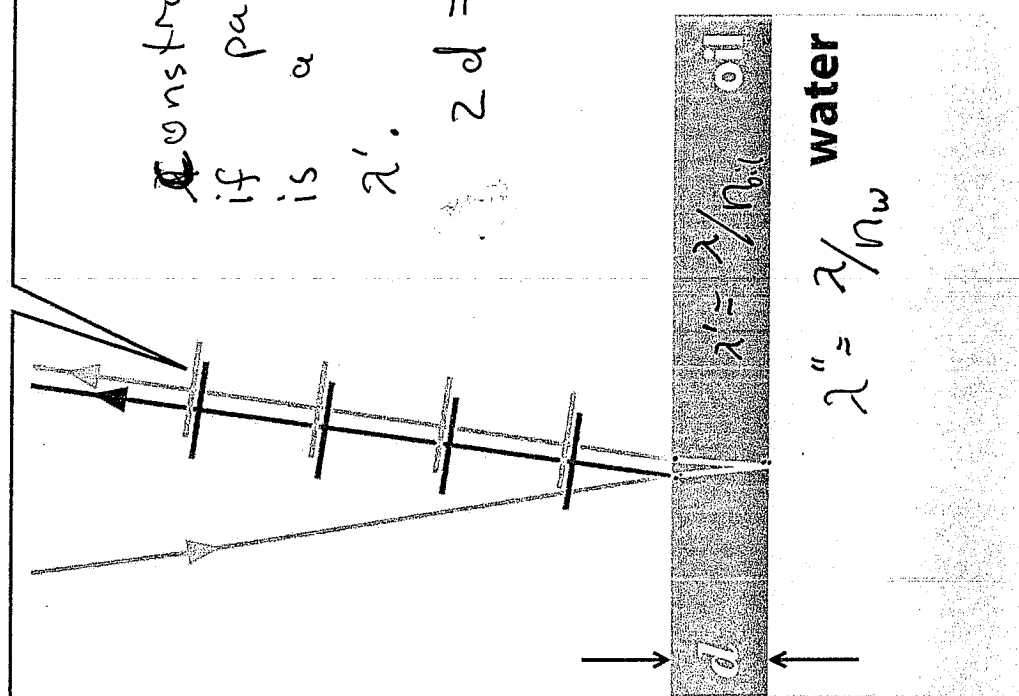


Lecture # 35

Diffraction

When  $d$  is such that crests of both reflected waves coincide, constructive interference occurs.



$n_{oil} = 1.25$   
 $n_{water} = 1.33$

Constructive interference if path length difference is a multiple of a wavelength  $\lambda'$ .

$2d = m\lambda' = \frac{\lambda m}{n_{oil}}$

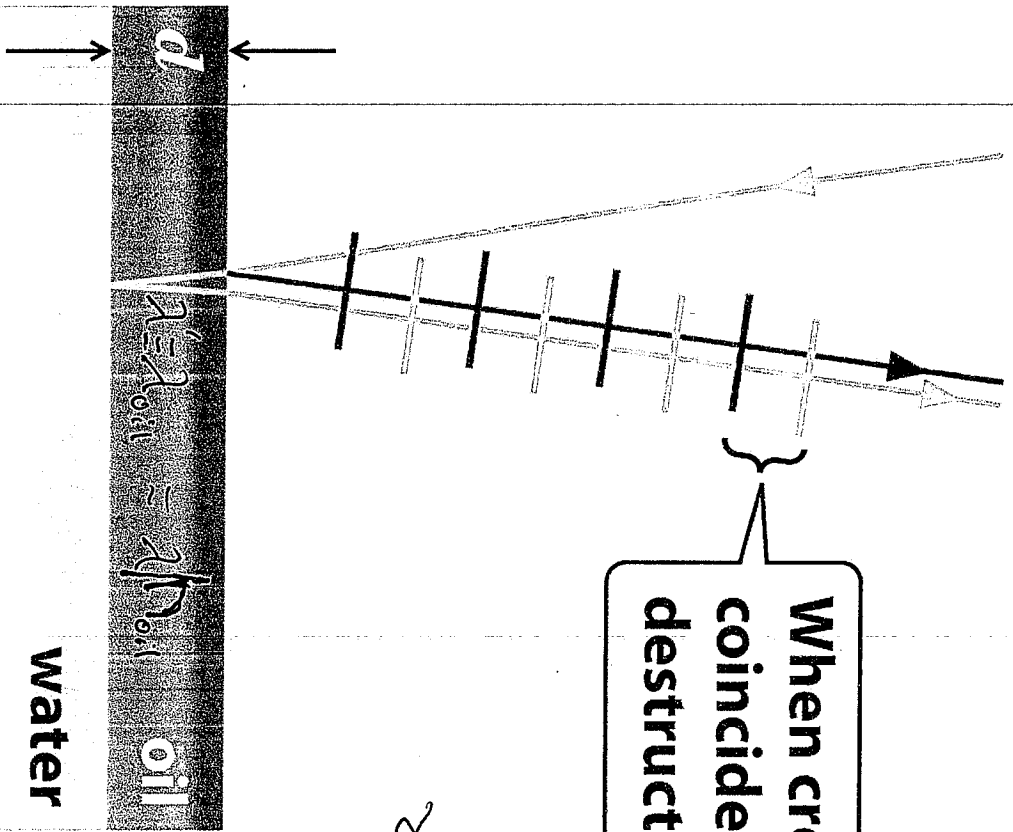
$d = \frac{\lambda m}{2 n_{oil}}$

destructive interference if

$2d = (m + \frac{1}{2}) \lambda' = \frac{(m + \frac{1}{2}) \lambda}{n_{oil}}$

However important modification occurs depending on film and backing material.

Figure 35-4 Physics for Engineers and Scientists 3/e © 2007 W. W. Norton & Company, Inc.



When crest of one reflected wave coincides with trough of other, destructive interference occurs.

$$2d = (m + \frac{1}{2}) \lambda' = (m + \frac{1}{2}) \frac{\lambda}{n_{oil}}$$

This result occurs if

$$n_{oil} < n_{water}$$

A twist when if

$$n_{oil} > n_{water}$$

$E$ -field changes sign if light reflection from larger index of refraction material. Leads to an interchange of formulas for destructive interference

Figure 35-5 Physics for Engineers and Scientists 3/e © 2007 W. W. Norton & Company, Inc.

The electric field at a point  $x$  of a monochromatic light wave is:  $\vec{E}_0(t) \hat{y}$  If

this light wave has a wavelength  $\lambda$ , how far in front of this point of the light wave will the electric field be  $-\vec{E}_0(t) \hat{y}$

(a)  $\lambda/4$

(b)  $\lambda/2$   $\vec{E}_0 \cos\left(\frac{ct - x}{\lambda} 2\pi\right)$

(c)  $\lambda$  at  ~~$x+d$~~   $x \rightarrow x+d$

$$+\vec{E}_0 \cos\left(\frac{ct - x + d}{\lambda} 2\pi\right)$$

$$d = \frac{\lambda}{2}$$

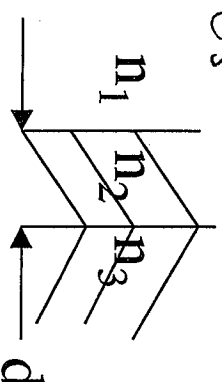
$$= -\vec{E}_0 \cos\left(\frac{ct - x}{\lambda} 2\pi\right)$$

$$= \vec{E}_0 \cos\left(\frac{ct - x}{\lambda} 2\pi - \frac{\lambda}{2\lambda} 2\pi\right)$$

# THIN-FILM INTERFERENCE

of Reflected Waves

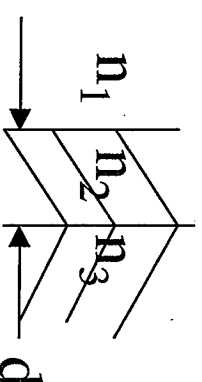
When  $1 = n_1 < n_2 < n_3$



Maxima:  $2d = \lambda_1/n_2, 2\lambda_1/n_2, 3 \lambda_1/n_2 \dots$

Minima:  $2d = \lambda_1/2n_2, 3 \lambda_1/2n_2, 5 \lambda_1/2n_2 \dots$

When  $1 = n_1 < n_2 > n_3$



Maxima:  $2d = \lambda_1/2n_2, 3 \lambda_1/2n_2, 5 \lambda_1/2n_2 \dots$

Minima:  $2d = \lambda_1/n_2, 2\lambda_1/n_2, 3 \lambda_1/n_2 \dots$

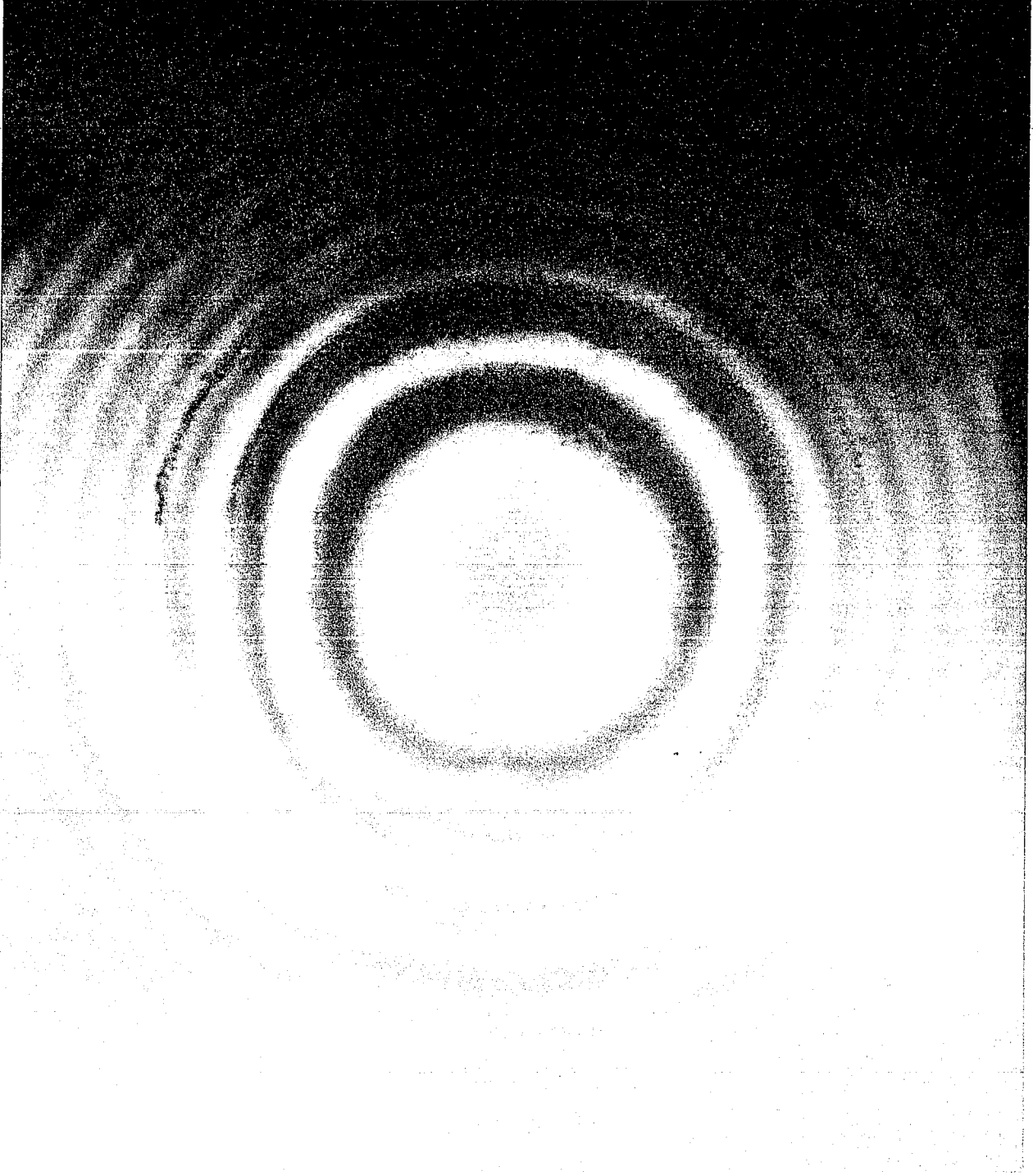


Figure 35-7 Physics for Engineers and Scientists 3/e  
Sciencephotos/Alamy

## Newton's Rings

$$d + R \cos \theta = R$$

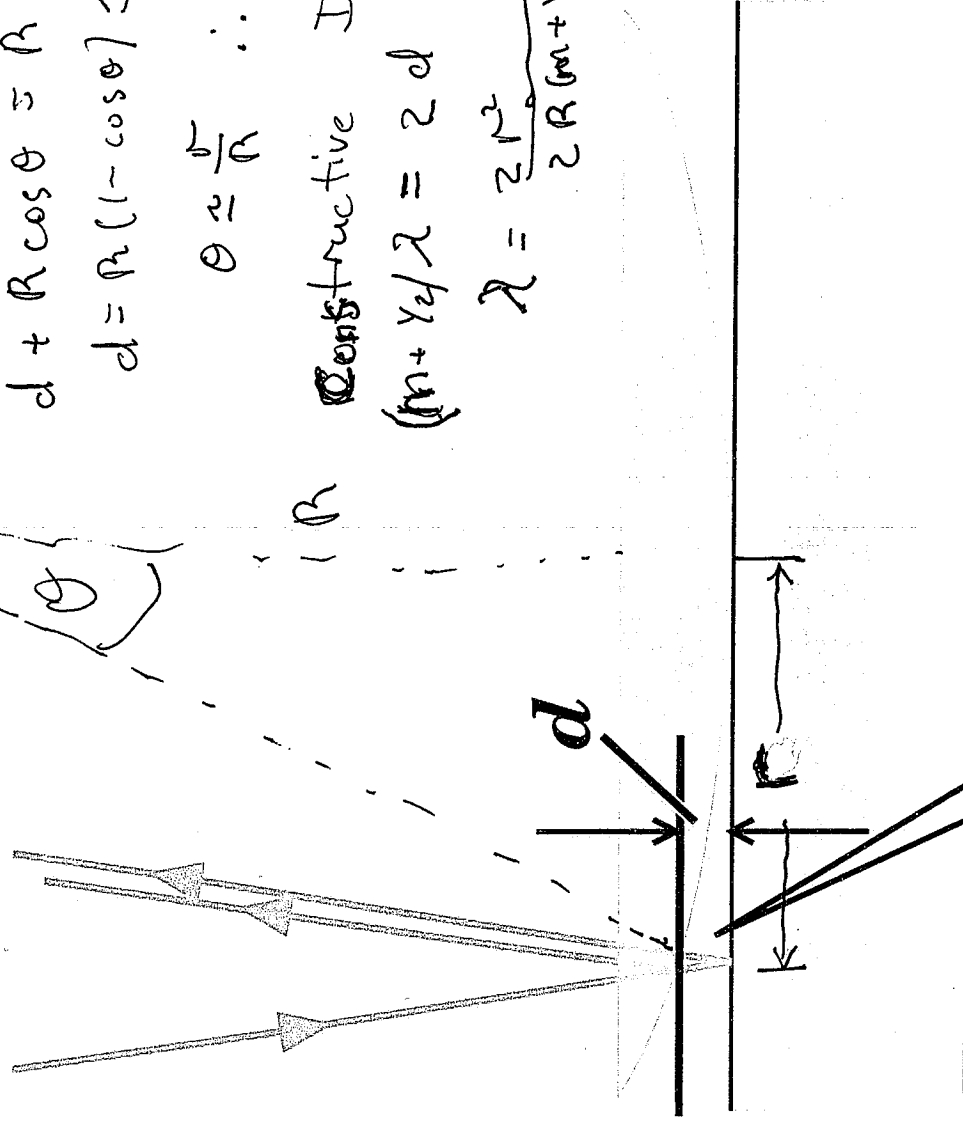
$$d = R(1 - \cos \theta) \approx \frac{R\theta^2}{2}$$

$$\theta \approx \frac{\lambda}{R} \quad \therefore d \approx \frac{\lambda^2}{2R}$$

Constructive Interference

$$(m + \frac{1}{2})\lambda = 2d; \quad \lambda = \frac{2d}{(m + \frac{1}{2})}$$

$$\lambda = \frac{2R^2}{2R(m + \frac{1}{2})} = \frac{R^2}{(m + \frac{1}{2})R}$$



**Here, thin film is air layer between flat and curved glass surfaces.**

Figure 35-8 Physics for Engineers and Scientists 3/e  
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Diffraction

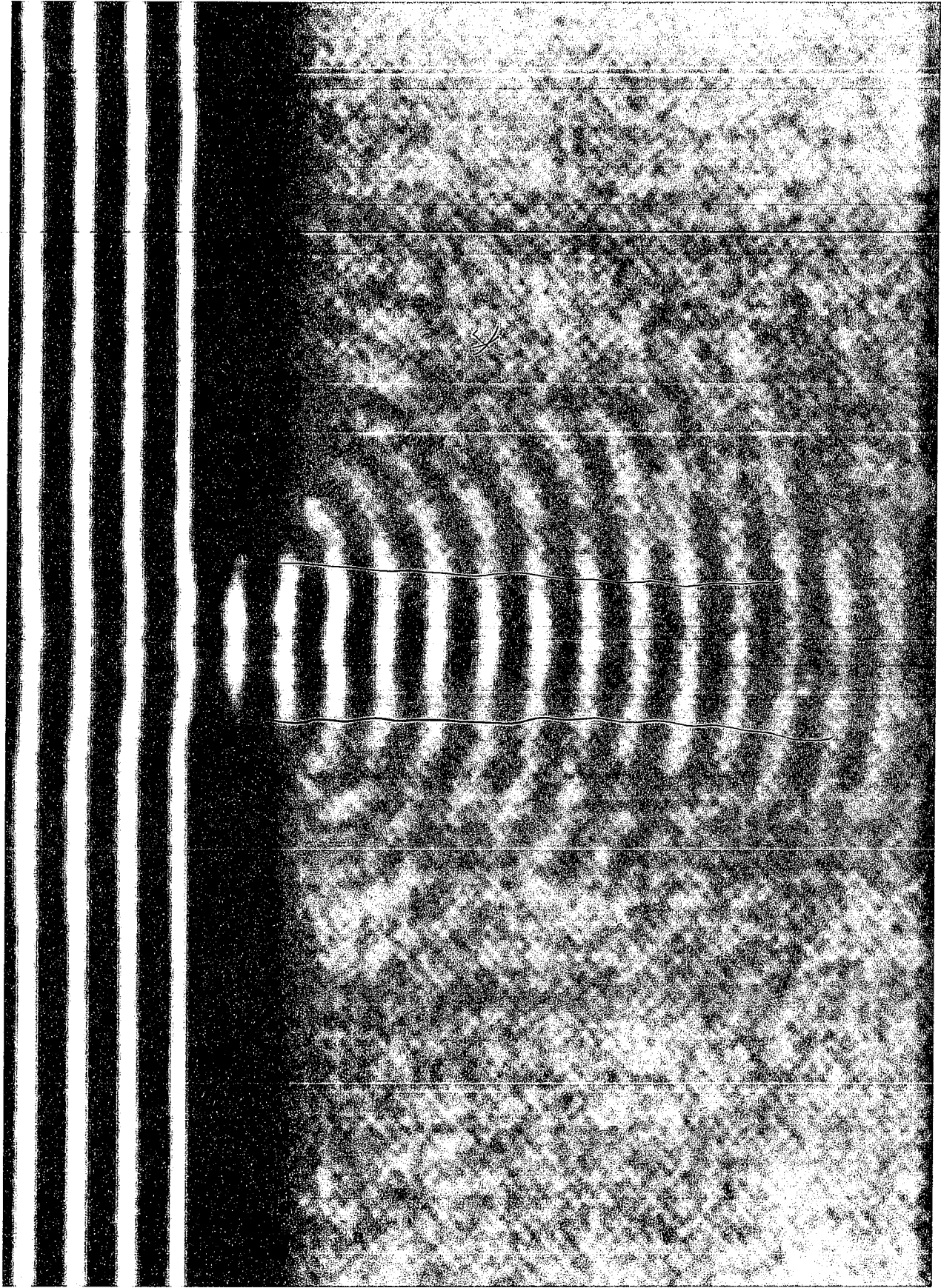


Figure 35-28 Physics for Engineers and Scientists 3/e  
*Principals of Physics* by Hans Ohanian



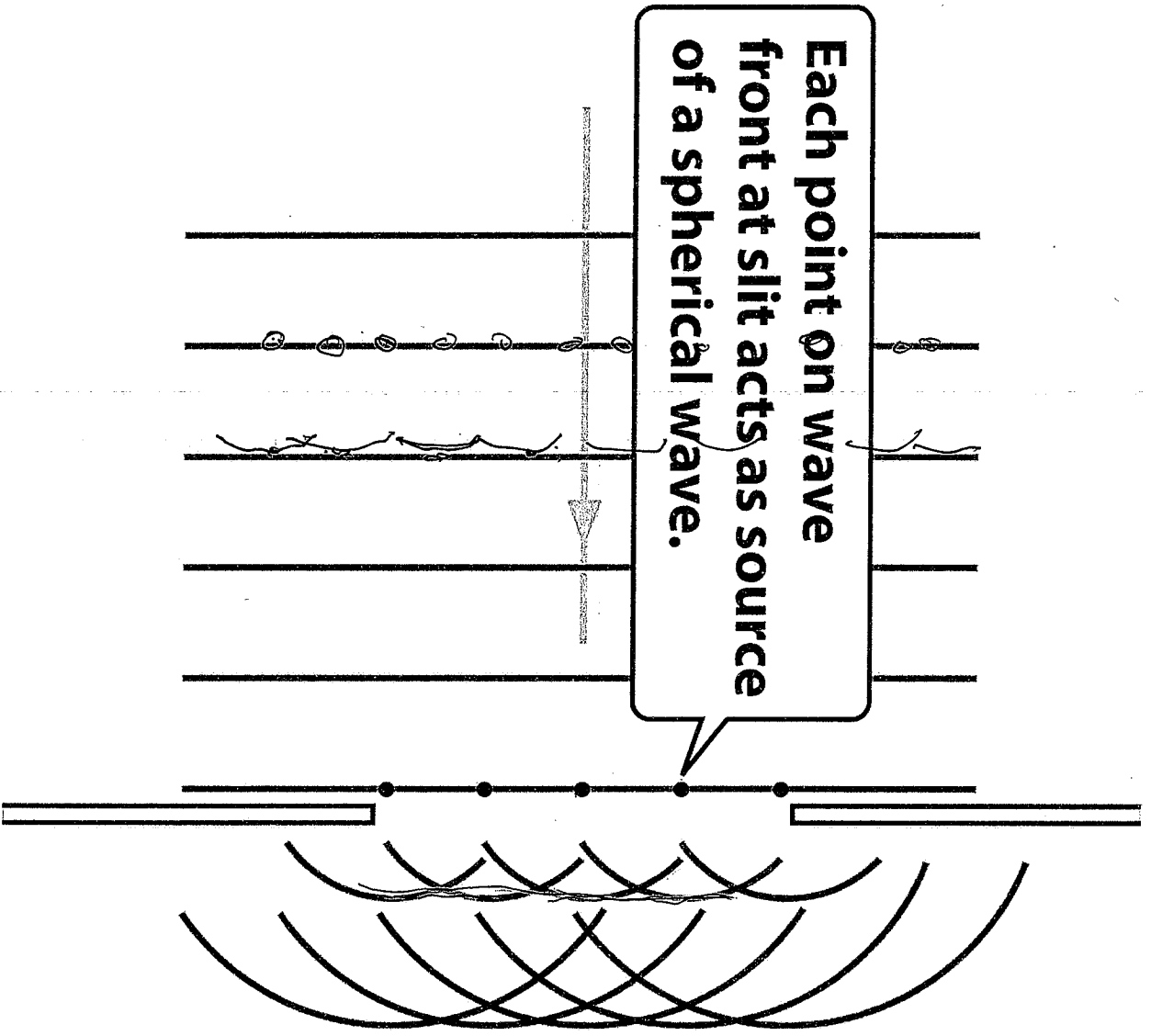
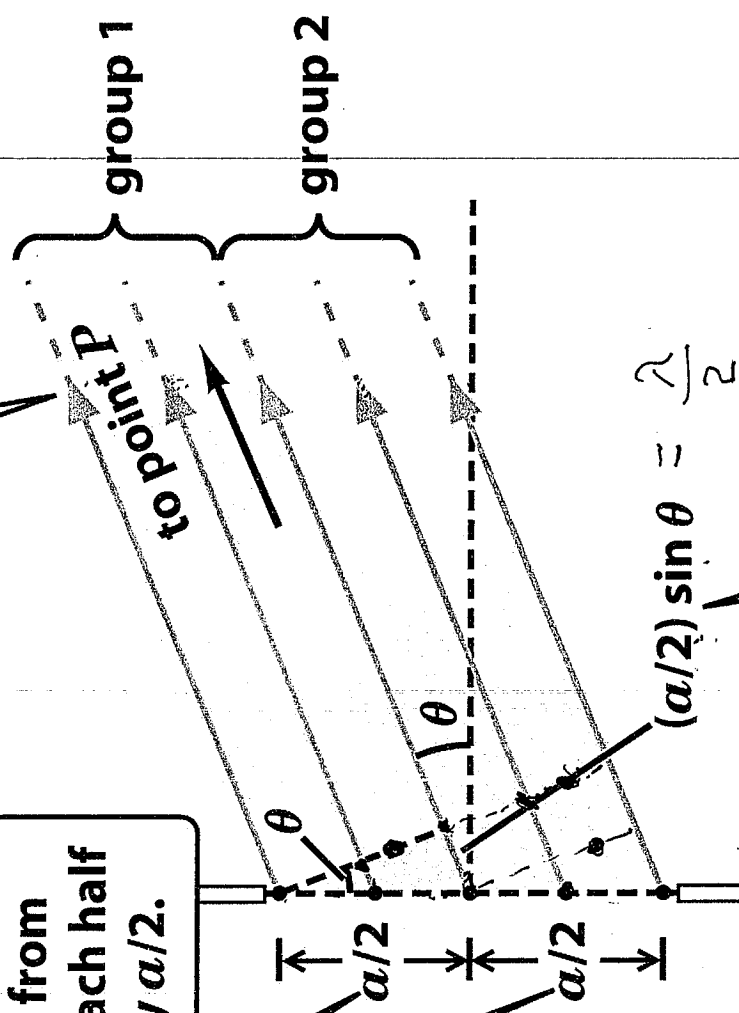


Figure 35-30 Physics for Engineers and Scientists 3/e  
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Firs + Minimum Condition

For a faraway point  $P$ , rays from any points in slit are nearly parallel.

We consider waves from pairs of points in each half of slit, separated by  $a/2$ .



This path difference for pairs of waves equals  $\lambda/2$  at first minimum.

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

Figure 35-31 Physics for Engineers and Scientists 3/e © 2007 W. W. Norton & Company, Inc.

Diffraction Pattern  
through a slit

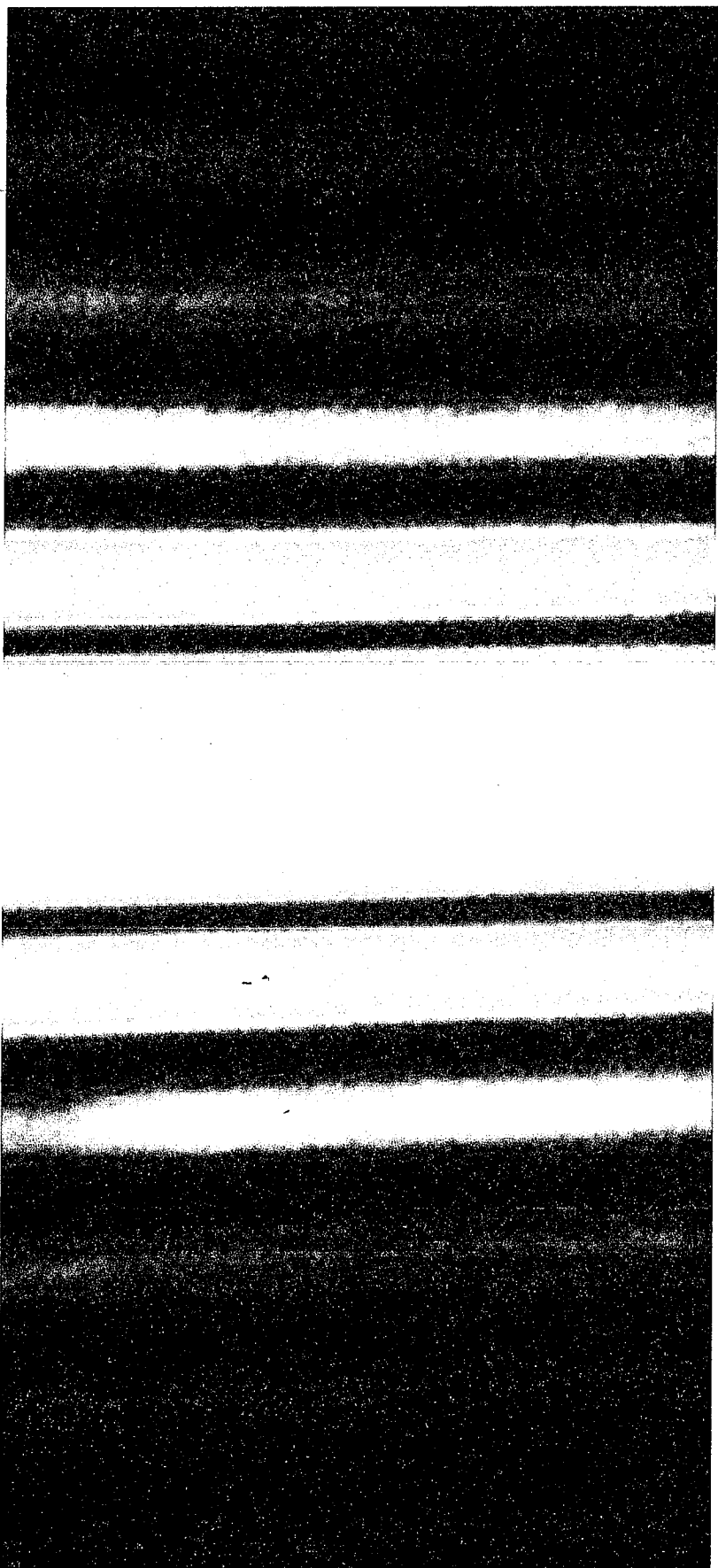


Figure 35-33 Physics for Engineers and Scientists 3/e  
Courtesy of Chris C. Jones

↑  
first  
null

↑  
2nd  
null

INTENSITY OF SINGLE-SLIT  
DIFFRACTION ~~APERTURE~~ APERTURE

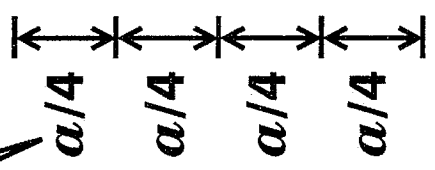
$$I = I_{\max} \left[ \frac{\sin(\phi/2)}{\phi/2} \right]^2$$

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

2<sup>nd</sup> minimum

group 1  
group 2  
group 3  
group 4

Now pairs of points from adjacent quarters of slit are separated by  $a/4$ .



to point P

$\theta$

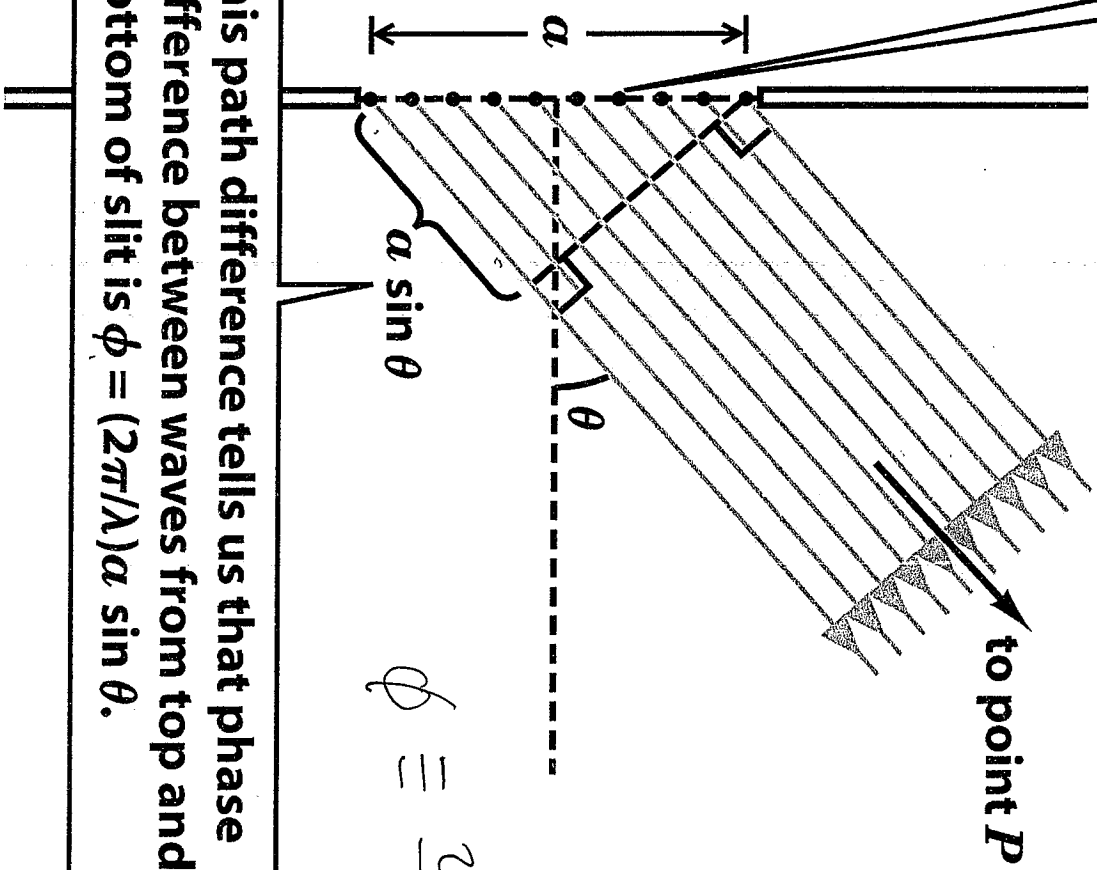
$(a/4) \sin \theta = \frac{\lambda}{2}$        $a \sin \theta = 2\lambda$

Now this path difference for pairs of waves from adjacent quarters equals  $\lambda/2$  at second minimum.

$a \sin \theta = m\lambda$   
m<sup>th</sup> dark spot

Figure 35-32 Physics for Engineers and Scientists 3/e  
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Think of slit as  $k$  evenly spaced sources.



This path difference tells us that phase difference between waves from top and bottom of slit is  $\phi = (2\pi/\lambda)a \sin \theta$ .

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

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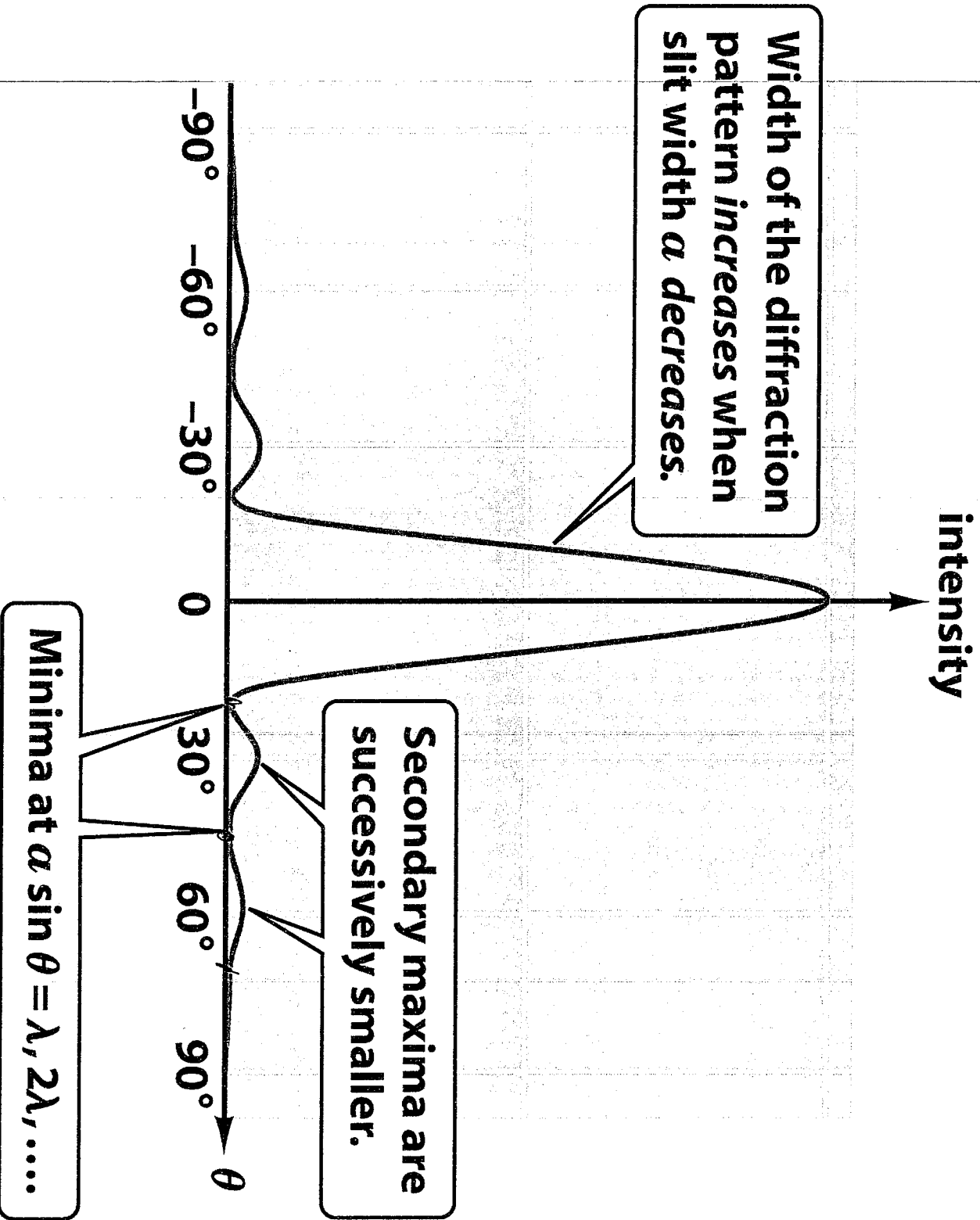


Figure 35-37 Physics for Engineers and Scientists 3/e  
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