

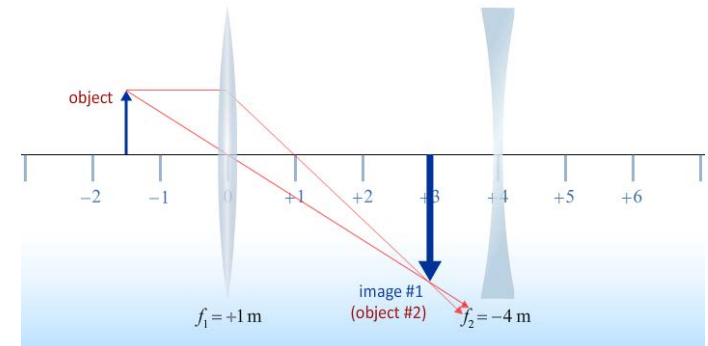
Physics 212

Lecture 28

a.k.a. The LAST Physics 212 Lecture!

Today's Concept:

Optical Devices



Your Comments

After this prelecture, now I can go annoy my optometrist and pretend like I know everything there. Also, so pumped for the final lecture, I have high hopes for awesome demo's!

Thank you professor! I really learned a lot from the lecture. Give me a high five!!!



1) will we be able to pick up our final exam 3 even though we don't have discussion next week? 2) any recommendations for studying for this final besides looking over past midterms?

Oh wow I can't believe I actually made it through the semester!

Can we go over telescopes and the whole concept of a near/far point?

Did you hear the one about the optician who fell into the lens grinder? He made a spectacle of himself.

Does my comment actually go in the lecture? because this never HAPPENED!

Are the lecture bonuses added to our overall grades? That'd help a lot.

End of Semester Logistics

- Check your grade book scores
 - If anything is not correct email appropriate person
 - Select your final exam day/time About 40 students still have not registered their iclicker
 - Do it in the course gradebook today or accept all zeroes for lectures
 - Course Grade: See “Course Description” link on homepage
 - Clicker points: Lecture = 100% if answer 75% of questions, Bonus = 15% per correct question
- Remaining Assignments
 - Homework (Mirrors) due 8:00 AM Tuesday.
 - Hour Exam 3 (w/ solutions) now posted
 - Prelecture 29 (Optional video of Tim solving problems)
 - No lectures Tuesday May 5th. Tim office hour 2-5 pm.

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%)
-
- Combined is Tuesday May 12th 1:30 - 4:30 PM
 - Conflict is Thursday May 14th 7:00 – 10:00 PM
- Extra Office Hours 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)

Executive Summary - Mirrors & Lenses:

$$S > 2f$$

real
inverted
smaller

$$2f > S > f$$

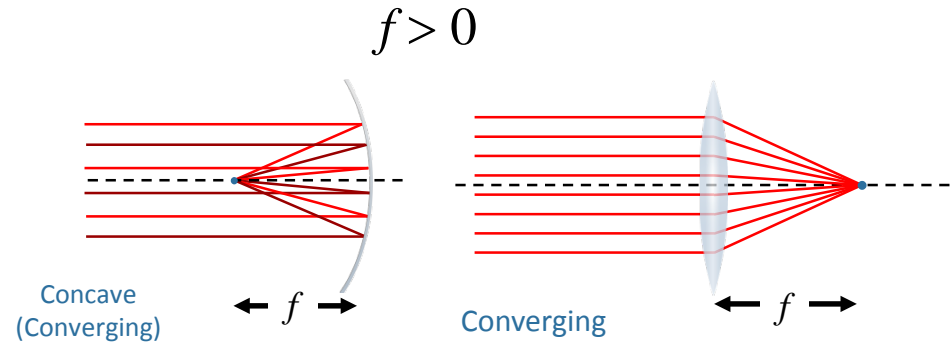
real
inverted
bigger

$$f > S > 0$$

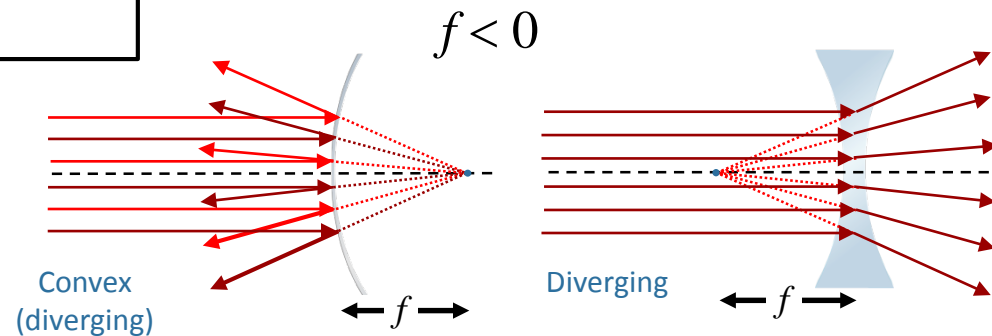
virtual
upright
bigger

$$S > 0$$

virtual
upright
smaller



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



It's Always the Same:

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

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 on side light comes from

S' : positive if image is on side light goes to

f : positive if converging lens (side light goes to)

Mirrors sign conventions

Shiny side is positive

S : positive if object is on side light comes from

S' : positive if image is on side light goes to

f : positive if converging mirror (side light goes to)

System of Lenses

Trace rays through lenses, beginning with most upstream lens

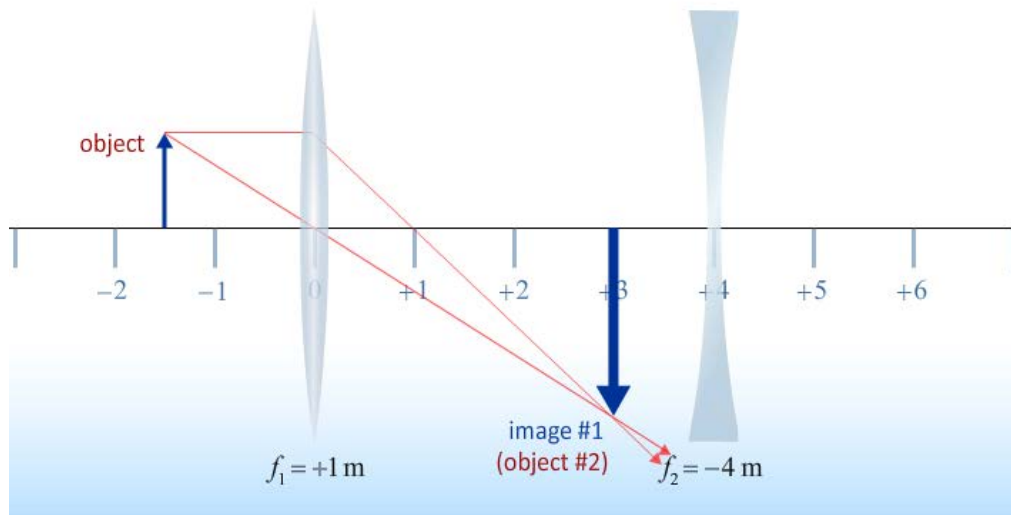
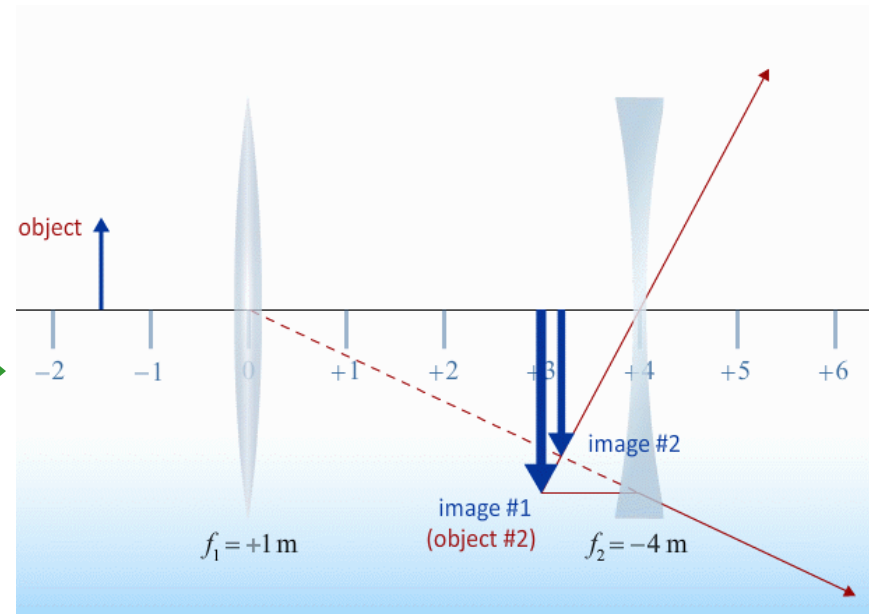


Image from first lens
Becomes object for second lens



System of Lenses

Virtual Objects are Possible !!

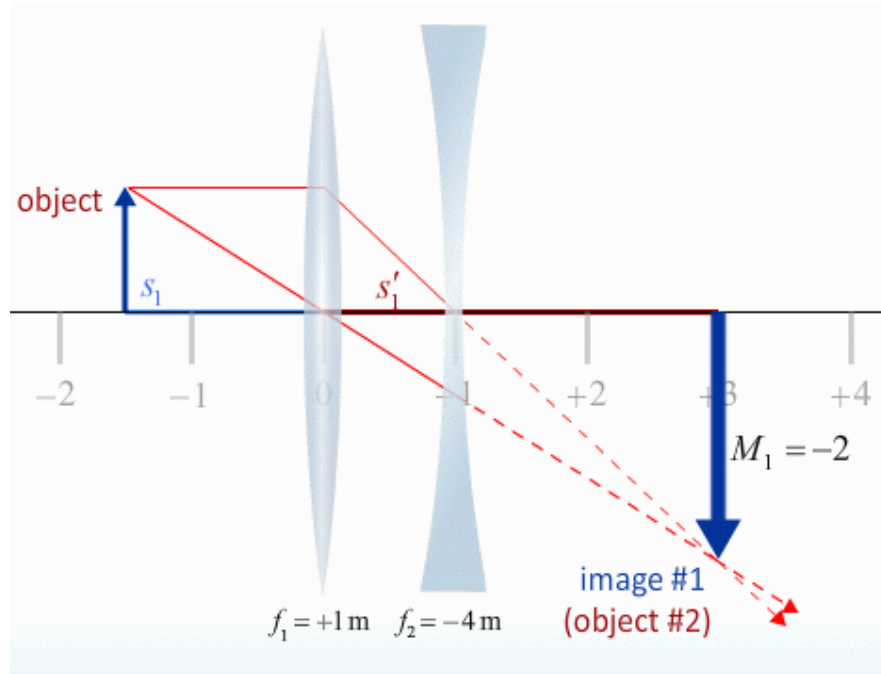
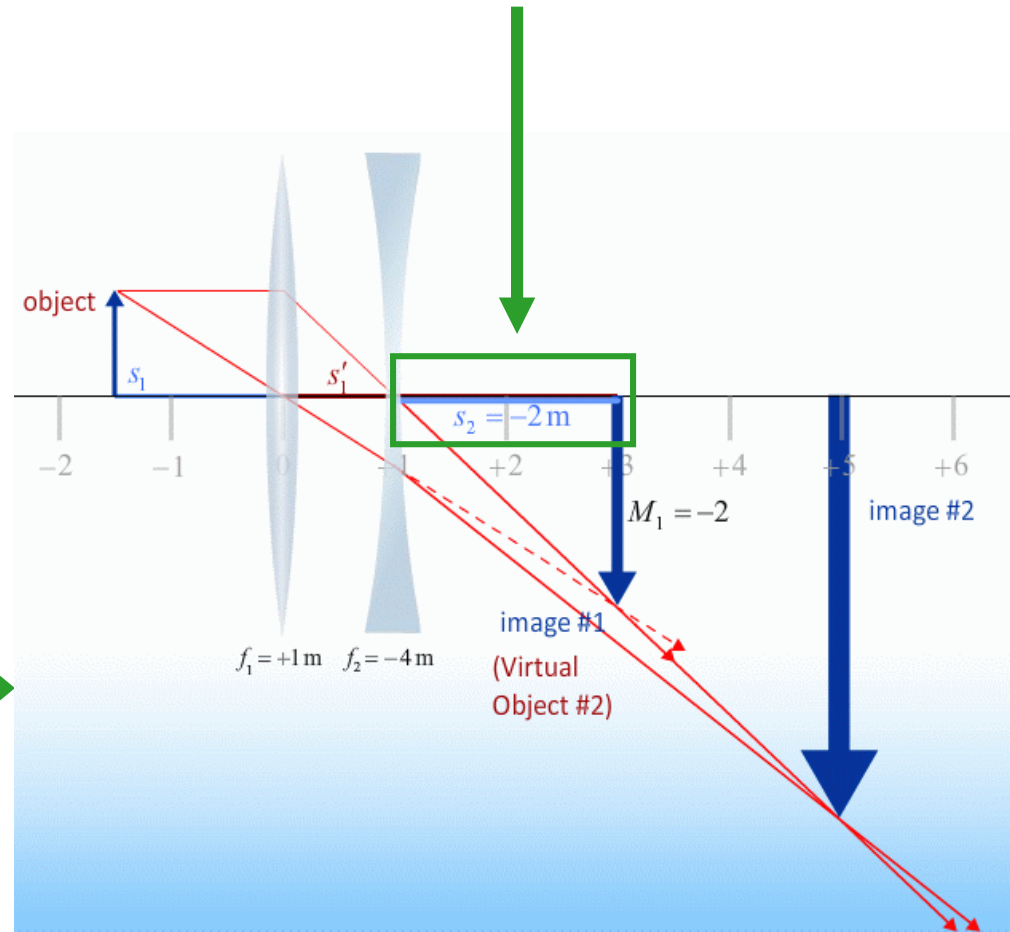


Image from first lens
Becomes object for second lens

We will do an example today!

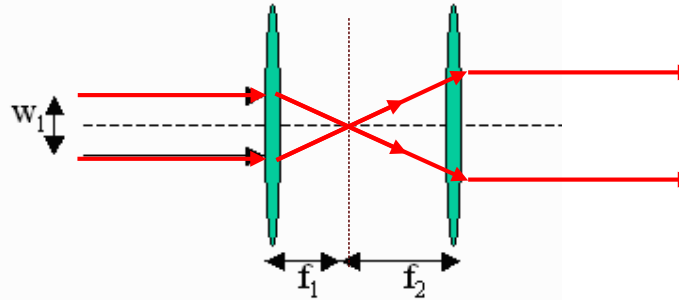
Object Distance is Negative!



CheckPoint 3



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

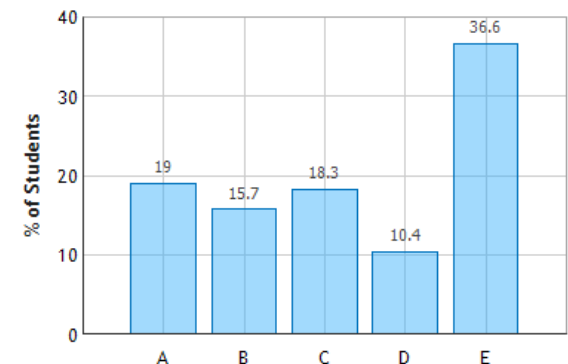


Each lens is converging. The second lens has a larger focal length than the first ($f_2 > f_1$). What does the beam look like when it emerges from the second lens?

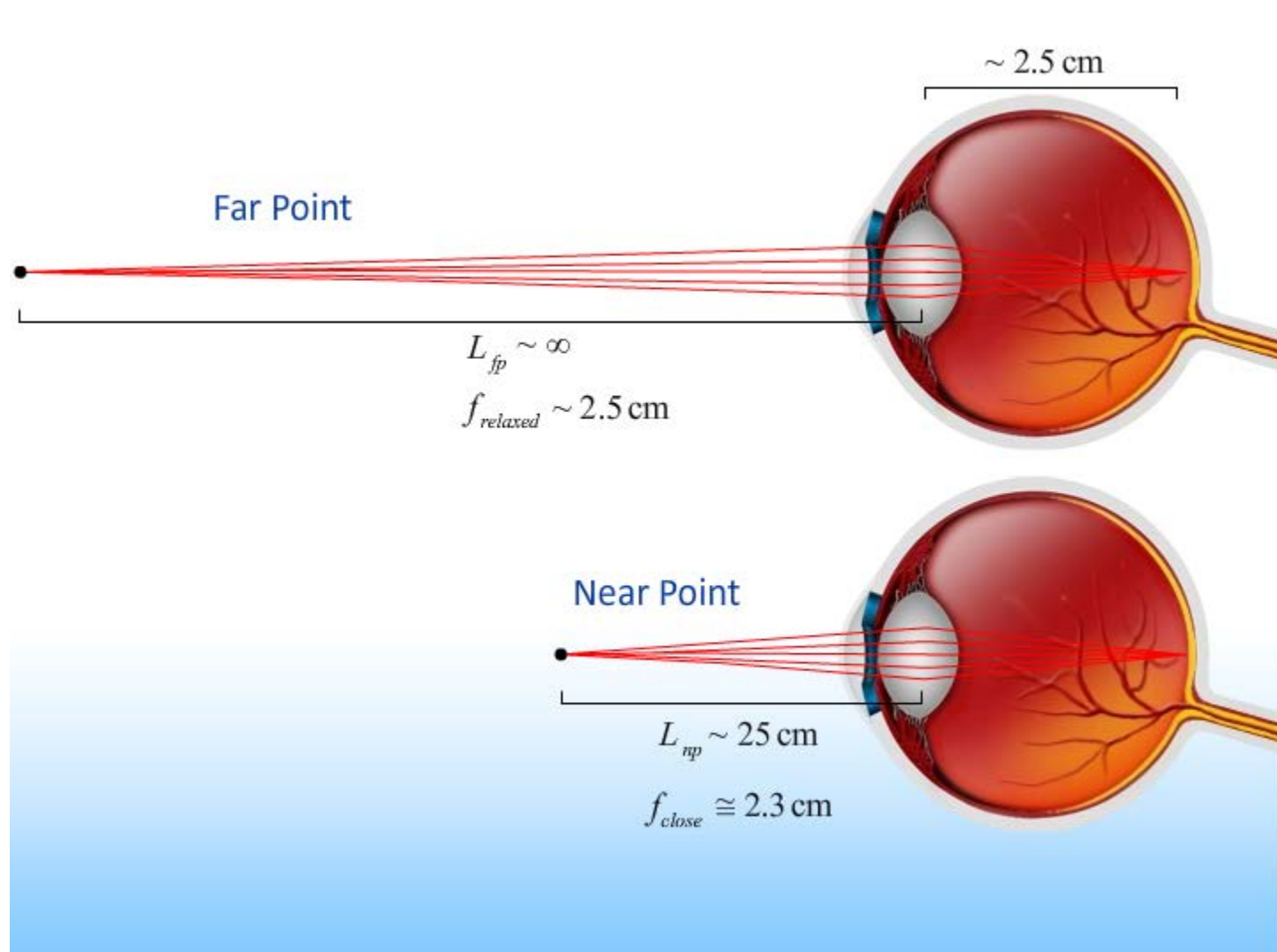
- A.** The beam is converging
- B.** The beam is diverging
- C.** The beam is parallel to the axis with a width $< w_1$
- D.** The beam is parallel to the axis with a width $= w_1$
- E.** The beam is parallel to the axis with a width $> w_1$

1. Parallel rays are transmitted and pass through 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 $> w_1$

Laser Beam: Question 1 (N = 689)



Normal Eye



CheckPoint 2



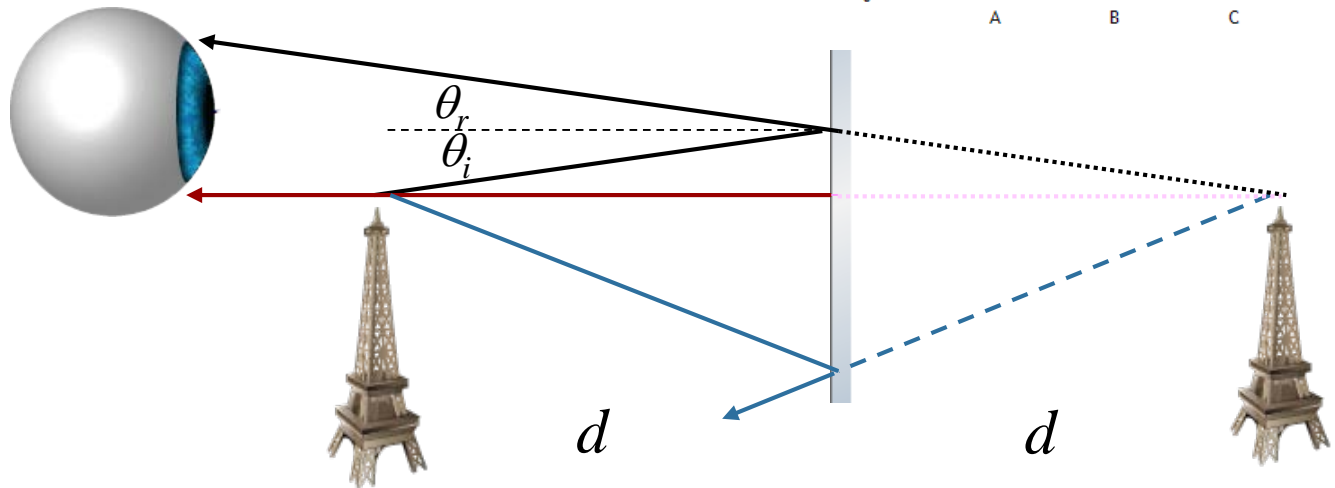
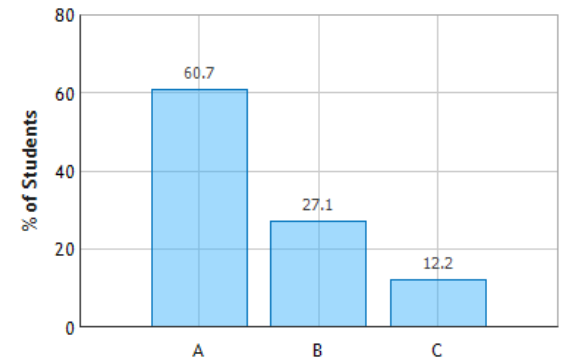
A person with normal vision (near point 28 cm) is standing in front of a plane mirror. What is the closest distance to the mirror the person can stand and still see herself in focus?

A. 14 cm

B. 28 cm

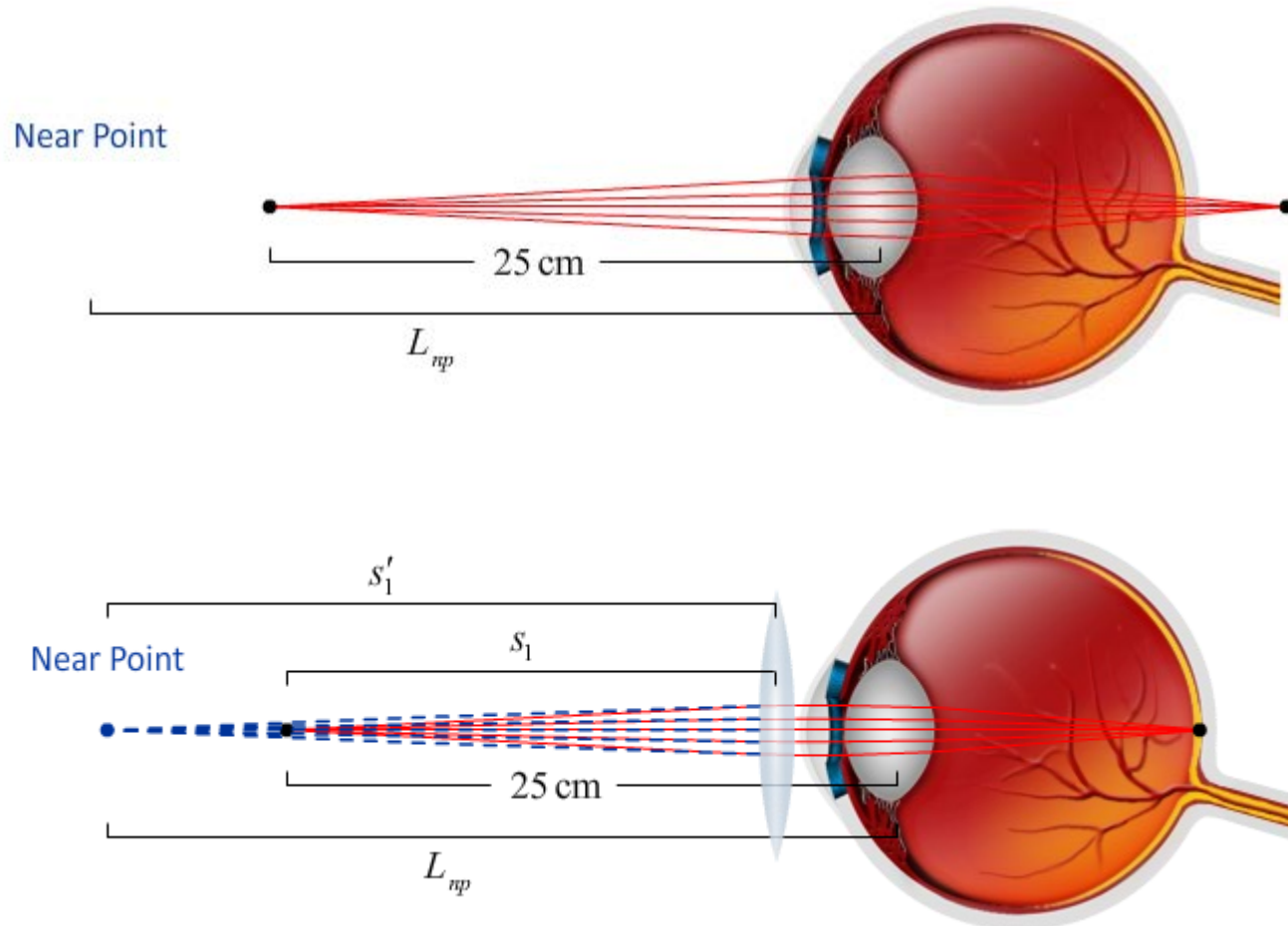
C. 56 cm

A Plane Mirror: Question 1 (N = 689)



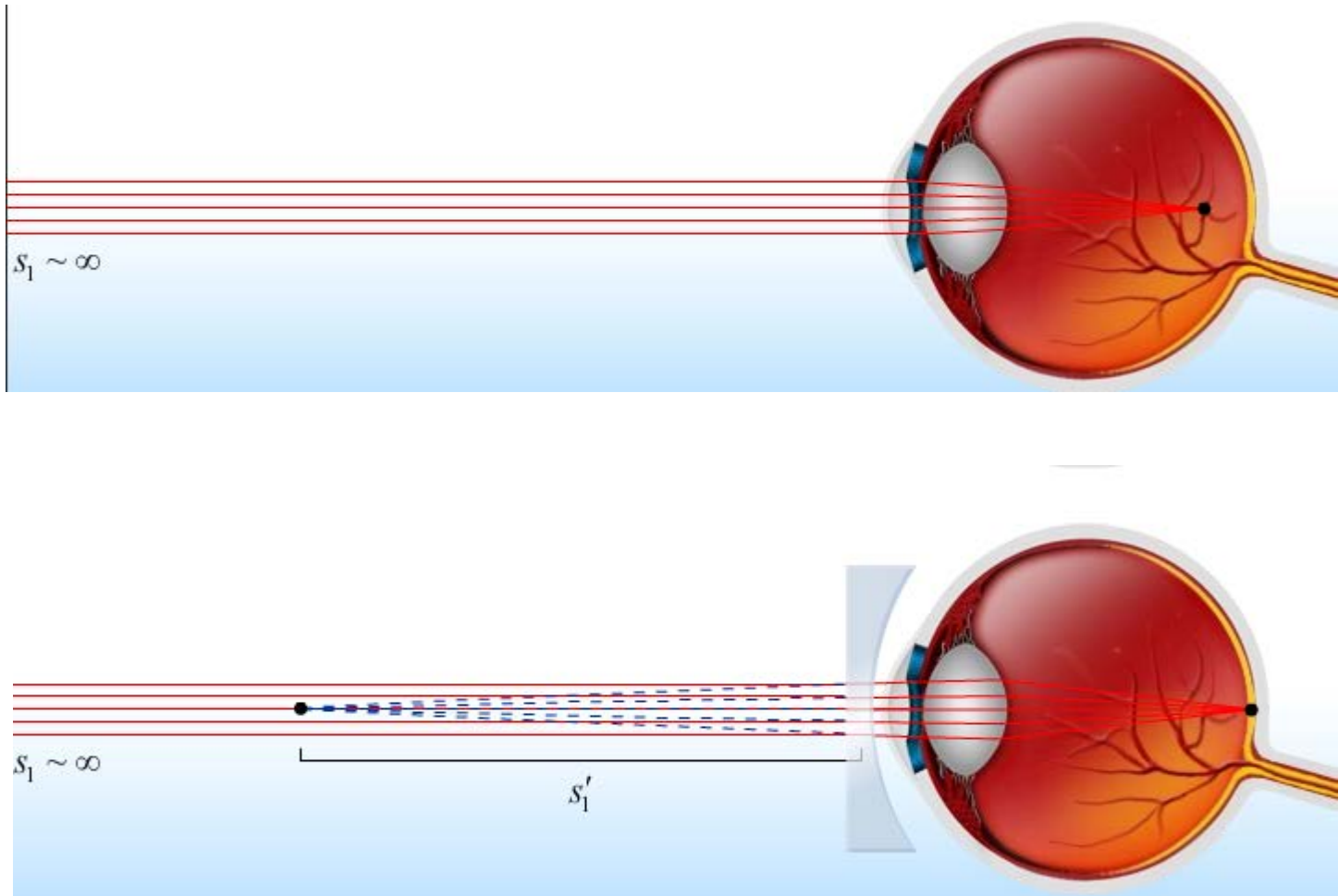
The image is formed an equal distance **behind** the mirror
Therefore, if you stand a distance = $\frac{1}{2}$ of your near point, the distance to the image will be the near point distance.

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



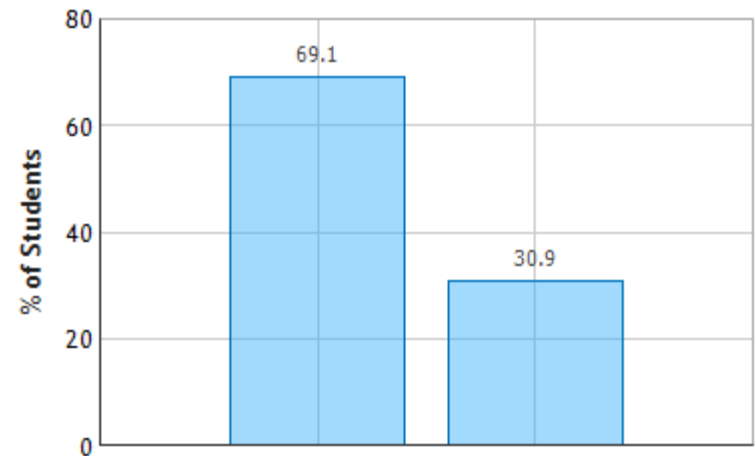
Two people who wear glasses are camping. One of them is nearsighted and the other is farsighted. Which person's glasses will be useful in starting a fire with the sun's rays?

A. The farsighted person's glasses

B. The nearsighted person's glasses

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

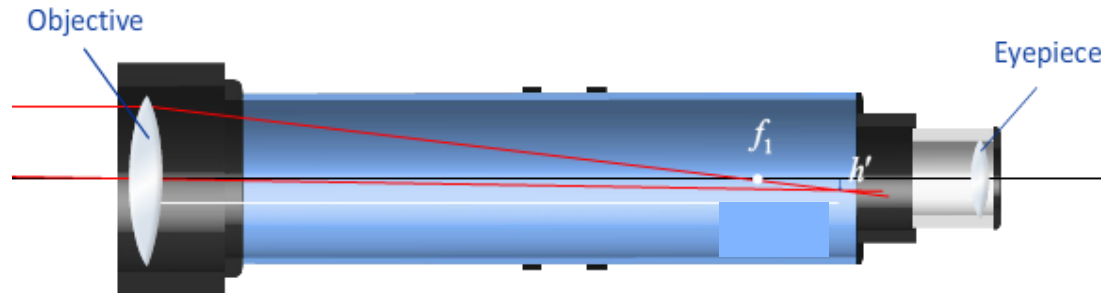
Fire: Question 1 (N = 690)



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) $s_1' \approx s_1$

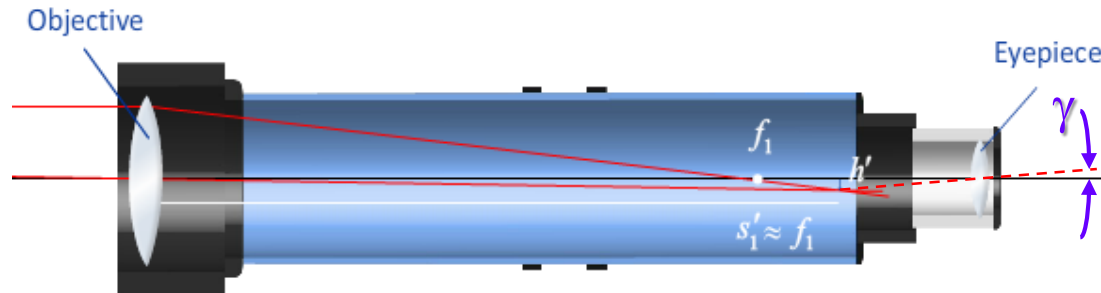
B) $s_1' \approx f_1$

C) $s_1' = \frac{f_1 s_1}{s_1 - f_1}$ (*no approximation*)

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”

$$s_1' \approx f_1$$

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

Eyepiece: “2”

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

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

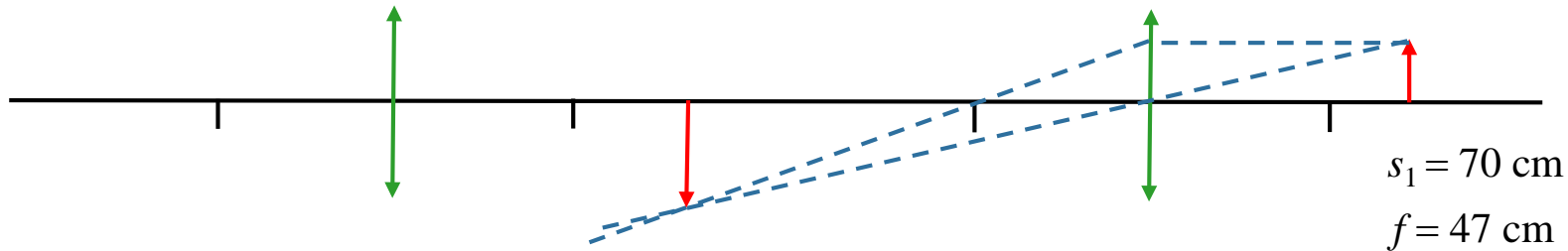
Geometry

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

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

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.



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

$$\frac{1}{s'} = \frac{1}{f} - \frac{1}{s} \quad \longrightarrow \quad s' = \frac{fs}{s - f}$$

$$s > f \quad \longrightarrow \quad s' > 0 \quad \longrightarrow \quad \text{real image}$$

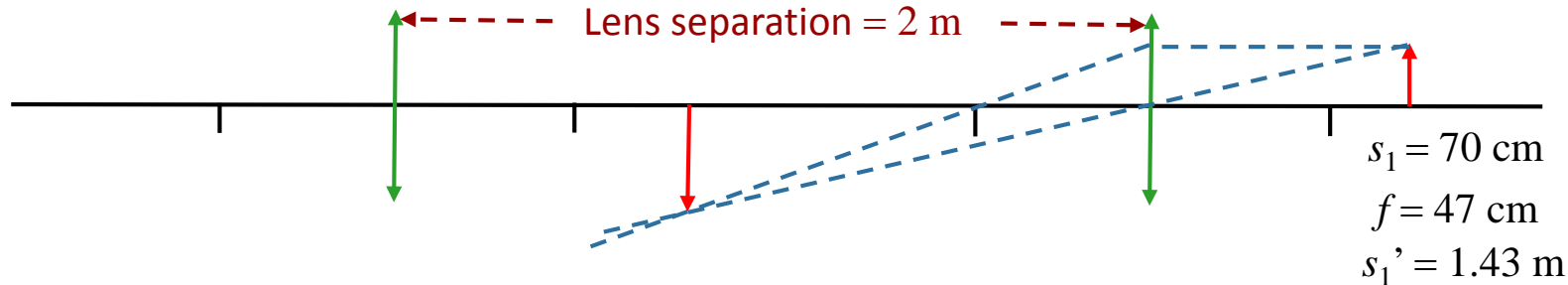
$$M = -\frac{s'}{s} \quad \longrightarrow \quad M < 0 \quad \longrightarrow \quad \text{inverted image}$$

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.



What is the object distance s_2 for lens 2?

- A) $s_2 = -1.43 \text{ m}$ B) $s_2 = +1.43 \text{ m}$ C) $s_2 = -0.57 \text{ m}$ **D) $s_2 = +0.57 \text{ m}$** E) $s_2 = +2.7 \text{ m}$

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

~~$s_2 = -0.57$~~

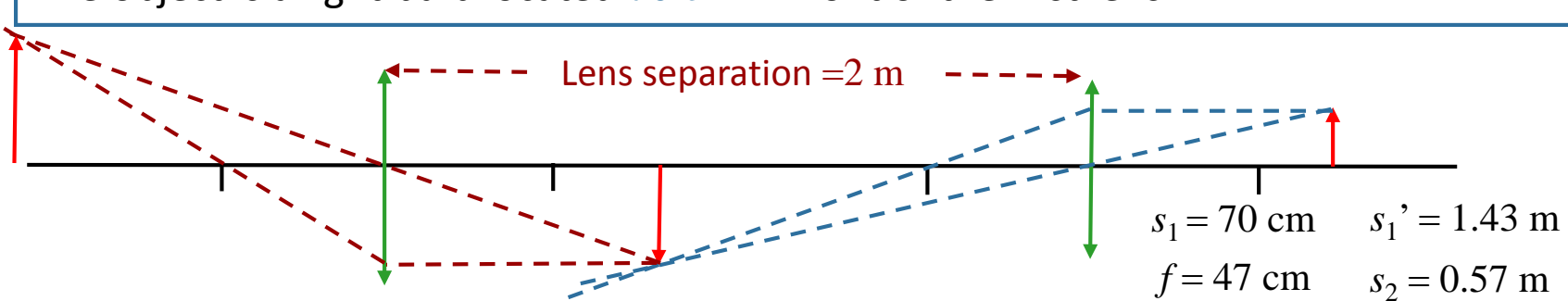
OR

$s_2 = +0.57$

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.



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

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

$$s_2 > f \quad \longrightarrow \quad s_2' > 0 \quad \longrightarrow \quad \text{real image}$$

$$M_2 = -\frac{s_2'}{s_2} \quad \longrightarrow \quad M_2 < 0 \quad \longrightarrow \quad M = M_1 M_2 > 0$$

$$\longrightarrow \text{upright image}$$

PICTURES

Draw Rays as above.

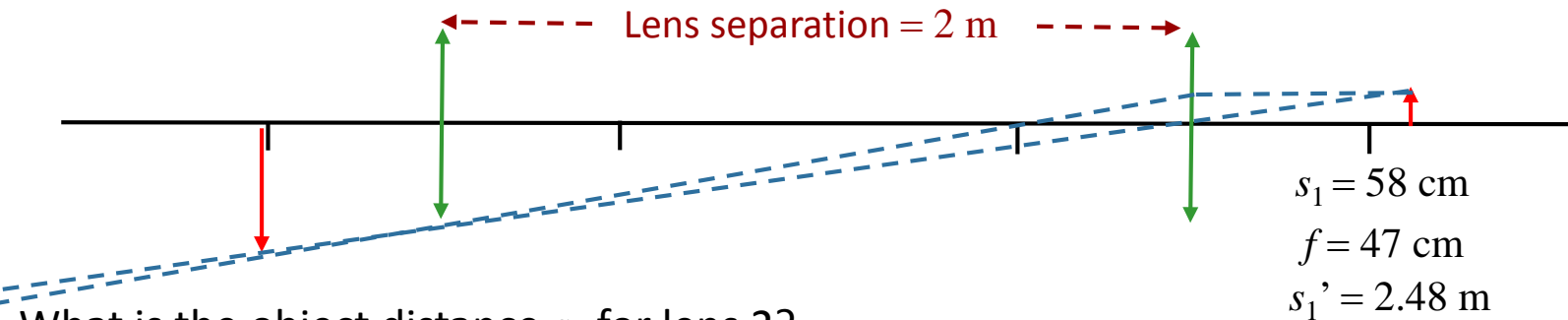
RESULTS

$$s_2' = 2.69 \text{ m}$$

$$M = 9.6$$

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) $s_2 = -0.48\text{ m}$

B) $s_2 = +0.48\text{ m}$

C) $s_2 = -2.48\text{ m}$

D) $s_2 = +2.48\text{ m}$

E) $s_2 = +2.58\text{ m}$

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



$s_2 = -0.48$

OR

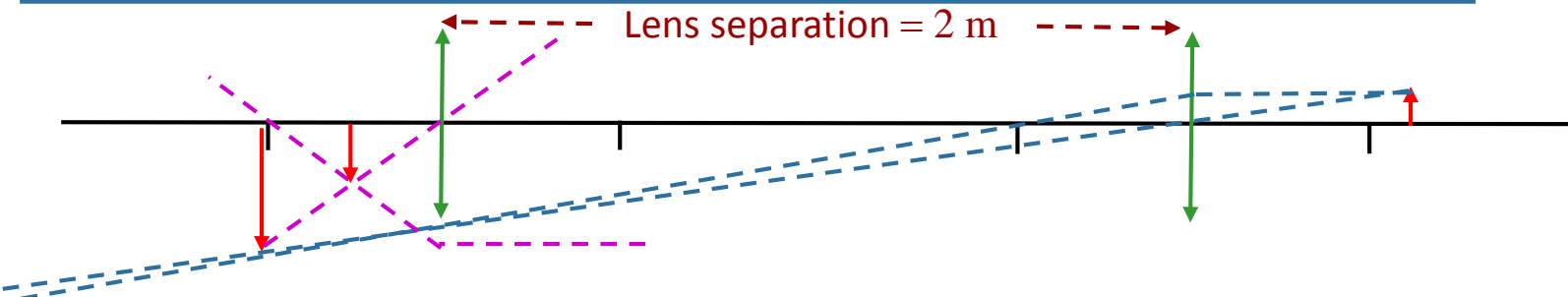
~~$s_2 = +0.48$~~

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 $s_1' = 2.48\text{m}$



$$\begin{aligned}s_1 &= 58 \text{ cm} \\ f &= 47 \text{ cm} \\ s_1' &= 2.48 \text{ m} \\ s_2 &= -0.48 \text{ m}\end{aligned}$$

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

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

$$s_2 < 0 \quad \longrightarrow \quad s_2' > 0 \quad \longrightarrow \quad \text{real image}$$

$$M_2 = -\frac{s_2'}{s_2} \quad \longrightarrow \quad M_2 > 0 \quad \longrightarrow \quad M = M_1 M_2 < 0$$

\longrightarrow inverted image

PICTURES

Draw Rays as above.

RESULTS

$$s_2' = 0.24 \text{ m}$$

$$M = -2.1$$

Thank you!

Thanks for a fantastic semester!

Study hard for your finals!