

Physics 1161: Lecture 17

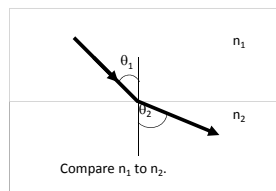
Refraction & Lenses

- Textbook sections 26-3 – 26-5, 26-8

Snell's Law

When light travels from one medium to another the speed changes $v=c/n$, but the frequency is constant. So the light bends:

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



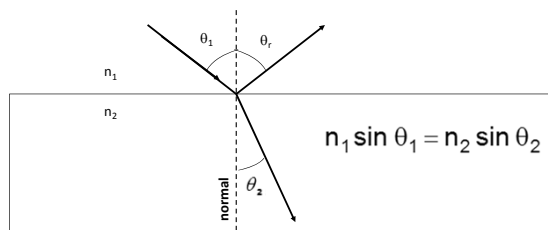
- 1) $n_1 > n_2$
- 2) $n_1 = n_2$
- 3) $n_1 < n_2$

Example

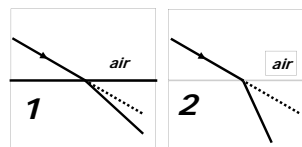
Snell's Law Practice

Usually, there is both reflection and refraction!

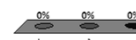
A ray of light traveling through the air ($n=1$) is incident on water ($n=1.33$). Part of the beam is reflected at an angle $\theta_r = 60^\circ$. The other part of the beam is refracted. What is θ_2 ?



Parallel light rays cross interfaces from air into two different media, 1 and 2, as shown in the figures below. In which of the media is the light traveling faster?

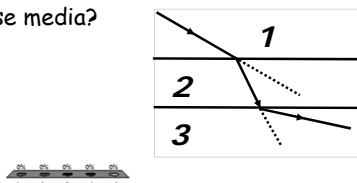


1. Medium 1
2. Medium 2
3. Both the same

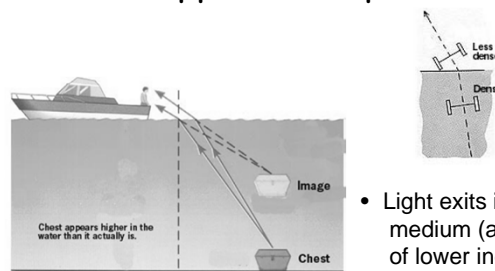


Parallel light rays cross interfaces from medium 1 into medium 2 and then into medium 3. What can we say about the relative sizes of the indices of refraction of these media?

1. $n_1 > n_2 > n_3$
2. $n_3 > n_2 > n_1$
3. $n_2 > n_3 > n_1$
4. $n_1 > n_3 > n_2$
5. none of the above

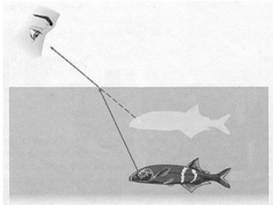


Apparent Depth

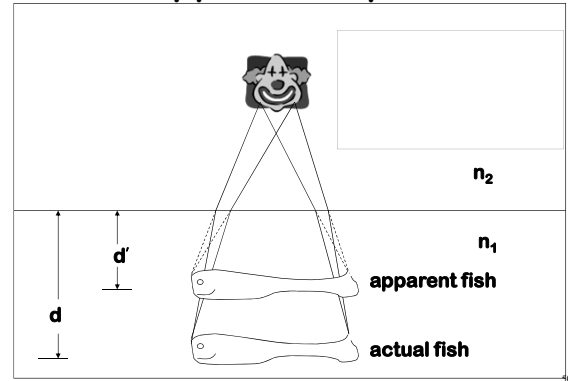


- Light exits into medium (air) of lower index of refraction, and turns left.

Spear-Fishing

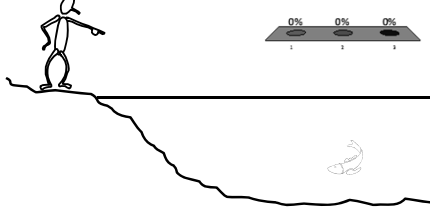


Apparent Depth

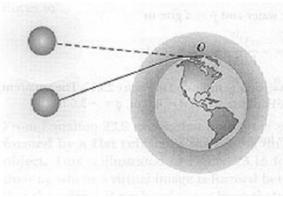


To spear a fish, should you aim directly at the image, slightly above, or slightly below?

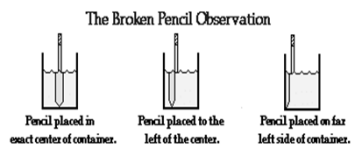
1. aim directly at the image
2. aim slightly above
3. aim slightly below



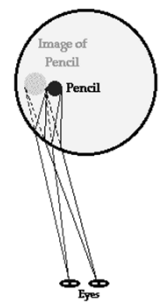
Delayed Sunset



Broken Pencil

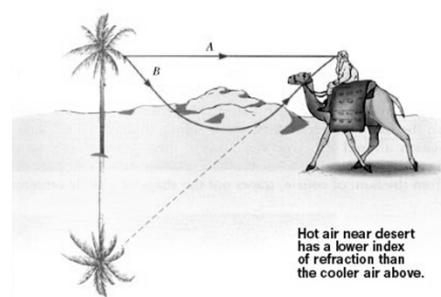


The Broken Pencil Observation
 Pencil placed in exact center of container.
 Pencil placed to the left of the center.
 Pencil placed on far left side of container.

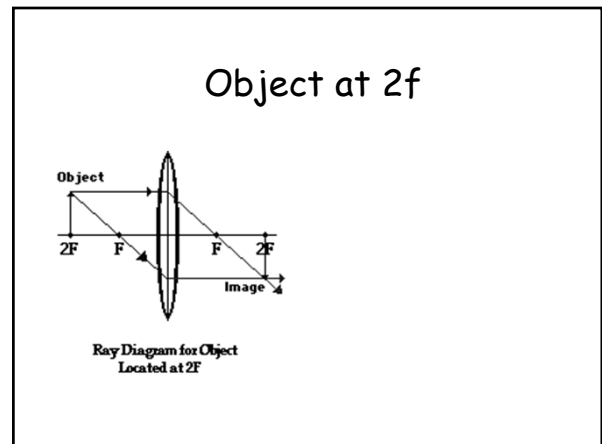
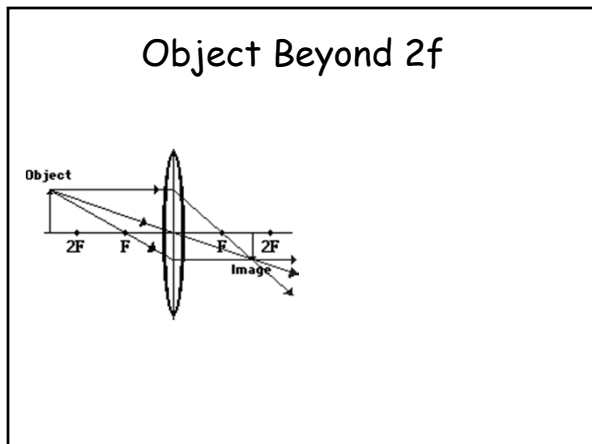
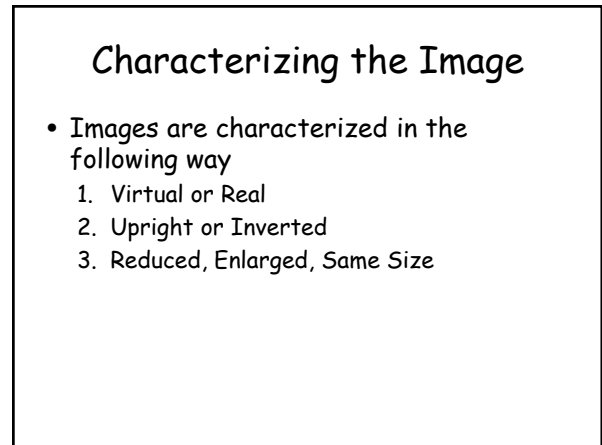
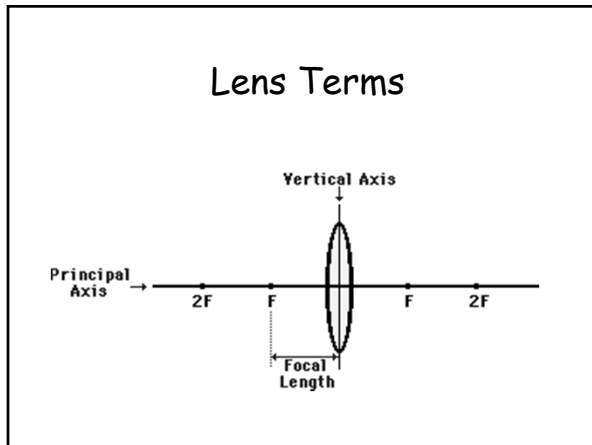
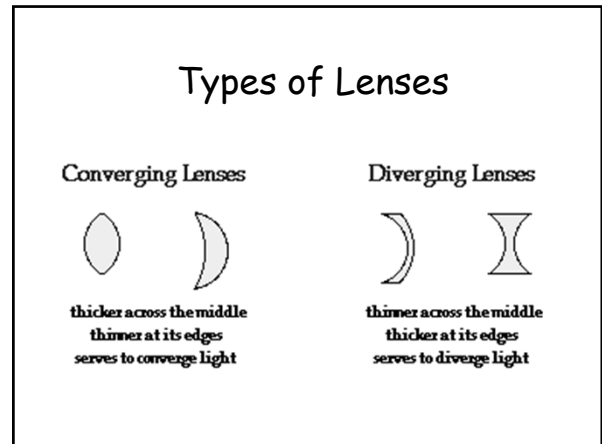
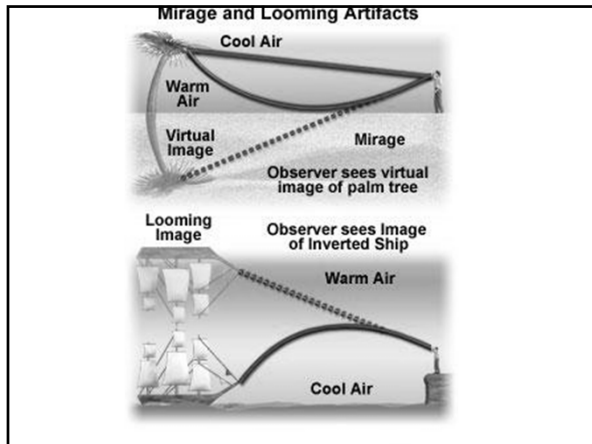


The image of the pencil is located where the refracted rays intersect.

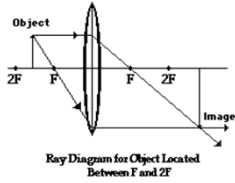
Palm Tree Mirage



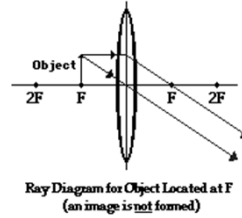
Hot air near desert has a lower index of refraction than the cooler air above.



Object Between 2f and f

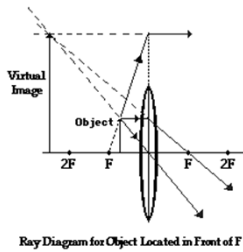


Object at F

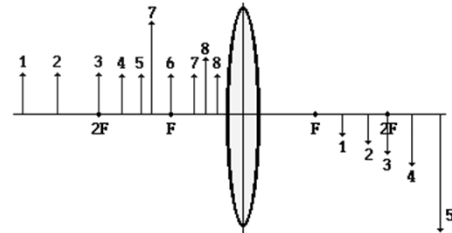


• No Image is Formed!

Object Closer than F



Converging Lens Images

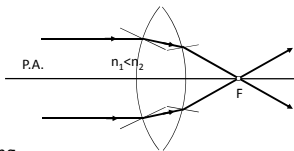


Each of the numbered objects (except #6) has an image with the corresponding number; its relative location, size, and orientation are shown.

Lens in Water Checkpoint

Focal point determined by geometry and Snell's Law:

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



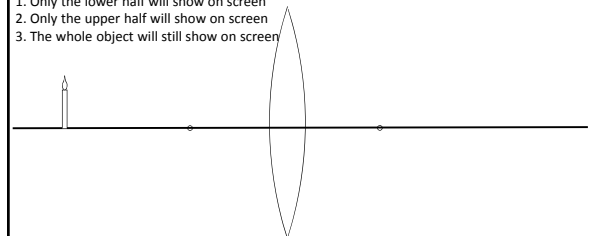
Fat in middle = Converging
Thin in middle = Diverging
Larger n_2/n_1 = more bending, shorter focal length.
 $n_1 = n_2 \Rightarrow$ No Bending, $f = \text{infinity}$

Lens in water has _____ focal length!

Half Lens Checkpoint

A converging lens is used to project a real image onto a screen. A piece of black tape is then placed over the upper half of the lens.

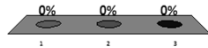
1. Only the lower half will show on screen
2. Only the upper half will show on screen
3. The whole object will still show on screen



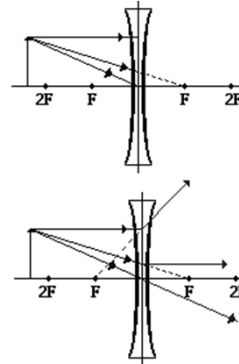
How much of the image appears on the screen?

Two very thin converging lenses each with a focal length of 20 cm are placed in contact. What is the focal length of this compound lens?

1. 10 cm
2. 20 cm
3. 40 cm

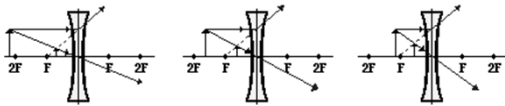


Concave (Diverging) Lens



- Ray parallel to axis refracts as if it comes from the first focus.
- Ray which lines up with second focus refracts parallel to axis.
- Ray through center of lens doesn't bend.

Image Formed by Concave Lens



Concave Lens Image Distance

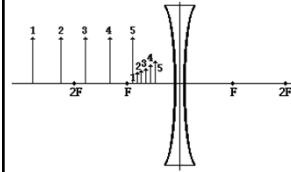


Image Characteristics

- CONVEX LENS - IMAGE DEPENDS ON OBJECT POSITION
- CONCAVE LENS - IMAGE ALWAYS SAME

Lens Equations



$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

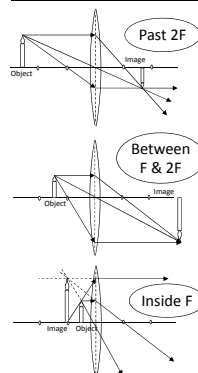
$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

Which way should you move object so image is real and diminished?

1. Closer to the lens
2. Farther from the lens
3. A converging lens can't create a real, diminished image.

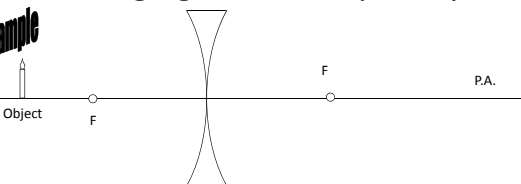


3 Cases for Converging Lenses



Diverging Lens Principal Rays

Example

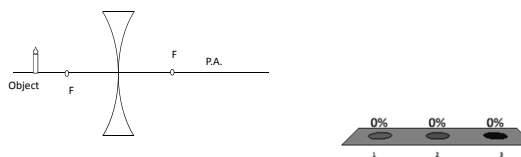


- 1) Rays parallel to principal axis pass through focal point.
- 2) Rays through center of lens are not refracted.
- 3) Rays toward F emerge parallel to principal axis.

Image is (always true):
 Real or Imaginary
 Upright or Inverted
 Reduced or Enlarged

Which way should you move the object to cause the image to be real?

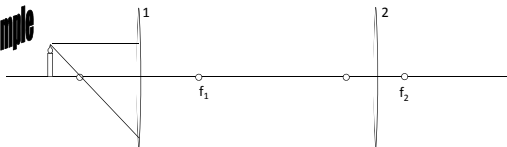
1. Closer to the lens
2. Farther from the lens
3. Diverging lenses can't form real images



Multiple Lenses

Image from lens 1 becomes object for lens 2

Example



Complete the Rays to locate the final image.

Multiple Lenses: Magnification

Example

