

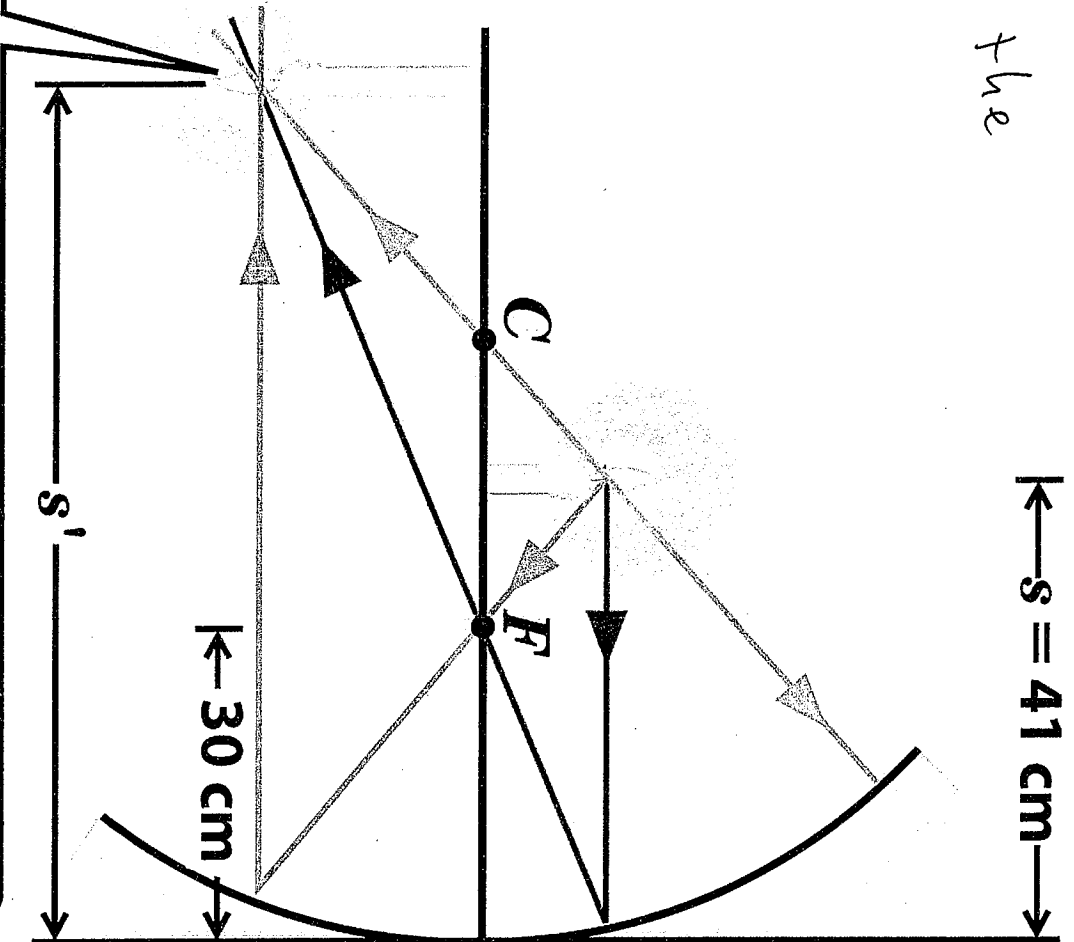
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# Optics of Lenses

Lecture 32

What is the position of the real image

1. 52 cm
2. 112 cm
3. 232 cm



**Image is real; light rays actually cross and diverge from image point.**

Figure 34-41a, Physics for Engineers and Scientists 3/e  
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In This ~~is~~ picture ~~of~~

~~the~~ ~~objects~~

~~are~~.

Which of these objects are closer to you?

- a. The upright '5'
- on the right.
- b. The inverted '5'
- on the left

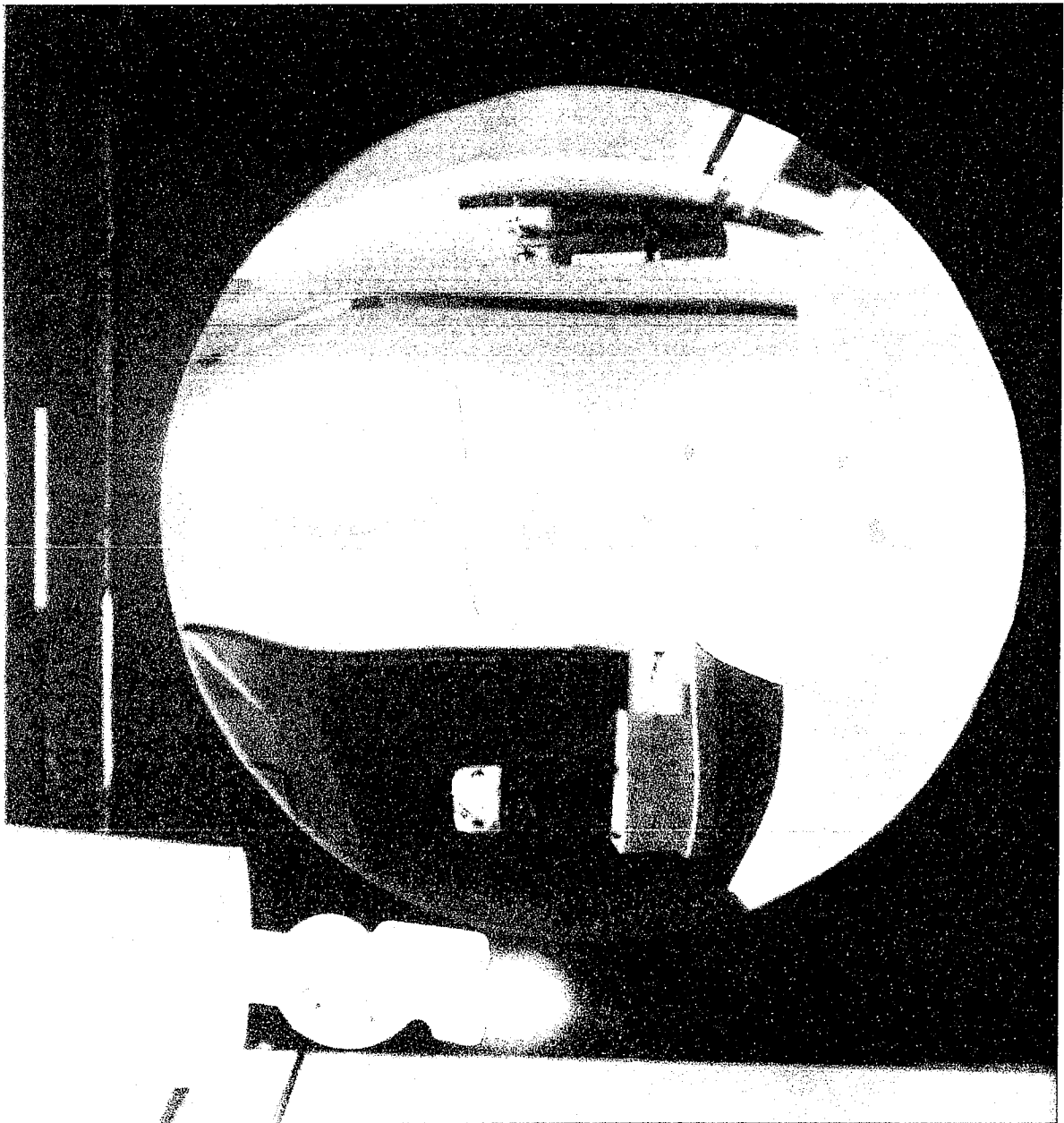
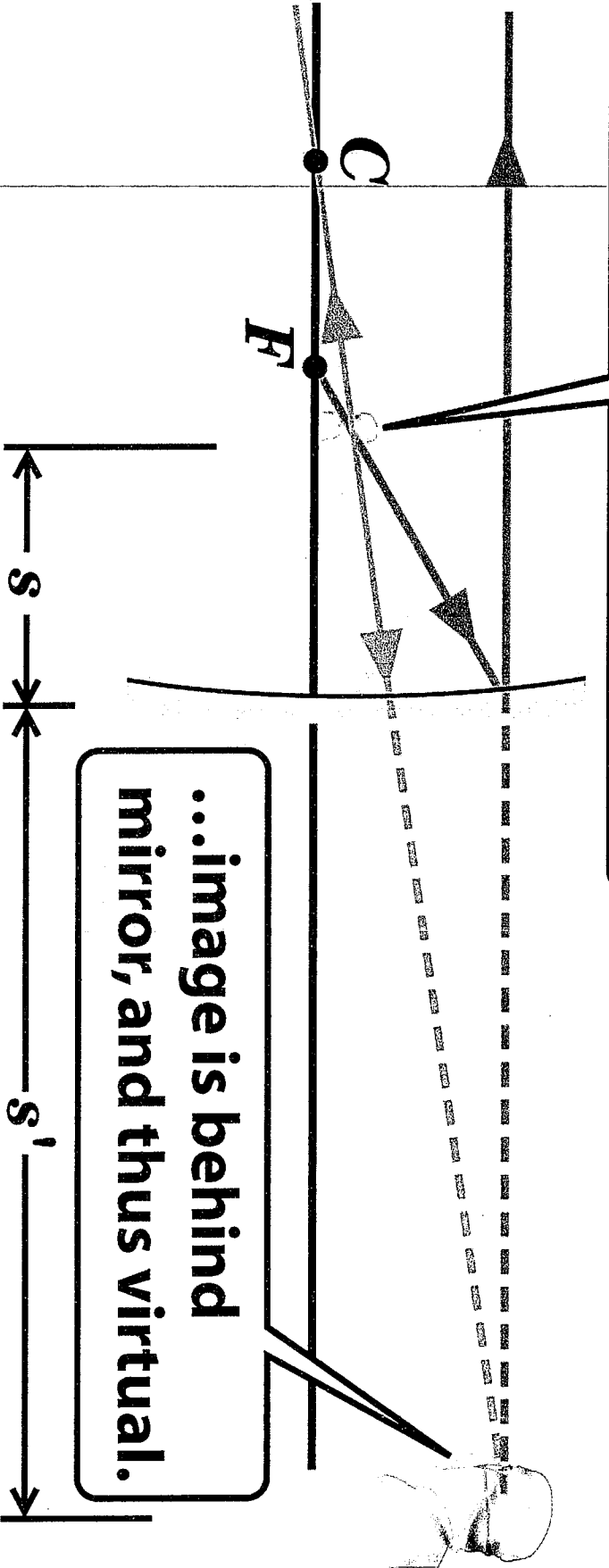


Figure 34-41b Physics for Engineers and Scientists 3/e  
Courtesy of John Markert

**For object closer to concave mirror than focal point...**



**...image is behind mirror, and thus virtual.**

Figure 34-42 Physics for Engineers and Scientists 3/e  
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Focusing lens ( $f > 0$ )

focal length =  $f$

**Incident parallel rays...**

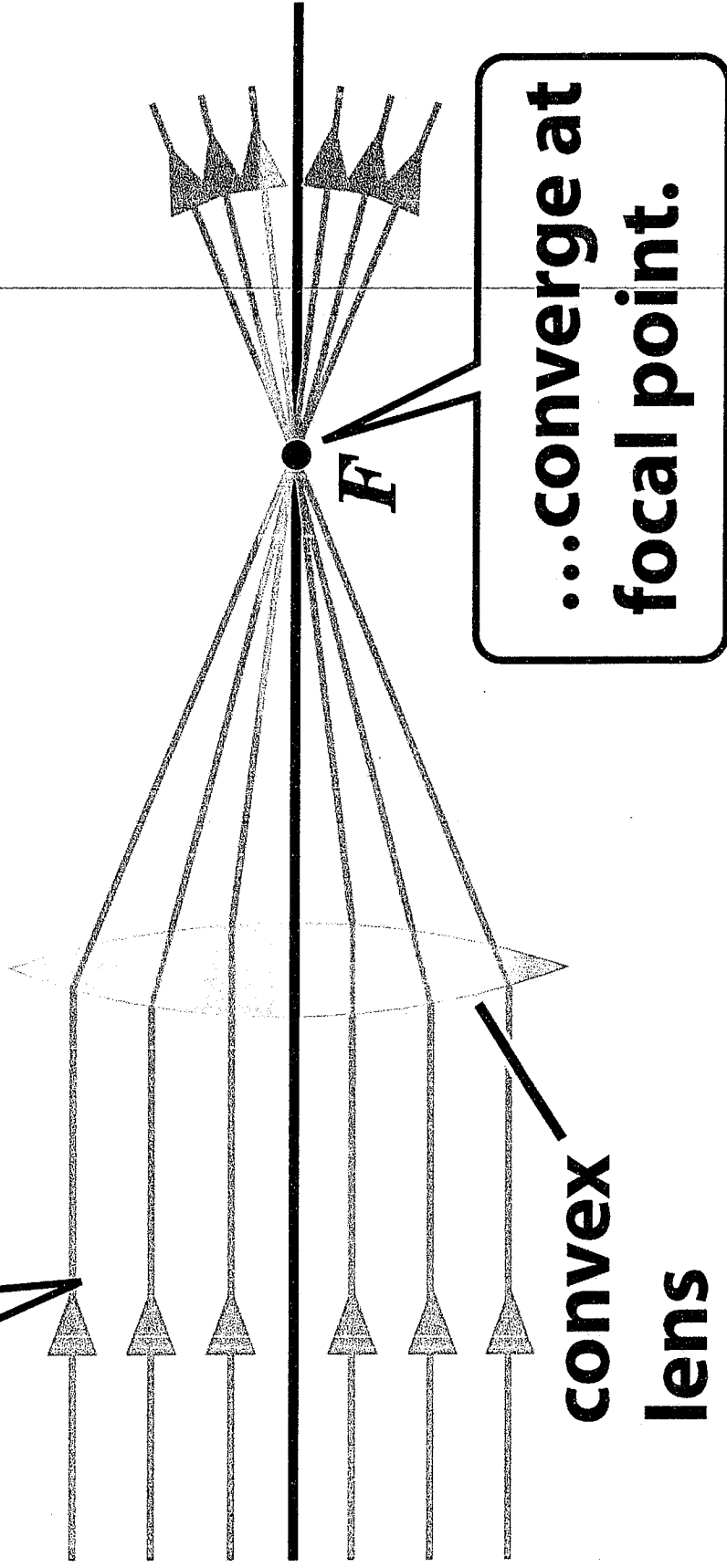


Figure 34-43a Physics for Engineers and Scientists 3/e  
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De focusing lens ( $f < 0$ )

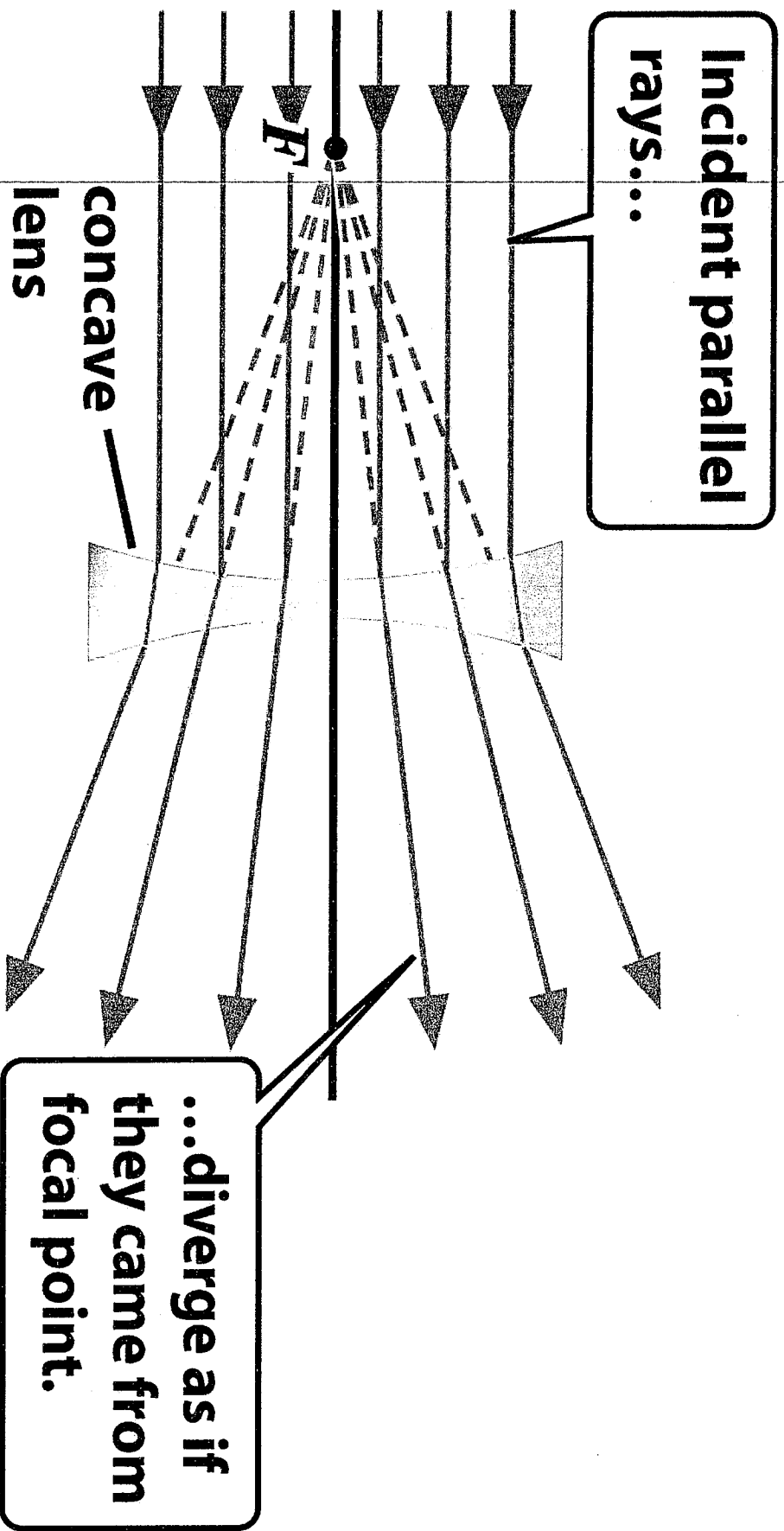
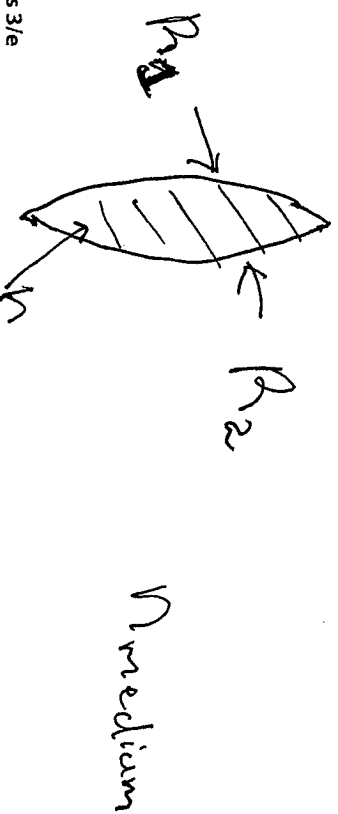


Figure 34-44a Physics for Engineers and Scientists 3/e  
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# LENS MAKER'S FORMULA

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



Equation 34-27 Physics for Engineers and Scientists 3/e  
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$$\frac{1}{f} = (n - n_{\text{medium}}) \left( \frac{1}{R_1} + \frac{1}{R_2} \right)$$

**Radius of curvature of concave surface ( $R_1$ ) is reckoned as negative.**

**Concave-convex lens with smaller convex radius of curvature produces convergence.**

**Radius of curvature of convex surface ( $R_2$ ) is reckoned as positive.**

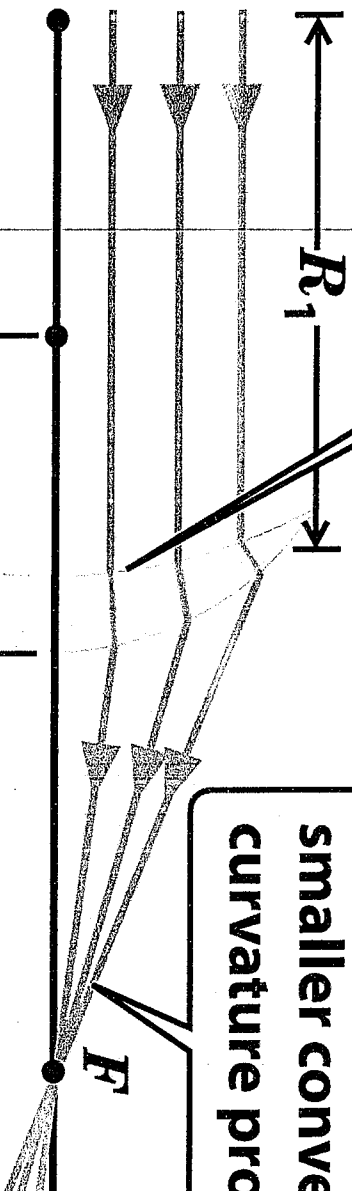


Figure 34-45a Physics for Engineers and Scientists 3/e  
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$$f = (n-1) \left( \frac{1}{R_1} + \frac{1}{R_2} \right)$$

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



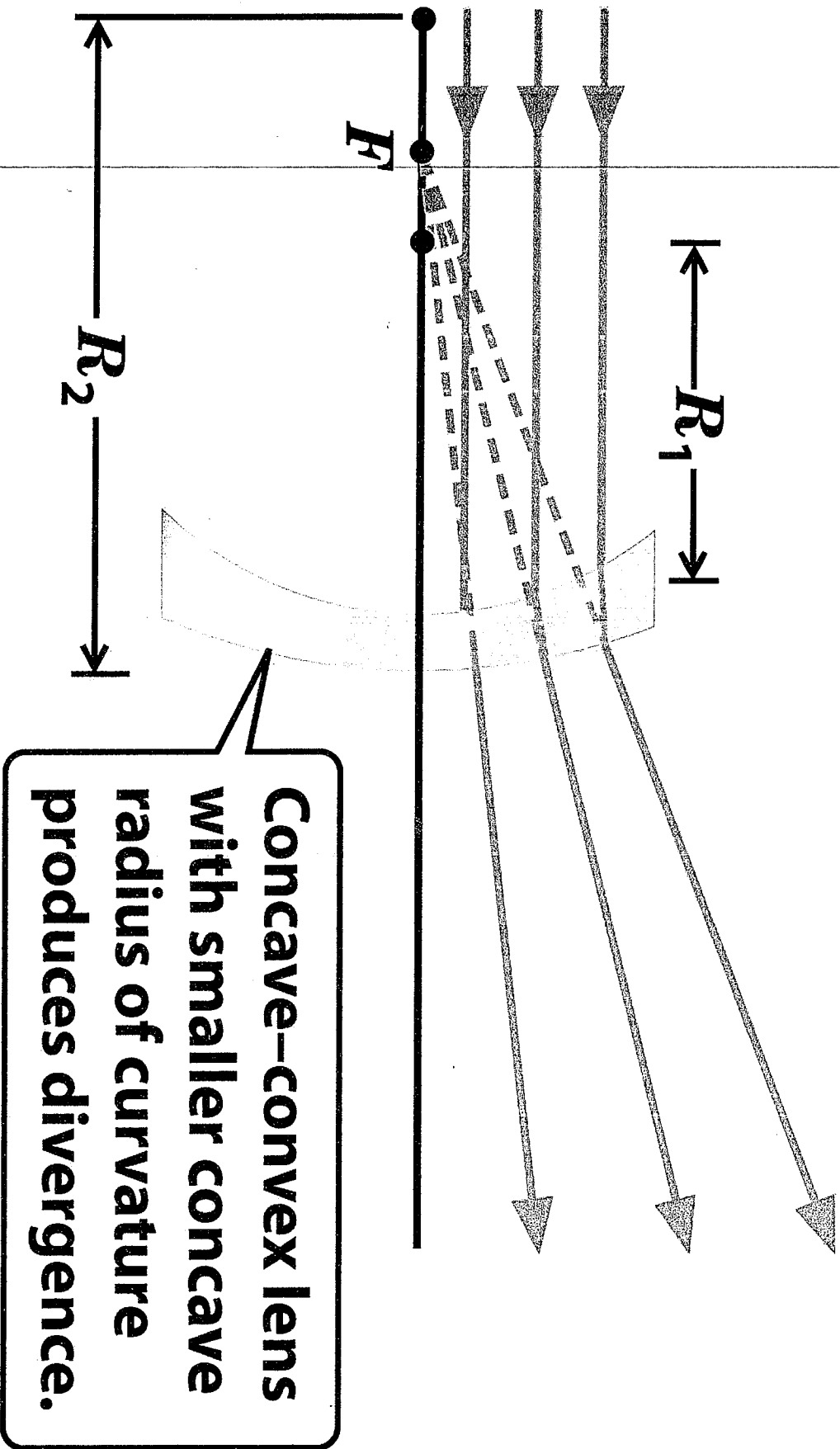
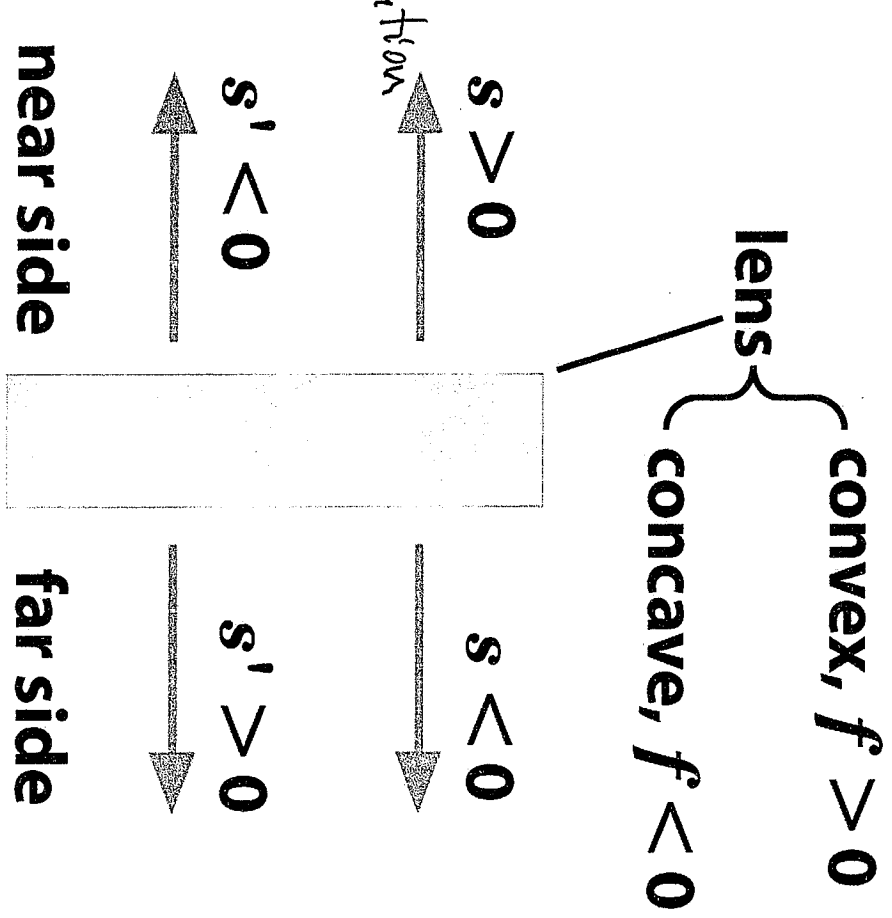


Figure 34-45b Physics for Engineers and Scientists 3/e  
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$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

Linear Magnification

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



**direction of propagation of light**

Figure 34-48 Physics for Engineers and Scientists 3/e  
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# MIRROR AND LENS EQUATION

But there is a difference in notation between mirror and lens

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}; \quad M = \frac{-s'}{s}$$

MIRROR;  $s > 0$  on left;

real image (inverted)

$s' > 0$ ,  $s'$  on left

$f = R/2 > 0$ , converging concave mirror

virtual upright image

$s' < 0$  on right

$f = R/2 < 0$ , diverging convex mirror

LENS;  $s > 0$  on left

real image (inverted)

$s' > 0$ ,  $s'$  on right

$1/f = (n-1)(1/R_1 + 1/R_2) > 0$ , converging convex lens

virtual upright image

$s' < 0$ , on left

$1/f = (n-1)(1/R_1 + 1/R_2) < 0$ ; diverging concave mirror

# Focusing of Image

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

Ray parallel to axis passes through far focal point.

Ray through near focal point emerges parallel to axis.

Ray through center goes straight through.

Rays converge; image is real and inverted.

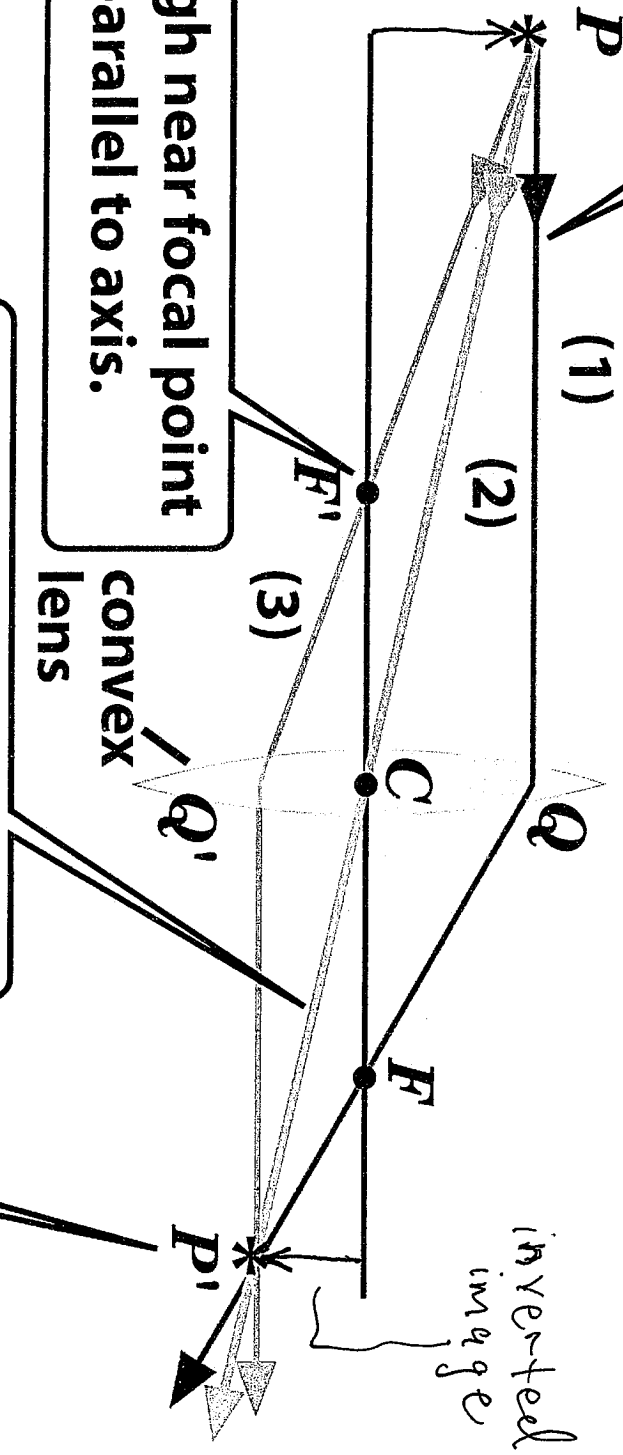
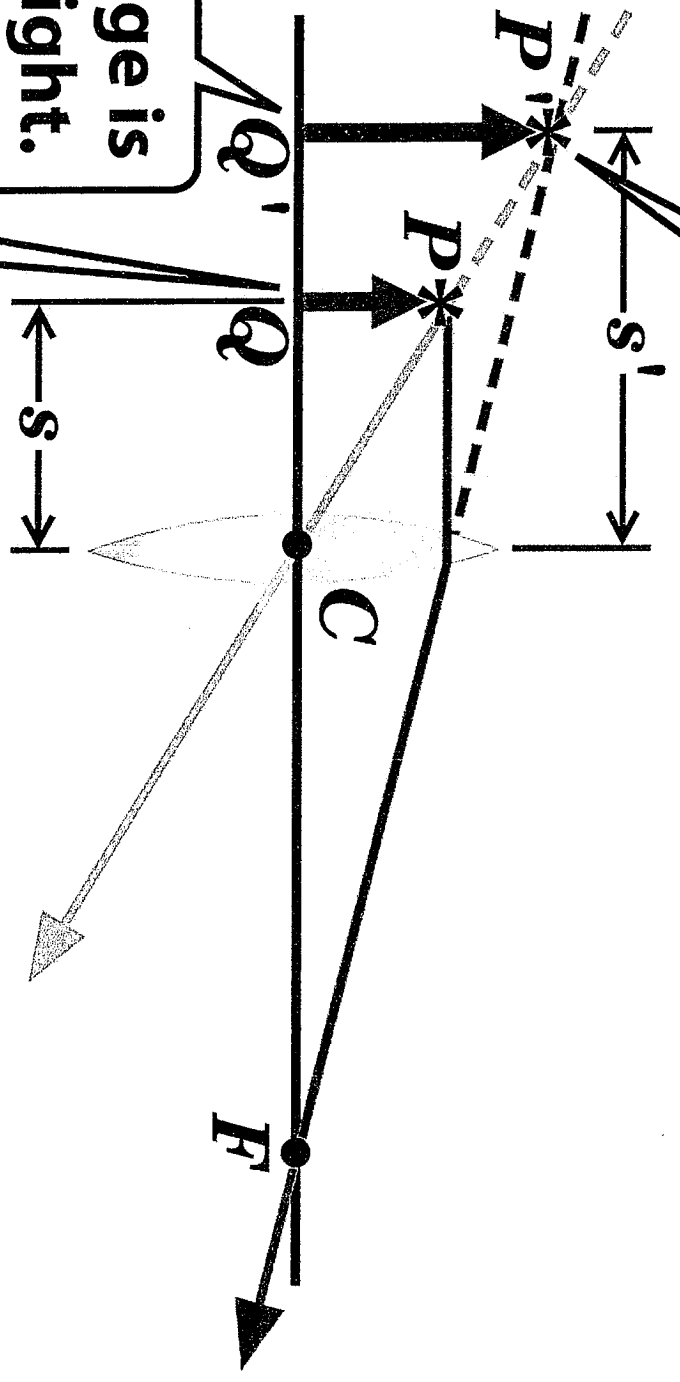


Figure 34-46 Physics for Engineers and Scientists 3/e  
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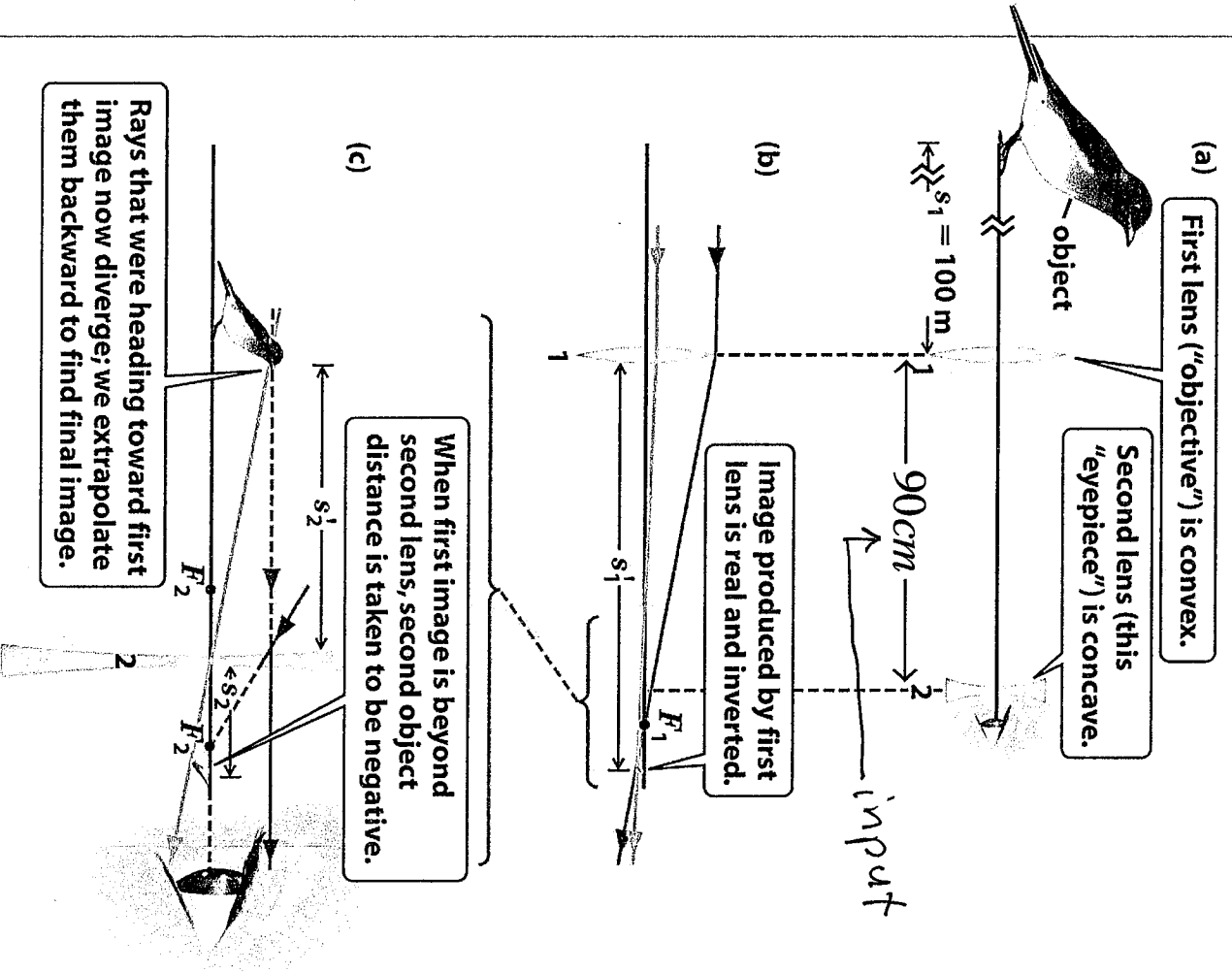
**Since rays only appear to come from image point, image is virtual.**



**Image is upright.**

**Object is closer than focal distance to lens.**

Figure 34-50 Physics for Engineers and Scientists 3/e  
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Input

$$\begin{aligned}
 s_1 &= 100\text{ m} = 10^4\text{ cm} \\
 f_1 &= 100\text{ cm} \\
 f_2 &= -8\text{ cm} \\
 s_1' &= 101\text{ cm} \\
 s_2 &= -11\text{ cm} \\
 s_2' &= -29\text{ cm}
 \end{aligned}$$

$$M_1 = -\frac{s_1'}{s_1} = -.0101$$

$$M_2 = -\frac{s_2'}{s_2} = -2.6$$

$$M = M_1 M_2 = .026 \quad \left( \begin{array}{l} \text{magnified in} \\ \text{size?} \end{array} \right)$$

Angular Width of Object

$$\Delta\theta_{obj} \approx \frac{h}{s} = 10^{-4} h$$

Angular Width of Image

$$\Delta\theta_{img} \approx \frac{Mh}{s_2'} = \frac{.026h}{29} \approx .001h$$

~ 10 fold gain in angular width

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