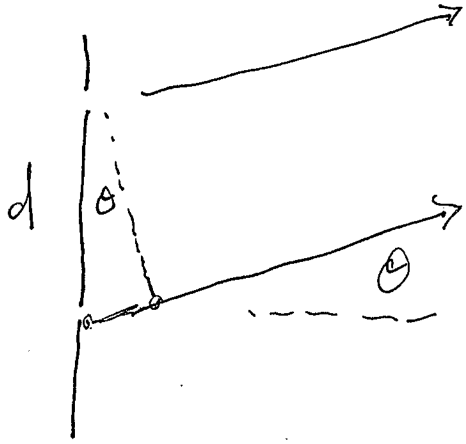
Lecture # 36

Diffraction &

Review

Interference



constructive interf.

$$d \sin\theta = m\lambda$$

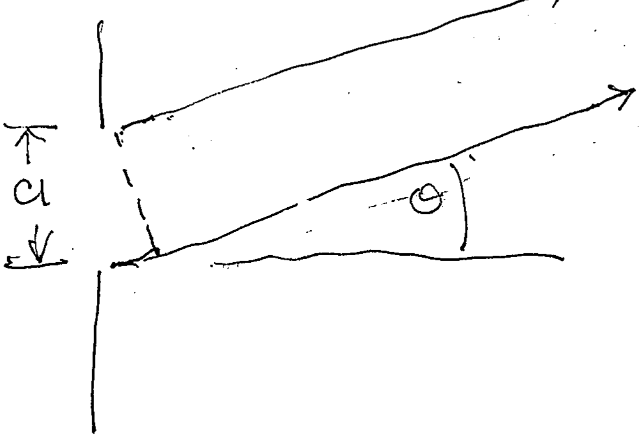
destructive interf.

$$d \sin\theta = (m + 1/2)\lambda$$

$$I = I_0 \cos^2\left(\frac{\phi}{2}\right)$$

$$\phi = \frac{d \sin\theta}{\lambda} 2\pi$$

Diffraction



null at

$$\frac{a}{\lambda} = m$$

$$I = I_0 \frac{\sin^2\beta}{\beta^2}$$

$$\beta \equiv \pi \frac{a \sin\theta}{\lambda}$$

What happened to "5"

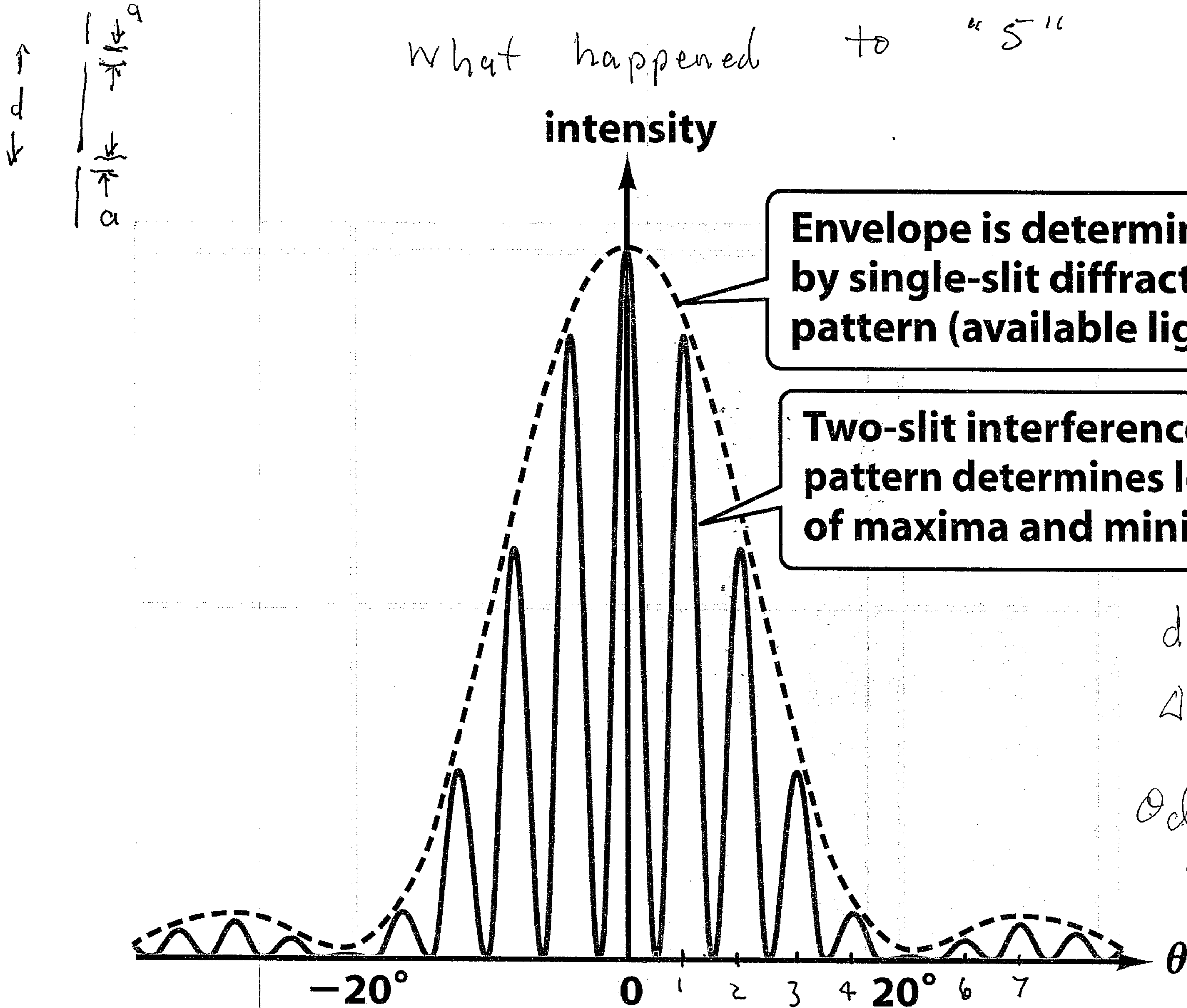


Figure 35-38 Physics for Engineers and Scientists 3/e

$\frac{d}{a} = ?\ 6$

$d\theta = m\lambda$ const

$\Delta\theta = \frac{\lambda}{d}$

$\theta d = 6 \cdot \lambda$

$\theta = 6\lambda/d = \frac{\lambda}{a}$

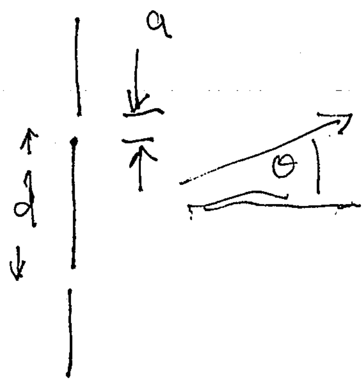
$a\theta = \lambda$

$\theta = \frac{\lambda}{a}$

Diffraction + Interference

Slits have finite size holes each one producing a diffraction pattern:

Result: Intertwing of diffraction and interferce



Single diffraction

$$I = I_0 \frac{\sin^2\beta}{\beta^2} \; ; \; \beta = \pi \frac{a \sin\theta}{\lambda}$$

Single slit

$$I = I_0 \cos^2\phi \; ; \quad \phi = \pi \frac{d \sin\theta}{\lambda}$$

Diffr + Interf.

$$I = I_0 \frac{\sin^2\beta}{\beta^2} \cos^2\phi$$

Diffraction of a circular aperature of radius a

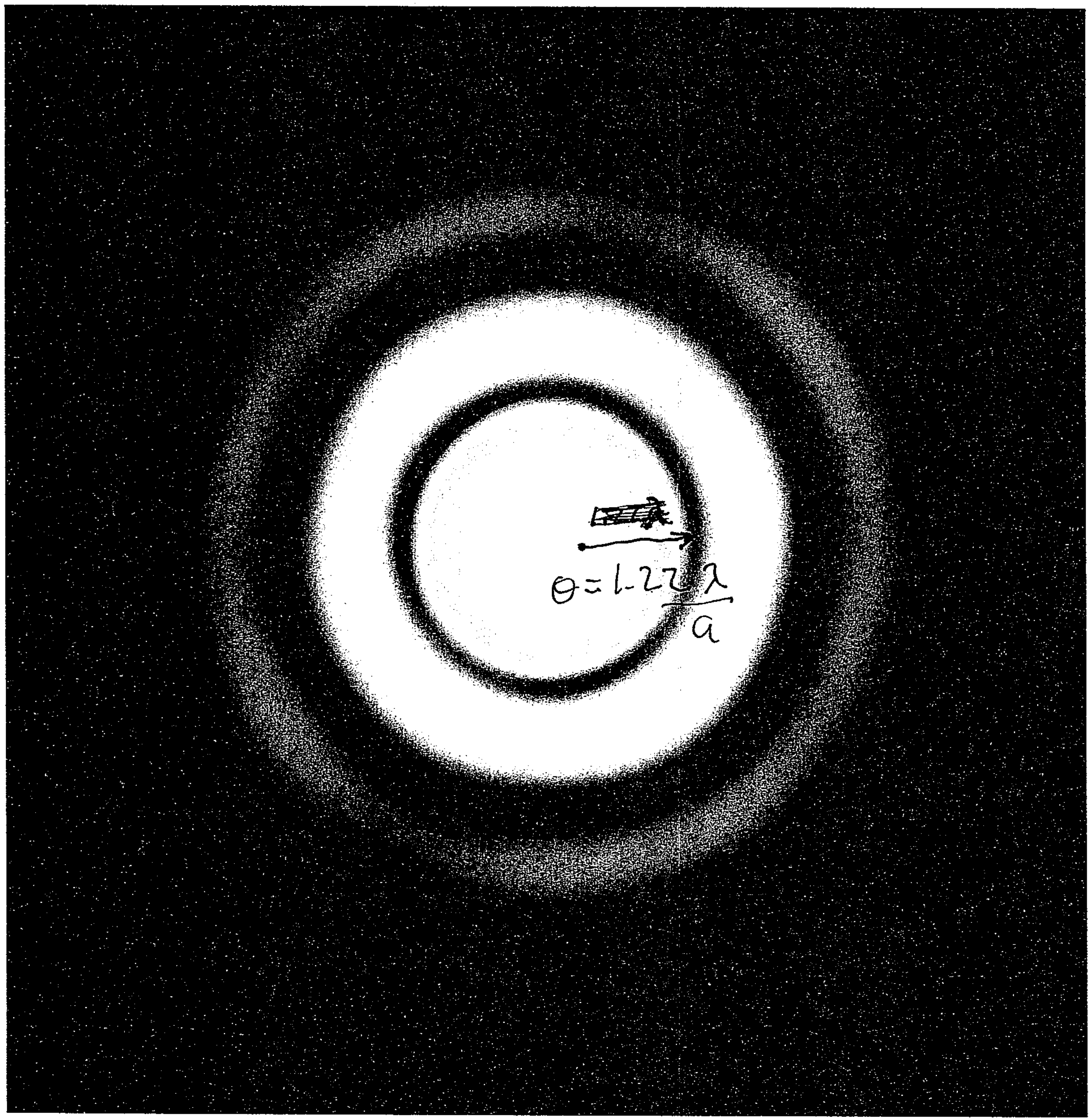
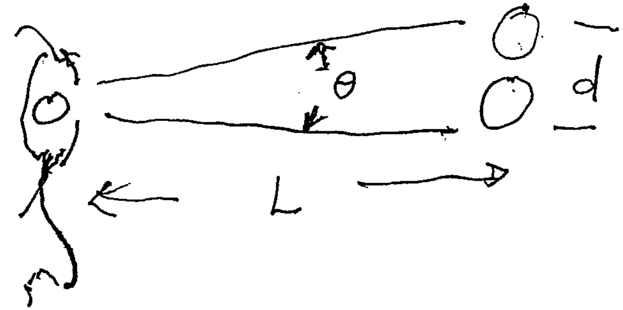


Figure 35-39 Physics for Engineers and Scientists 3/e
Courtesy of Chris C. Jones



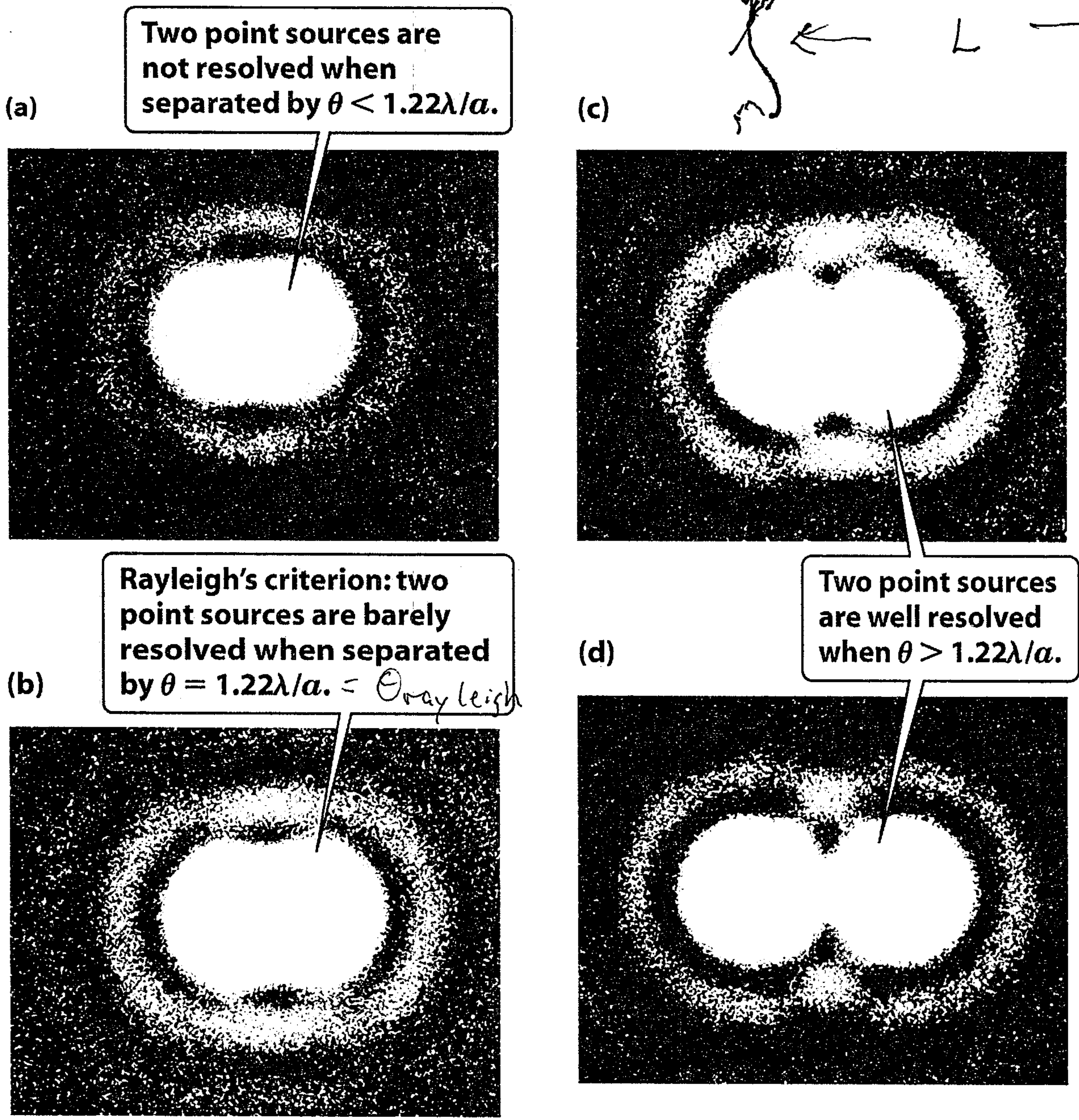


Figure 35-40 Physics for Engineers and Scientists 3/e
Courtesy of Chris C. Jones

Checkup 35.6

Two dots of red ink on a page are separated by 0.2 mm. Suppose your eye has an aperture of 0.5 cm. Of the following, what is the largest distance at which it is possible to resolve the dots, assuming otherwise perfect eyesight?

a. 3 cm
b. 10 cm
c. 30 cm
d. 100 cm ✓
e. 300 cm

$\lambda_{red} = .7 \times 10^{-6}$ m

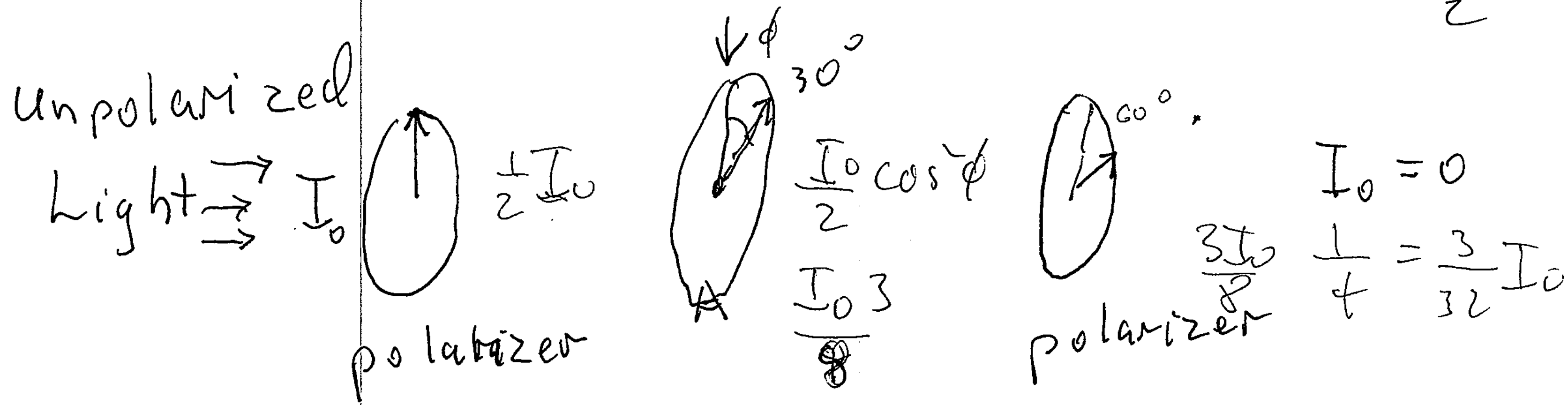
$\theta_{ray} = \frac{1.22\lambda}{a} = \frac{1.22 \times .7 \times 10^{-6}}{2 \times 10^{-4}}$

$= \frac{5 \times 10^{-3} \text{ m}}{L}$

~~$L = \frac{1.22 \times .7 \times 10^{-7}}{5 \times 2 \times 10^{-8}}$~~ $L = 5 \times 10^{-3}$

~~$L = \frac{1.22 \times .7 \times 10^{-6}}{2 \times 10^{-4} \times 5}$~~

$\cos 30^\circ = \frac{\sqrt{3}}{2}$



Two polarizers perpendicular to each other block all the incident light of intensity I_0. If we now insert, at A, a polarizer; polarized at an angle 30° to the first polarizer, What is the light intensity that passes through the second polarizer

(a) 0 (b) $\frac{3}{8} I_0$ (c) $\frac{3}{16} I_0$ (d) $\frac{I_0}{2}$

(e) $3I_0/32$

(1)

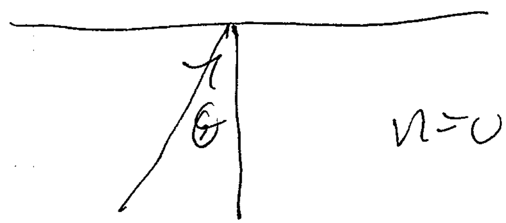
Checkup 34.3

Light within a material with index of refraction $n = 2.0$ is incident upon an interface with air; the incident ray makes an angle θ with the perpendicular. Which of the following is the full range of angles of incidence for which total internal reflection occurs?

a. $0 < \theta < 30°$
b. $0 < \theta < 60°$
c. $30° < \theta < 60°$
d. $30° < \theta < 90°$ ✓
e. $60° < \theta < 90°$

$2 \sin\theta_c = 1$

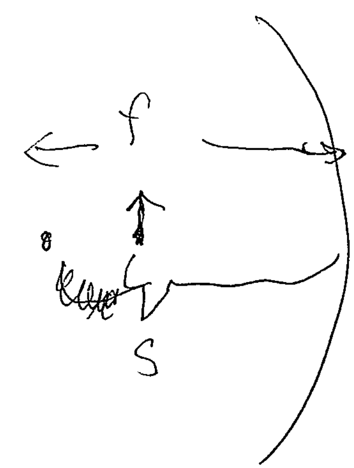
$\sin\theta_c = \frac{1}{2}$ $\quad\theta_c = 30°$



Checkup 34.4

Consider a concave mirror, with an object closer to the mirror than the focal point. Which of the following is true? The image is:

a. Virtual and upright, with $s' < 0$
b. Virtual and inverted, with $s' < 0$
c. Real and inverted, with $s' > 0$
d. Real and upright, with $s' < 0$
e. Virtual and upright, with $s' > 0$



Checkup 34.5

A thin lens has one convex surface with radius of curvature 2.0 m and one concave surface with radius of curvature 1.0 m. If the lens is made of glass of index of refraction 1.5, what is its focal length?

a. 4.0 m
b. -2.0 m
c. 1.3 m
d. 2.0 m
e. -4.0 m ✓

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

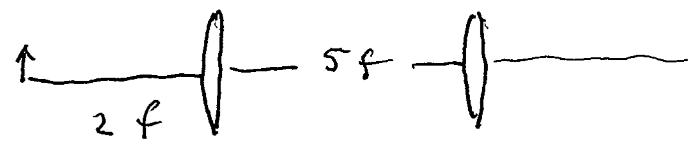
$$= .5\left(\frac{1}{2} - \frac{1}{1}\right) = -\frac{1}{2} \cdot \frac{1}{2} = -\frac{1}{4}$$

$f = -4\,m$

Checkup 34.6

Two converging lenses have the same focal length f. An object is a distance $s_1 = 2f$ from the first lens, and the lenses are separated by a distance $5f$. With respect to the upright object, the final image of the second lens is:

a. Upright and real
b. Upright and virtual
c. Inverted and real
d. Inverted and virtual

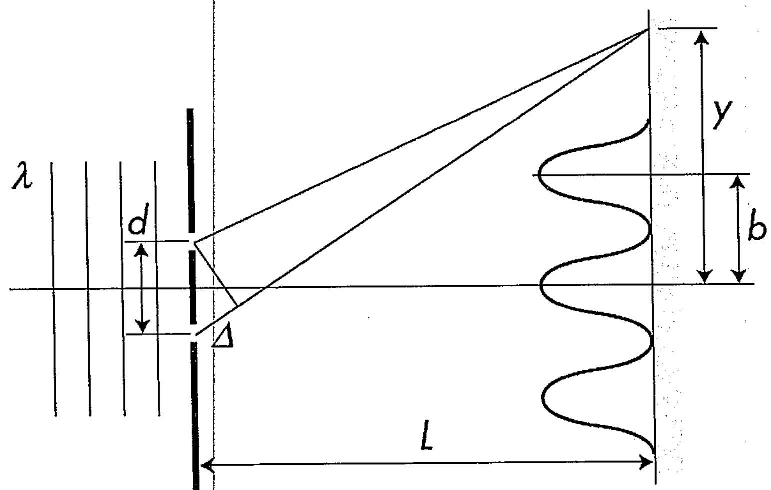


Checkup 35.1

A "nonreflective" coating is sometimes put on glass lenses to increase the light entering an optical system. For a wavelength of 500 nm in air, what is the smallest coating thickness that could be used to minimize reflection? The index of refraction of the coating is 1.25, and that of the glass is 1.50.

a. 100 nm
b. 125 nm
c. 156 nm
d. 200 nm
e. 250 nm

PhysiQuiz 35-4



In the double-slit experiment shown here, λ represents the wavelength of the incident light, L represents the slit screen distance, d is the slit separation, and b is the spacing between adjacent maxima. Consider these statements:

I. A bigger L leads to a bigger b.

II. A bigger λ leads to a bigger b.

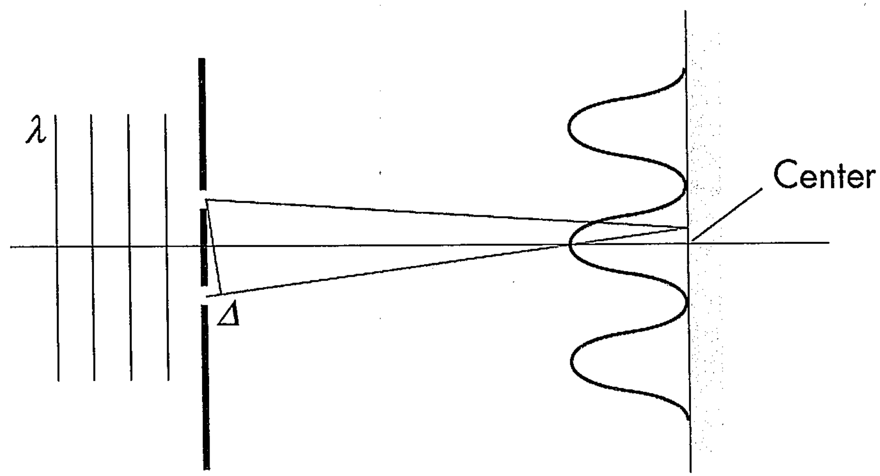
III. A bigger d leads to a bigger b.

Which set of statements is correct?

A	B	C	D
I and II only	I and III only	II and III only	I, II, and III

Hint: Use the small-angle approximation: $\theta \approx \Delta/d \approx y/L$.

PhysiQuiz 35-3



Consider the setup of a double-slit experiment. Denote the intensity at the center of the screen as I_0. For a path difference $\Delta = \lambda/6$, the corresponding intensity is which of the following?

	A	B	C
I	$I_0/4$	$I_0/2$	$3I_0/4$

Hint: The intensity $I = I_0 \cos^2(\phi/2)$, $\phi = k\Delta$, $k = 2\pi/\lambda$.

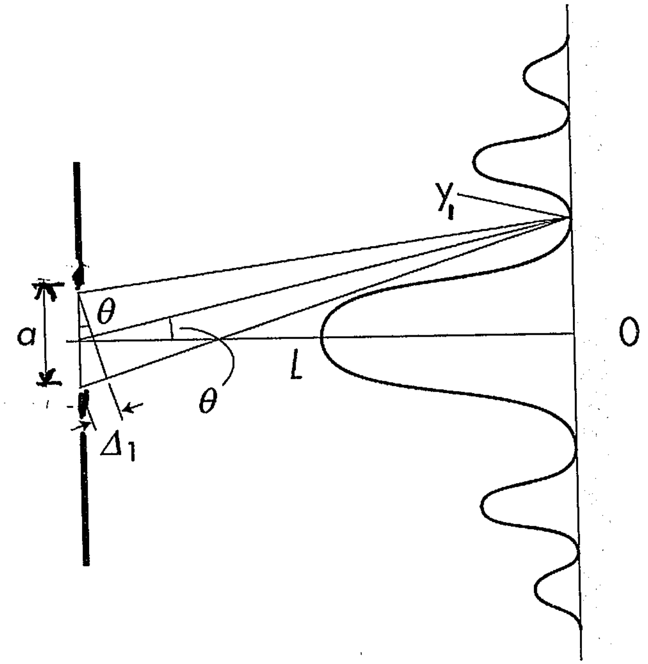
Extra: What is the least positive value of Δ that leads to $I = I_0/4$?

PhysiQuiz 35-7

Consider a single-slit experiment. At the first minimum the quantities shown in the sketch are y_1 and Δ_1. By definition $\beta_1 = 2\pi\Delta_1/\lambda$. Find β at $y = y_1/6$.

	A	B	C	D
β	$\pi/6$	$\pi/5$	$\pi/4$	$\pi/3$

Hint: Since $\beta = 2\pi\Delta/\lambda$, assume the small-angle approximation:
$\theta \approx \Delta/a \approx y/L$.



Extra: Show that $\Delta/\Delta_1 = 1/6$ and

$$\frac{I(\beta)}{I(0^0)} = \frac{\sin^2(\beta/2)}{(\beta/2)^2} = 9/\pi^2.$$