Your Comments

The concept of angular magnification and telescope and microscope(especially the total magnification, how is it derived? There are too many equations)

the angular magnification where you hold the magnifying glass up to your eye and need to use gamma

For the near sighted person why is the near point considered around 25 cm when people can easily focus on text within that distance? Also, please go over the use of the image of one lens as the object of the other.

The process of completing eye correction and angular magnification problems.

This lecture was really interesting. The nearsighted and farsightedness still confuses me though.

This is the last prelecture. I think I learned a lot in this prelecture and I know the application of the Physics in life through this prelecture. Cool!

I've really enjoyed this class! And I've learned a lot! Thanks!!!

End of Semester Logistics

- Check your grade book scores
  - If anything is not correct email appropriate person
  - About 40 students still have not registered their iclicker
    - Do it now or accept all zeroes for lectures
  - Course Grade: See "Course Description" link on homepage
    - Clicker points: Lecture = 100% if answer 75% of questions, Bonus = 10% per correct question
  - Exam 3: Average ~ 70%

- Remaining Assignments
  - Homework (Mirrors) due 5pm on Wed.
    - Note that there is no 80% extension, cannot correct delayed feedback
  - Prelecture 29 (Optional video of Tim solving problems) & Survey
  - Most course deadlines are Dec. 10 (tomorrow!)

Final Exam

50 questions uniformly distributed over semester

- Electric Fields/Gauss' Law/Potential (34%)
- Faraday's Law (12%)
- RC/RL Circuits (14%)
- AC Circuits (11%)
- Geometric Optics (13%)
- Magnetic Fields & Forces (7%)
- Electromagnetic Waves/Polarization (8%)
- DC Circuits (3%)

- Conflict is Tuesday Dec. 16th 1:30 - 4:30 PM
- Combined is Friday Dec. 19th 1:30 - 4:30 PM

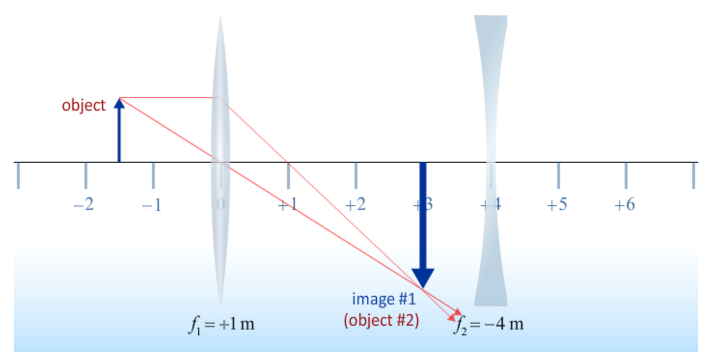
→ Extra Office Hours Mon & Thurs: check webpage

Study: Prelectures, HW, Discussion, Lab write-ups, Old Exams
(don't forget Mirrors and Optical Instruments → on Final, but not on Hour Exams)

Physics 212
Lecture 28

Today's Concept:

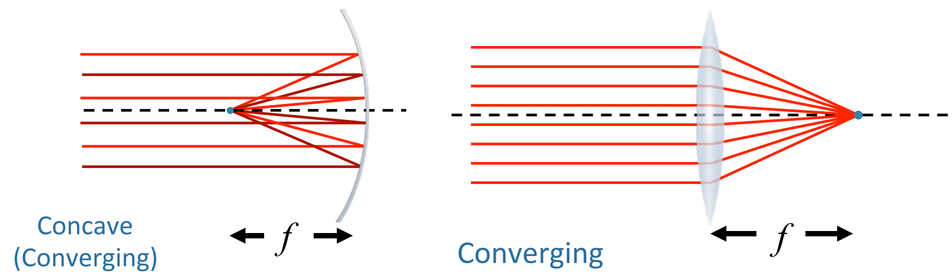
Optical Devices



Executive Summary - Mirrors & Lenses:

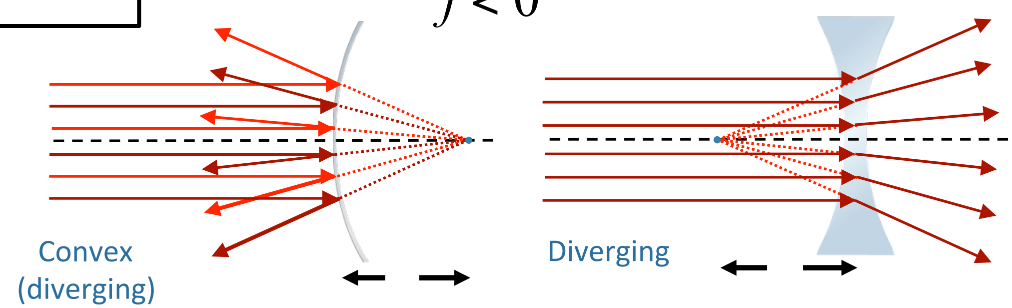
$S > 2f$	real inverted smaller
$2f > S > f$	real inverted bigger
$f > S > 0$	virtual upright bigger
$S > 0$	virtual upright smaller

$f > 0$



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

$f < 0$



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

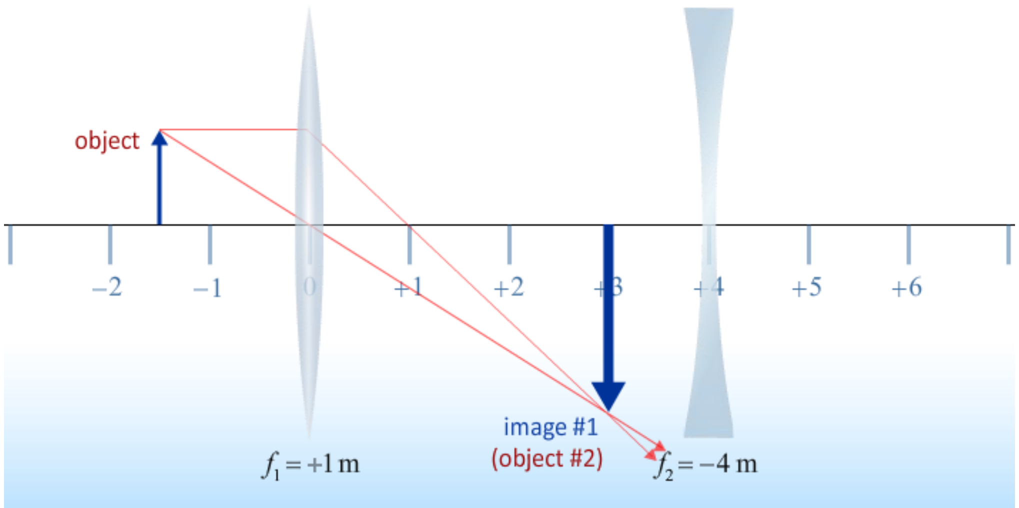
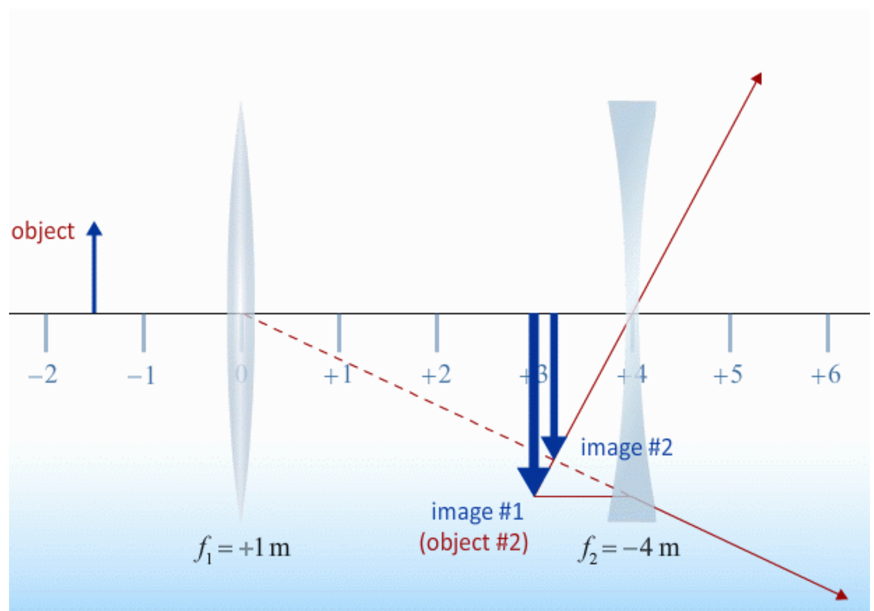
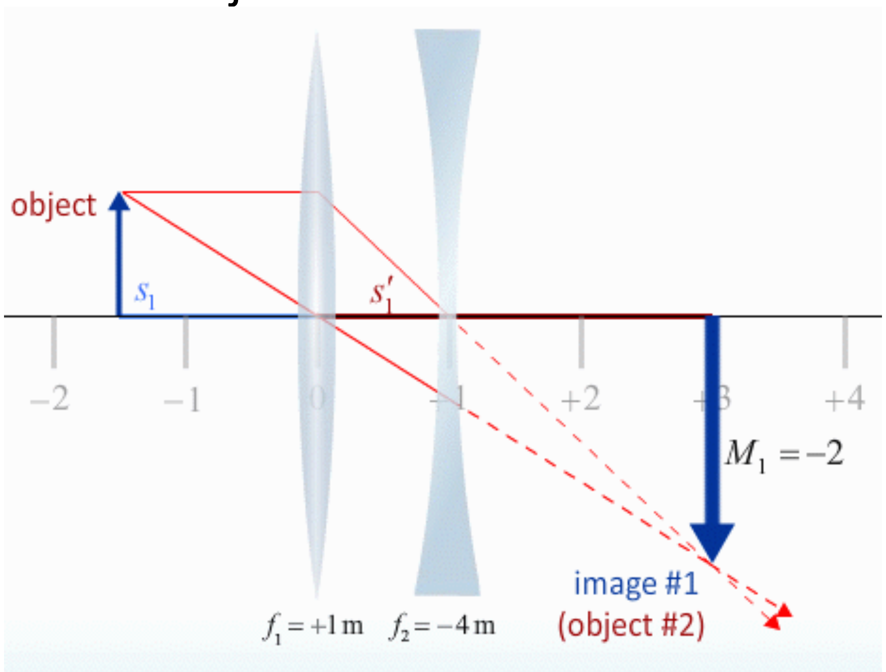


Image from first lens
Becomes object for second lens



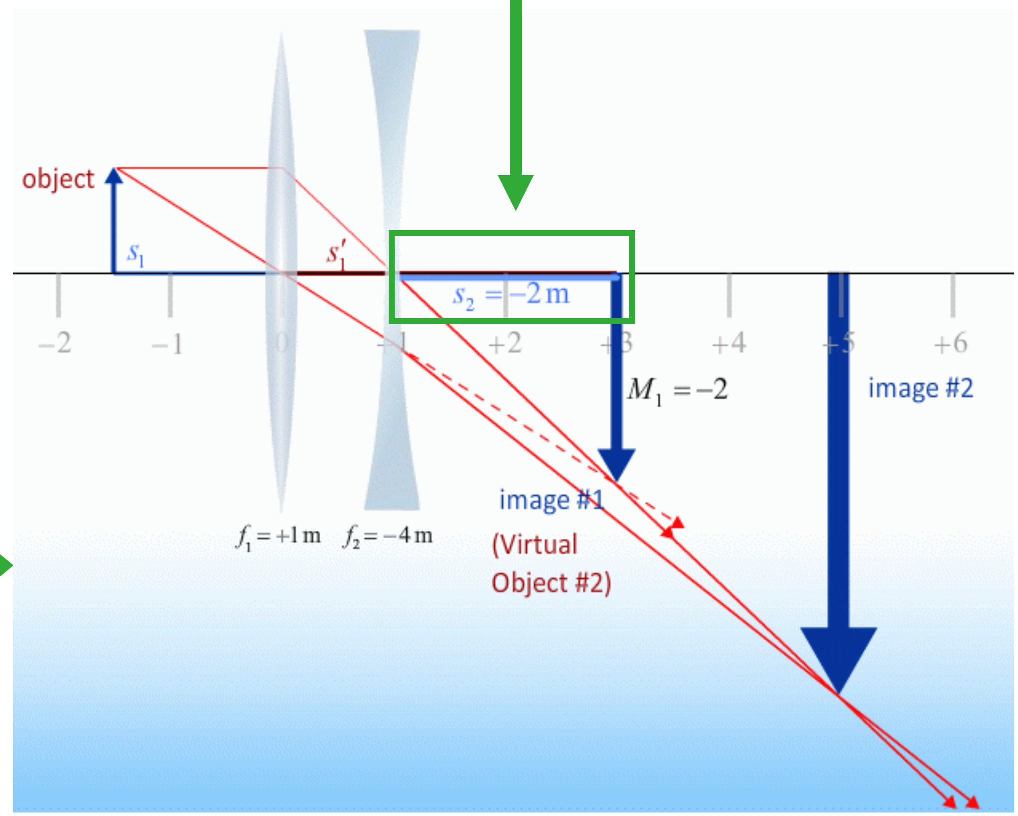
System of Lenses

Virtual Objects are Possible !!



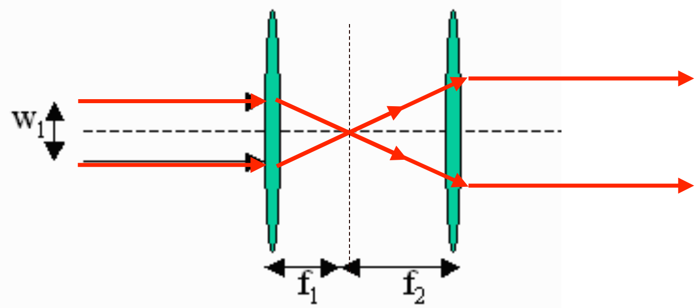
Object Distance is Negative!

Image from first lens
Becomes object for second lens



CheckPoint 3

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

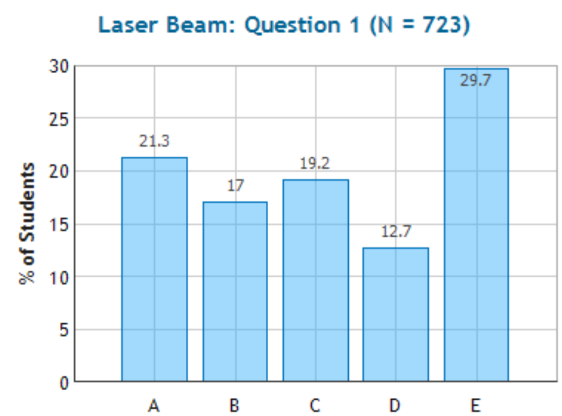
B. The beam is diverging

C. The beam is parallel to the axis with a width < w_1

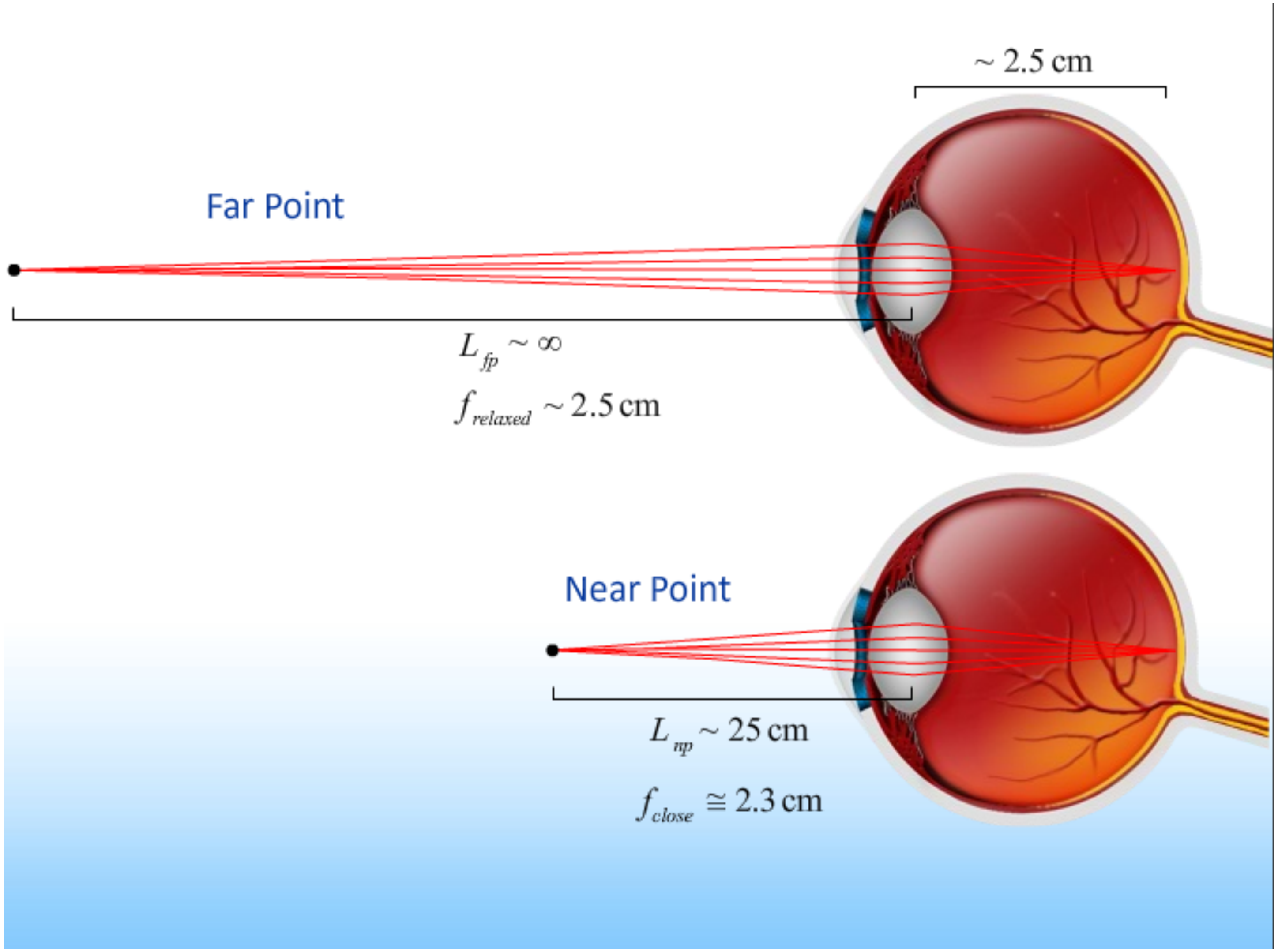
D. The beam is parallel to the axis with a width = w_1

E. The beam is parallel to the axis with a width > w_1

1. Parallel rays are transmitted and pass through foc 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



Normal Eye

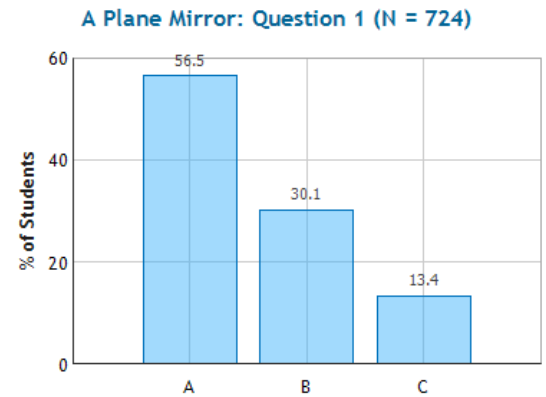


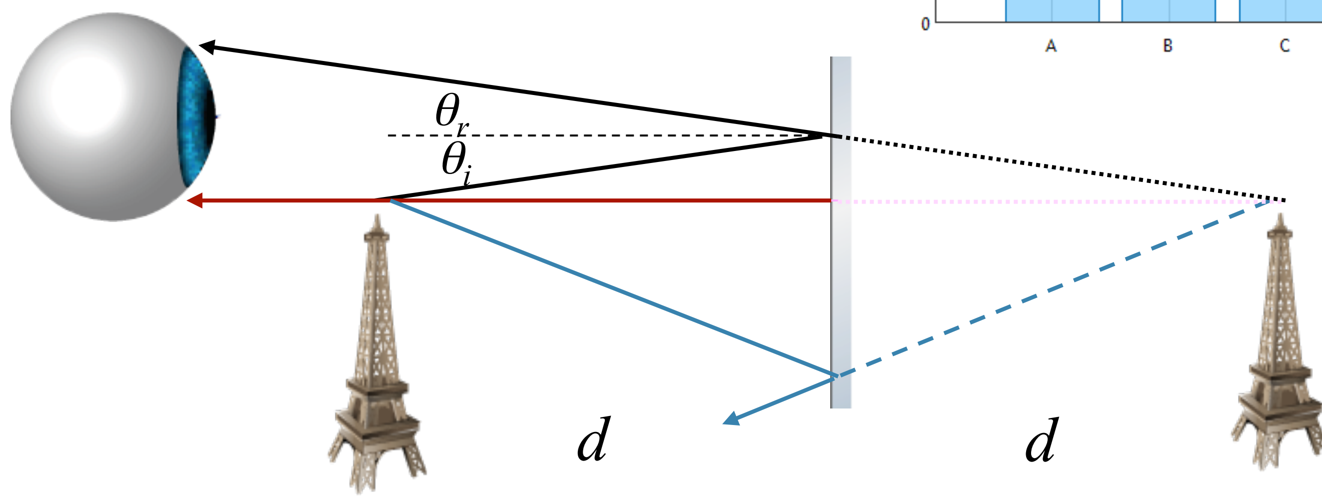
~ 2.5 cm
Far Point
$L_{fp} \sim \infty$
$f_{relaxed} \sim 2.5\,\text{cm}$
Near Point
$L_{np} \sim 25\,\text{cm}$
$f_{close} \cong 2.3\,\text{cm}$

CheckPoint 2

A person with normal vision (near point 28 cm) is standing in front of a plane mirror. What is the closest distance to the mirror the person can stand and still see herself in focus?

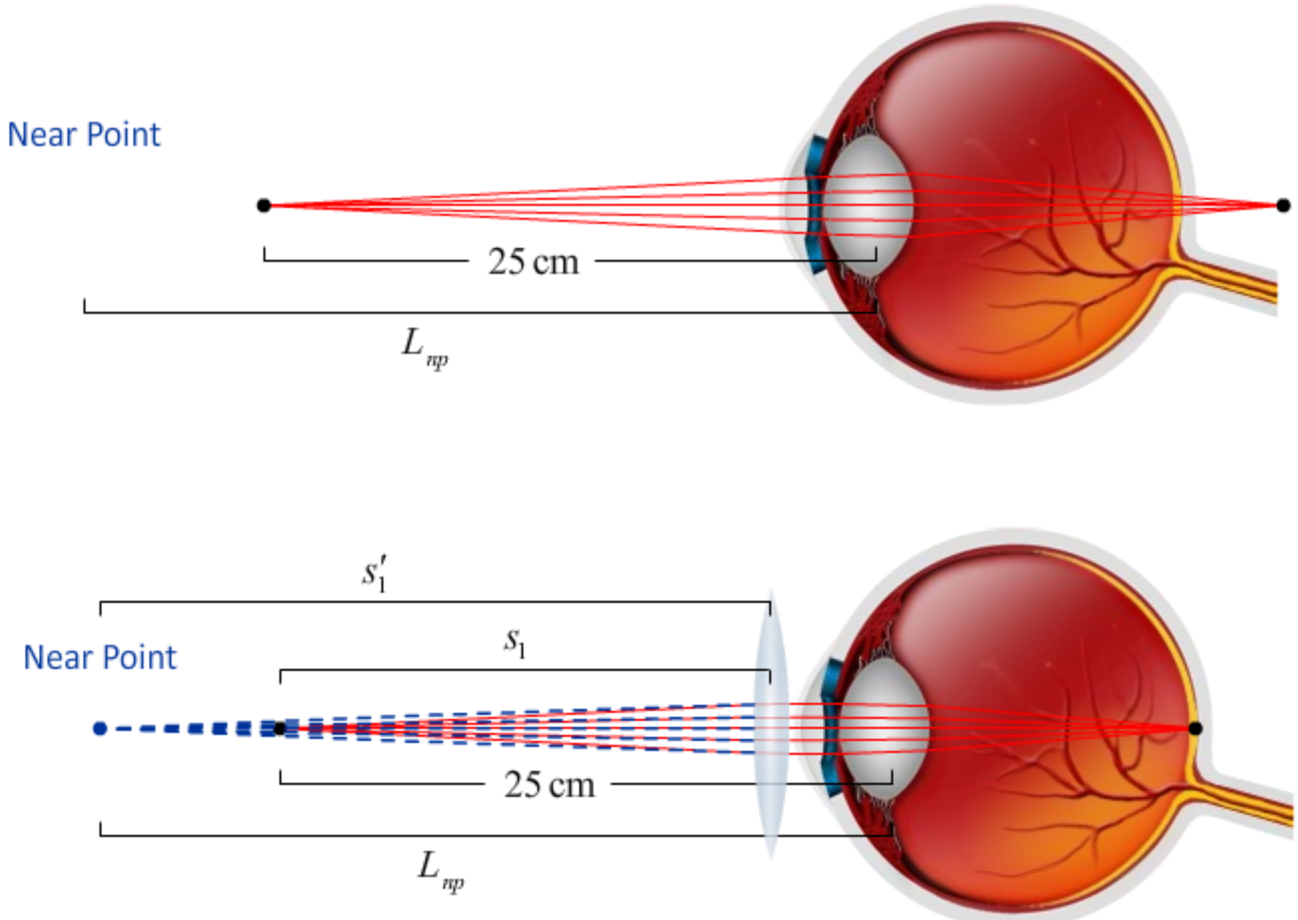
A. 14 cm ***B.*** 28 cm ***C.*** 56 cm





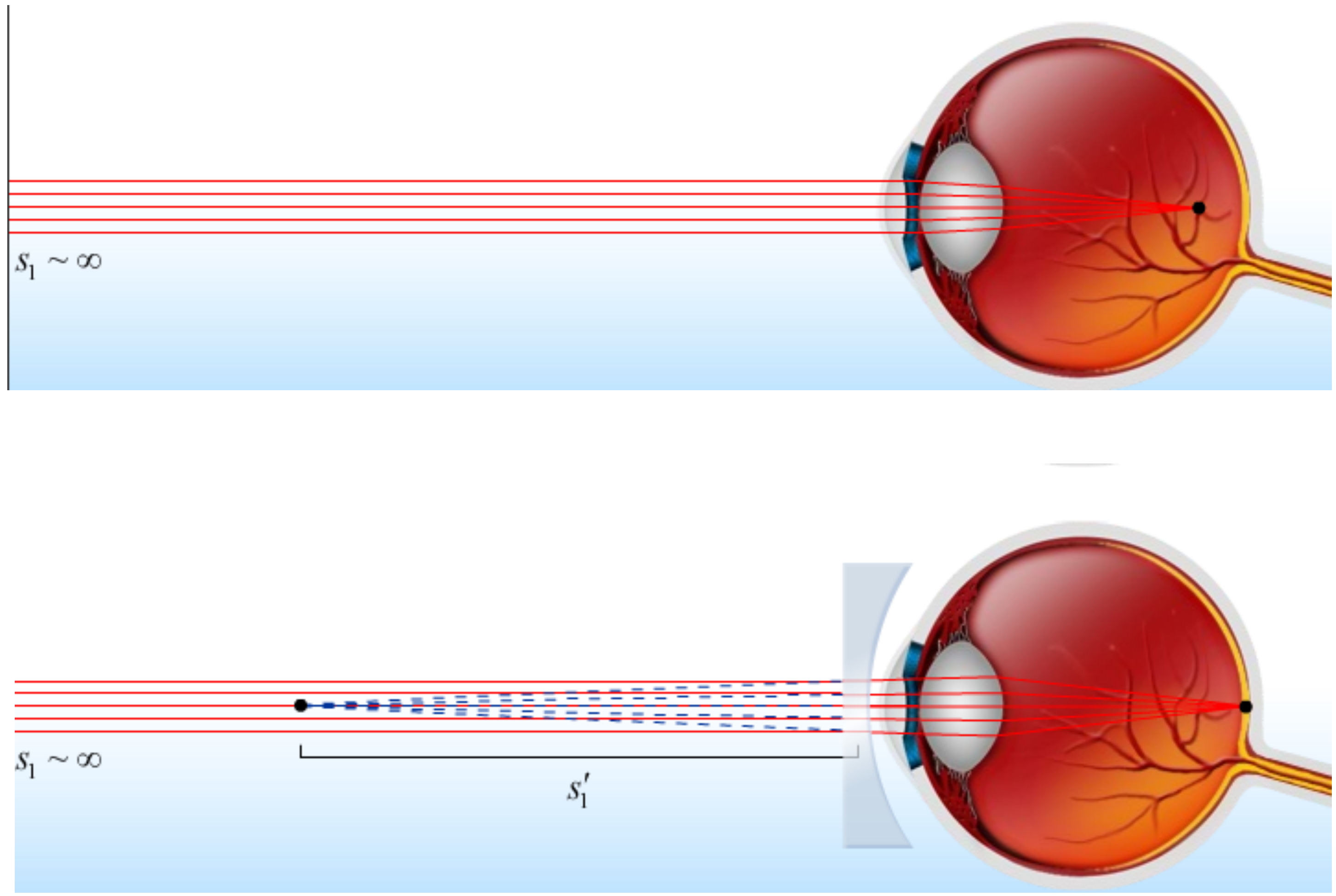
The image is formed an equal distance behind the mirror
Therefore, if you stand a distance = ½ of your near point, the distance to the image will be the near point distance.

Far-Sighted



Converging Lens creates virtual image at person's near point

Near-Sighted



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

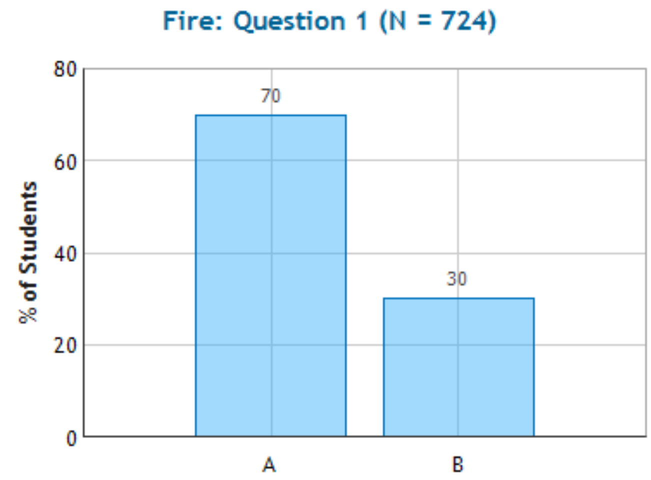
CheckPoint 1

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

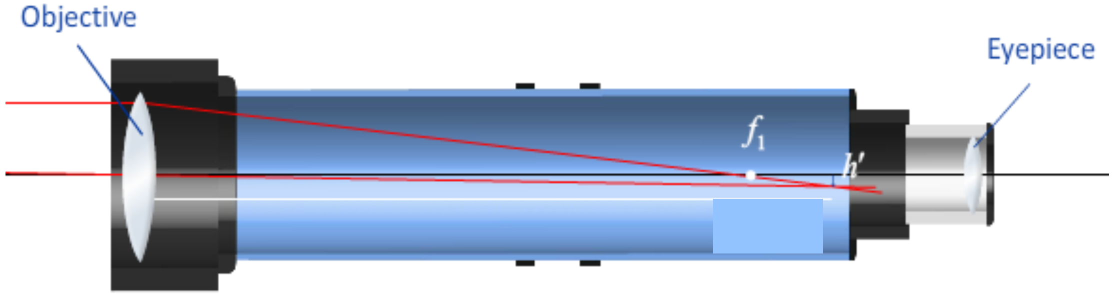
B. The nearsighted person's glasses

Farsighted = Converging Lens
Only Converging Lens can produce a real image!



Angular Magnification: Telescope

How does this apply to things far away? E.g. the moon



- Your eye can focus rays that are parallel or slightly diverging
  - Assume for simplicity that the rays from the eyepiece are parallel

The math:

First, what is the approximate image distance for the objective, s_1'?

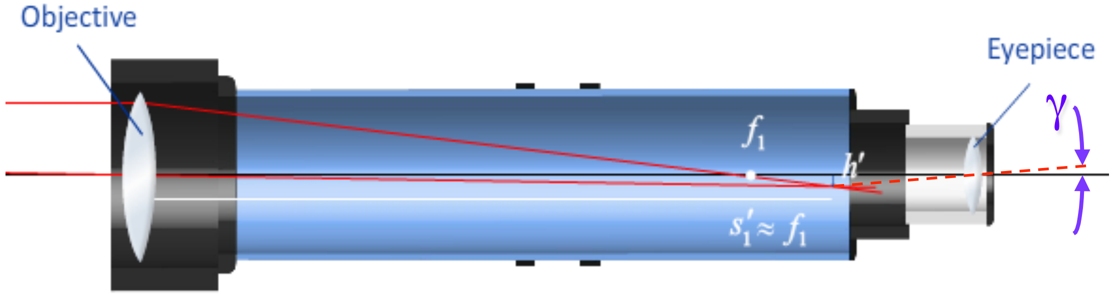
A) $s_1' \approx s_1$

B) $s_1' \approx f_1$

C) $s_1' = \dfrac{f_1 s_1}{s_1 - f_1} \left(no\ approximation\right)$

Angular Magnification: Telescope

How does this apply to things far away? E.g. the moon



- Your eye can focus rays that are parallel or slightly diverging
  - Assume for simplicity that the rays from the eyepiece are parallel

The math:

Objective: "1" | Eyepiece: "2" | Geometry

$$s_1' \approx f_1$$

$$s_2 \approx f_2 \Rightarrow s_2' \to -\infty$$

$$\alpha \approx \frac{h'}{f_1}; \quad \gamma \approx \frac{h'}{f_2}; \quad M = \frac{\gamma}{\alpha} \approx \frac{f_1}{f_2}$$

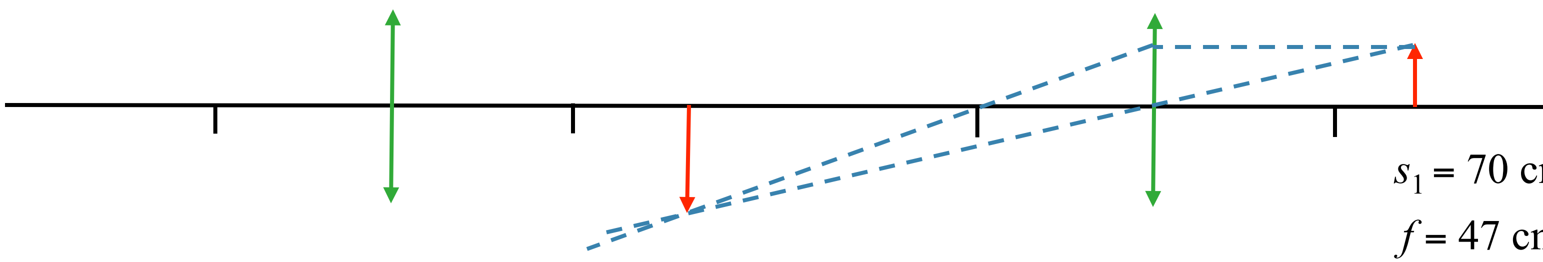
$$M_1 = -\frac{s_1'}{s_1} = -\frac{f_1}{s_1}$$

$$M_2 = -\frac{s_2'}{s_2} = -\frac{s_2'}{f_2}$$

$$M = M_1 M_2 = \frac{f_1}{f_2}\frac{s_2'}{s_1} \approx \frac{f_1}{f_2}$$

Multiple Lenses Exercises

Two converging lenses are set up as shown. The focal length of each lens is 47 cm. The object is a light bulb located 70 cm in front of the first lens.



$s_1 = 70$ cm

$f = 47$ cm

What is the nature of the image from the first lens alone?

A) REAL UPRIGHT

B) REAL INVERTED

C) VIRTUAL UPRIGHT

D) VIRTUAL INVERTED

EQUATIONS

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

s > f → s' > 0 → real image

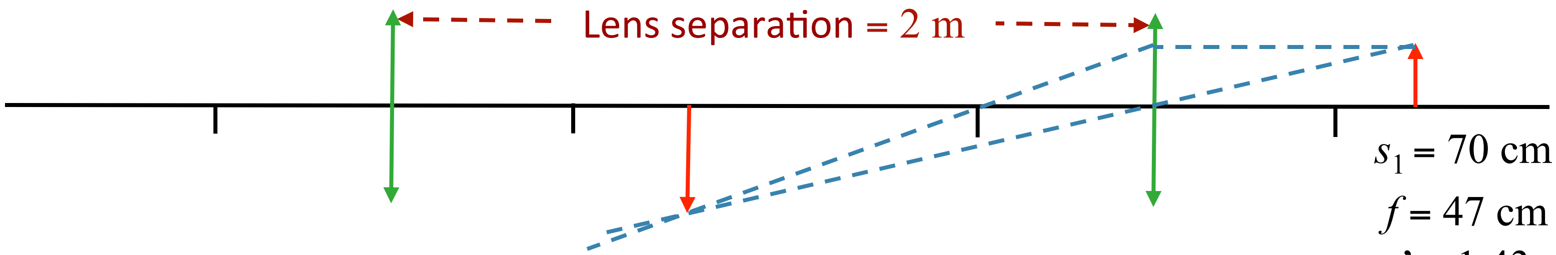
$$M = -\frac{S'}{S} \rightarrow M < 0 \rightarrow \text{inverted image}$$

PICTURES

Draw Rays as above.

Multiple Lenses Exercises

Two converging lenses are set up as shown. The focal length of each lens is 47 cm. The object is a light bulb located 70 cm in front of the first lens.



$s_1 = 70$ cm

$f = 47$ cm

$s_1' = 1.43$ m

What is the object distance s_2 for lens 2?

A) $s_2 = -1.43$ m

B) $s_2 = +1.43$ m

C) $s_2 = -0.57$ m

D) $s_2 = +0.57$ m

E) $s_2 = +2.7$ m

THE OBJECT FOR THE SECOND LENS IS THE IMAGE OF THE FIRST LENS

~~$s_2 = -0.57$~~

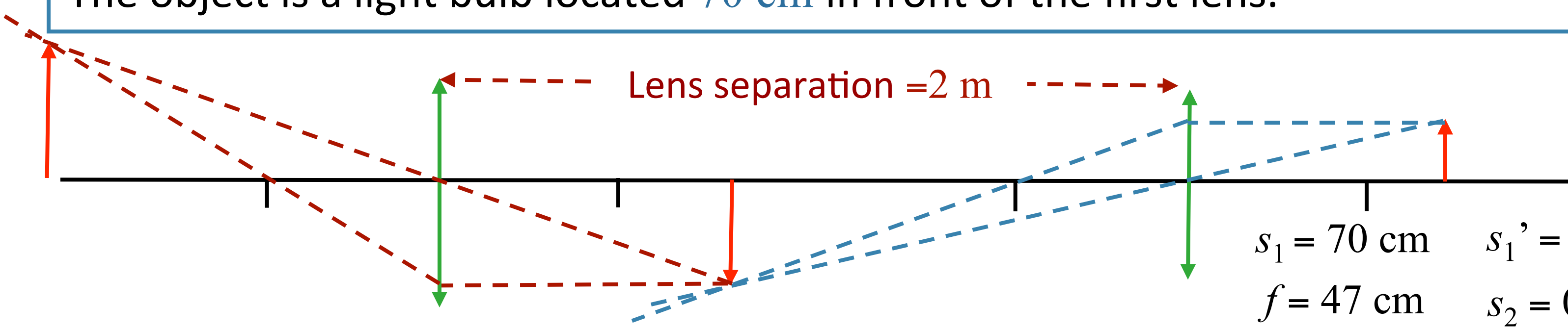
OR

$s_2 = +0.57$

Image of first lens is a REAL object for the second lens

Multiple Lenses Exercises

Two converging lenses are set up as shown. The focal length of each lens is 47 cm. The object is a light bulb located 70 cm in front of the first lens.



$s_1 = 70$ cm $\quad s_1' = 1.43$ m

$f = 47$ cm $\quad s_2 = 0.57$ 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

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

$s_2 > f$ → $s_2' > 0$ → real image

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

→ $M_2 < 0$ → $M = M_1 M_2 > 0$

→ upright image

PICTURES

Draw Rays as above.

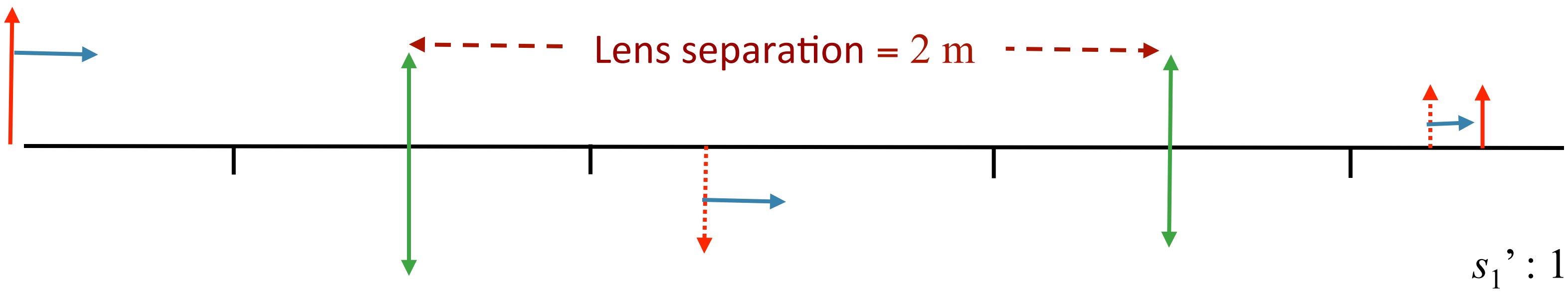
RESULTS

$s_2' = 2.69$ m

$M = 9.6$

Multiple Lenses Exercises

Suppose we increase the initial object distance to 74 cm.



$s_1 = 74$ cm

$f = 47$ cm

RESULTS

s_1' : 1.43 m [illegible] 1.29 m

s_2' : 2.69 m [illegible] 1.38 m

How does the L, the distance to the final image, change?

A) L increases

B) L decreases

C) L remains the same

Step through images, one at a time

WORDS

Increasing s_1 will decrease s_1' (moving closer to focal point would increase the image distance)

Decreasing s_1' will increase s_2 Increasing s_2 will decrease s_2'

EQUATIONS

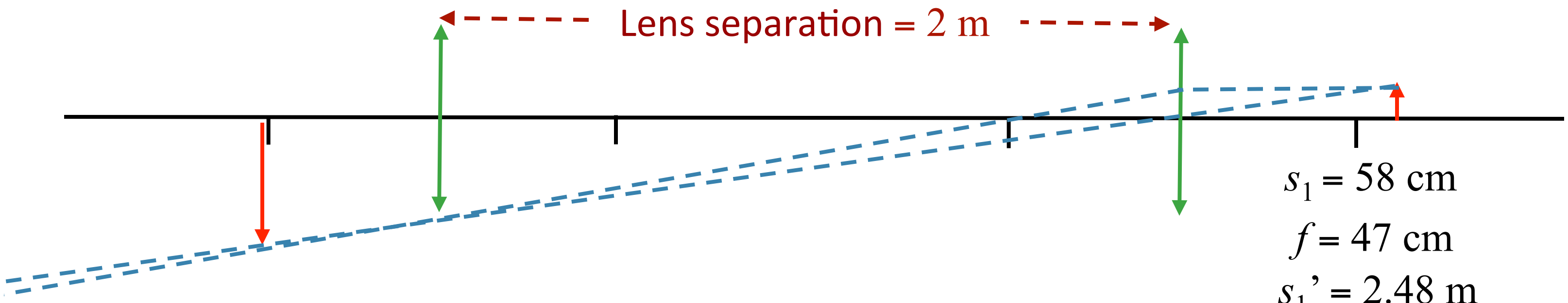
$$\frac{1}{s_1'} = \frac{1}{f} - \frac{1}{s_1} \rightarrow \frac{1}{s_1'} \text{ increases}$$

$$S_2 = 2m - s_1' \rightarrow s_2 \text{ increases}$$

$$\frac{1}{s_2'} = \frac{1}{f} - \frac{1}{s_2} \rightarrow \frac{1}{s_2'} \text{ increases}$$

Multiple Lenses Exercises

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



What is the object distance s_2 for lens 2?

A) $s_2 = -0.48$ m B) $s_2 = +0.48$ m C) $s_2 = -2.48$ m D) $s_2 = +2.48$ m E) $s_2 = +2.58$ m

THE OBJECT FOR THE SECOND LENS IS THE IMAGE OF THE FIRST LENS

$s_2 = -0.48$

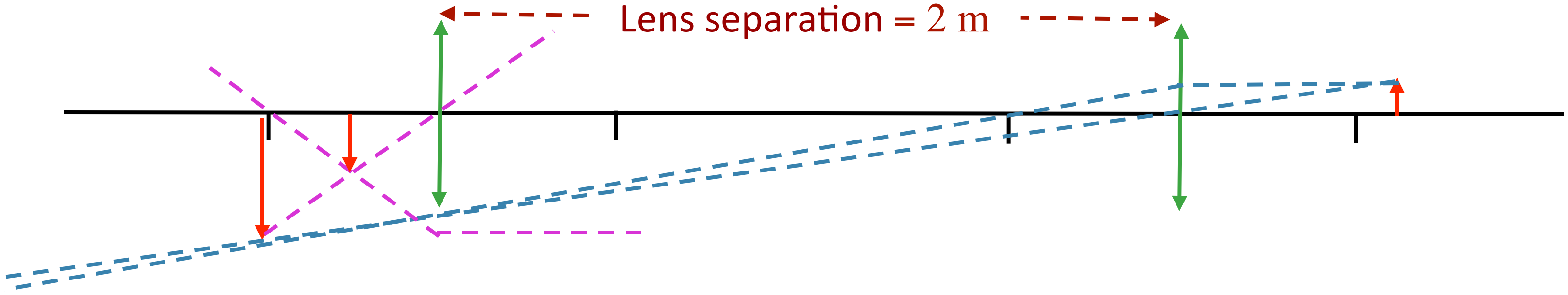
OR

~~$s_2 = +0.48$~~

Image of first lens is a VIRTUAL object for the second lens

Multiple Lenses Exercises

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



$s_1 = 58$ cm

$f = 47$ cm

$s_1' = 2.48$ m

$s_2 = -0.48$ 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

$s_2' = 0.24$ m

$M = -2.1$

Thank you!

Thanks for a fantastic semester!

Study hard for your finals!