Lecture # 33

Applied Optics

2

Interference

f number - focal length/lens diameter (adjusted by diaphragm)
depth of field - range of object distances to achieve focusing

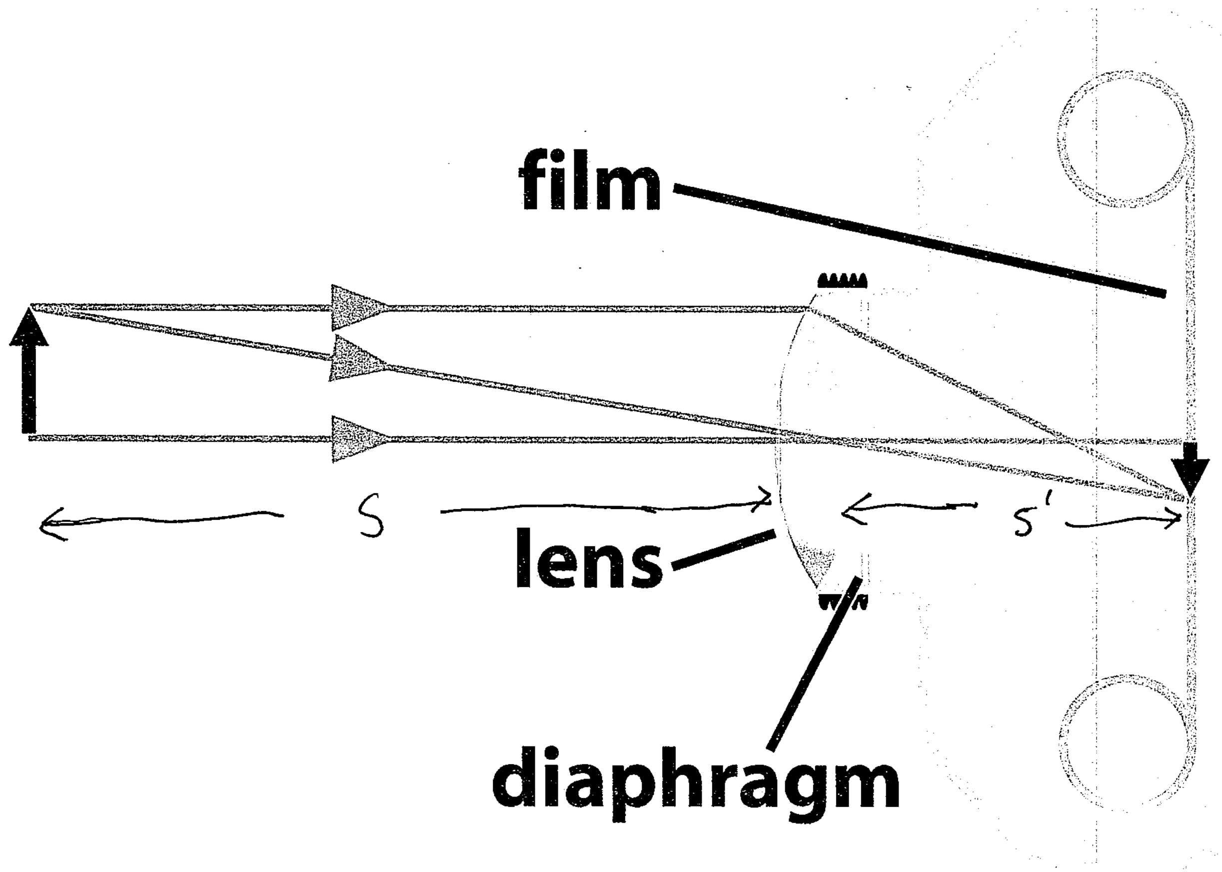


Figure 34-53 Physics for Engineers and Scientists 3/e

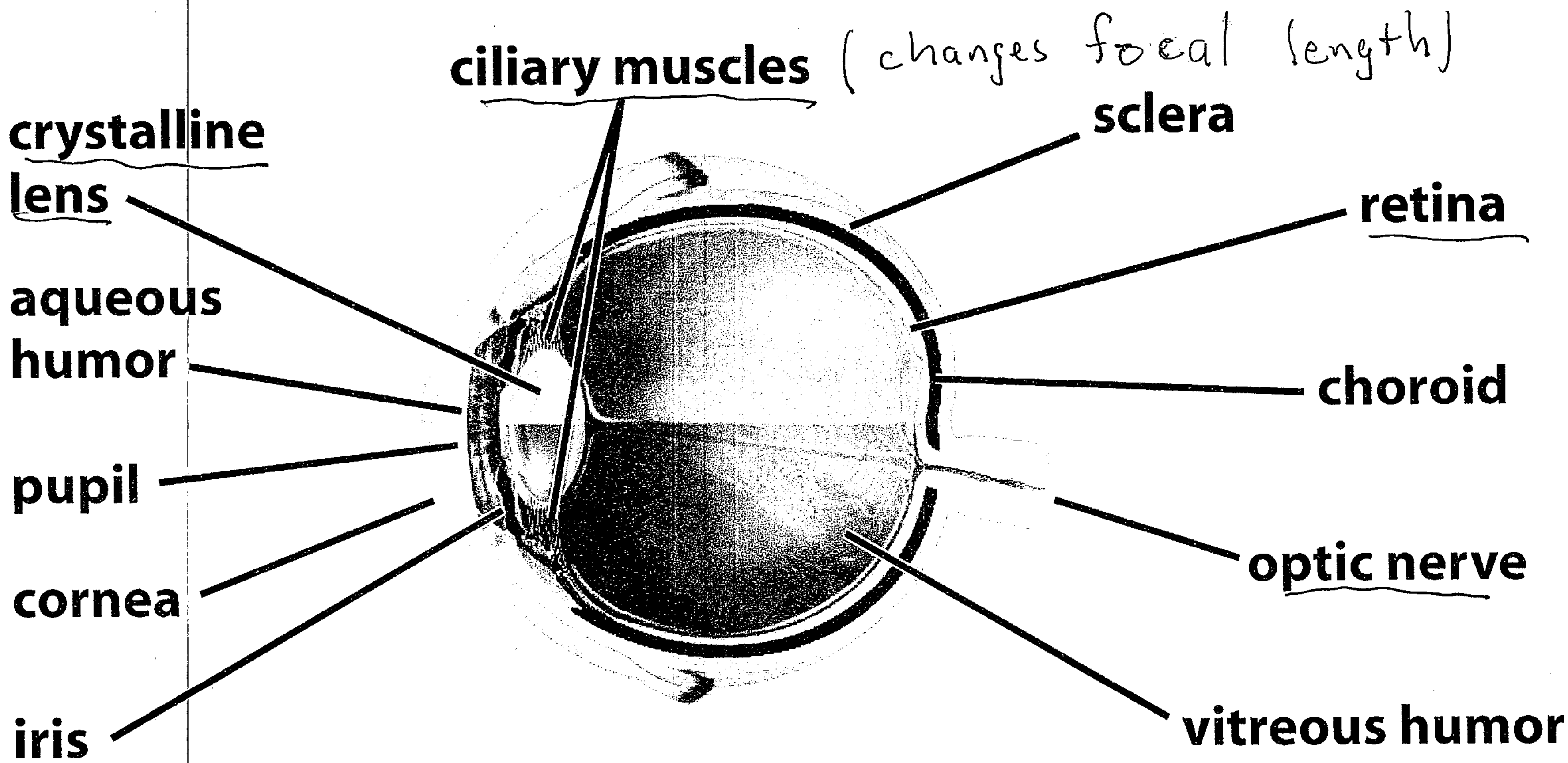
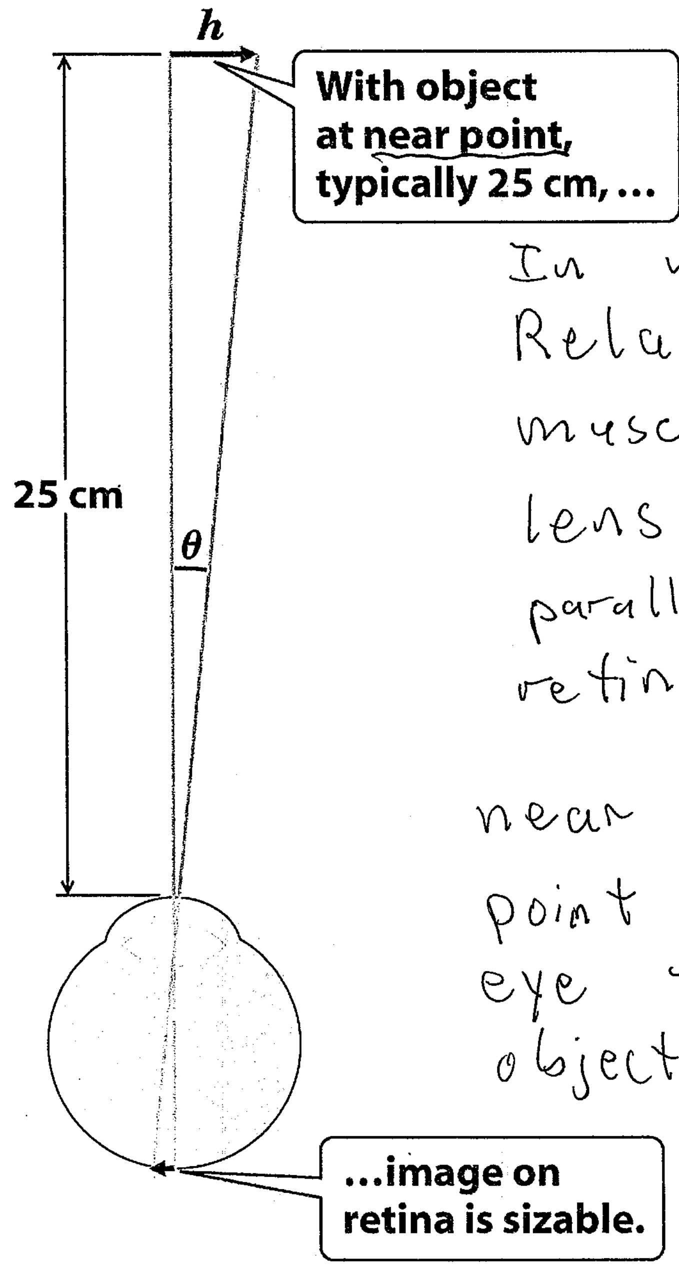


Figure 34-55 Physics for Engineers and Scientists 3/e

Normal Eye



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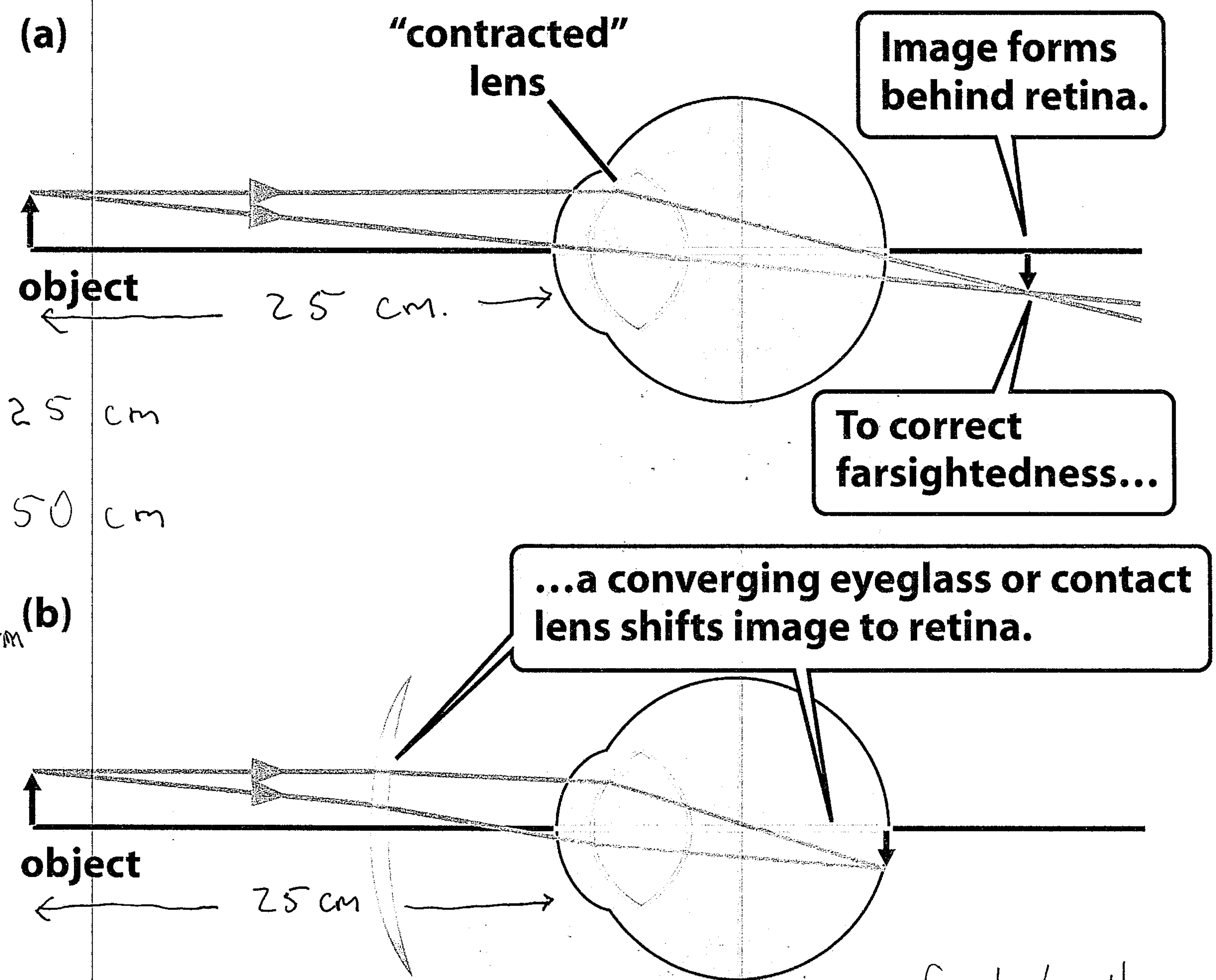
In normal eye Relaxed ciliary muscles allows lens to focus parallel light on retina

near point. Closest point that allows eye to focus on object

Far-sightedness (near point > 25 cm)



(a) $f = 25$ cm

(b) $f = 50$ cm

(c) $f = 100$ cm

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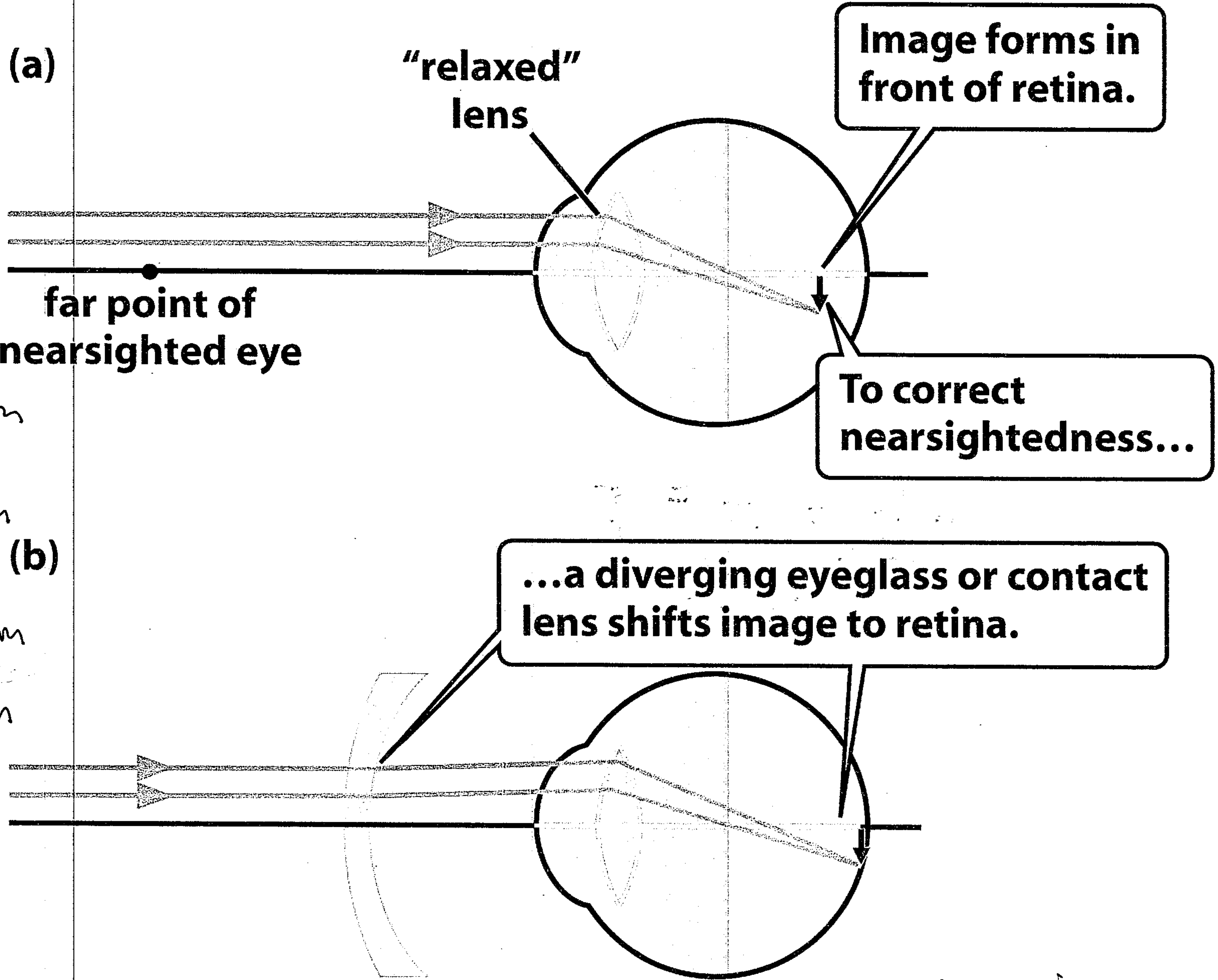
If near point 50 cm, what is ~~f-number~~ focal length of required lens?

near sightedness



(a) f = -5m

(b) f = -10m

(c) f = -.50 m

(d) f = -2 m

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If Far point is 10 m, what is focal length of lens?

5.

Magnifier

Eye sees object, of height h, at 25 cm, with angular width

$$\theta \equiv \Delta\theta_{25} = \frac{h}{25}$$

If object placed near focal point of lens, virtual image at infinity subtends angle

$$\theta' \equiv \Delta\theta_{image} = \frac{h}{f}.$$

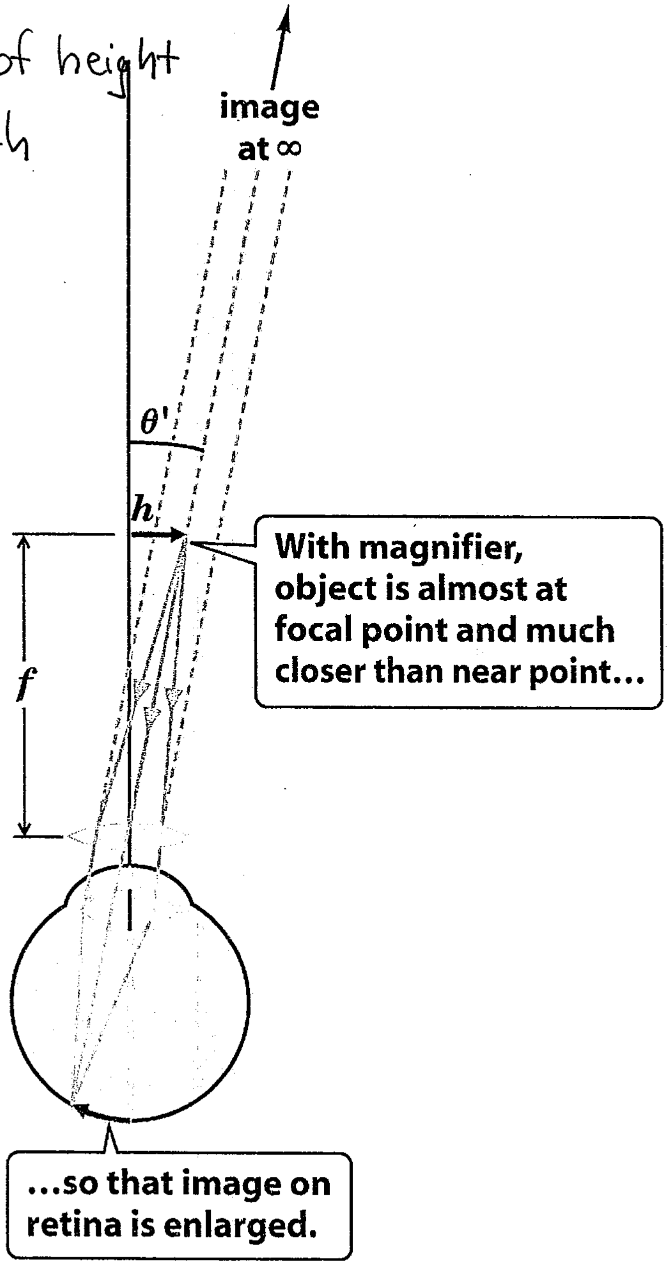


Figure 34-62 Physics for Engineers and Scientists 3/e

Angular Magnification

$$\equiv \frac{\Delta\theta_{image}}{\Delta\theta_{25}} = \frac{h}{f} \Big/ \frac{h}{25} = \frac{25}{f}$$

$\equiv$ True Magnification for sight $= \frac{25}{f}$

Microscope

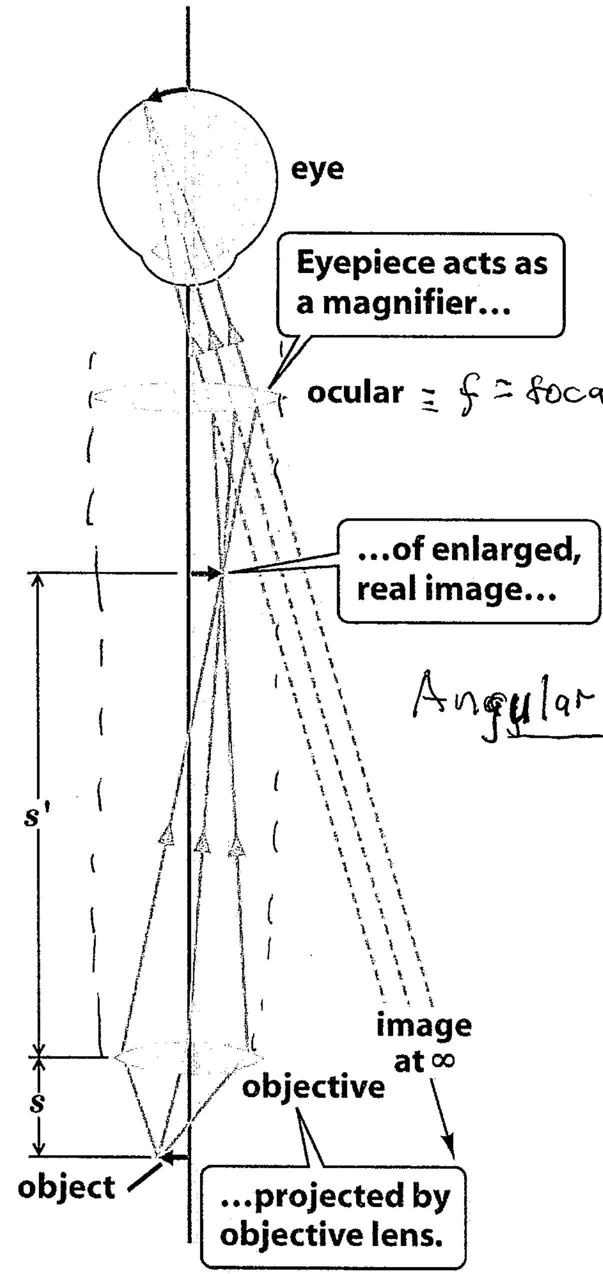


Figure 34-63 Physics for Engineers and Scientists 3/e

Angular Magnification

$$M_{ang} = \frac{-s'}{s} \frac{25}{f}$$

Telescope

Angular Magnification

$$M_{mag} = \frac{\theta'}{\theta} = \frac{FP'/FB}{FP'/f_{obj}} = \frac{f_{obj}}{FB} = \frac{f_{obj}}{f_{ocular}}$$

$FB = f_{ocular}$

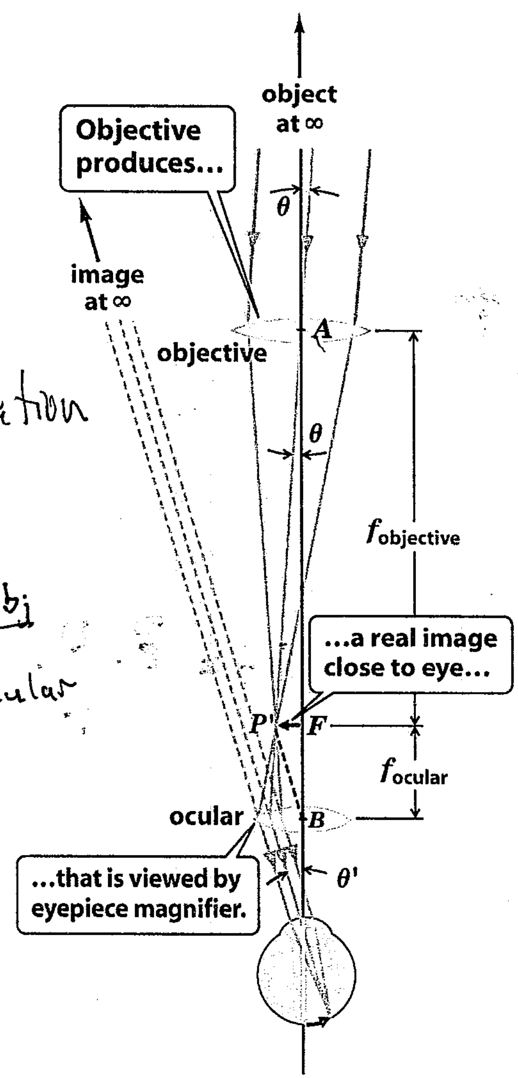


Figure 34-64 Physics for Engineers and Scientists 3/e

Mirror Telescope

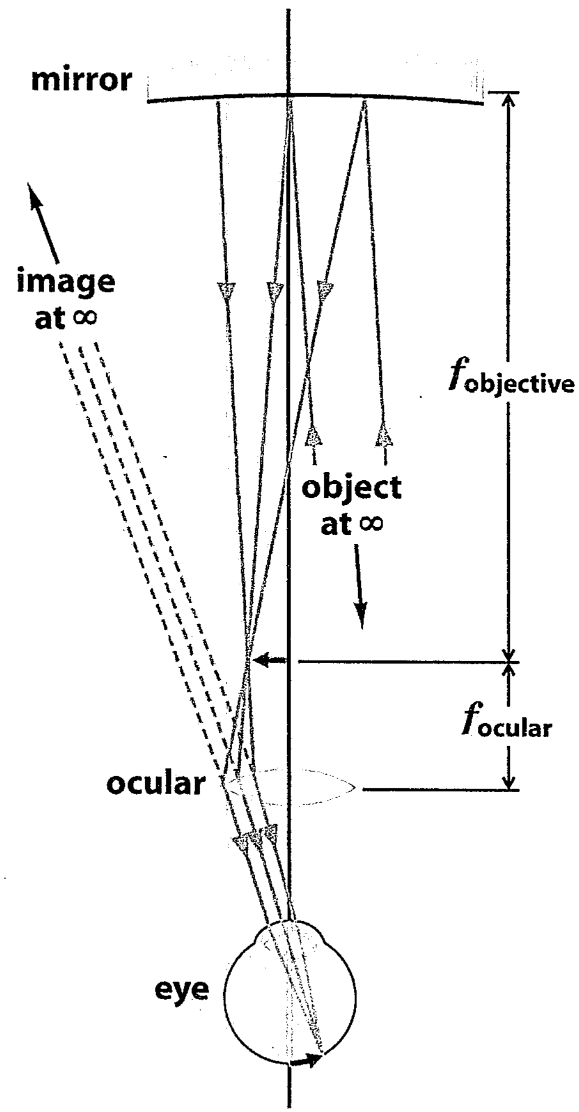


Figure 34-65 Physics for Engineers and Scientists 3/e

$$M_{ang} = \frac{f_{obj}}{f_{ocular}}$$

Consider two beams with electric field

$$\vec{E}_1 = \hat{\vec{E}}_0 \cos(\omega t - kr + \phi)$$

$$\vec{E}_2 = \hat{\vec{E}}_0 \cos(\omega t - kr - \phi)$$

The intensity of $\vec{E}_1$ is proportional to $|\hat{\vec{E}}_0|^2$; $I_1 = \alpha|\hat{\vec{E}}_0|^2$ $\left(I = \frac{E \times B}{\mu_0}\right)$

and intensity of $\vec{E}_2$ is also proportional to $\vec{E}_0^{\,2}$

specifically $I_2 = \alpha|\hat{\vec{E}}_0|^2$

$$\left(\alpha = c\,\frac{\epsilon_0}{2}\right) = (\epsilon_0/\mu_0)^{1/2}/2 \qquad c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

Thus $I_1 + I_2$

Now consider the intensity of

$$\vec{E}_{12} = \vec{E}_1 + \vec{E}_2 = \hat{\vec{E}}_0 \cos(\omega t - kr + \phi) + \hat{\vec{E}}_0 \cos(\omega t - kr - \phi)$$

What is the intensity of $\vec{E}_{12}$

(1) $2|\vec{E}_0|^2\alpha$, (2) $|\vec{E}_0|^2\alpha$, (3) $4|\vec{E}_0|^2\alpha$

(4) 0 (5) $0 \leq I_{12} \leq 4\vec{E}_0^{\,2}\alpha$

$$\bar{E}_1 + \bar{E}_2$$

$$= \hat{E}_0 \cos(\omega t - kr + \phi) + \hat{E}_0 (\cos \omega t - kr - \phi)$$

$$= \hat{E}_0 \left\{ \begin{array}{l} \cos(\omega t - kr)\cos\phi - \sin(\omega t - kr)\sin\phi \\ + \\ \cos(\omega t - kr)\cos\phi + \sin(\omega t - kr)\sin\phi \end{array} \right\}$$

$$= 2\hat{E}_0 \cos(\omega t - kr)\cos\phi$$

$$\overline{E_{12}^2} = \overline{4\hat{E}_0^2 \cos^2(\omega t - kr)\cos^2\phi}$$

$$= 4\hat{E}_0^2 \frac{1}{2}\cos^2\phi$$

$$\overline{E_1^2} = \frac{\hat{E}_0^2}{2}, \quad \overline{E_2^2} = \frac{\hat{E}_0^2}{2}$$

$$\overline{E_{12}^2} = 2\hat{E}_0^2 \cos^2\phi$$

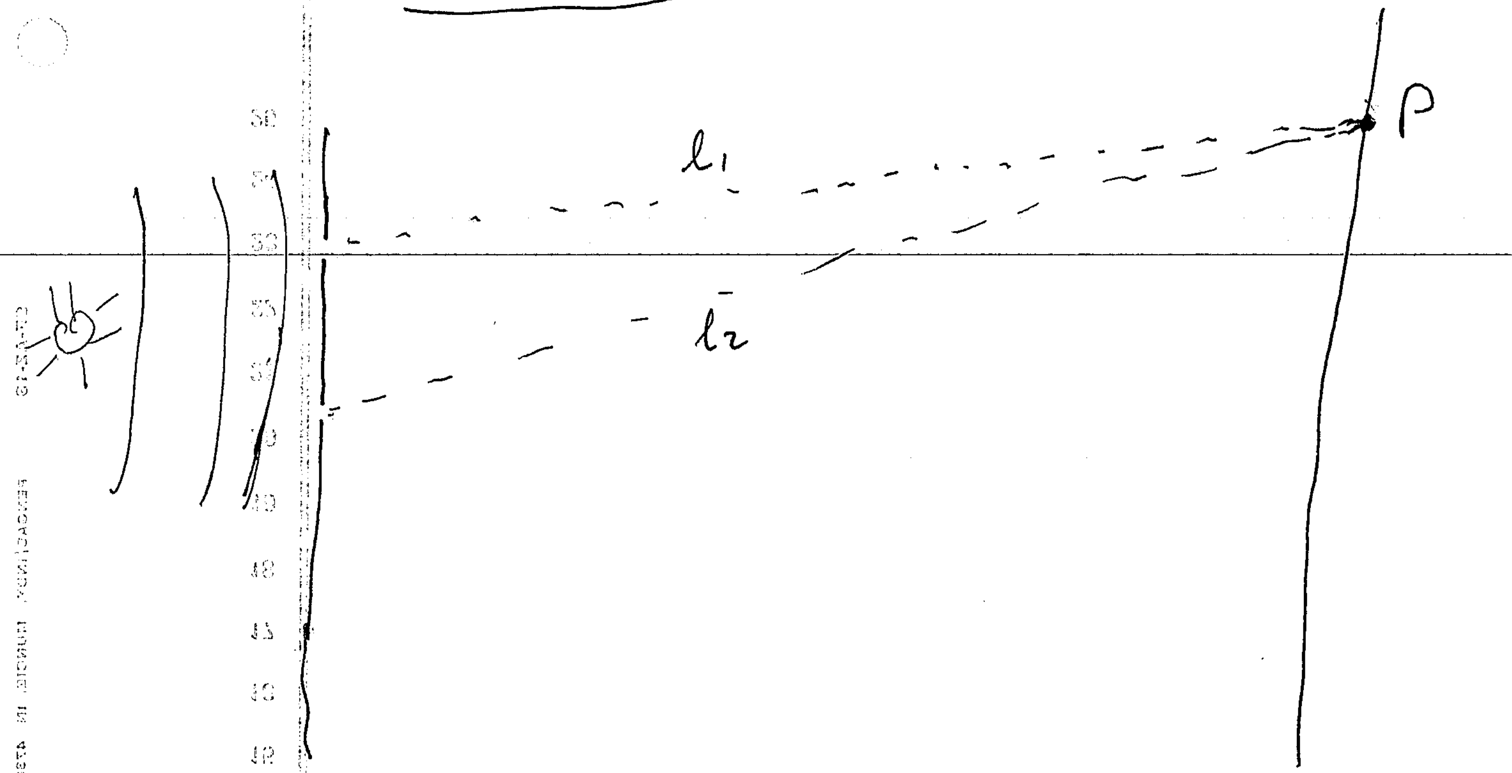
$$\therefore$$

$$\phi = (n+\tfrac{1}{2})\pi, \quad 0 \le 2\hat{E}_0^2\cos^2\phi \le 4\left(\frac{\hat{E}_0^2}{2}\right), \quad \phi = n\pi$$

$\phi = n\pi$ constructive interference

$\phi = (n+1/2)\pi$ destructive interference

Interference from two slits



Young's Slit Experiment

$$E_{12} = E_0 \cos(\omega t - k l_1) + E_0 \cos(\omega t - k l_2)$$

$$= E_0 \Big[\cos\big(\omega t - \underbrace{k\tfrac{(l_1+l_2)}{2}}_{A} - \underbrace{k\tfrac{(l_1-l_2)}{2}}_{\phi = B}\big) + \cos\big(\omega t - \tfrac{k(l_1+l_2)}{2} + \underbrace{\tfrac{k(l_1-l_2)}{2}}_{\phi}\big)\Big]$$

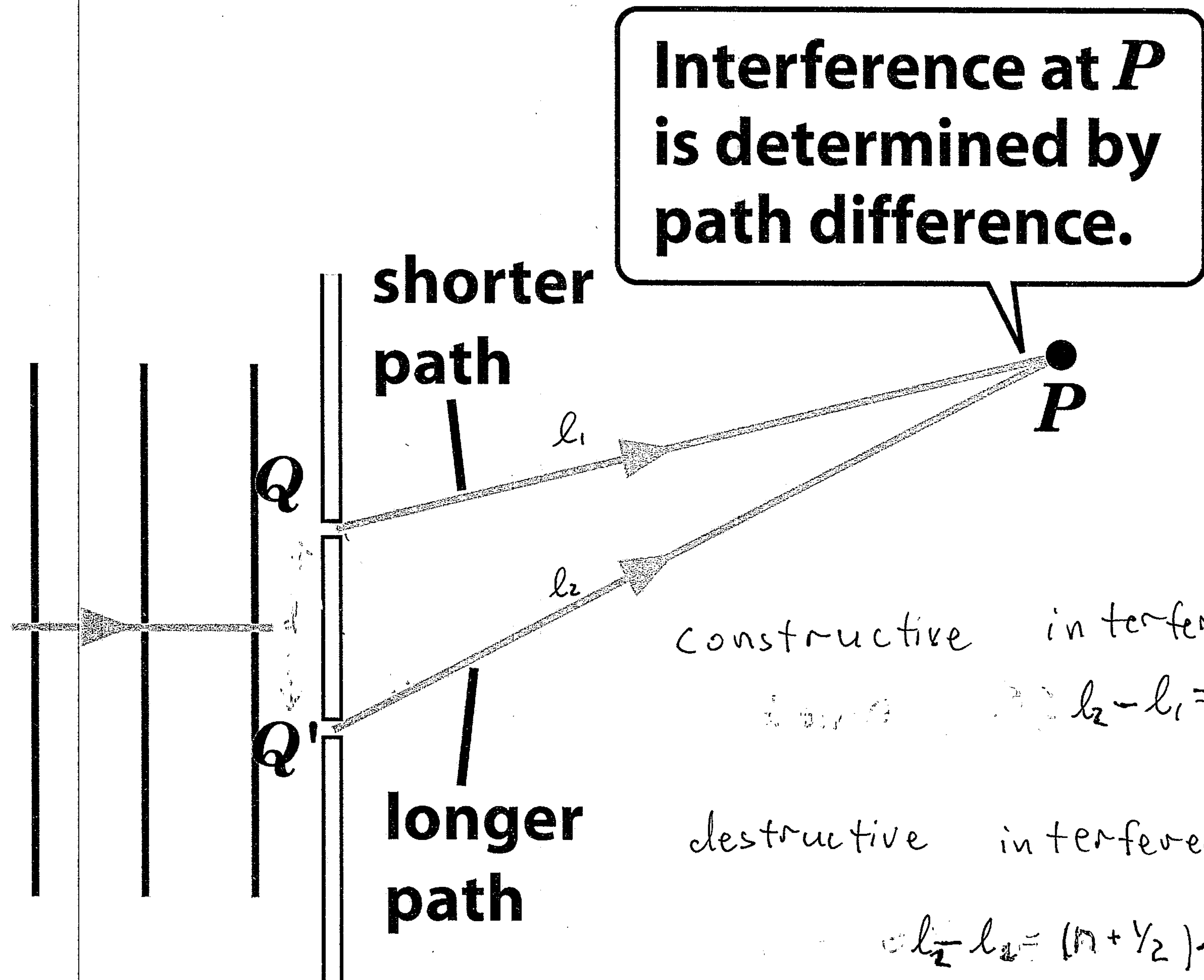
if $\phi \equiv k\frac{(l_1-l_2)}{2} = n\pi$; constructive interference

as $k = \frac{2\pi}{\lambda}$, $\frac{l_1-l_2}{\lambda} = n$

constructive interference $l_1 - l_2 = n\lambda$

similarly; destructive inference if
$\phi = k(l_1-l_2)/2 = (n+1/2)\pi \Rightarrow l_1 - l_2 = (n+1/2)\lambda$

12)



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constructive interference

$\ell_2 - \ell_1 = n\lambda$

destructive interference

$\ell_2 - \ell_1 = (n + 1/2)\lambda$

constructive interference

$d \sin\theta = n\lambda$; $n < \frac{d}{\lambda}$

destructive interference

$d \sin\theta = (n+\frac{1}{2})\lambda$

$n+\frac{1}{2} < \frac{d}{\lambda}$

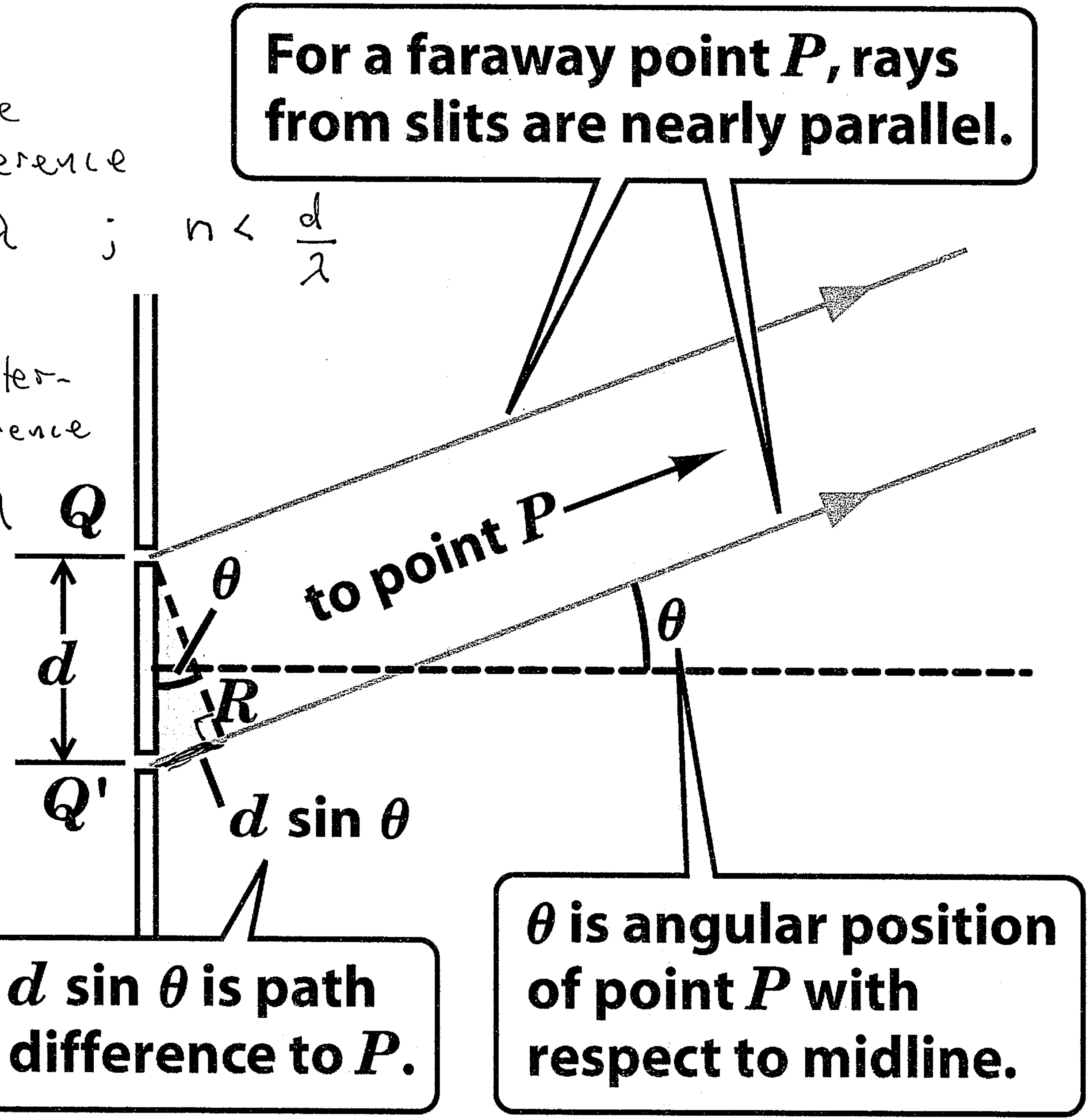

Figure 35-15 Physics for Engineers and Scientists 3/e