Lecture #21

Optics and Mirrors

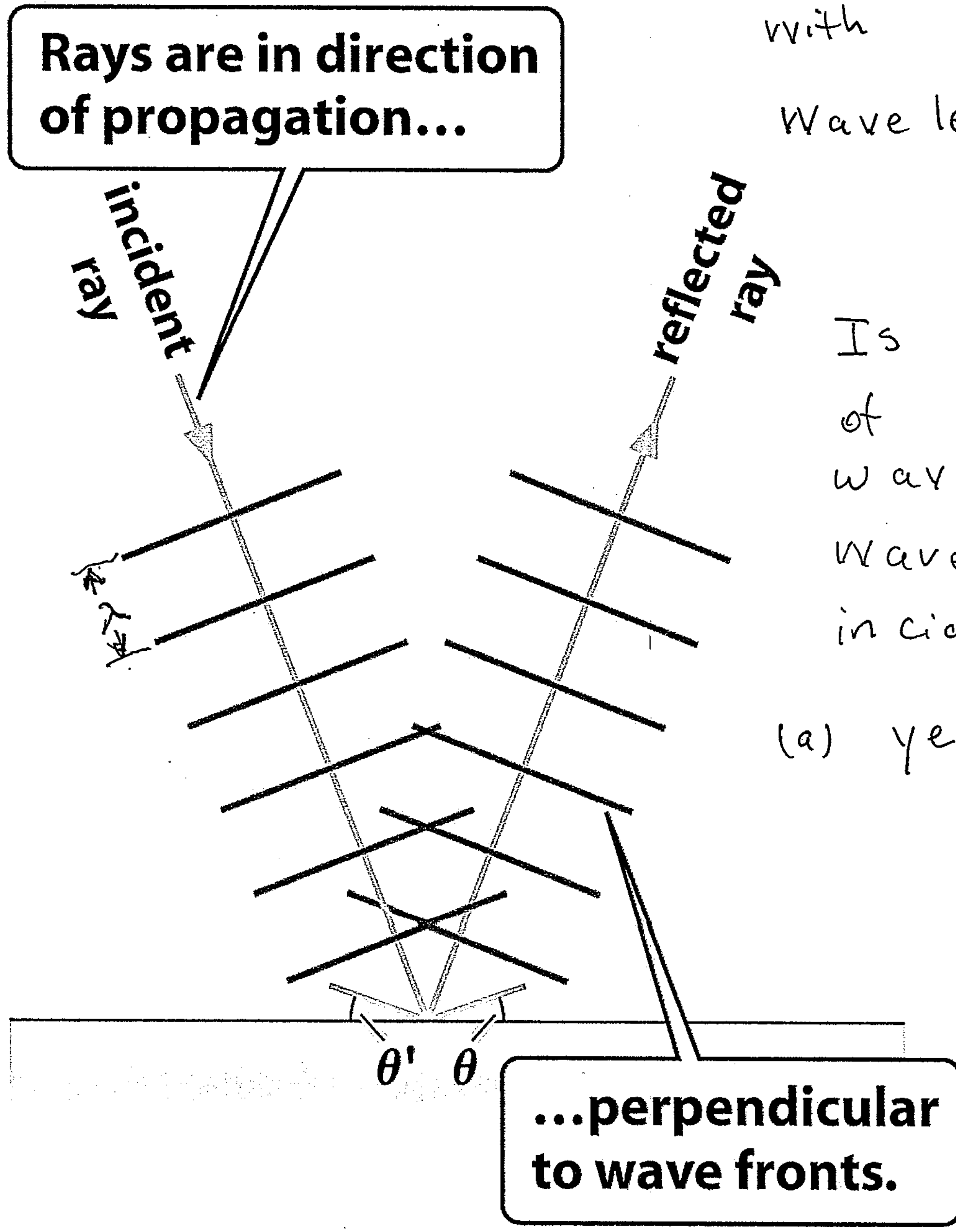


Figure 34-8 Physics for Engineers and Scientists 3/e

Wave comes in with a frequency f.

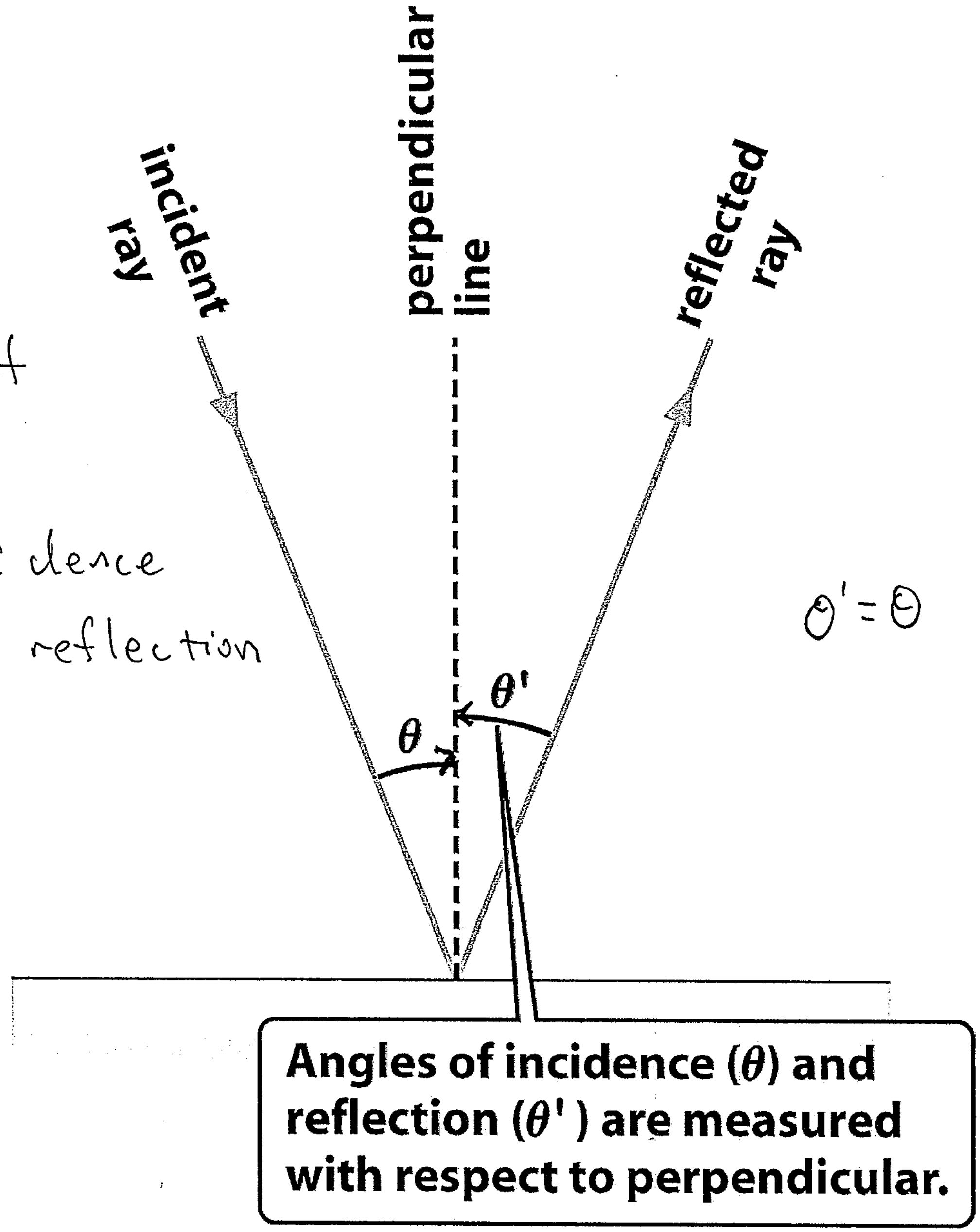
Wave length is $\lambda = c/f$

Is wave length of reflected wave, equal to wave length of incident wave?

(a) yes (b) no

Basic law of optics

angle of incidence = angle of reflection



$\theta' = \theta$

Figure 34-9 Physics for Engineers and Scientists 3/e

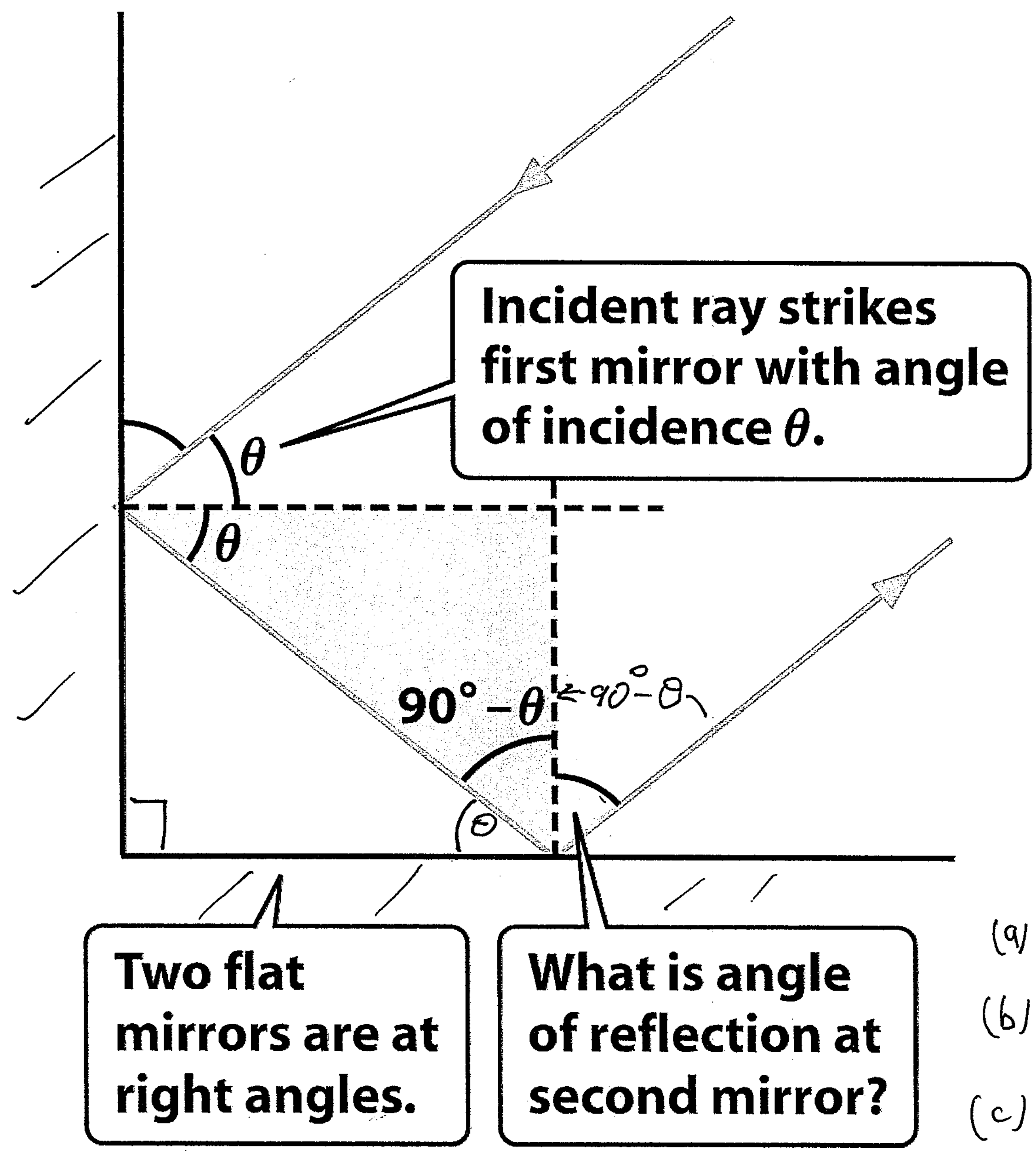


Figure 34-10 Physics for Engineers and Scientists 3/e

(a) θ

(b) 45°

(c) $90^\circ - \theta$ ✓

Image may not be where you think it appears to be.

Virtual image arises from law of reflection

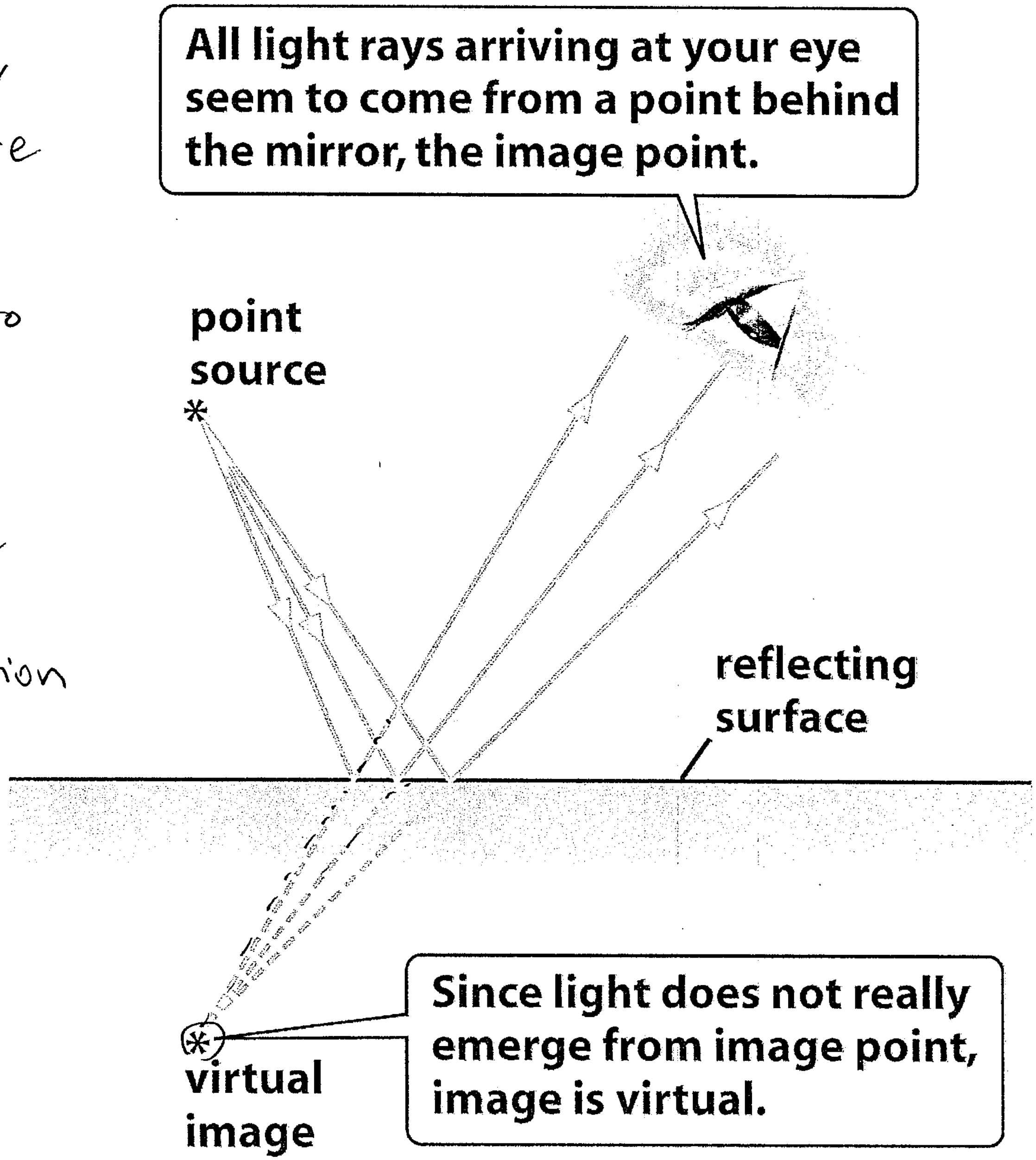


Figure 34-12 Physics for Engineers and Scientists 3/e

Mirror images from plane surfaces:

Image is erect, but image is reversed.

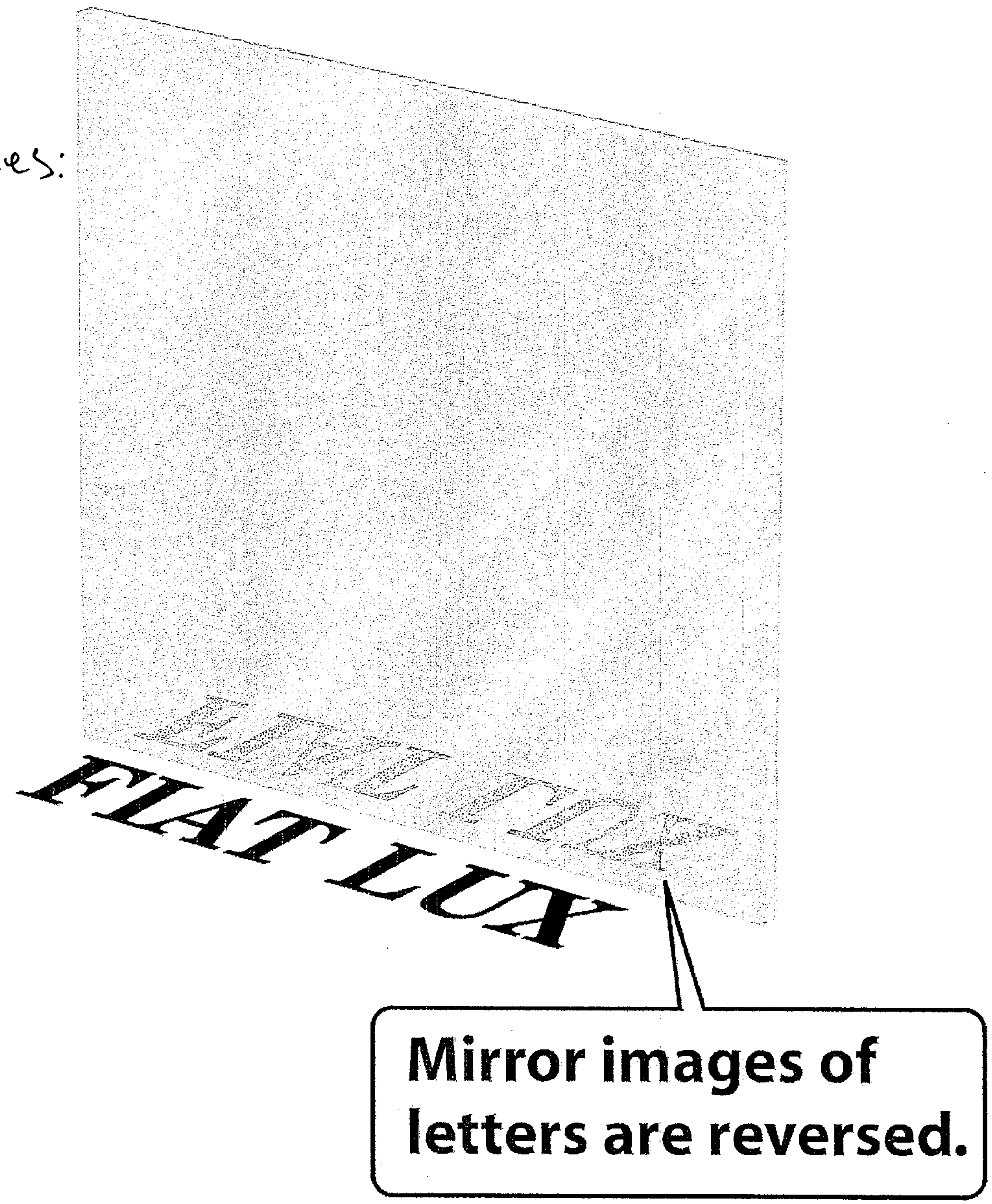


Figure 34-13 Physics for Engineers and Scientists 3/e

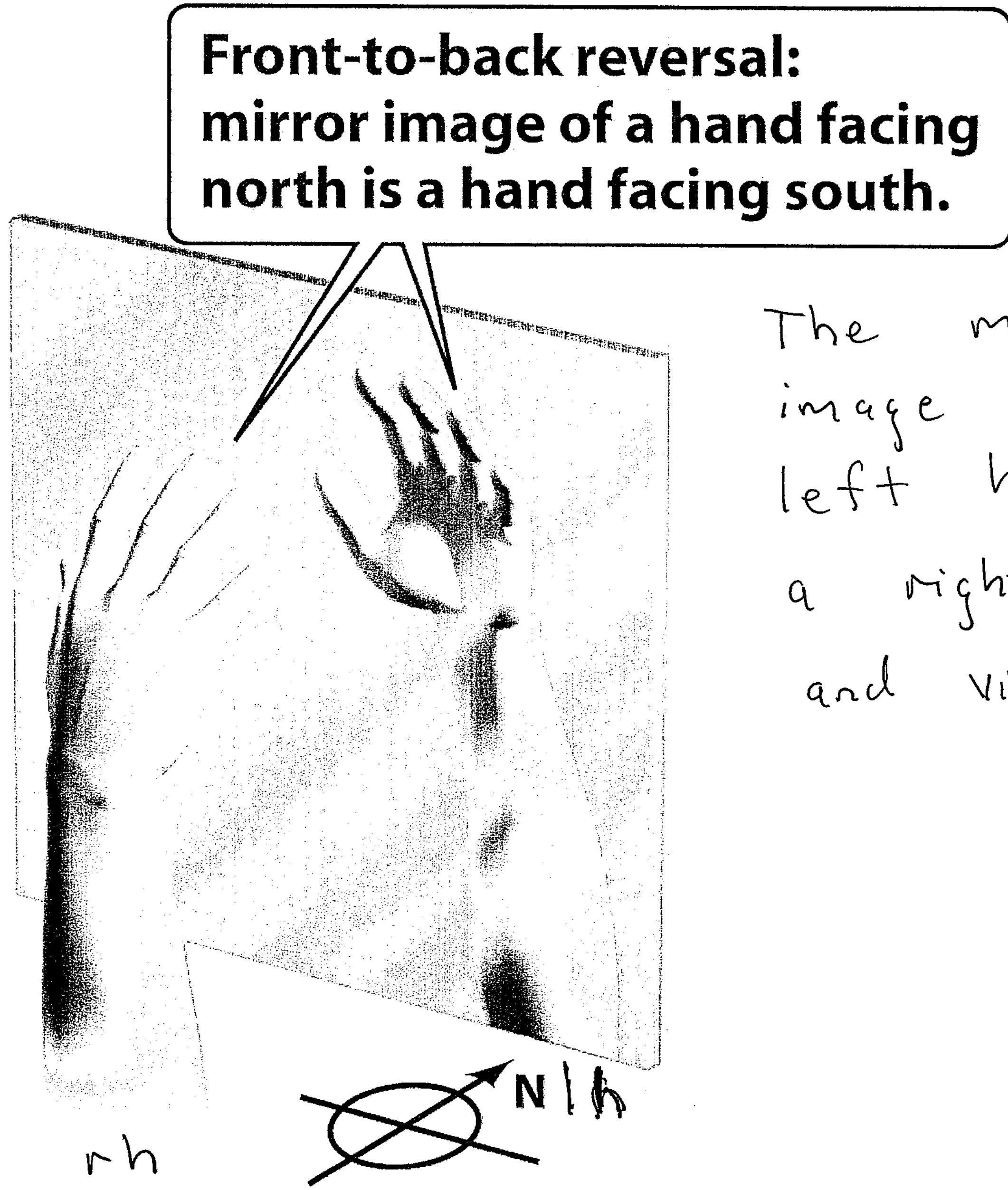


Figure 34-14 Physics for Engineers and Scientists 3/e

The mirror image of a left hand is a right hand, and vice versa velocity of light changes in different materials

index of refraction $n \equiv \frac{c \text{ (velocity of light in vacuum)}}{V_m \text{ (velocity of light in material)}}$

frequency of light signal the same in vacuum and material

$\lambda_{air} \simeq 0.5 \times 10^{-6}$ m

wavelength changes from vacuum to material

$$\lambda_m = \frac{\lambda_{vac}}{n}$$

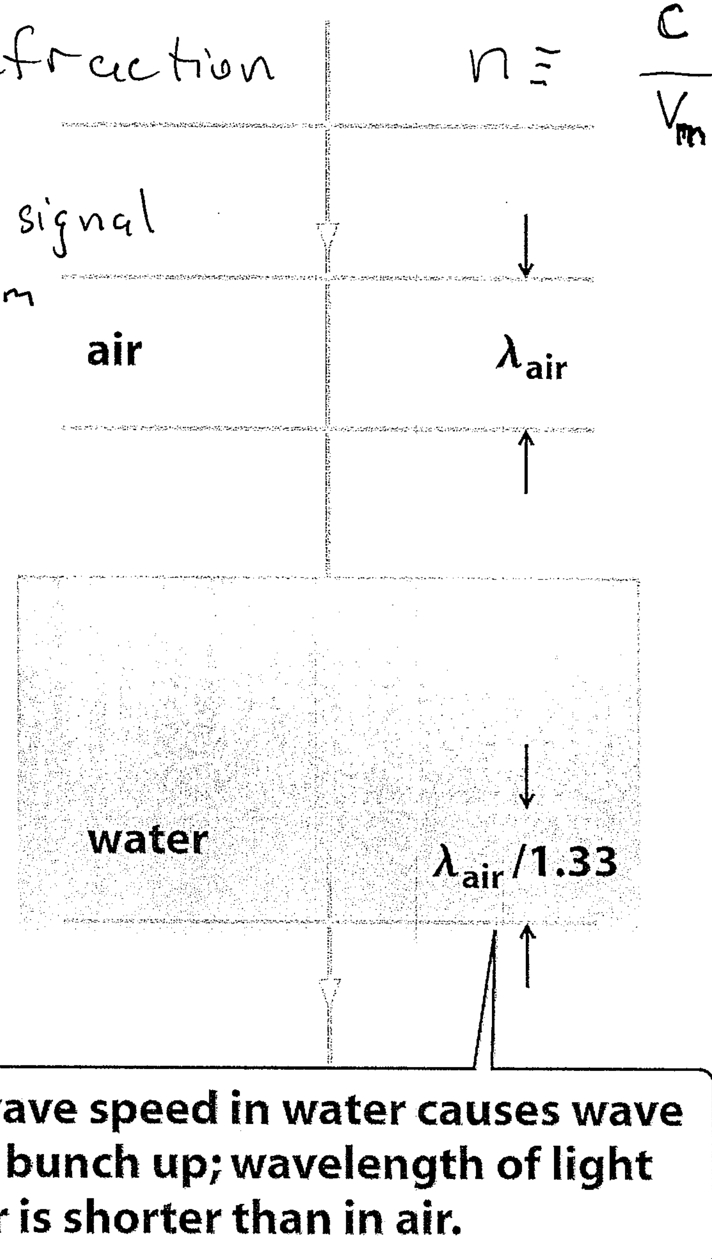


Figure 34-15 Physics for Engineers and Scientists 3/e

TABLE 34.1 INDICES OF REFRACTION OF SOME MATERIALS[a]

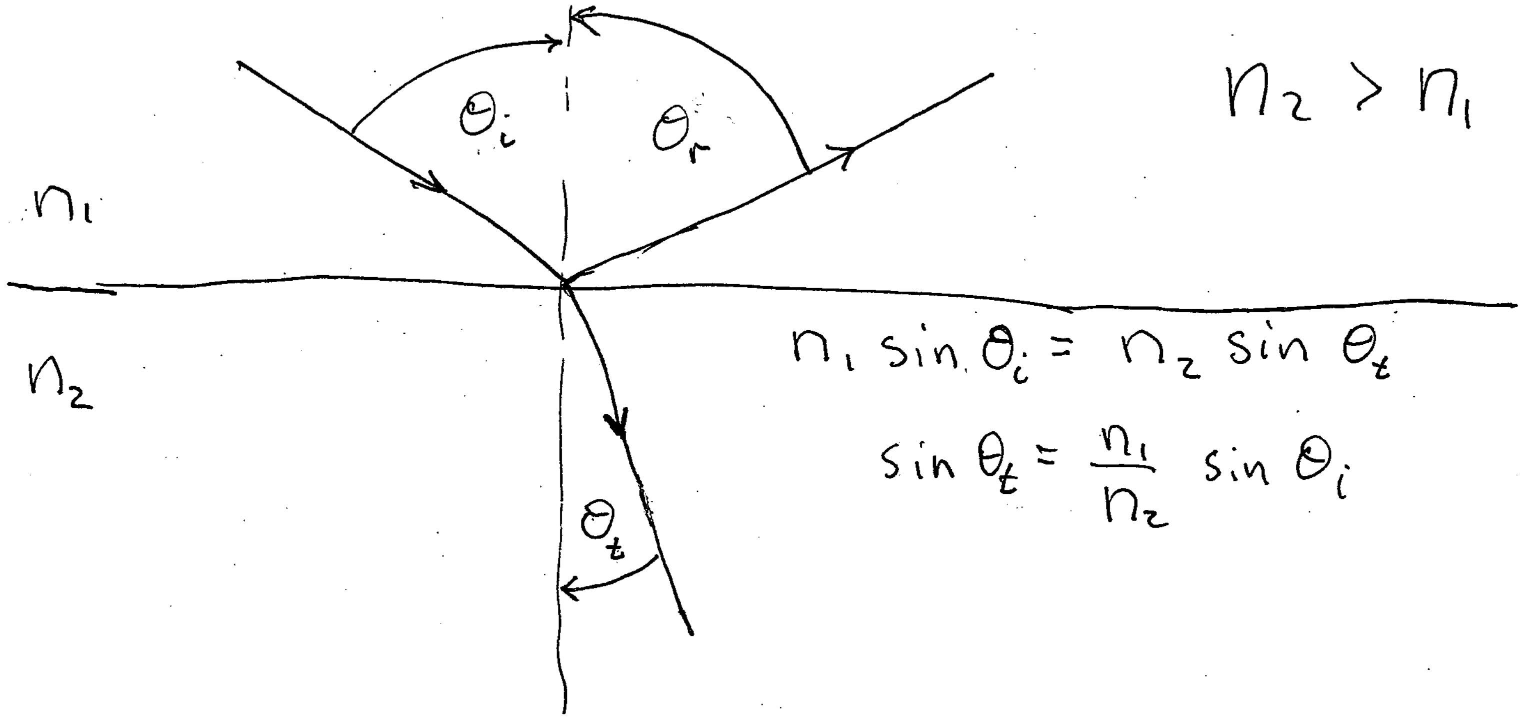
MATERIAL	n
Air, 1 atm, 0°C	1.000 29
1 atm, 15°C	1.000 28
1 atm, 30°C	1.000 26
Water	1.33
Ethyl alcohol	1.36
Castor oil	1.48
Quartz, fused	1.46
Glass, crown	1.52
light flint	1.58
heavy flint	1.66

[a]For light of wavelength ≈ 550 nm.

Table 34-1 Physics for Engineers and Scientists 3/e

Law of Refraction (Snell's Law)

$\theta_i = \theta_r$



$n_2 > n_1$

$$n_1 \sin\theta_i = n_2 \sin\theta_t$$

$$\sin\theta_t = \frac{n_1}{n_2} \sin\theta_i$$

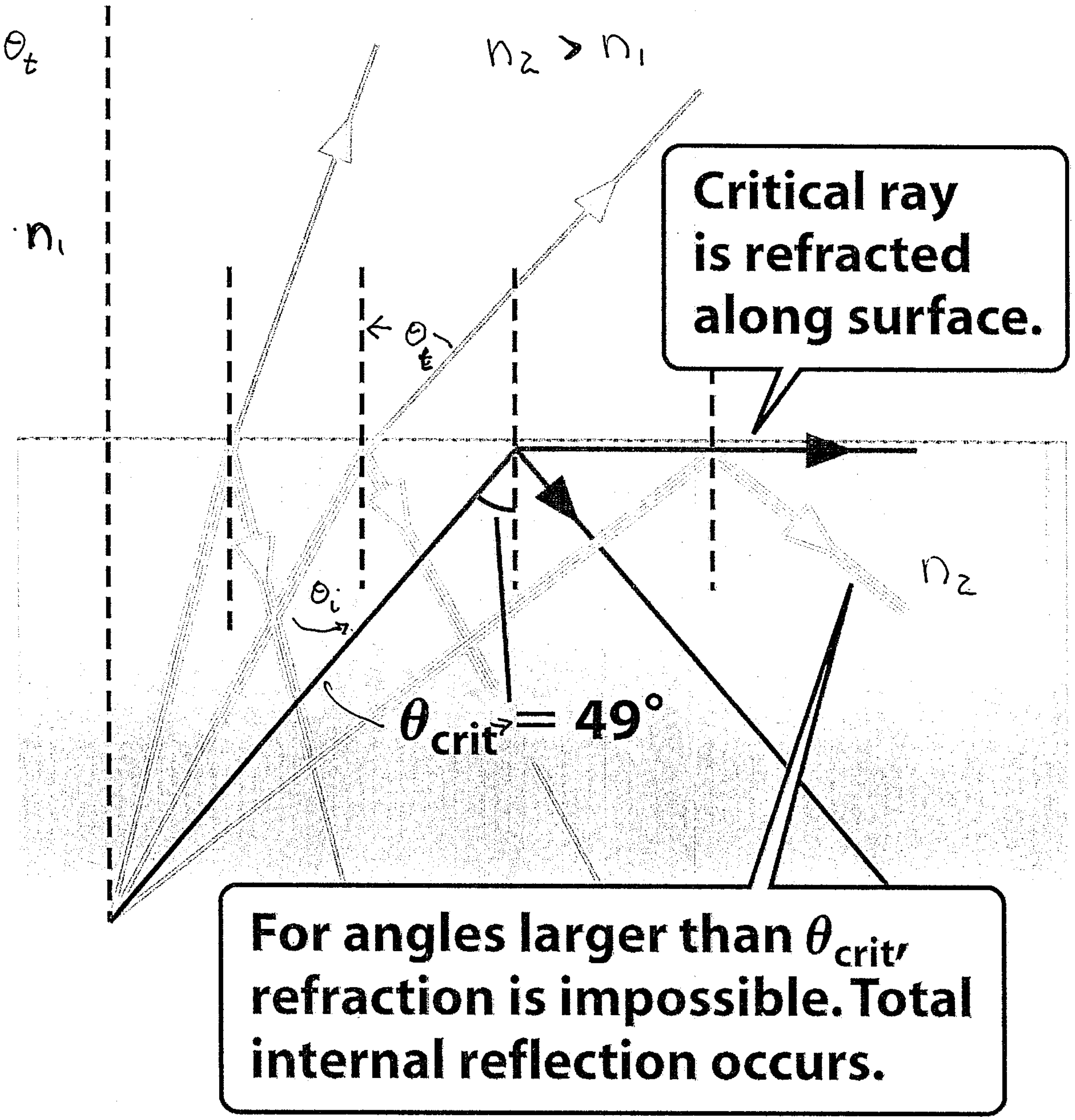
If $n_2 > n_1$, wave is refracted towards normal

Also note: Incident intensity can be partially reflected, and partially transmitted.

Is there any other possibility?

Law of Refraction holds if $n_2 > n_1$
Waves refracted away from normal

$n_2 \sin\theta_i = n_1 \sin\theta_t$



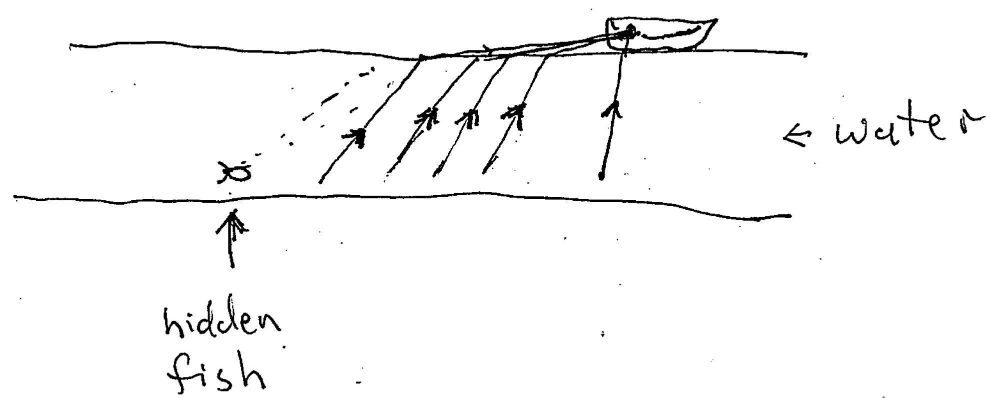
$n_2 \sin\theta_{cr} = n_1$

$\sin\theta_{cr} = \frac{n_1}{n_2}$

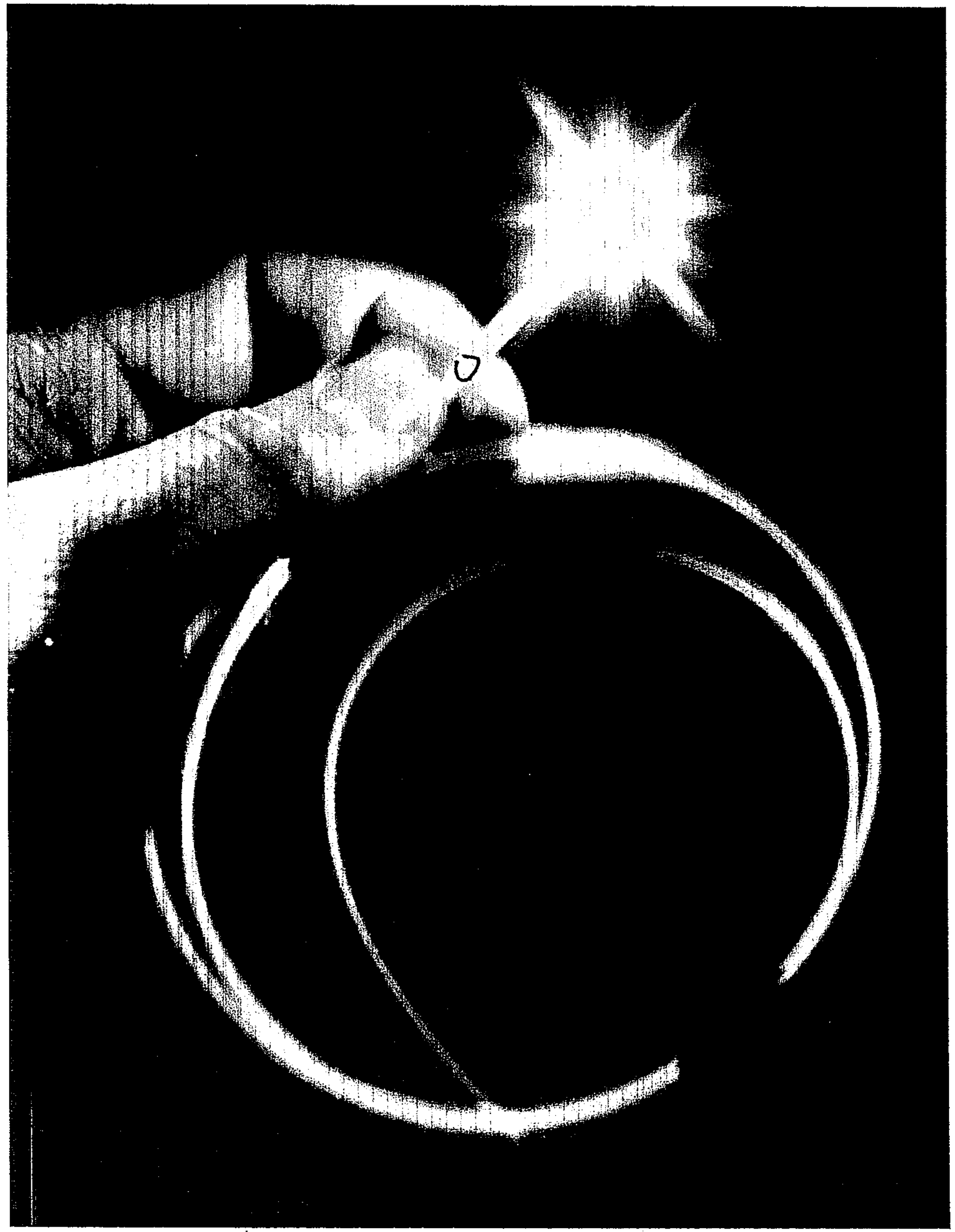
$n_2 > n_1$

$\theta_i > \theta_{cr}$

Figure 34-21 Physics for Engineers and Scientists 3/e


← water
hidden
fish

Light Pipe (optical communication)
(or optical fiber)



PIP 34 figure 1 Physics for Engineers and Scientists 3/e
Hank Morgan/Photo Researchers, Inc.

Refraction also leads to virtual image

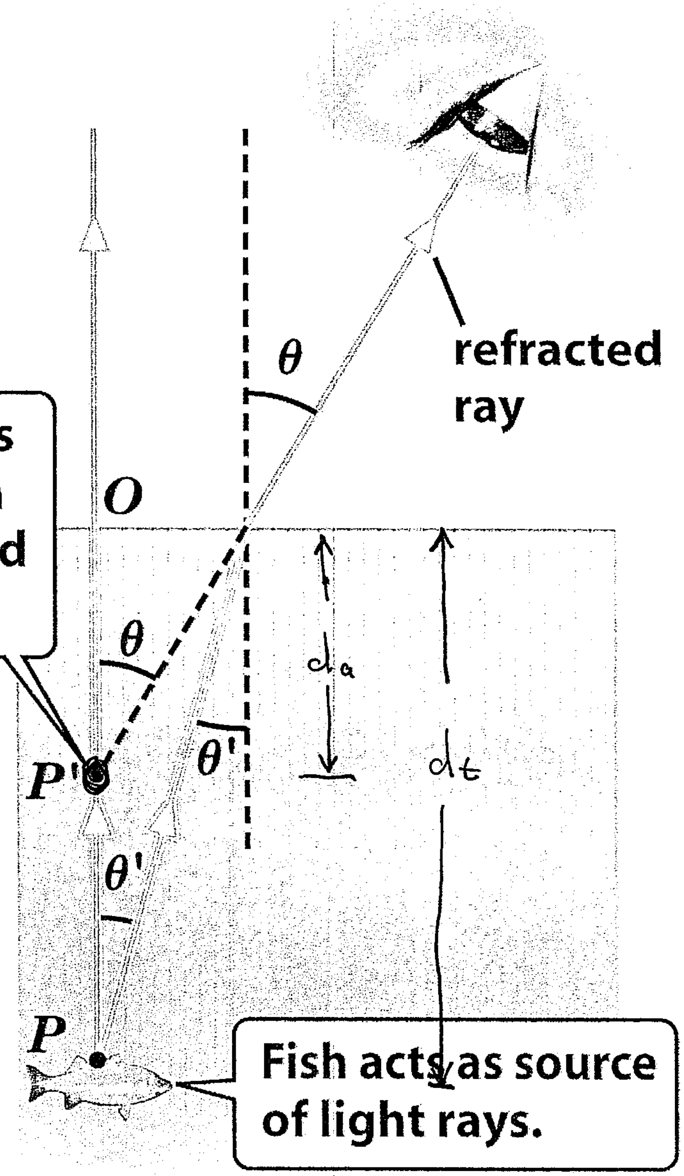


Figure 34-19 Physics for Engineers and Scientists 3/e

Where do you aim to spear a fish?

Generally reflected wave is partially and even totally polarized

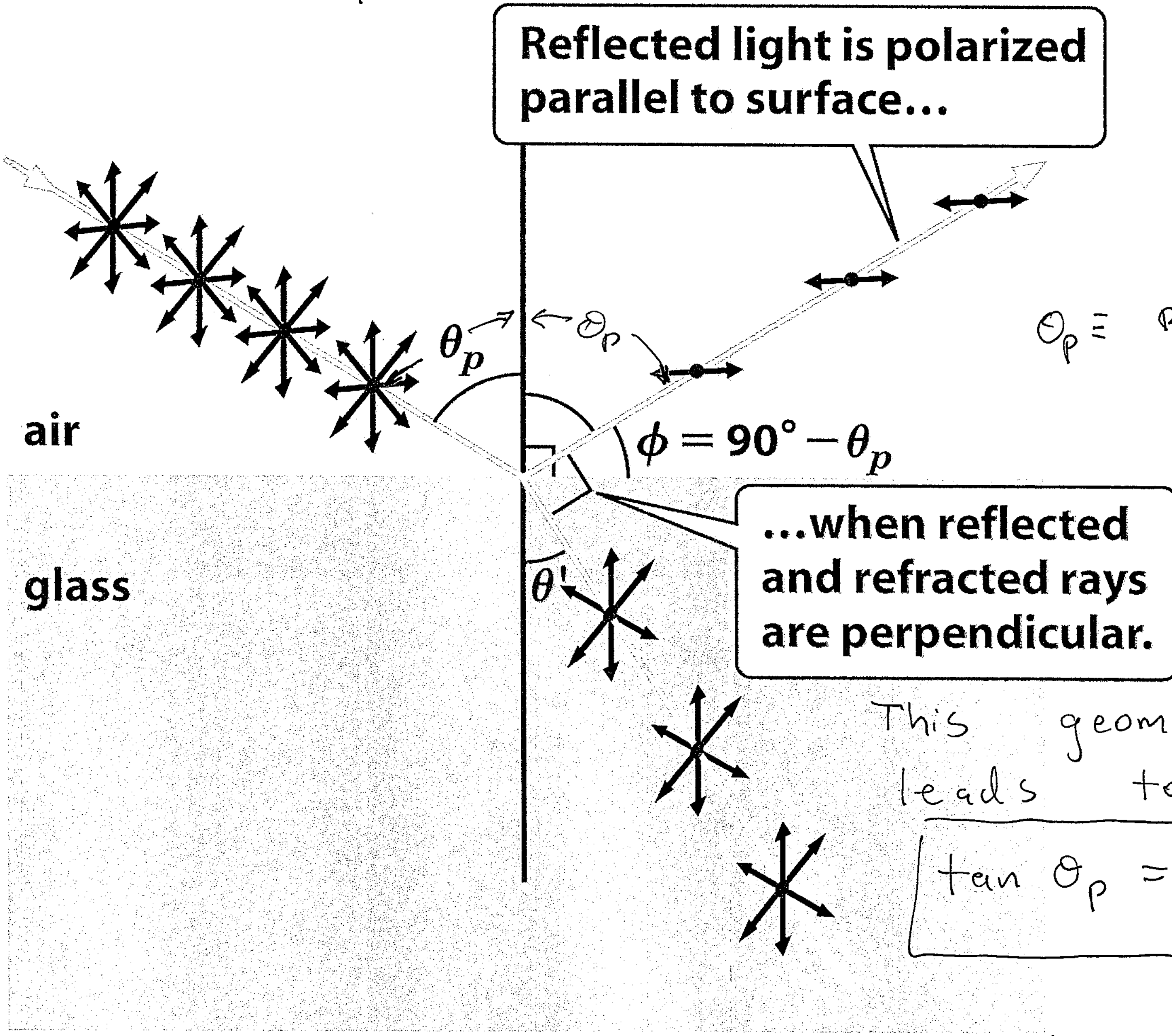


Figure 34-23 Physics for Engineers and Scientists 3/e

$\theta_p \equiv$ Brewster's angle

This geometry leads to

$$\tan \theta_p = n$$

Is the transmitted wave partially polarized?
(a) yes (b) no

velocity of light depends on frequency $\left(\frac{c}{V_w} \equiv n\right)$

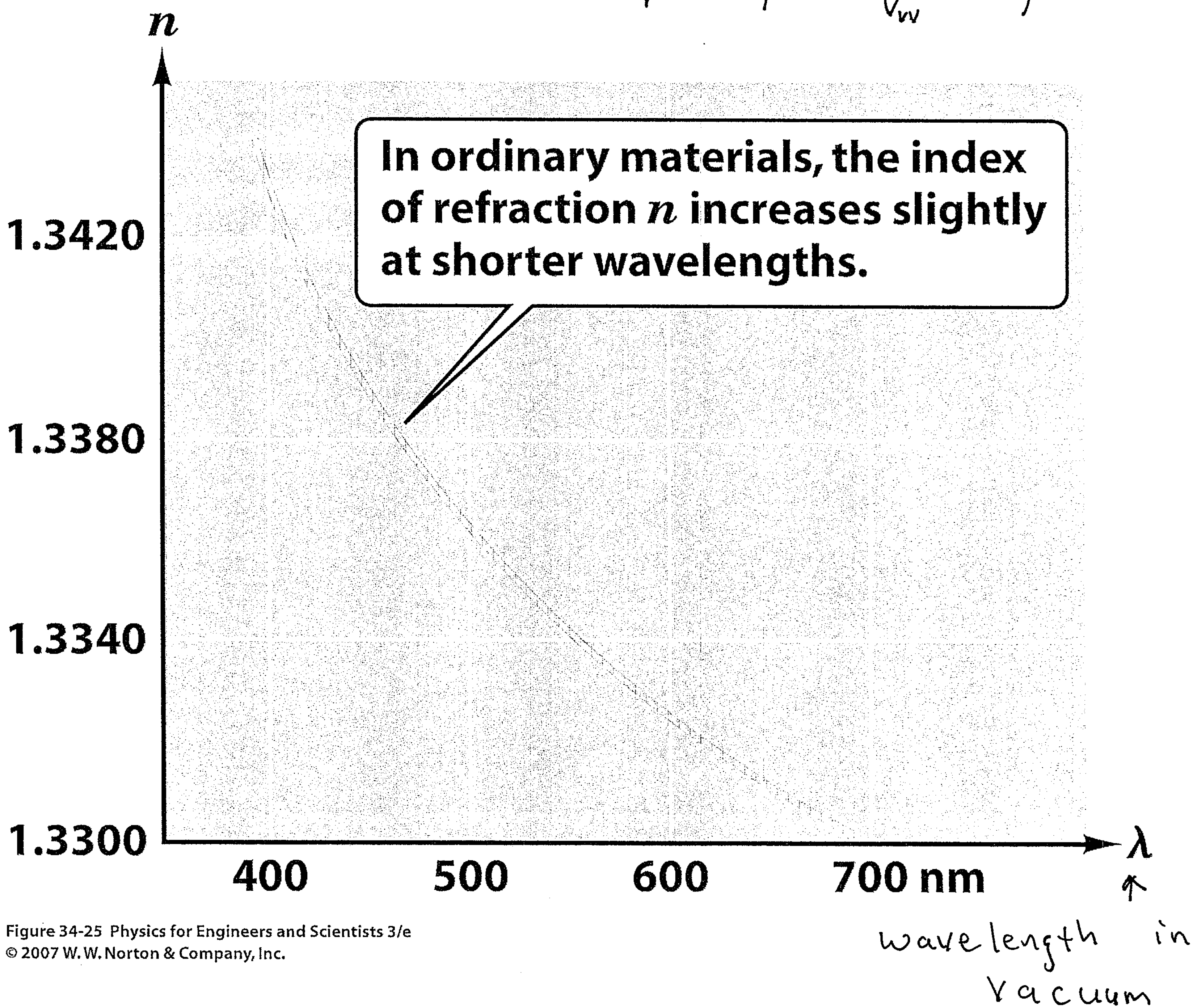


Figure 34-25 Physics for Engineers and Scientists 3/e

Consequence: long wavelength refracted less than short wavelength

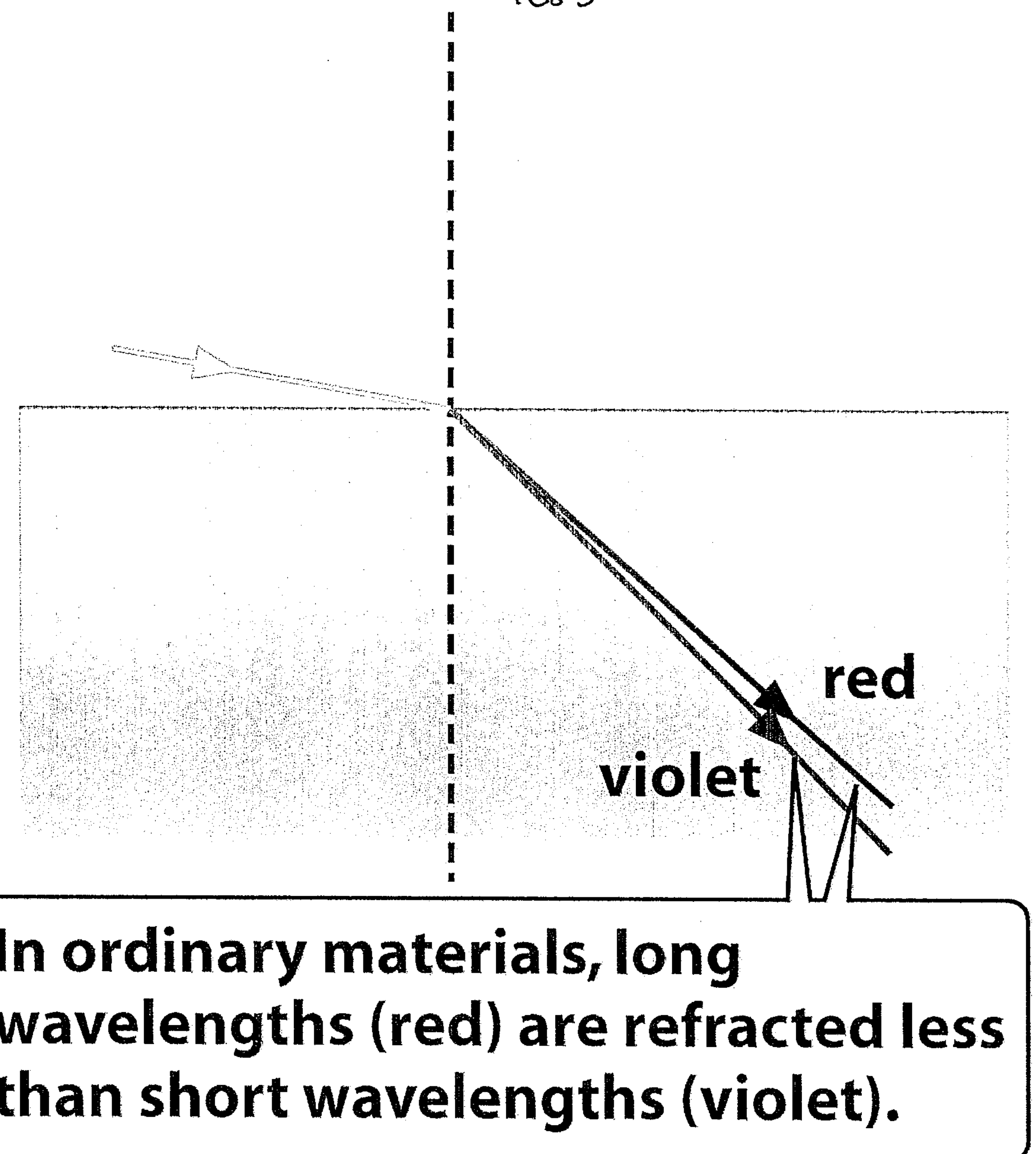


Figure 34-26 Physics for Engineers and Scientists 3/e

Refraction can lead to splitting of colors of white light.

& Identifying frequencies of molecules (a "light print")

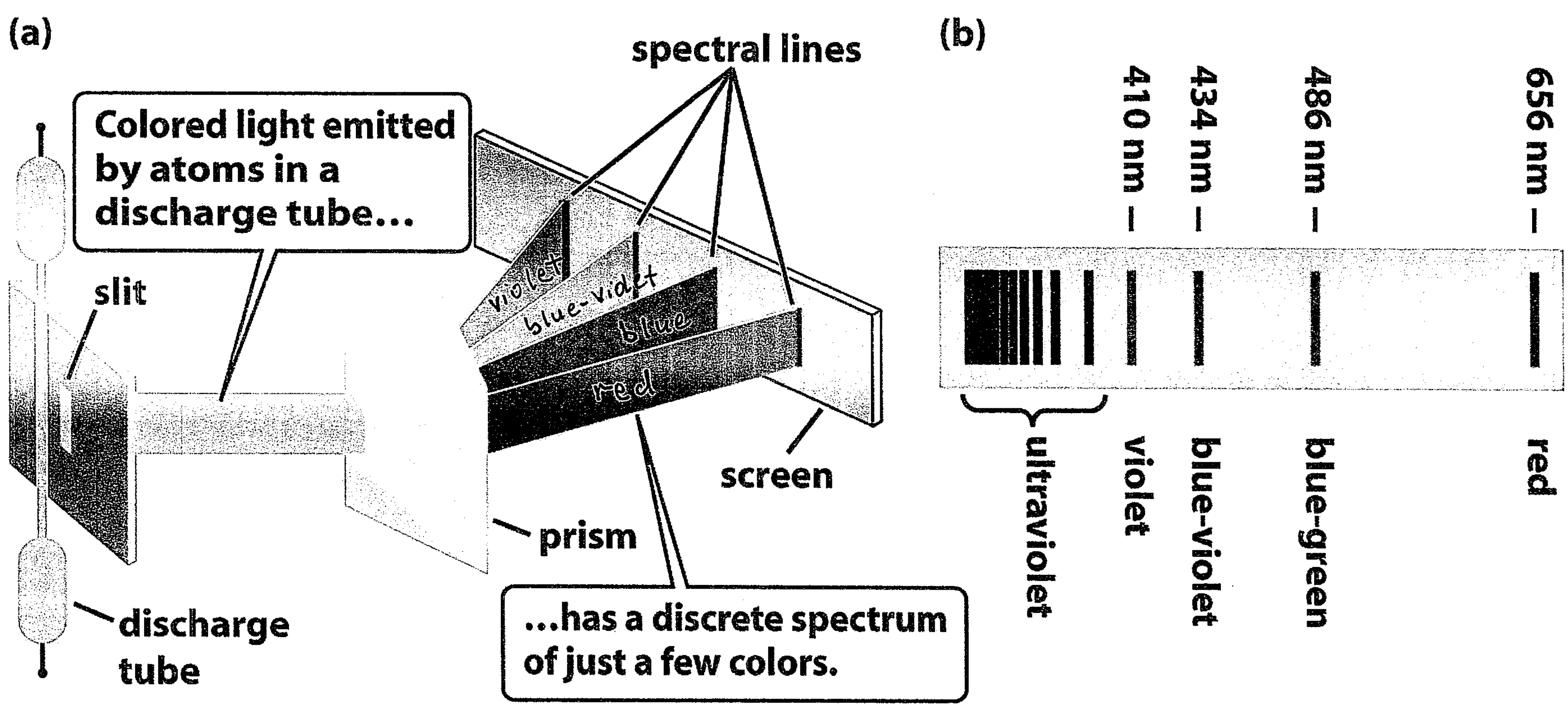
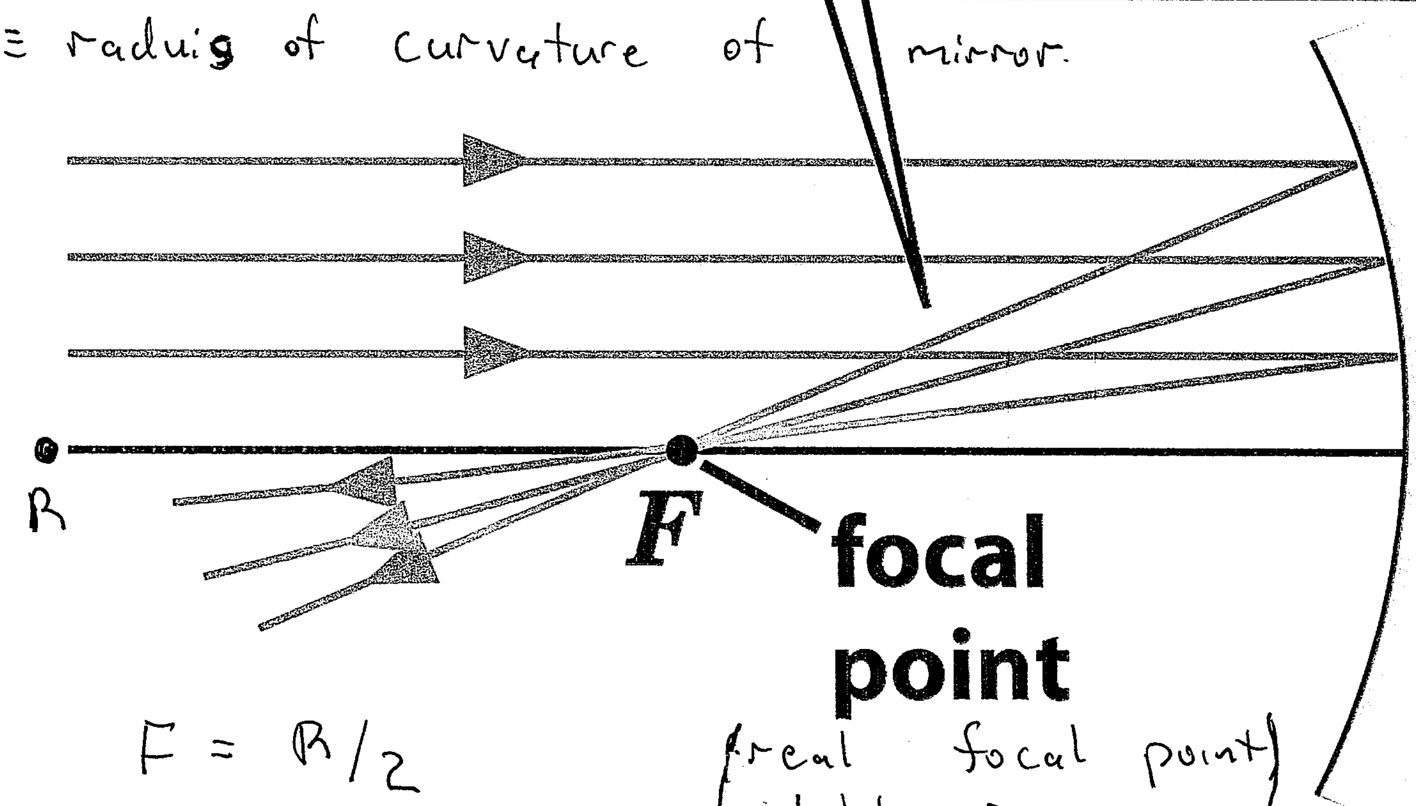


Figure 34-29 Physics for Engineers and Scientists 3/e

Focusing of light on concave mirror

For any incident ray parallel to axis, reflected ray crosses focal point, at $F = R/2$

$R \equiv$ radius of curvature of mirror.



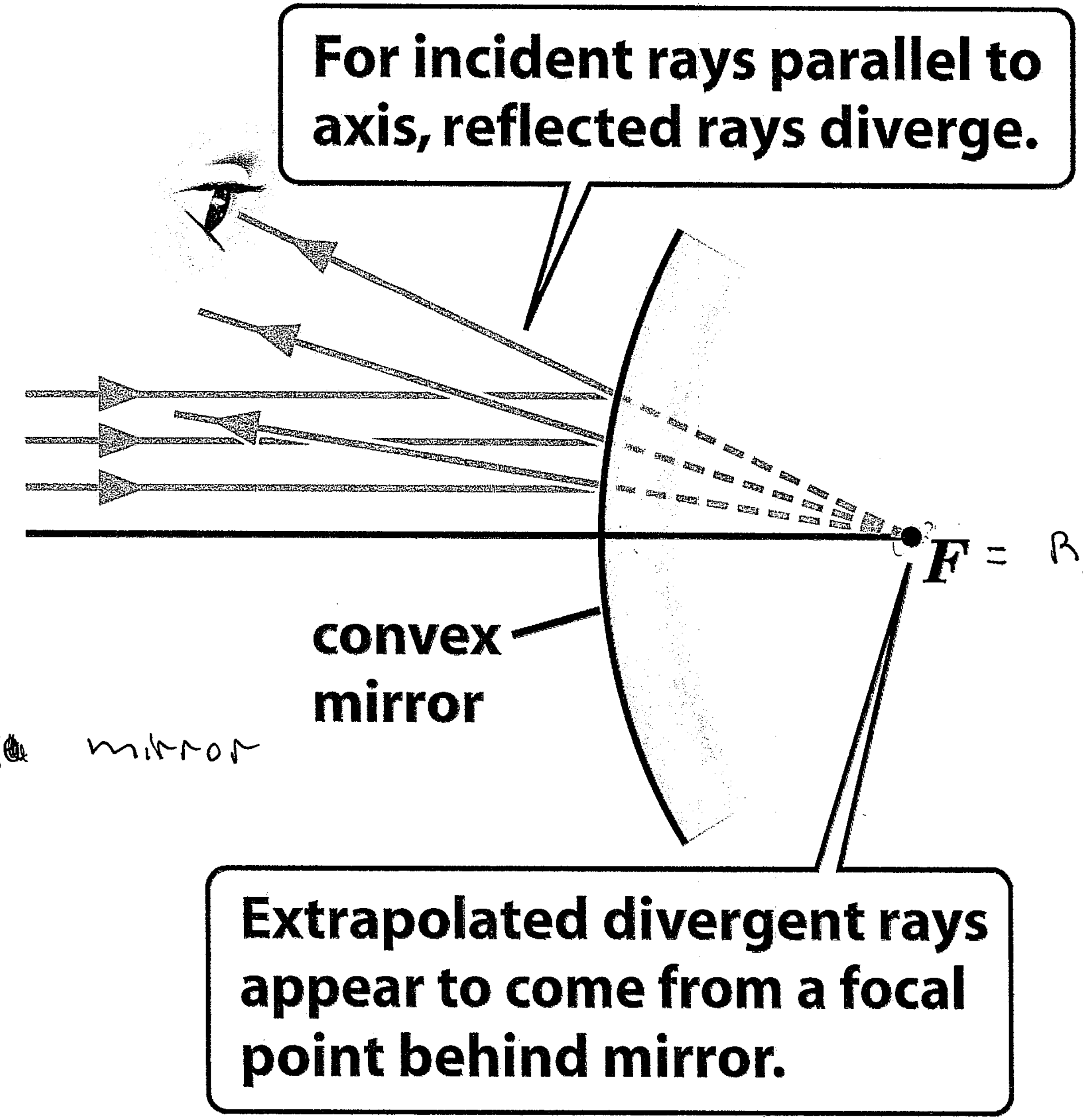
$F = R/2$

(real focal point: light rays go through F, in front of mirror)

Figure 34-31a Physics for Engineers and Scientists 3/e

For a concave mirror, $F > 0$ is convention

Convex mirror leads to a virtual focal point



$F = R/2$ (behind mirror)

For convex mirror
$F < 0$

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

Image of Point P (the source)

All Rays from P focus on P' (the image)

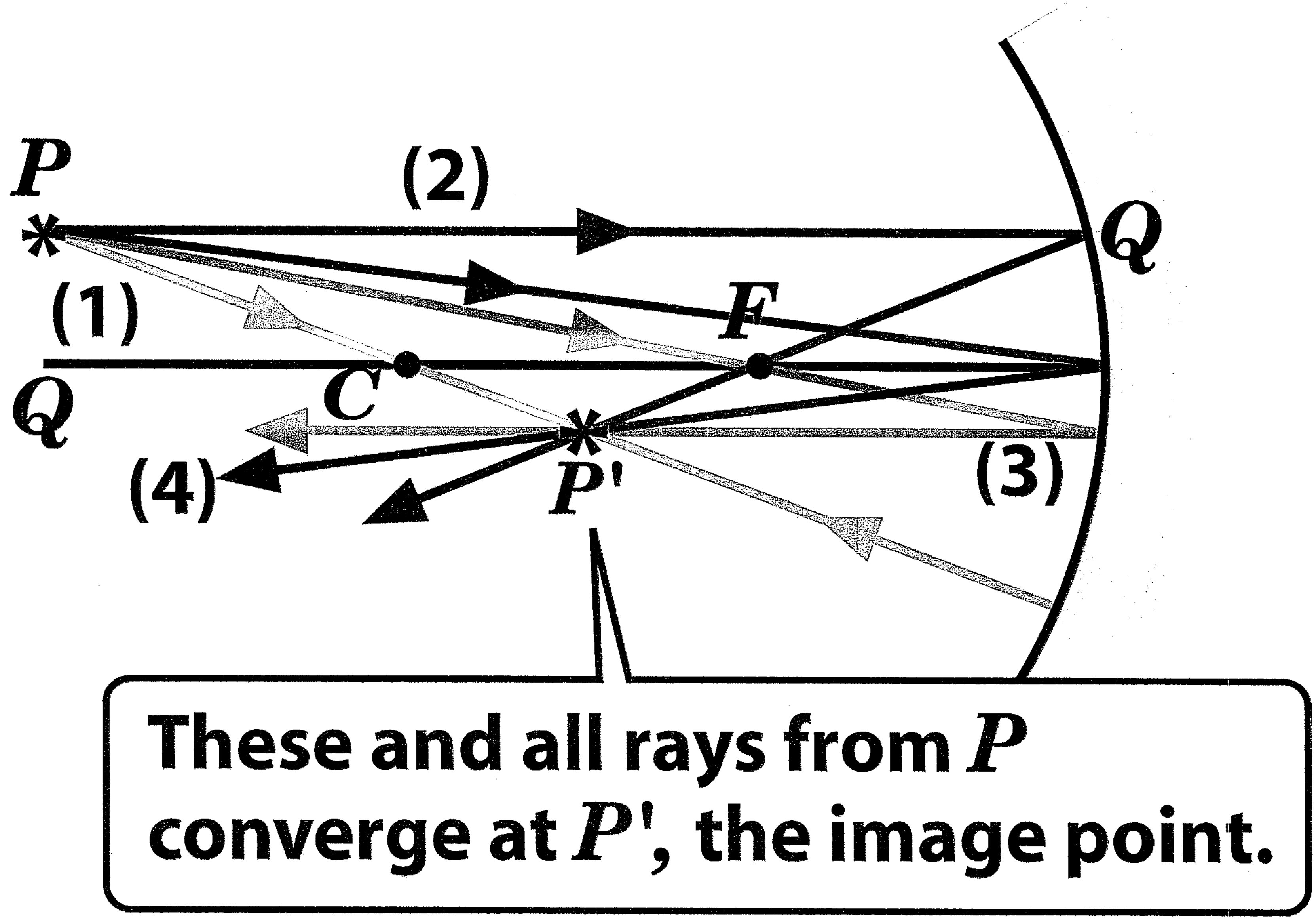


Figure 34-35e Physics for Engineers and Scientists 3/e

$s \equiv$ distance of source to mirror

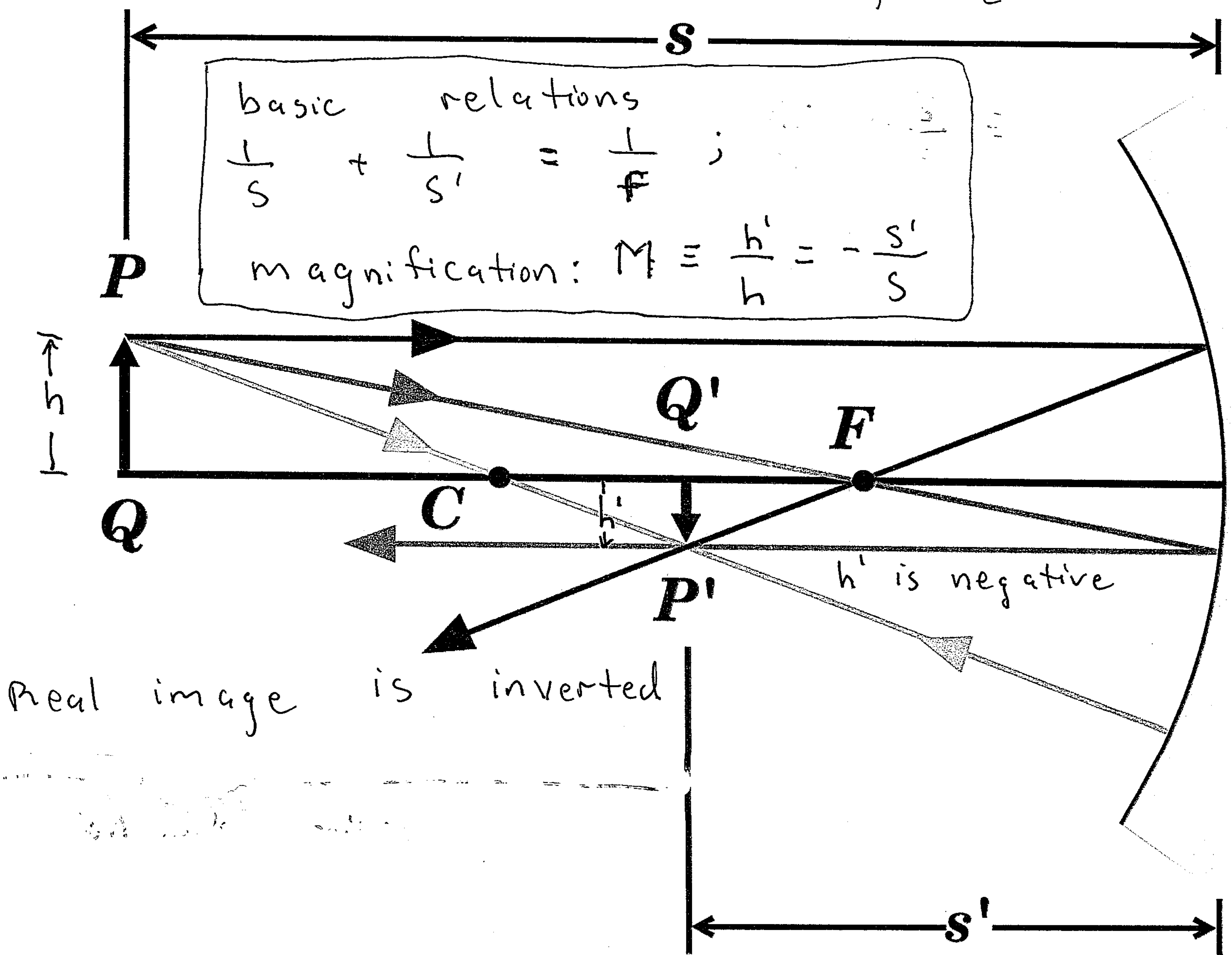


Figure 34-36 Physics for Engineers and Scientists 3/e

$s' \equiv$ distance of image to mirror

$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$; $f < 0$ for convex mirror, $s' < 0$

$M = \frac{h'}{h} = -\frac{s'}{s}$

$0 < M < 1$

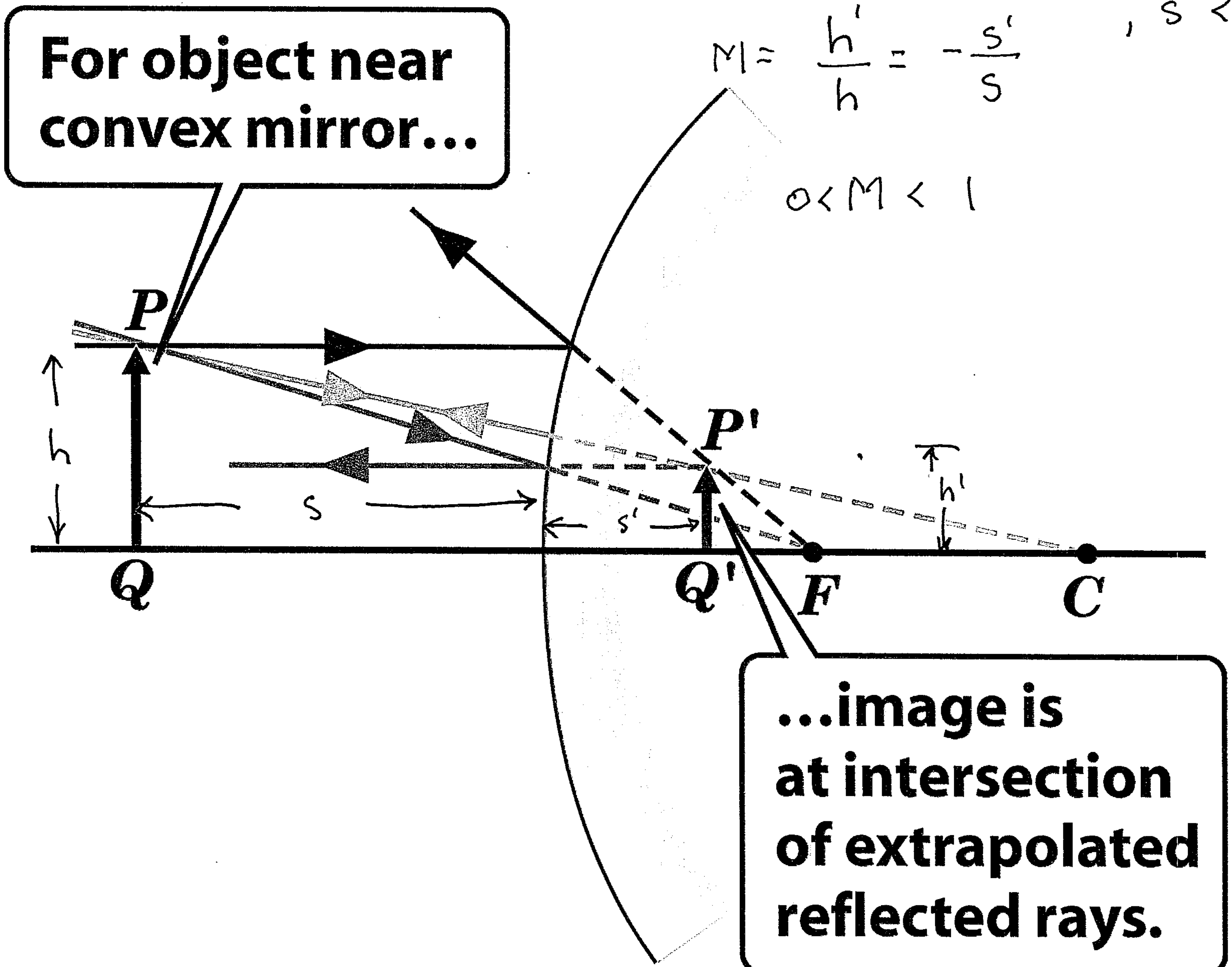
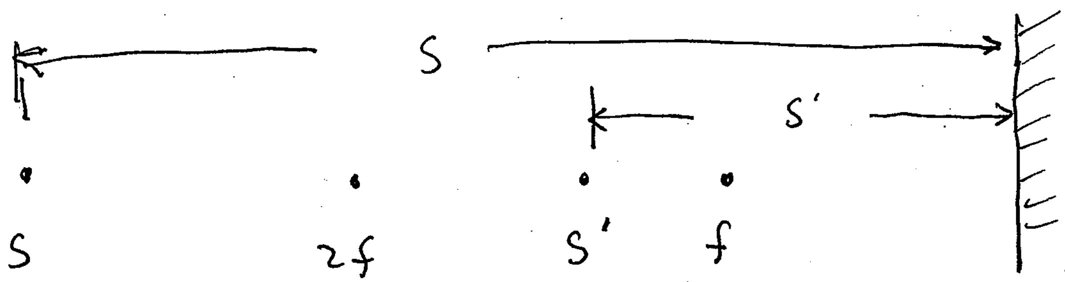


Figure 34-37 Physics for Engineers and Scientists 3/e

Conventions for mirrors

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$



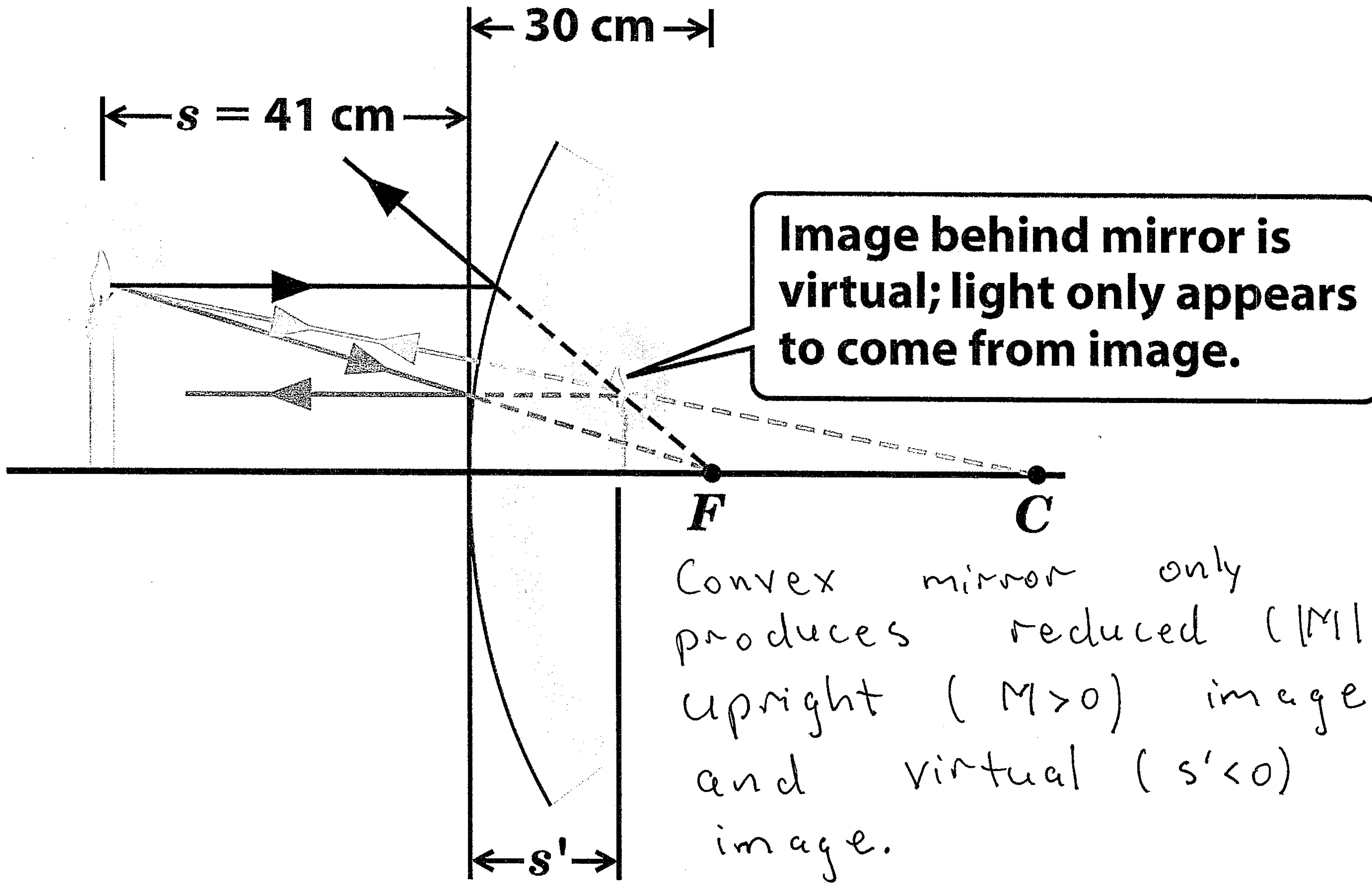
$s > 0 \equiv$ source distance to left of mirror

$s' > 0 \equiv$ real image distance to left of mirror

$s' < 0 \equiv$ virtual image distance to right of mirror

$f > 0 \equiv$ focal distance of concave mirror

$f < 0 \equiv$ focal distance of convex mirror



Convex mirror only produces reduced ($|M| < 1$), upright ($M > 0$) image, and virtual ($s' < 0$) image.

Figure 34-40 Physics for Engineers and Scientists 3/e

Concave mirrors can produce

(a) virtual, upright and magnified ($|M|>1$) image if $0 < s < f$

(b) real, inverted ($M<0$), and magnified ($|M|>1$) if $f < s < 2f$

(c) real, inverted and reduced ($|M|<1$) if $2f < s < \infty$

(example: optical mirror telescope)

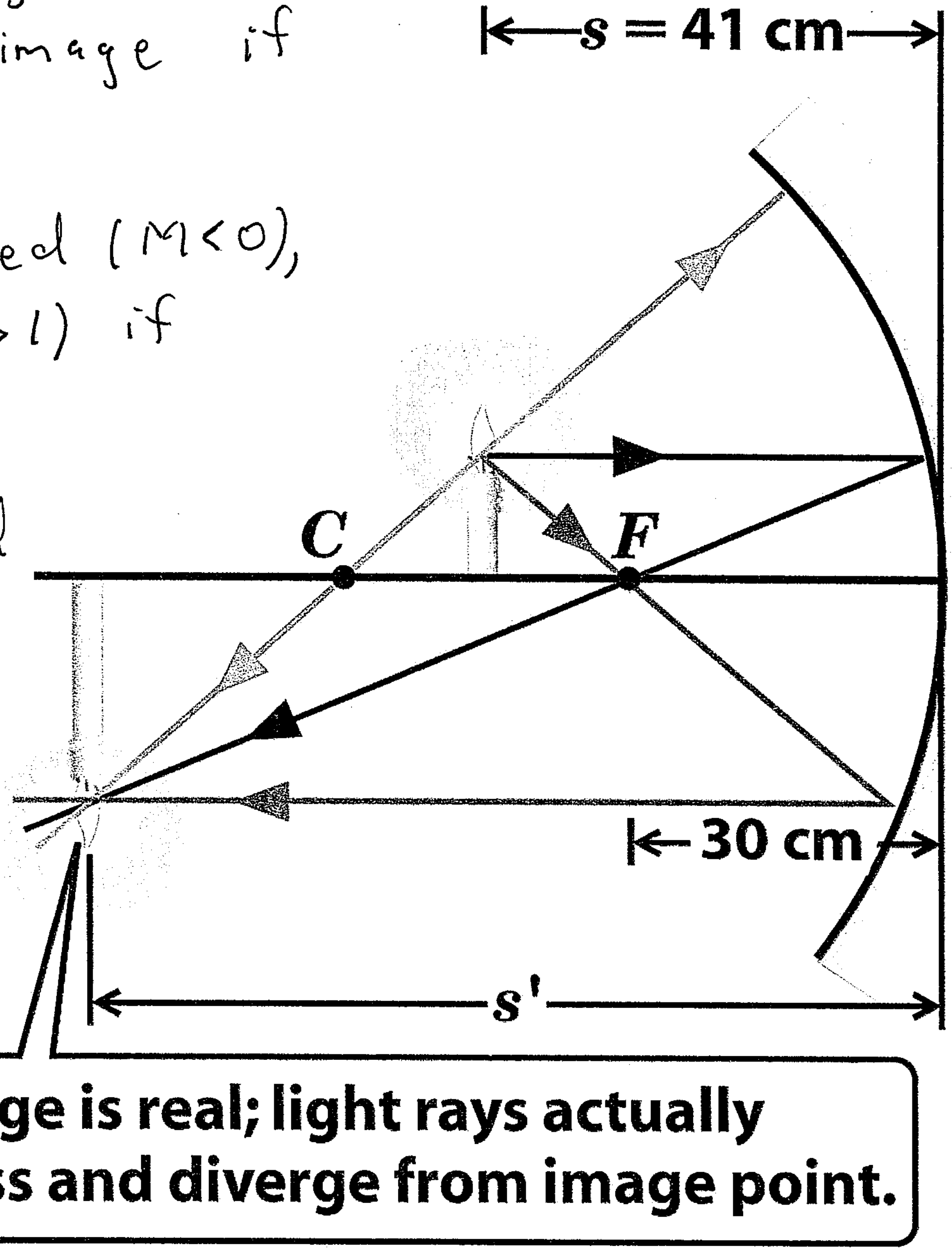


Figure 34-41a Physics for Engineers and Scientists 3/e