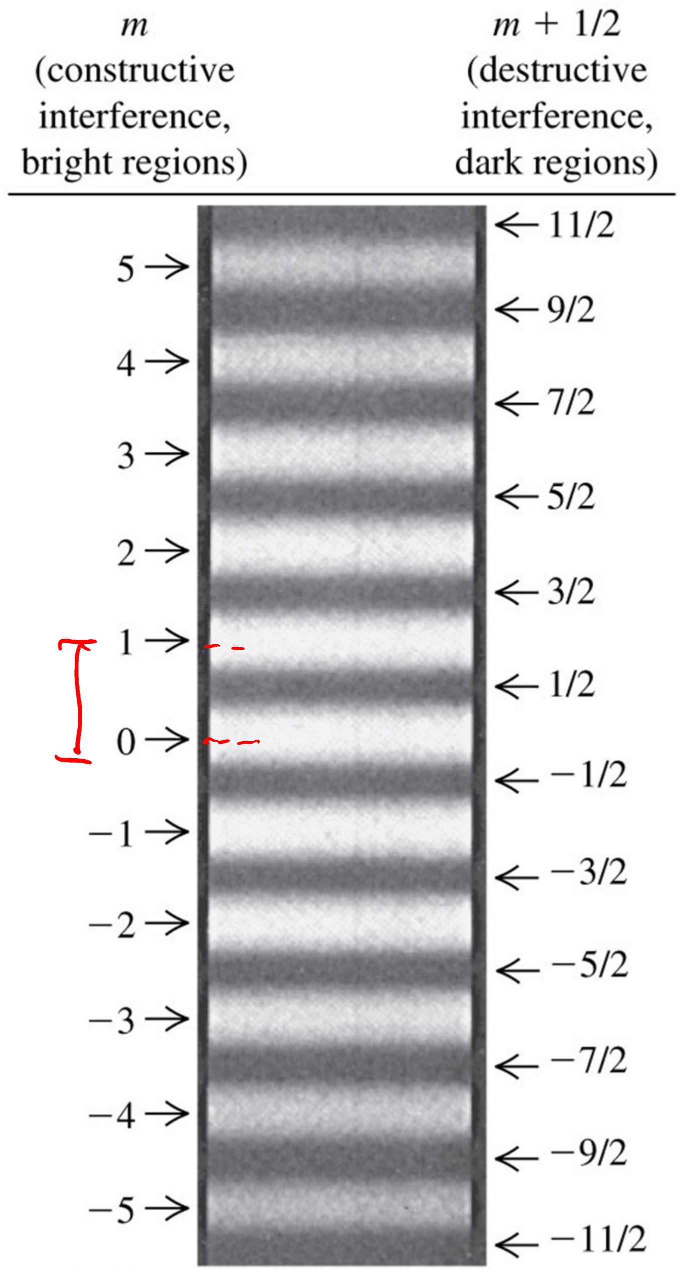
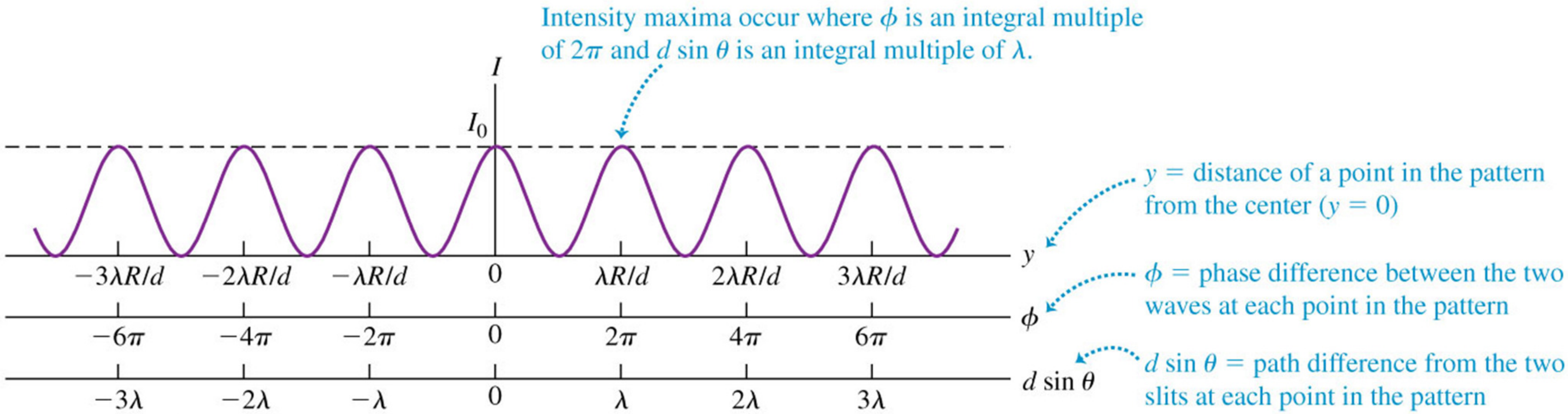


"two-slit interference"

$m\lambda = d \sin\theta$

for bright fringes



$E_1 = E_0 \sin(\omega t)$ E_0 = initial amplitude

$E_2 = E_0 \sin(\omega t + \phi)$

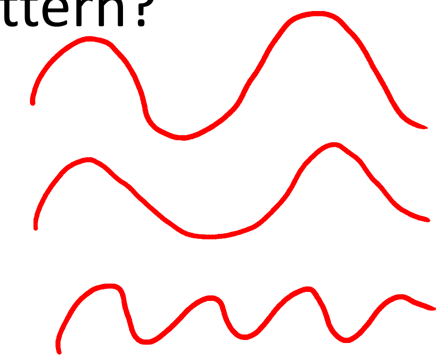
$I \propto E^2$ (~~[illegible]~~)

$E_{Tot} = 2E_0 \left|\cos\left(\frac{\phi}{2}\right)\right|$ $I = S_{av} = \frac{E_{Tot}^2}{2\mu_0 c}$

$I = \underbrace{2\varepsilon_0 c E_0^2}_{I_0} \cos^2 \frac{\phi}{2}$

The only light in the room originates from two identical bare, incandescent light bulbs. One is located on the wall to your left; and the other is located on the wall to your right. Bored, you look up at the ceiling and realize there is no interference pattern. Why is there no interference pattern?

1. The two light sources are not polarized.
2. The two light sources are not coherent.
3. The two light sources are in phase.
4. The interference pattern is too small to observe with the naked eye.
5. Interference of light is never observed, but the diffraction of light can easily be observed.



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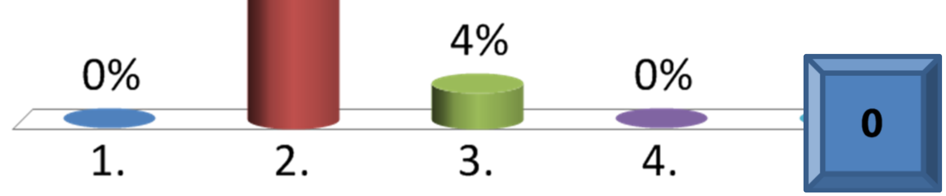
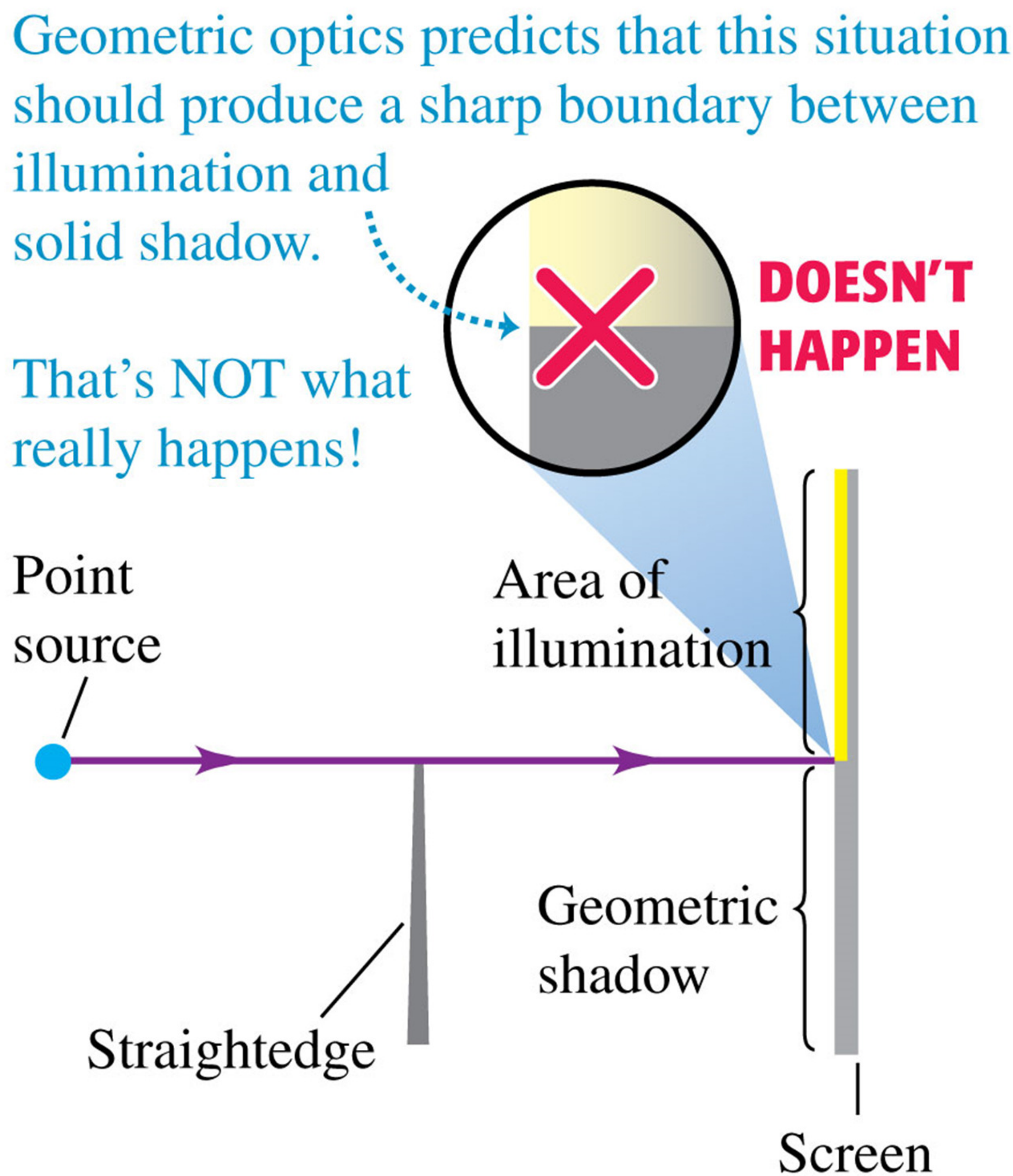
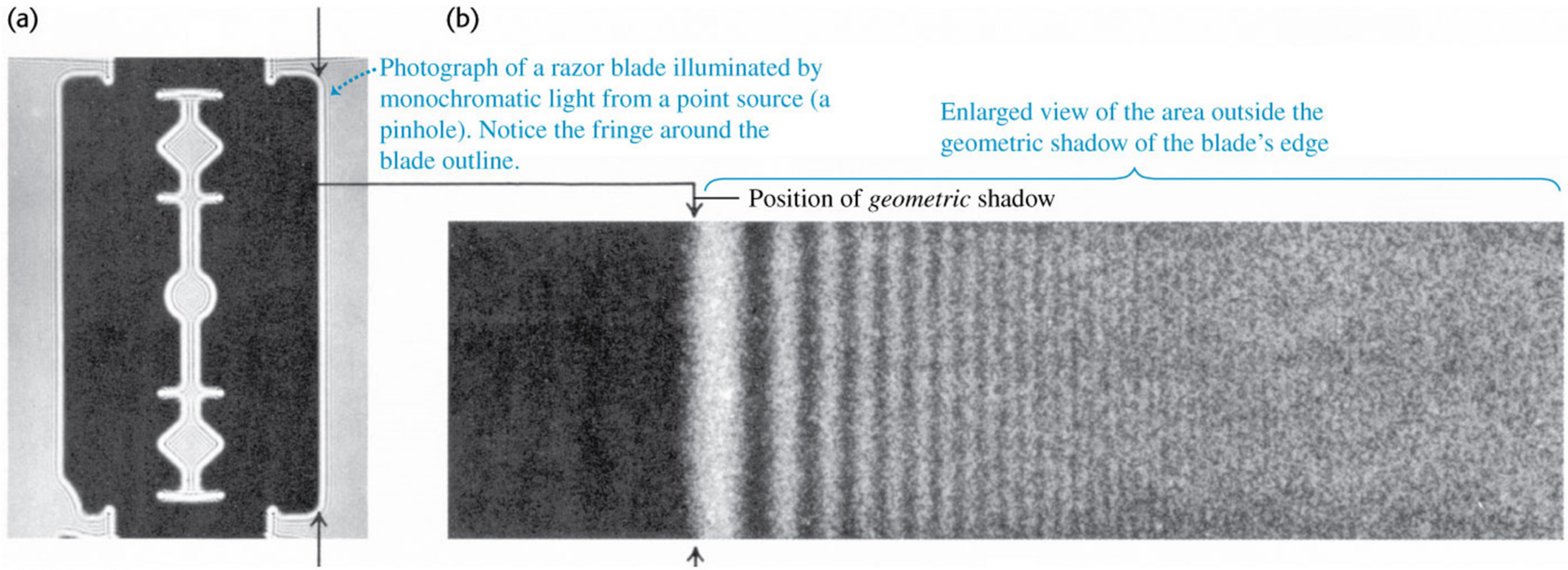
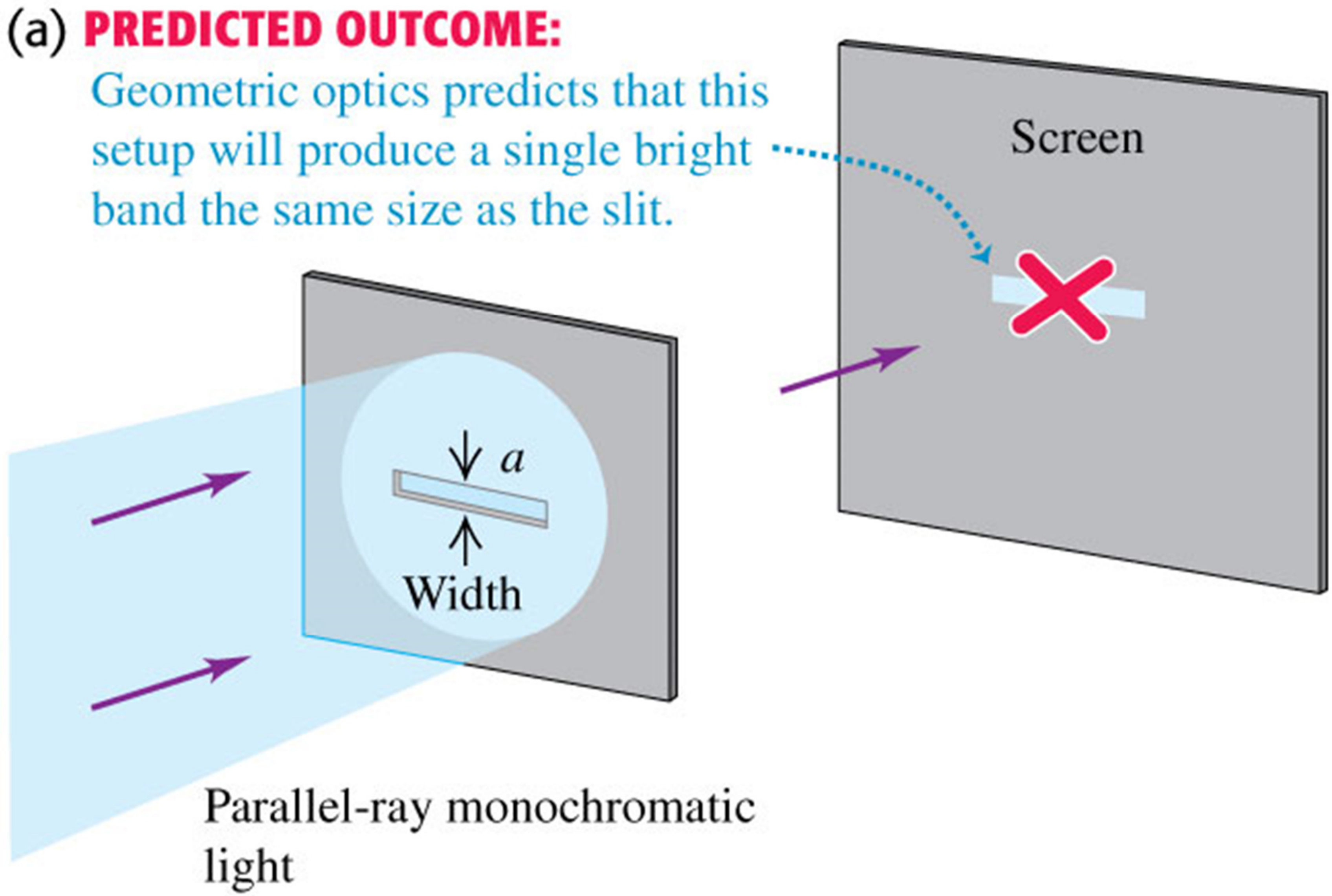
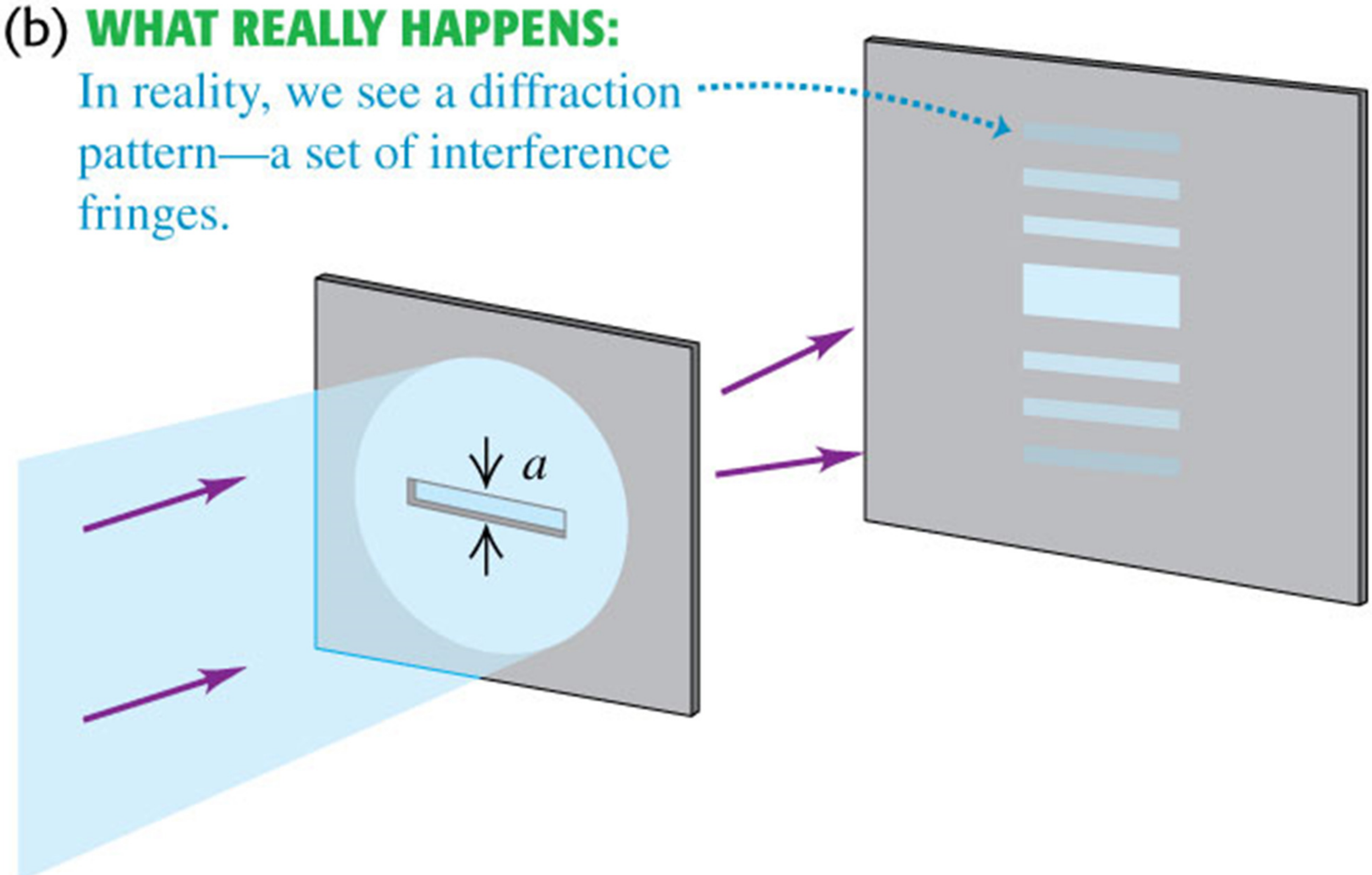
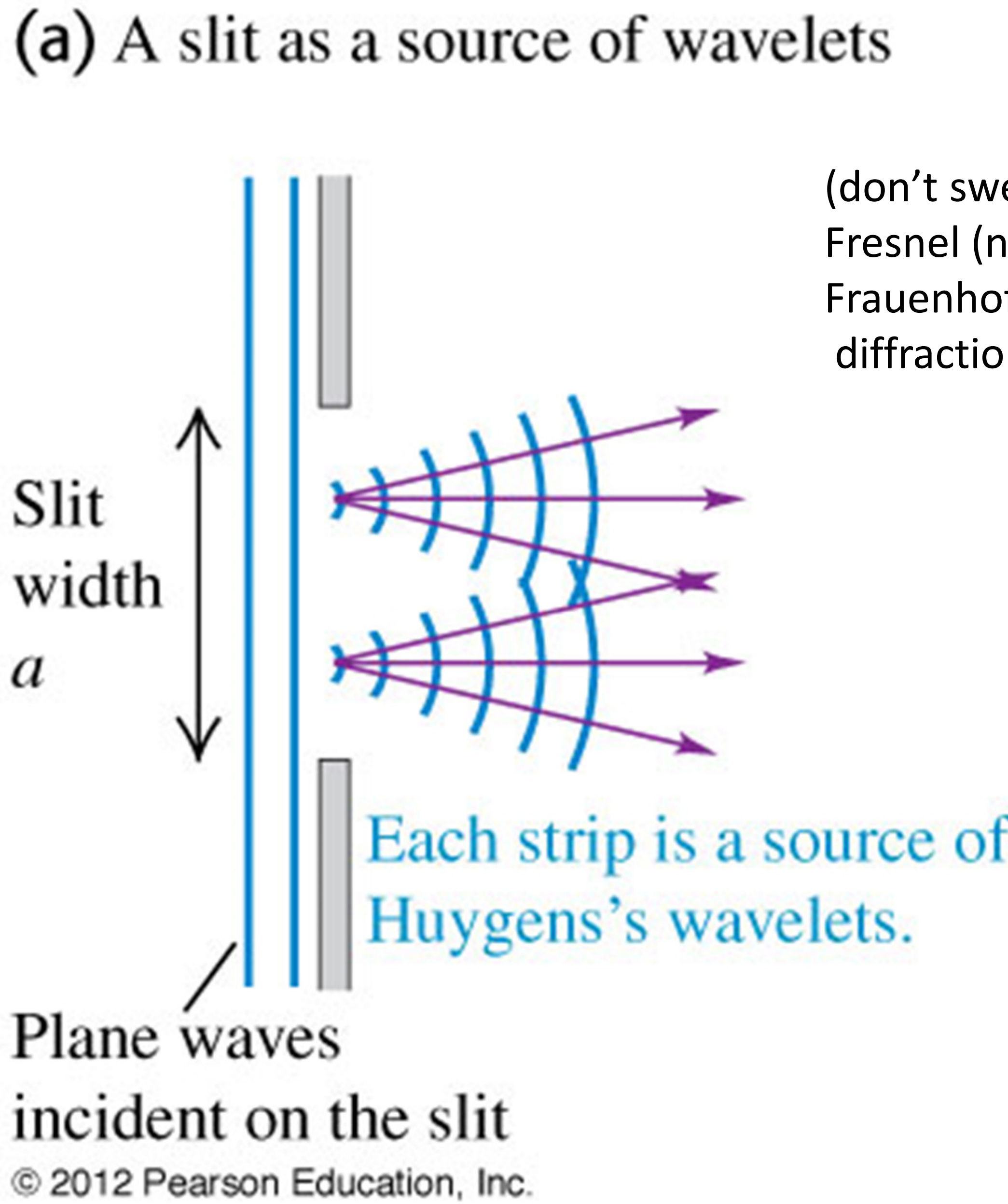



Geometric optics predicts that this situation should produce a sharp boundary between illumination and solid shadow.
That's NOT what really happens!
DOESN'T HAPPEN
Point source
Area of illumination
Geometric shadow
Straightedge
Screen

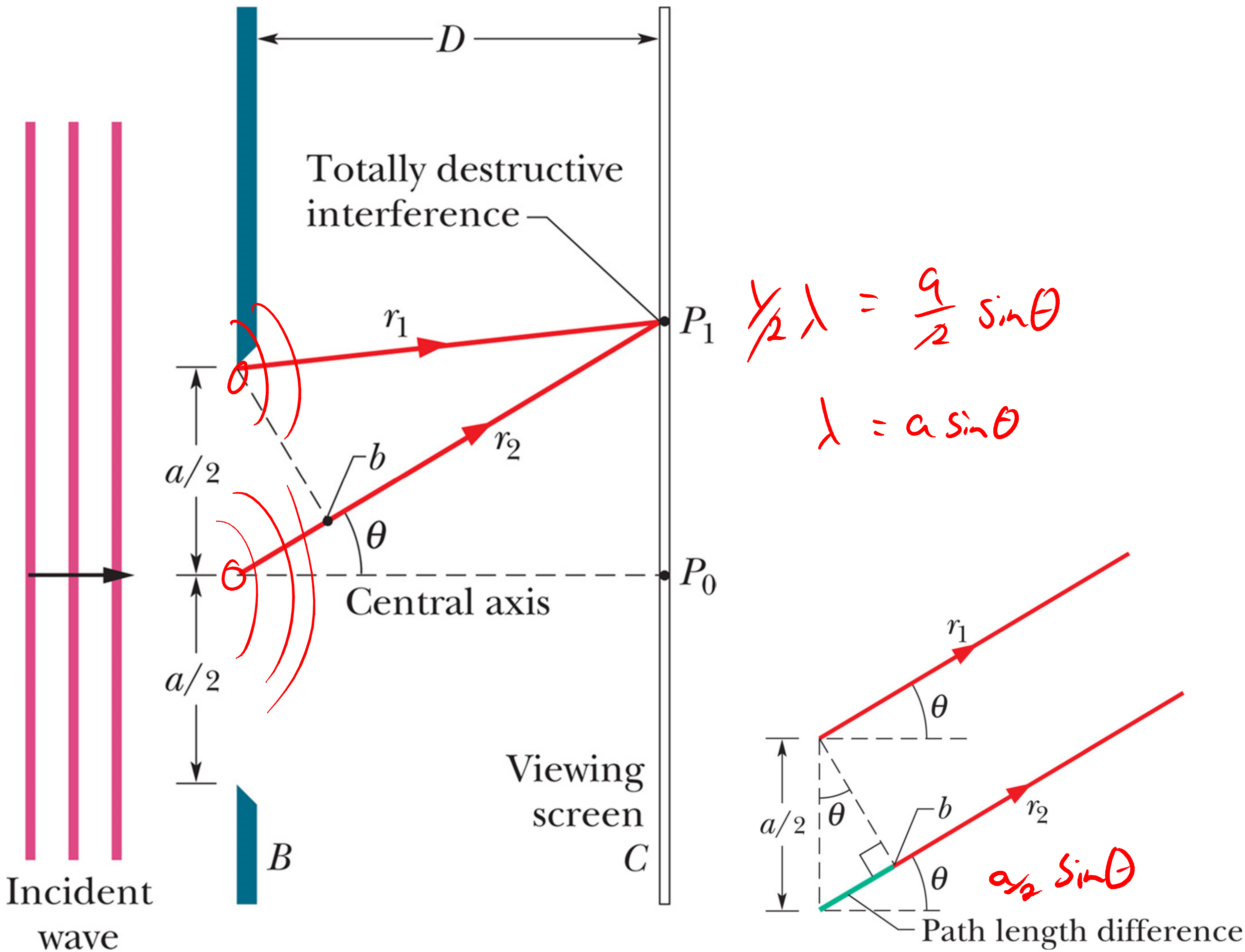

(a)
(b)
Photograph of a razor blade illuminated by monochromatic light from a point source (a pinhole). Notice the fringe around the blade outline.
Enlarged view of the area outside the geometric shadow of the blade's edge
Position of *geometric* shadow

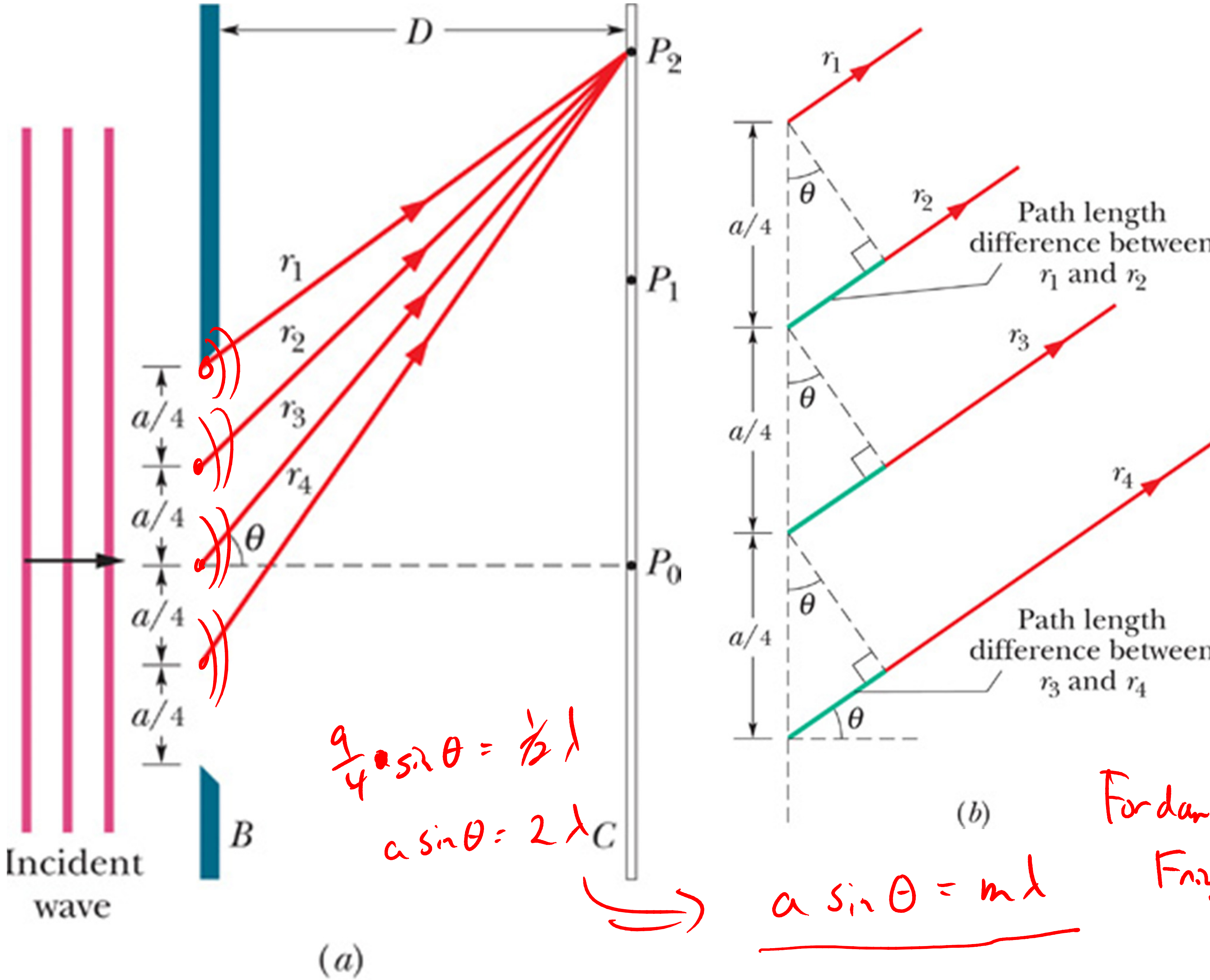

(a) PREDICTED OUTCOME:
Geometric optics predicts that this setup will produce a single bright band the same size as the slit.
Screen
a
Width
Parallel-ray monochromatic light


(b) WHAT REALLY HAPPENS:
In reality, we see a diffraction pattern—a set of interference fringes.
a



(don't sweat the differences between
Fresnel (nearby) and
Frauenhofer (far away or parallel ray)
diffraction)


D
Totally destructive
interference
P_1
r_1
r_2
b
θ
$a/2$
$a/2$
P_0
Central axis
Viewing
screen
C
B
Incident
wave
$\frac{1}{2}\lambda = \frac{a}{2}\sin\theta$
$\lambda = a\sin\theta$
r_1
θ
$a/2$
θ
b
r_2
θ
$\frac{a}{2}\sin\theta$
Path length difference



$\frac{a}{4} \sin\theta = \frac{1}{2}\lambda$

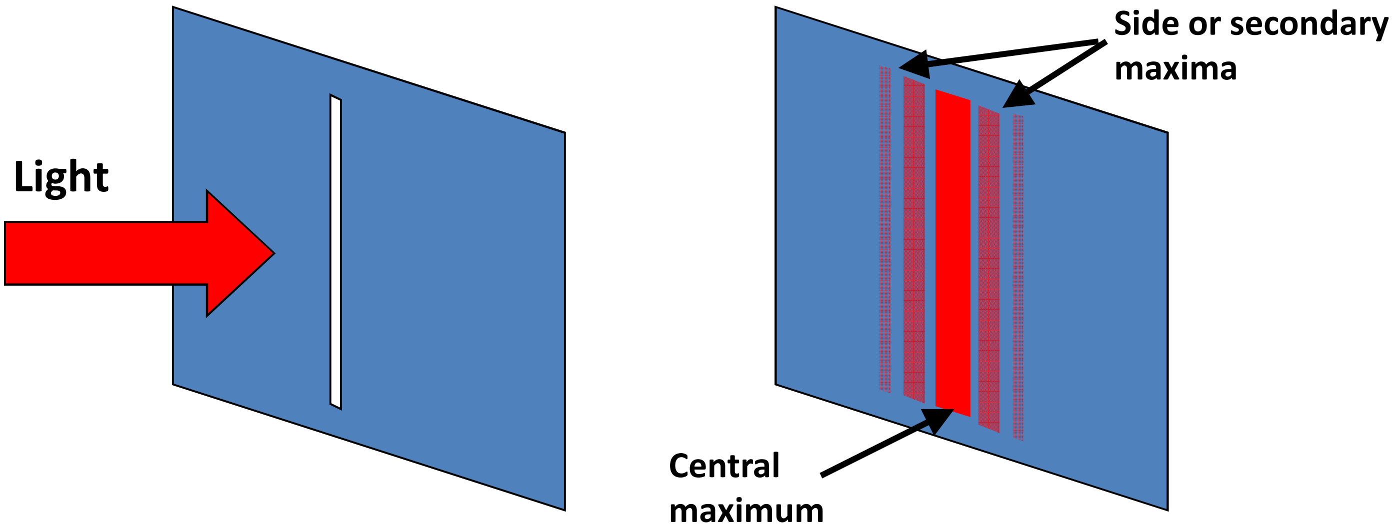
$a \sin\theta = 2\lambda$

$a \sin\theta = m\lambda$

For dark Fringes

Diffraction and the Wave Theory of Light

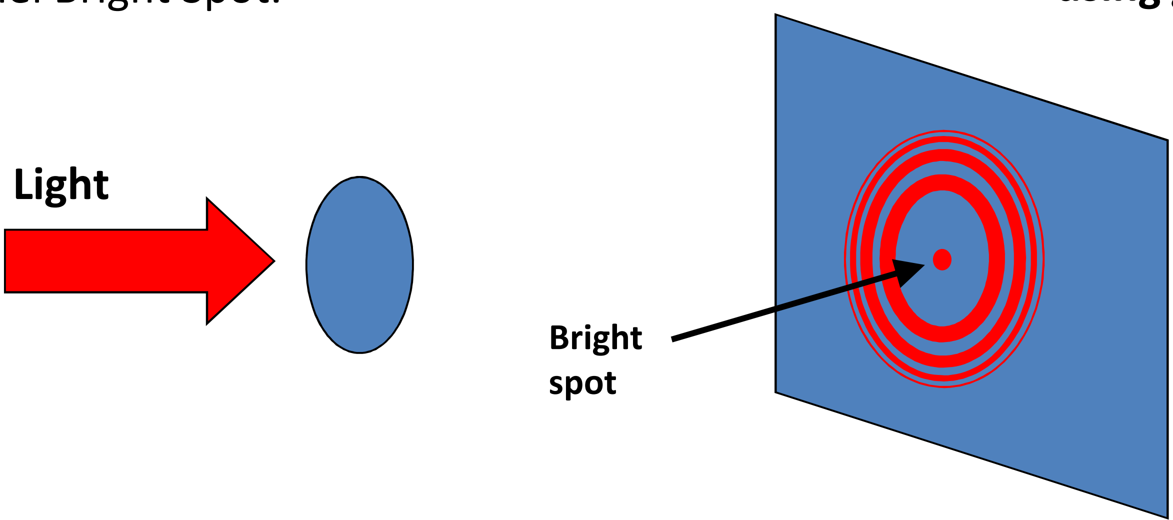
Diffraction pattern from a single narrow slit.

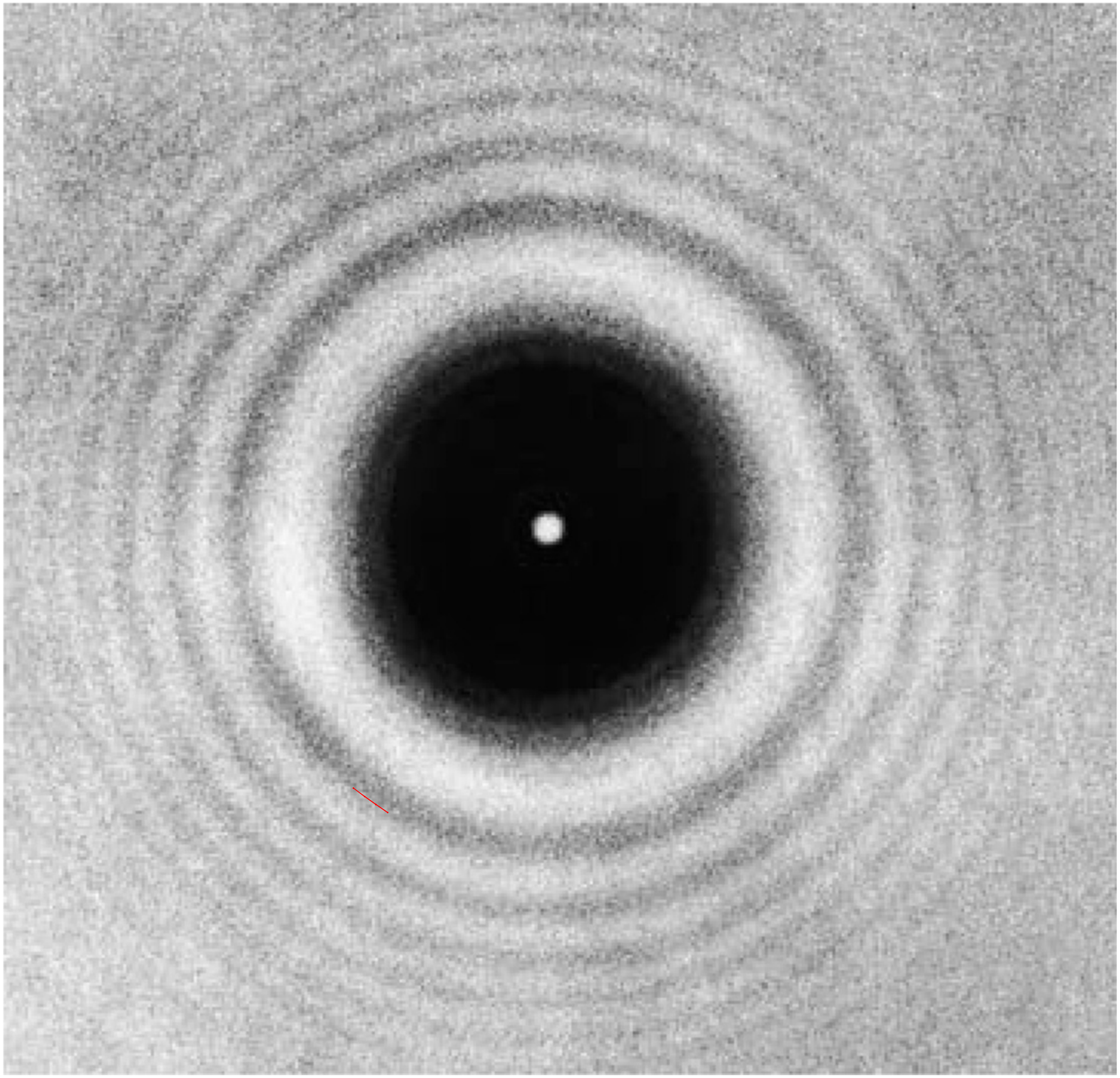


$a \sin\theta = m\lambda$

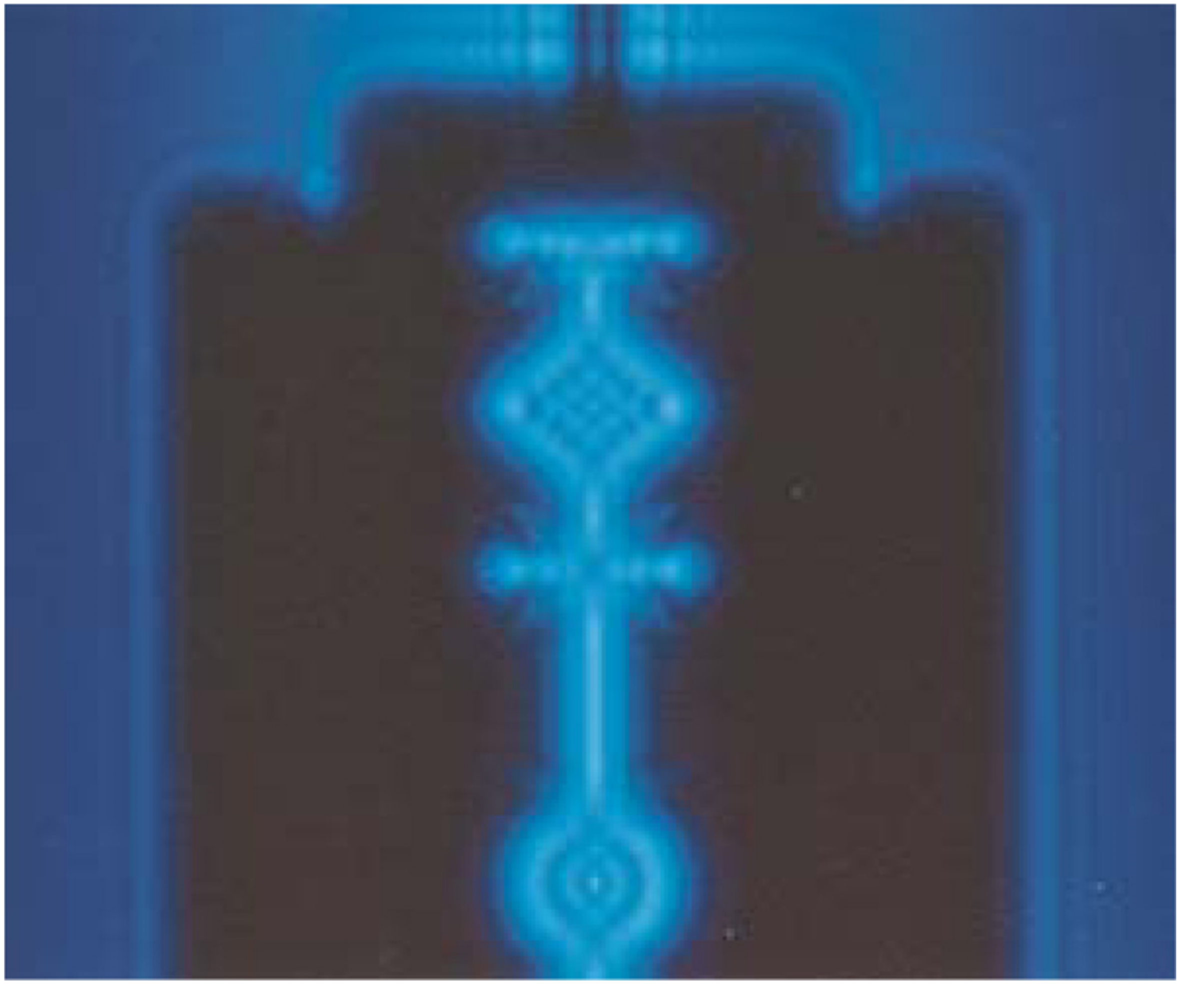
These patterns cannot be explained using geometrical optics (Ch. 37)!

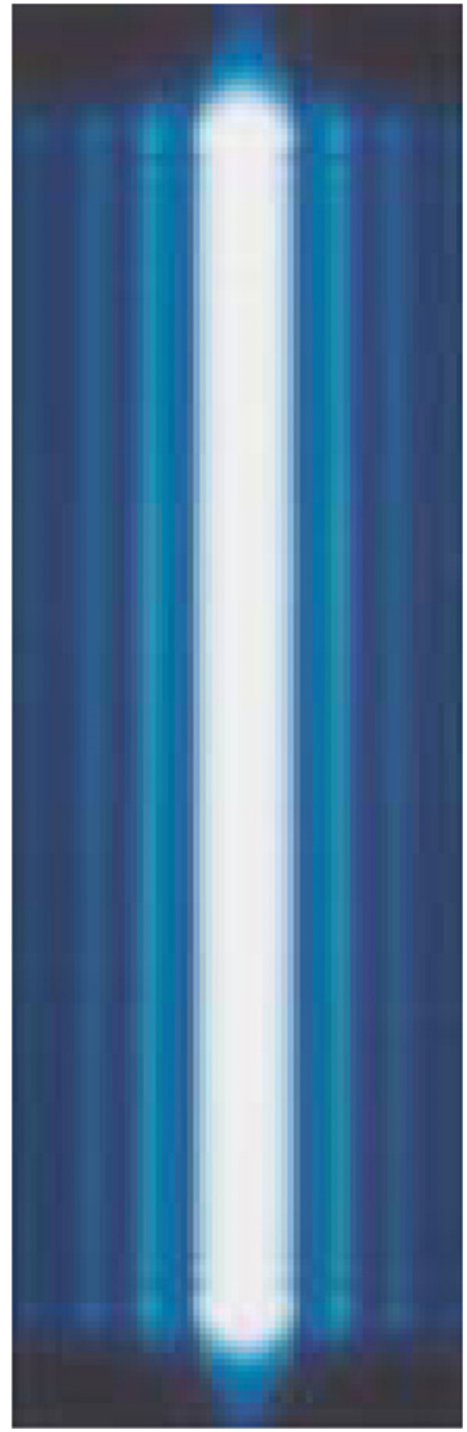
Fresnel Bright Spot.



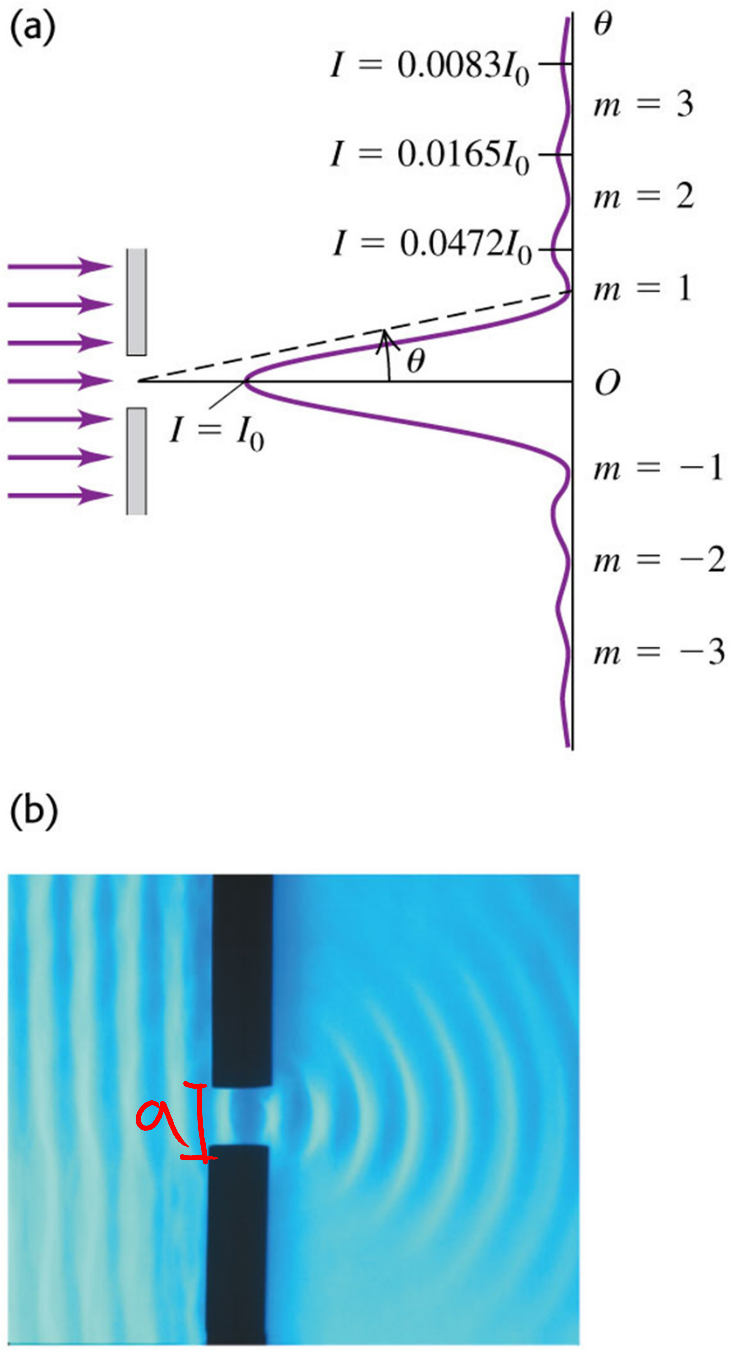


Airey Disk





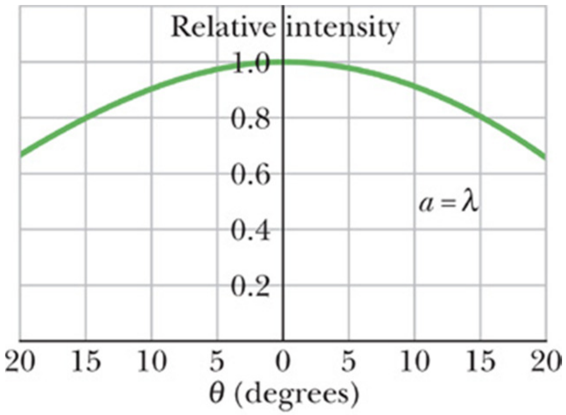
diffraction
(interference)



$$I = I_0 \left(\frac{\sin\left(\beta/2\right)}{\beta/2} \right)^2$$

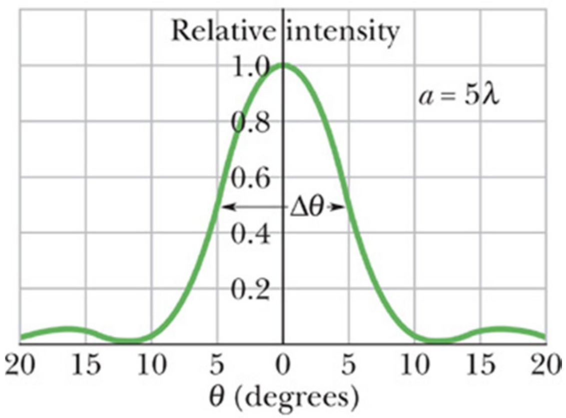
$$\beta = \frac{2\pi}{\lambda} a \sin\theta$$

$$m\lambda = a \sin\theta$$



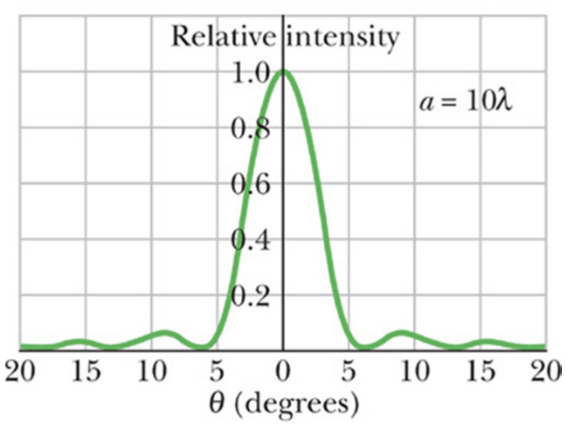
Relative intensity
1.0
0.8
0.6
0.4
0.2
$a = \lambda$
20 15 10 5 0 5 10 15 20
θ (degrees)

(*a*)



Relative intensity
1.0
0.8
0.6
0.4
0.2
$a = 5\lambda$
Δθ
20 15 10 5 0 5 10 15 20
θ (degrees)

(*b*)



Relative intensity
1.0
0.8
0.6
0.4
0.2
$a = 10\lambda$
20 15 10 5 0 5 10 15 20
θ (degrees)

(*c*)

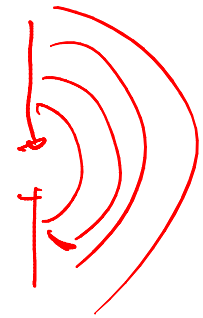
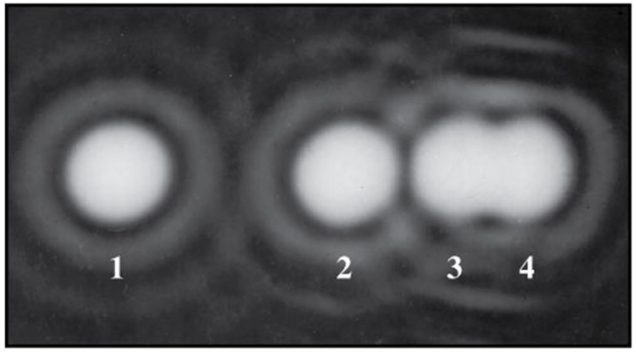
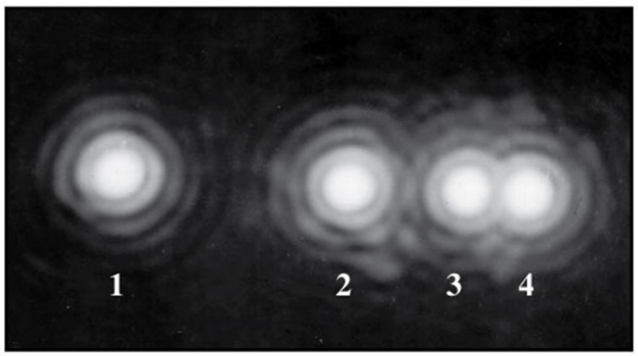


Fig.36.27

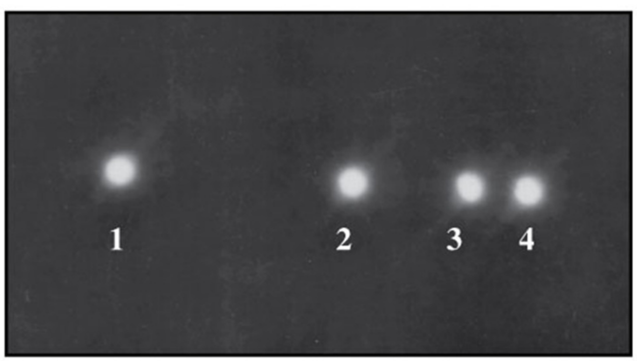
(a) Small aperture



(b) Medium aperture



(c) Large aperture



$a \sin\theta = m\lambda$

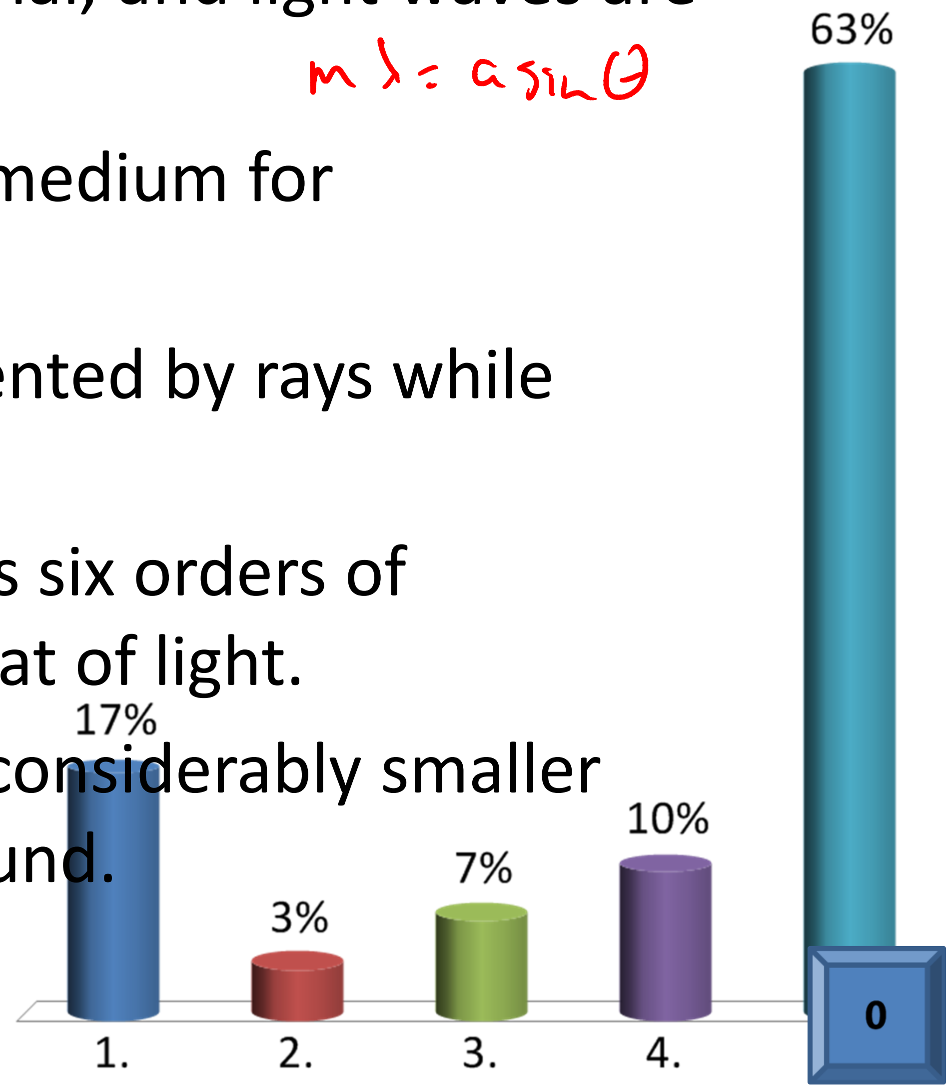
(dark lines, diffraction)

Which one of the following statements best explains why the diffraction of sound is more apparent than the diffraction of light under most circumstances?

1. Sound waves are longitudinal, and light waves are transverse.

   $m\lambda = a\sin\theta$

2. Sound requires a physical medium for propagation.
3. Light waves can be represented by rays while sound waves cannot.
4. The speed of sound in air is six orders of magnitude smaller than that of light.
5. The wavelength of light is considerably smaller than the wavelength of sound.



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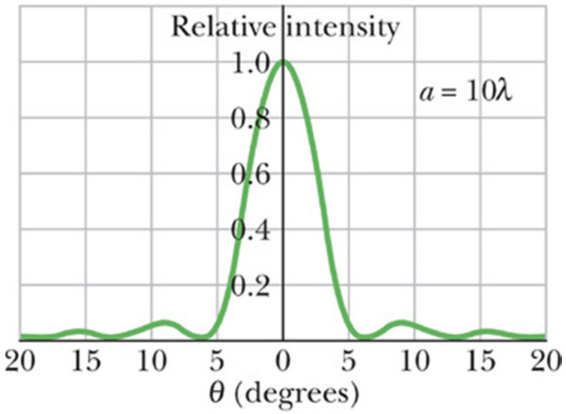
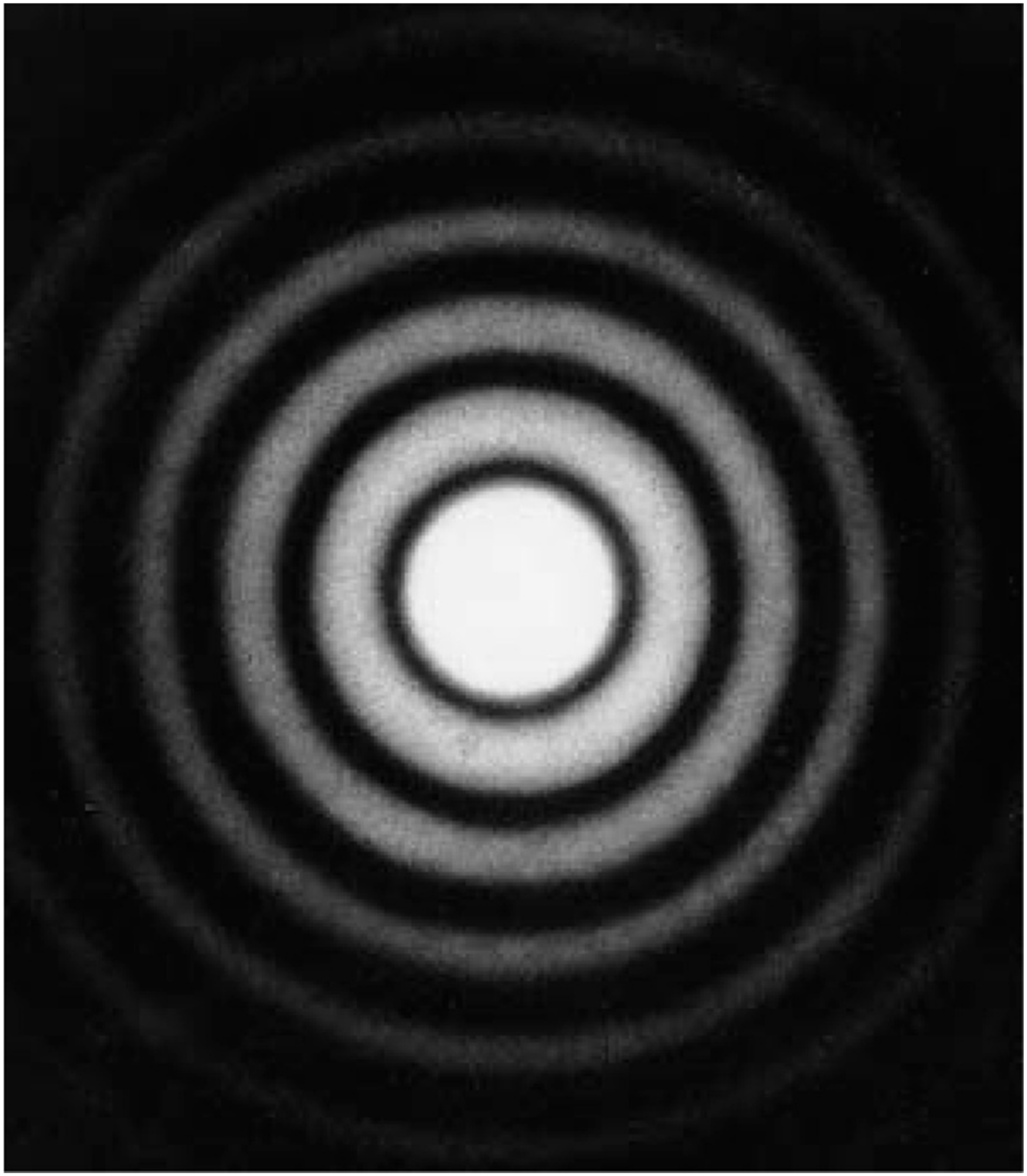


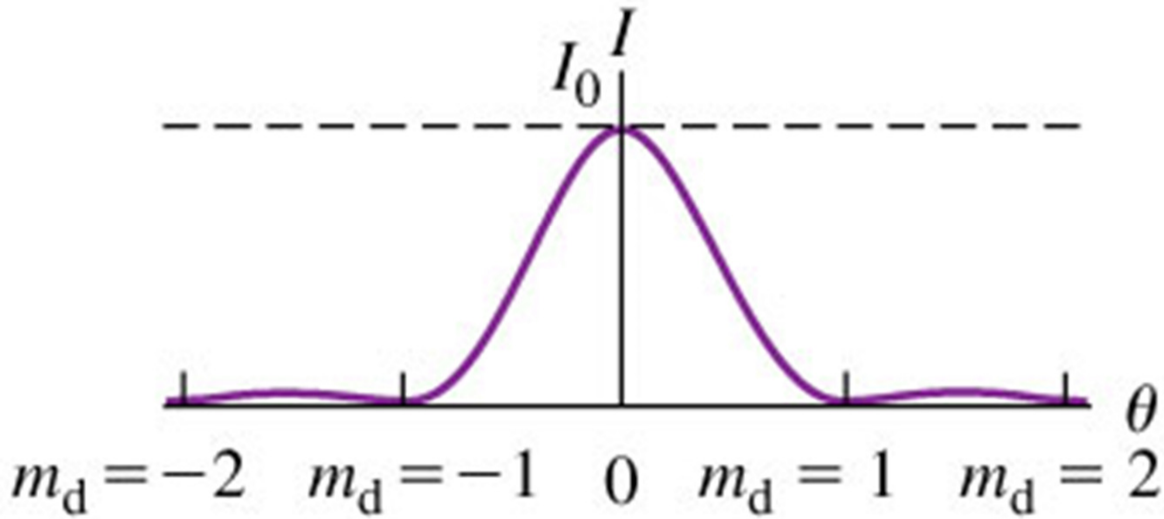
(c)

$$I = I_0 \left(\frac{\sin(\beta/2)}{\beta/2} \right)^2$$

$$\beta = \frac{2\pi}{\lambda} a \sin\theta$$

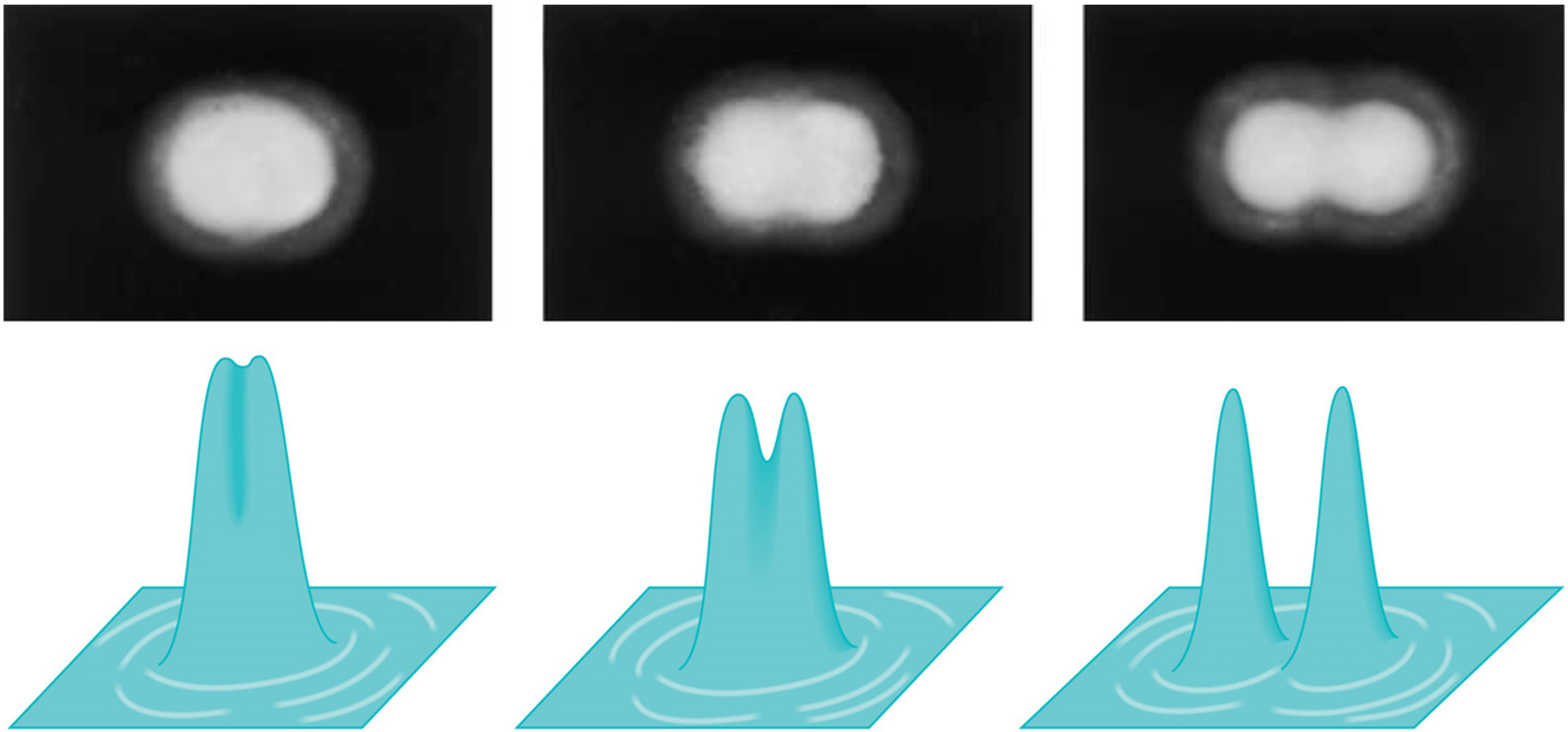


(a) Single-slit diffraction pattern for a slit width a

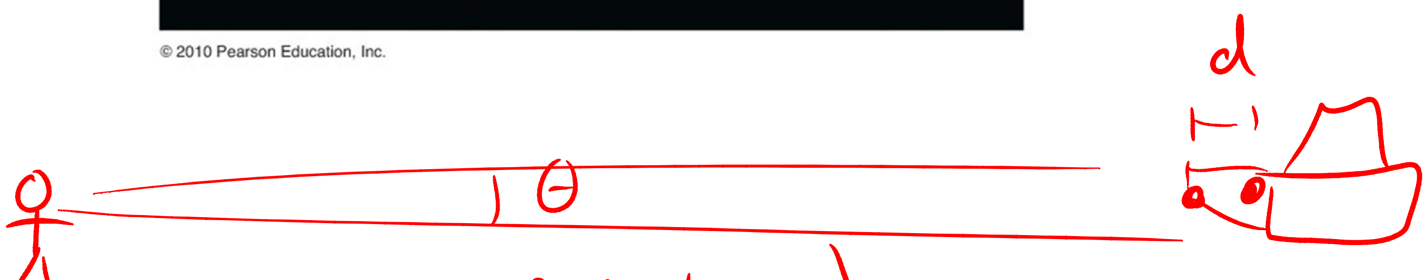


Rayleigh's Criterion

$$\sin\theta_R = 1.22\frac{\lambda}{D}$$

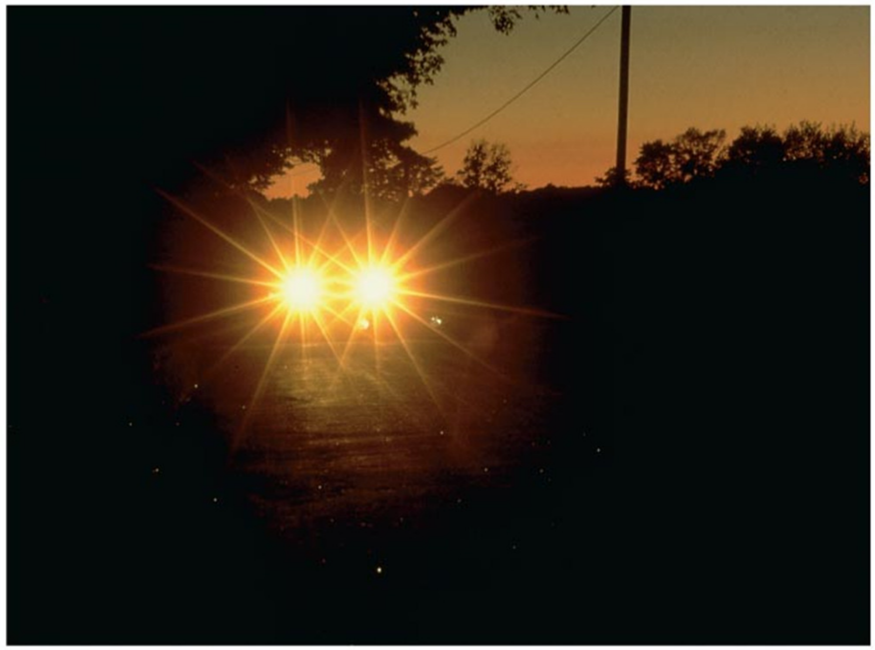


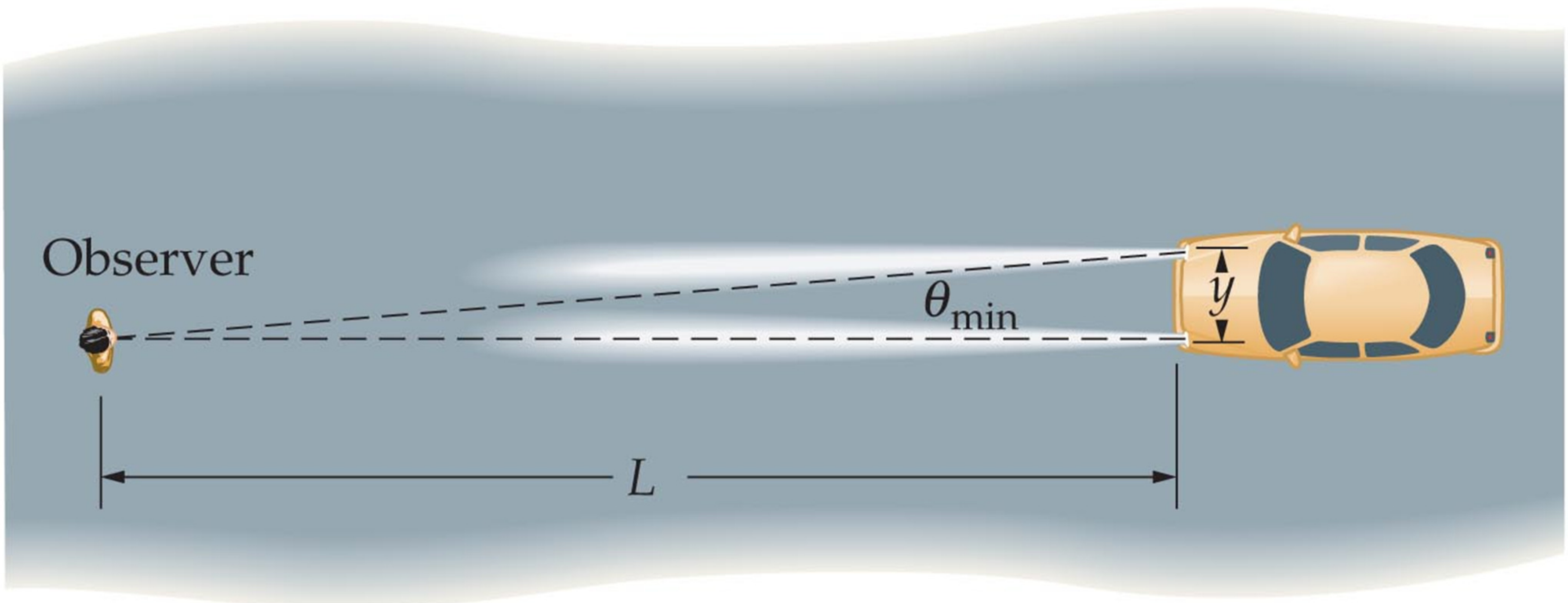
(a) (b) (c)



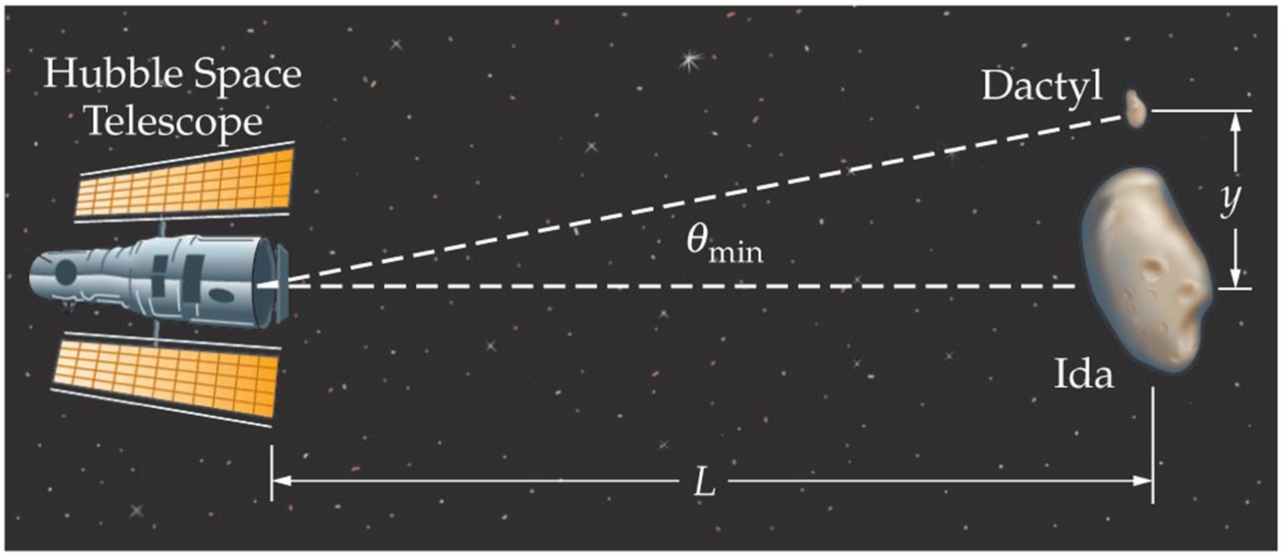
$$\sin\theta \geq 1.22\frac{\lambda}{a}$$

$$\approx \quad \theta \geq 1.22\frac{\lambda}{a} \quad \text{(if } \theta \text{ is in radians)}$$

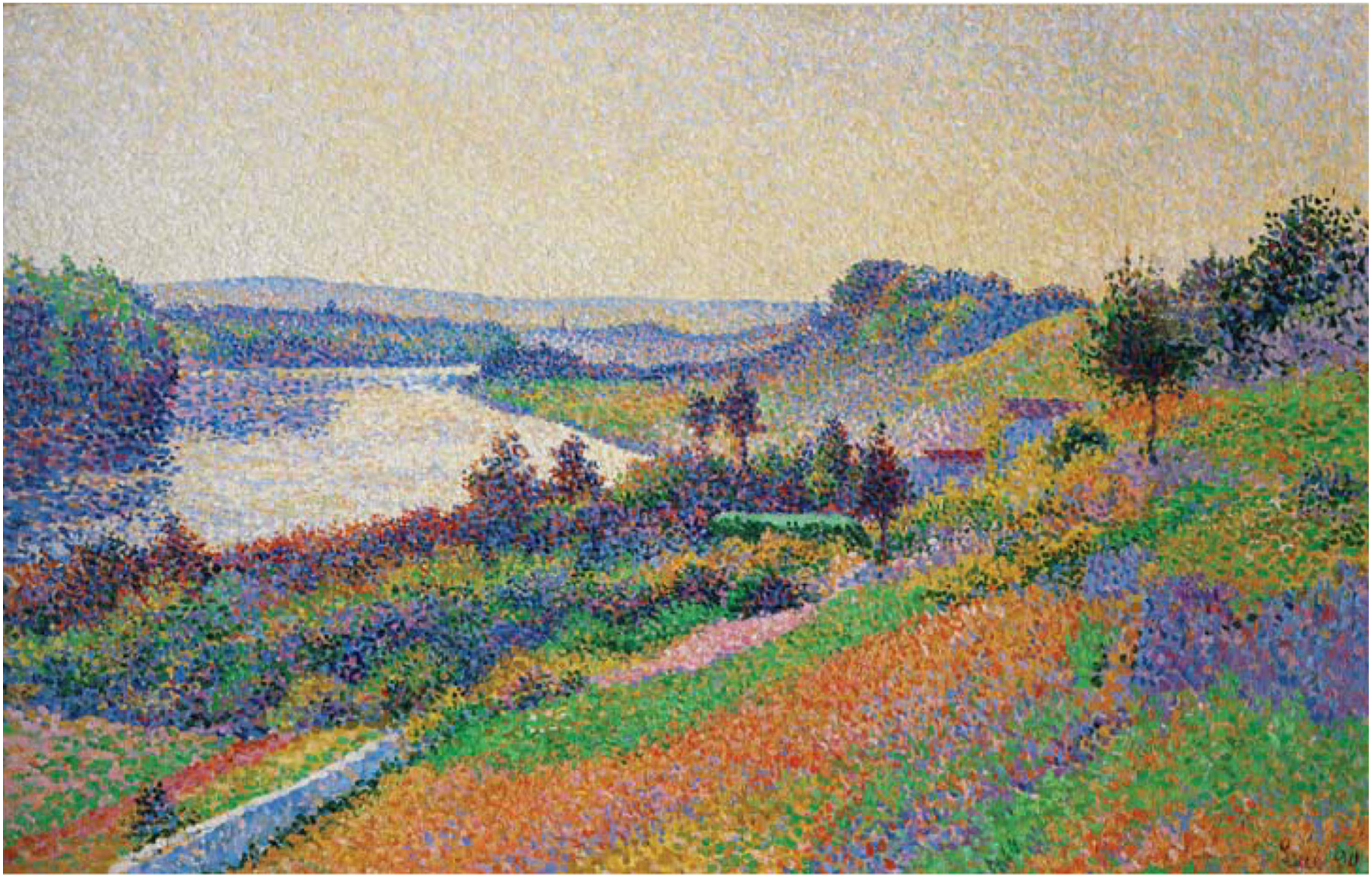


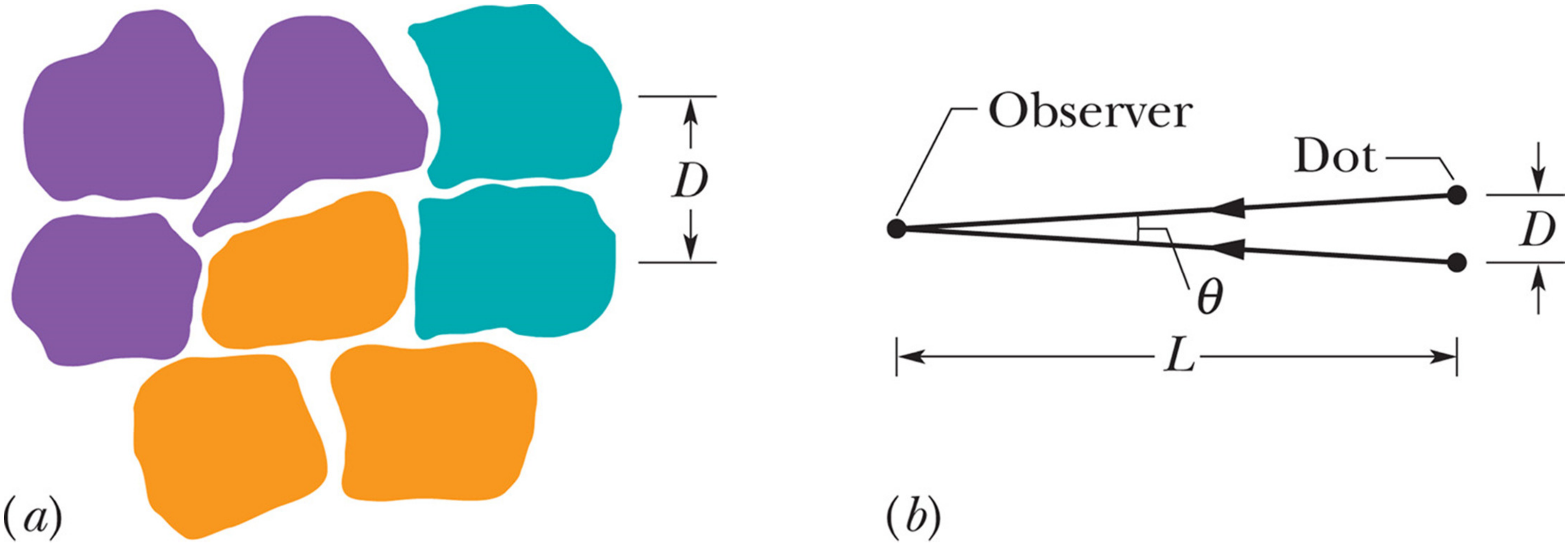

Observer
θ_{min}
y
L

$$\sin \theta \geq 1.22 \frac{\lambda}{a}$$

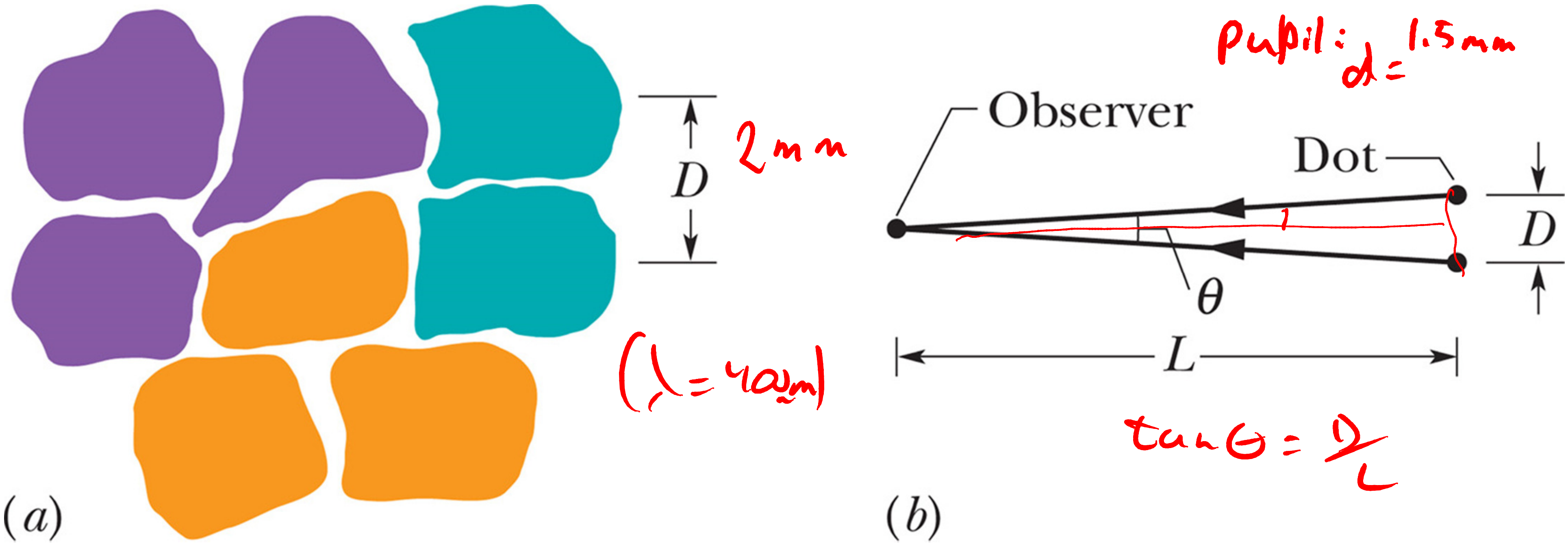


The Seine at Herblay (Maxmillian Luce)





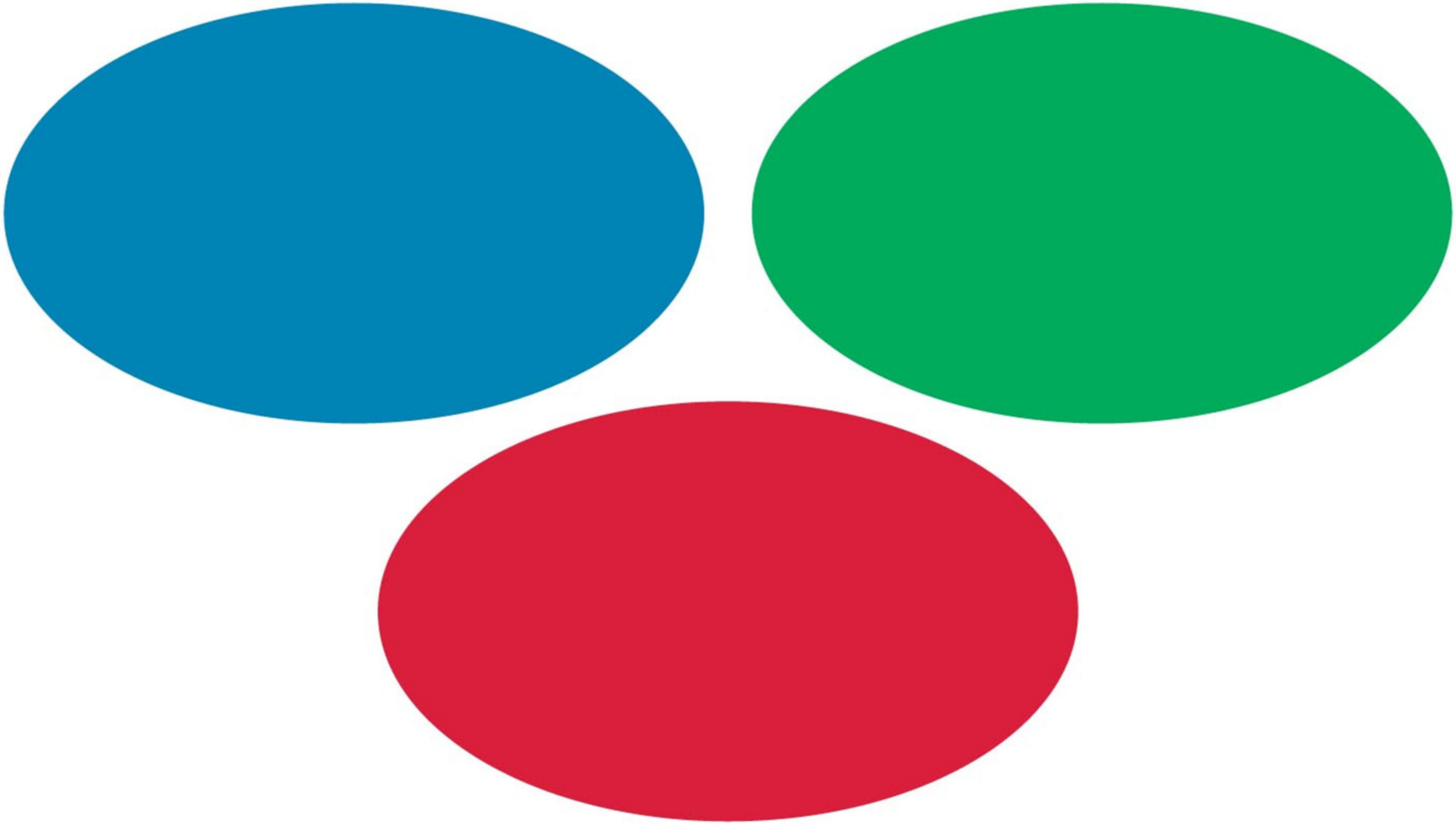
For 400nm light, if these dots are 2mm apart, how far away should you stand from the painting to not notice that they're individual dots using your 1.5mm pupils?



$$\sin\theta \le \theta_R = 1.22\frac{\lambda}{d} = \frac{D}{L}$$

$$L = \frac{Dd}{1.22\lambda} = \frac{(2\times10^{-3}\,m)(1.5\times10^{-3}\,m)}{1.22\,(400\times10^{-9}\,m)}$$

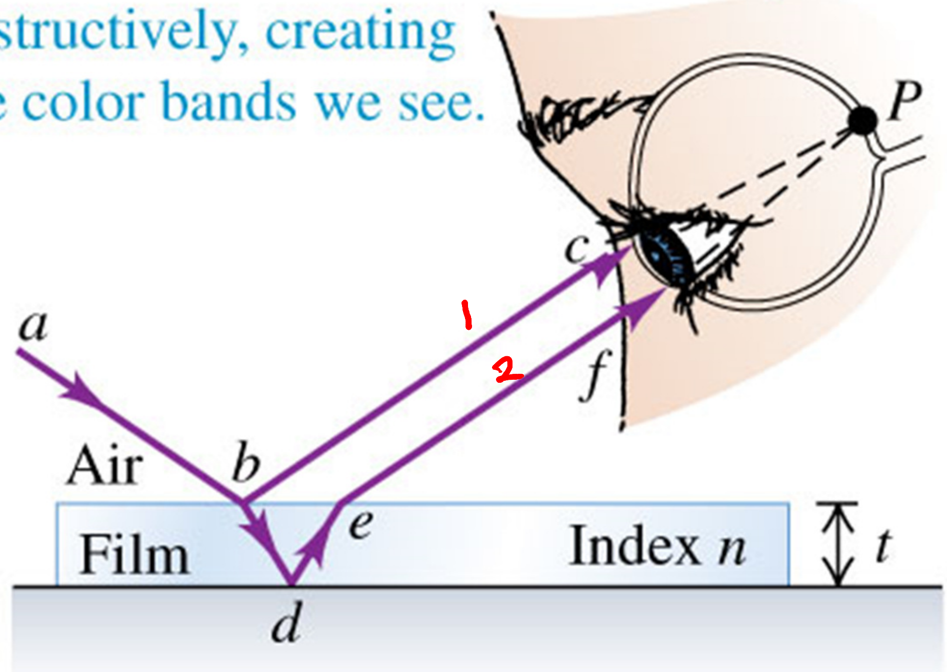
$$= 6.1\,m$$



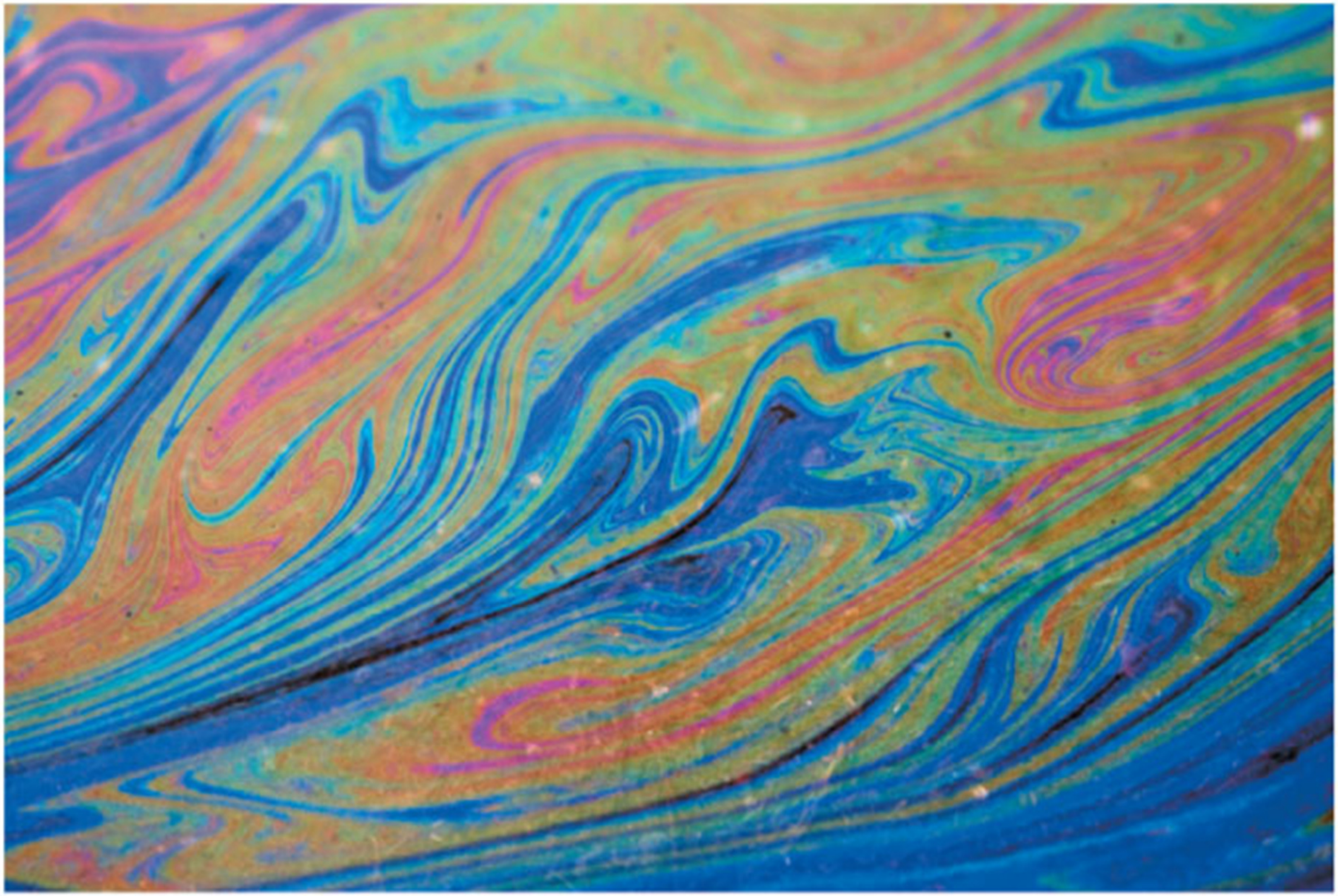
(a) Interference between rays reflected from the two surfaces of a thin film

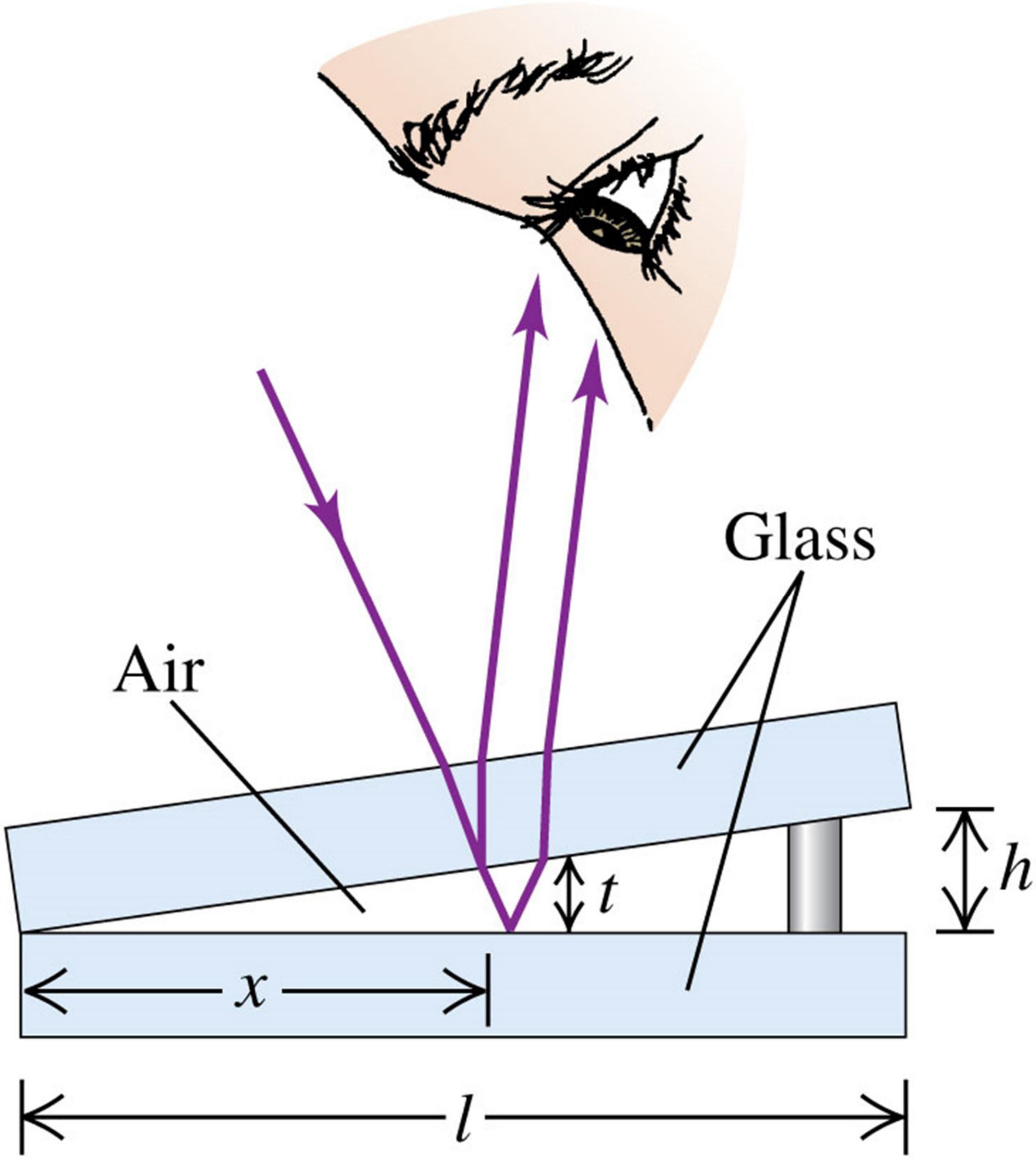
Light reflected from the upper and lower surfaces of the film comes together in the eye at *P* and undergoes interference.

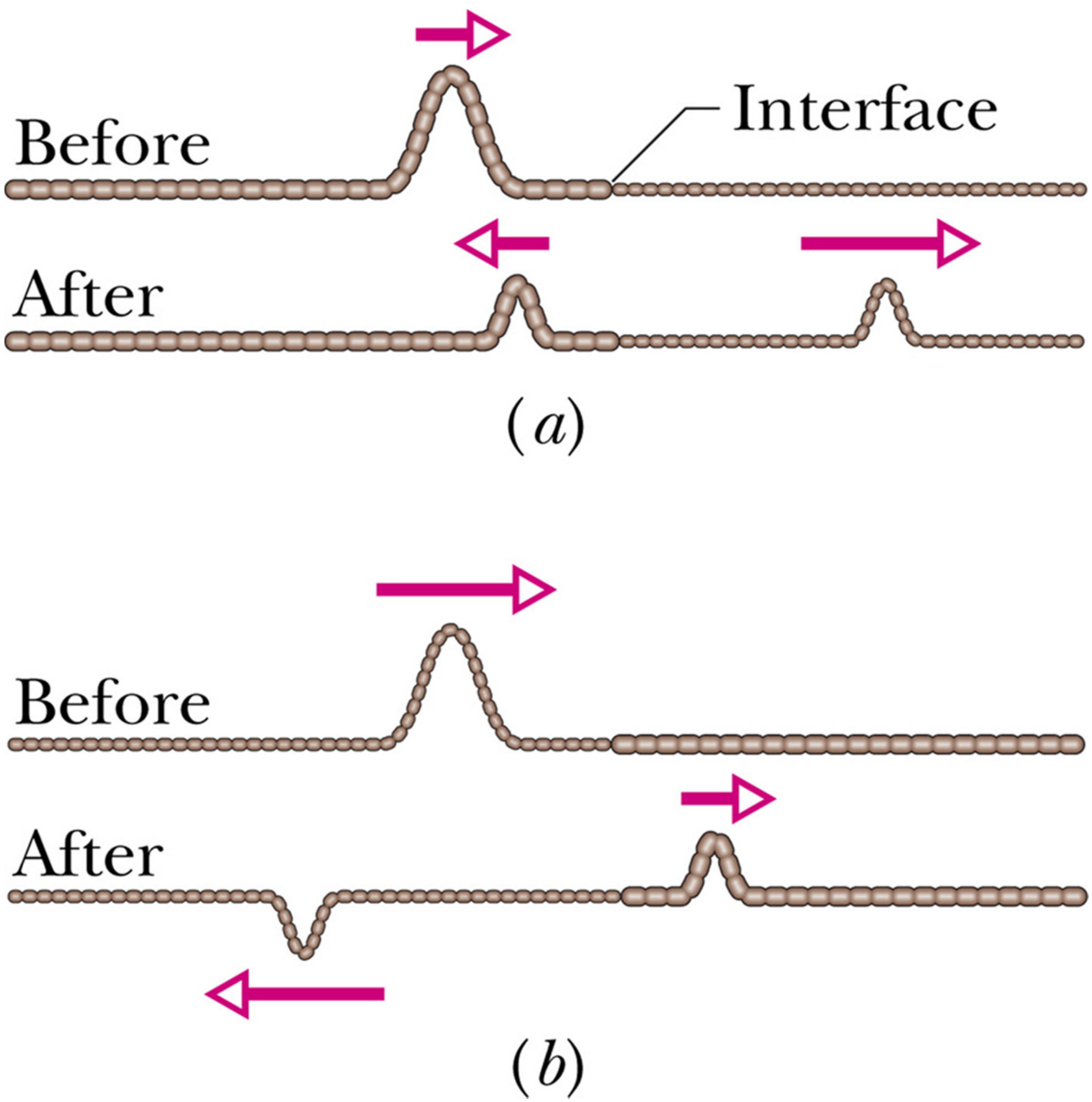
Some colors interfere constructively and others destructively, creating the color bands we see.



(b) The rainbow fringes of an oil slick on water




Glass
Air
t
h
x
l


Before
Interface
After
(a)
Before
After
(b)

n is factor speed slows down by

$v = c/n$

$v = f\lambda$

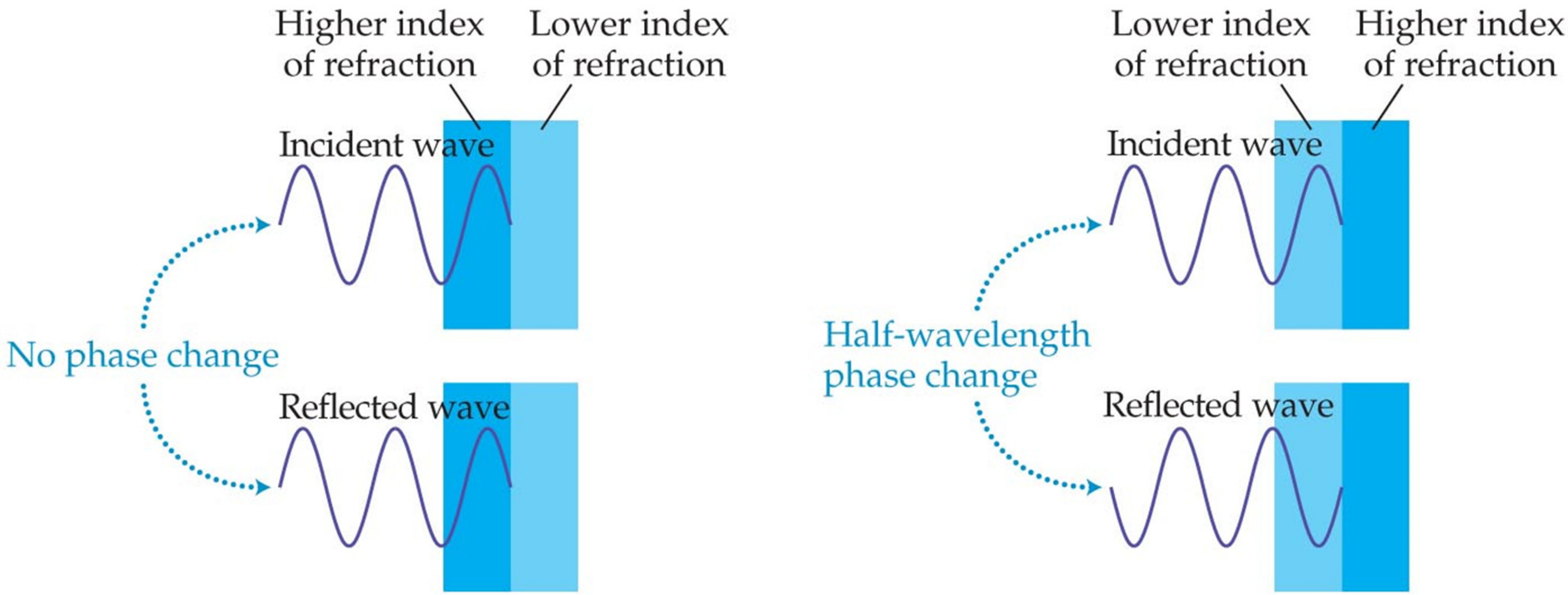
$E = hf$

$\lambda_n = \frac{\lambda}{n}$

Table 33.1 Index of Refraction for Yellow Sodium Light, λ_0 = 589 nm

Substance	Index of Refraction, *n*
Solids	
Ice (H_2O)	1.309
Fluorite (CaF_2)	1.434
Polystyrene	1.49
Rock salt (NaCl)	1.544
Quartz (SiO_2)	1.544
Zircon ($ZrO_2 \cdot SiO_2$)	1.923
Diamond (C)	2.417
Fabulite ($SrTiO_3$)	2.409
Rutile (TiO_2)	2.62
Glasses (typical values)	
Crown	1.52
Light flint	1.58
Medium flint	1.62
Dense flint	1.66
Lanthanum flint	1.80
Liquids at 20°C	
Methanol (CH_3OH)	1.329
Water (H_2O)	1.333
Ethanol (C_2H_5OH)	1.36
Carbon tetrachloride (CCl_4)	1.460
Turpentine	1.472
Glycerine	1.473
Benzene	1.501
Carbon disulfide (CS_2)	1.628

$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$

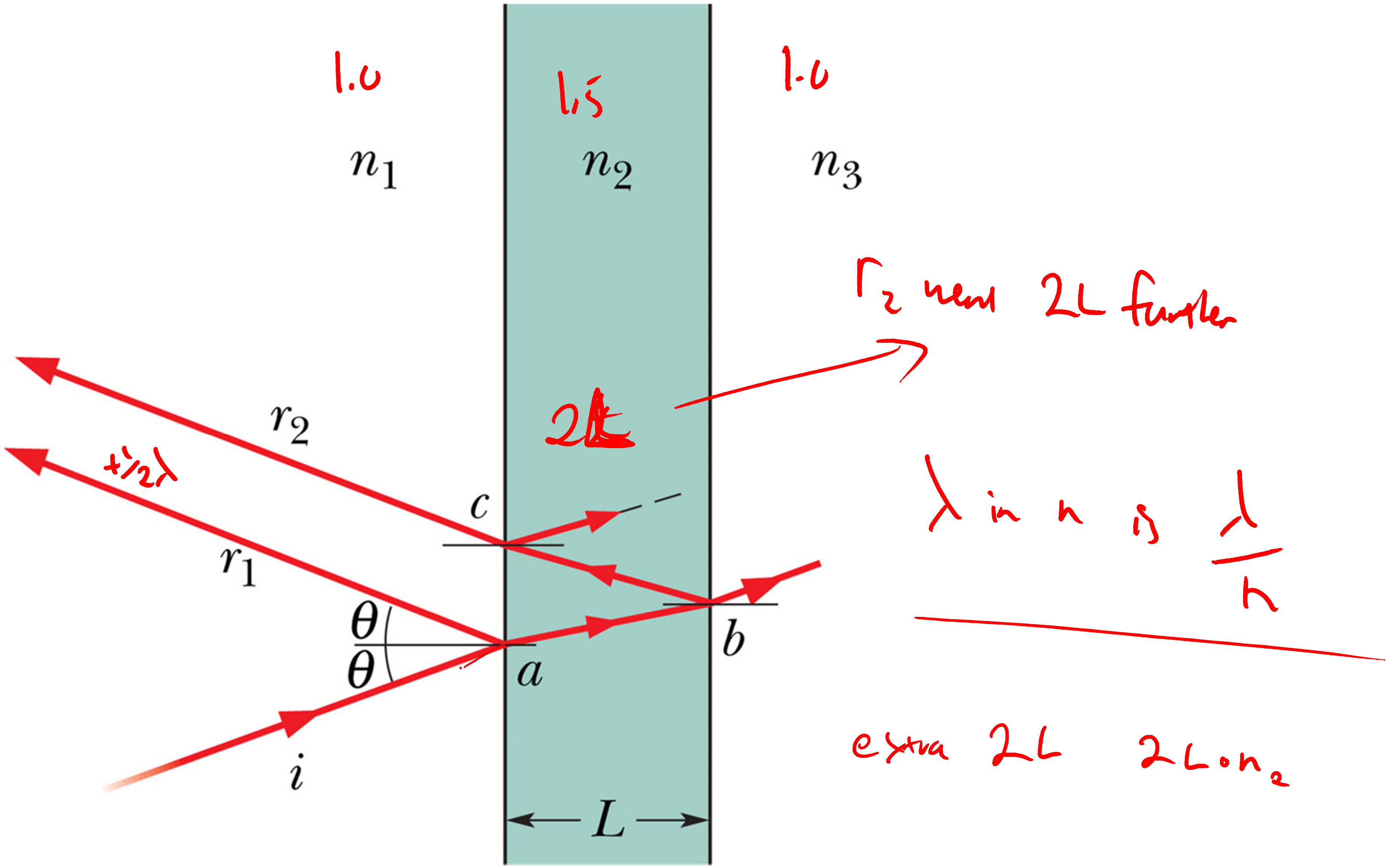


(a) Reflection from lower index of refraction

(b) Reflection from higher index of refraction

No bonus phase change

Bonus ½ λ phase change

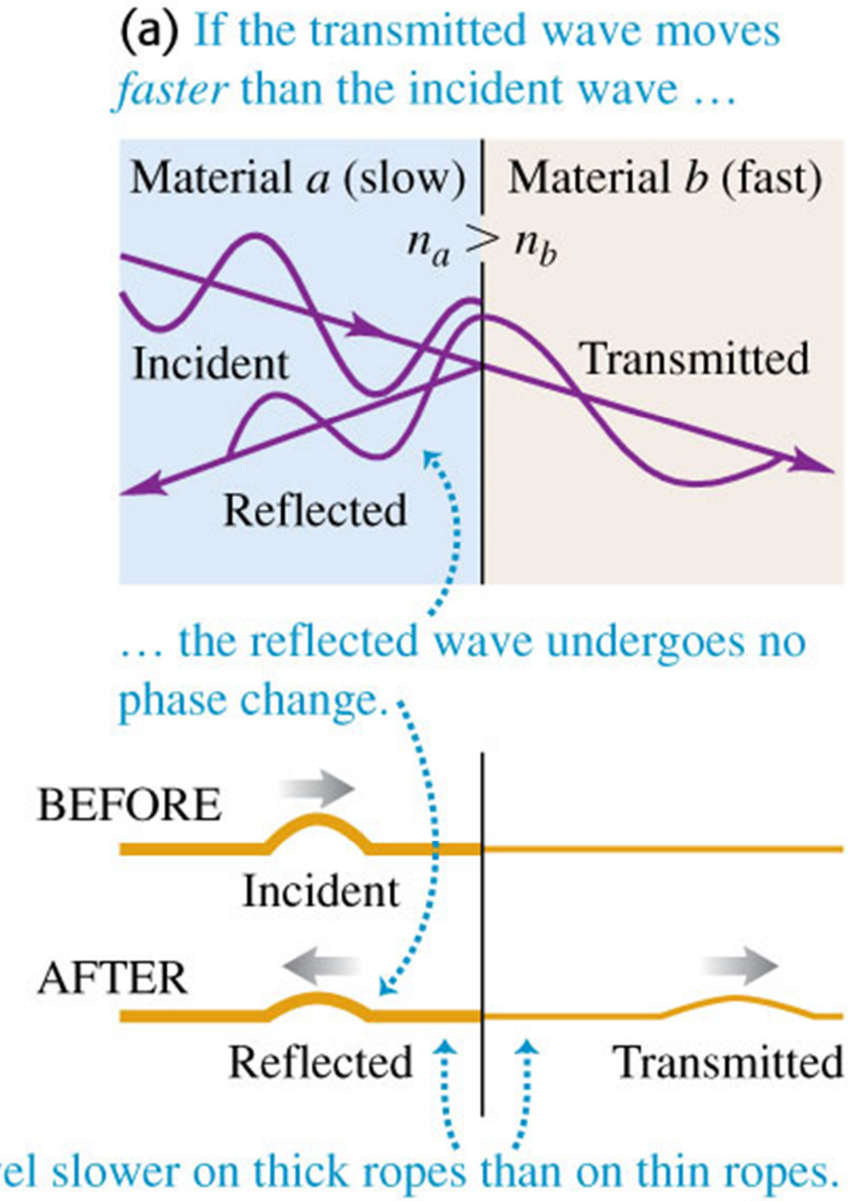


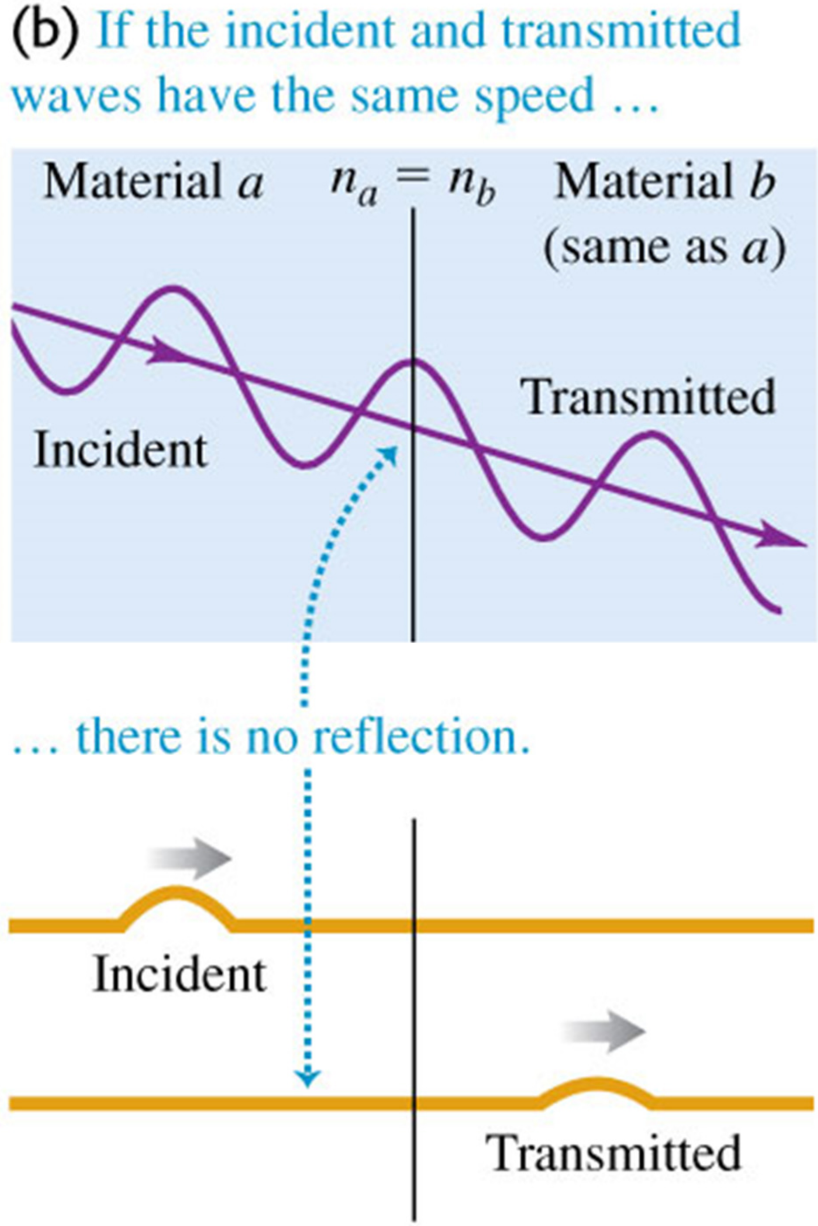
Three things to note:

1) Which reflections get an extra ½ λ?
2) Is some of the pathlength in a different n?
3) Transmitted light does not change phase

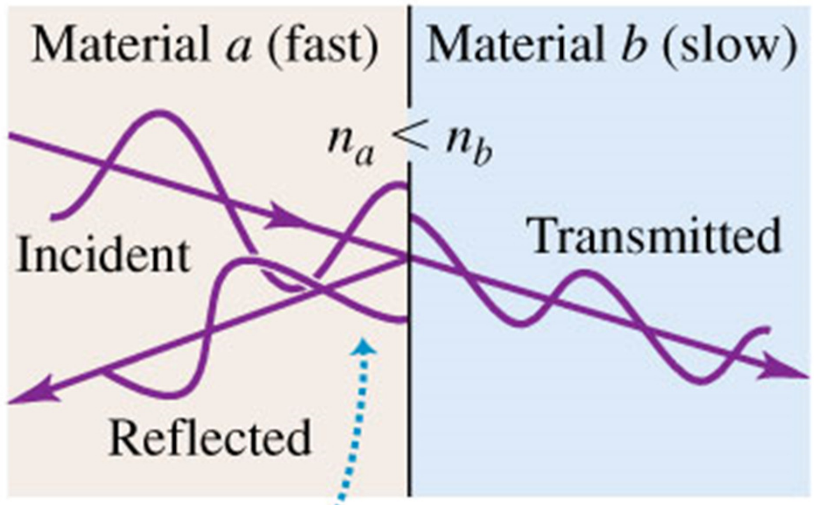
Electromagnetic waves propagating in optical materials

Mechanical waves propagating on ropes

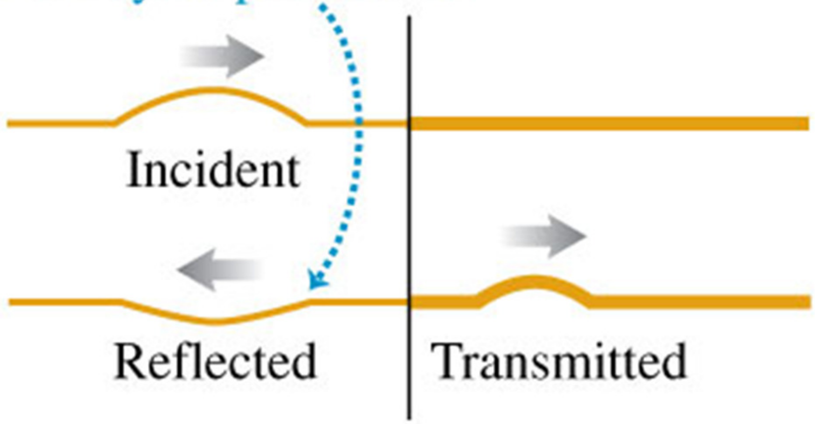


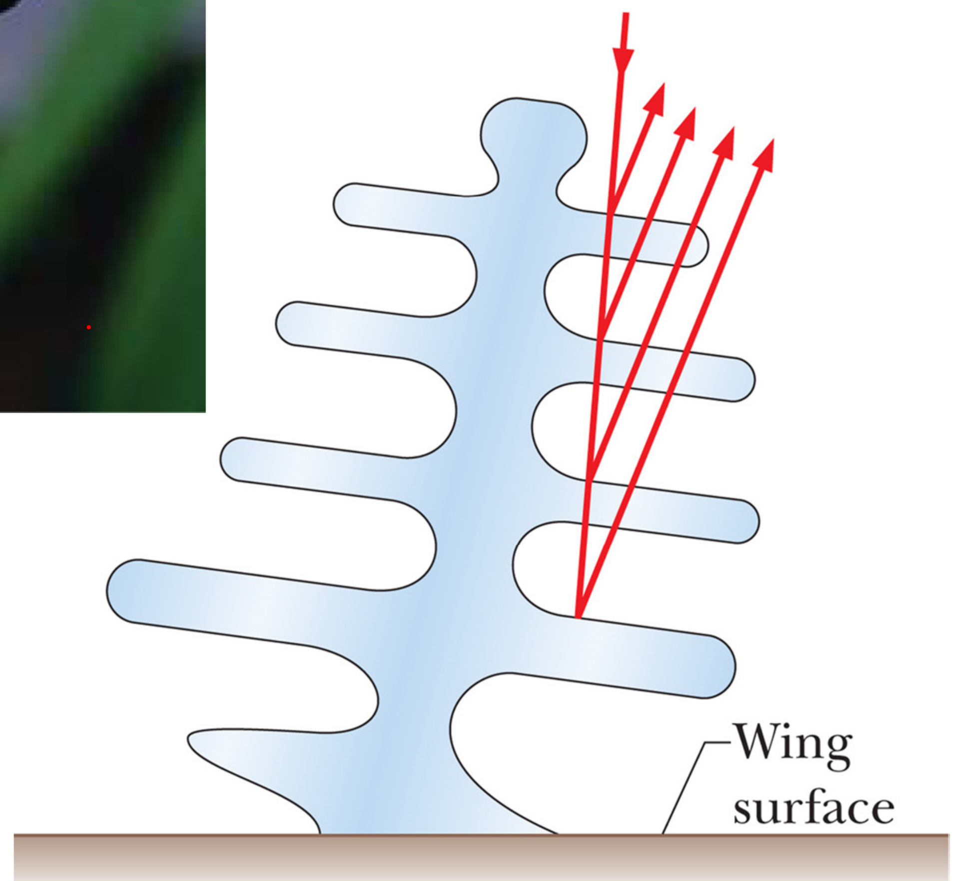

(b) If the incident and transmitted waves have the same speed …
Material a
$n_a = n_b$
Material b (same as a)
Transmitted
Incident
… there is no reflection.
Incident
Transmitted

(c) If the transmitted wave moves *slower* than the incident wave …



… the reflected wave undergoes a half-cycle phase shift.

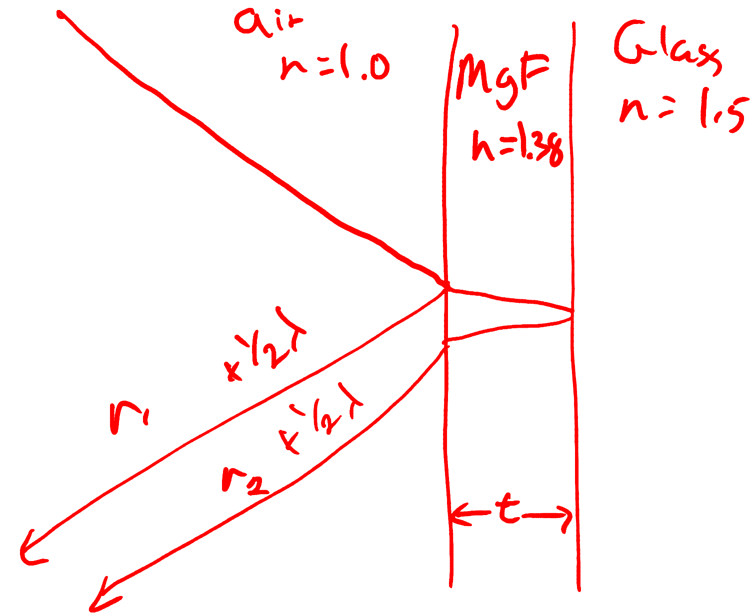


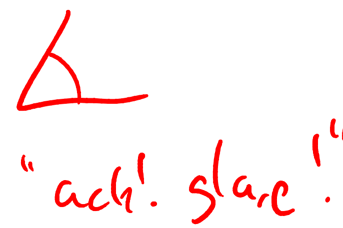

Wing surface

Do Problem #4 on the "Interference" handout from last week

We want $(r_2 - r_1) = (m + \tfrac{1}{2})\lambda$

for destructive interference





$(r_1 - r_2) = \Delta L$

$(~~+\frac{1}{2}\lambda~~ - ~~+\frac{1}{2}\lambda~~ + 2L) = \Delta L$

$\Delta L = 2L = (m+\frac{1}{2})\lambda$

$\Downarrow$

$2L = \frac{1}{2}\lambda_n$

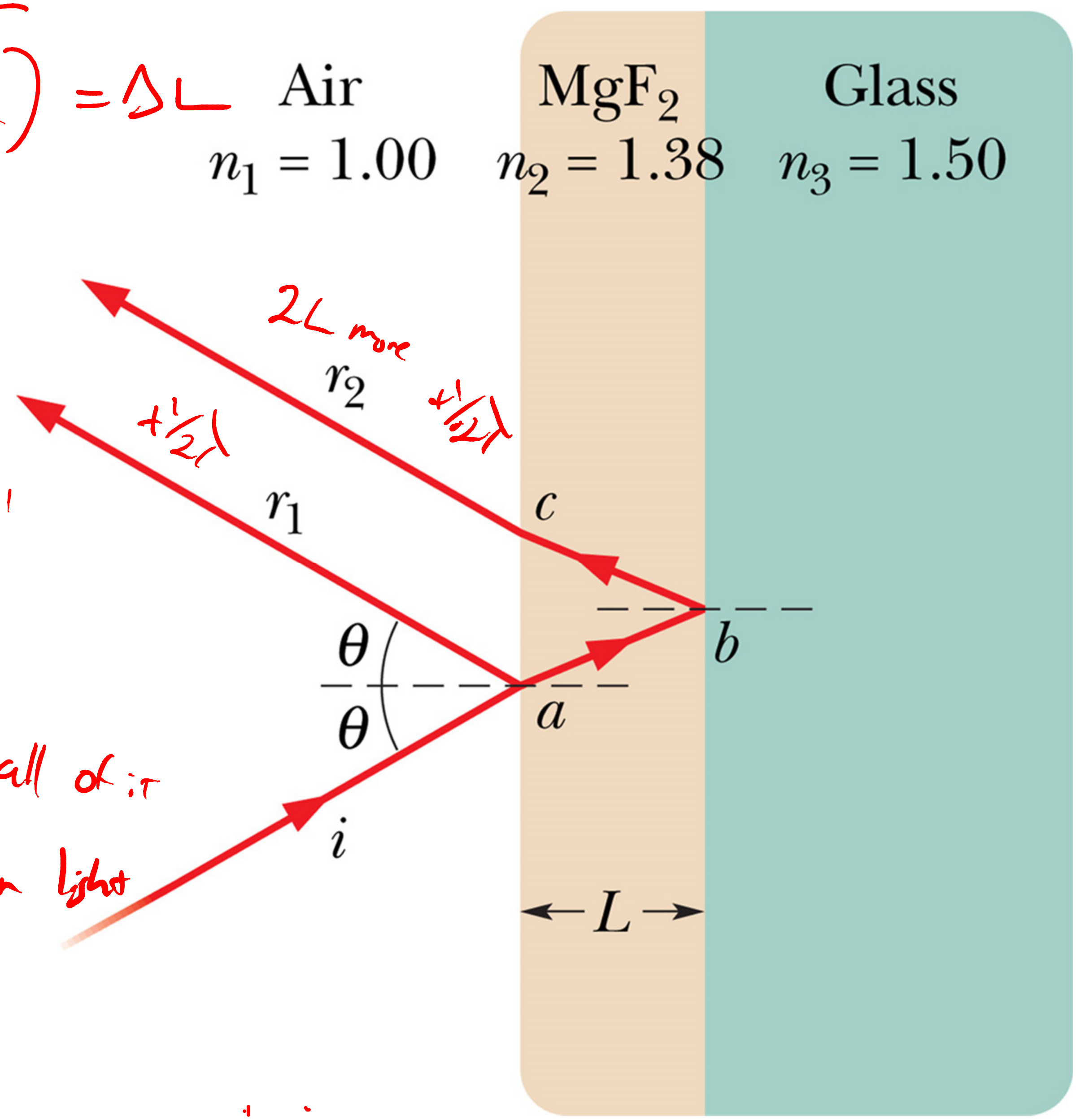
then r_1, r_2, cancel

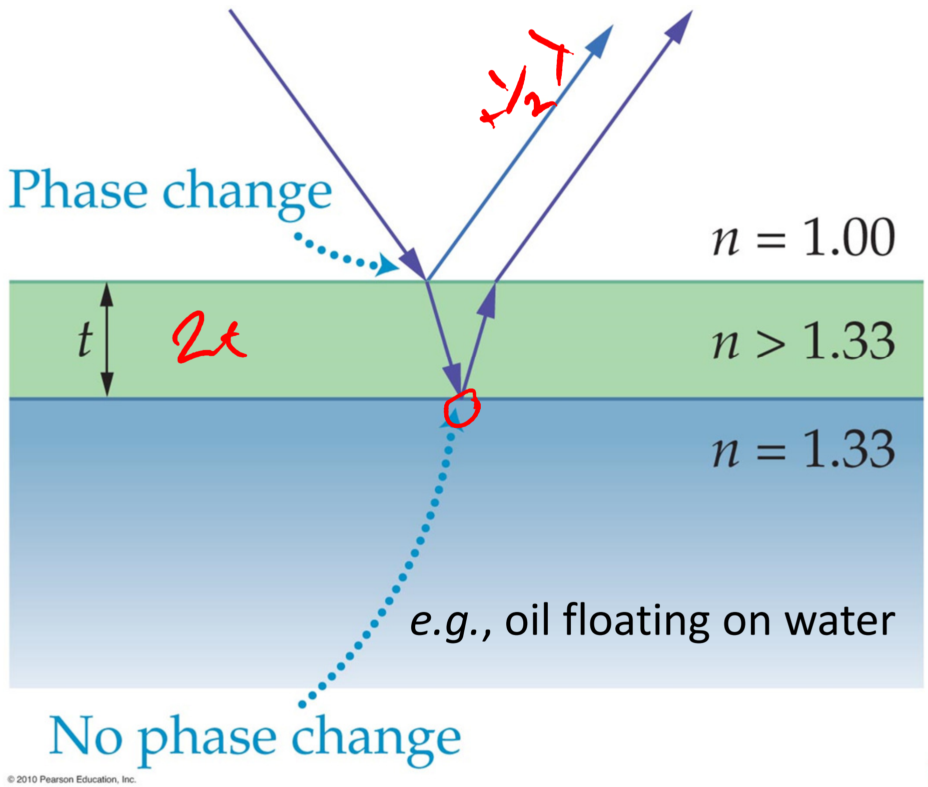
$L = \frac{\lambda}{4n_2}$

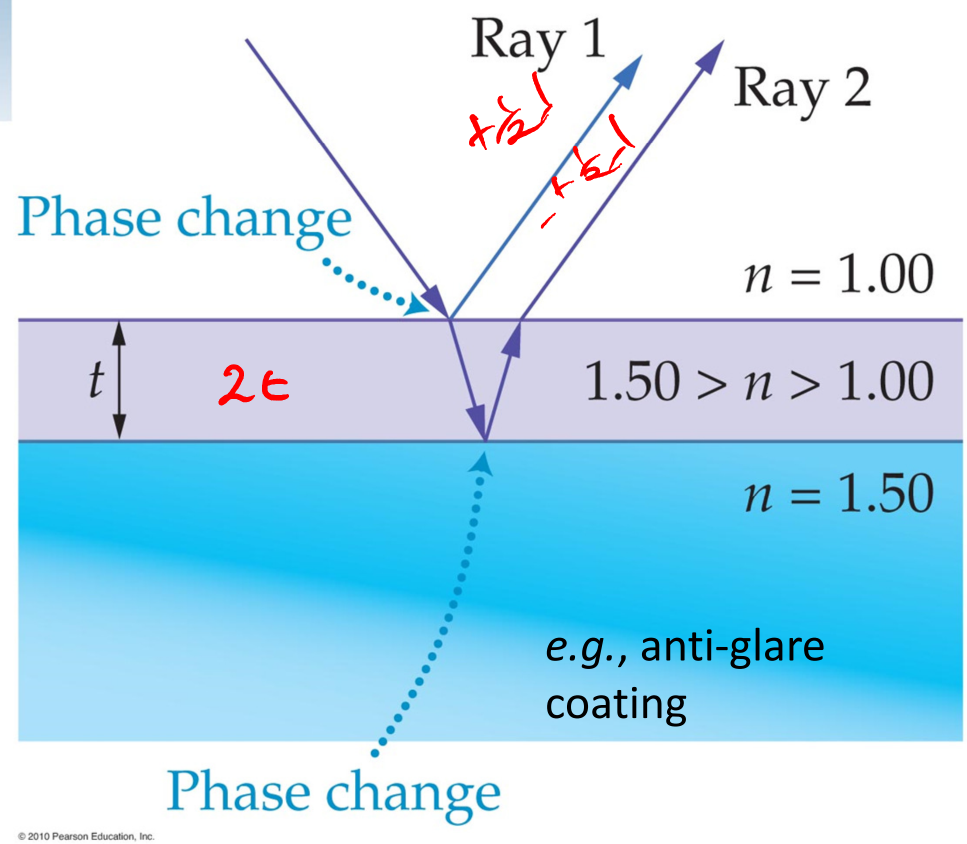
white light? can't do all of it

let's kill 550nm green light

$L = 99.6\,nm$







"Low to high, shift of pi,
High to low, shift of no"