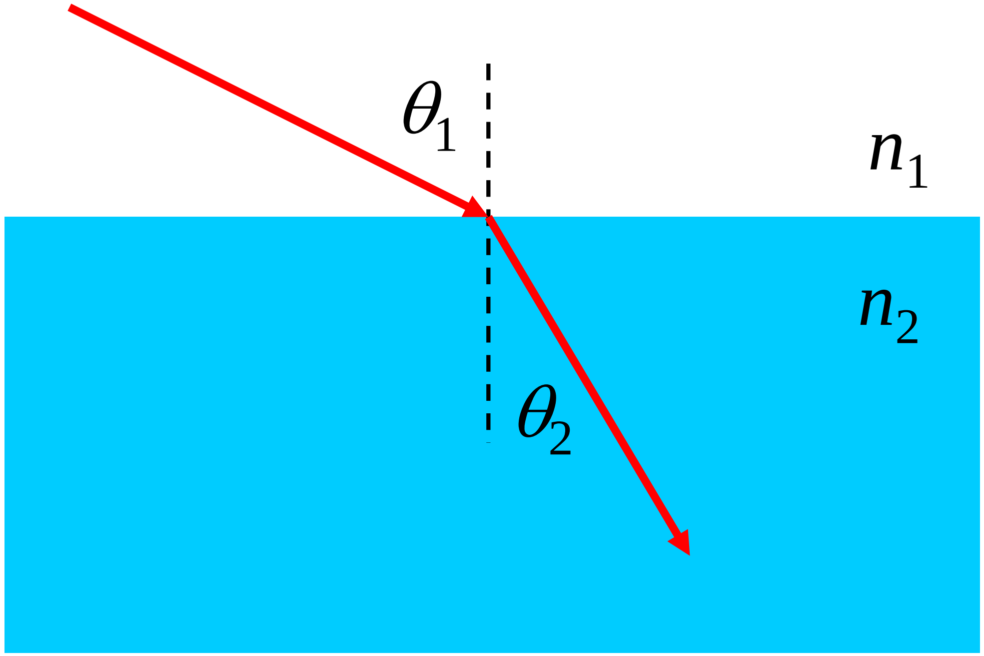


Yes Laptop No Laptop

Refraction

Snell's Law

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



That's all of the physics –

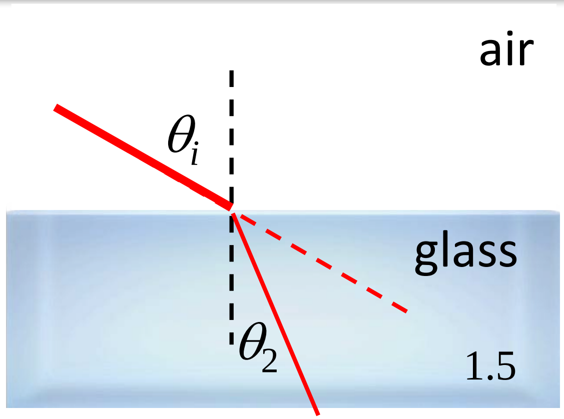
everything else is just geometry!

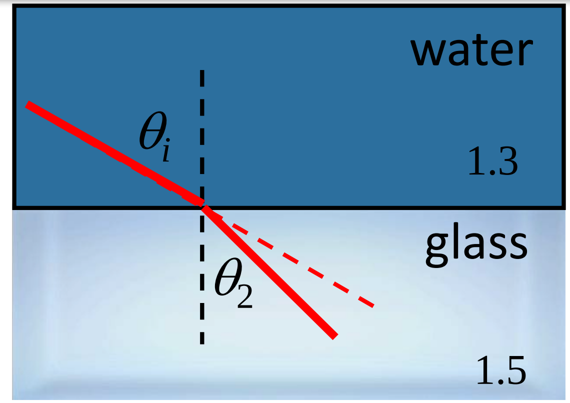
For spherical lens

$$\frac{1}{f} = (n_1 - n_2)\frac{1}{R}$$

CheckPoint Warmup

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 is bigger for the water – glass interface:

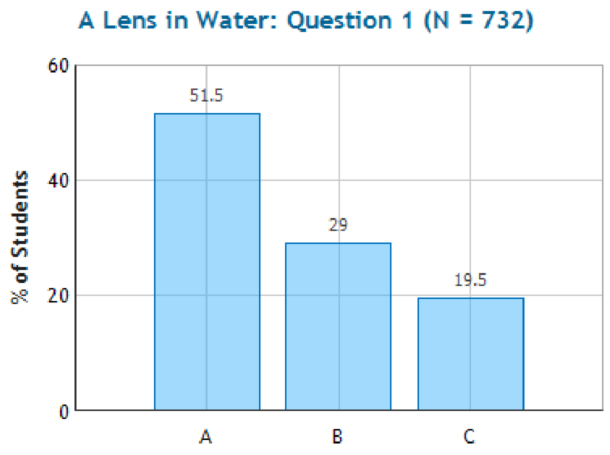
$$n_1\sin(\theta_1) = n_2\sin(\theta_2) \quad \longrightarrow \quad \sin(\theta_2)/\sin(\theta_1) = n_1/n_2$$

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

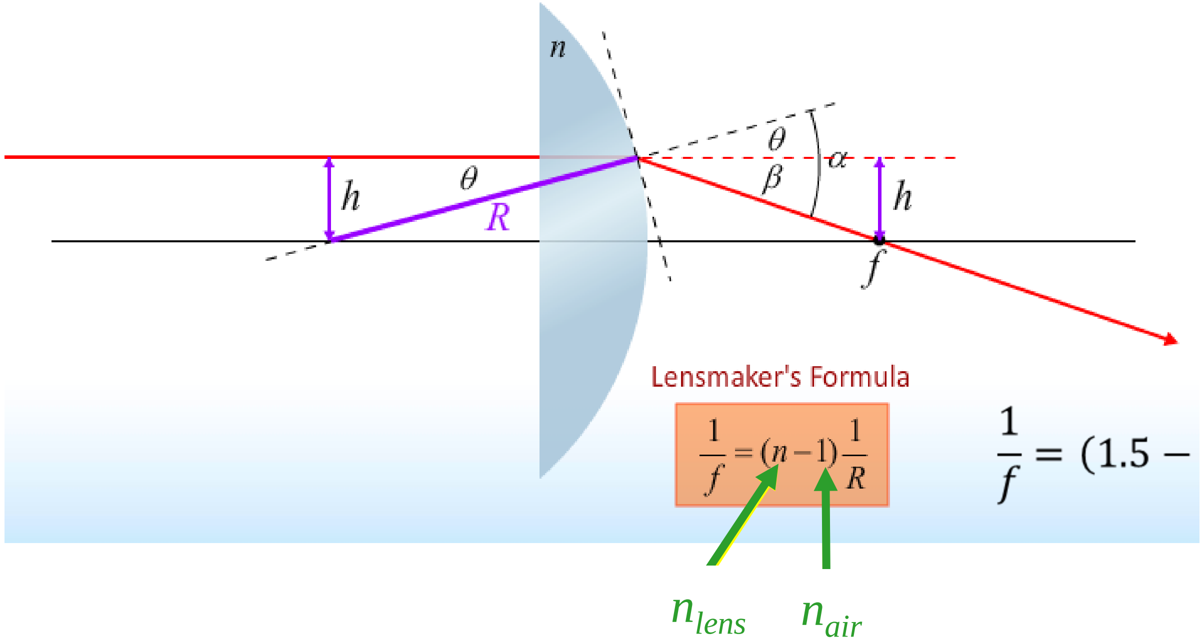
CheckPoint 2

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

A. Increases
B. Decreases
C. Stays the same



We can see this also from Lensmaker's Formula

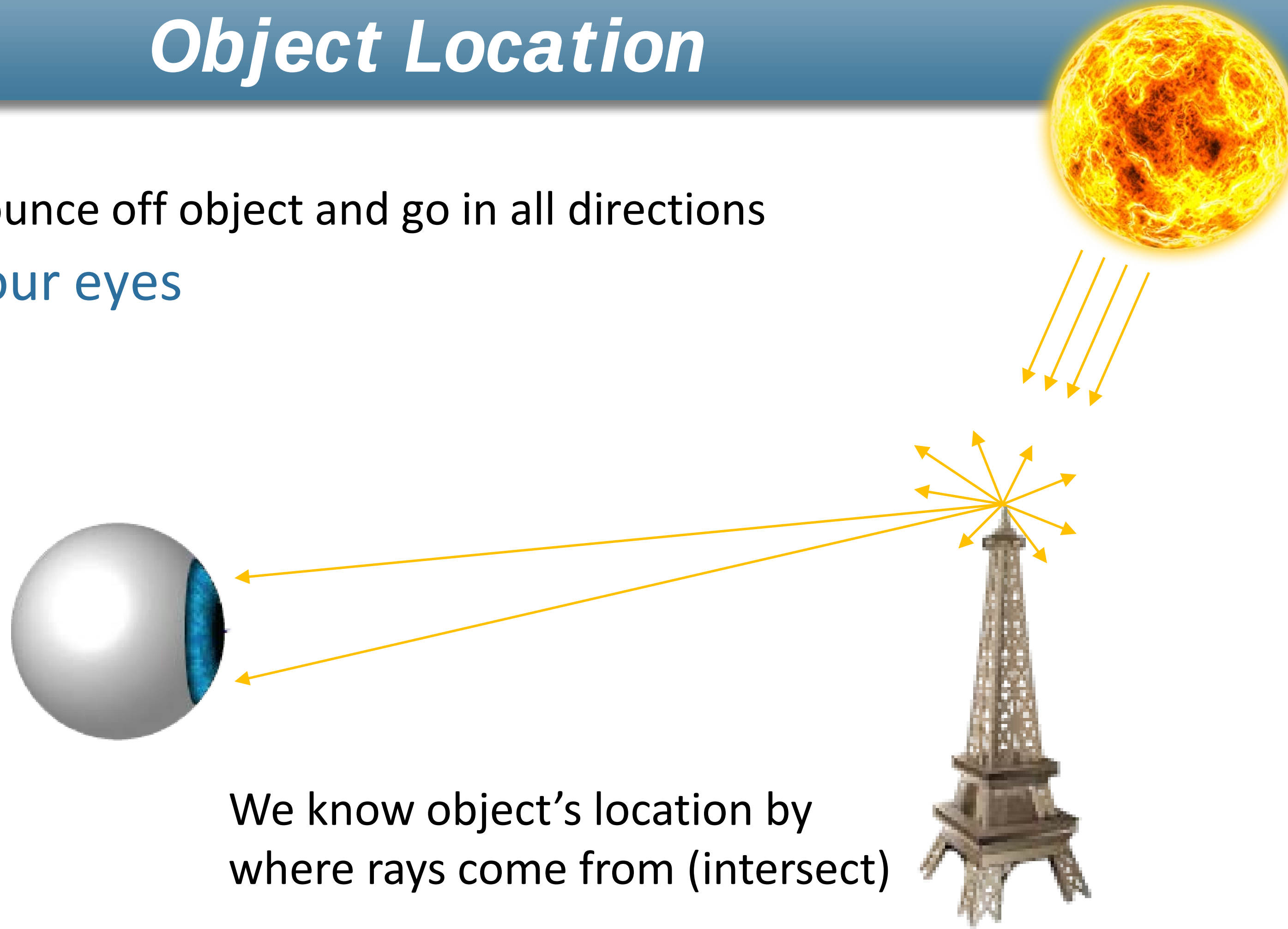


$$\frac{1}{f} = (1.5 - 1.1)\frac{1}{R} \Rightarrow \frac{1}{f} = (1.5 - 1.3)\frac{1}{R}$$

Object Location

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

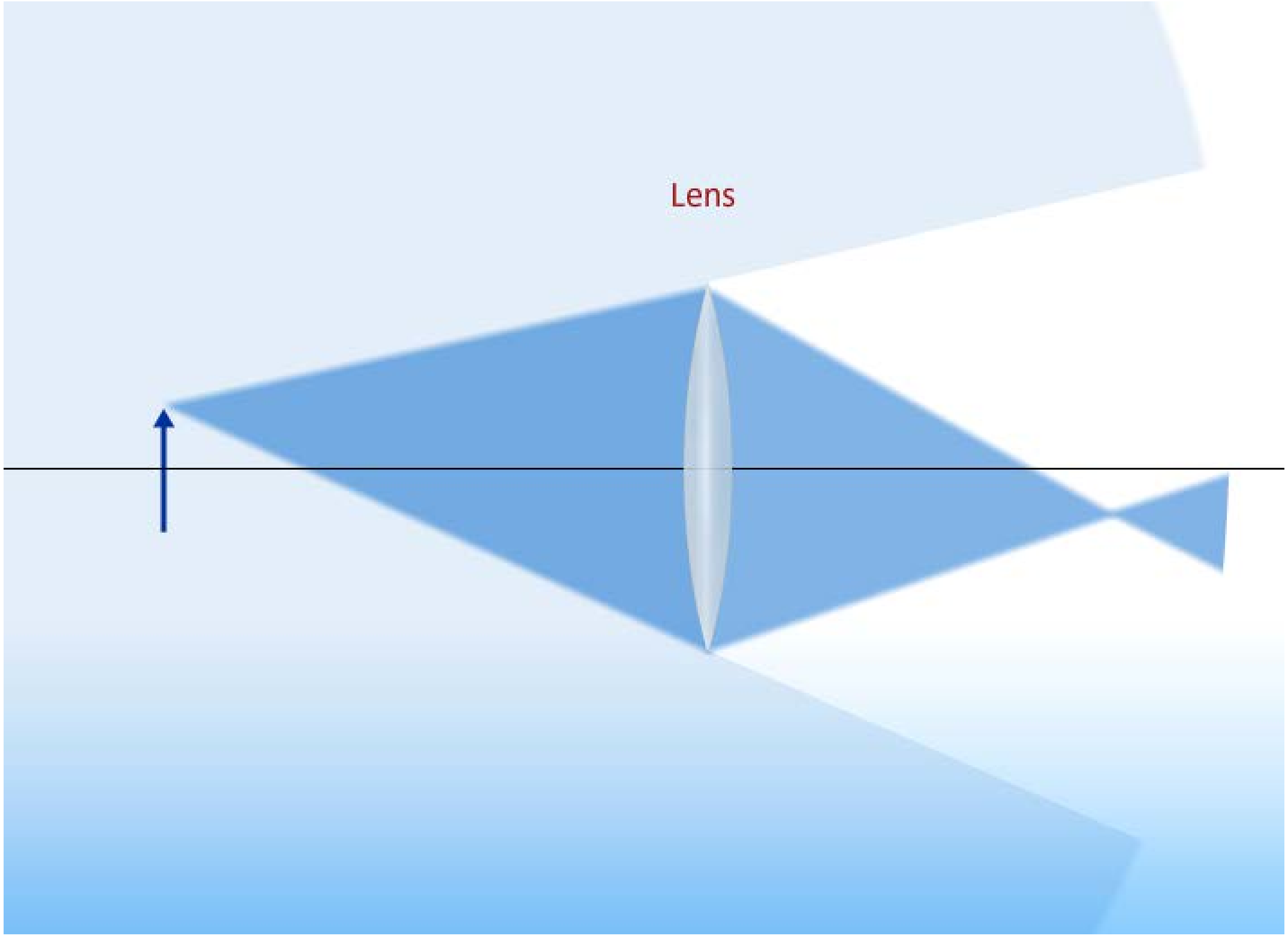
- Some hits your eyes



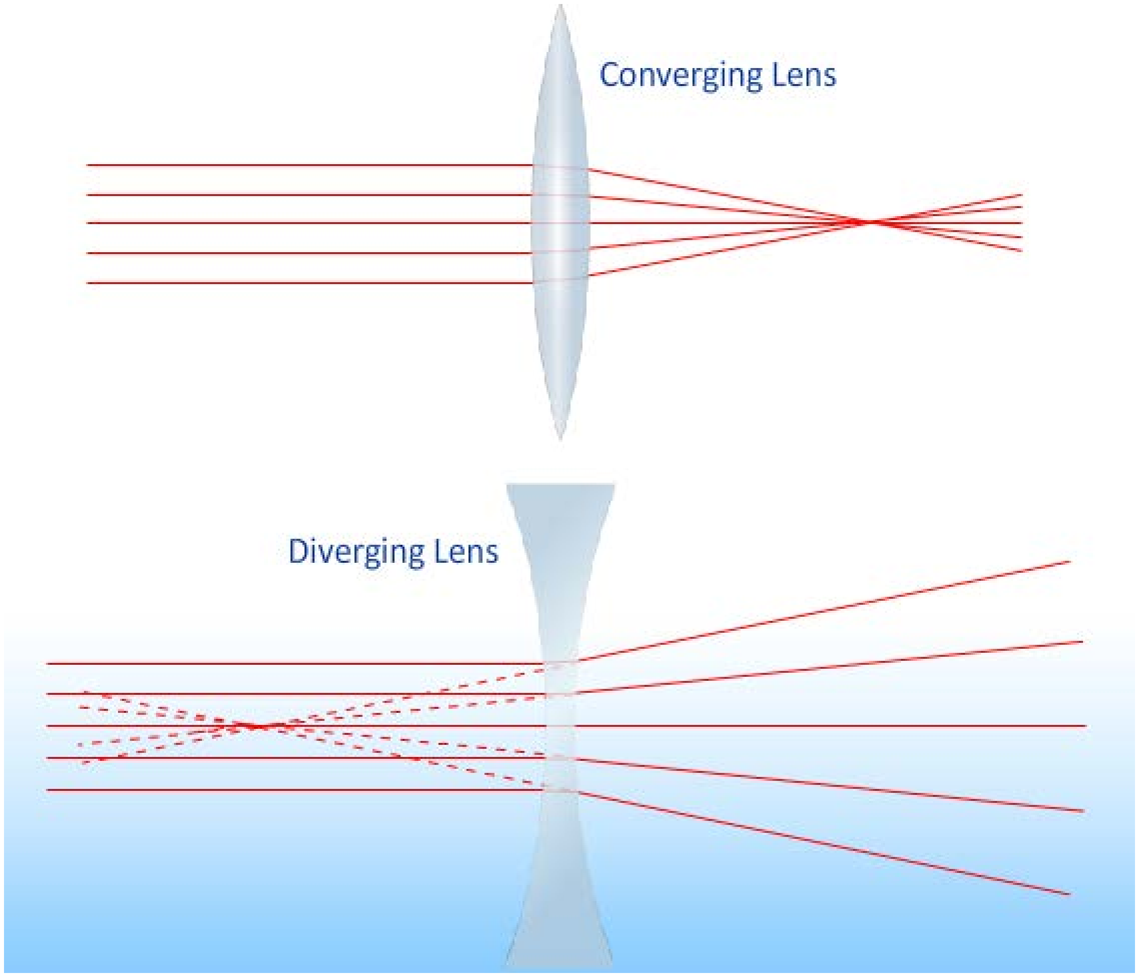
We know object's location by where rays come from (intersect)

We will discuss eyes in lecture 28…

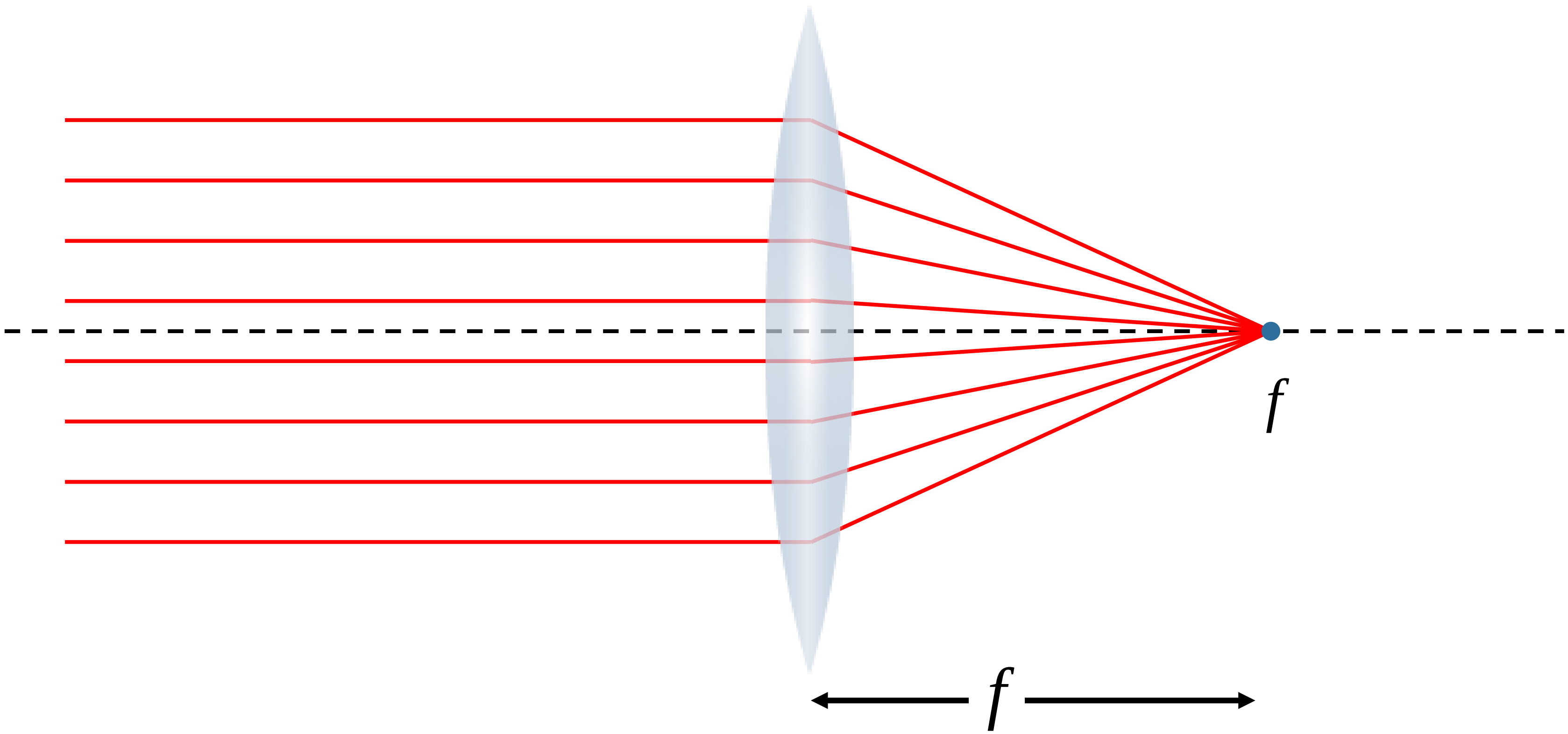
Waves from Objects are Focused by Lens



Two Different Types of Lenses



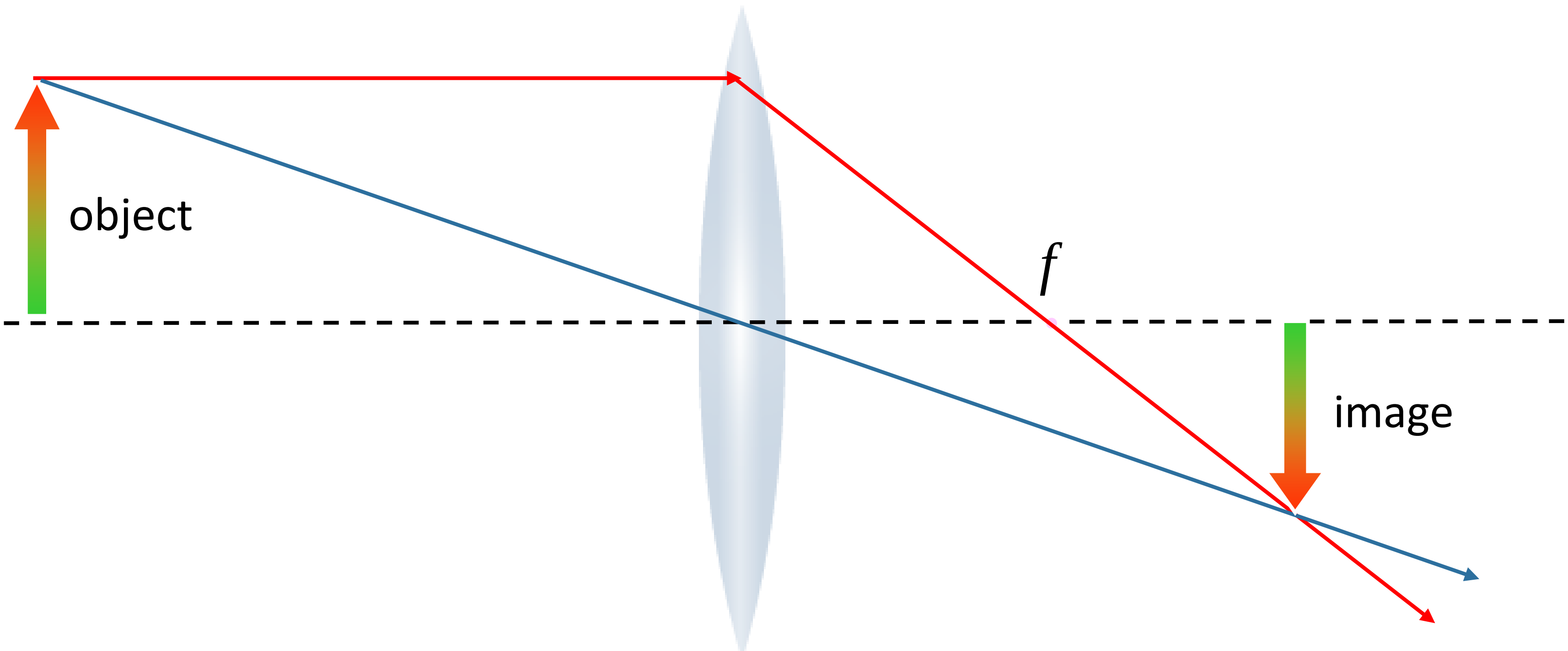
Converging Lens: Consider the case where the shape of the lens is such that light rays parallel to the axis of the mirror are all "focused" to a common spot a distance f behind the lens:



Recipe for Finding Image:

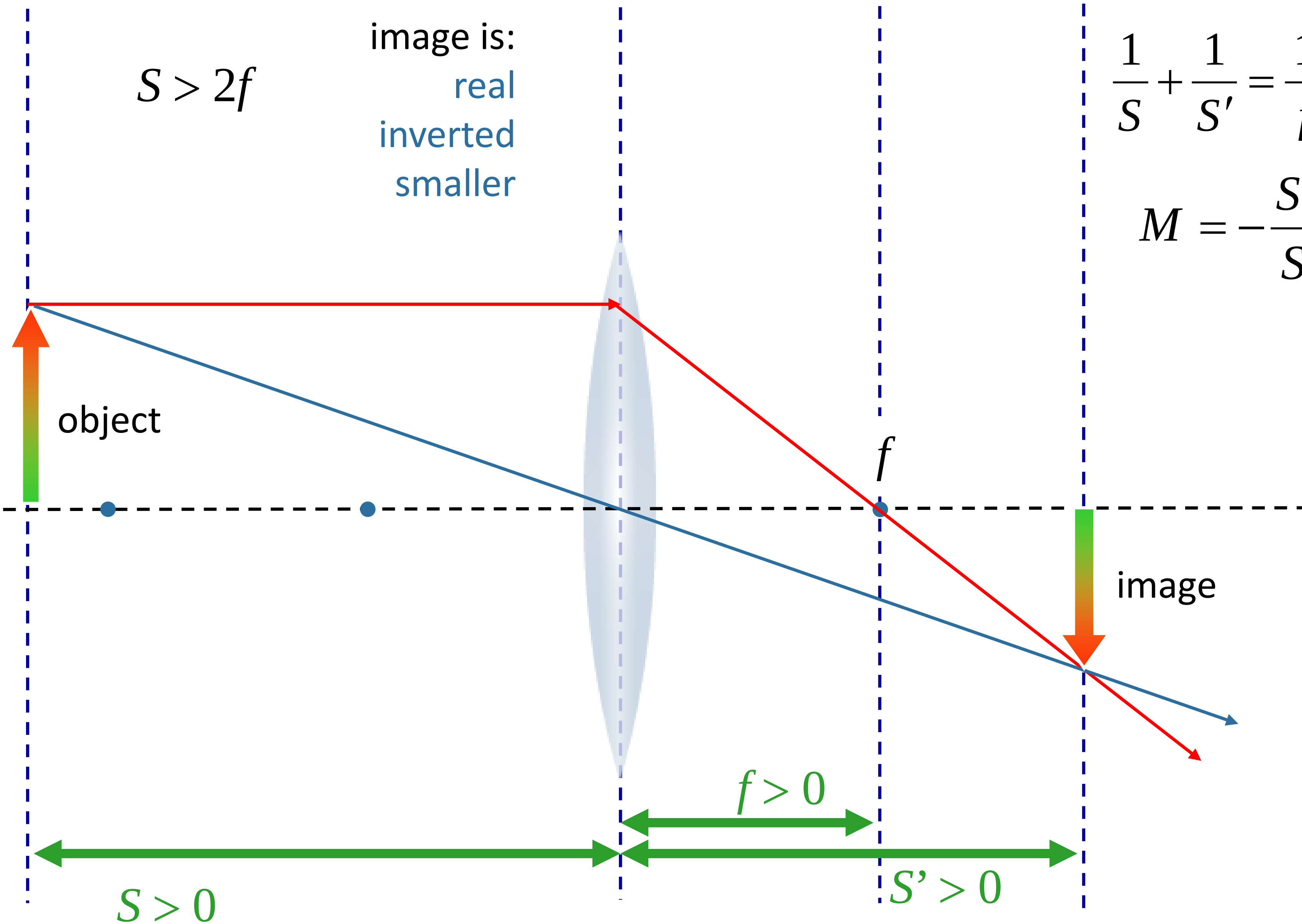
1) Draw ray parallel to axis — refracted ray goes through focus

2) Draw ray through center — refracted ray is symmetric



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

Example



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

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

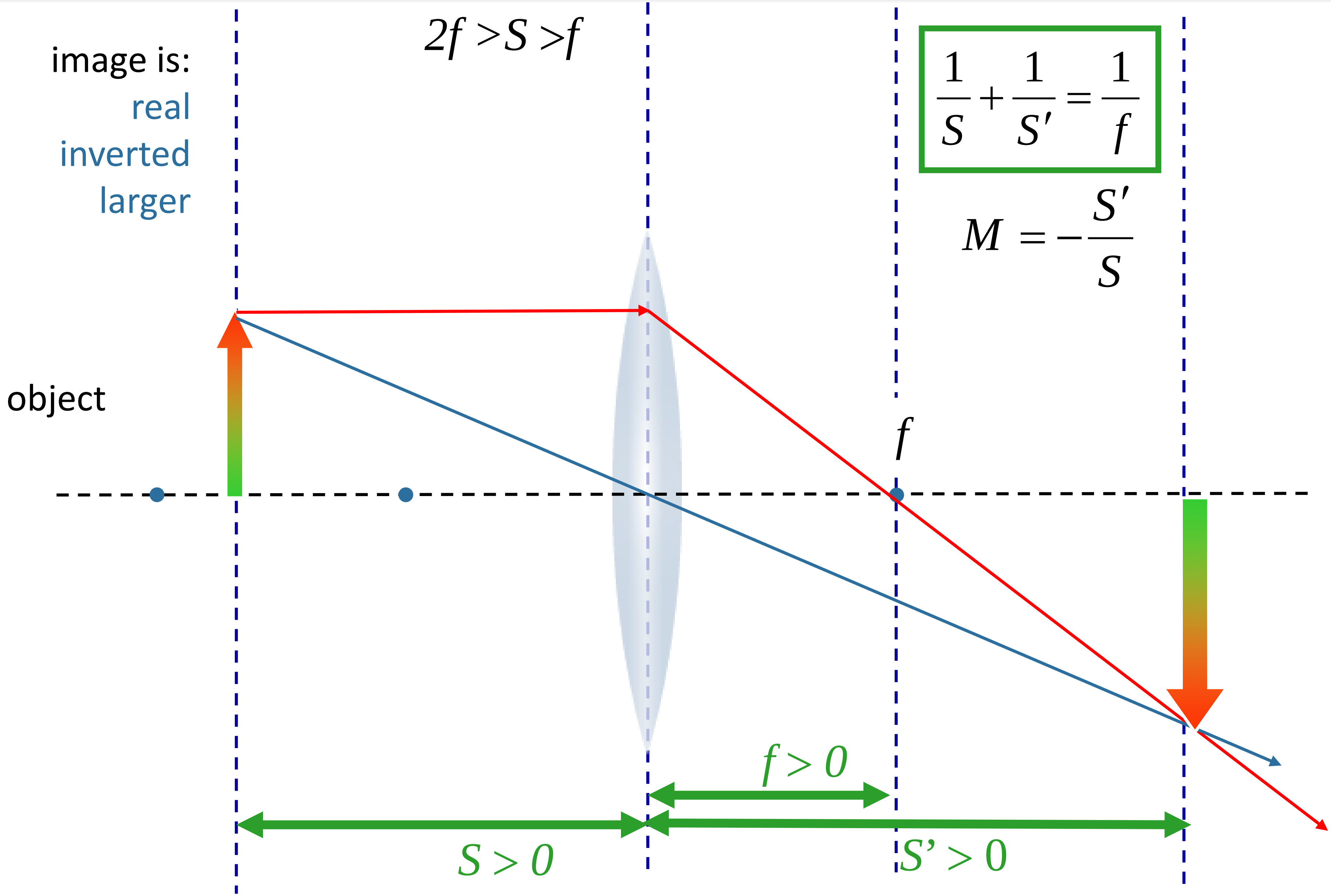
Example

image is:
real
inverted
larger

$$2f > S > f$$

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

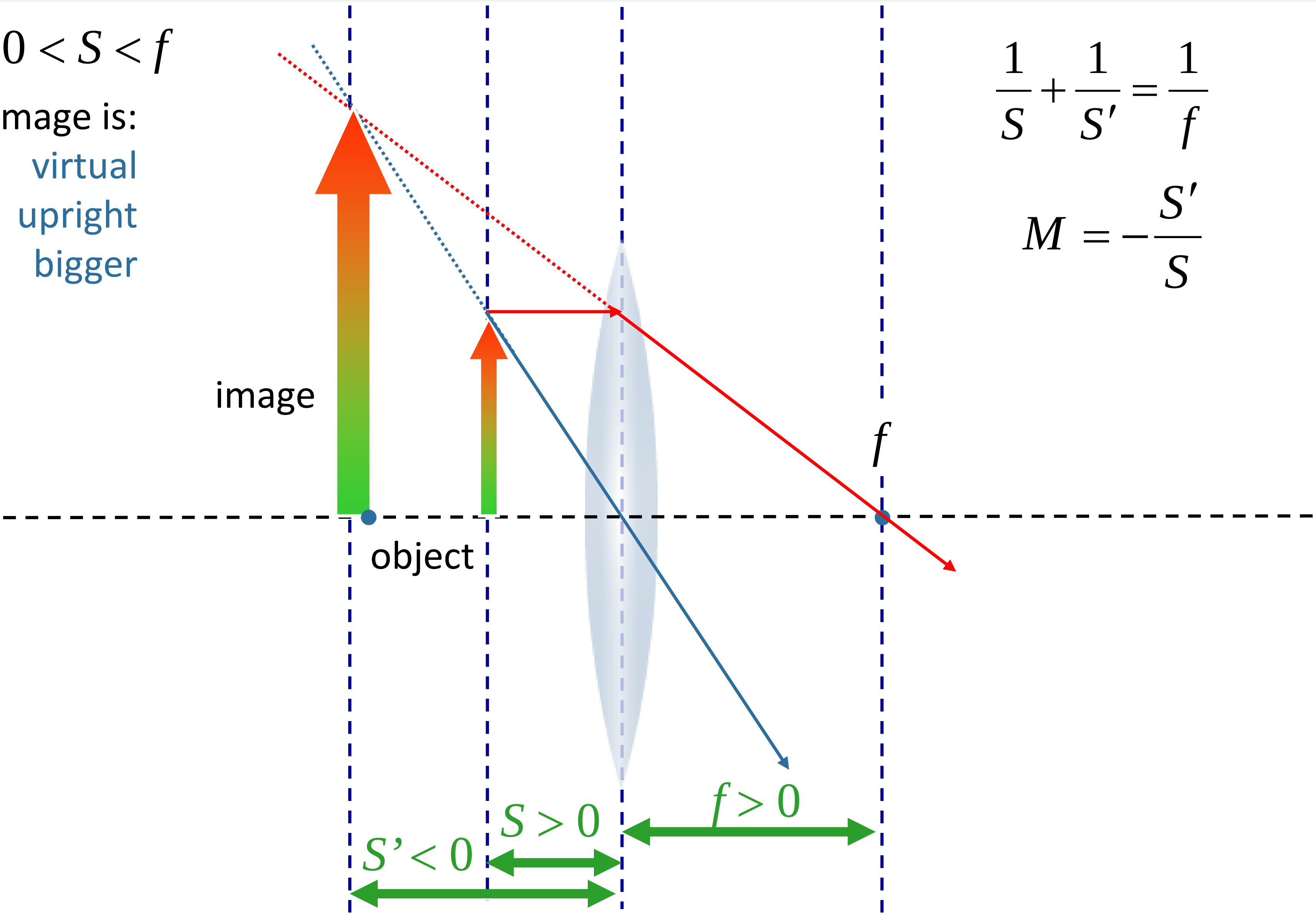
$$M = -\frac{S'}{S}$$



Example

$$0 < S < f$$

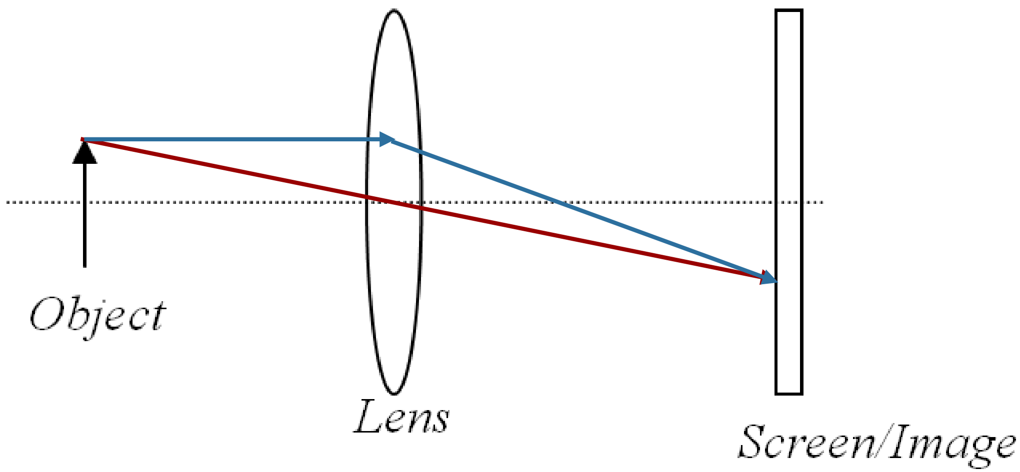
image is:
virtual
upright
bigger



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

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

CheckPoint 1a



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

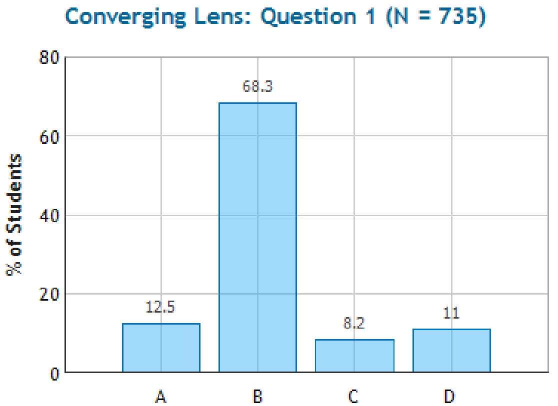
The image is:
A. Real
B. Virtual

The image is:
A. Inverted
B. Upright

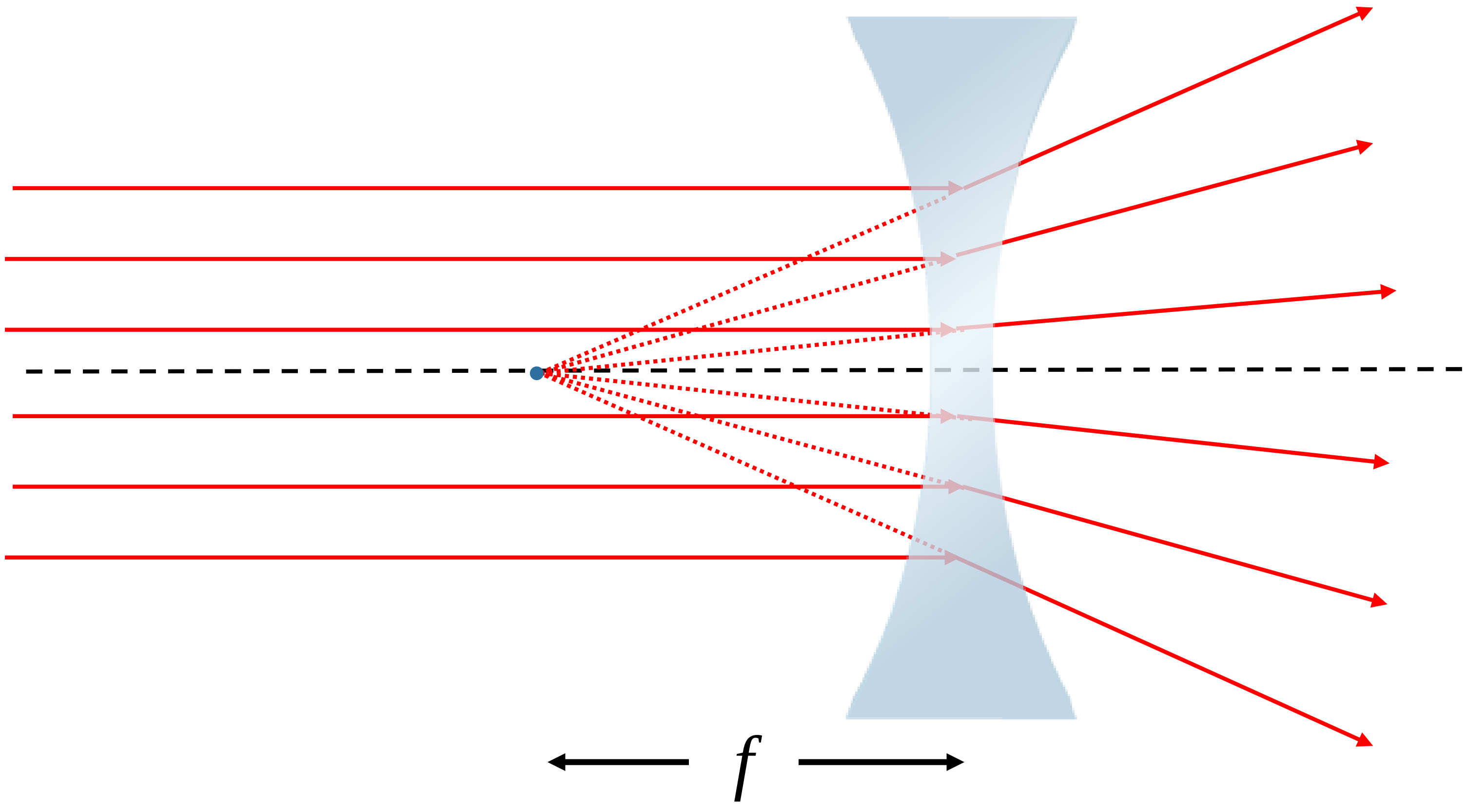
Image on screen
MUST BE REAL

$s' > 0$

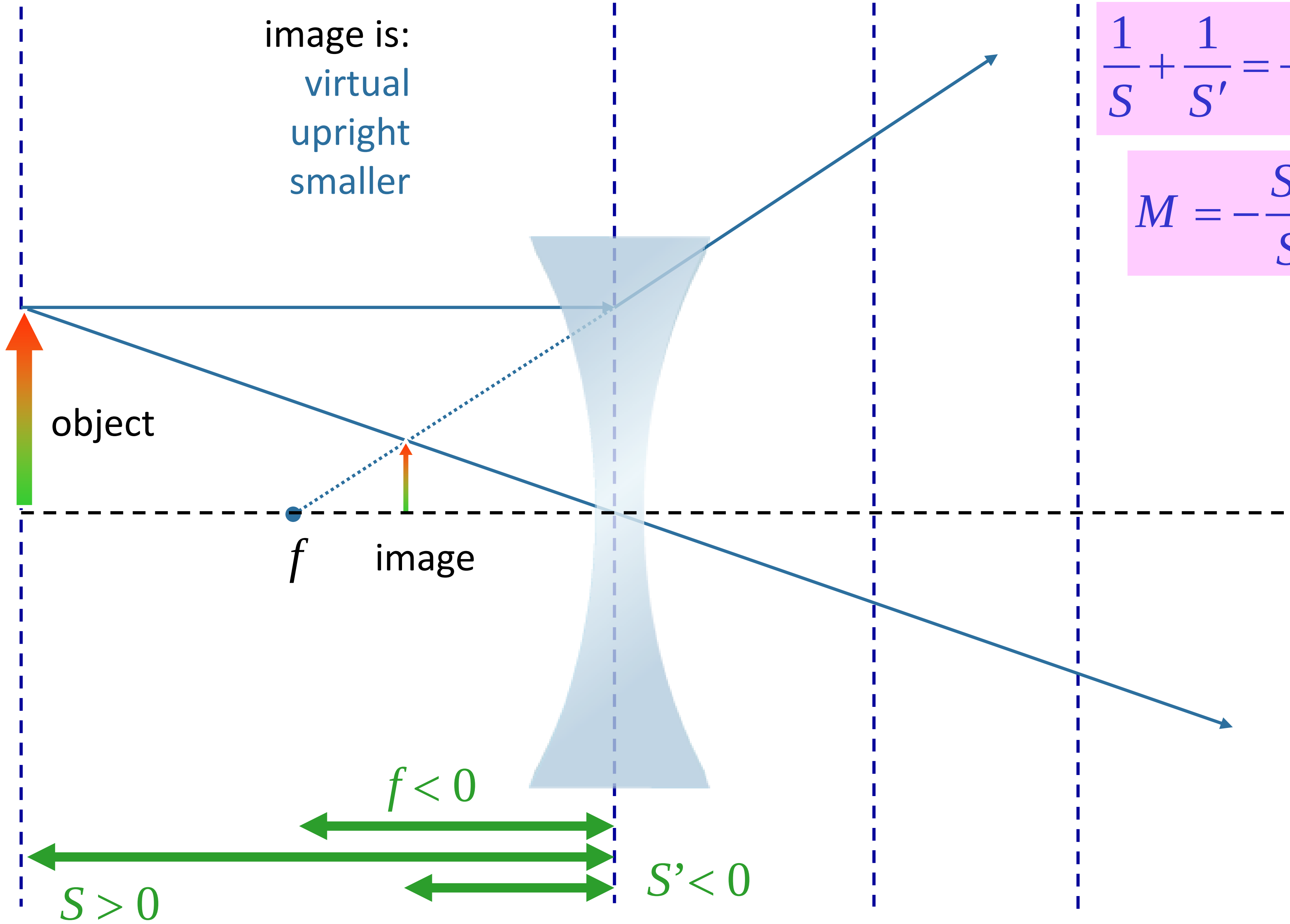
$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \qquad M = -\frac{s'}{s}$$



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



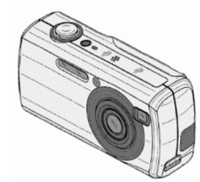
$$\frac{1}{S}+\frac{1}{S'}=\frac{1}{f}$$

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

Executive Summary - Lenses

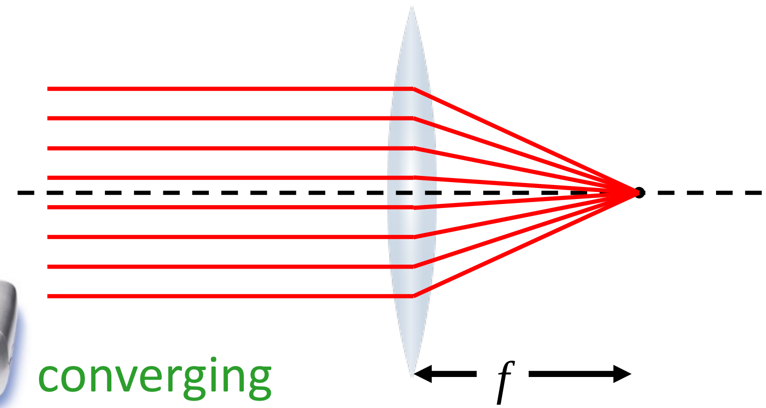
$S > 2f$

real
inverted
smaller



$2f > S > f$

real
inverted
bigger



converging

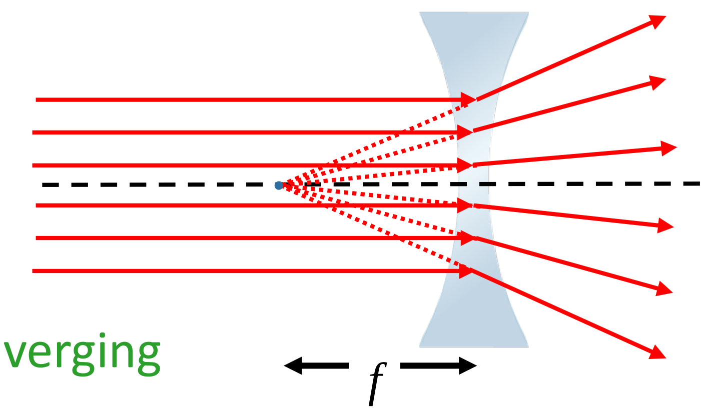
$f > S > 0$

virtual
upright
bigger

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

$S > 0$

virtual
upright
smaller



diverging

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:

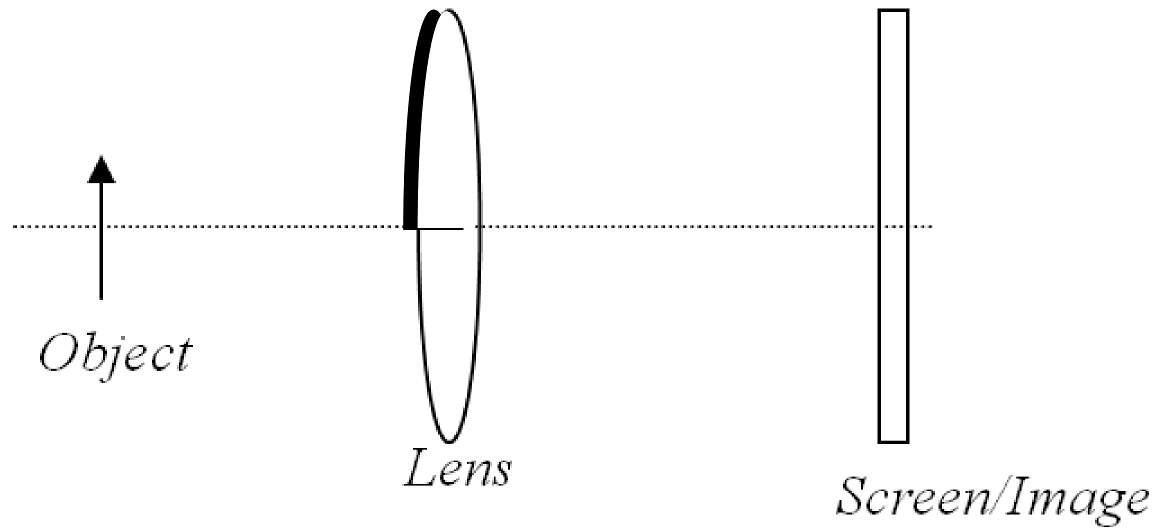
The sign conventions

S: positive if object is “upstream” of lens

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

f: positive if converging lens

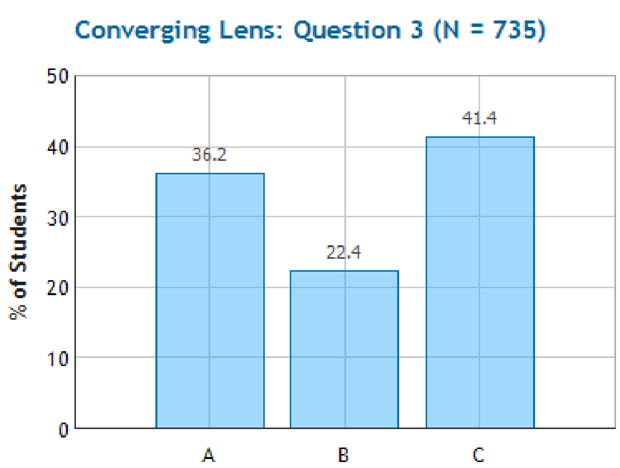
CheckPoint 1b



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

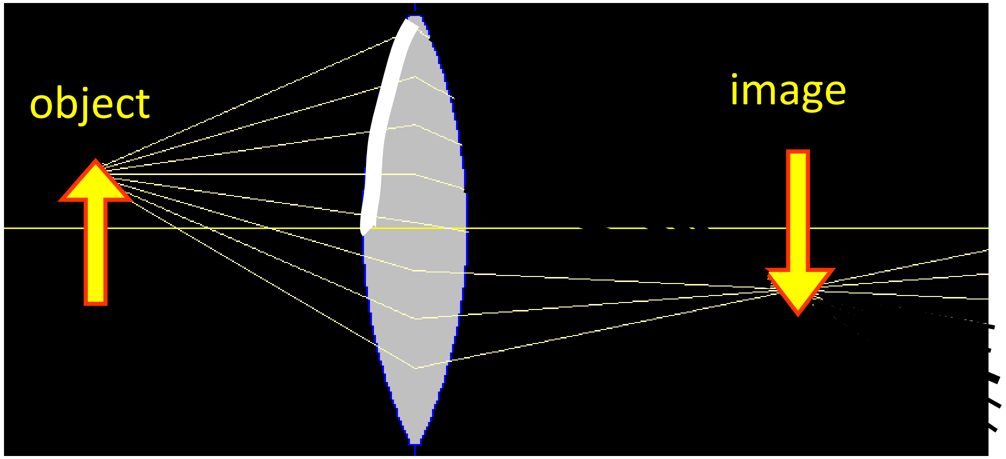
A piece of black tape is now placed over the upper half of the lens. Which of the following is true?

A. Only the lower half of the object will show on the screen
B. Only the upper half of the object will show on the screen
C. The whole object will show on the screen



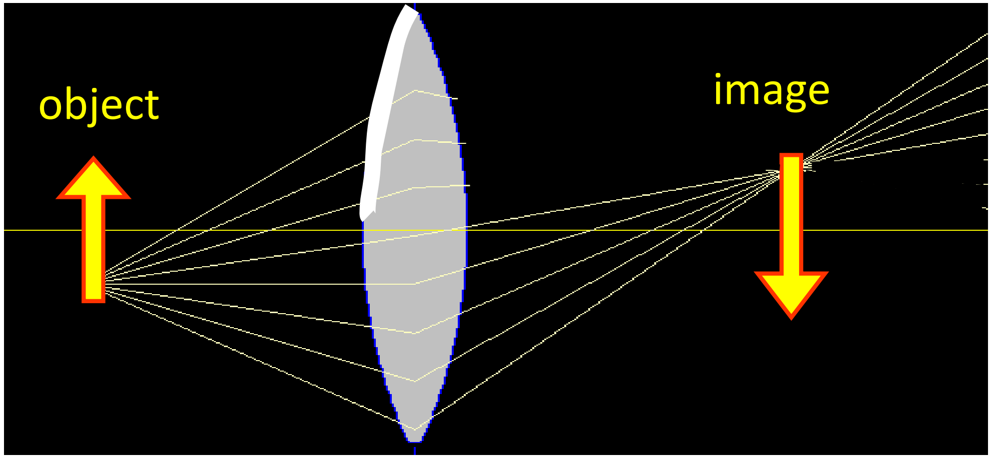
Cover top half of lens

Light from top of object



Cover top half of lens

Light from bottom of object



What's the Point?

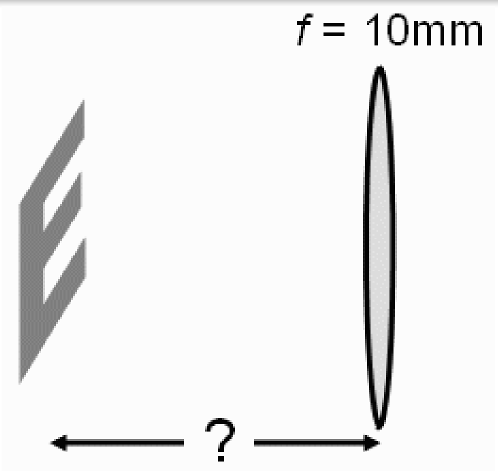
The rays from the bottom half still focus
The image is there, but it will be dimmer!

A. Only the lower half of the object will show on the screen
B. Only the upper half of the object will show on the screen
C. The whole object will show on the screen

Calculation

A magnifying glass is used to read the fine print on a document. The focal length of the lens is 10mm.

At what distance from the lens must the document be placed in order to obtain an image magnified by a factor of 5 that is not inverted?



Conceptual Analysis

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

Magnification: $M = -s'/s$

Strategic Analysis

Consider nature of image (real or virtual?) to determine relation between object position and focal point

Use magnification to determine object position

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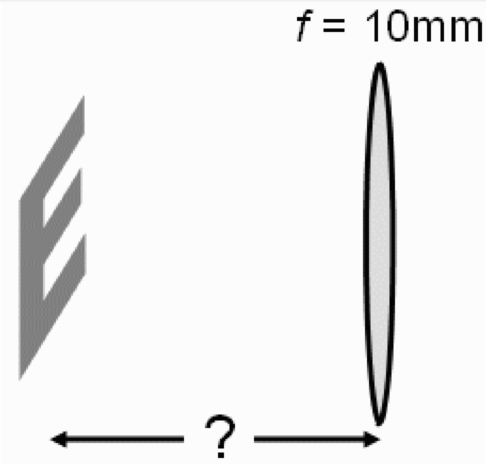
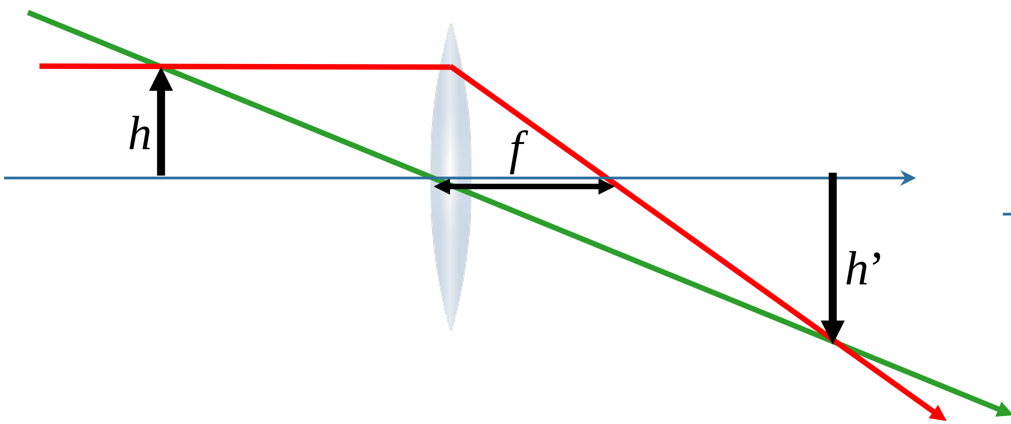


Is the image real or virtual?

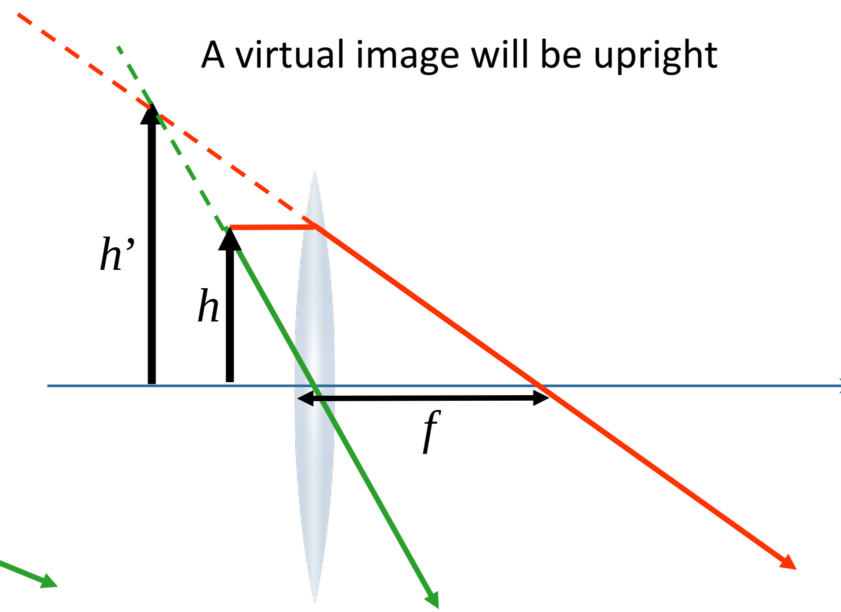
A) REAL

B) VIRTUAL

A real image would be inverted



A virtual image will be upright



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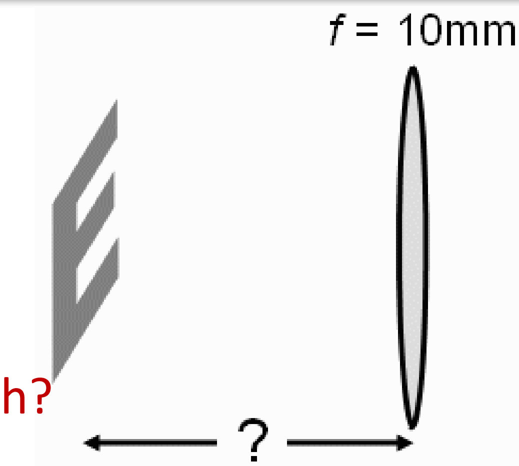
At what distance from the lens must the document be placed in order to obtain an image magnified by a factor of 5 that is not inverted?



How does the object distance compare to the focal length?

$\boxed{\text{A) } |s| < |f|}$ B) $|s| = |f|$ C) $|s| > |f|$

Lens equation $\rightarrow$ $$\frac{1}{S'} = \frac{1}{f} - \frac{1}{S}$$

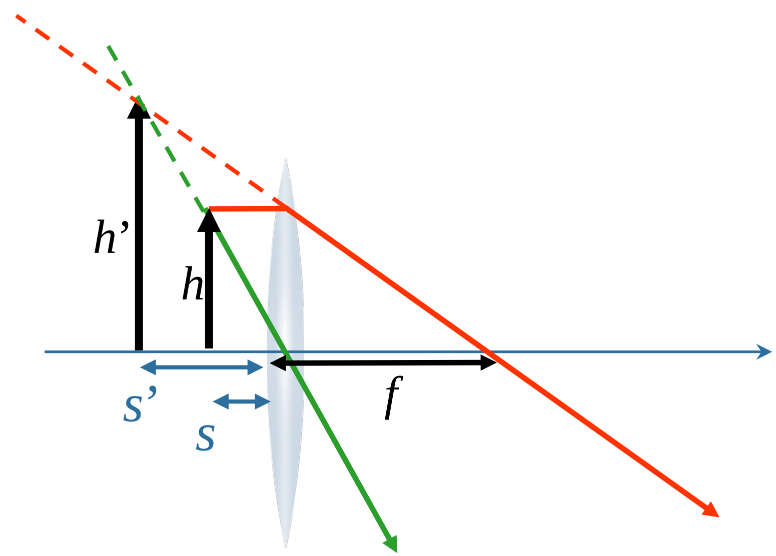
$\rightarrow$ $$S' = \frac{f\,S}{S - f}$$

Virtual Image Þ $s' < 0$

Real object Þ $s > 0$

Converging lens Þ $f > 0$

$$S - f < 0$$



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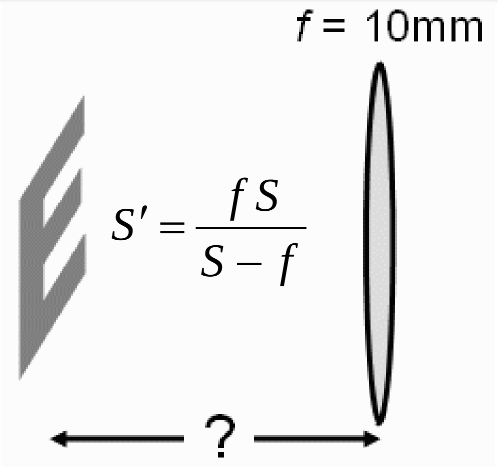
At what distance from the lens must the document be placed in order to obtain an image magnified by a factor of 5 that is not inverted?



What is the magnification M in terms of s and f?

A) $M = \frac{s-f}{f}$

B) $M = \frac{f-s}{f}$

C) $\boxed{M = \frac{-f}{s-f}}$

D) $M = \frac{f}{s-f}$

Lens equation:

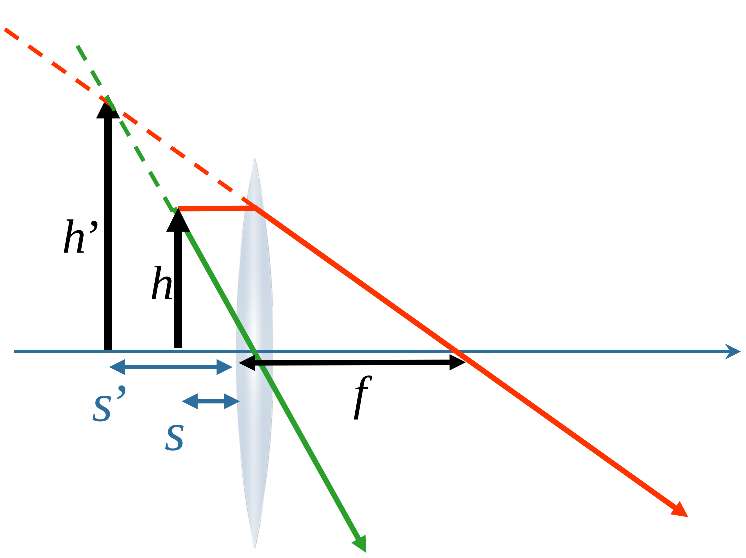
$$\frac{1}{S'} = \frac{1}{f} - \frac{1}{S}$$

$$S' = \frac{f\,S}{S-f}$$

Magnification equation:

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

$$M = \frac{-f}{s-f}$$



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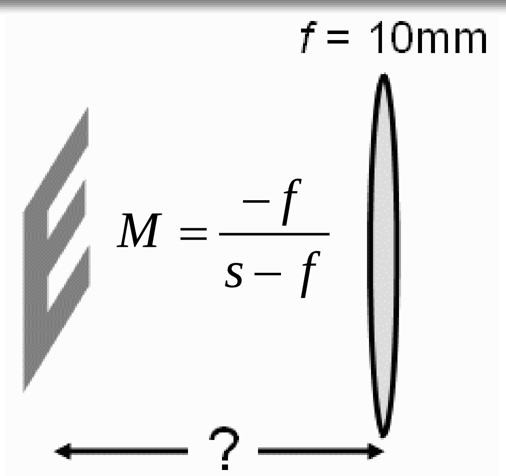


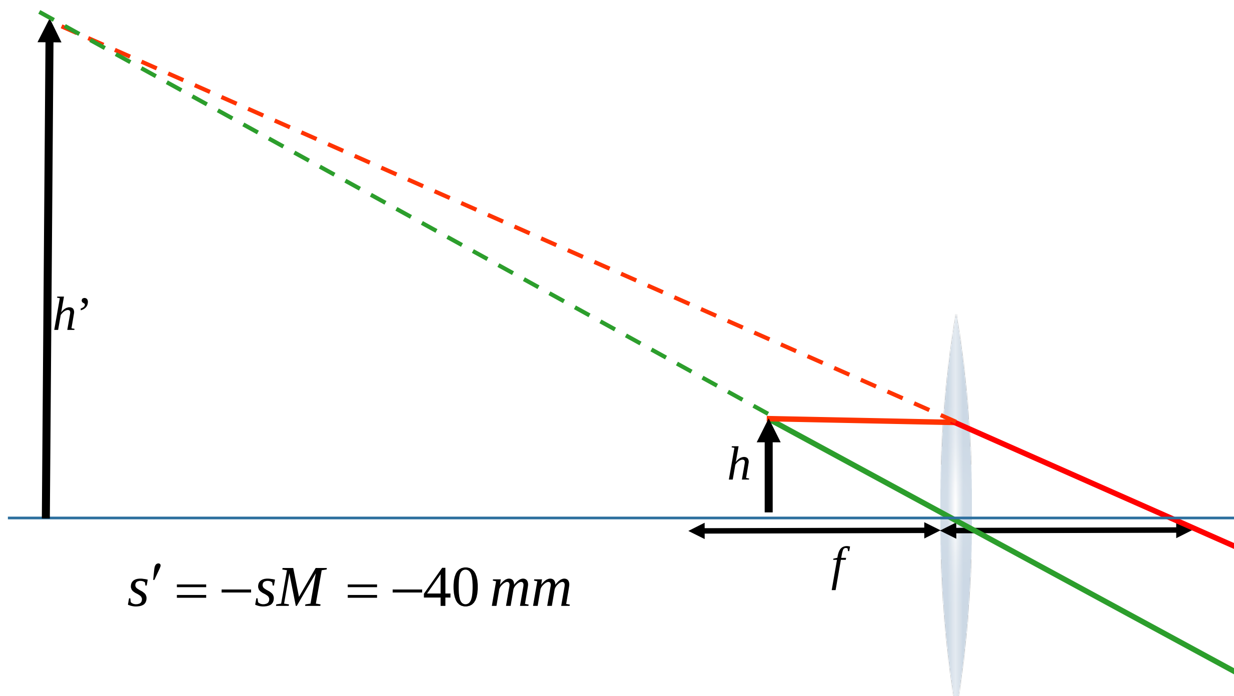
A) 1.7mm B) 6mm $\boxed{\text{C) 8mm}}$ D) 40 mm E) 60 mm

$$M = +5$$

$$f = +10\ mm$$

$$M = \frac{-f}{s-f} \rightarrow s = f\frac{(M-1)}{M}$$

$$\rightarrow s = \frac{4}{5}f = 8\ mm$$

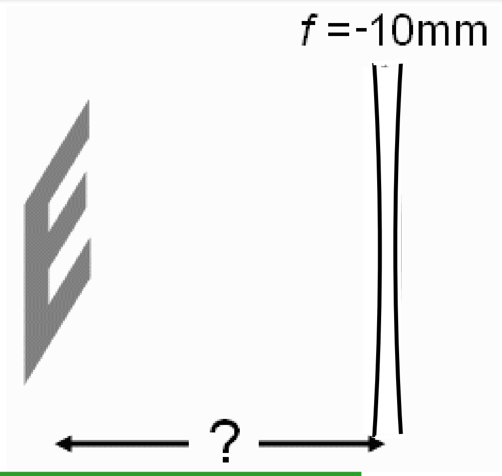


$$s' = -sM = -40\ mm$$

Follow Up

Suppose we replace the converging lens with a diverging lens with focal length of 10mm.

If we still want to get an image magnified by a factor of 5 that is not inverted, how does the object s_{div} compare to the original object distance s_{conv}?



A) $s_{div} < s_{conv}$

B) $s_{div} = s_{conv}$

C) $s_{div} > s_{conv}$

D) s_{div} doesn't exist

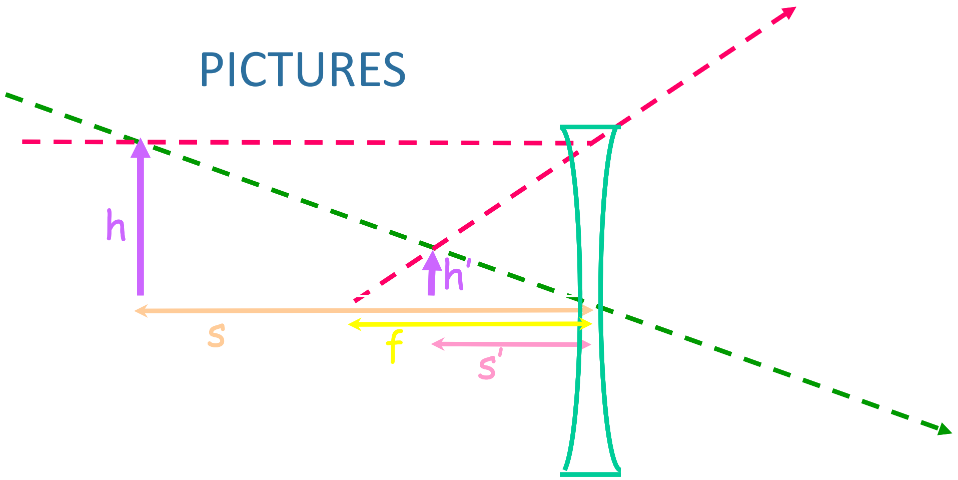
EQUATIONS

$$M = \frac{-f}{s-f} \rightarrow s = f\,\frac{(M-1)}{M}$$

$$M = +5$$
$$f = -10mm \rightarrow s = \frac{4}{5} f = -8mm$$

s negative Þ not real object

PICTURES

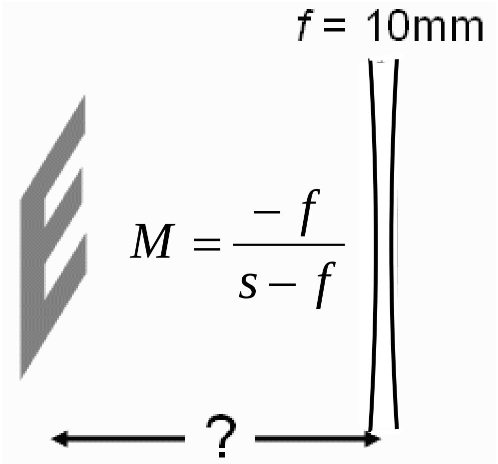


Draw the rays: s' will always be smaller than s
Magnification will always be less than 1

Follow Up

Suppose we replace the converging lens with a diverging lens with focal length of 10mm.

What is the magnification if we place the object at $s = 8\text{mm}$?



A) $M = \frac{1}{2}$

B) $M = 5$

C) $M = \frac{3}{8}$

D) $\boxed{M = \frac{5}{9}}$

E) $M = \frac{4}{5}$

EQUATIONS

$$M = \frac{-f}{s-f}$$

$$s = 8\,mm$$

$$f = -10\,mm$$

$$M = -\frac{-10}{8-(-10)} = \frac{10}{18} = \frac{5}{9}$$

PICTURES