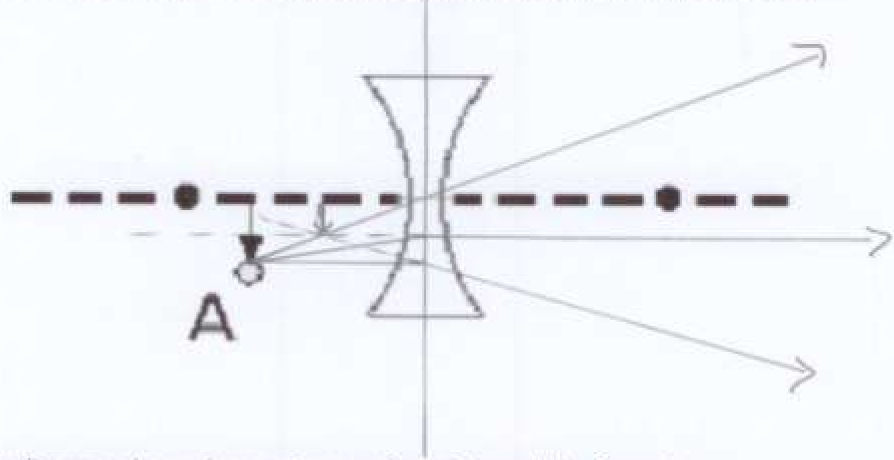
The diverging lens

In the figure shown below, point A (marked by a circle) is the top of a small object (indicated as an arrow). Near it, is a concave lens, as shown. The focal points of the lens are marked with black dots.



E. Anywhere on this side of the lens will be able to see the image

Diverging lens

A. Using a ray diagram, show where an image of point A would be formed.
B. If the focal length of the lens is 8 cm and the object is 6 cm from the lens, where will the image be? f= -8cm s = 6 cm
C. If the object is 1 cm tall, how tall will the image be? $\frac{1}{6} + \frac{1}{s'} = \frac{1}{-8}$ $s' = -3.43cm$
D. Will the image created by the lens be real or virtual?
E. Where will you have to be to see the image?

Anywhere on the right side of the lens. These three rays are the special rays, not the only rays. $m = -s'/s = h'/h$ $h' = \frac{-s'h}{s}$ 0.57cm

The world in a spoon

Look at your reflection in a shiny metal spoon, or a curved mirror. If it's curved towards you, like looking into the bowl of the spoon, we call it concave and if it's curved outward, like looking at the back of the spoon, we call it convex. Use a concave mirror for this, such as your reflection off the inside of a spoon.

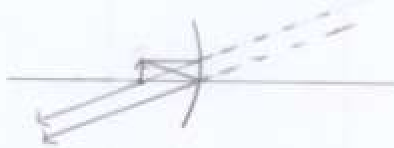
a. When you look at your reflection (start with the spoon touching your eyelashes), is it magnified or reduced? Can you account for that, using our ray model of light? Draw a diagram. magnified

b. Move the spoon or curved mirror away. What happens to your reflection? Can you account for that, using our ray model of light? Draw a diagram. I become fuzzy and then I'm inverted.

on eye lashes

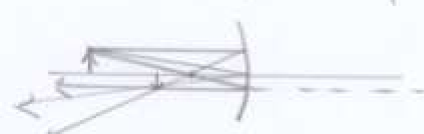
virtual, magnified, upright

fuzzy (object at focal point)



rays never converge

spoon far away

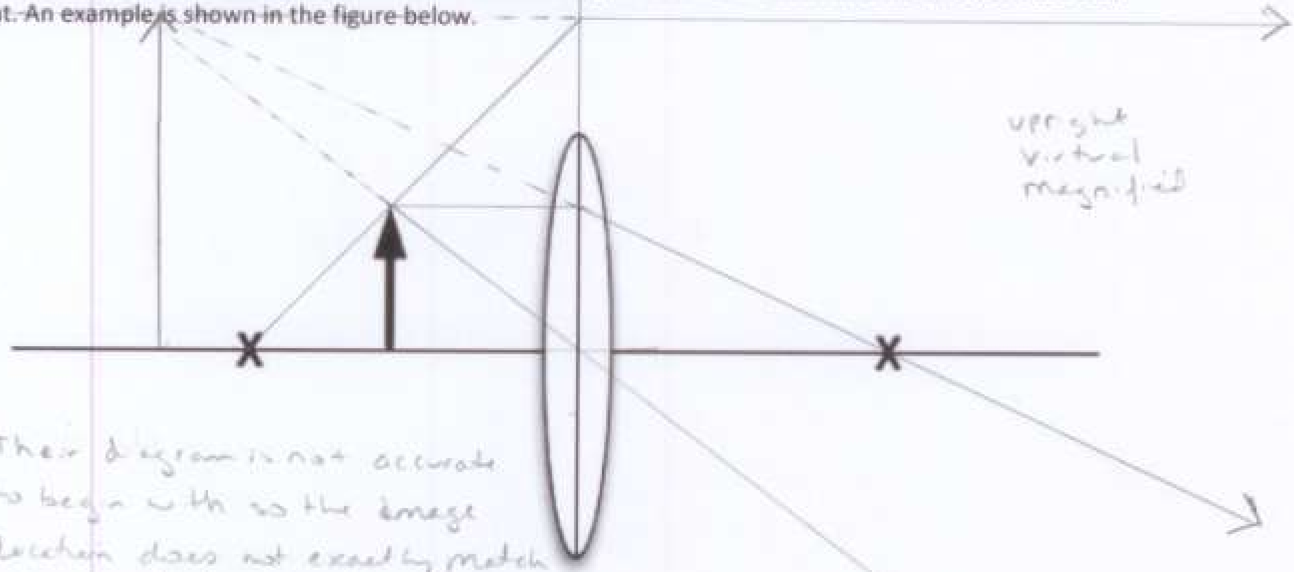


inverted, real, reduced

(note: magnified if 2f < s < f)

The Magnifying Glass

A magnifying glass is a converging lens used so that the object observed is closer to the lens than the focal point. ~~An example is shown in the figure below.~~



upright
virtual
magnified

Their diagram is not accurate to begin with so the image location does not exactly match the math! But it's generally the same.

a) On the figure, draw a ray diagram that will help you identify where the image is located.

b) Is the image real or virtual? Explain why you say so.

Virtual because the light is not actually where the image appears to be.

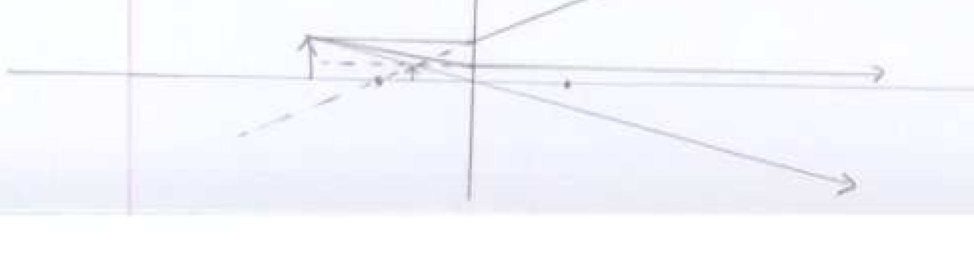
c) The focal length is a distance of 16 cm from the lens, the object is a distance of 8 cm from the lens, and the object is 8 cm high. Calculate the location and the size of the image using the lens equations. Does your calculation agree with your drawing? If not, explain why not. $f = 16cm \quad S = 8cm \quad h = 8cm$

$\frac{1}{8} + \frac{1}{S'} = \frac{1}{16}$ $\boxed{S' = -16\,cm}$ $M = h'/h = -S'/S$ $h' = \frac{-S'h}{S} = -\frac{-16cm \cdot 8cm}{8cm} = \boxed{16cm}$

A fishy lens

In the picture at the right is shown a sketch of two fish in an aquarium. At the instant of time shown, one of the fish is looking at the other through a bubble of air. What kind of image do you expect the fish to see? Will it appear larger or smaller than the object? Nearer or farther? Give an explanation and draw a careful ray diagram to support your argument.

The bubble is thicker in the middle which would make it a converging lens if it were water or glass in air. But the bubble is air in water. $n_{air} < n_{water}$ so it's reversed, the bubble acts as a diverging lens.



Each fish will see a virtual image of the other that is smaller but a little closer.

Closer than they appear

When a *T. rex* pursues a jeep in the movie *Jurassic Park*, we see a reflected image of the (very large) *T. rex* via a side-view mirror, on which is printed the (then darkly humorous) warning: "Objects in mirror are closer than they appear."

A. Is the mirror flat, convex, or concave? Why do you think so?

Let's analyze the warning "Objects in mirror are closer than they appear." to see whether this is really true.

B. If the radius of the mirror is 2 meters and the T-Rex is 10 meters from the mirror and stands 5 meters tall, how big is the image and how far is it from the mirror? $R = 2m$ $s = 10m$ $h = 5m$

C. Draw a careful ray diagram indicating the distance *p* of the object from the mirror, *q* the distance of the image from the mirror and the image size *h'* and *h* for the object size.

D. Did you find that the image is bigger or smaller than the original object? Is it farther from the mirror than the object or closer? Does your result support or contradict the statement on the mirror? If it contradicts the statement, explain why they say it.

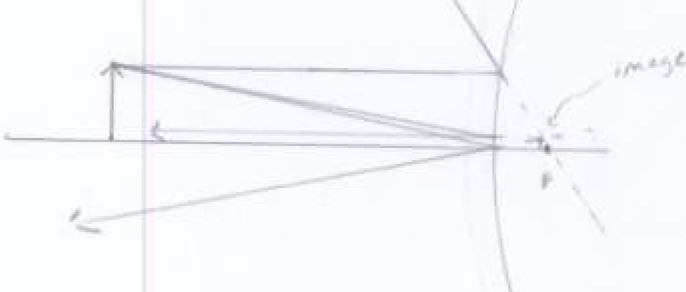
A. Concave mirrors have a range of outcomes depending on how close the object is to the mirror relative to the focal point. $s < f$ image is upright, magnified. if $s = f$ no image! if $s > f$ image is inverted! This would be bad.

Convex mirrors always produce an upright image.

B. $R = 2m$ $f = -1m$ ← diverging $s = 10m$ $h = 5m$

$\frac{1}{10m} + \frac{1}{s'} = \frac{1}{-1m}$ $s' = \boxed{-0.91\,m}$ $h' = \frac{-s'h}{s} = -\frac{-0.91m\ 5m}{10m} = \boxed{0.45}$

C.



D. The statement claims the image is further away than the object "Object closer than it appears" ← implies image location.

But we can see $s' = 0.91m$ & $s = 10m$

It's the image that is closer!

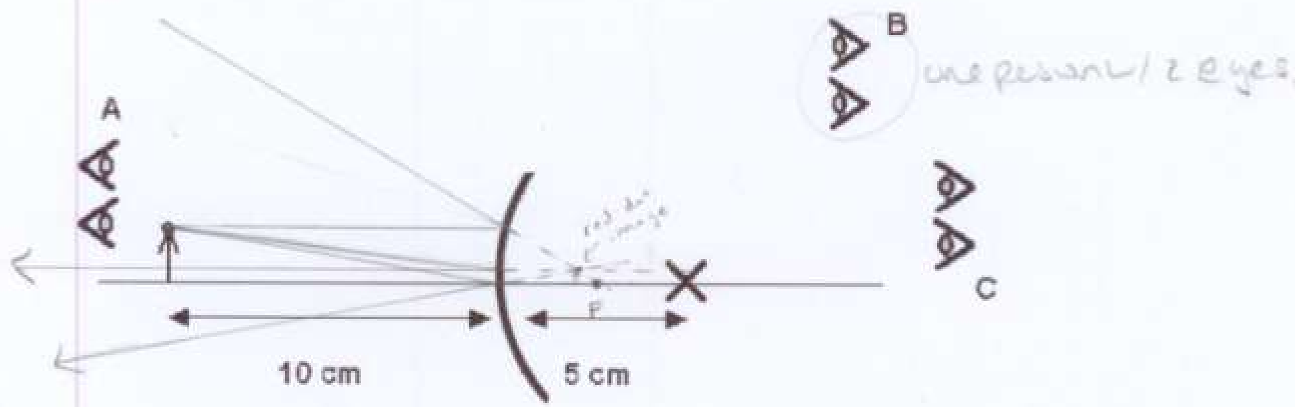
The reason it contradicts is because the image is reduced (tiny) and our brain interprets this as far away.

Who sees what?

In the figure below is shown a small object (represented by an arrow) in front of a curved mirror. At the tip of the arrow is a red dot. The mirror is a piece of a sphere. **The center of the sphere is marked in the picture with an x.** The triangular objects are the eyes corresponding to three different observers.

For each question, explain how you got your result. Be sure to include a ray diagram as part of your explanation.

a. How many red dots will the observer at position A see? Where will the dots appear to be? Specify quantitatively how far from the mirror the dots will appear to be and how far off the axis they will be.
b. How many red dots will the observer at position B see? Explain how you know.
c. How many red dots will the observer at position C see? Explain how you know.



A. A sees two red dots, the object and its image.

$s = 4.5\,cm$ $f = -1.25\,cm$ $s' = -1\,cm$

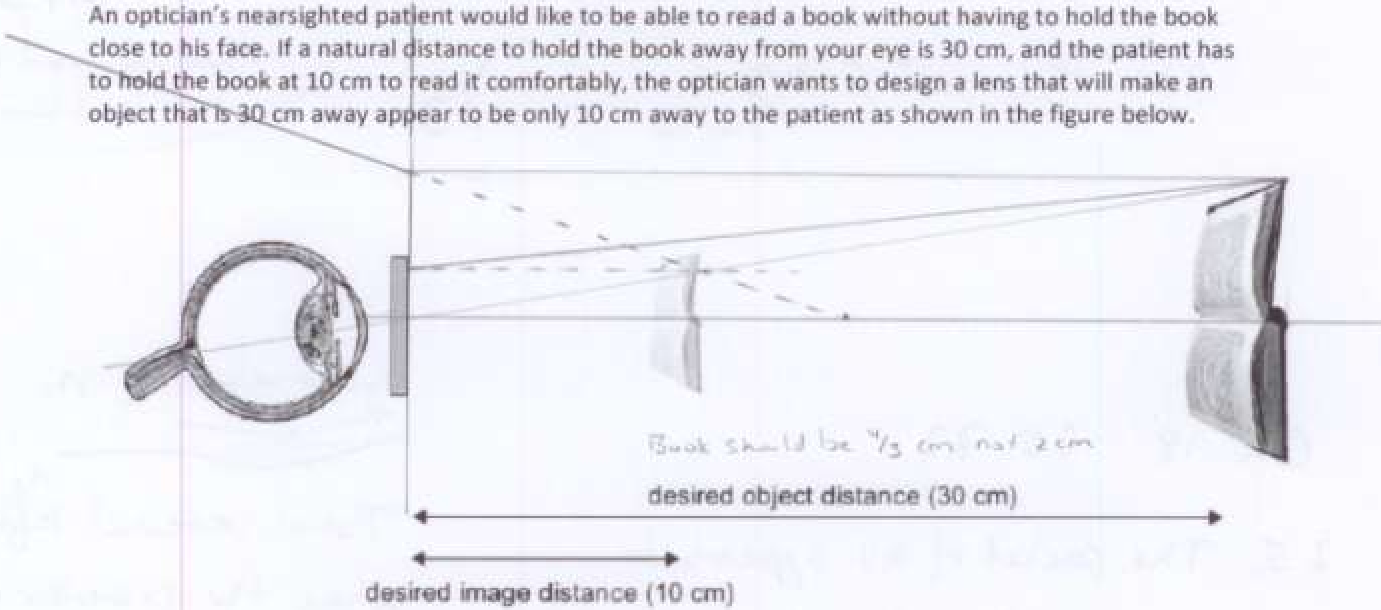
$h = 0.75\,cm$ $h' = -\frac{-s'h}{s} = -\frac{-1cm \cdot 0.75}{4.5} = 0.16\,cm \sim 2\,mm$

B. B will only see the object because none of the light that reflects off the mirror will hit B's eyes.

C. C will not see any red dots. The mirror physically blocks the image and, as with B, no reflected light from the mirror hits C's eyes.

Choosing a lens

An optician's nearsighted patient would like to be able to read a book without having to hold the book close to his face. If a natural distance to hold the book away from your eye is 30 cm, and the patient has to hold the book at 10 cm to read it comfortably, the optician wants to design a lens that will make an object that is 30 cm away appear to be only 10 cm away to the patient as shown in the figure below.



A. The optician wants the image to be right-side up and on the same side of the lens as the object. Should he use a converging lens or a diverging lens? Explain your reasoning.

B. The picture shows the image as smaller than the object. Is this correct? If the distances are as shown, what will be the magnification factor (ratio of the image size to object size)?

C. What is the focal length of the lens the optician needs to use to get the desired result?

Note! In this problem instead of giving us the reader's near point and asking us to fix it, we are given one specific example of reading at 30cm. So we just use what they gave us.

A. Nearsighted correction is a diverging lens. Light focuses before the retina so spreading the light before it hits the cornea will cause a focal point further back. Also you could consider the types of images converging and diverging lenses produce. Only a diverging lens creates a virtual image closer to the lens than the object.

B. Yes, a smaller image is expected, see ray diagram.

$M = h'/h = \frac{2cm}{4cm} = 1/2$ (as measured) But $M = -s'/s = \frac{-10cm}{30cm} = 1/3$ Not drawn correctly!

C. $s = 30cm$ $s' = -10 cm$ ← virtual image

$$\frac{1}{30} + \frac{1}{-10} = \frac{1}{f} \quad \boxed{f = -15cm}$$

$$M = -s'/s = -\frac{-10cm}{30cm} = 1/3$$

Reflective Power
$P = -6.7D$
*Not requested in the problem

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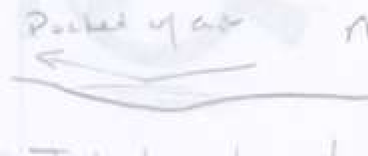

75. The pocket of air appears to be a pool of water because

Total internal reflection where the cooler air above is considered the "internal part"

[A.] Light reflects at the boundary between hot and cool air.

76. Which of these changes would allow you to get closer to the mirage before it disappears?

[C.] Increasing the difference in temperature between the pocket of hot air and the air above it

77. If you could clearly see the image of an object in a mirage, the image would appear

[B.] With up and down reversed.

That's why a mirage looks like a Lake