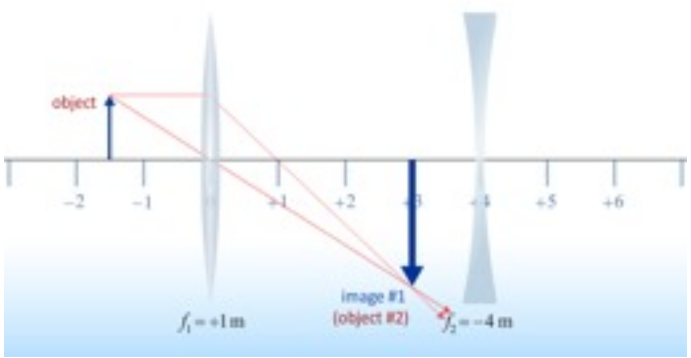
Physics 141
Lecture 28

Today's Concept:

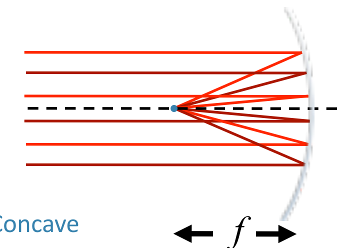
A) Optical Devices



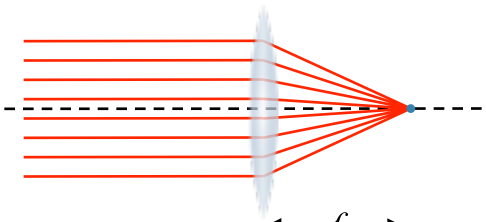
Executive Summary - Mirrors & Lenses:

$S > 2f$	real inverted smaller
$2f > S > f$	real inverted bigger
$f > S > 0$	virtual upright bigger
$S > 0$	virtual upright smaller

$f > 0$



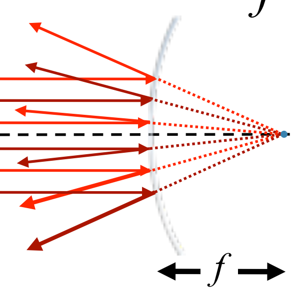
Concave (Converging)



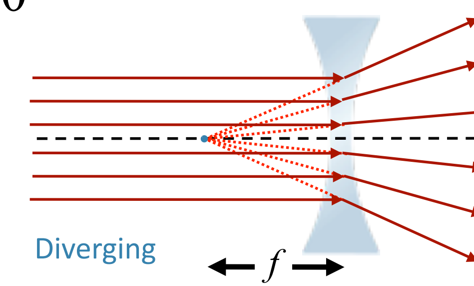
Converging

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

$f < 0$



Convex (diverging)



Diverging

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:

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

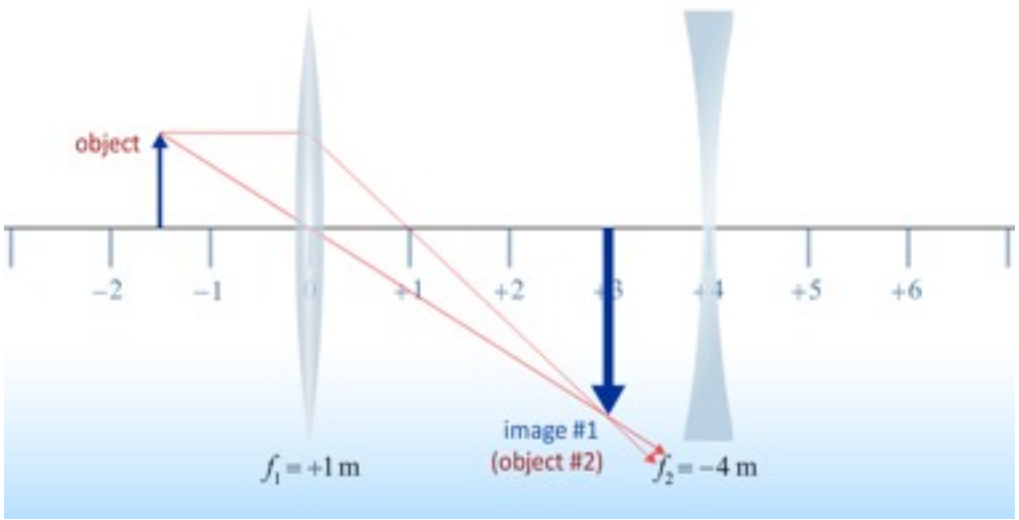
S: positive if object is "upstream" of mirror

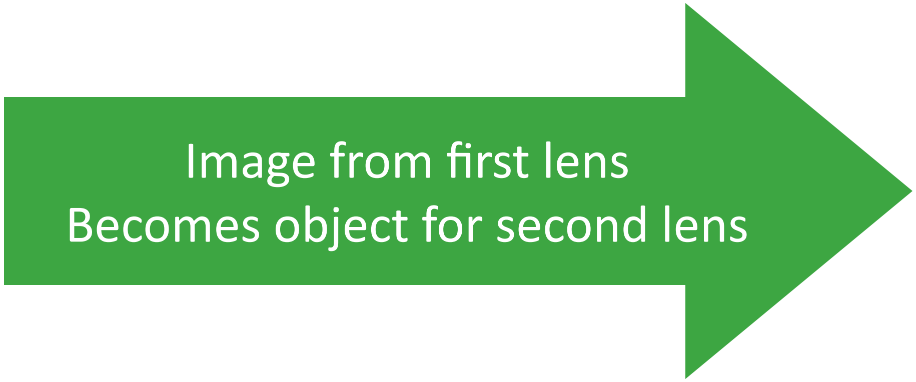
S': positive if image is "upstream" of mirror

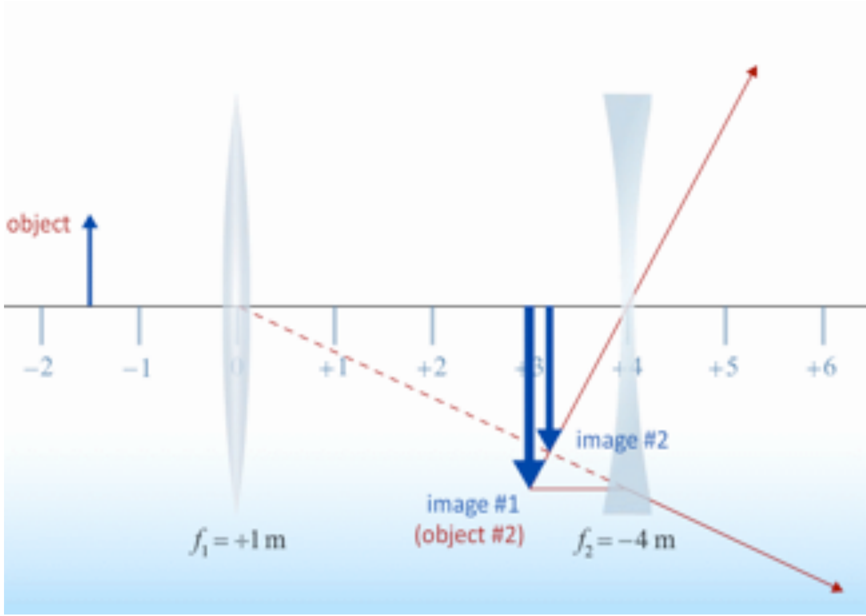
f: positive if converging mirror (concave)

System of Lenses

Trace rays through lenses, beginning with most upstream lens

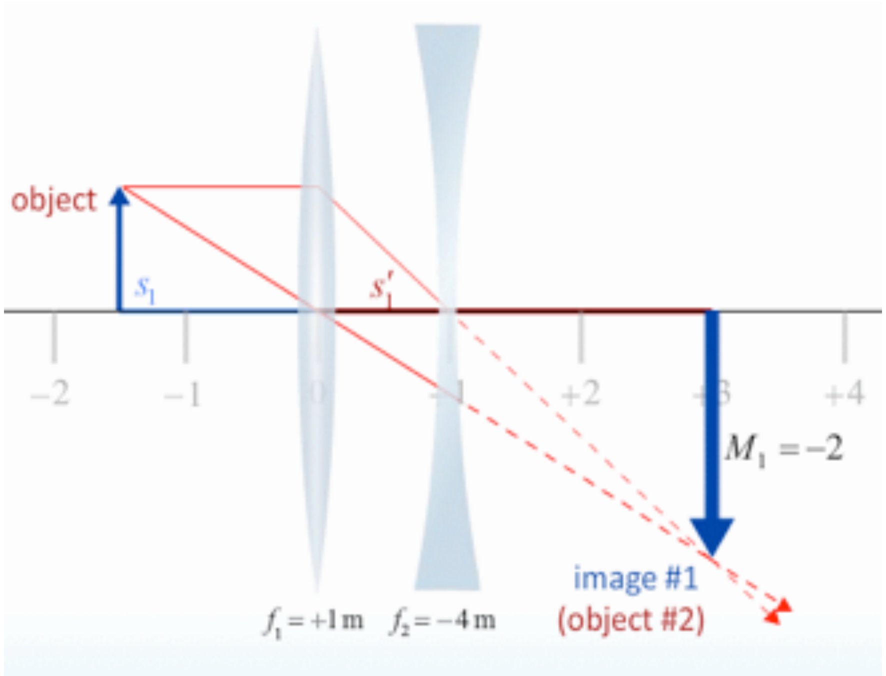






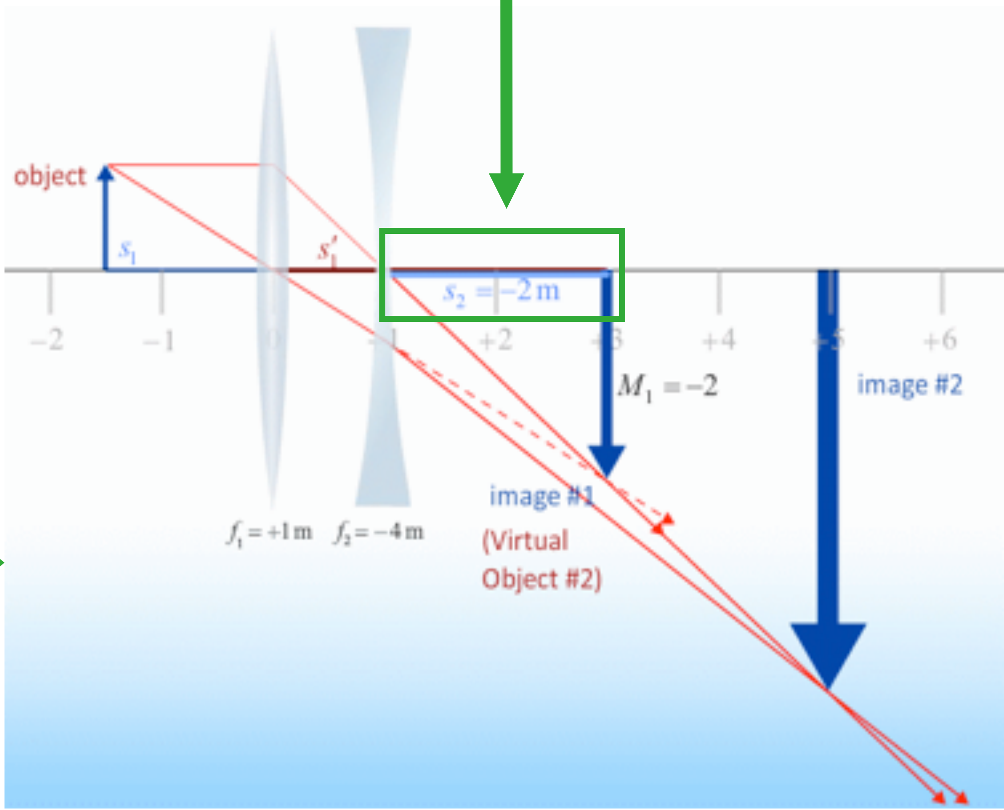
System of Lenses

Virtual Objects are Possible !!

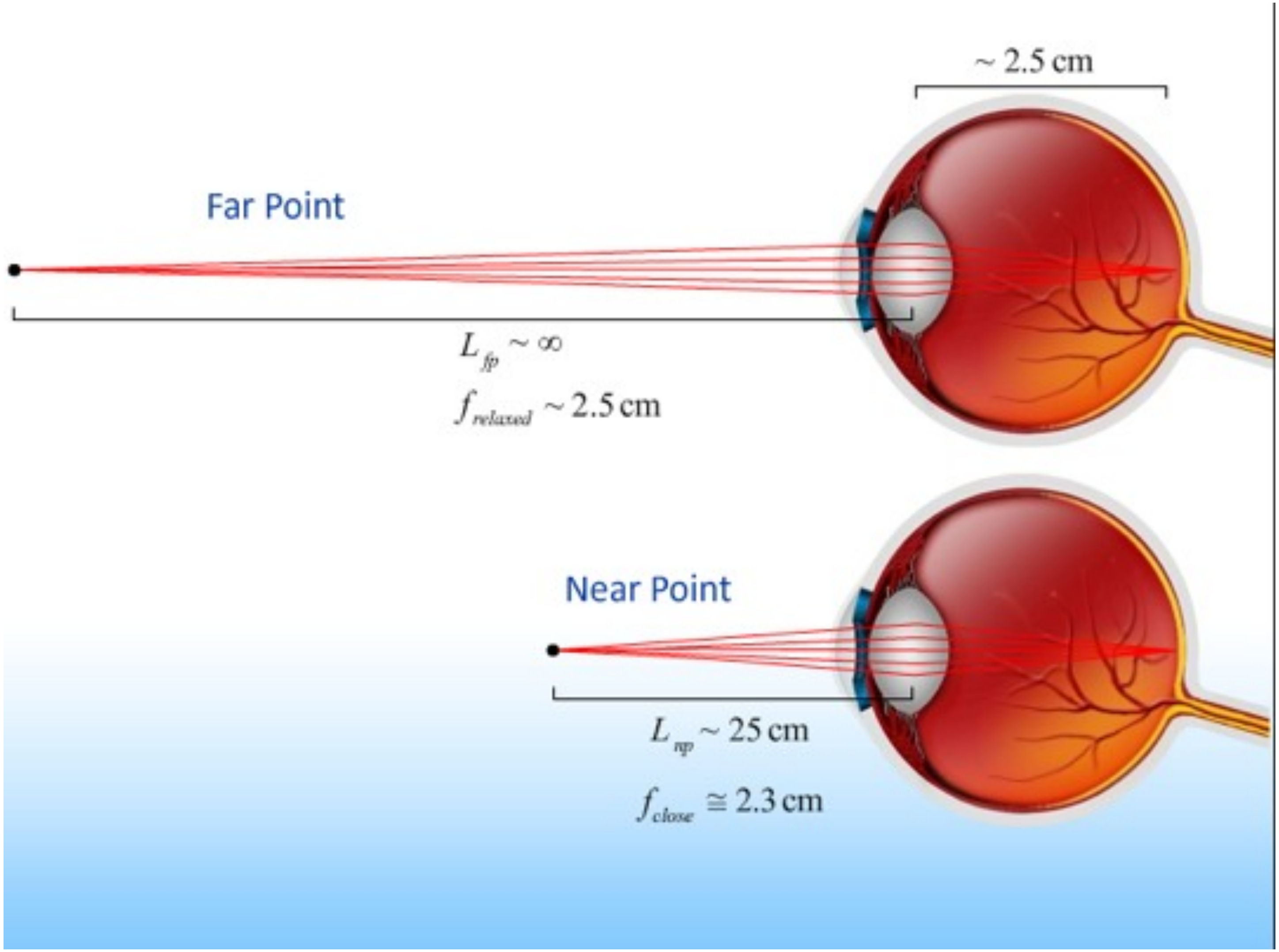


Object Distance is Negative!

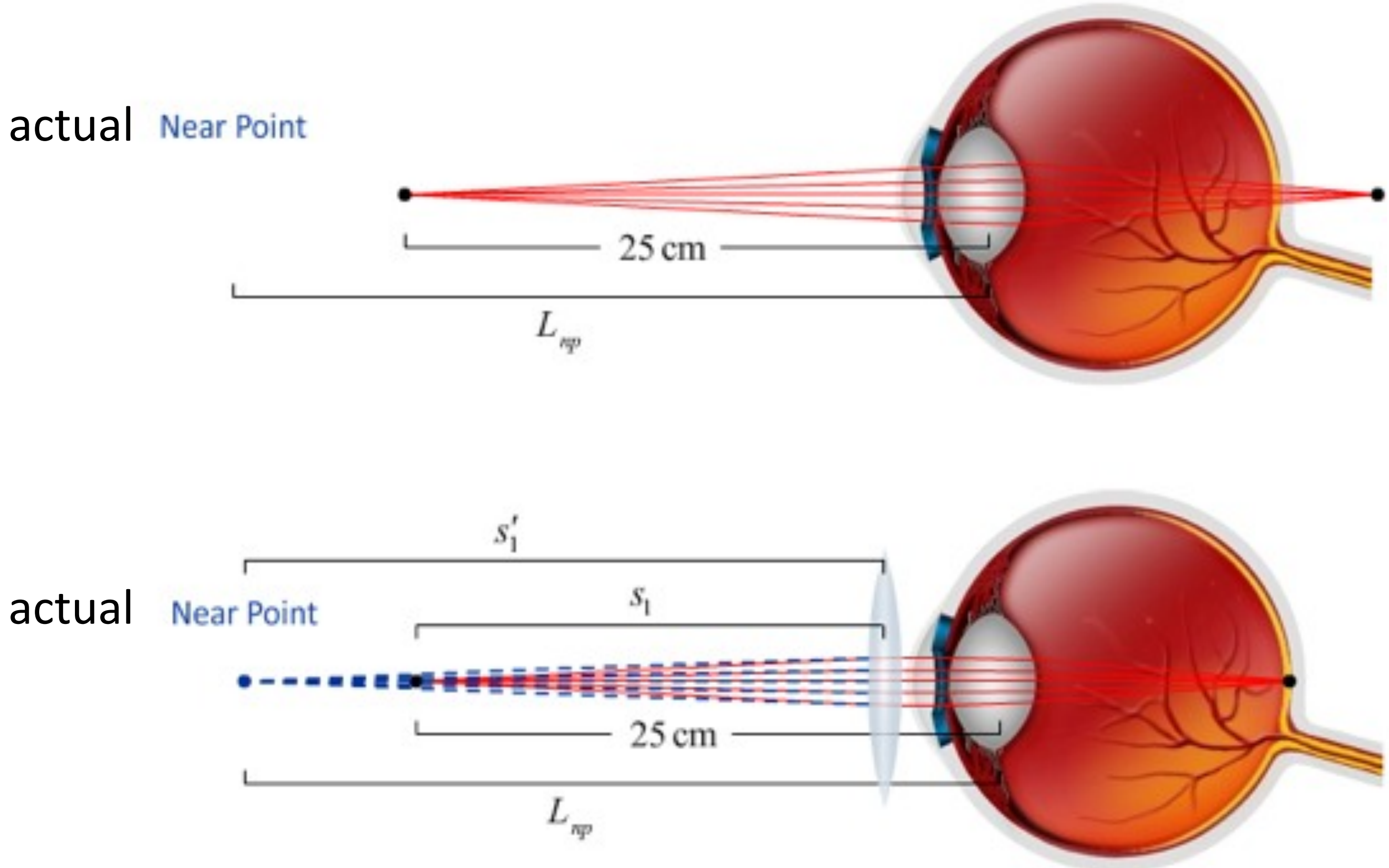
Image from first lens
Becomes object for second lens



Normal Eye

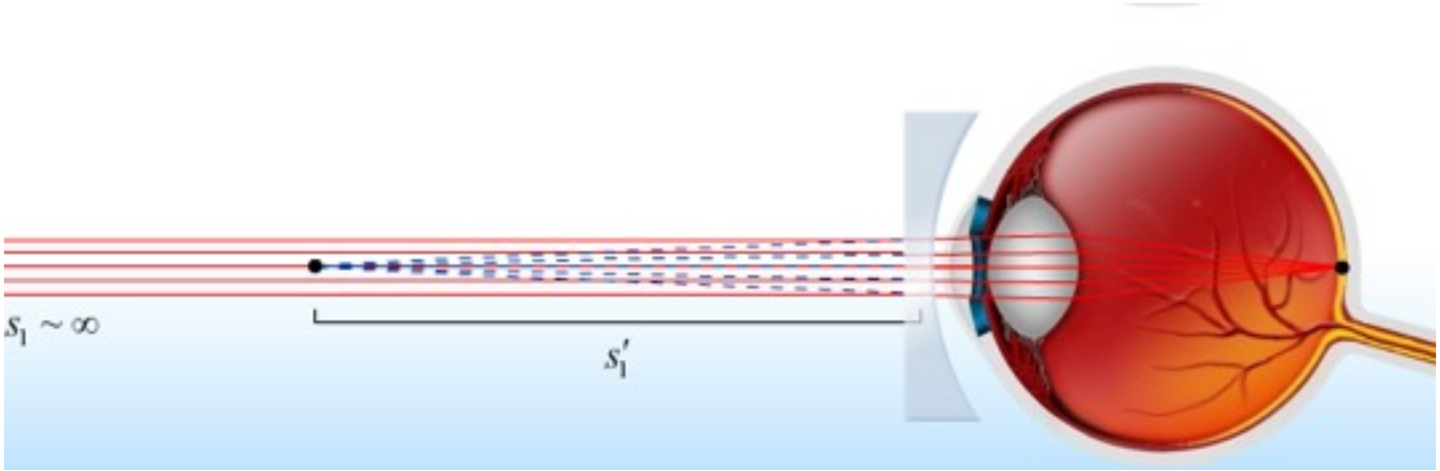

~ 2.5 cm
Far Point
$L_{fp} \sim \infty$
$f_{relaxed} \sim 2.5\,\text{cm}$
Near Point
$L_{np} \sim 25\,\text{cm}$
$f_{close} \cong 2.3\,\text{cm}$

Far-Sighted



Converging Lens creates virtual image at person's actual near point

Near-Sighted



Fix with diverging lens that creates virtual image at far point.

CheckPoint 2

2) Two people who wear glasses are camping. One of them is nearsighted and the other is farsighted.

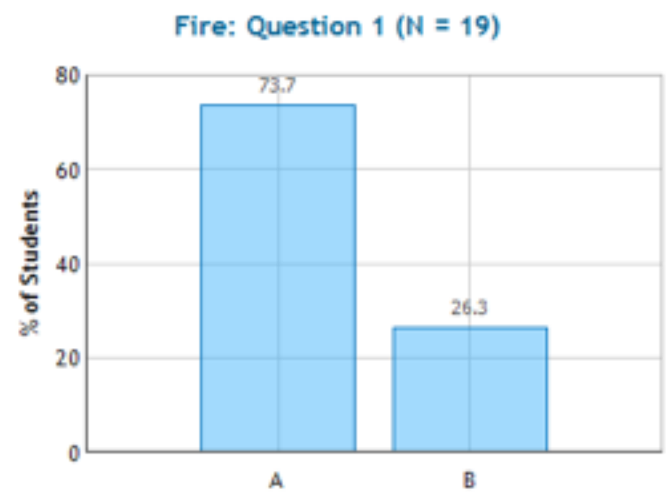
Which person's glasses will be useful in starting a fire with the sun's rays?

A ○ the farsighted person's glasses

B ○ the nearsighted person's glasses

Farsighted = Converging Lens

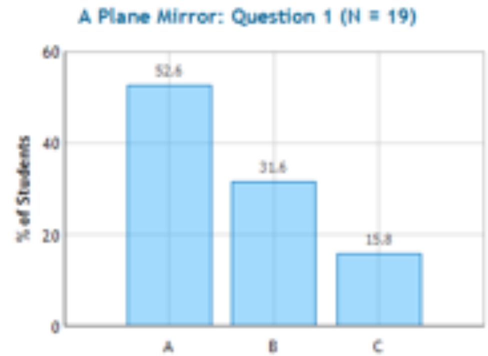
Only Converging Lens can produce a real image!

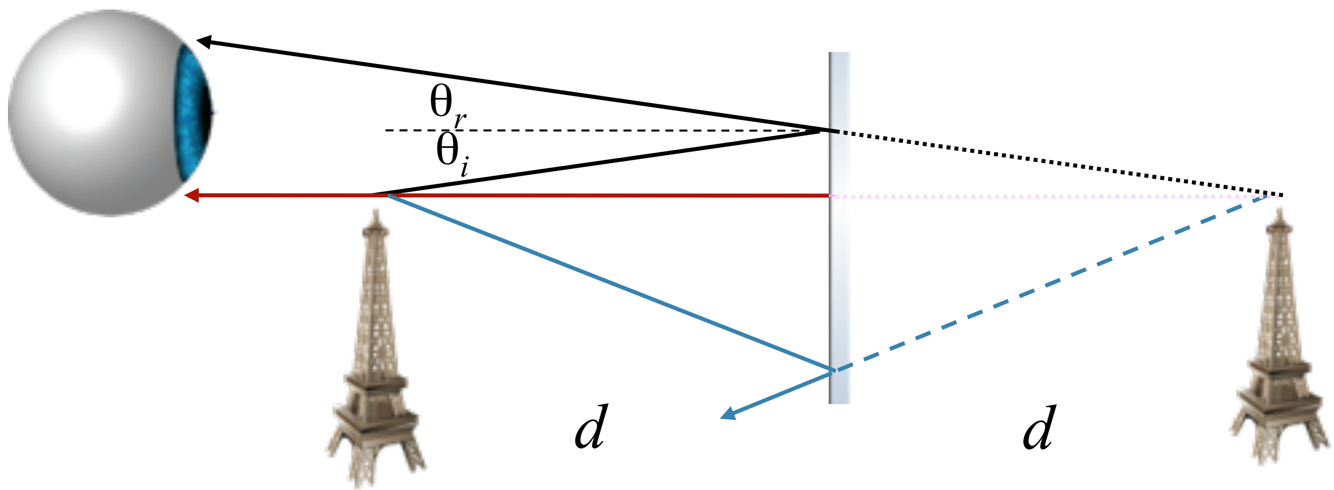


4) A person with normal vision (near point 28cm) is standing in front of a plane mirror.

What is the closest distance to the mirror the person can stand and still see himself in focus?

- A ○ 14cm
- B ○ 28cm
- C ○ 56cm



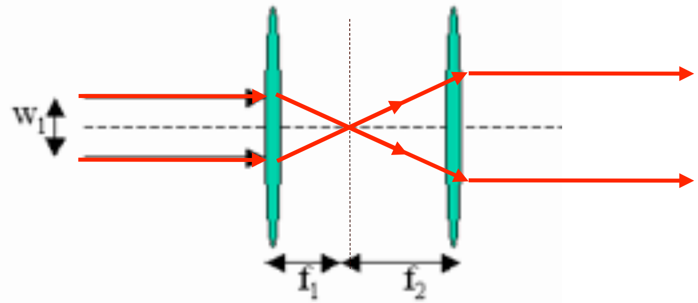


The image is formed an equal distance behind the mirror

Therefore, if you stand a distance = ½ of your near point, the distance to the image will be the near point distance.

CheckPoint 6

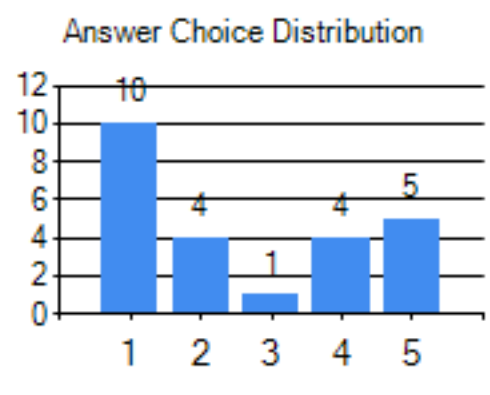
6) A parallel laser beam of width w_1 is incident on a two lens system as shown below.



Each lens is converging. The second lens has a larger focal length than the first ($f_2 > f_1$).

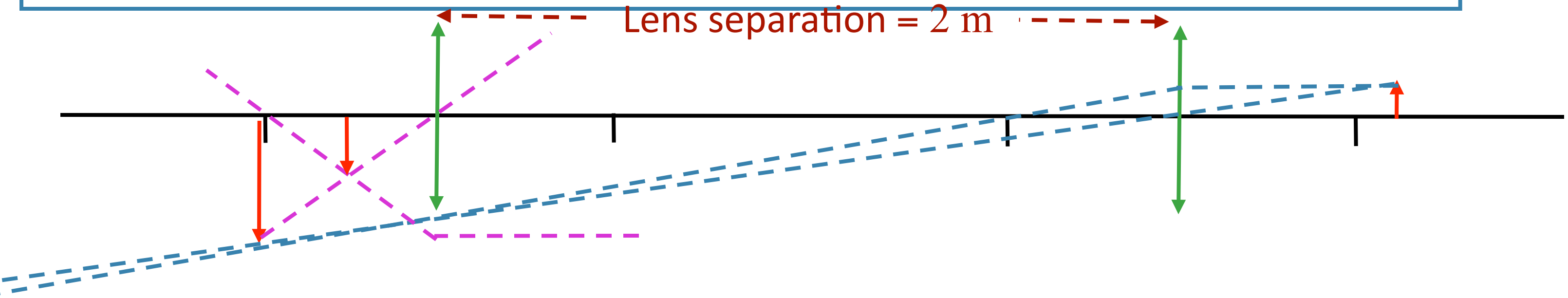
What does the beam look like when it emerges from the second lens?

A ○ The beam is converging
B ○ The beam is diverging
C ○ The beam is parallel to the axis with a width < w_1
D ○ The beam is parallel to the axis with a width = w_1
E ○ The beam is parallel to the axis with a width > w_1



1. Parallel rays are transmitted and pass through focal point (f_1)
2. Those rays also pass through focal point of second lens (f_2) and therefore are transmitted parallel to the axis.
3. $f_2 > f_1$ implies that the width > w_1

Suppose we now decrease the initial object distance to 58 cm. Applying the lens equation, we find $s_1' = 2.48\text{m}$



$s_1 = 58\text{ cm}$

$f = 47\text{ cm}$

$s_1' = 2.48\text{ m}$

$s_2 = -0.48\text{ m}$

What is the nature of the final image in terms of the original object?

A) REAL UPRIGHT

B) REAL INVERTED

C) VIRTUAL UPRIGHT

D) VIRTUAL INVERTED

EQUATIONS

$$S_2' = \frac{fs_2}{s_2 - f}$$

$s_2 < 0$ → $s_2' > 0$ → real image

$$M_2 = -\frac{S_2'}{S_2}$$

→ $M_2 > 0$ → $M = M_1 M_2 < 0$

→ inverted image

PICTURES

Draw Rays as above.

RESULTS

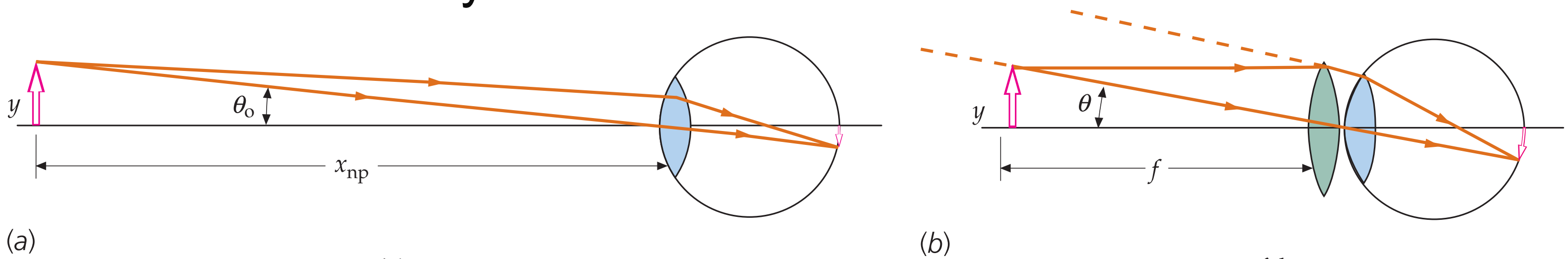
$s_2' = 0.24\text{ m}$

$M = -2.1$

Magnifying Glass

The Magnifying Glass is just a lens which creates a virtual image!.

"Naked" eye

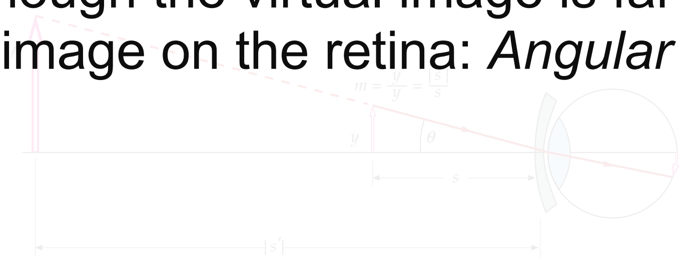


$$\theta_o = \frac{y}{x_{np}}$$

$$\theta = \frac{y}{f}$$

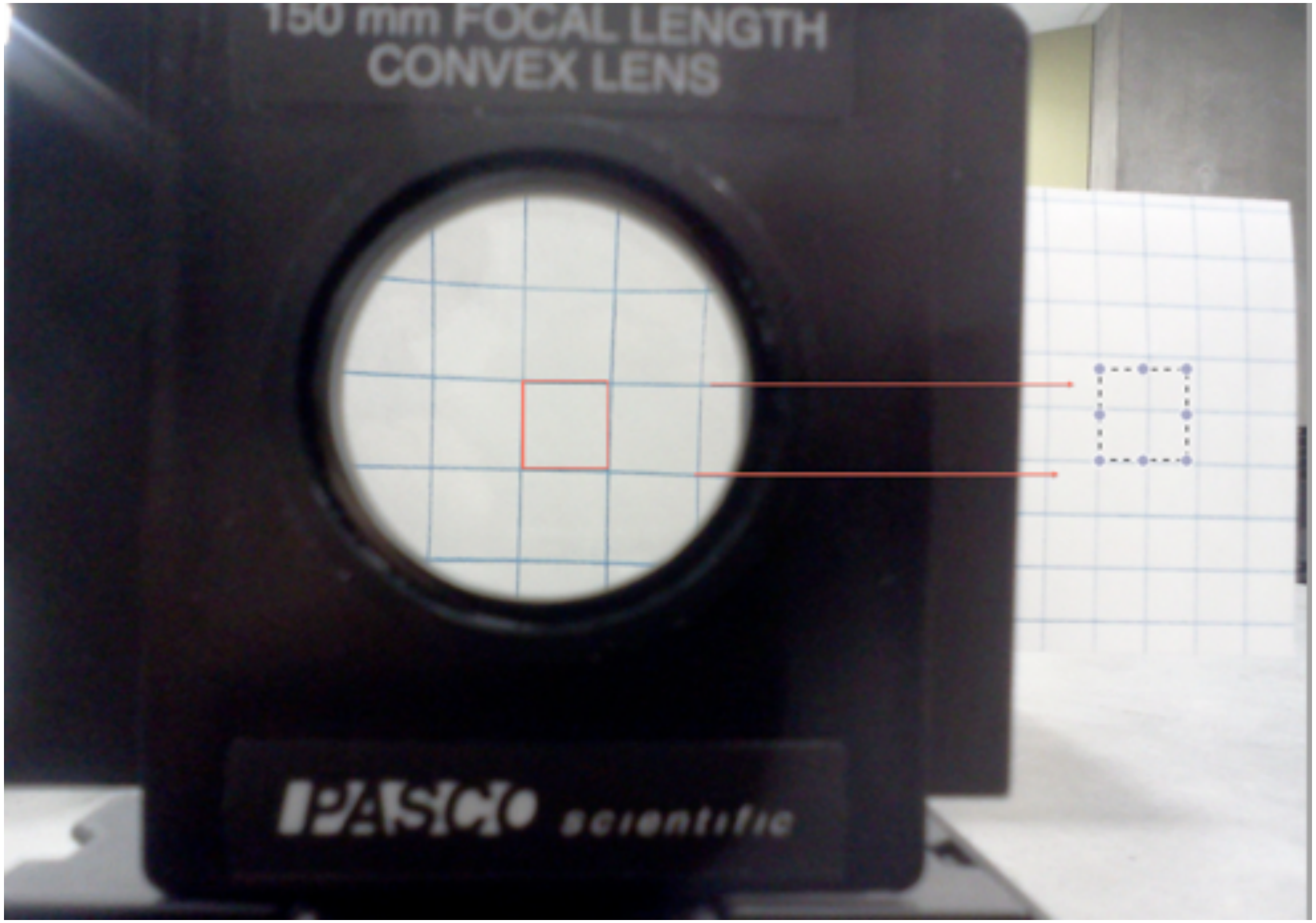
$$M = \frac{\theta}{\theta_o} = \frac{x_{np}}{f}$$

Even though the virtual image is far away, θ is bigger and makes a bigger image on the retina: *Angular magnification*




f =
150 mm
x_{np} =250 mm

Experimental Measurement of M



The Compound Microscope

A combination of two converging lens makes a Microscope.

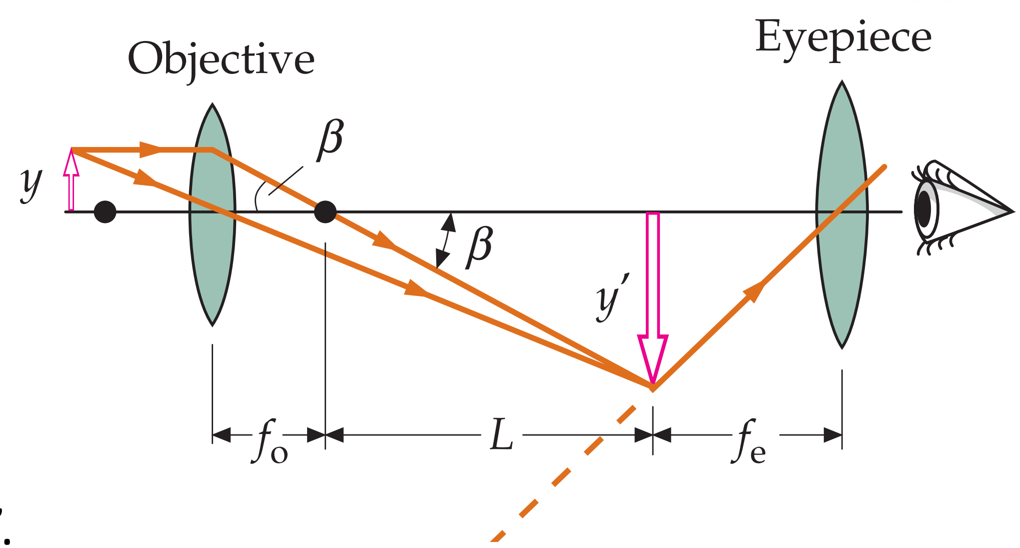
In a Microscope the distance between the two lens that is comparable to the focal length of the two lens.

The first lens is the Objective lens, the second one called Eyepiece.

$$m_o = \frac{y'}{y} = -\frac{L}{f_o}$$

$$M_e = \frac{x_{np}}{f_e}$$

$$M = m_o M_e = -\frac{L}{f_o}\frac{x_{np}}{f_e}$$



L is called the "tube length".

How to Make a Big Telescope Mirror

Melt it & Spin it.

24 000 kg of borosilicate glass when filled

Telescope

Like microscope, a (Newtonian) telescope is also made of two converging lenses.

In a Microscope the distance between the two lens that is comparable to the focal length of the two lens.

Both object and image in telescope are at infinity.

$$\tan\theta_o = \frac{y}{s} = -\frac{y'}{f_o} \approx \theta_o$$

$$\tan\theta_e = \frac{y'}{f_e} \approx \theta_e$$

$$M = \frac{\theta_e}{\theta_o} = -\frac{f_o}{f_e}$$