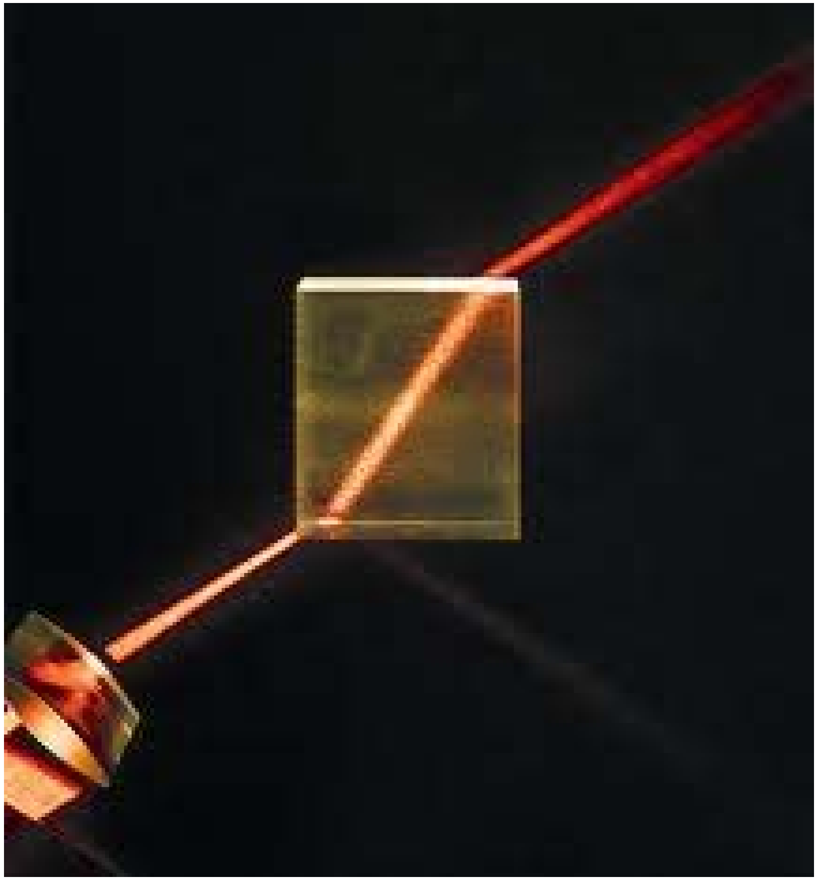
Algebra-based Physics II

Oct 20th: Chap 26. 1-3

- Refraction and refraction index (*n*)
- Snell's law
- Total internal reflection

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

$$\sin \theta_c = \frac{n_2}{n_1} \quad (n_1 > n_2)$$



Sign Conventions

Focal Length

f is positive for concave mirrors
f is negative for convex mirrors

Object Distance

d_o is positive if the object is in front of the mirror
d_o is negative if the object is behind the mirror

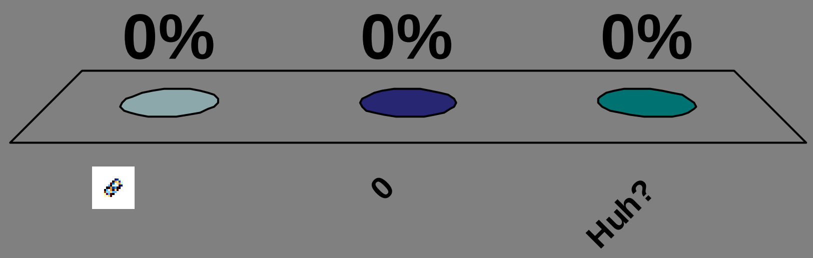
Image Distance

d_i is positive if the image is in front of the mirror (real image)
d_i is negative if the image is behind the mirror (virtual image)

Clicker Question 25 - 5

Based on the mirror equation, what is the focal length of a plane mirror?

1. ∞
2. 0
3. Huh?



Example

A spherical mirror is used to reflect light from an object that is 66 cm in front of the mirror. The focal length of the mirror is -46 cm. Find the location of the image and its magnification.

Solution

What we know:

d_o **= 66 cm** f **= - 46cm** **Mirror is convex**

What we need to find:

d_i m

$$\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f} \Rightarrow \frac{1}{d_i}=\frac{1}{f}-\frac{1}{d_o} \Rightarrow \frac{1}{d_i}=\frac{1}{-46}-\frac{1}{66} \Rightarrow \frac{1}{d_i}=-0.036891$$

$$\Rightarrow \boxed{d_i=-27.1\,\text{cm}}$$

So, the image is virtual, located 27.1 cm behind the mirror.

$$m=\frac{-d_i}{d_o} \Rightarrow m=\frac{-(-27.1)}{66} \Rightarrow \boxed{m=0.41}$$

The image is reduced and upright wrt the object.

Ch. 26 The Refraction of Light

Visible light, and all EM waves travel thru a vacuum with speed c.

But light can also travel thru many different materials.

The atoms in these materials absorb, reemit, and scatter the light.

Thus, the speed of light slows down as it travels thru a material.

The actual speed of light in some material depends on the material.

$$c = \frac{1}{\sqrt{\mu_o \varepsilon_o}}$$

Speed of light in vacuum.

$$v = \frac{1}{\sqrt{\underset{\underset{\text{Material dependent}}{\uparrow}}{\mu\varepsilon}}}$$

Speed of light in some material.

To describe the speed of light in a material, we use a parameter called the index of refraction (n):

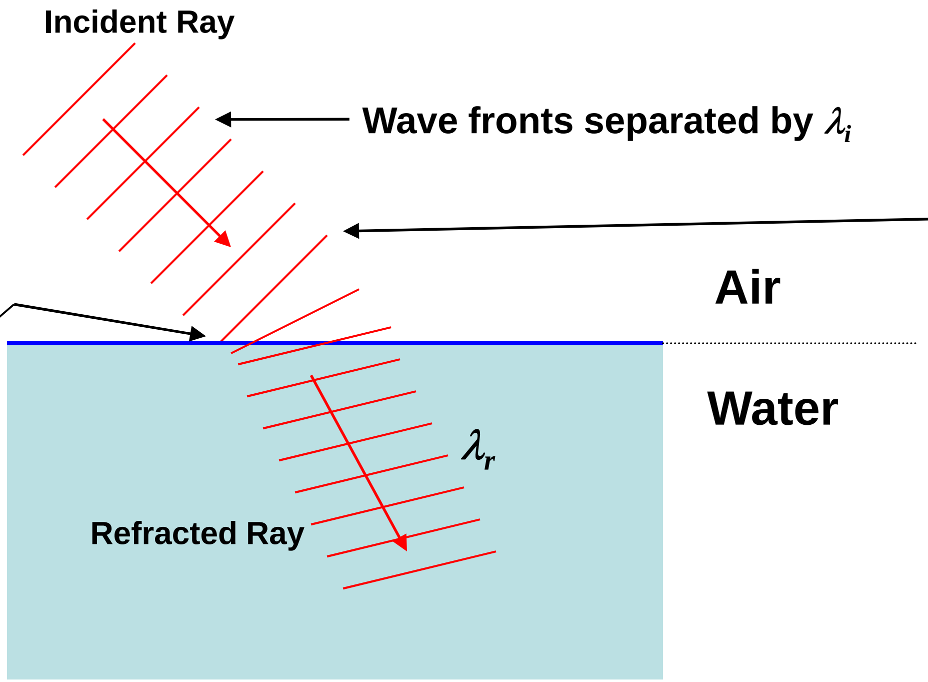
$$\boxed{n = \frac{c}{v}}$$

*** Note:** $n \geq 1$

26.2 Snell's Law

When light in a vacuum enters a more dense material, like water for example, the light not only slows down, but it also changes direction.

This bending of light as it travels between two different materials is called **refraction.**


Incident Ray
Wave fronts separated by λ_i
Air
Water
λ_r
Refracted Ray

As the incident wave strikes the water's surface, the lower part of the wave front hits first – slowing that side of the wave.

The wave bunches up here, but not on the top side where it's still moving fast.

This causes the wave to turn or bend.

*Note: The refracted wave has a new wavelength. Shorter in this case.

As the light passes thru different media, it's frequency stays the same, but its wavelength changes!

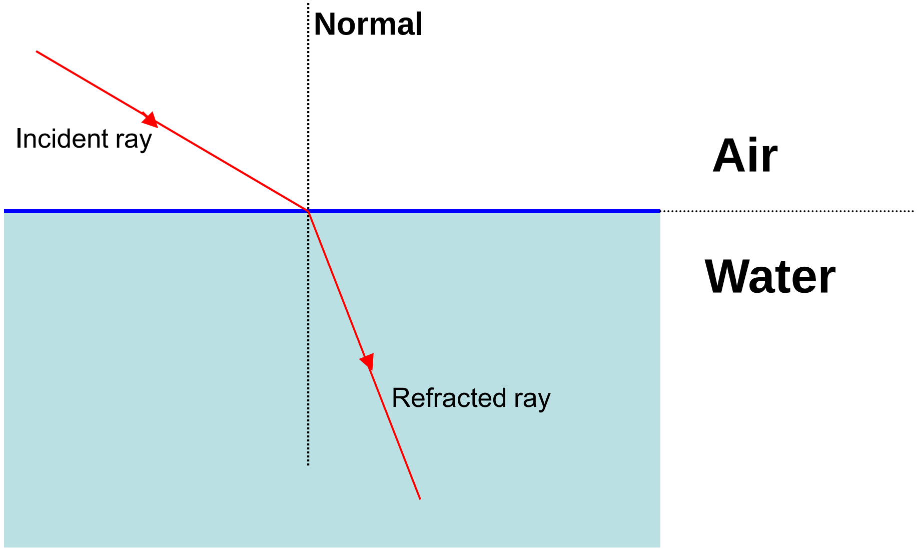
$$f = \frac{v}{\lambda}$$

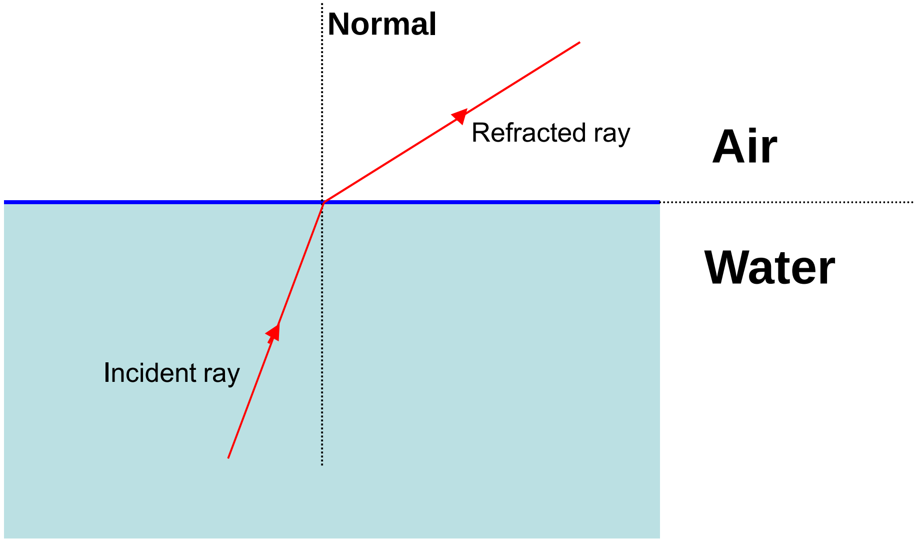
Since λ changes, the speed changes too to keep f constant.

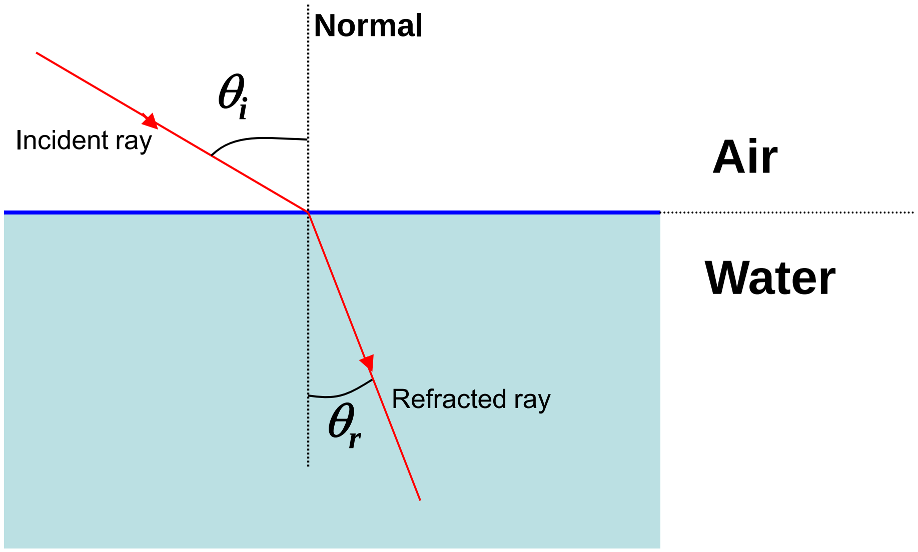
So how does the light get bent (refracted)?

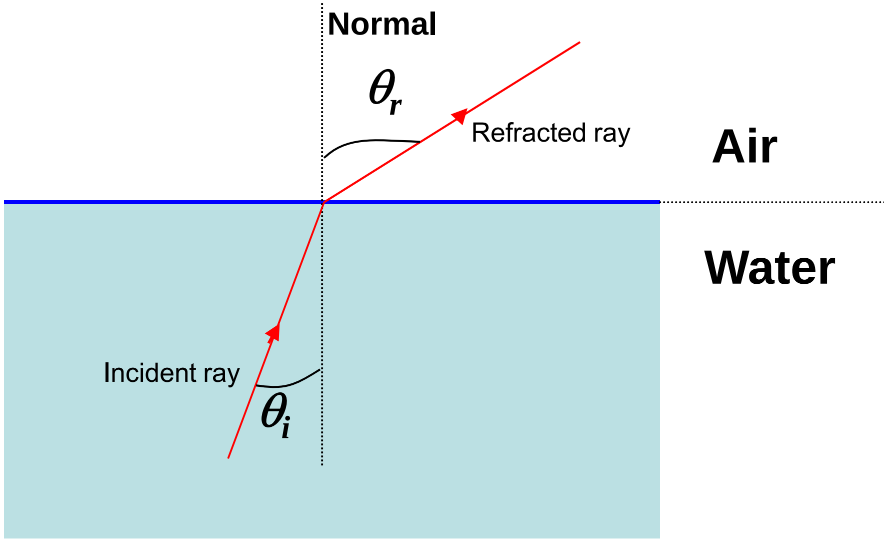
If the light is passing from a less dense medium into a more dense medium, it gets bent toward the normal.

If the light is passing from a more dense medium into a less dense medium, it gets bent away from the normal.


Normal
Incident ray
Air
Water
Refracted ray


Normal
Refracted ray
Air
Water
Incident ray


Normal
θ_i
Incident ray
Air
Water
Refracted ray
θ_r

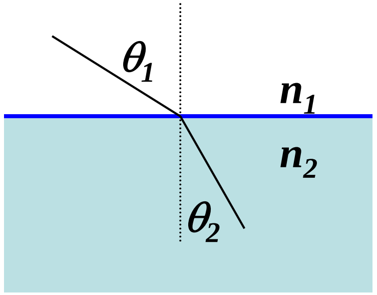

Normal
θ_r
Refracted ray
Air
Water
Incident ray
θ_i

Notice that the incident and refracted angles are measured with respect to the normal.

The relationship between the two angles is given by Snell's Law of Refraction.

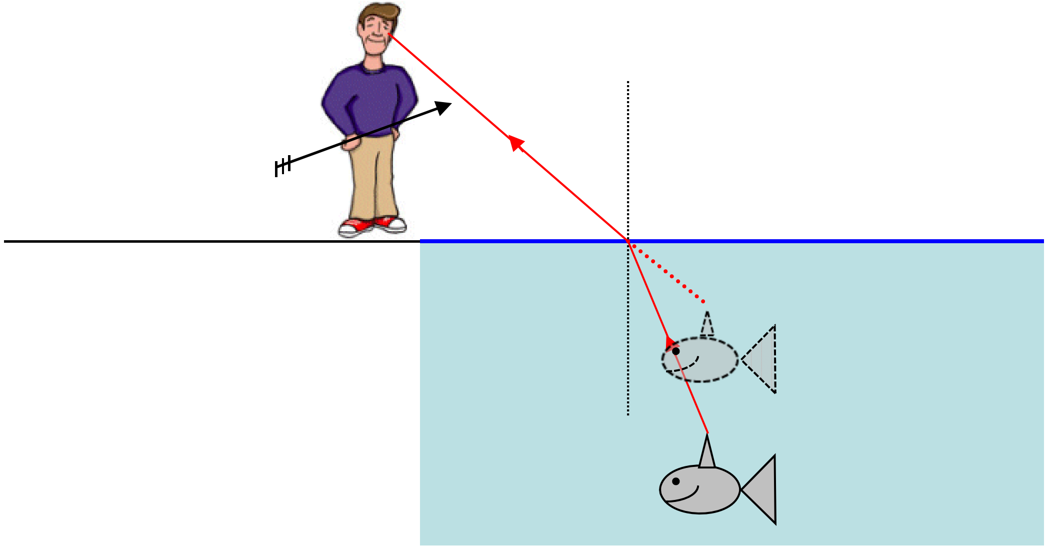
$$\boxed{n_1 \sin\theta_1 = n_2 \sin\theta_2}$$

n_1 is the index of refraction in medium 1 and n_2 is the index of refraction in medium 2.


θ_1
n_1
n_2
θ_2

Apparent Depth

Let’s say you’re standing on the shore of a lake and you want to kill a little fishy with a spear.



Pick one little point on the fish, say his dorsal fin, and look at a light ray from there.

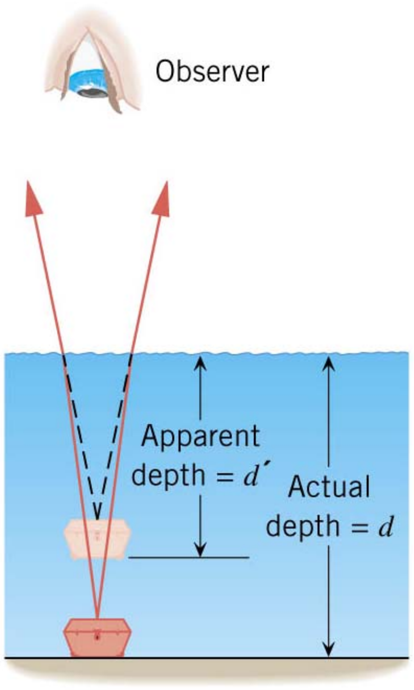
The ray gets bent away from the normal as it leaves the water before it enters your eye.

Thus, you see the fish at a different position.

By extrapolating the ray back, we see the fish appears closer to the surface than he actually is.

Thus, in order to kill the fish with the spear, you learn to aim slightly below the fish’s apparent position!

Calculating the apparent depth is easy if you are looking directly down from above at the object.



(b)

Light rays from a treasure chest sitting on the bottom of the ocean floor refract at the water's surface, making the chest look closer to the surface than it actually is.

Apparent depth for observer directly above object:

$$\boxed{d' = d\left(\frac{n_2}{n_1}\right)}$$

Refracted ray

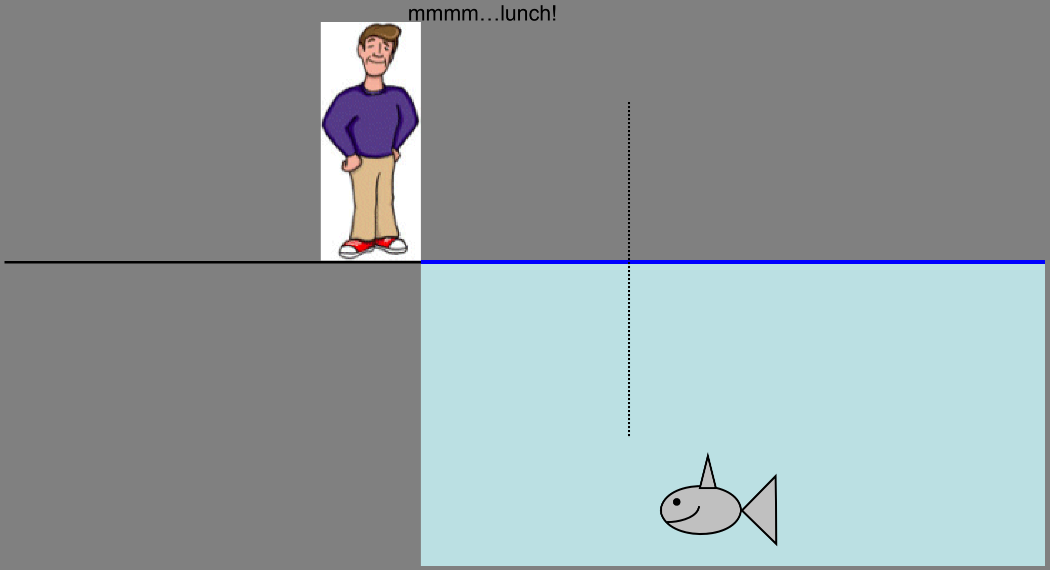
Incident ray

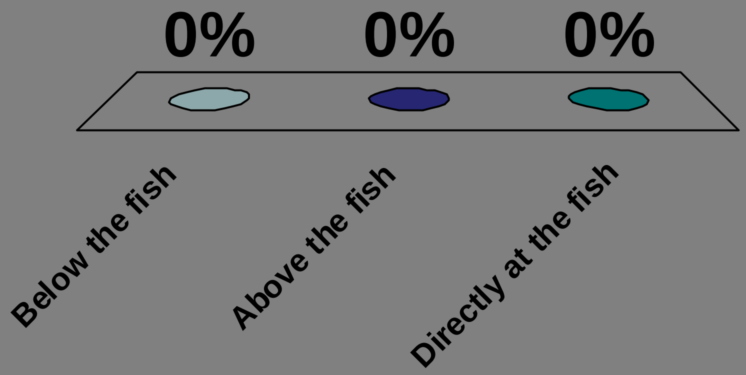
What if the observer is sitting in the water looking at something in the air above it ????????

Clicker Question 25 - 6

Now I’m standing on the dock again, but this time I want to kill the fishy with a laser beam. Where should I aim?

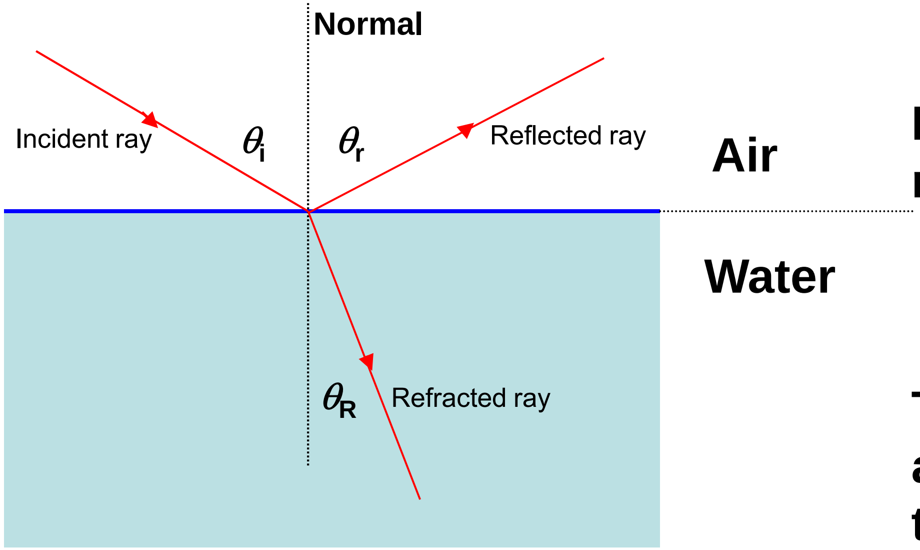
1. Below the fish
2. Above the fish
3. [✓ Directly at the fish]





26.3 Total Internal Reflection

Consider a light ray in air striking the surface of water:



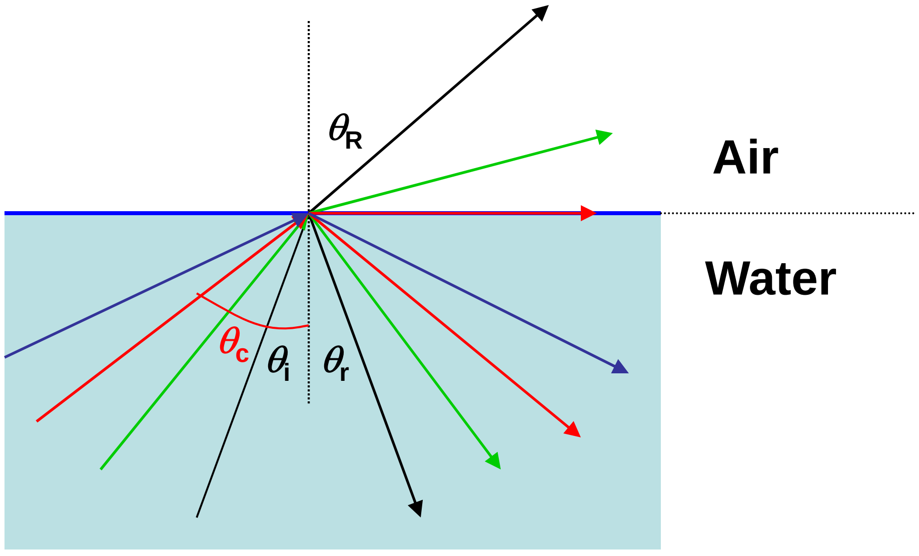
Normal
Incident ray
θ_i
θ_r
Reflected ray
Air
Water
θ_R
Refracted ray

Part of the ray is refracted, and part is reflected.

The refracted (θ_R) and reflected (θ_r) angles will both change if we change the incident angle (Law of Reflection and Snell's Law of Refraction).

Now consider what happens when a light ray emerges from a more dense medium into a less dense medium: water to air, for example.

Part of the ray is reflected, and part is refracted.



Notice that the refracted angle is greater than the incident angle since $n_{air} < n_{water}$.

Now let's keep increasing the incident angle so that the refracted angle keeps increasing.

Notice: There is a point when the refracted angle = 90^o (red ray).

This occurs when $\theta_i = \theta_c$, where θ_c is known as the critical angle.

Thus, when $\theta_i = \theta_c$, $\theta_{refracted} = 90^0$.

Now, if $\theta_i > \theta_c$, then there is no refracted ray (purple ray)!

All the incident light is completely reflected back into the medium.

This is called total internal reflection.

From Snell's Law: $n_1 \sin\theta_1 = n_2 \sin\theta_2$

But we know when $\theta_1 = \theta_c$, $\theta_2 = 90^o$.

Thus, $n_1 \sin\theta_c = n_2 \sin 90^o \Rightarrow \boxed{\sin\theta_c = \frac{n_2}{n_1}}$ **True for $n_1 > n_2$.**

Example:

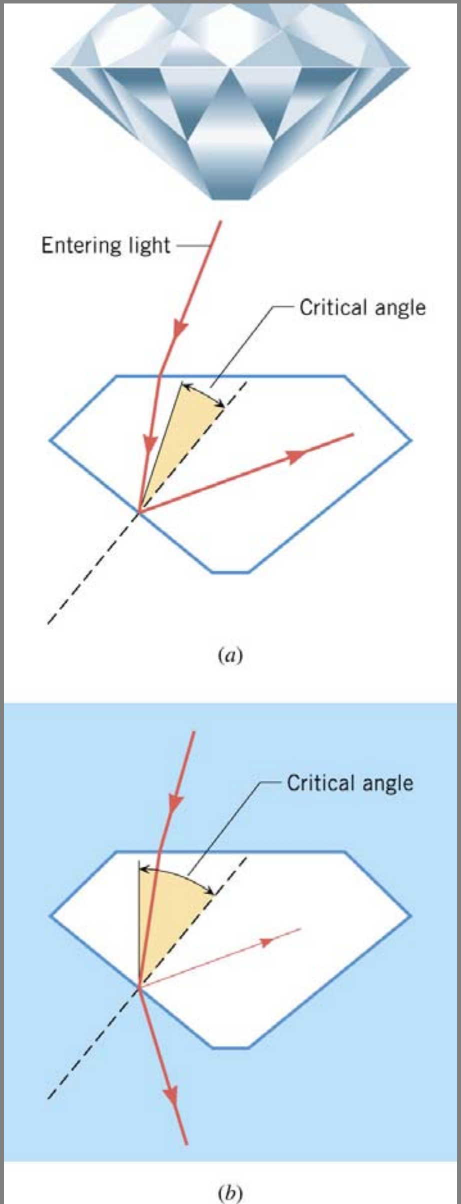
What is θ_c for water to air?

$$\sin\theta_c = \frac{n_2}{n_1} = \frac{1.00}{1.33} \Rightarrow \theta_c = \sin^{-1}\left(\frac{1.00}{1.33}\right) = 48.8^o$$

Thus, for light rays traveling in water toward air, if the incident angle is greater than 48.8°, the water acts like a perfect mirror.

Clicker Question 26 - 2

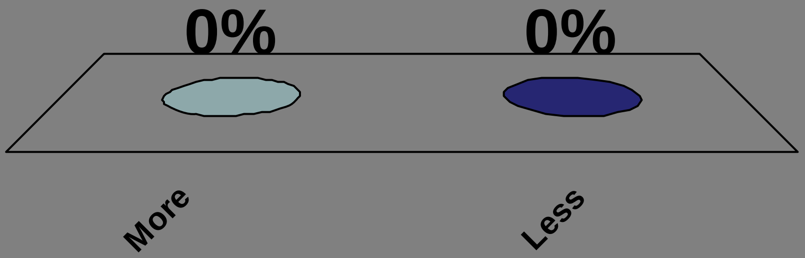
Under bright lights diamonds sparkle. If you immerse the diamond in water, will it shine with more brilliance, or less?


Entering light
Critical angle
Critical angle

(a)

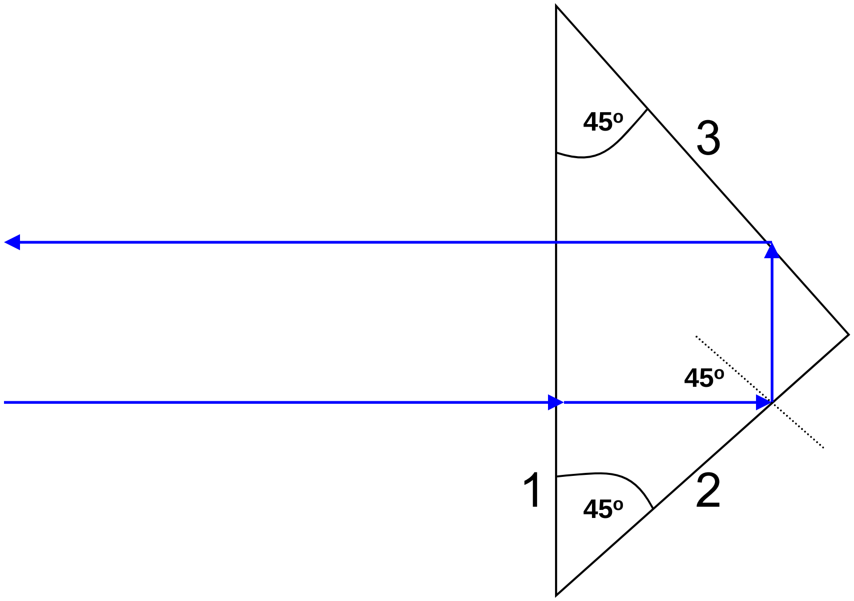
(b)

1. More
2. ✓ Less



Because of total internal reflection, glass prisms can be used to turn light rays around.

Consider a light ray striking a right-triangular glass prism:



$$\theta_c = \sin^{-1}\left(\frac{n_{air}}{n_{glass}}\right) = \sin^{-1}\left(\frac{1.00}{1.52}\right) = 42^o$$

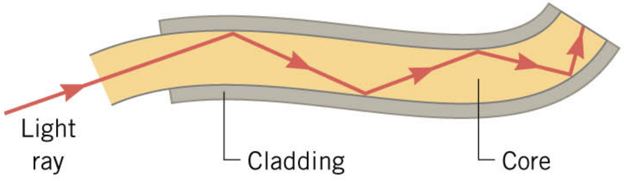
The ray strikes surface 1 perpendicularly and travels straight thru to surface 2.

At surface 2, the incident angle is greater than θ_c, so we get total internal reflection.

At surface 3, the incident angle is again greater than θ_c, so we get total internal reflection.

The ray turns completely around!

Total internal reflection is utilized in fiber optics:



(a)

(b)

Light enters essentially a glass “tube” and gets totally internally reflected since the glass cladding has a smaller index of refraction than the glass core.

The glass fibers are flexible, and as long as they are not bent too sharply, will reflect all of the light down them internally.

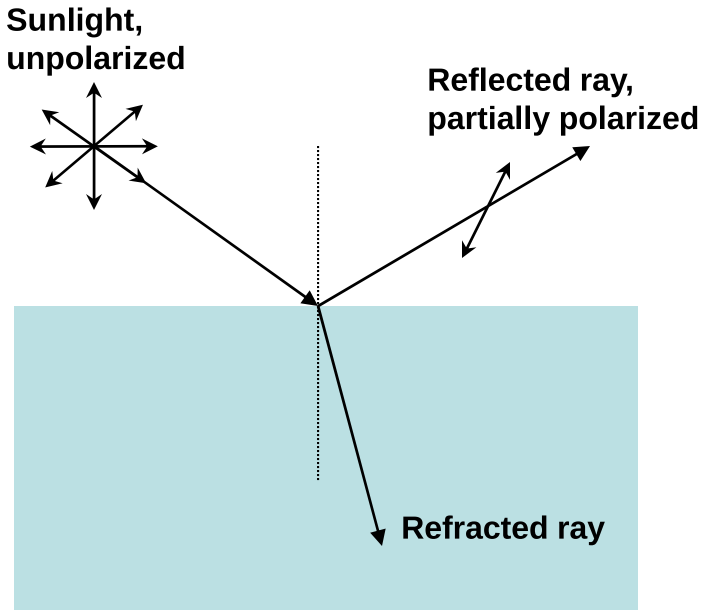
Used primarily as a low-loss, high-speed transmission cable for information, such as voice communications.

Also used by doctors and surgeons for endoscopic examinations and procedures.

26.4 Polarization, Reflection, and Refraction of Light

Light that gets reflected at some angle off of a non-metallic surface becomes partially polarized.

Consider, for example, sunlight reflecting off of water:



Sunlight is unpolarized, but upon reflection, becomes partially polarized.

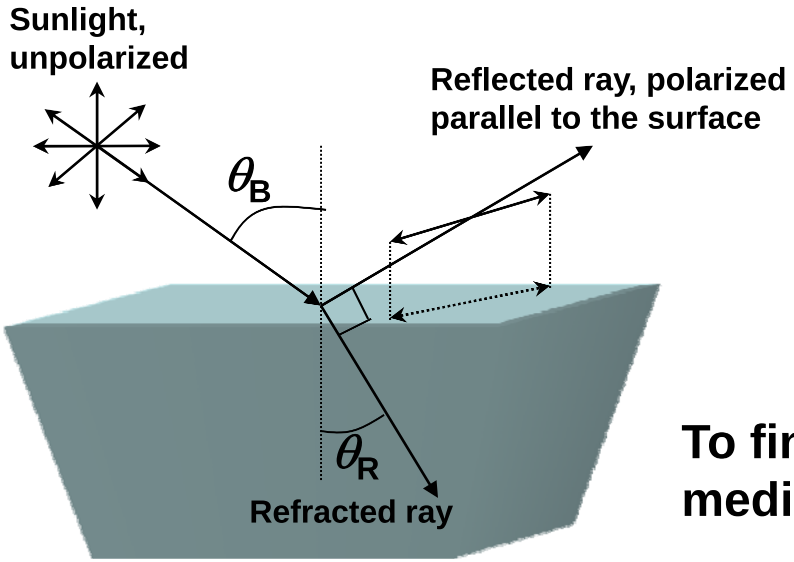
Polarized sunglasses are polarizers with a vertical transmission axis.

Thus, they block the reflected glare that comes from the surface of the water.

Most of the reflected light is polarized parallel to the surface of the water (i.e. horizontally), so it gets blocked by the sunglasses.

However, there is a special incident angle such that the reflected ray is completely polarized parallel to the surface.

This is called the Brewster Angle (θ_B).


Sunlight, unpolarized
Reflected ray, polarized parallel to the surface
θ_B
θ_R
Refracted ray

So, at the Brewster angle, the reflected light is polarized parallel to the surface.

And…..the angle between the reflected and refracted rays is 90º – they are perpendicular to each other!

To find the Brewster angle between two media:

$$\boxed{\tan\theta_B = \frac{n_2}{n_1}}$$

Refracted ray

Incident ray

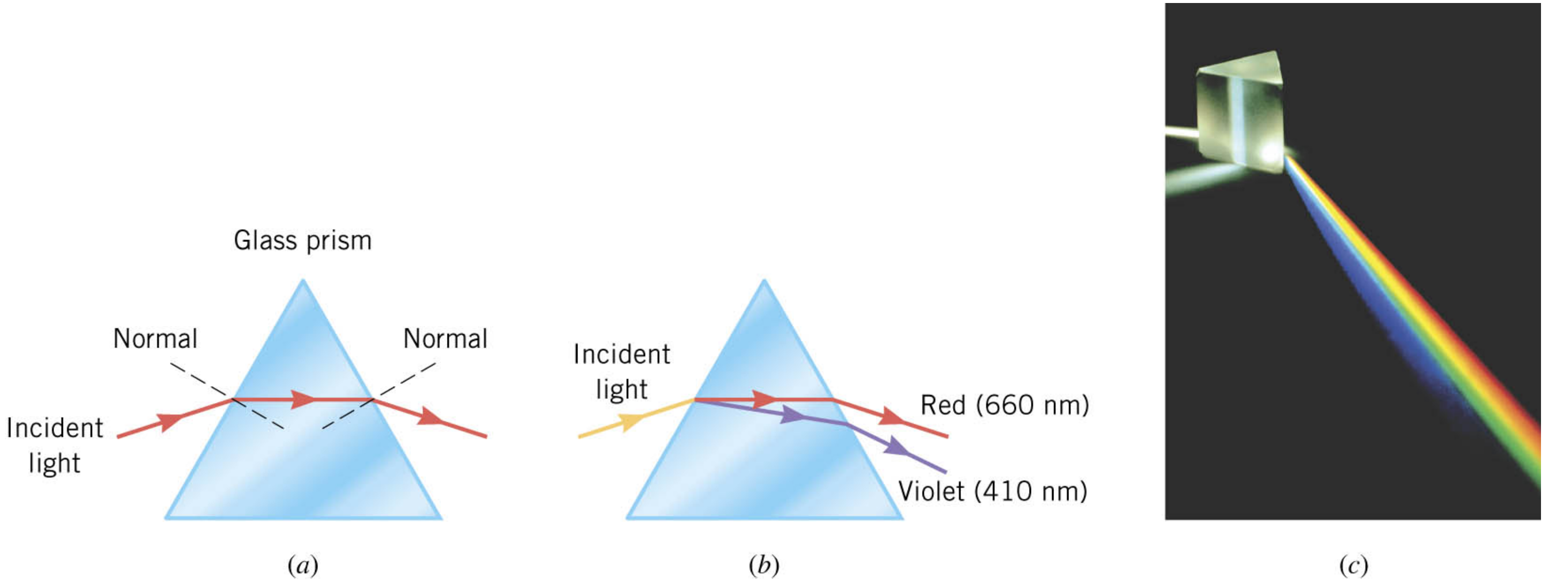
Thus, at the Brewster angle:

$$\boxed{\theta_B + \theta_R = 90^o}$$

26.5 Dispersion of Light

Light passing thru a prism gets bent or refracted.

However, how much it gets bent depends on the "color" of the light, i.e. its wavelength.

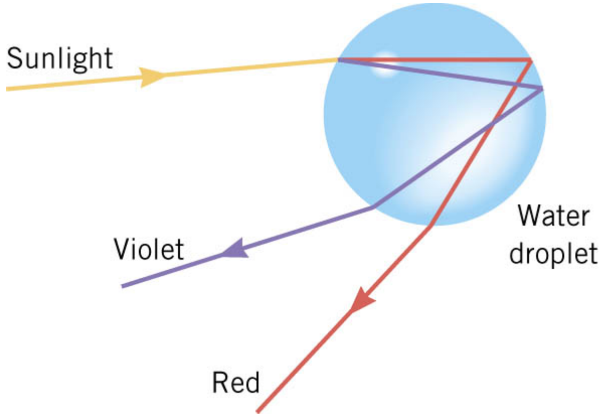

Glass prism
Normal
Normal
Incident light
(a)
Incident light
Red (660 nm)
Violet (410 nm)
(b)
(c)

Violet light has a higher refractive index than red light, so it gets bent more, in accord with Snell's Law.

Thus, a prism can separate white light into all the visible colors.

The spreading out of light into its component colors (or wavelengths) is called dispersion. It is a refraction effect!

Dispersion is responsible for the formation of rainbows:


Sunlight
Water droplet
Violet
Red

Algebra-based Physics II

Oct 20th: Chap 26. 6-8

- Lenses
- Image formation by lenses
- Lens equation and magnification

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

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

26.6 Lenses

A lens is an optical system that refracts (bends) light to form an image of the object.

A lens consists of two or more surfaces, at least one of which is curved.

An optical system with just one lens is called a simple lens system.

An optical system more than one lens is called a compound lens system.

We know that prisms bend light, so can we use a prism to form an image?

Rays don’t intersect
at same point.

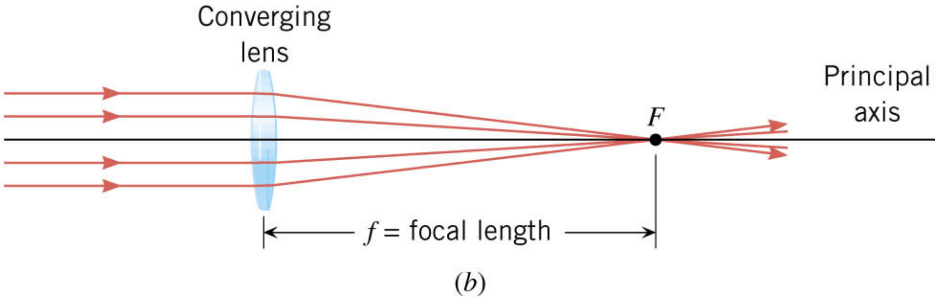
Prisms bend the light, but they don’t form clear images.

But, if we make the lens with a spherical surface, then incoming parallel rays converge at a common point (*F*), the focal point.

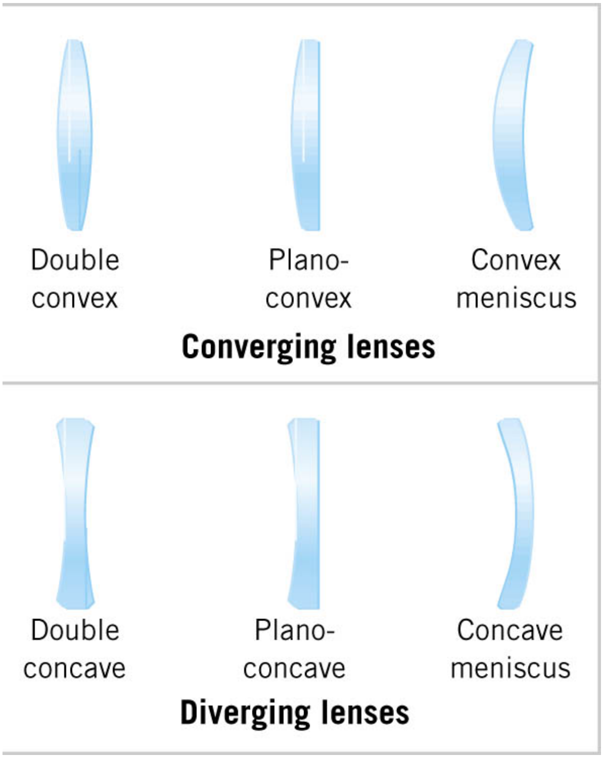
Like for mirrors, we can identify a focal length for the lens (*f*).

*Remember, parallel light rays come from objects that are very far away.

For this lens (bowed outward) the rays converge at a common point: Converging Lens or Convex Lens.


Converging lens
Principal axis
F
f = focal length
(b)

If the parallel rays are bent away from the principal axis, they appear to diverge from a common pont: Diverging Lens or Concave Lens.


Double convex
Plano-convex
Convex meniscus
Converging lenses
Double concave
Plano-concave
Concave meniscus
Diverging lenses

Lenses come in a variety of shapes:

Snell's Law at the interface controls the refraction!

26.7 Formation of Images by Lenses

Like mirrors, lenses can form images of objects.

But lenses are different, since the light rays actually pass thru the lens.

We will again use ray tracing diagrams to determine the location, size, and orientation of images formed by lenses.

In doing so, we will assume the lens is thin relative to it's focal length.

This ensures that both d_i and d_o can be measured from the center of the lens.

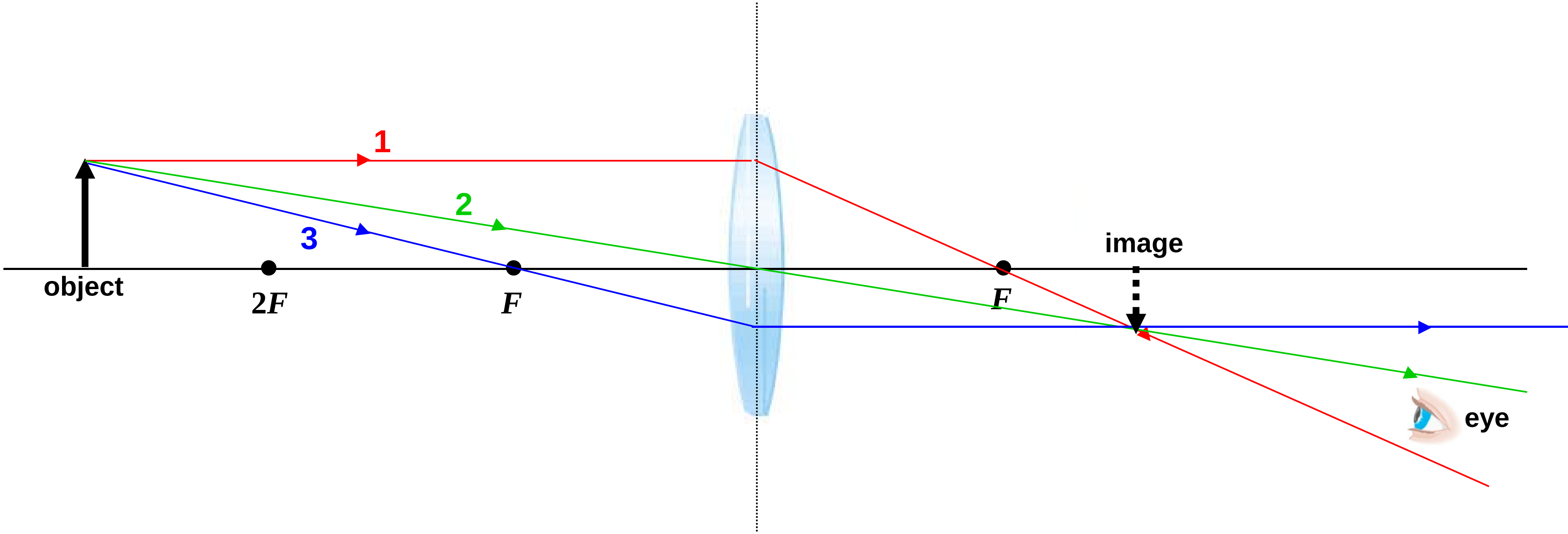
Also, we will assume, unless otherwise stated, that the object is located on the principal axis to the *left* of the lens.

Again, we will use three principle rays to locate the image:

1. **A ray traveling parallel to the principal axis gets refracted thru the focal point.**
2. **A ray traveling thru the center of the lens is unaffected.**
3. **A ray traveling thru the focal point gets refracted parallel to the principal axis.**

There are 3 cases for a converging lens. Let's take them one at a time.

Case 1: The object is located beyond 2*F*:



Ray 1 is a paraxial ray from the object that gets refracted thru *F*.

Ray 2 travels thru the center of the lens unaffected.

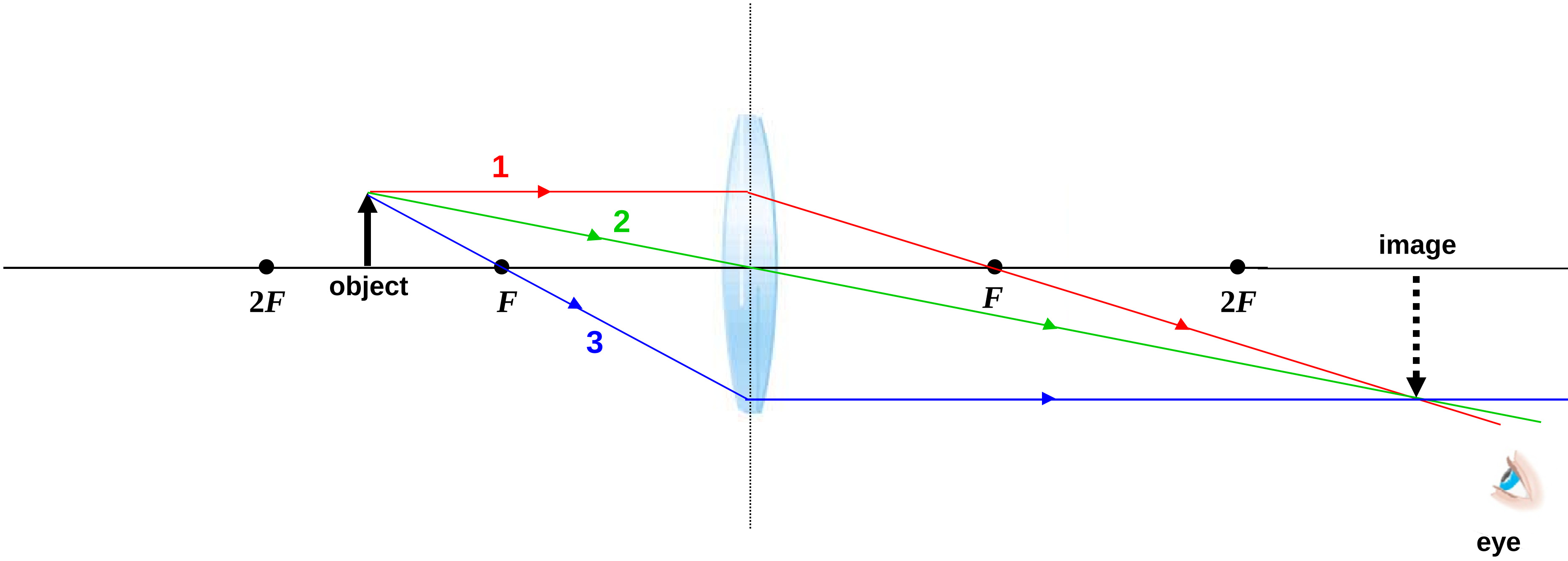
Ray 3 travels thru *F* and comes out parallel.

Now we can see where the rays intersect, and thus the image position.

What are the image properties? Real, inverted, and reduced.

Camera

Case 2: The object is between *F* and 2*F*:



Ray 1 is a paraxial ray from the object that gets refracted thru *F*.

Ray 2 travels thru the center of the lens unaffected.

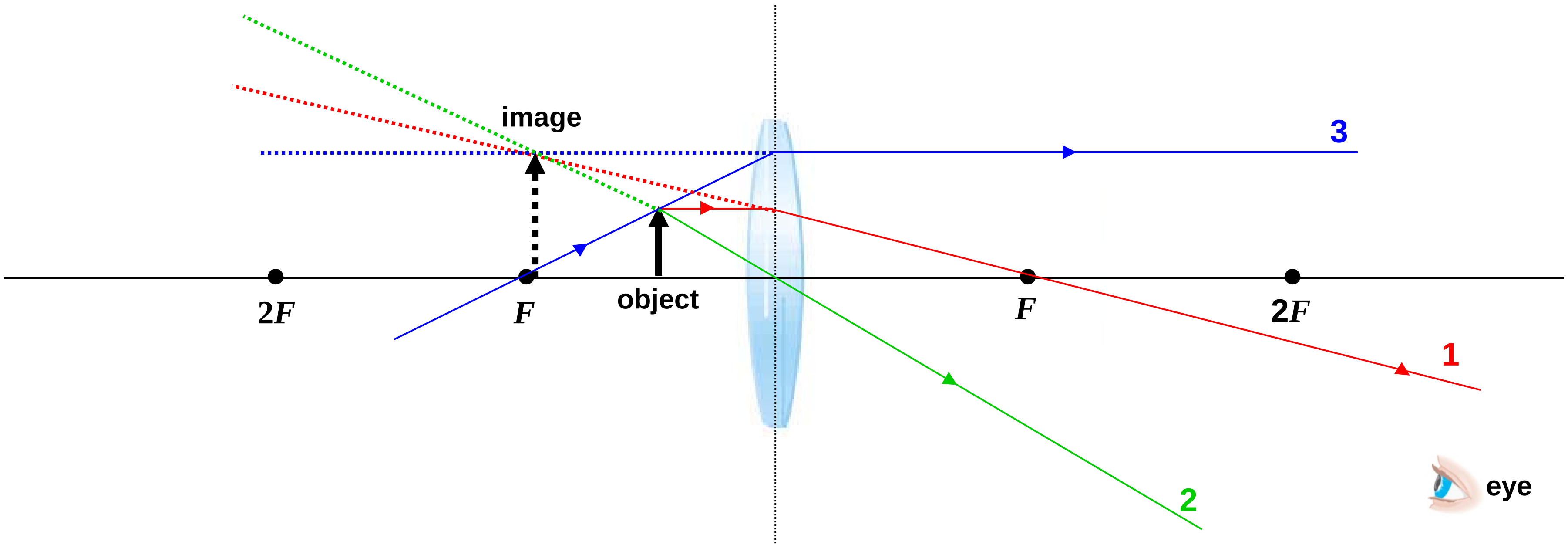
Ray 3 travels thru *F* and comes out parallel.

Now we can see where the rays intersect, and thus the image position.

What are the image properties? **Real, inverted, and enlarged.**

Projector

Case 3: The object is within *F*:



Ray 1 is a paraxial ray from the object that gets refracted thru *F*.

Ray 2 travels thru the center of the lens unaffected.

Ray 3 travels thru *F* and comes out parallel.

Magnifying Glass

Notice: Rays 1,2, and 3 don't converge! They diverge!

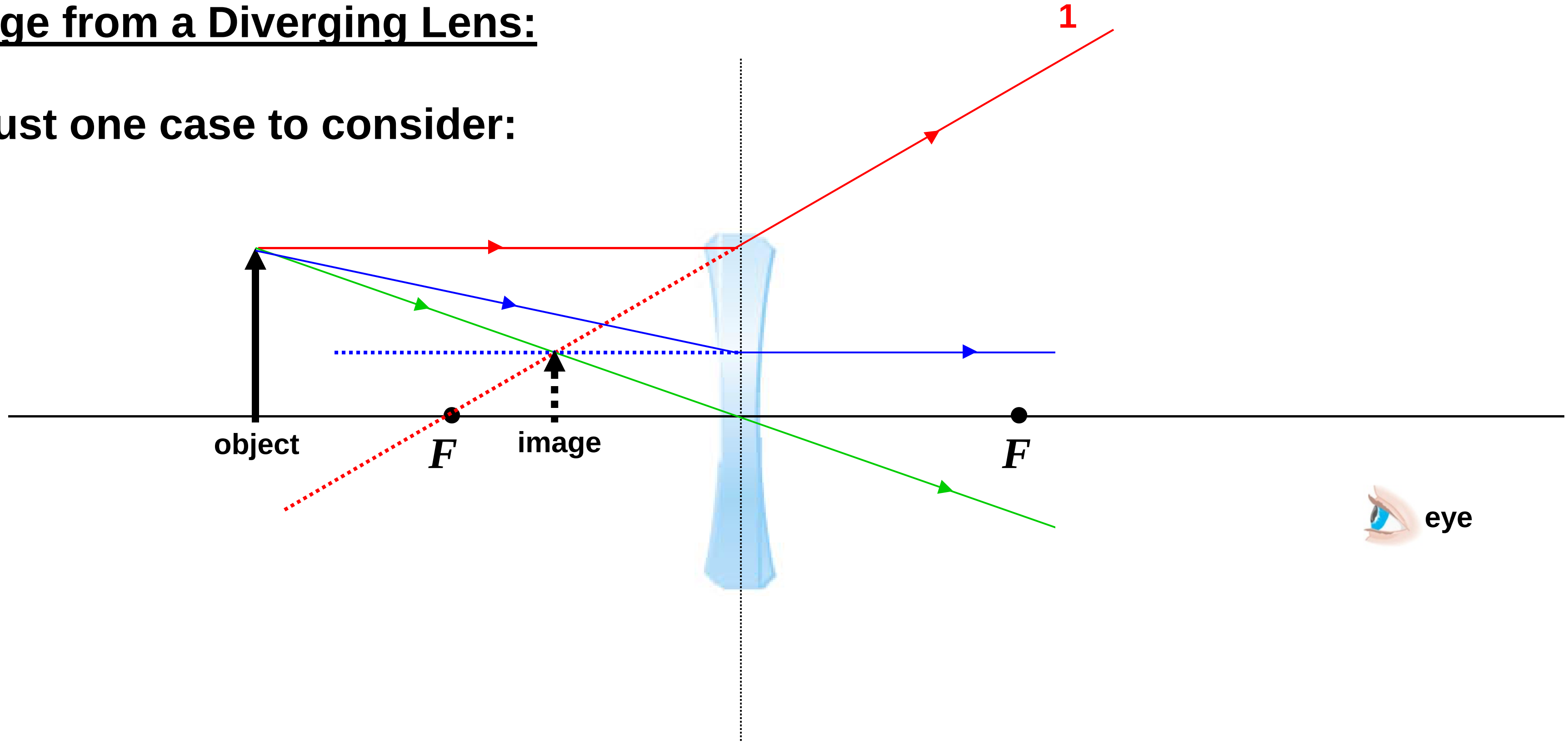
Extrapolate the refracted rays back to find the image.

Now we can see where the rays intersect, and thus the image position.

What are the image properties? Virtual, upright, and enlarged.

Image from a Diverging Lens:

Just one case to consider:



Ray 1 is a paraxial ray from the object that gets refracted as if it came from *F*.

Ray 2 travels thru the center of the lens unaffected.

Ray 3 travels toward the opposite *F* and comes out parallel.

Now we can see where the rays intersect, and thus the image position.

What are the image properties?

Virtual, upright, and reduced.

26.8 The Thin Lens and Magnification Equation

We used the law of reflection to find a relationship between the focal length (f), the object distance (d_o), and the image distance (d_i) for mirrors.

We can do the same thing for lenses using Snell's law.

The result we find is the same:

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

Thin Lens Equation

As before, the magnification is:

$$\boxed{m = \frac{h_i}{h_o} = \frac{-d_i}{d_o}}$$

Algebra-based Physics II

Oct 20th: Chap 26. 6-8

- Lenses
- Image formation by lenses
- Lens equation and magnification

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

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

Sign conventions for lenses:

This assumes the object is located to the left of the lens, and your eye is located to the right of the lens.

Focal length:

f is positive for converging lenses.

f is negative for diverging lenses.

Object Distance:

d_o is positive for objects left of the lens (real).

d_o is negative for objects right of the lens (virtual).

Image Distance:

d_i is positive for images right of the lens (real).

d_i is negative for images left of the lens (virtual).

Magnification:

m is positive for images upright wrt the object.

m is negative for images inverted wrt the object.

Example:

A movie camera has a converging lens with a focal length of 85.0 mm. It takes a picture of a 145-cm tall person standing 16.0 m away. What is the height of the image on the film? Is the image upright or inverted wrt the object. Give your reasoning.

Solution:

We know: $f = 0.085\,\mathrm{m}$ $h_o = 1.45\,\mathrm{m}$ $d_o = 16.0\,\mathrm{m}$

We need: h_i

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \Rightarrow \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} \Rightarrow \frac{1}{d_i} = \frac{1}{0.085} - \frac{1}{16} \Rightarrow \frac{1}{d_i} = 11.7$$

$$\Rightarrow d_i = 0.085\,\mathrm{m} = 8.5\,\mathrm{cm}$$

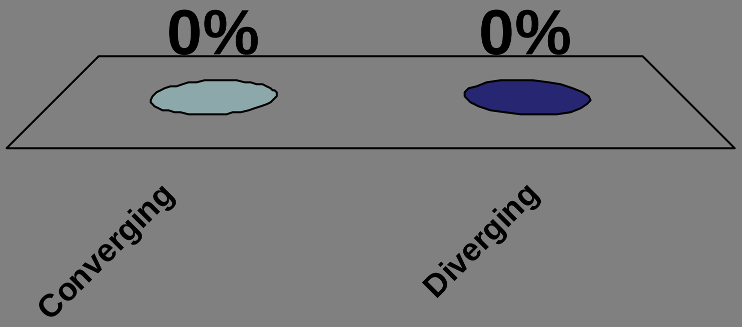
$$m = \frac{h_i}{h_o} = \frac{-d_i}{d_o} \Rightarrow h_i = \frac{-d_i \cdot h_o}{d_o} \Rightarrow h_i = \frac{(-0.085 \cdot 1.45)}{16} = \boxed{-7.74\,\mathrm{mm}}$$

Image is inverted, since m is negative!

Clicker question 26 - 4

An object is located at a distance do in front of a lens. The lens produces an upright image that is twice as tall as the object. What kind of lens is it?

1. [✓ Converging]
2. Diverging

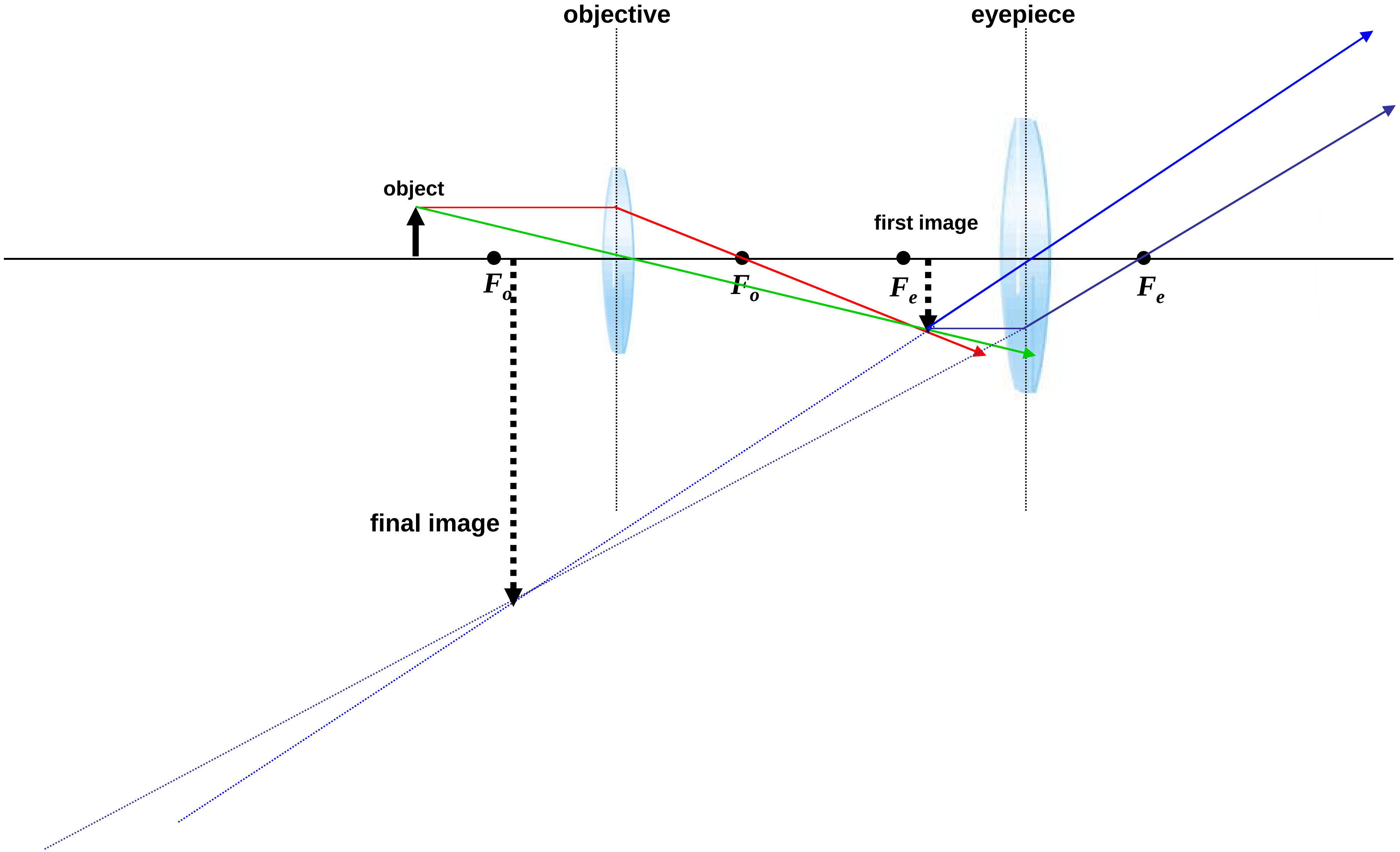


26.9 Lenses in Combination

We have been studying single-element optical systems known as simple lenses.

Now let's look at optical systems with more than one lens – a compound lens system.

A compound microscope, for example, consists of two lenses – an objective and an eyepiece.

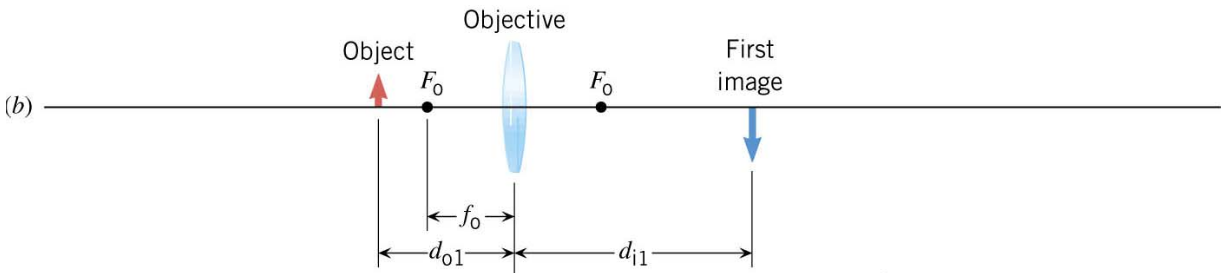

objective
eyepiece
object
first image
final image
F_o
F_o
F_e
F_e

Now we see the location of the final image.

The final image is virtual, inverted wrt the original object, and it is greatly enlarge

Example

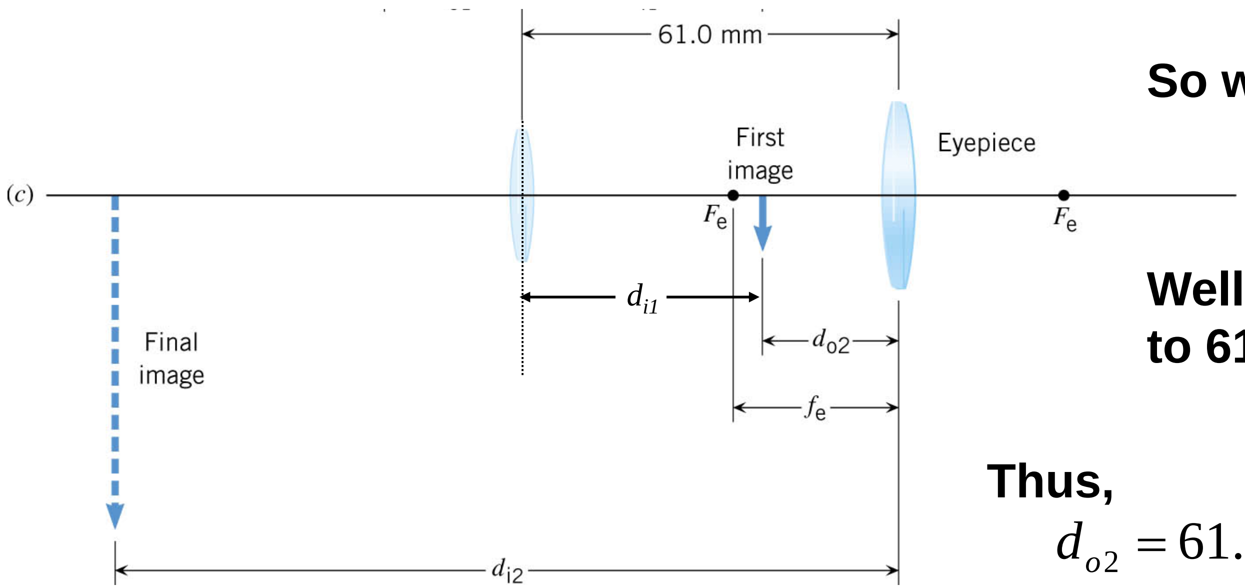
The objective an eyepiece of a compound microscope have focal lengths f_o = 15 mm and f_e = 25.5 mm. A distance of 61.0 mm separates the lenses. The microscope is being used to examine an object placed at d_{o1} = 24.1 mm in front of the objective. What is the final image distance?



First, we need to find the first image location.

$$\frac{1}{d_{i1}} = \frac{1}{f_o} - \frac{1}{d_{o1}} = \frac{1}{15} - \frac{1}{24.1} \Rightarrow d_{i1} = 39.7\ \text{mm}$$

This first image now becomes the object for the eyepiece.


61.0 mm
First image
Eyepiece
(c)
F_e
F_e
d_{i1}
d_{o2}
f_e
Final image
d_{i2}

So what do we use for d_{o2}?

Well, it's going to be equal to 61.0 mm – d_{i1}.

Thus,

$$d_{o2} = 61.0\,\text{mm} - 39.7\,\text{mm} = 21.3\,\text{mm}$$

$$\frac{1}{d_{i2}} = \frac{1}{f_e} - \frac{1}{d_{o2}} = \frac{1}{25.5} - \frac{1}{21.3} \Rightarrow \boxed{d_{i2} = -129\,\text{mm}}$$

This is 129 mm to the left of the eyepiece.

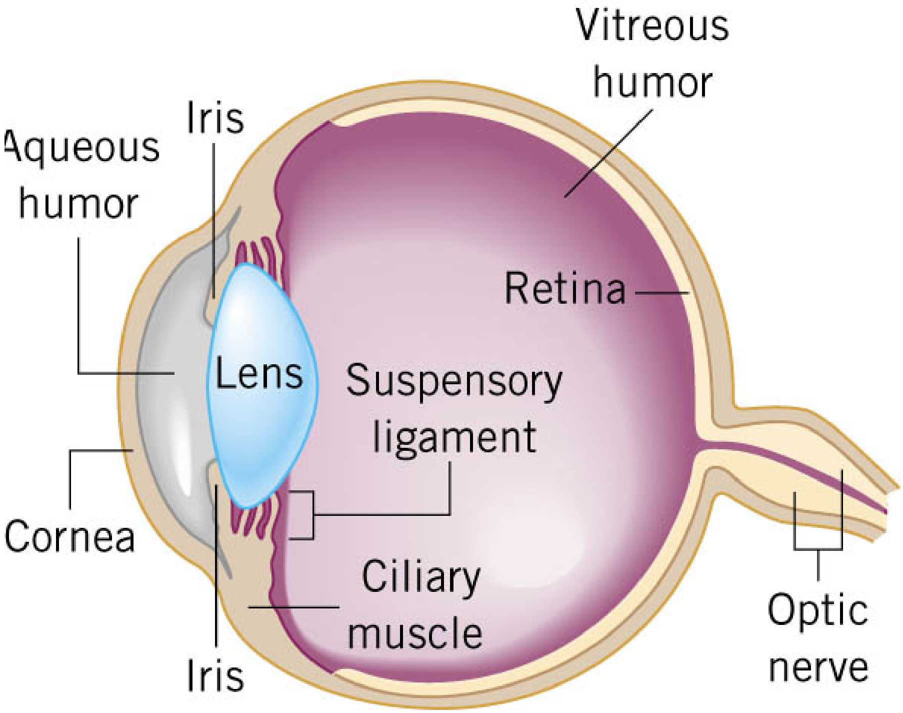
The fact that d_{i2} is negative tells us the final image lies to the left of the eyepiece and is therefore a virtual image.

26.10 The Human Eye

The eye is an optical system very similar to a camera.

Each has a lens, an aperture, and each forms a real, inverted and reduced image.

A camera forms an image on film, and the eye forms an image on the retina.



Vitreous humor
Iris
Aqueous humor
Retina
Lens
Suspensory ligament
Cornea
Ciliary muscle
Optic nerve
Iris

The **iris** is the colored part of they eye. It can be blue, brown, gray, green or hazel.

The **cornea** is a transparent covering over the lens.

The majority of the refraction takes place in the cornea (25%) and the lens (~75%).

The **lens** is the shape of a small bean. It's about 9 mm tall and 4 mm thick.

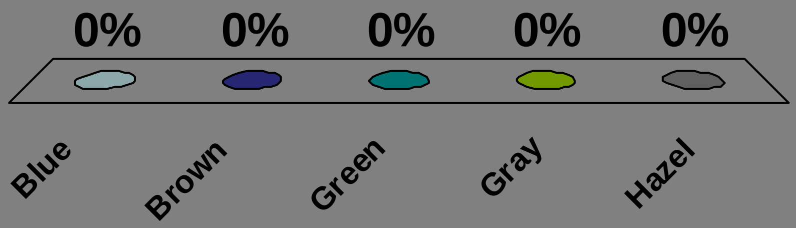
It is a complex, layered, fibrous mass, similar to a transparent onion. It contains about 22,000 fine layers.

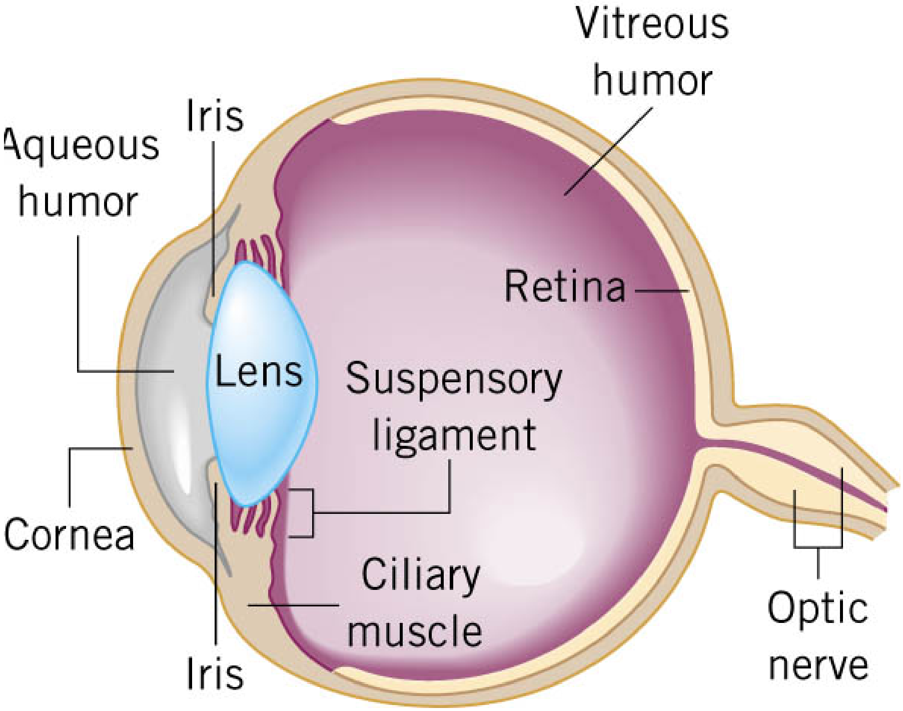
The index of refraction varies throughout the lens. The average is n = 1.40

Warm-up question

What color are your eyes?

1. Blue
2. Brown
3. Green
4. Gray
5. Hazel




Vitreous humor
Iris
Aqueous humor
Retina
Lens
Suspensory ligament
Cornea
Ciliary muscle
Optic nerve
Iris

Vitreous humor – mostly water.

→ Muscae volitantes

So how does the eye form an image?

It has a fixed image distance (d_i), so if the object distance (d_o) changes, then f has to change.

By contracting and relaxing the ciliary muscles, the lens gets stretched or compressed, thus changing its focal length.

When an object changes its distance, the ciliary muscles respond to change f and keep the object in focus. This process is called accomodation.

Your eyes do this automatically, and it happens very quickly.

The point nearest the eye to which an object can be placed and still be in focus is called the near point.

For objects at the near point, the ciliary muscles are completely contracted with the lens being squashed.

The point farthest from the eye to which an object can be placed and still be in focus is called the far point.

For objects located at the far point, the ciliary muscles are completely relaxed and the lens is elongated.

For young adults in their early twenties, the near point is about 25 cm.

You can expect this to roughly double by the time your 40.

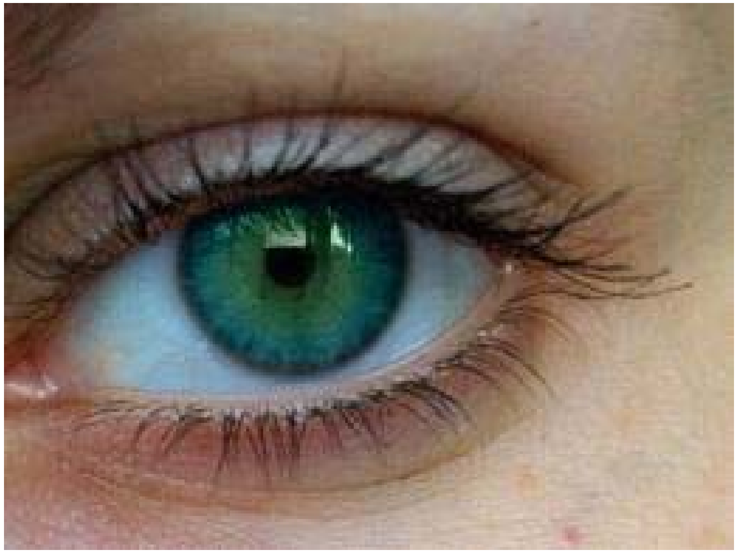
The far point is the location of objects very far away, like stars and planets, and is therefore at infinity.

There are several common problems with human vision:

Algebra-based Physics II

Oct 20th: Chap 26. 8-10

- Human eyes
- Refractive power of a lens
- Compound optics
- Examples



Announcements:

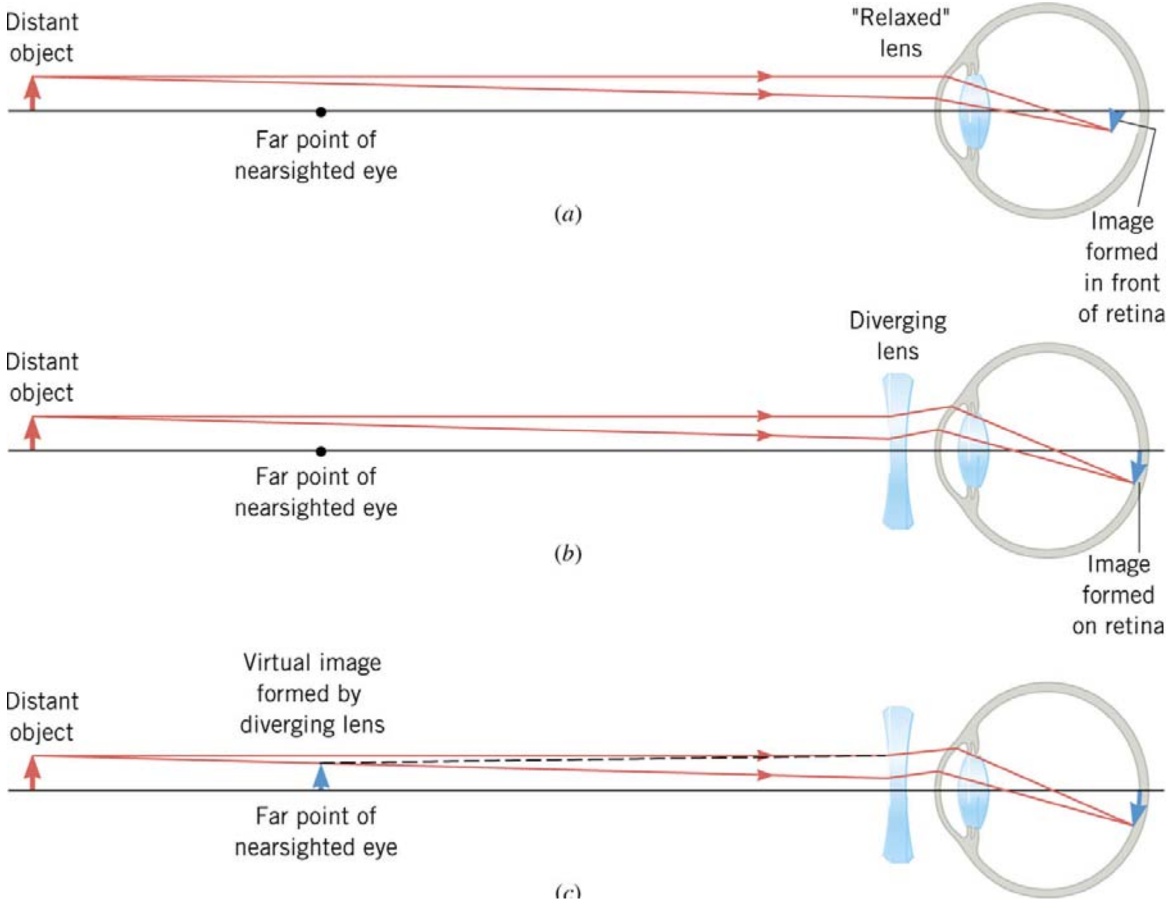
- HW8 was posted and due on Sunday

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

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

Nearsightedness (myopia)

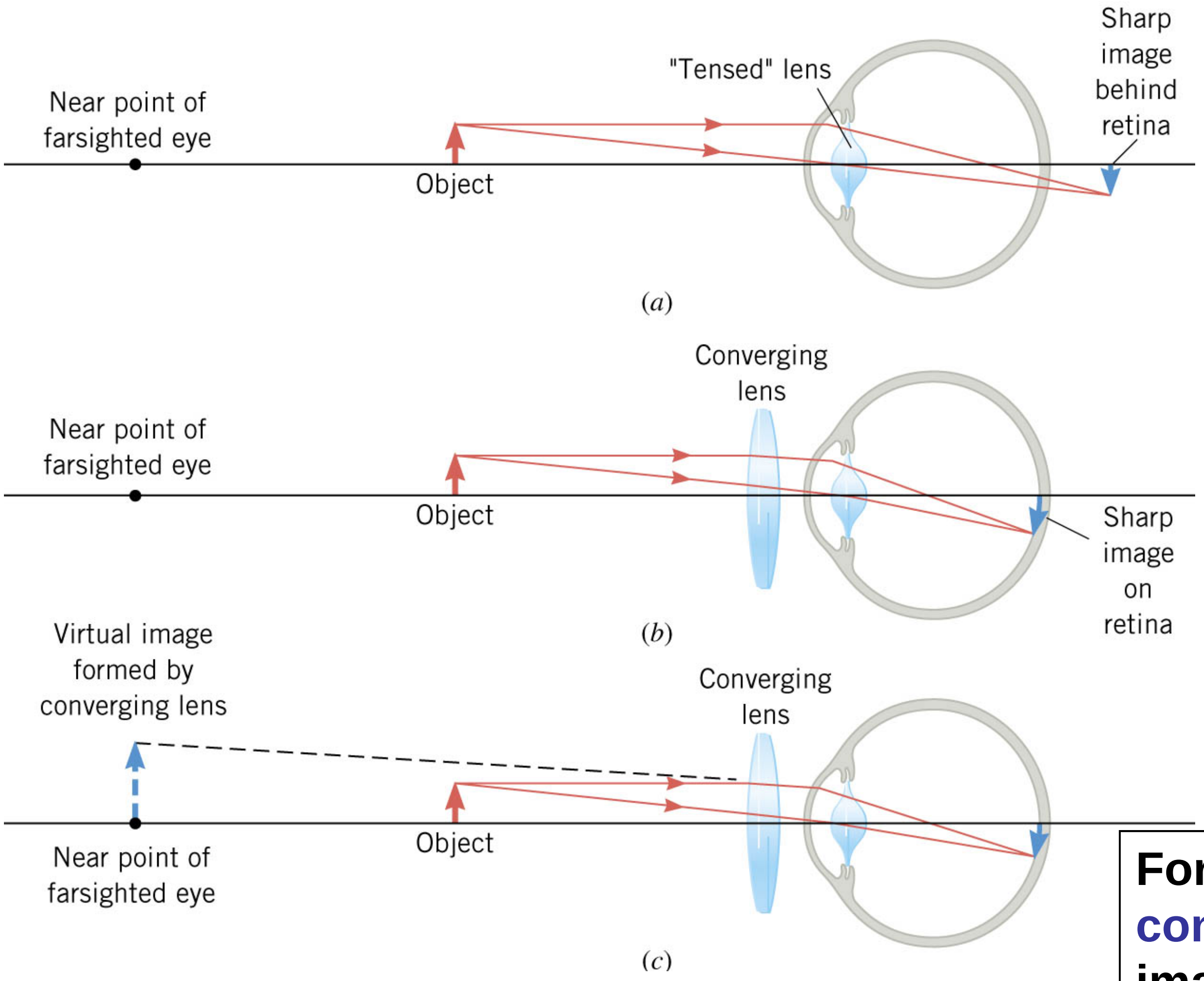
A person who is nearsighted can focus on objects close up, but not on objects far away.


Distant object
"Relaxed" lens
Far point of nearsighted eye
(a)
Image formed in front of retina
Distant object
Diverging lens
Far point of nearsighted eye
(b)
Image formed on retina
Distant object
Virtual image formed by diverging lens
Far point of nearsighted eye
(c)

For nearsightedness, a diverging lens forms a virtual image at the far point.

Farsightedness (hyperopia or presbyopia)

A person who is farsighted can focus on objects far away, but not on objects close up.

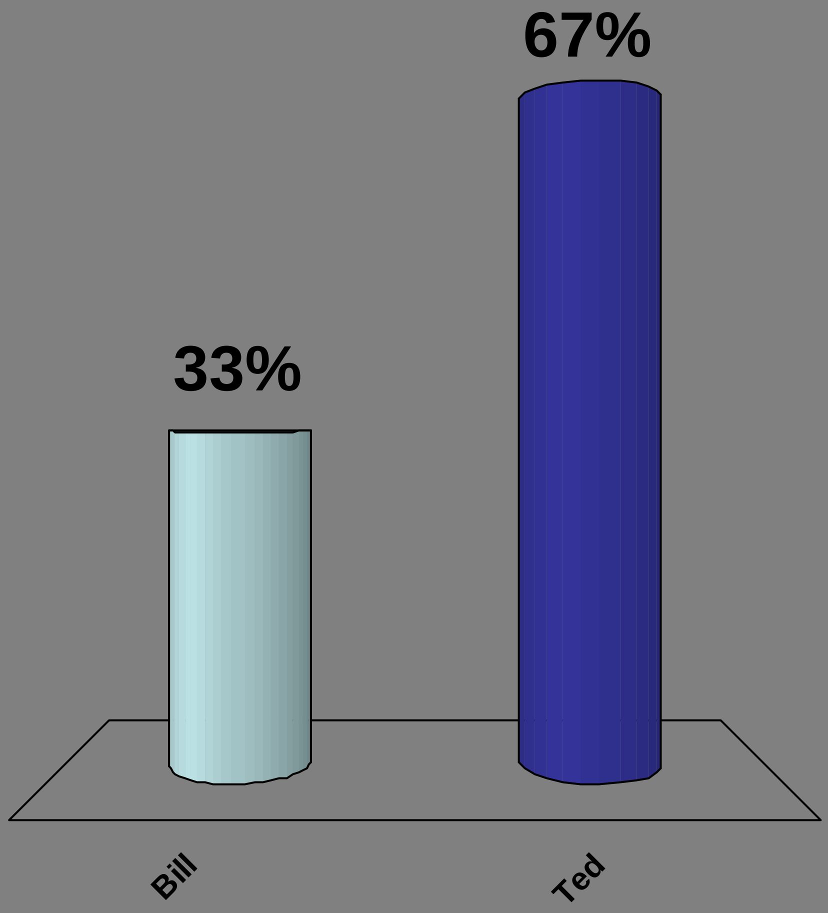

Near point of farsighted eye
Object
"Tensed" lens
Sharp image behind retina
(a)
Near point of farsighted eye
Object
Converging lens
Sharp image on retina
(b)
Virtual image formed by converging lens
Converging lens
Object
Near point of farsighted eye
(c)

For farsightedness, a **converging lens** forms a virtual image at the near point.

Clicker Question 26 - 6

Bill and Ted are lost in the desert and need to start a fire. Both wear glasses. Ted is farsighted and Bill is nearsighted. Whose glasses should they use to start the fire?

1. Bill
2. [✓ Ted]



Ted's glasses would be the more excellent choice.

The Refractive Power of a Lens

The refractive or bending power of a lens depends on *f*, the focal length.

However, optometrists and opticians do not use *f* in specifying prescription eyewear. They use Refractive Power:

$$\boxed{\text{Refractive Power} = \frac{1}{f\,[\text{m}]}}$$

Units?

Refractive power is measured in Diopters [D].

$1\ \text{D} = 1\ \text{m}^{-1}$

Thus, what would be the refractive power of a lens with a focal length *f* = 25 cm?

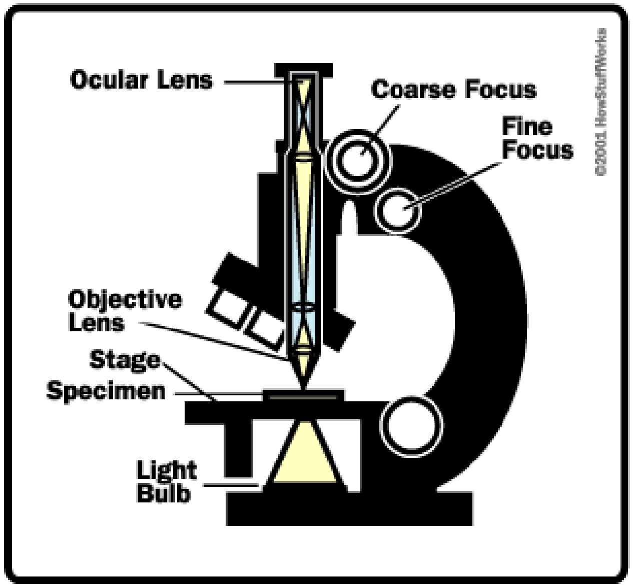
$$\text{Refractive Power} = \frac{1}{0.25\ \text{m}} = 4\ \text{D}$$

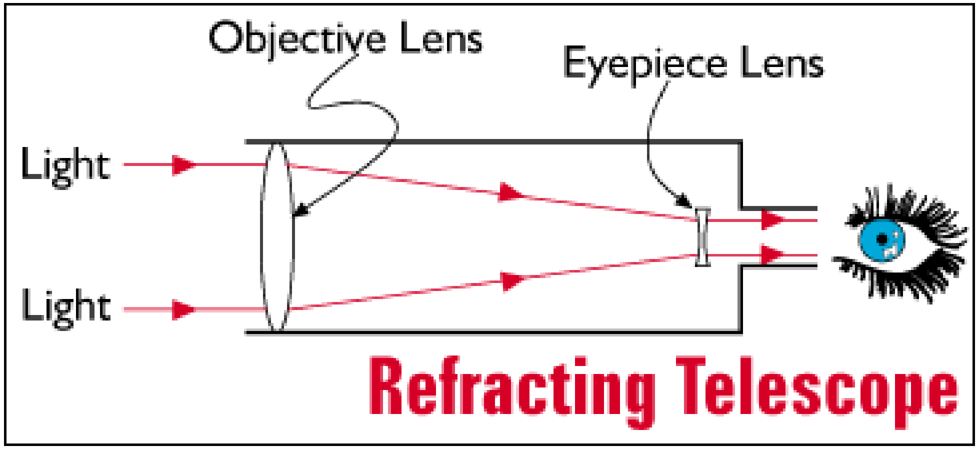
Compound optics

With just one lens there is a very limited range of possibilities.

Coupling two lenses (or more) allows more control over the image produced, especially if the distances between the lenses can be varied . . .

Two of the more common and important examples in science are the optical microscope and refracting telescope.

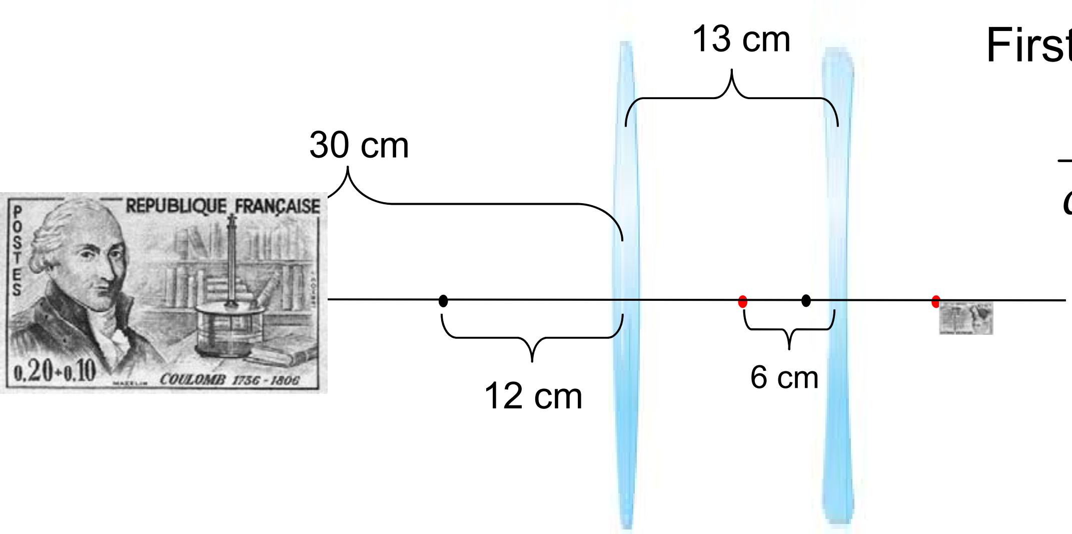

Ocular Lens
Coarse Focus
Fine Focus
Objective Lens
Stage
Specimen
Light Bulb
©2001 HowStuffWorks


Objective Lens
Eyepiece Lens
Light
Light
Refracting Telescope

To understand how a compound optical system behaves, you calculate the properties of the image of the first optical element, and then treat the image from the first element as the object for the next optical element, I.e.

$$d_o' = x - d_i$$

A converging lens ($f = 12cm$) is located 13 cm to the left of a diverging lens ($f = -6cm$). A postage stamp is placed 30 cm to the left of the converging lens. Locate the final image relative to the diverging lens. What is the overall magnification?



First consider only the converging lens

$$\frac{1}{d_{o1}} + \frac{1}{d_{i1}} = \frac{1}{f_1} \quad \text{or} \quad \frac{1}{d_{i1}} = \frac{1}{f_1} - \frac{1}{d_{o1}}$$

$$\frac{1}{d_{i1}} = \frac{1}{12cm} - \frac{1}{30cm} = 0.05\frac{1}{cm}$$

$$\Rightarrow d_{i1} = 20cm$$

$$m_1 = \frac{h_{i1}}{h_{o1}} = -\frac{d_{i1}}{d_{o1}} = -\frac{20cm}{30cm} = -\frac{2}{3}$$

Now consider only the diverging lens

The object is located to the right of the lens!

$$d_{o2} = x - d_{i1} = 13cm - 20cm = -7cm$$

$$\frac{1}{d_{i2}} = \frac{1}{f_2} - \frac{1}{d_{o2}} = \frac{1}{-6cm} - \frac{1}{-7cm} = -\frac{1}{42cm}$$

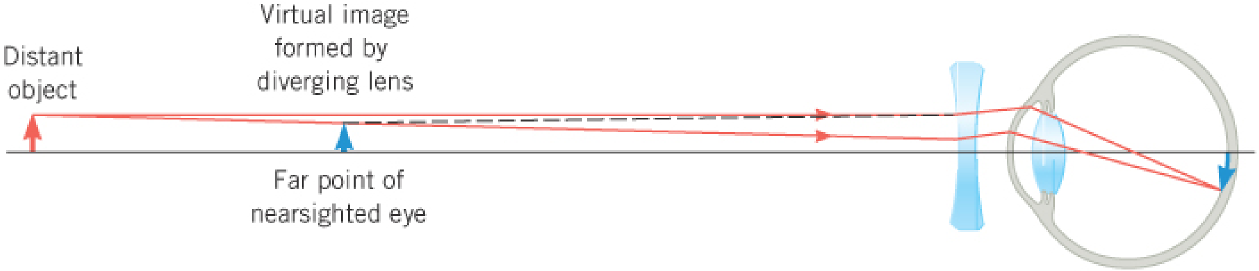
$\Rightarrow d_{i2} = -42cm$ to the left of the diverging lens almost where the original object was

$$m_2 = \frac{h_{i2}}{h_{o2}} = -\frac{d_{i2}}{d_{o2}} = -\frac{-42cm}{-7cm} = -6$$

Total magnification is

$$m_{tot} = m_1 \cdot m_2 = \frac{2}{3}6 = 4$$

I'm very myopic. My far point is only 20cm away. What's the refractive power of my contacts?


Distant object
Virtual image formed by diverging lens
Far point of nearsighted eye

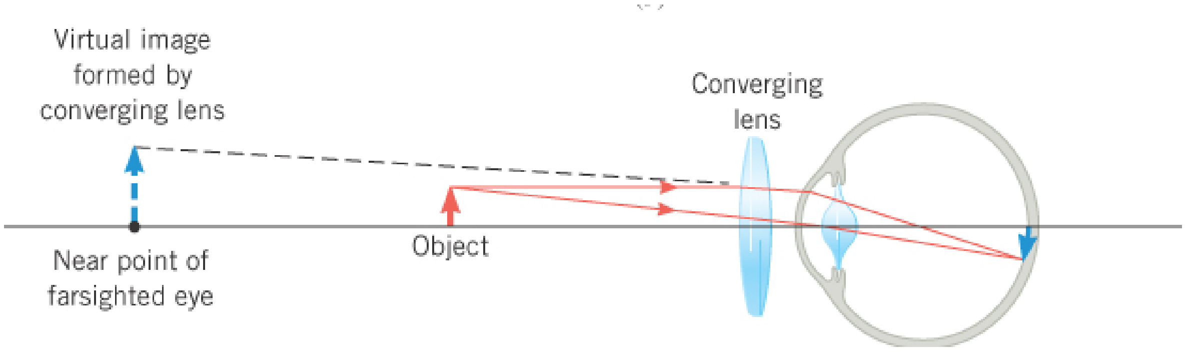
If an object is very far away, my contacts will put the image at my far point (20 cm).

$$d_o = \infty \qquad d_i = -20cm = -0.2m$$

Refractive power $= \dfrac{1}{f} = \dfrac{1}{d_o} + \dfrac{1}{d_i}$

$$= \frac{1}{\infty} + \frac{1}{-0.2m} = -5\frac{1}{m} = -5D$$

Presbyopia is getting to me, but my contacts allow me to see objects as close as ***25 cm*** clearly. Without my contacts, my near point is ***79 cm*** from my eyes. When I am looking at a poster on the wall, the contacts form an image at a distance of ***217 cm*** from my eyes. How far away is the poster from me, and how much do my contacts magnify the image?


Virtual image formed by converging lens
Converging lens
Near point of farsighted eye
Object

$$d_o = 25cm$$

$$d_i = -79cm$$

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

$$\frac{1}{f} = \frac{1}{0.25m} + \frac{1}{-0.79m}$$

$$\frac{1}{f} = 2.7\frac{1}{m} = +2.7D$$

When I am looking at the poster, the image distance is 217 cm away, so $d_i = -2.17m$

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \quad \Rightarrow \quad \frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i}$$

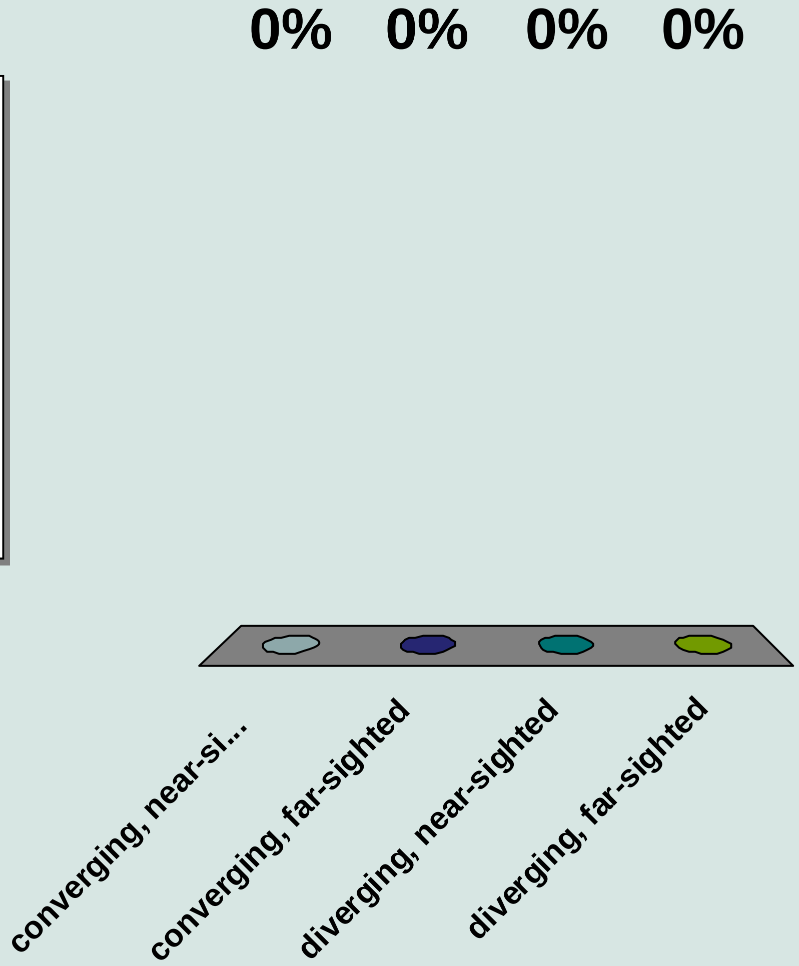
$$\frac{1}{d_o} = 2.7\frac{1}{m} - \frac{1}{-2.17m} \quad = 3.16\frac{1}{m}$$

$$d_o = 0.316m$$

$$m = -\frac{d_i}{d_o} \quad = -\frac{-2.17m}{0.316m} = 6.9$$

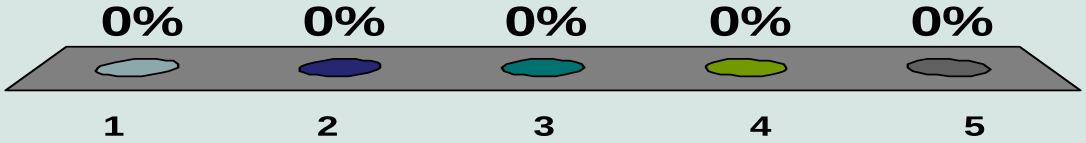
The prescription for your contacts says +2.0D. Are the lens converging or diverging, and are you near-sighted or far-sighted?

1. converging, near-sighted
2. [✓ converging, far-sighted]
3. diverging, near-sighted
4. diverging, far-sighted

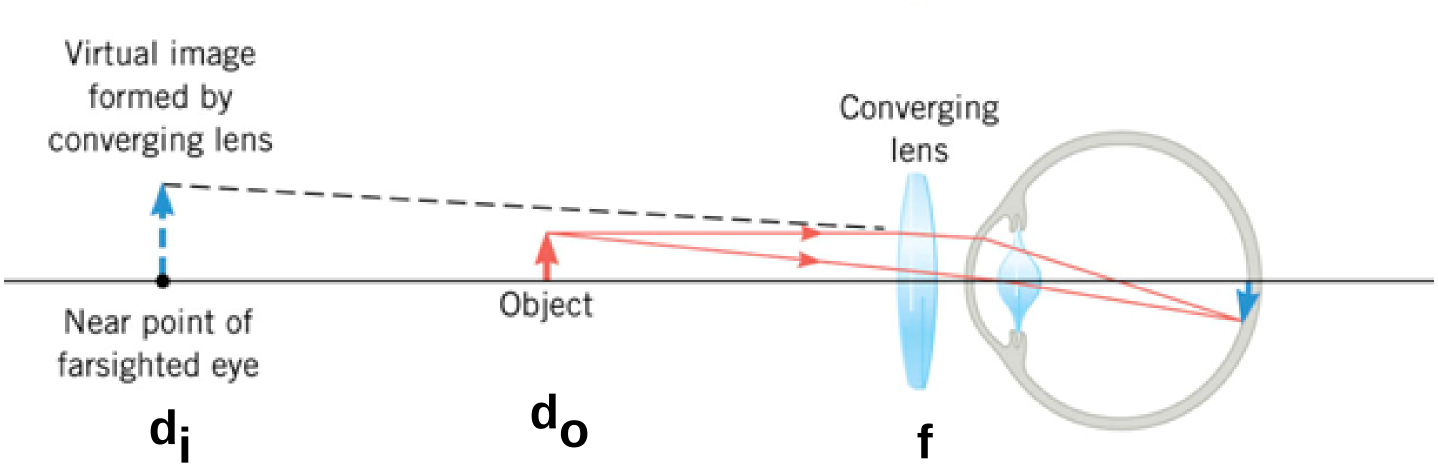


The prescription on my contacts is +3.0D. My near point is 1.5m when I'm not wearing my contacts. How close can I hold a book when wearing my contacts and still read it clearly?

1. *0.27 m*
2. *0.43 m*
3. *1.00 m*
4. *1.50 m*
5. *3.00 m*



Farsightedness (presbyopia)


Virtual image formed by converging lens
Converging lens
Near point of farsighted eye
Object
d_i
d_o
f

Focus on the lens!!!!

$d_i = -1.5$ m

$$\text{Refractive power} = \frac{1}{\text{f}} = 3.0\ D = 3.0\ \text{m}^{-1}; \quad f = 0.33\ \ m$$

$$\frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i} = \frac{1}{0.33} - \frac{1}{-1.5} = 3.69\ m^{-1}$$

$$d_0 = 0.27\ \ m$$