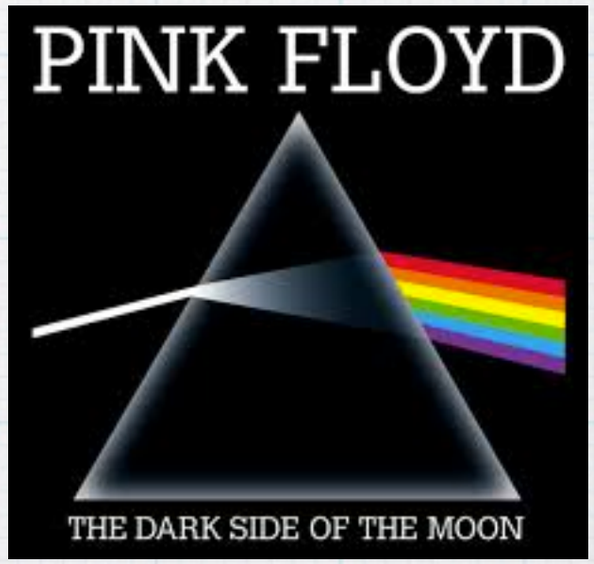
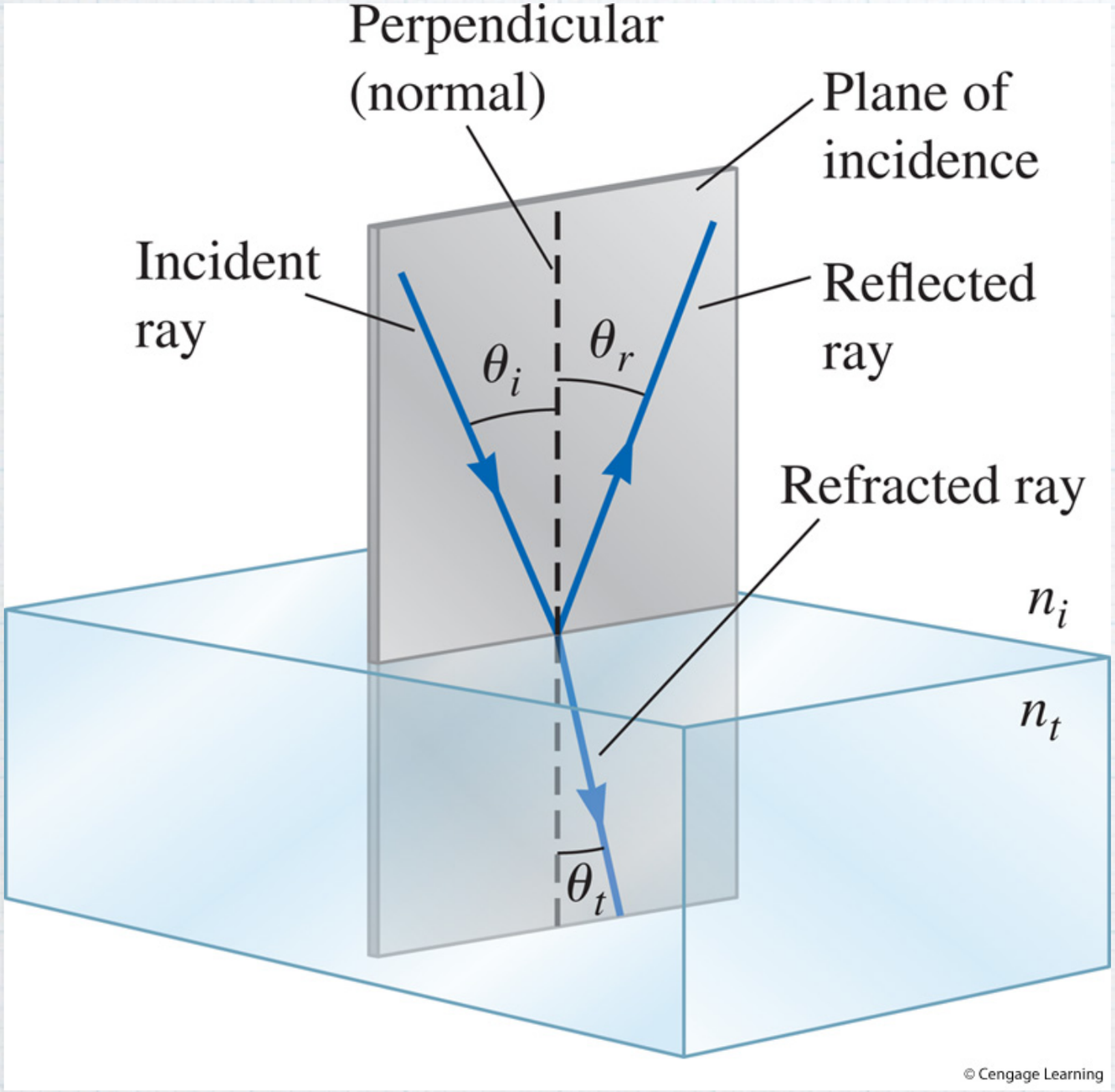
Refraction and Images Formed by Refraction



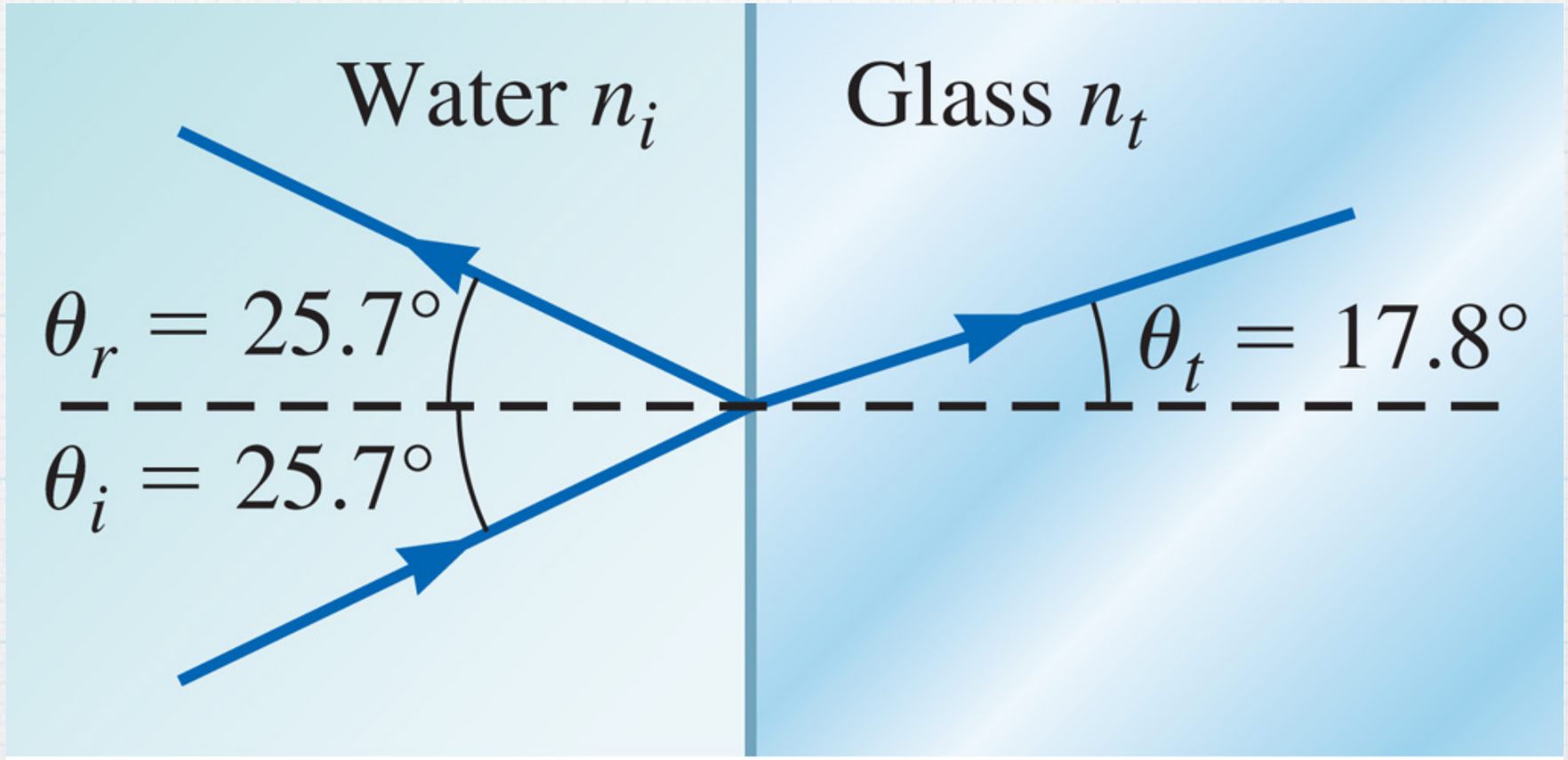


$$n_i sin(\theta_i) = n_t sin(\theta_t)$$

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

Light is refracted when it changes media
The refracted component bends towards the normal when
$n_t > n_i$

Water



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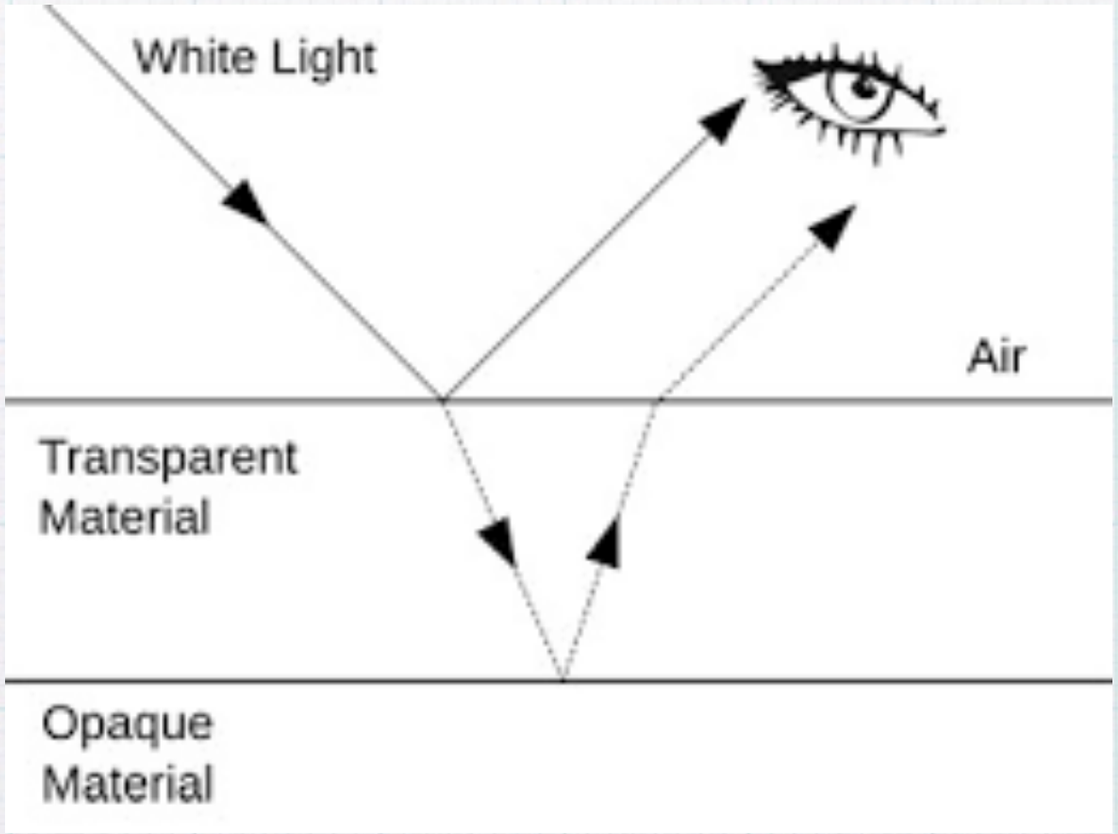
$n_{water} = 1.33$

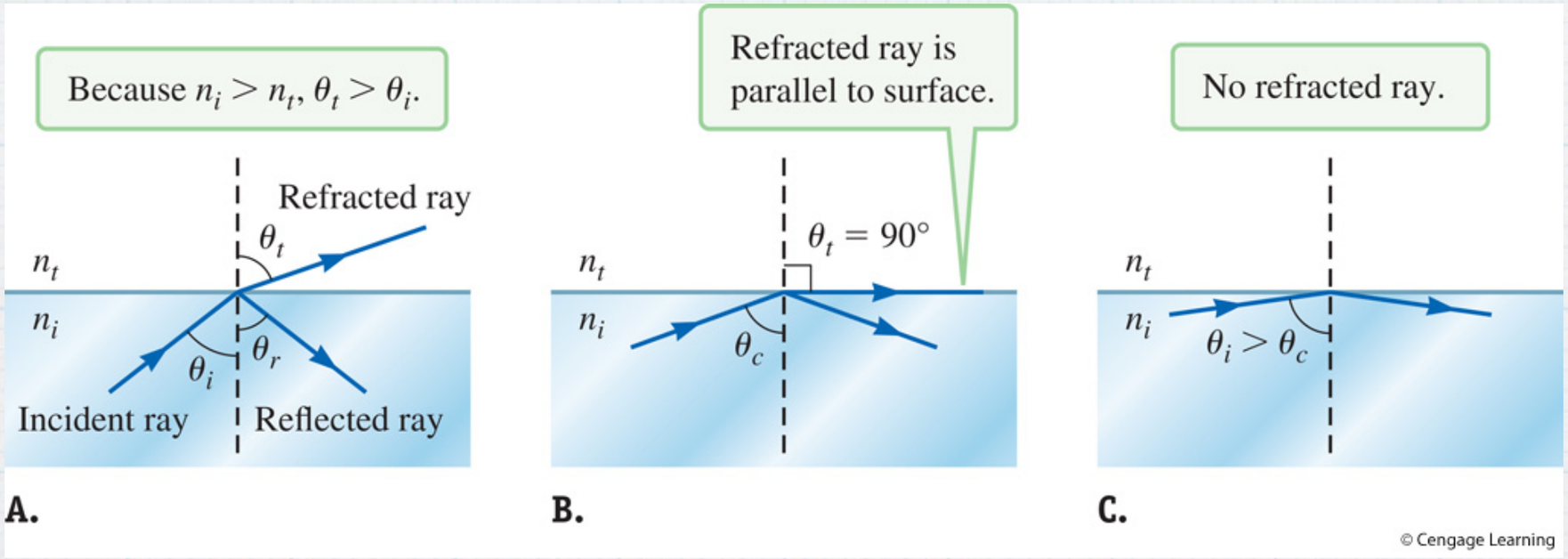
$n_{glass} = 1.89$

Fill in the angles



Total Internal Reflection

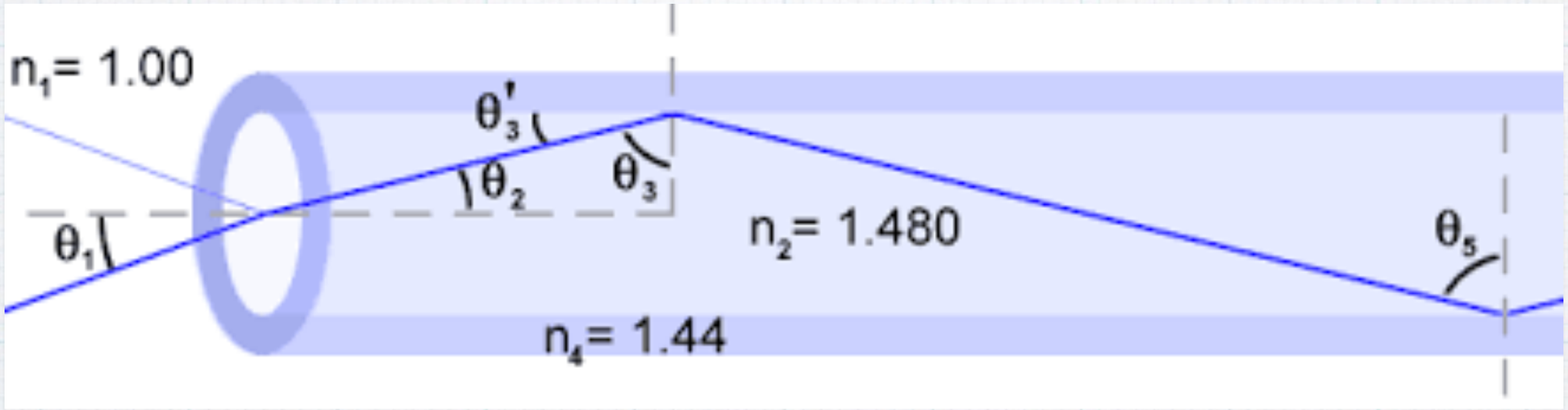
Or, how you get information through fiber optics

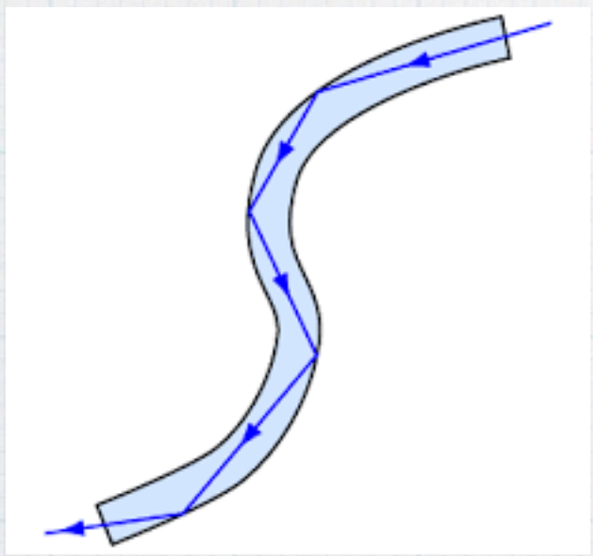


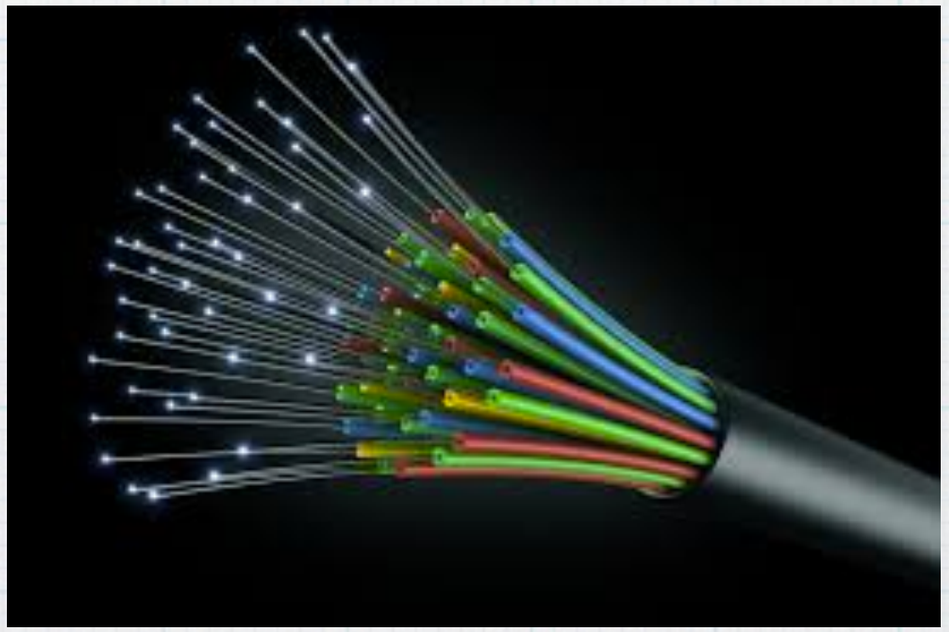
Only a possibility when $n_t < n_i$

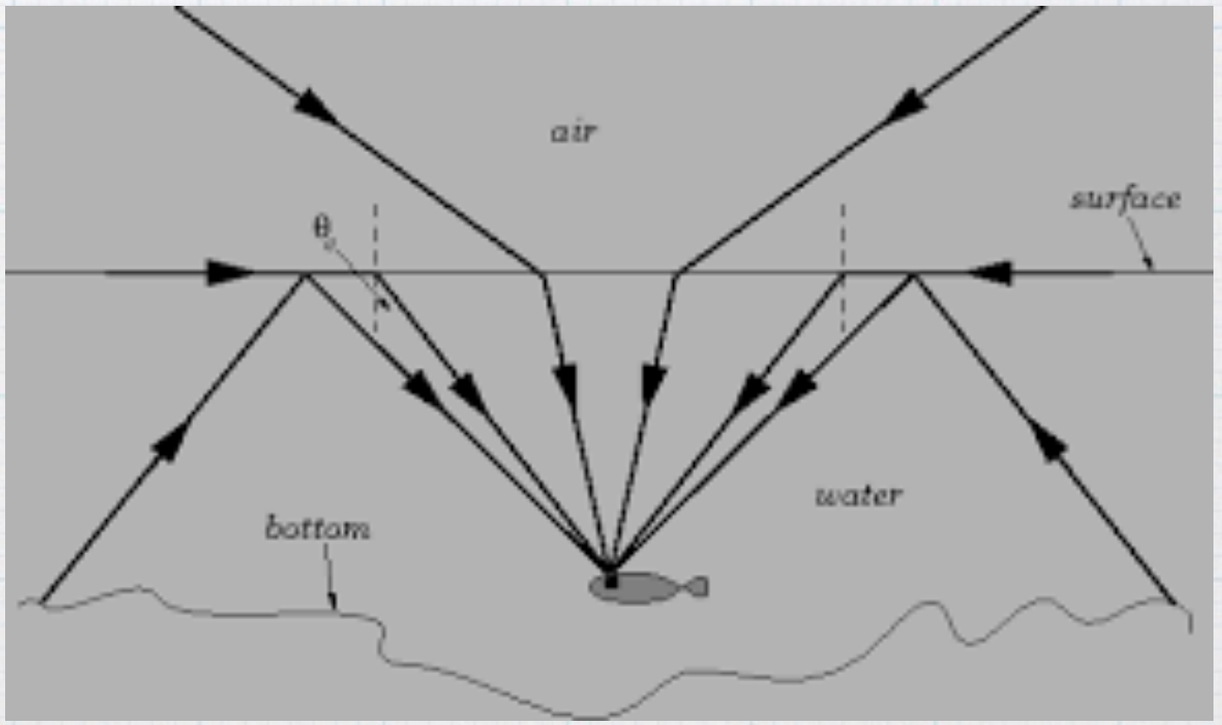
$$sin(\theta_c) = \frac{n_t}{n_i}$$ Show

Fiber Optics



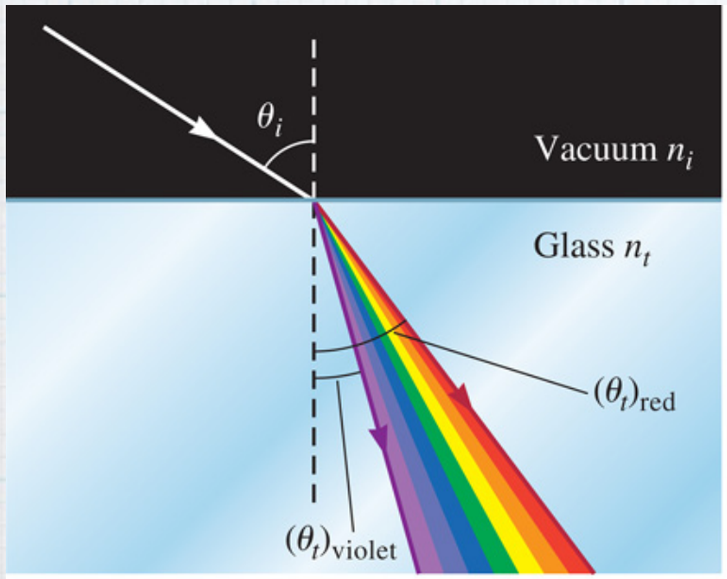




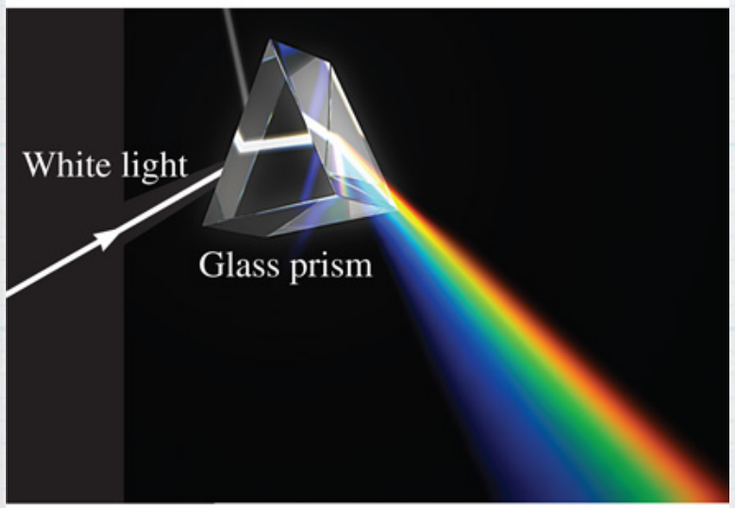

air
surface
θ
water
bottom

Dispersion

Or, the index of refraction is really wavelength dependent

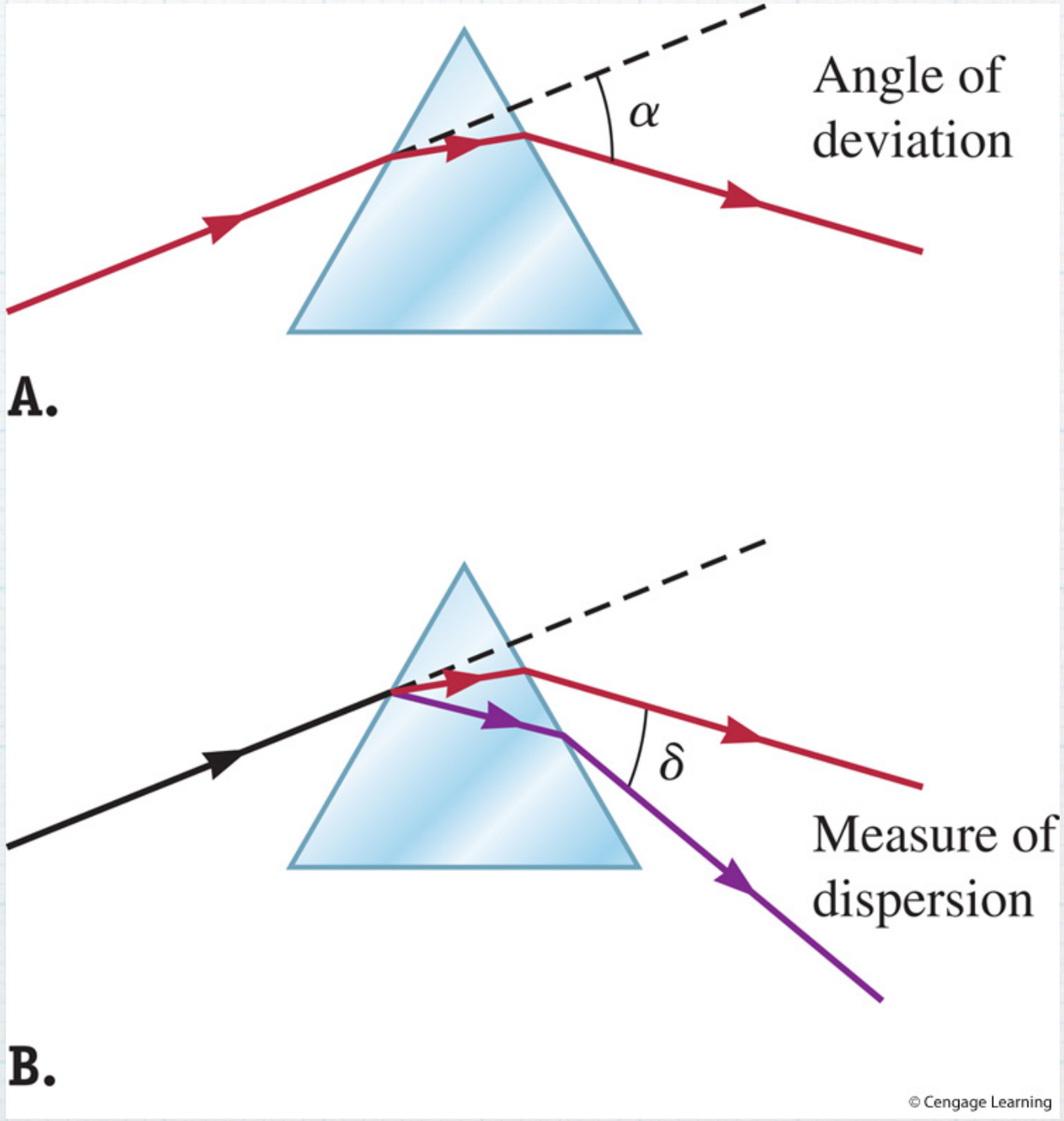


A.

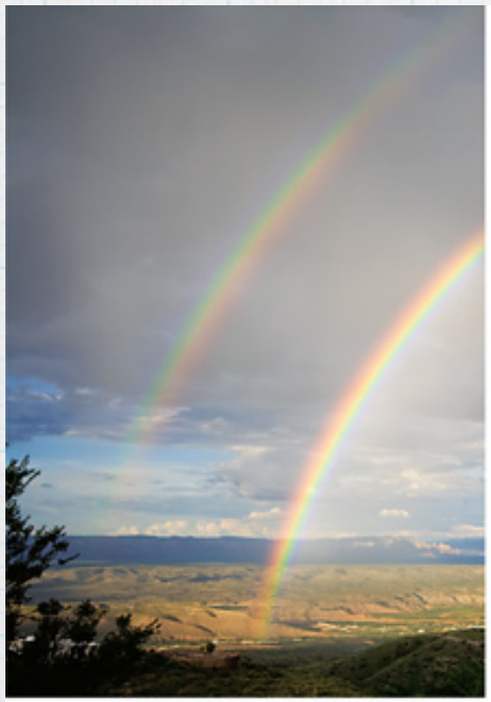


B.

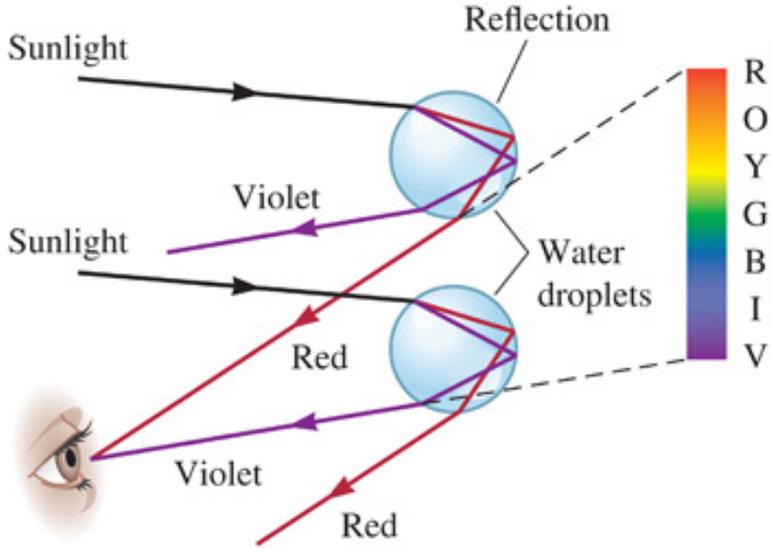
a) © Cengage Learning; b) Mopic/Shutterstock.com



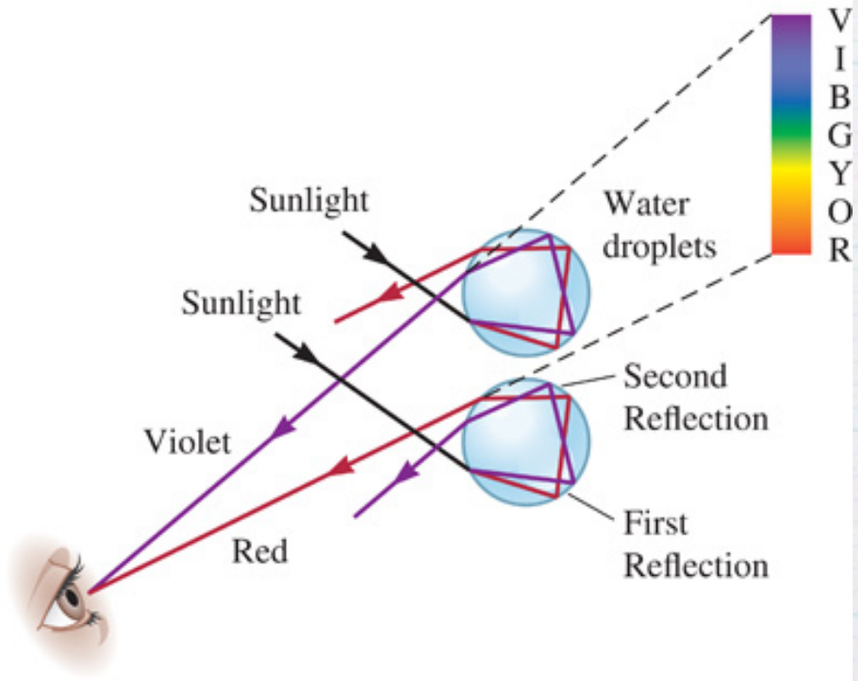
This is how Rainbows are Formed



A. Double rainbow



B. Lower rainbow

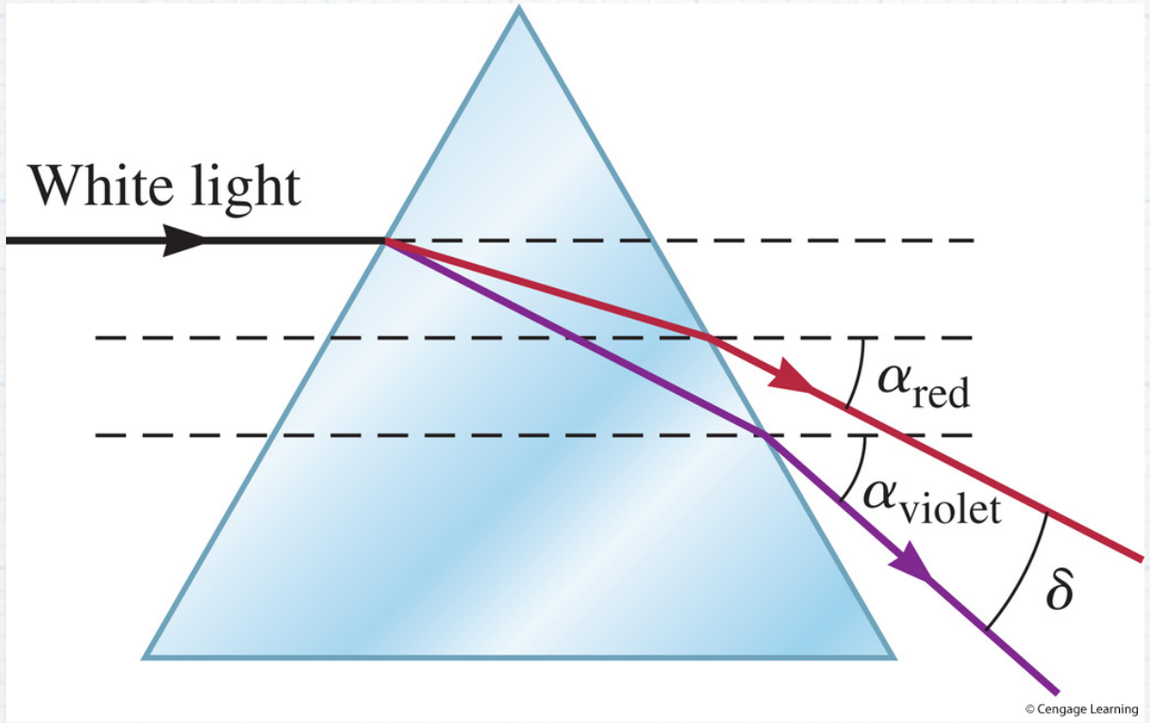


C. Upper rainbow

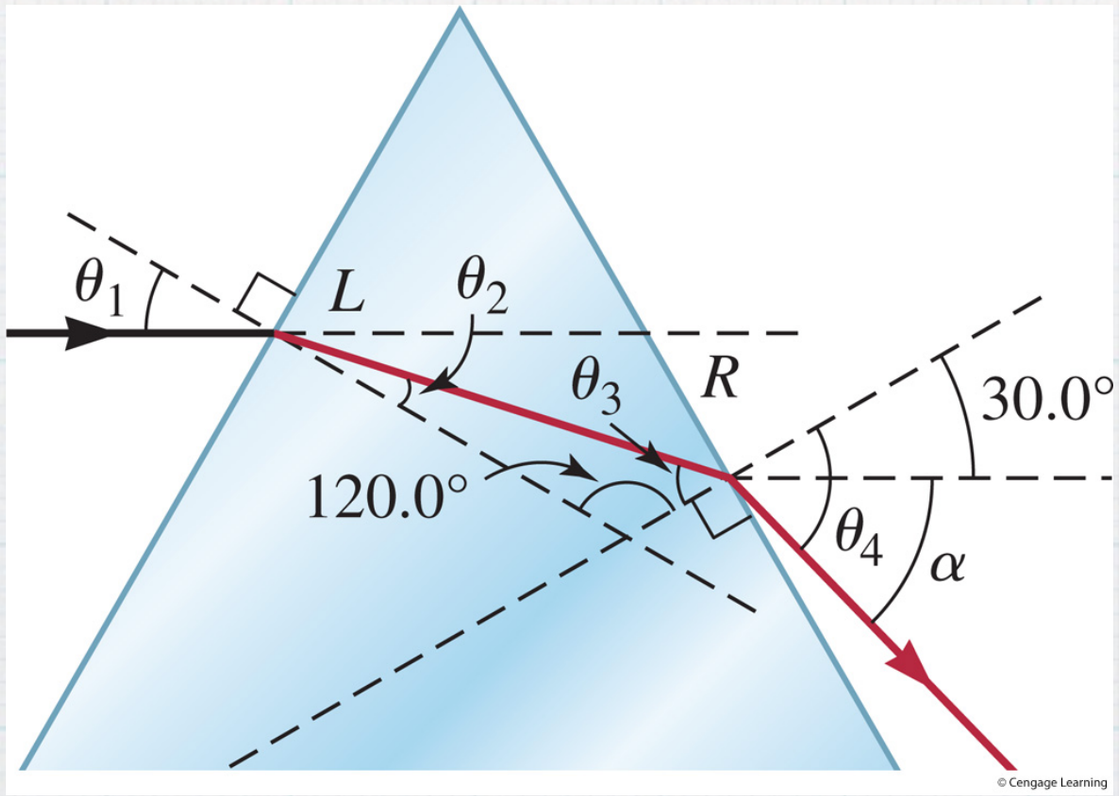
a) Alexey Stiop/Shutterstock.com; b-c) © Cengage Learning

Notice, the ordering of colored is reversed

Example



δ?

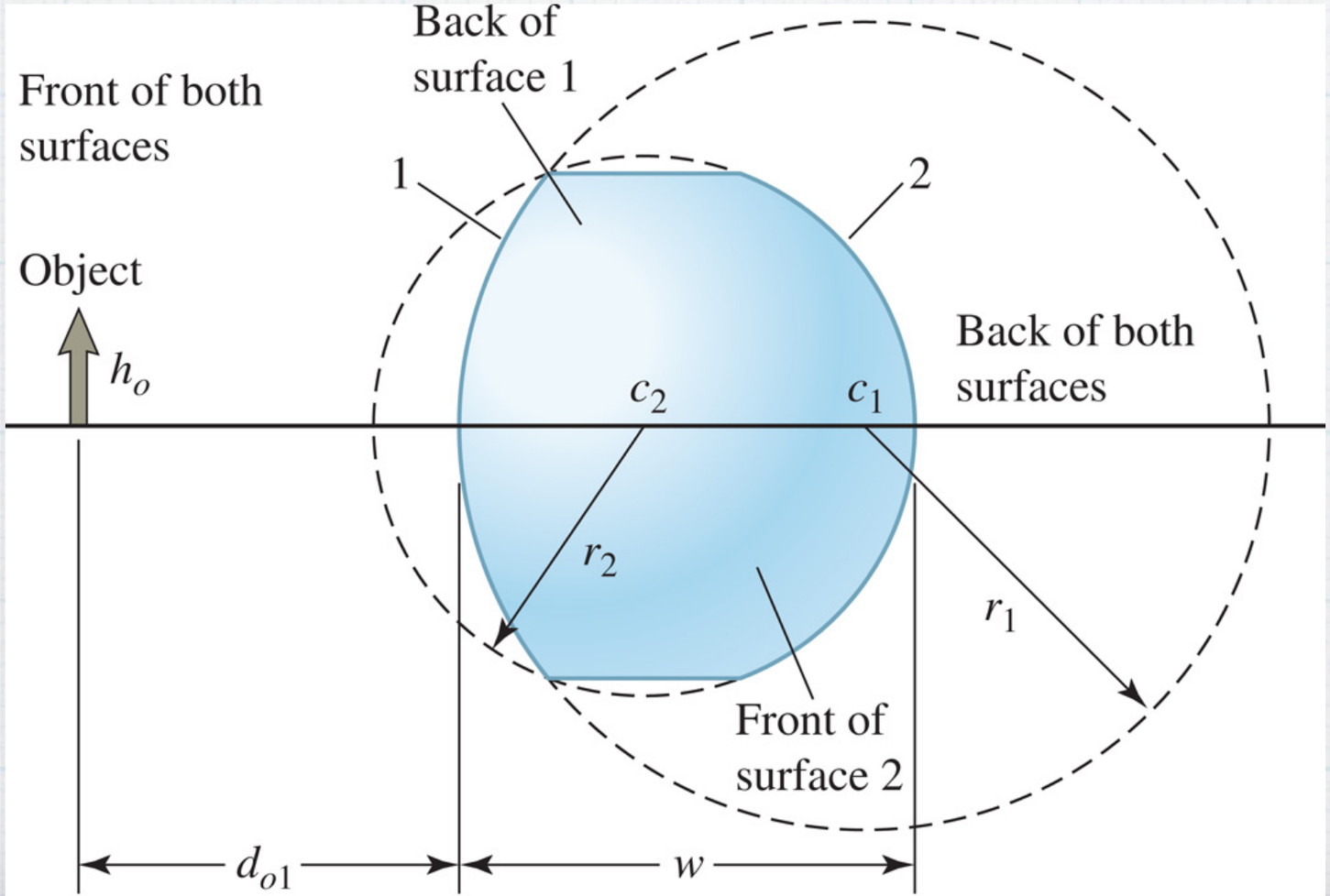


Thin Lenses

Formed by piecing together 2 pieces of spheres

Lens Maker Equation

$$\frac{1}{f} = (n-1)[\frac{1}{r_1} - \frac{1}{r_2}]$$



Need More to Discuss

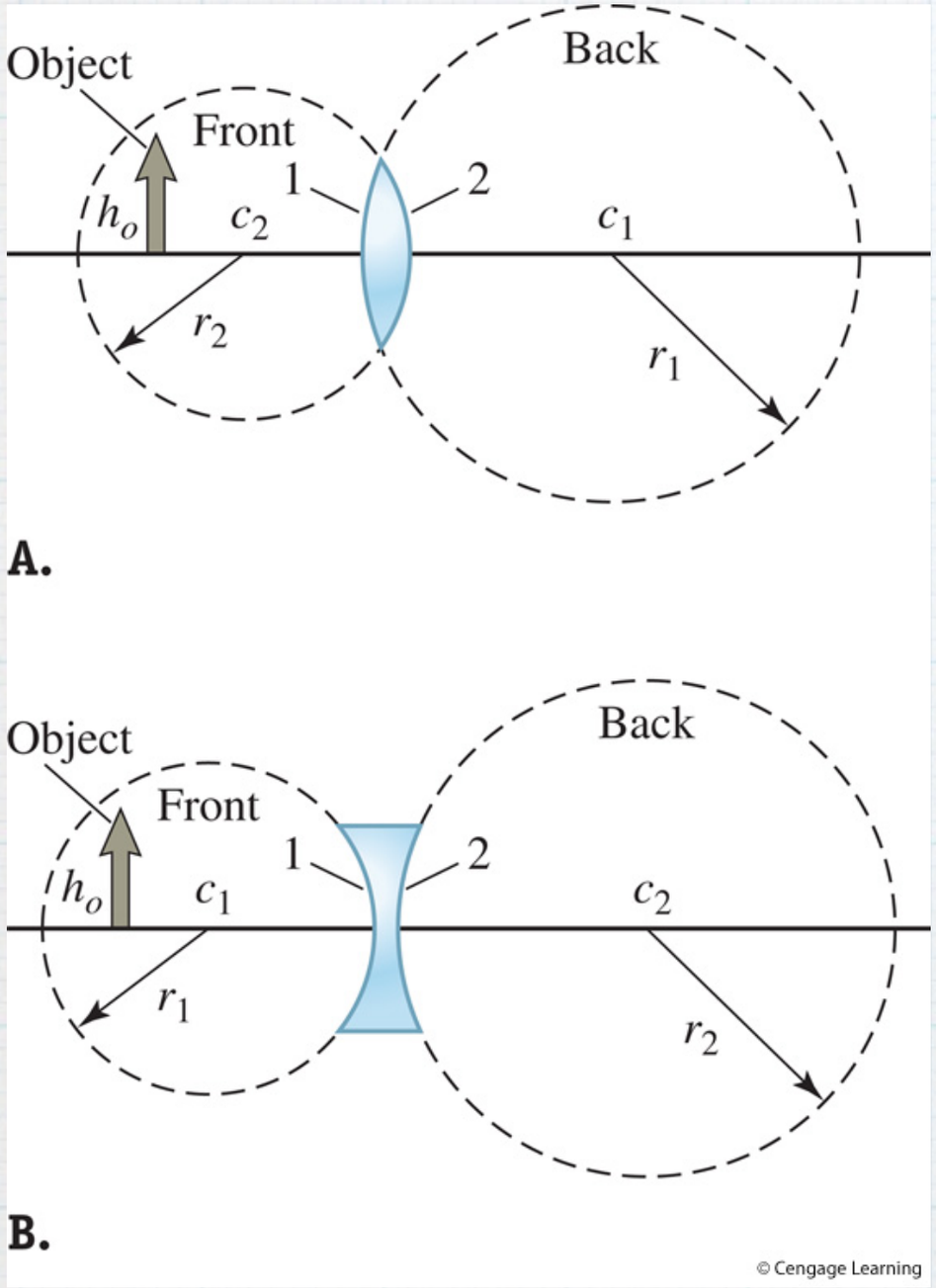
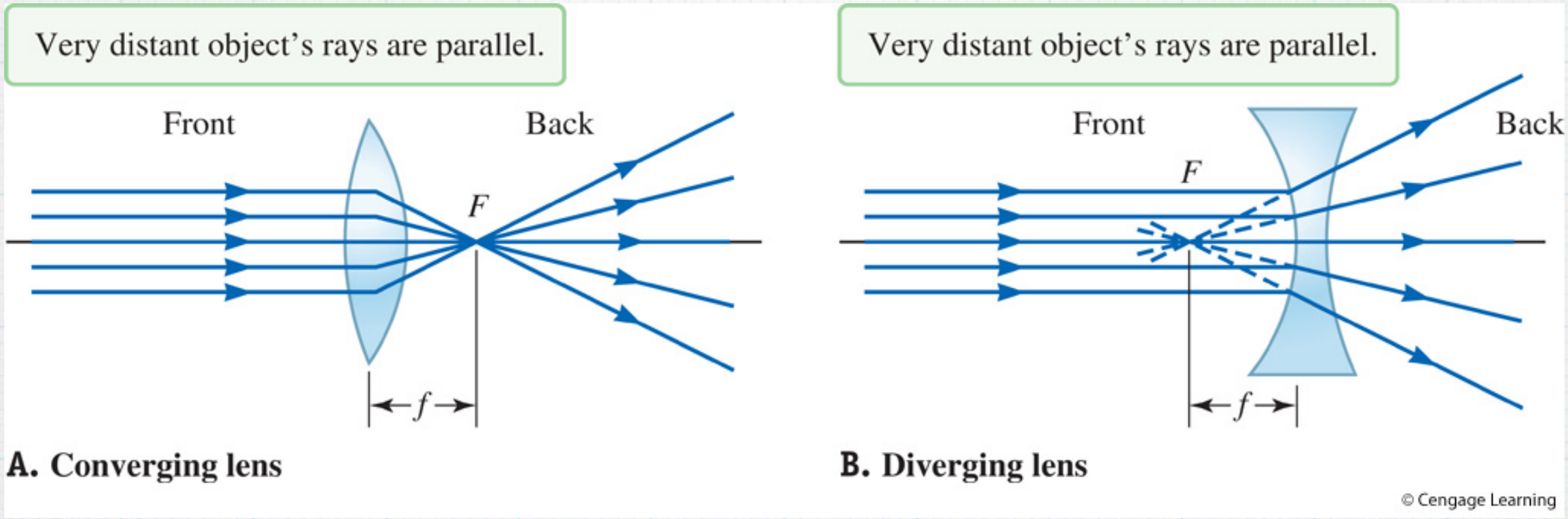


TABLE 38.3 Sign conventions for thin spherical lenses.

Quantity	Positive	Negative
1. Image height h_i and magnification M	If image is **upright**	If image is **inverted**
2. Object distance d_o	If object is **real** (in front)	If object is **virtual** (behind)
3. Image distance d_i	If image is **real** (behind)	If image is **virtual** (in front)
4. Radius of curvature r	If surface is **convex**	If surface is **concave**
5. Focal length f	If lens is **converging**	If lens is **diverging**

What's the sign for the focal lengths of these two?

Converging Vs Diverging



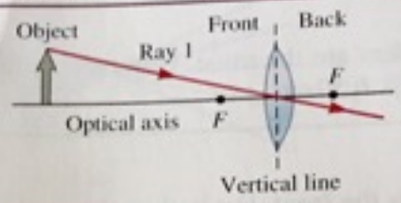
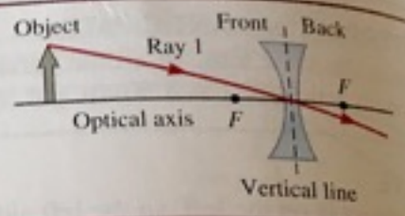
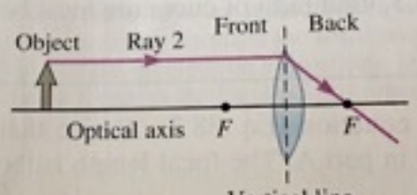
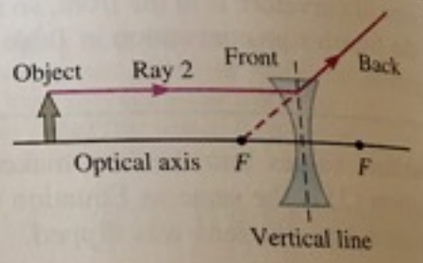
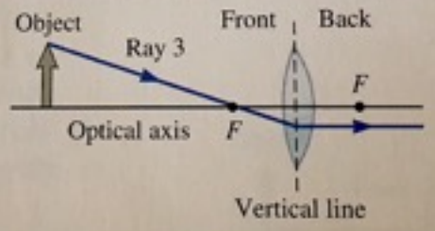
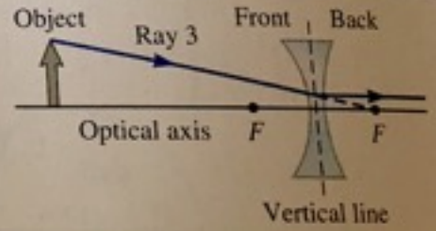
Let's design a lens

Generic Image Formation

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

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

TABLE 38.4 *Primary rays for thin lenses.*

Ray	Converging lens	Diverging lens
Ray 1 *passes through the center of the lens. It is not deflected because any ray that passes through the center of the lens goes through two nearly parallel surfaces.*		
Ray 2 *is parallel to the optical axis. For a converging lens, ray 2's refraction passes through the focal point on the back of the lens. For a diverging lens, ray 2's refraction is bent away from the optical axis. When you extend the refracted ray backward, it passes through the focal point on the front of the lens. Notice that you draw the bend in the ray only where it strikes the vertical line through the middle of the lens.*		
For a converging lens, ***ray 3*** *passes through the focal point on the front of the lens. For a diverging lens, ray 3 is aimed at the focal point on the back of the lens. For both lenses, the refracted ray is parallel to the optical axis.*		

Examples, Math and Rays

Image Behind Focal Point

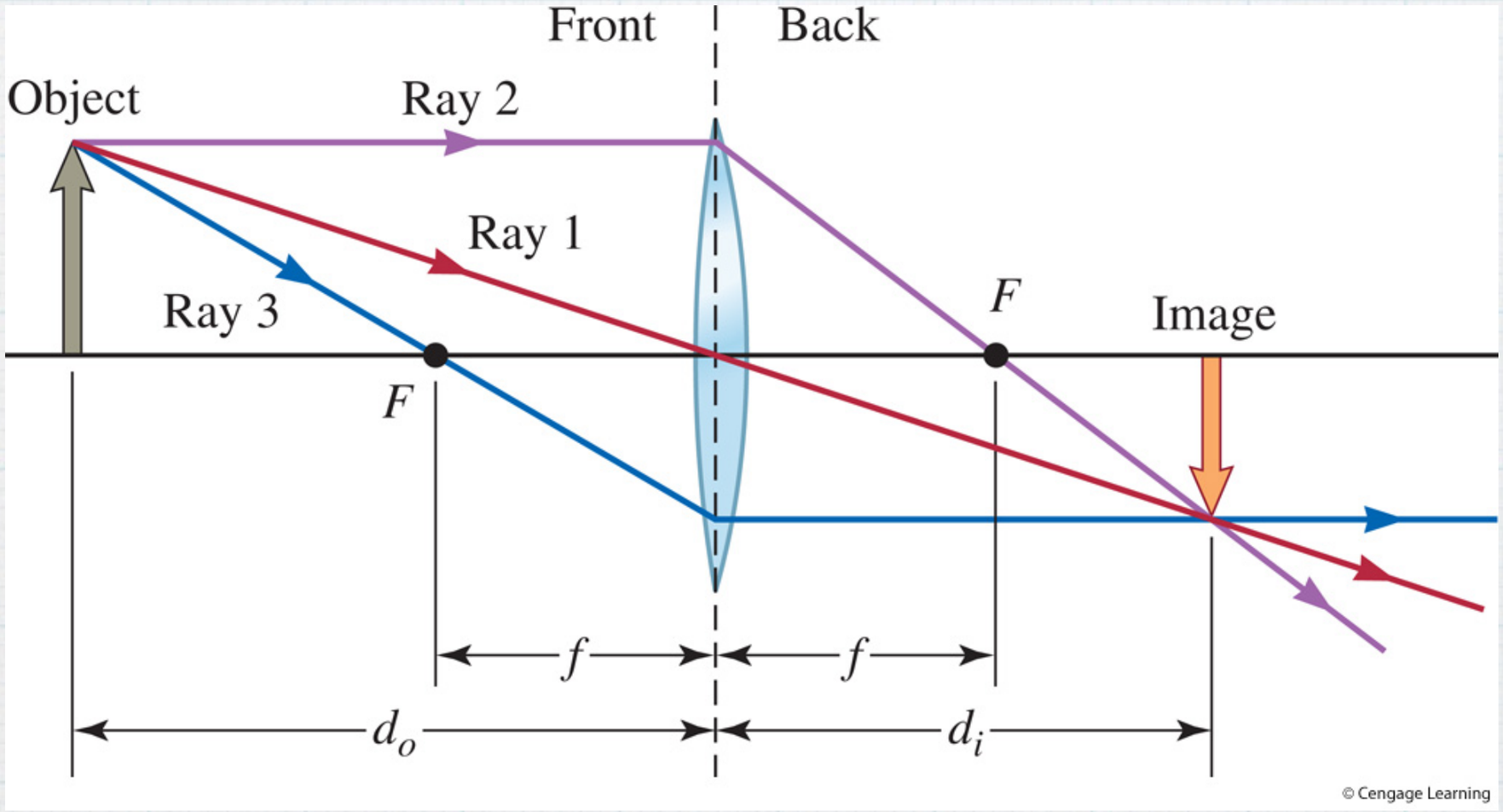
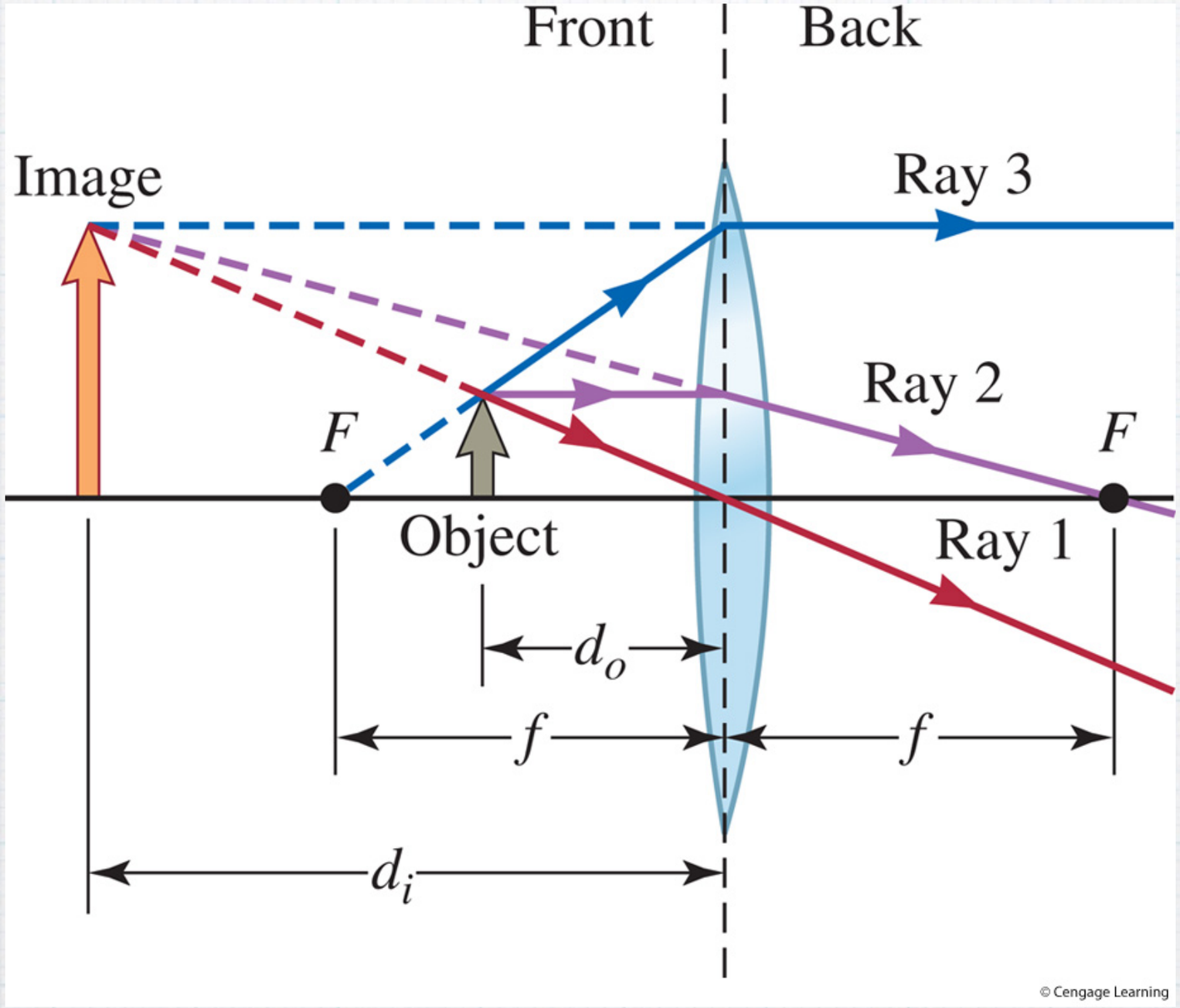
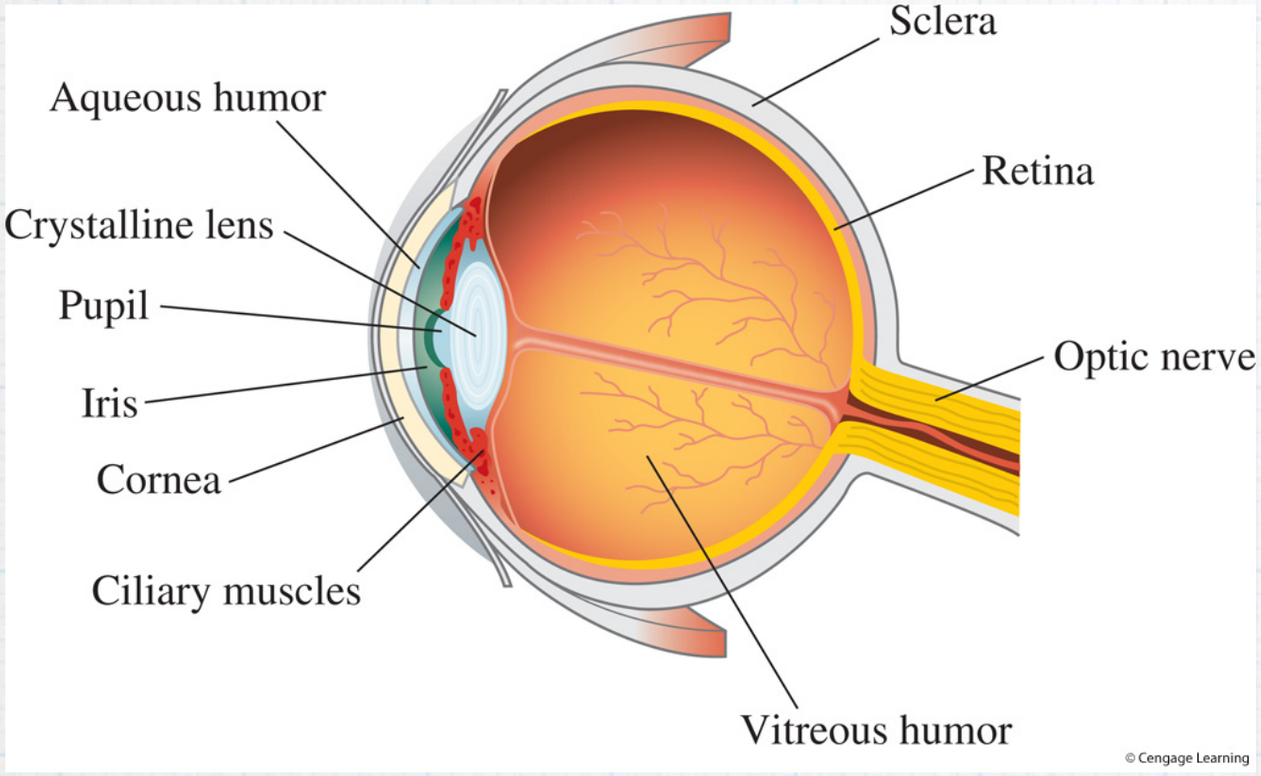
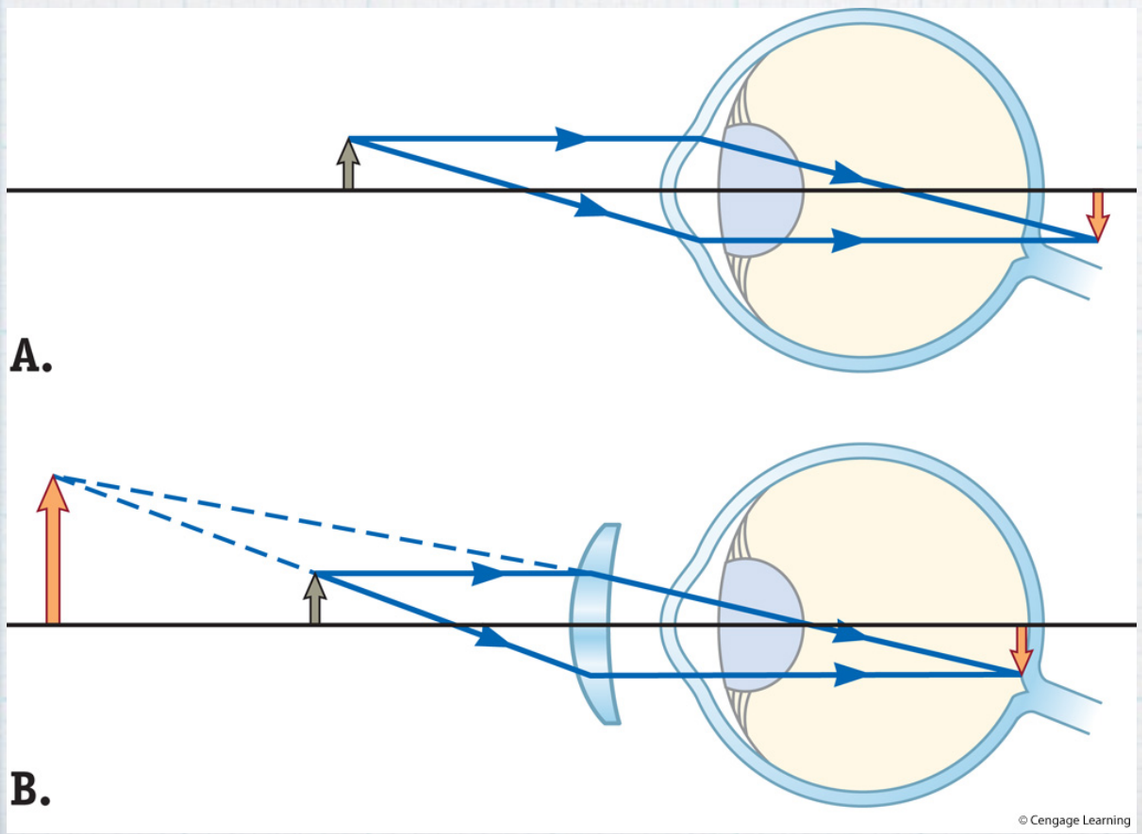


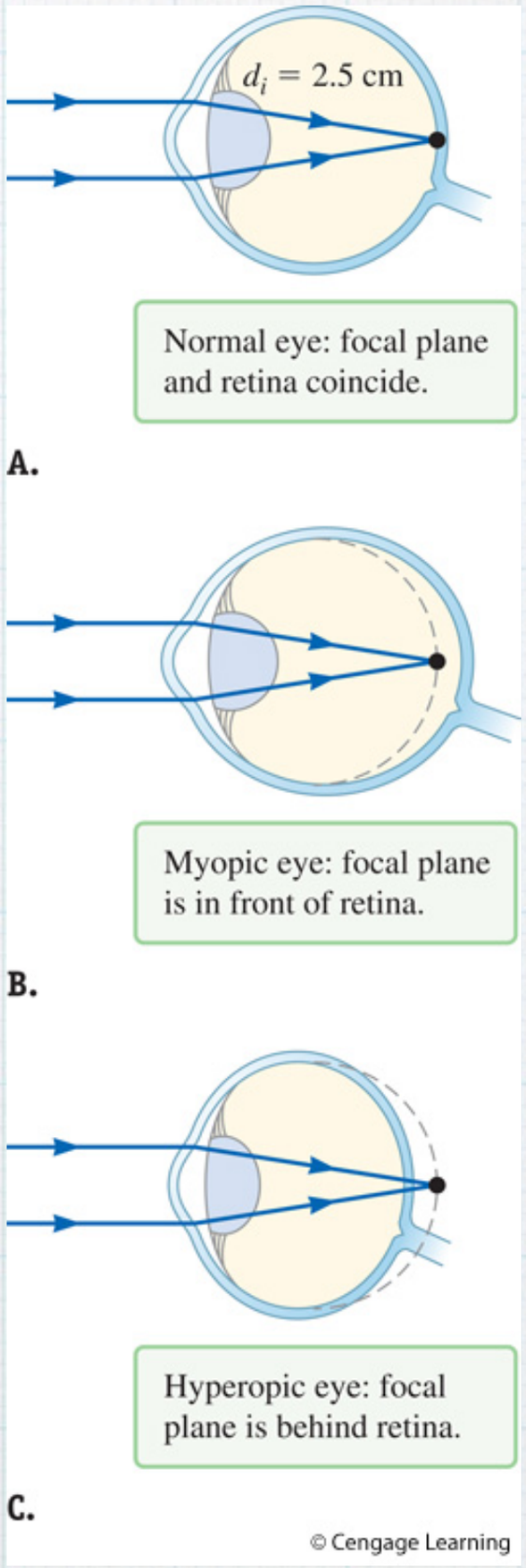
Image in Front of Focal Point



The Eye


Sclera
Aqueous humor
Retina
Crystalline lens
Pupil
Optic nerve
Iris
Cornea
Ciliary muscles
Vitreous humor
© Cengage Learning

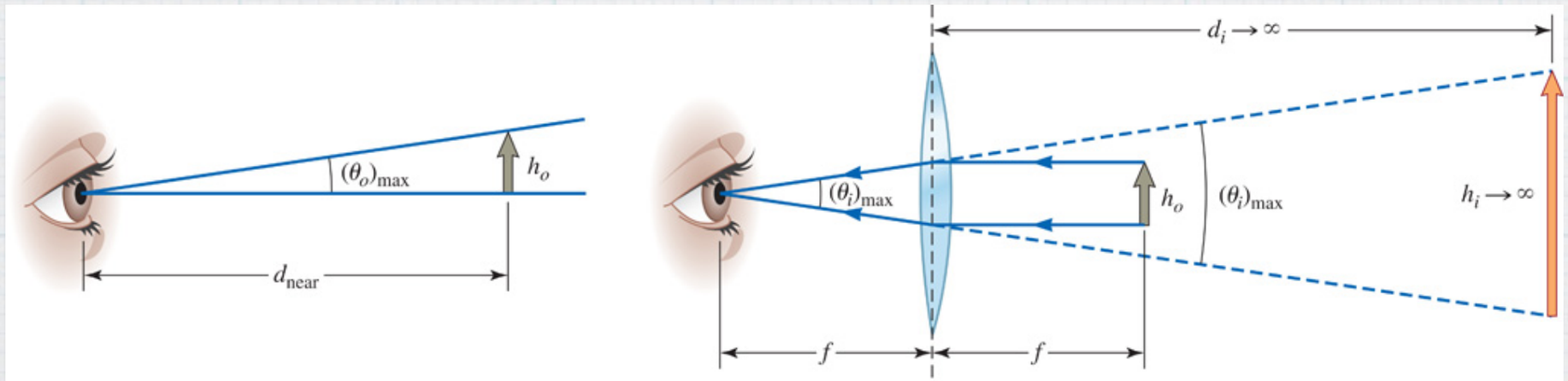

A.
B.
© Cengage Learning


d_i = 2.5 cm
Normal eye: focal plane and retina coincide.
A.
Myopic eye: focal plane is in front of retina.
B.
Hyperopic eye: focal plane is behind retina.
C.
© Cengage Learning

Magnifying Glass

A.

Christian Musat/Shutterstock.com



A. B.

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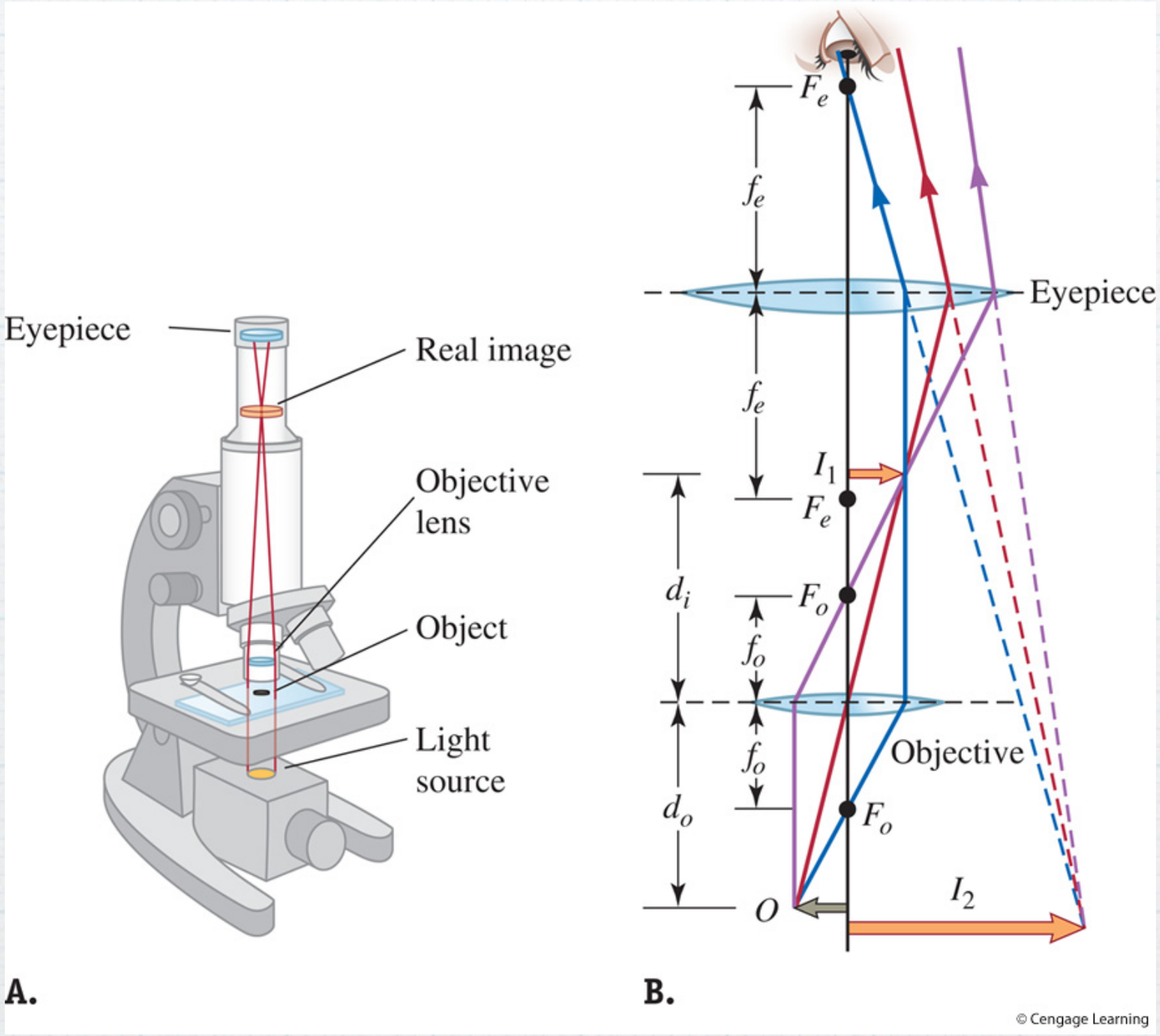
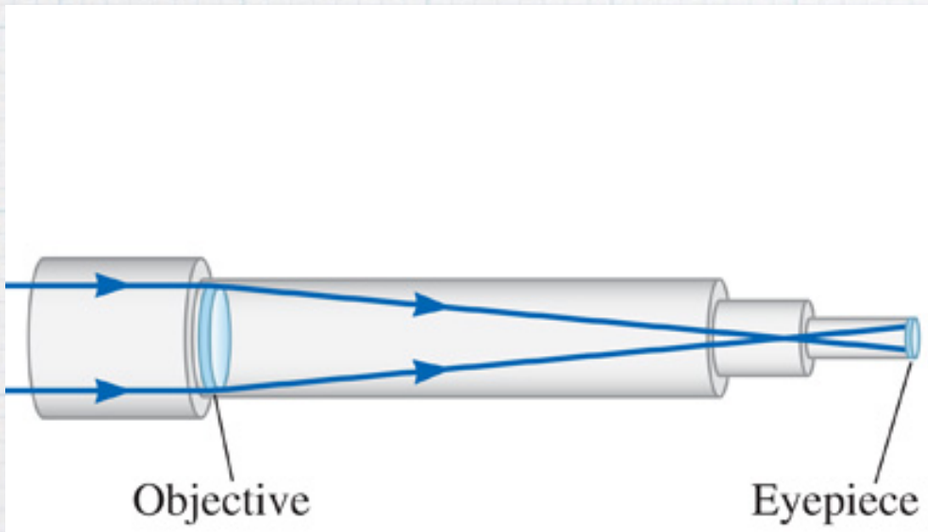
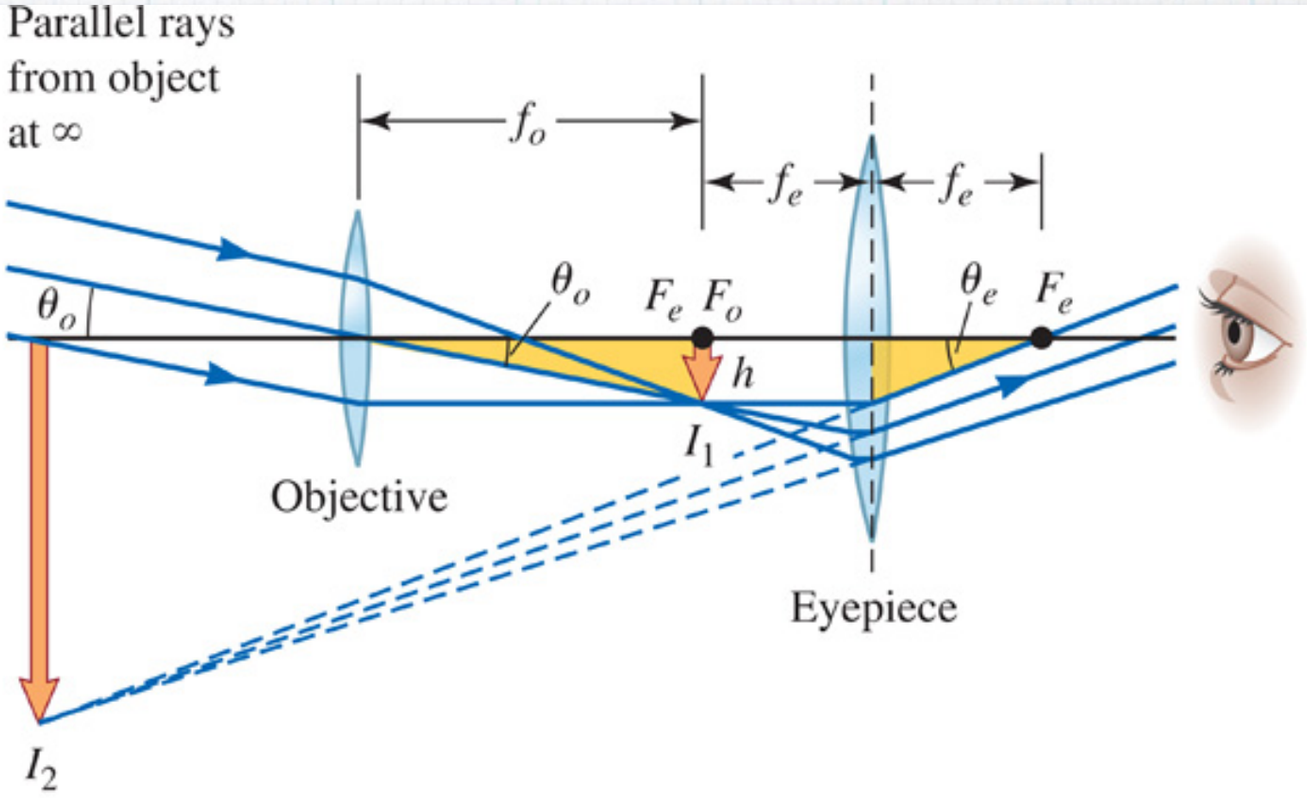
Microscope


Eyepiece
Real image
Objective lens
Object
Light source
A.
F_e
f_e
Eyepiece
f_e
I_1
F_e
d_i
F_o
f_o
f_o
Objective
d_o
F_o
O
I_2
B.
© Cengage Learning

Telescope



A.



B.

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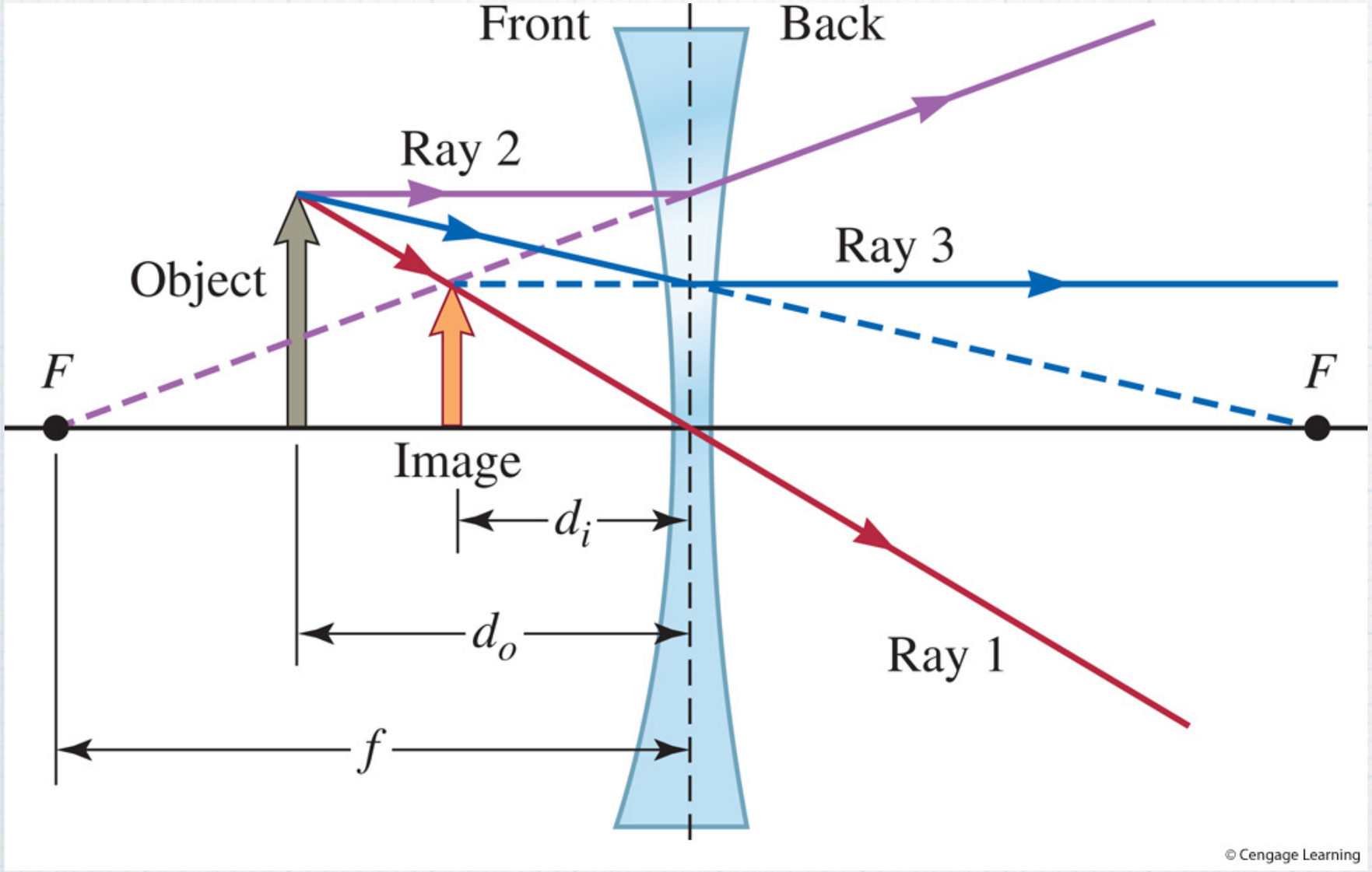
Front
Back
Ray 2
Ray 3
Object
F
F
Image
d_i
d_o
Ray 1
f
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