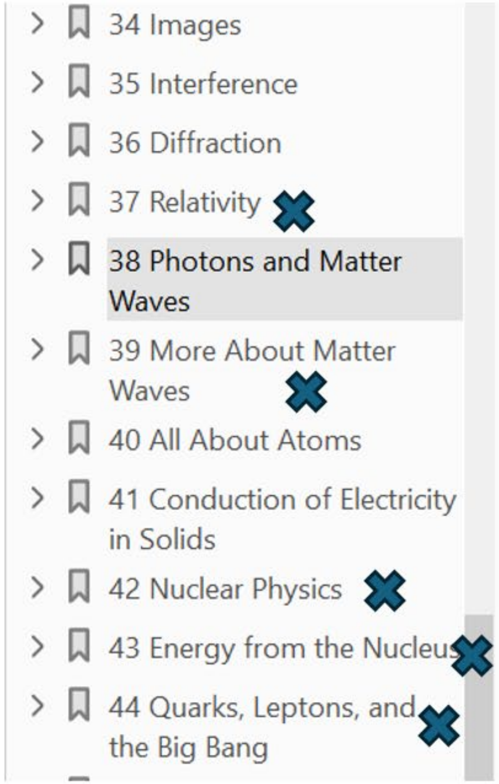


11	**Images, Interference, (Ch34-35)**
12	Diffraction, Photons and Matters Waves (Ch36, 38)
13	Atoms, Conduction of Electricity in Solids (Ch40-41)
14	Review week
15	Module 3 exam

M3 考试选择题没大题，选择题里会有对概念的理解和计算

Chapter 34

Images

Summary (1 of 5)

Real and Virtual Images

- If the image can form on a surface, it is a real image and can exist even if no observer is present. If the image requires the visual system of an observer, it is a virtual image.

Image Formation

- Spherical mirrors, spherical refracting surfaces, and thin lenses can form images of a source of light—the object — by redirecting rays emerging from the source.

Summary (2 of 5)

- **Spherical Mirror:**

$$\frac{1}{p}+\frac{1}{i}=\frac{1}{f}=\frac{2}{r},$$

Equation 34-3& 4

- **Spherical Refracting Surface:**

$$\frac{n_1}{p}+\frac{n_2}{i}=\frac{n_2-n_1}{r}$$

Equation 34-8

Summary (3 of 5)

- **Thin Lens:**

$$\frac{1}{p}+\frac{1}{i}=\frac{1}{f}=(n-1)\left(\frac{1}{r_1}-\frac{1}{r_2}\right),$$ **Equation 34-9& 4**

Optical Instruments

- Three optical instruments that extend human vision are:

Summary (4 of 5)

1. The simple magnifying lens, which produces an angular magnification m_θ given by

$$m_\theta = \frac{25\,\text{cm}}{f}$$

Equation 34-12

2. The compound microscope, which produces an overall magnification M given by

$$M = mm_0 = -\frac{s}{f_{\text{ob}}}\frac{25\,\text{cm}}{f_{\text{ey}}}$$

Equation 34-14

Summary (5 of 5)

3. The refracting telescope, which produces an angular magnification mu given by

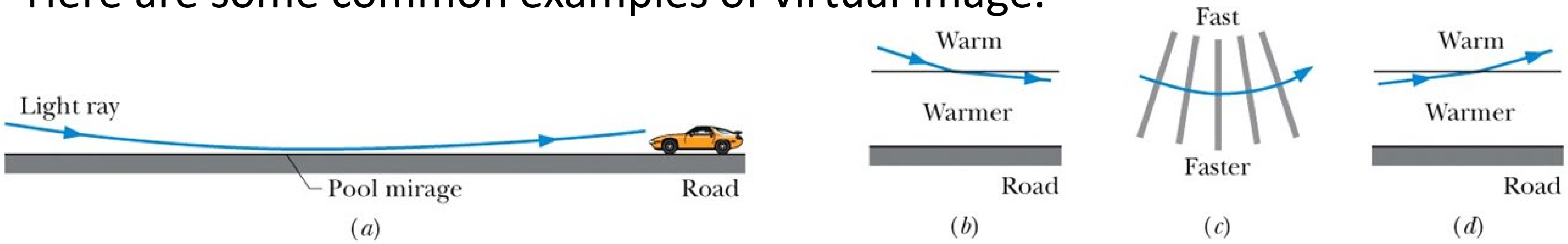
$$m_\theta = -\frac{f_{\mathrm{ob}}}{f_{\mathrm{ey}}}$$

Equation 34-15

34-1 Images and Plane Mirrors (2 of 5)

An image is a reproduction of an object via light. If the image can form on a surface, it is a real image and can exist even if no observer is present. If the image requires the visual system of an observer, it is a virtual image.

Here are some common examples of virtual image.



(a) A ray from a low section of the sky refracts through air that is heated by a road (without reaching the road). An observer who intercepts the light perceives it to be from a pool of water on the road.

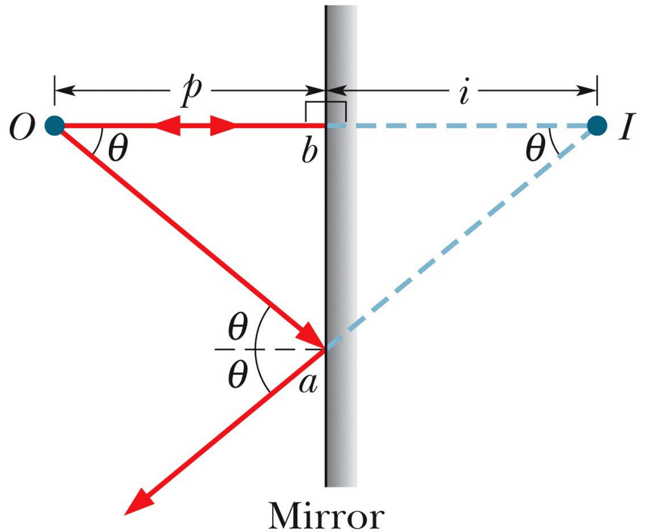
(b) Bending (exaggerated) of a light ray descending across an imaginary boundary from warm air to warmer air.

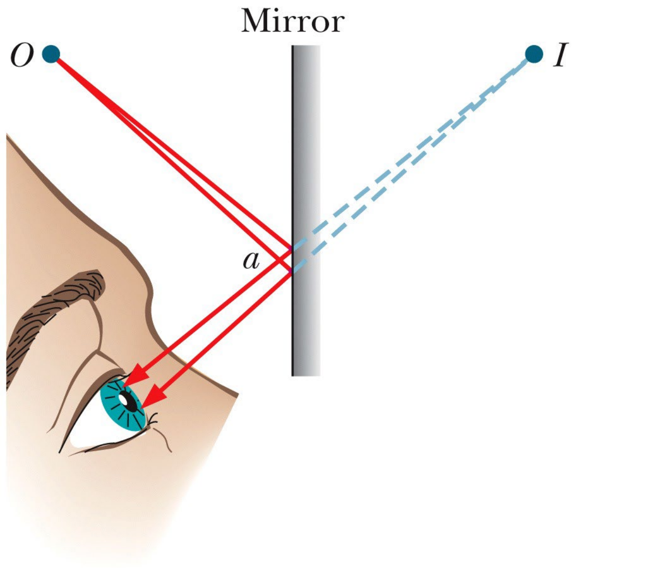
(c) Shifting of wavefronts and associated bending of a ray, which occur because the lower ends of wavefronts move faster in warmer air.

(d) Bending of a ray ascending across an imaginary boundary to warm air from warmer air.

34-1 Images and Plane Mirrors (4 of 5)

As shown in figure (a), a plane (flat) mirror can form a virtual image of a light source (said to be the object, O) by redirecting light rays emerging from the source. The image can be seen where backward extensions of reflected rays pass through one another. The object's distance p from the mirror is related to the (apparent) image distance i from the mirror by





$$i = -p$$

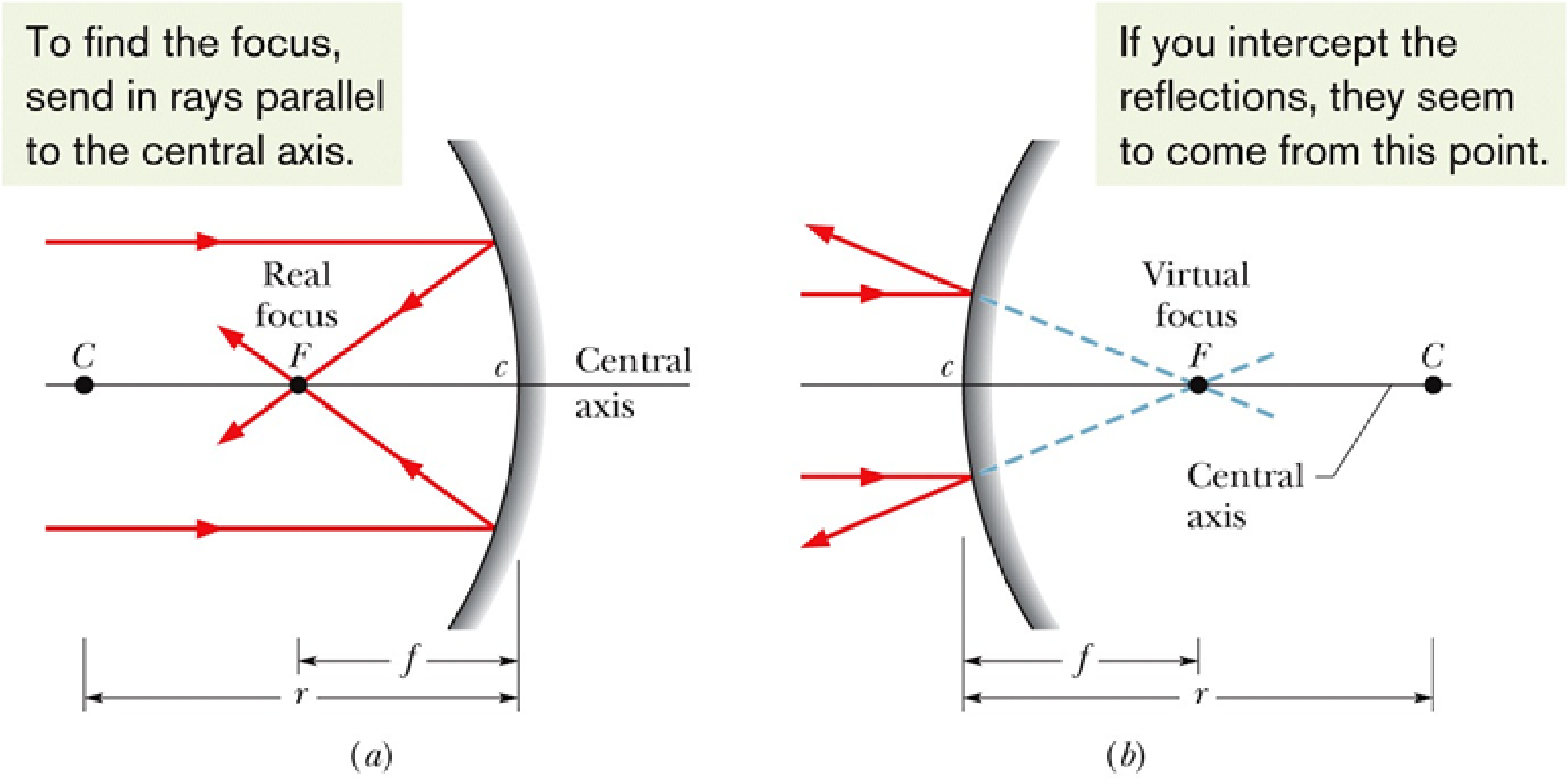
- Object distance p is a positive quantity.
- Image distance i for a virtual image is a negative quantity.

Only rays that are fairly close together can enter the eye after reflection at a mirror. For the eye position shown in Fig. (b), only a small portion of the mirror near point a (a portion smaller than the pupil of the eye) is useful in forming the image.

34-2 Spherical Mirrors (6 of 13)

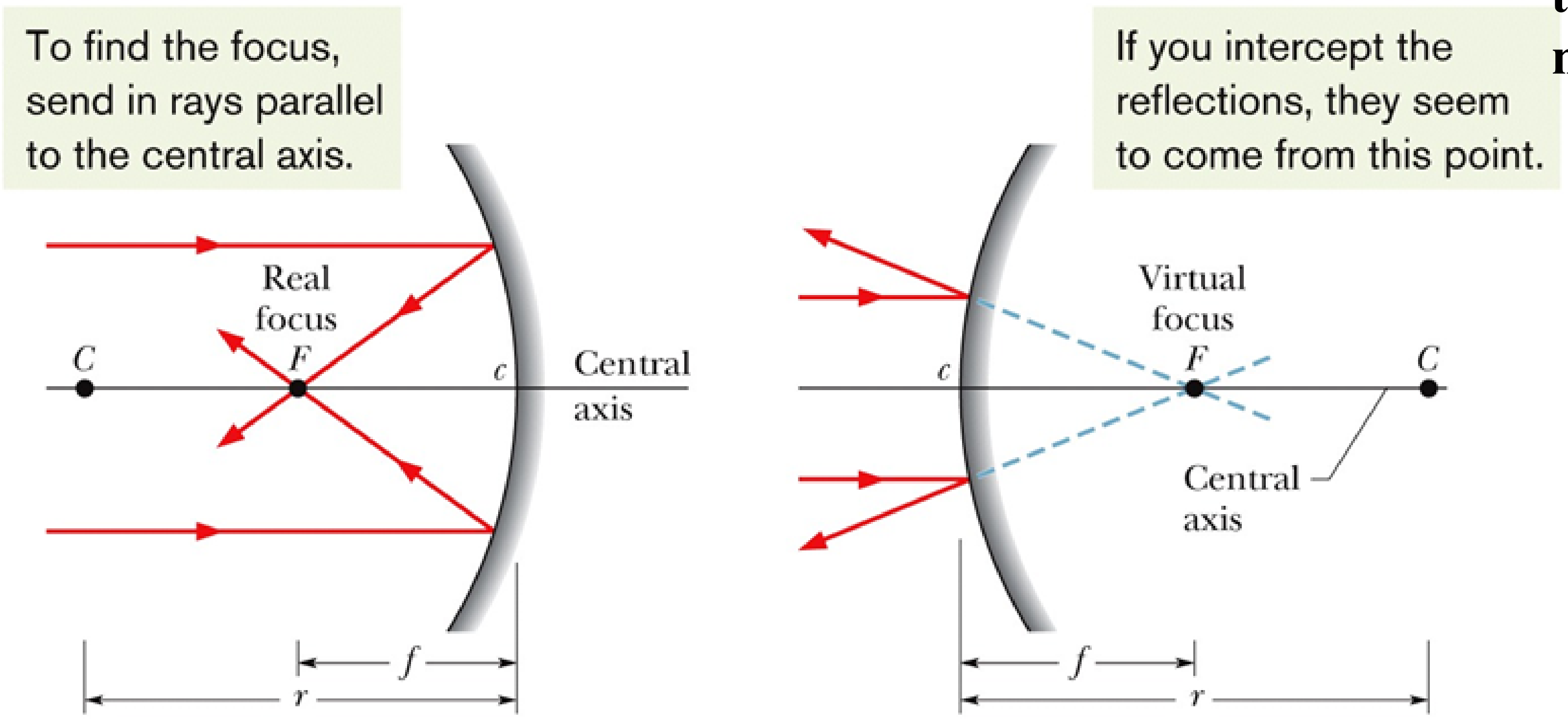
If parallel rays are sent into a (spherical) concave (凹的) mirror parallel to the central axis, the reflected rays pass through a common point **(a real focus *F*) at a distance *f* (a positive quantity)** from the mirror (figure a).

If they are sent toward a (spherical) convex (凸的) mirror, backward extensions of the reflected rays pass through a common point **(a virtual focus *F*) at a distance *f* (a negative quantity)** from the mirror (figure b).



34-2 Spherical Mirrors (7 of 13)

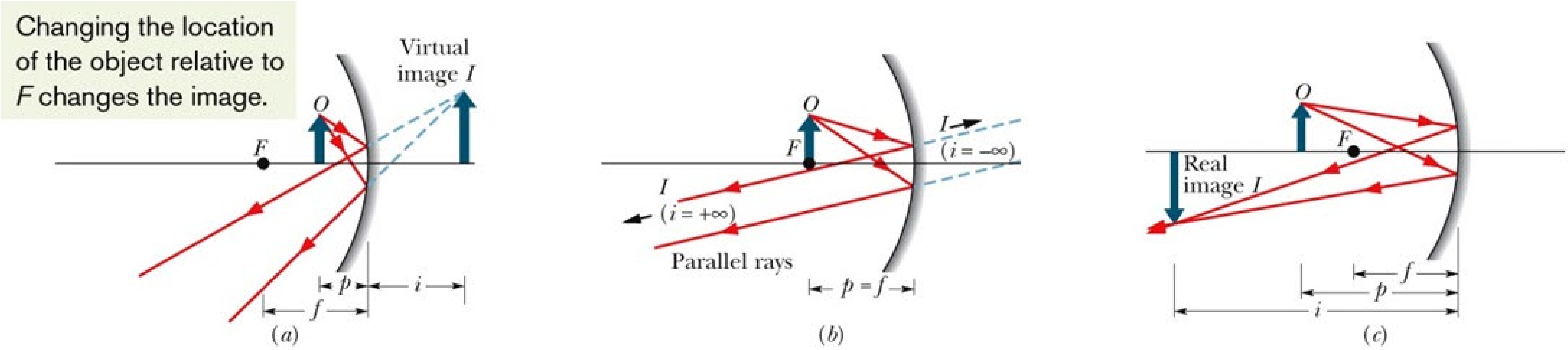
The focal length *f* is related to the radius of curvature *r* of the mirror by 曲率半径



$$f = \frac{1}{2} r$$

where r (and f) is positive for a concave mirror and negative for a convex mirror.

34-2 Spherical Mirrors (8 of 13)

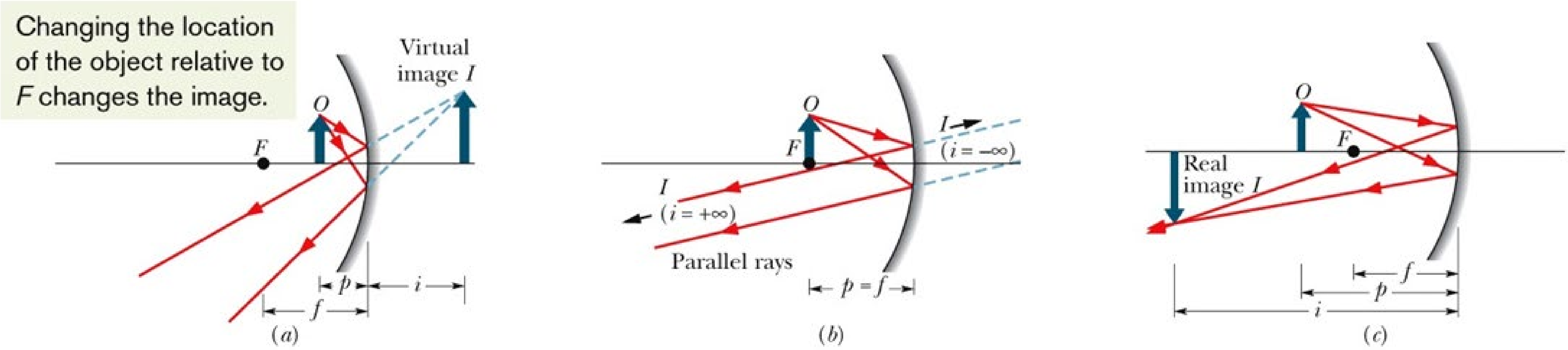


(a) An object *O* inside the focal point of a concave mirror, and its virtual image *I*.

(b) The object at the focal point *F*.

(c) The object outside the focal point, and its real image *I*.

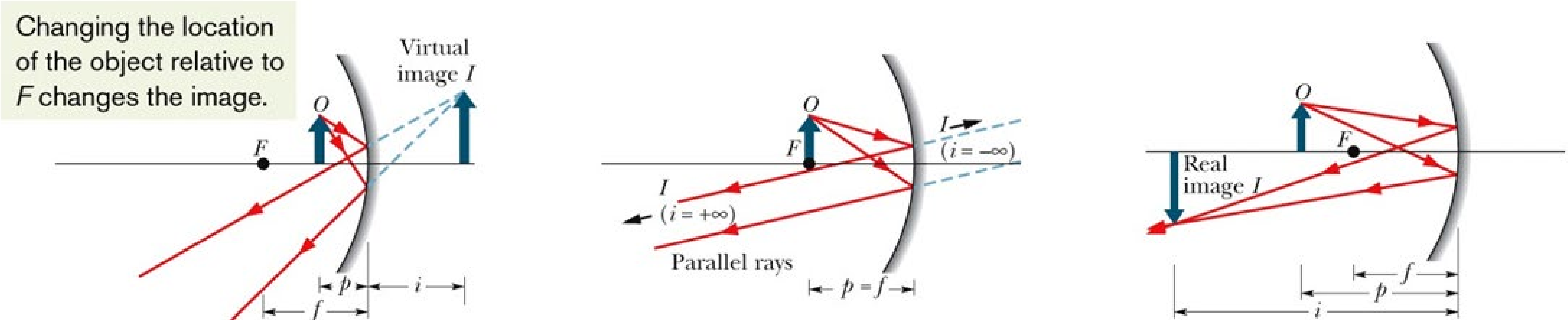
34-2 Spherical Mirrors (8 of 13)



a simple equation relates the object distance *p*, the image distance *i*, and the focal length *f*

$$\frac{1}{p} + \frac{1}{i} = \frac{1}{f}$$

34-2 Spherical Mirrors (9 of 13)

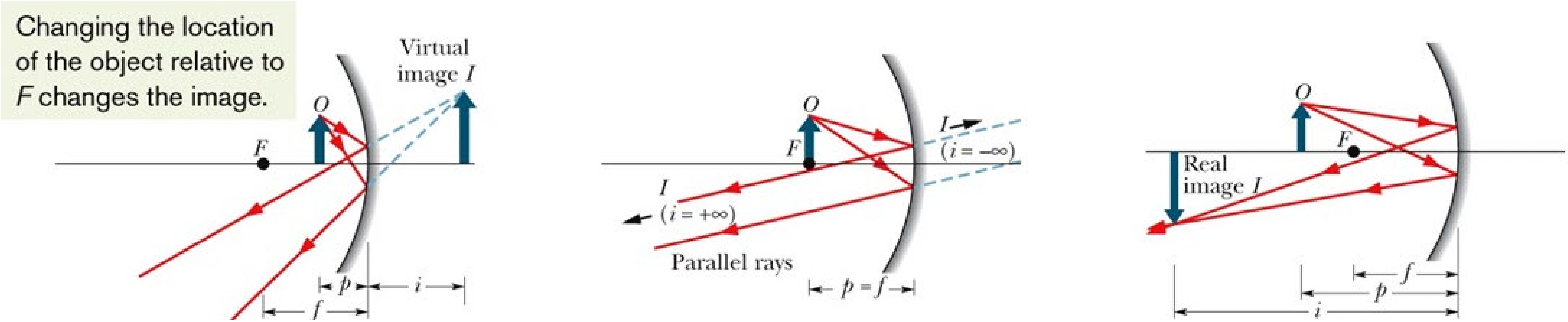


- A concave mirror can form a real image (if the object is outside the focal point)

or a virtual image (if the object is inside the focal point).

$$\frac{1}{p}+\frac{1}{i}=\frac{1}{f}$$

34-2 Spherical Mirrors (10 of 13)



横向放大倍数

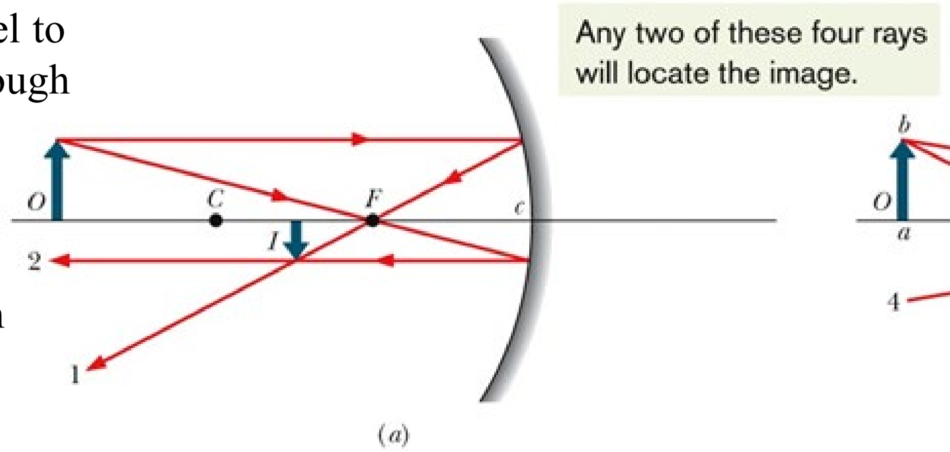
- The magnitude of the **lateral magnification** m of an object is the ratio of the image height h' to object height h,

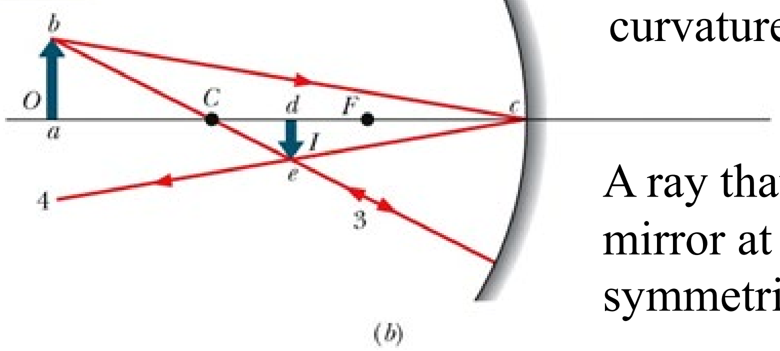
$$|m| = \frac{h'}{h} \quad \Longrightarrow \quad m = -\frac{i}{p}$$

34-2 Spherical Mirrors (11 of 13)

A ray that is initially parallel to the central axis reflects through the focal point *F*

A ray that reflects from the mirror after passing through the focal point emerges parallel to the central axis

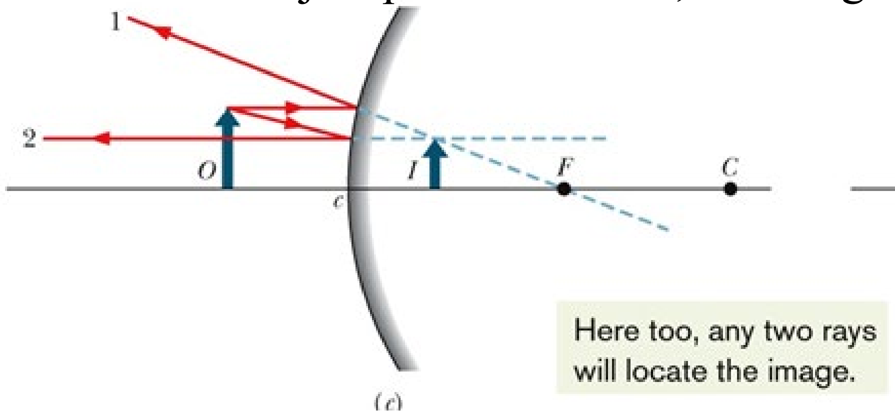


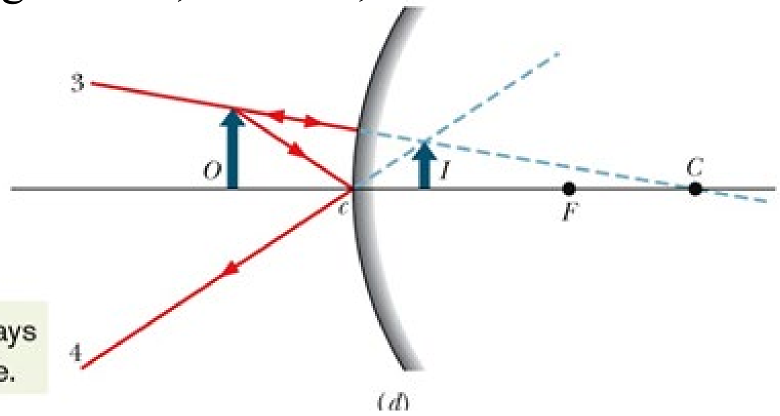


A ray that reflects from the mirror after passing through the center of curvature *C* returns along itself

A ray that reflects from the mirror at point *c* is reflected symmetrically about that axis

For the object position shown, the image is real, inverted, and smaller than the object





For a convex mirror, the image is always virtual, oriented like the object, and smaller than the object.

Table 34-1 Your Organizing Table for Mirrors

Mirror Type	Object Location	Image Location	Image Type	Image Orientation	Sign of f	Sign of r	Sign of i	Sign of m
Plane	Anywhere							
Concave	Inside F							
	Outside F							
Convex	Anywhere							

Mirror Type	Object Location	Image Location	Image Type	Image Orientation	sgn(f) sgn(r)	sgn(m)
Plane	Anywhere	Opposite	Virtual	Not Inverted	NA	+
Concave	Inside F	Opposite	Virtual	Not Inverted	+	+
Concave	Outside F	Same	Real	Inverted	+	−
Convex	Anywhere	Opposite	Virtual	Not Inverted	−	+

34-2 Spherical Mirrors (13 of 13)

The image of the point is at the intersection of the two special rays you choose. The image of the object can then be found by locating the images of two or more of its off-axis points (say, the point most off axis) and then sketching in the rest of the image. You need to modify the descriptions of the rays slightly to apply them to convex mirrors, as in Figures *c* and *d*.

34-2 Spherical Mirrors

A tarantula of height h sits cautiously before a spherical mirror whose focal length has absolute value $|f| = 40$ cm. The image of the tarantula produced by the mirror has the same orientation as the tarantula and has height $h' = 0.20h$.

(a) Is the image real or virtual, and is it on the same side of the mirror as the tarantula or the opposite side?

(b) Is the mirror concave or convex, and what is its focal length f, sign included?

34-2 Spherical Mirrors (13 of 13)

A tarantula of height h sits cautiously before a spherical mirror whose focal length has absolute value $|f| = 40$ cm. The image of the tarantula produced by the mirror has the same orientation as the tarantula and has height $h' = 0.20h$.

(a) Is the image real or virtual, and is it on the same side of the mirror as the tarantula or the opposite side?

(b) Is the mirror concave or convex, and what is its focal length f, sign included?

Because the image has the same orientation as the tarantula (the object), it must be virtual and on the opposite side of the mirror.

$$|m| = \frac{h'}{h} = 0.20.$$

Because the object and image have the same orientation, m must be positive: $m = +0.20$

$$m = -\frac{i}{p} \Rightarrow i = -0.20p$$

$$\frac{1}{f} = \frac{1}{i} + \frac{1}{p} = \frac{1}{-0.20p} + \frac{1}{p} = \frac{1}{p}(-5+1)$$

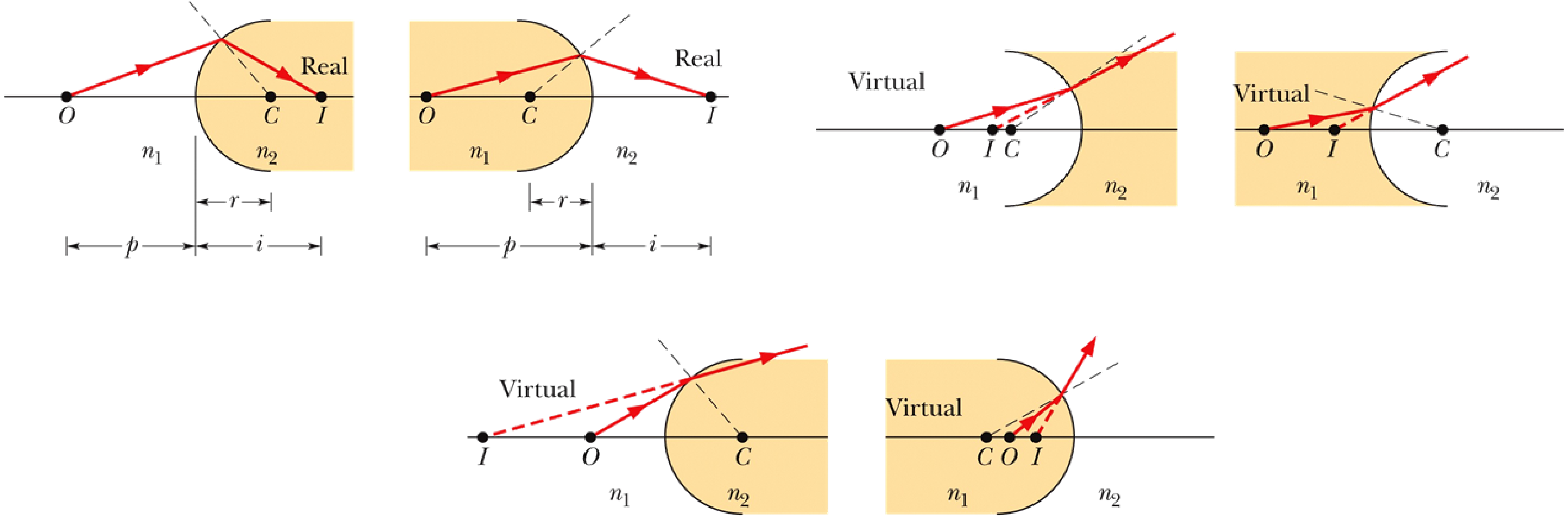
$$f = -p/4.$$

Because p is positive, f must be negative, which means that the mirror is convex with

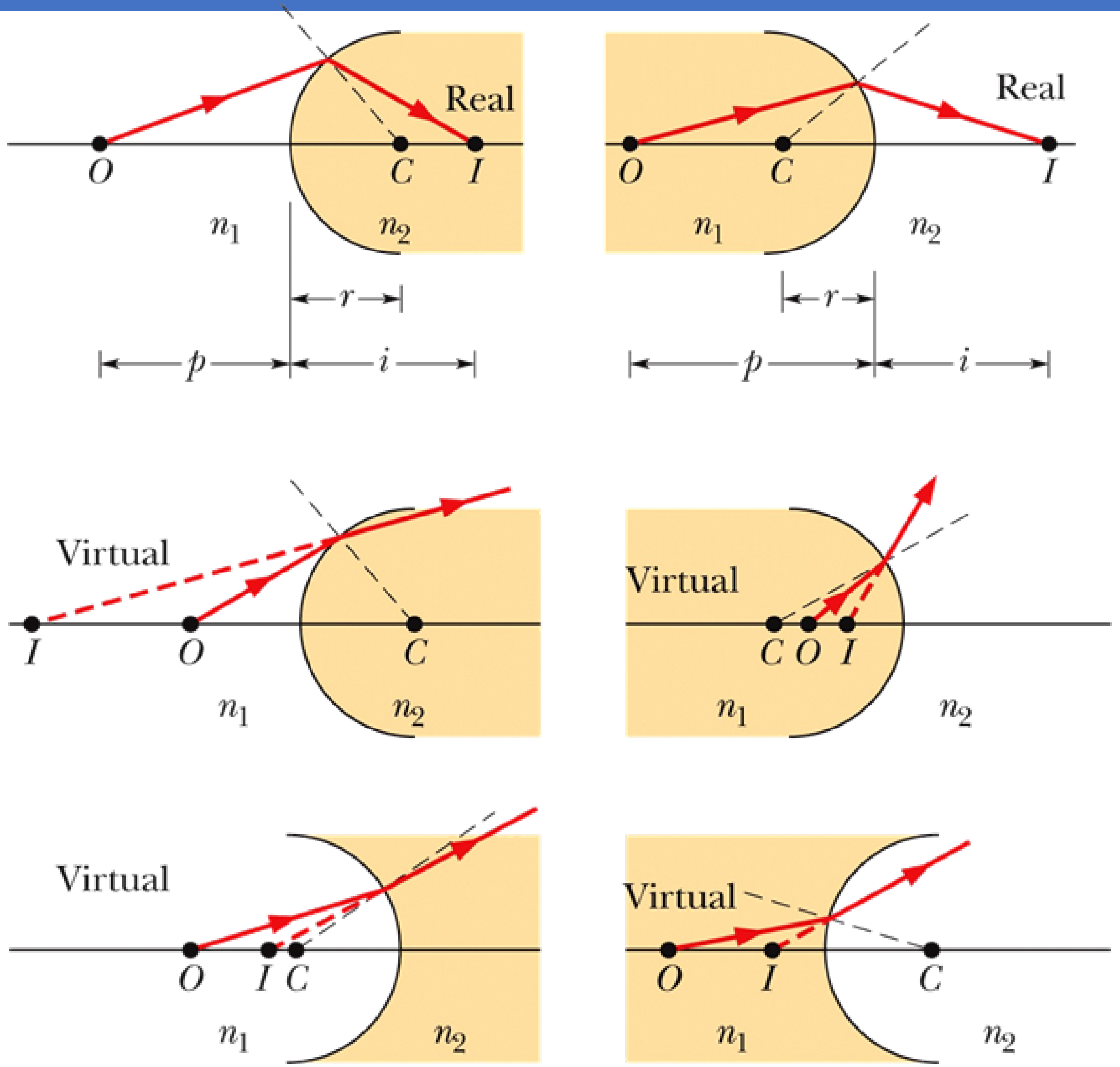
$$f = -40 \text{ cm}.$$

34-3 Spherical Refracting Surface (3 of 5)

Six possible ways in which an image can be formed by refraction through a spherical surface of radius r and center of curvature C.



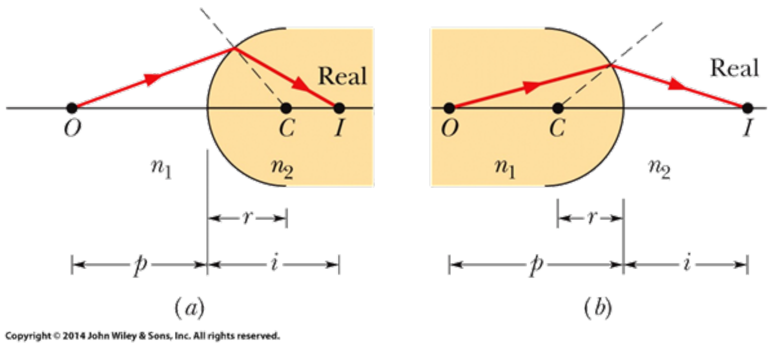
Real images are formed in the top left panel, virtual images are formed in the other four situations.

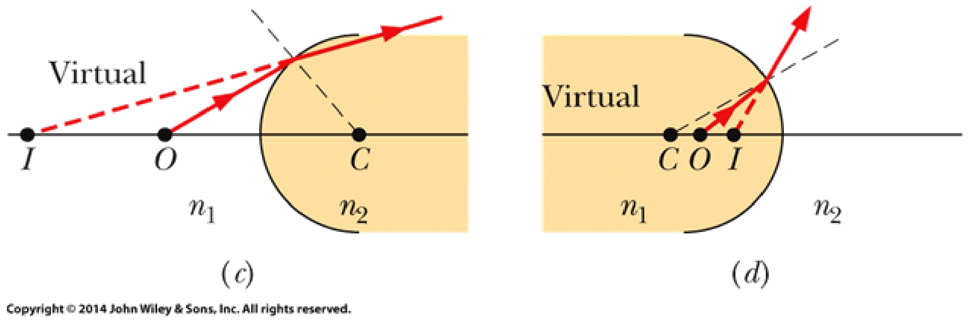


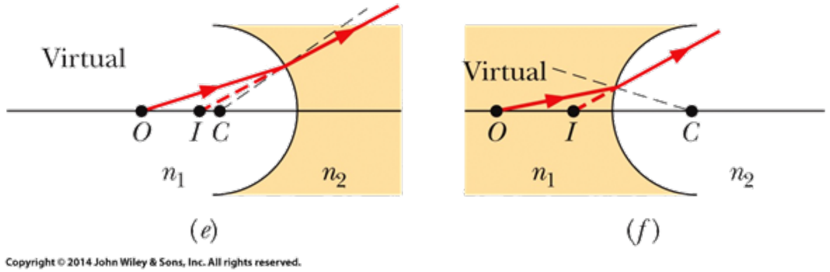
Dr. Paul A. Zahl/Science Source

This insect has been entombed in amber for about 25 million years. Because we view the insect through a curved refracting surface, the location of the image we see does not coincide with the location of the insect (see Fig. 34-12*d*).

34-3 Spherical Refracting Surface (3 of 5)







$$\frac{n_1}{p} + \frac{n_2}{i} = \frac{n_2 - n_1}{r}$$

Real images are formed in (a) and (b); virtual images are formed in the other four situations.

34-3 Spherical Refracting Surface (4 of 5)

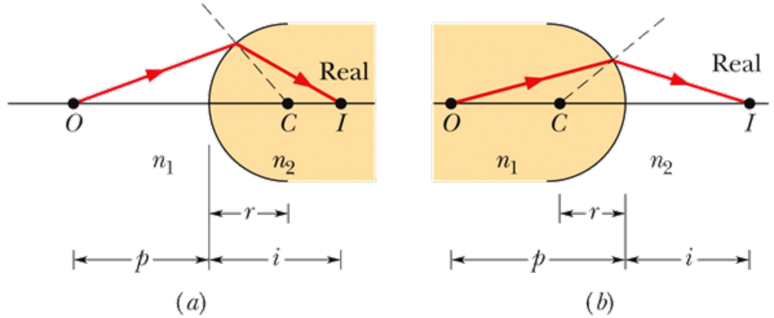
- A single spherical surface that refracts light can form an image.
- The object distance p, the image distance i, and the radius of curvature r of the surface are related by

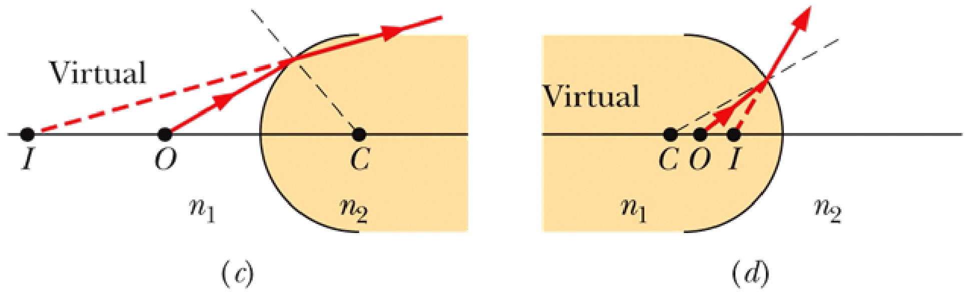
$$\frac{n_1}{p} + \frac{n_2}{i} = \frac{n_2 - n_1}{r}$$

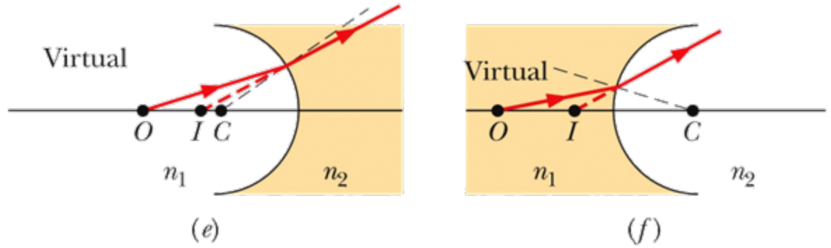
where n_1 is the index of refraction of the material where the object is located and n_2 is the index of refraction on the other side of the surface.

- If the surface faced by the object is convex (凸的) , r is positive, and if it is concave (凹的), r is negative.

34-3 Spherical Refracting Surface (3 of 5)







$$\frac{n_1}{p} + \frac{n_2}{i} = \frac{n_2 - n_1}{r}$$

- If the surface faced by the object is **convex, *r* is positive**, and if it is **concave, *r* is negative**.

34-3 Spherical Refracting Surface (3 of 5)

A Jurassic mosquito is discovered embedded in a chunk of amber, which has index of refraction 1.6. One surface of the amber is spherically convex with radius of curvature 3.0 mm (Fig. 34-13). The mosquito's head happens to be on the central axis of that surface and, when viewed along the axis, appears to be buried 5.0 mm into the amber. How deep is it really?

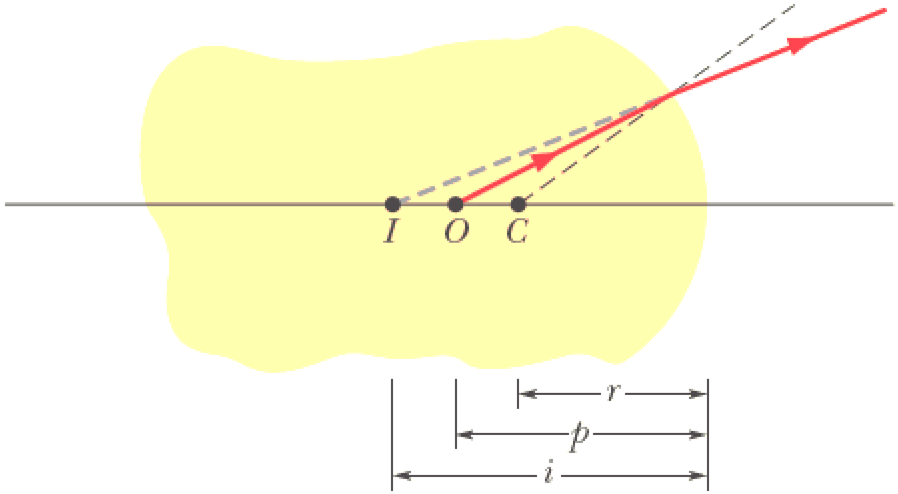


Figure 34-13 A piece of amber with a mosquito from the Jurassic period, with the head buried at point O. The spherical refracting surface at the right end, with center of curvature C, provides an image I to an observer intercepting rays from the object at O.

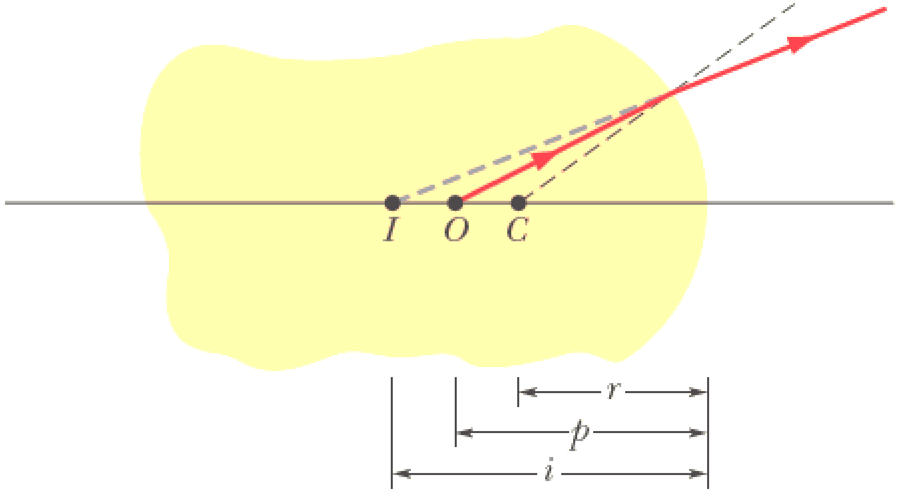
34-3 Spherical Refracting Surface (3 of 5)

A Jurassic mosquito is discovered embedded in a chunk of amber, which has index of refraction 1.6. One surface of the amber is spherically convex with radius of curvature 3.0 mm (Fig. 34-13). The mosquito's head happens to be on the central axis of that surface and, when viewed along the axis, appears to be buried 5.0 mm into the amber. How deep is it really?

1. Because the object (the head) and its image are on the same side of the refracting surface, the image must be virtual and so $i = -5.0$ mm.

2. Because the object is always taken to be in the medium of index of refraction n_1, we must have $n_1 = 1.6$ and $n_2 = 1.0$.

3. Because the *object* faces a concave refracting surface, the radius of curvature r is negative, and so $r = -3.0$ mm.

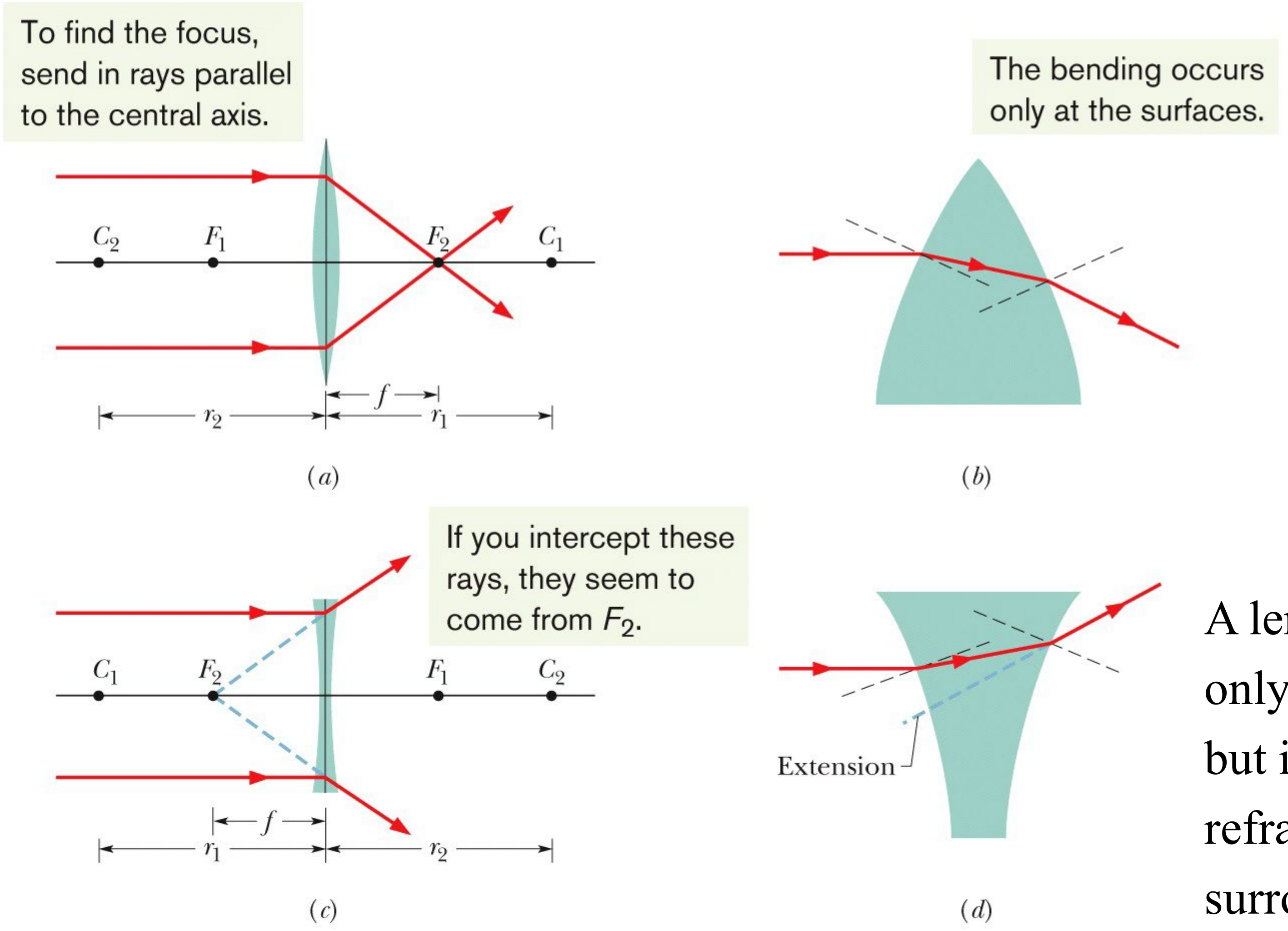


$$\frac{n_1}{p} + \frac{n_2}{i} = \frac{n_2 - n_1}{r},$$

$$\frac{1.6}{p} + \frac{1.0}{-5.0\text{ mm}} = \frac{1.0 - 1.6}{-3.0\text{ mm}}$$

$$p = 4.0\text{ mm}.$$

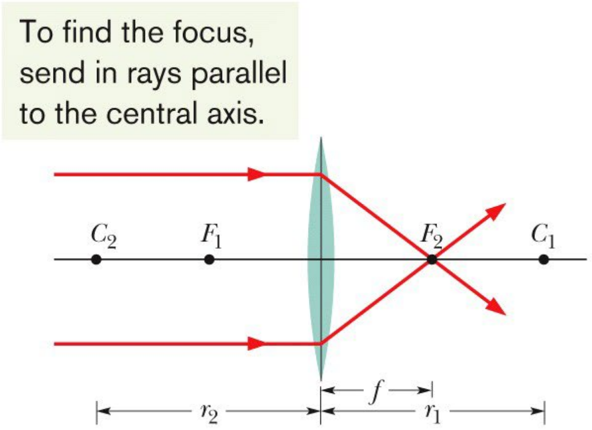
34-4 Thin Lenses (8 of 16)



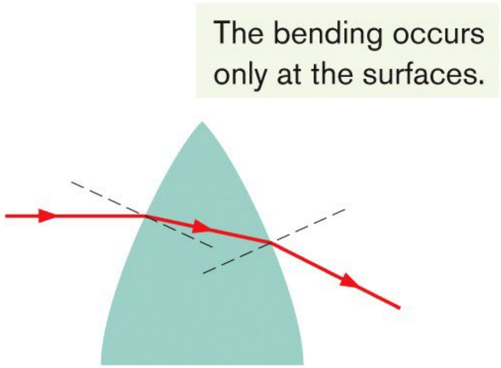
A lens can produce an image of an object only because the lens can bend light rays, but it can bend light rays only if its index of refraction differs from that of the surrounding medium.

34-4 Thin Lenses (7 of 16)

Forming a Focus. Figure (a) shows a thin lens with convex refracting surfaces, or sides. When rays that are parallel to the central axis of the lens are sent through the lens, they refract twice, as is shown enlarged in Figure (b). This double refraction causes the rays to converge and pass through a common point F_2 at a distance f from the center of the lens. Hence, this lens is a converging lens 聚透镜; further, a real focal point (or focus) exists at F_2 (because the rays really do pass through it), and the associated focal length is f. When rays parallel to the central axis are sent in the opposite direction through the lens, we find another real focal point at F_1 on the other side of the lens. For a thin lens, these two focal points are equidistant from the lens.



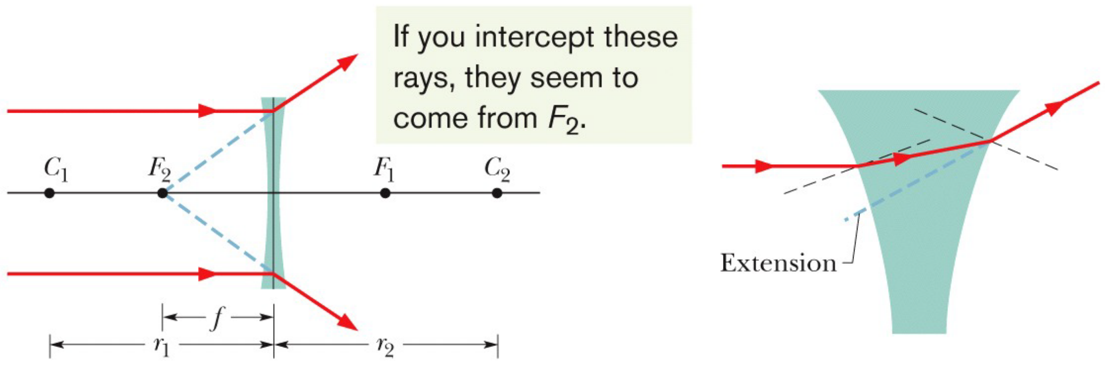
(a)



(b)

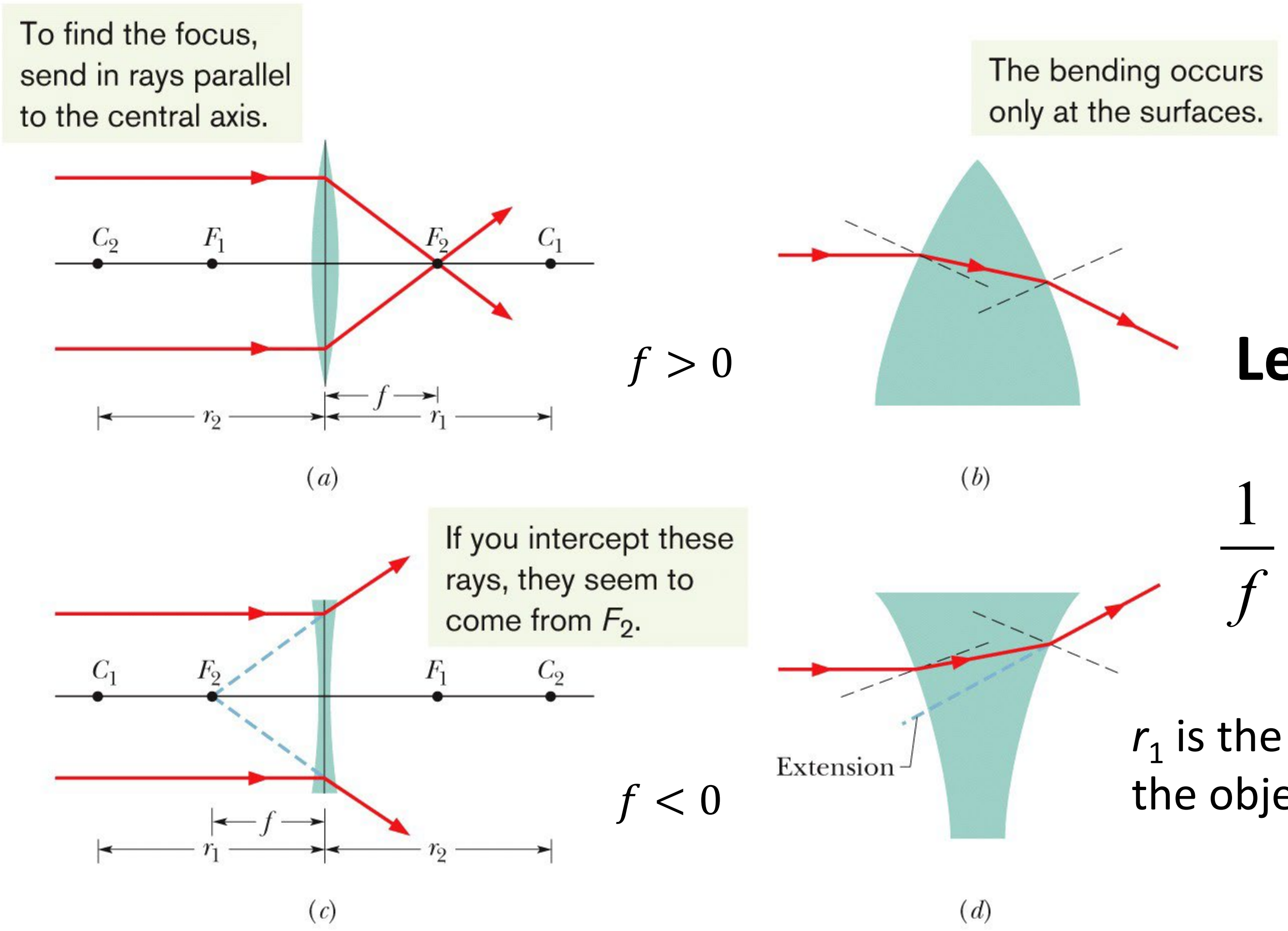
34-4 Thin Lenses (9 of 16)

Forming a Focus. Figure (c) shows a thin lens with concave sides. When rays that are parallel to the central axis of the lens are sent through this lens, they refract twice, as is shown enlarged in Fig. (d); these rays diverge, never passing through any common point, and so this lens is a diverging lens 发散透镜. However, extensions of the rays do pass through a common point F_2 at a distance f from the center of the lens. Hence, the lens has a virtual focal point at F_2. (If your eye intercepts some of the diverging rays, you perceive a bright spot to be at F_2, as if it is the source of the light.) Another virtual focus exists on the opposite side of the lens at F_1, symmetrically placed if the lens is thin. Because the focal points of a diverging lens are virtual, we take the focal length f to be negative.



(c) (d)

34-4 Thin Lenses (8 of 16)



Lens maker's equation

$$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \quad \text{(thin lens in air)},$$

r_1 is the radius of curvature of the lens surface nearer the object and r_2 is that of the other surface.

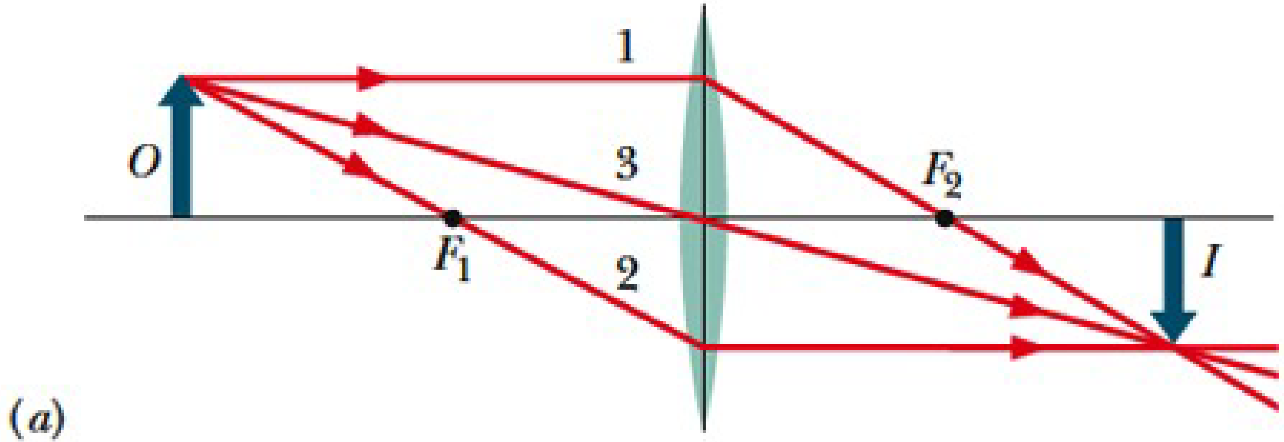
34-4 Thin Lenses (5 of 16)

$$\frac{1}{f}=(n-1)\left(\frac{1}{r_1}-\frac{1}{r_2}\right) \quad (\text{thin lens in air}),$$

which is often called the **lens maker's equation**. Here r_1 is the radius of curvature of the lens surface nearer the object and r_2 is that of the other surface. *If the lens is surrounded by some medium other than air (say, corn oil) with index of refraction* n_{medium}, *we replace n in above Equation with* $\frac{n}{n_{medium}}$

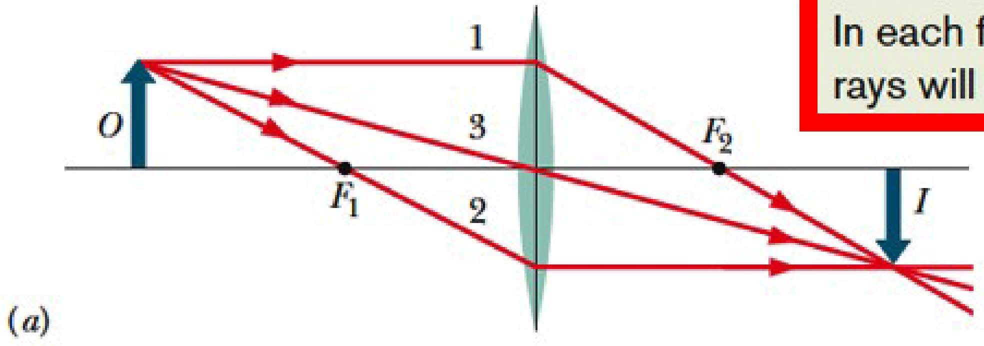
34-4 Thin Lenses (11 of 16)

Locating Images of Extended Objects by Drawing Rays

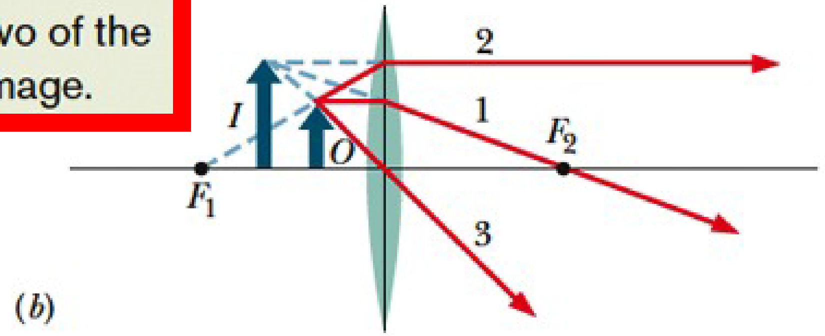


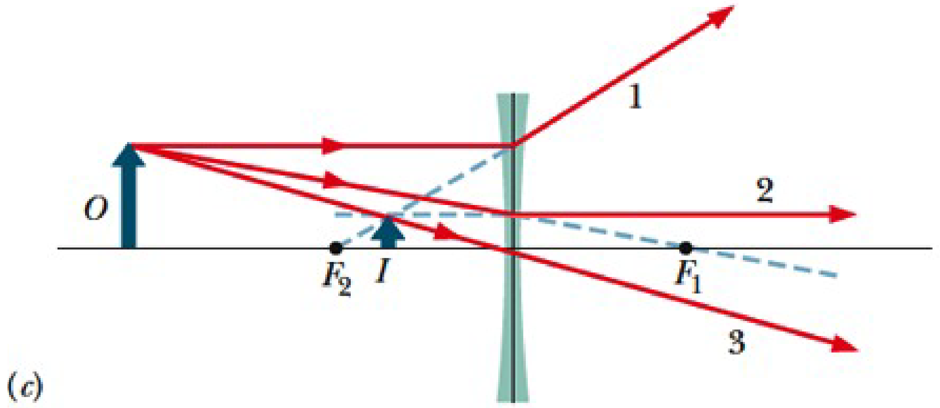
1. A ray that is initially parallel to the central axis of the lens will pass through focal point F_2 (**ray 1**)
2. A ray that initially passes through focal point F_1 will emerge from the lens parallel to the central axis (**ray 2**).
3. A ray that is initially directed toward the center of the lens will emerge from the lens with no change in its direction (**ray 3**).

34-4 Thin Lenses (13 of 16)



In each figure, any two of the rays will locate the image.





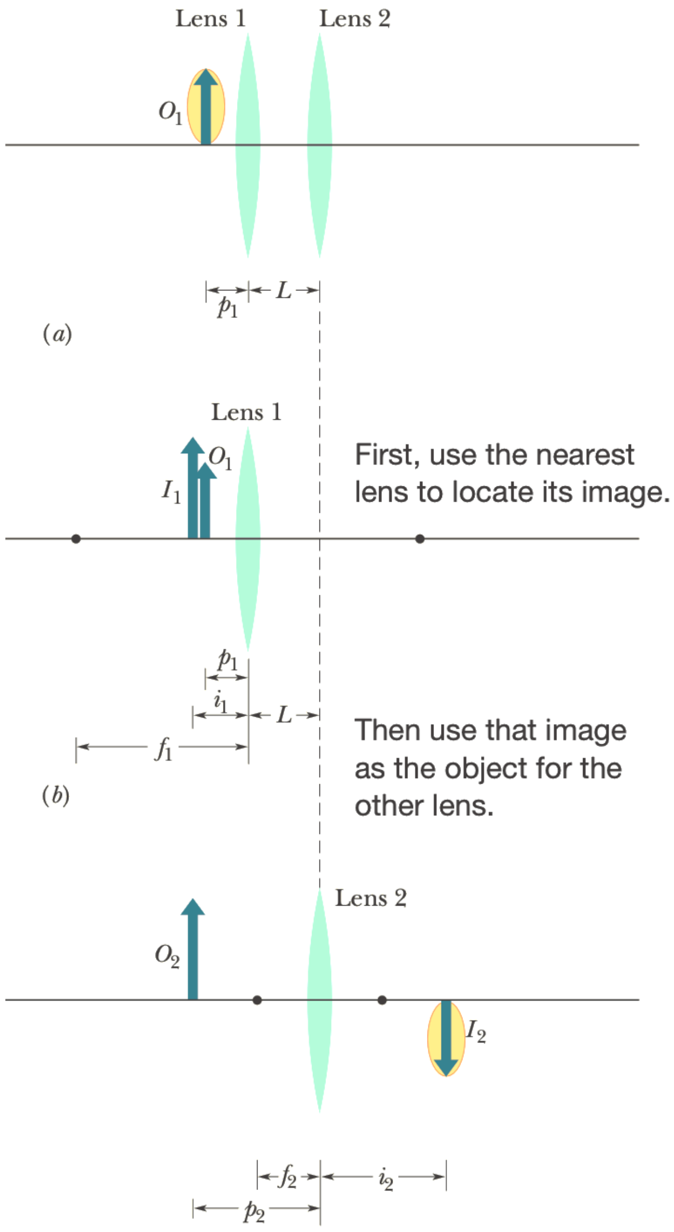
$$\frac{1}{p}+\frac{1}{i}=\frac{1}{f}$$

34-4 Thin Lenses (14 of 16)

Two Lens System

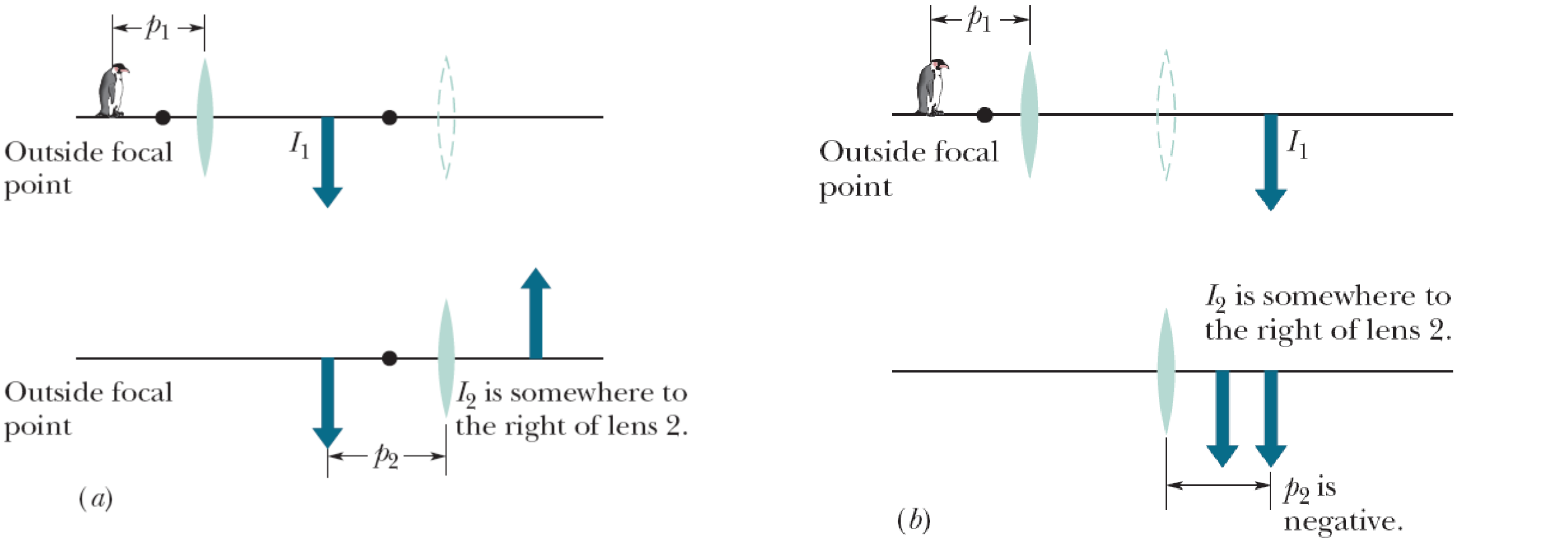
Step 1: Neglecting lens 2, use thin lens equation to locate the image I_1 produced by lens 1.

Step 2: Neglecting lens 1, treat I_1 as though it is the object for lens *i*.



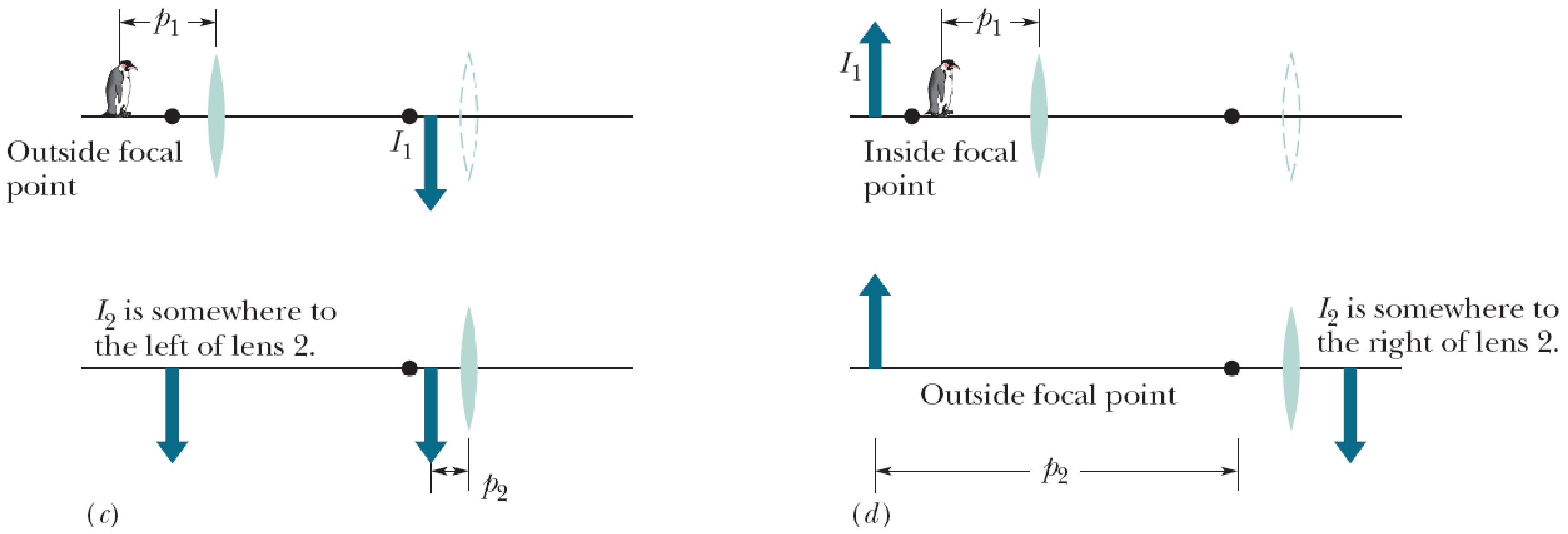
34-4 Thin Lenses (14 of 16)

Two Lens System



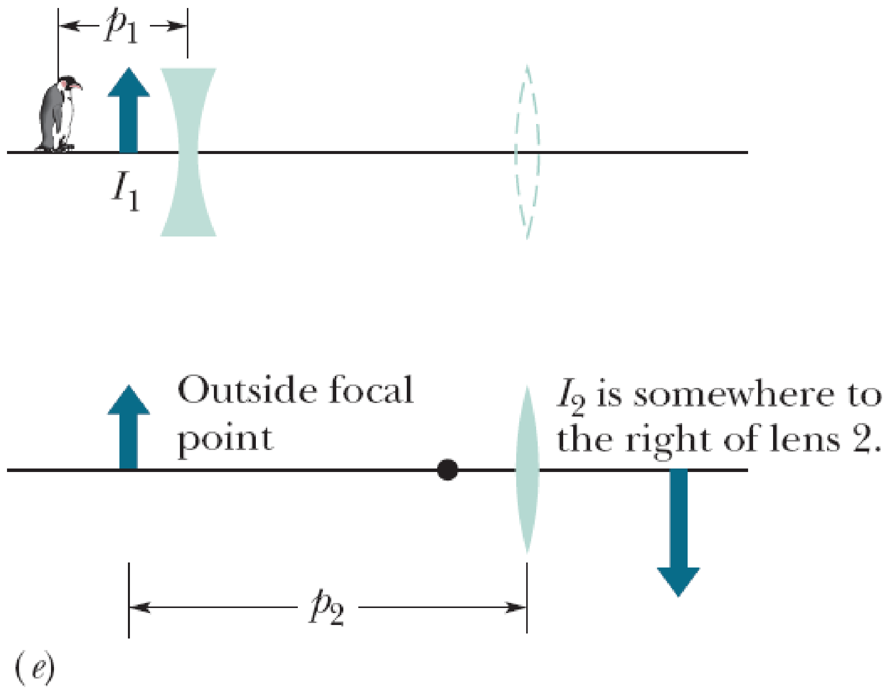
34-4 Thin Lenses (14 of 16)

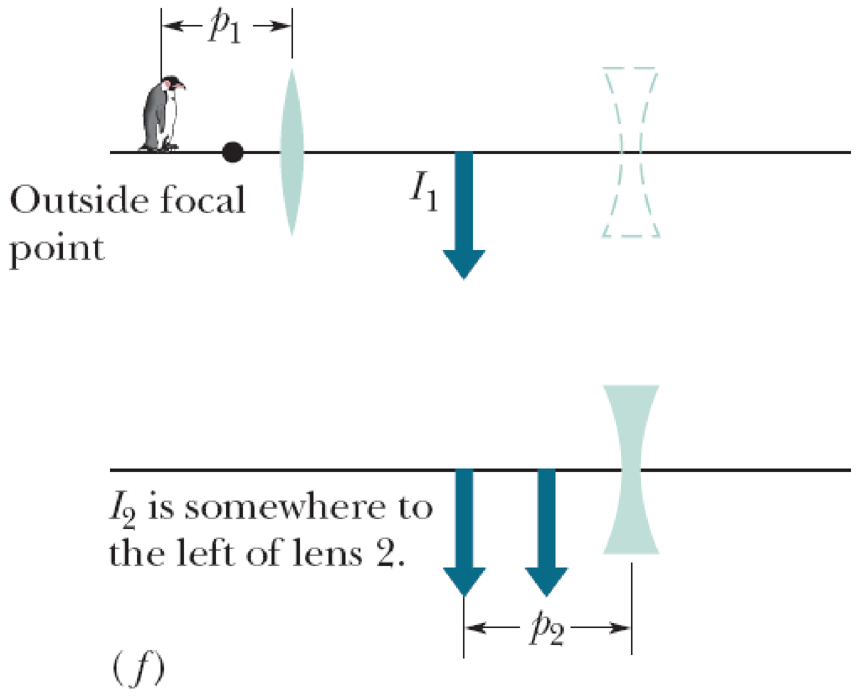
Two Lens System



34-4 Thin Lenses (14 of 16)

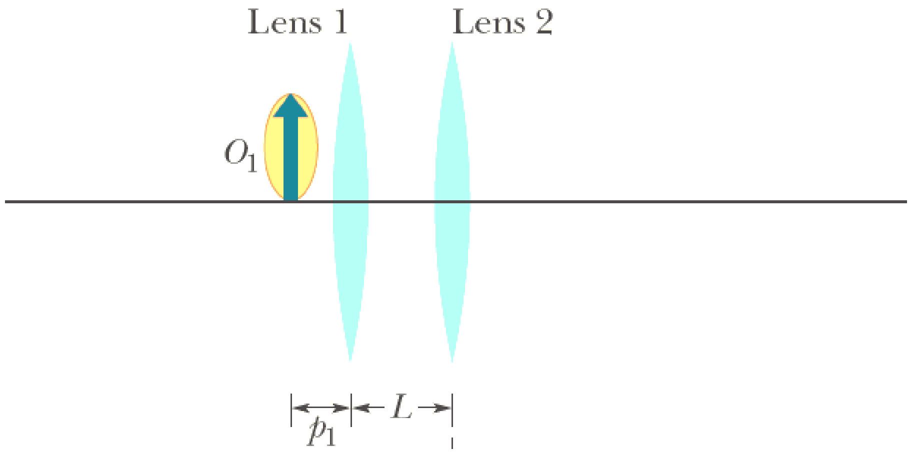
Two Lens System





34-4 Thin Lenses (14 of 16)

Figure 34-18*a* shows a jalapeño seed O_1 that is placed in front of two thin symmetrical coaxial lenses 1 and 2, with focal lengths $f_1 = +24$ cm and $f_2 = +9.0$ cm, respectively, and with lens separation $L = 10$ cm. The seed is 6.0 cm from lens 1. Where does the system of two lenses produce an image of the seed?

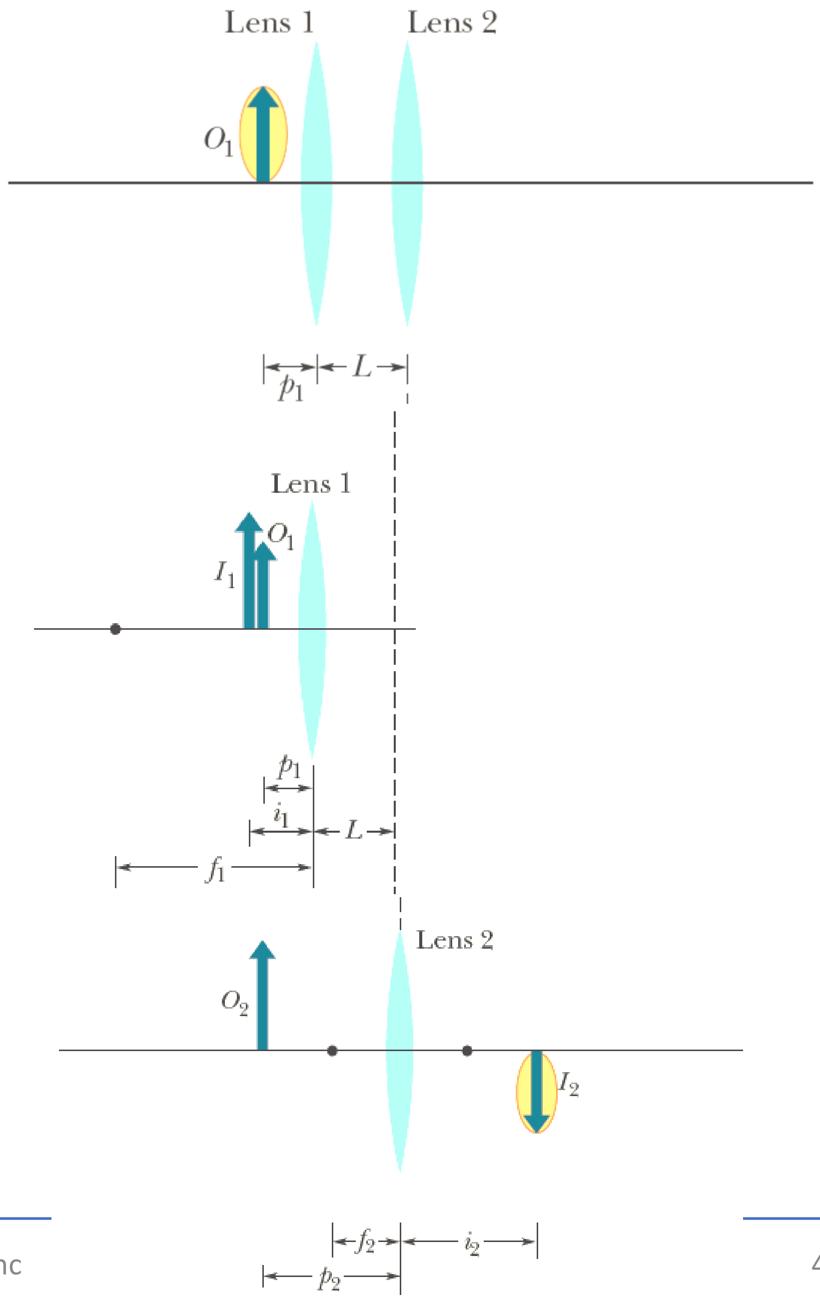


$$\frac{1}{p} + \frac{1}{i} = \frac{1}{f}$$

$$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \quad \text{(thin lens in air)},$$

34-4 Thin Lenses (14 of 16)

Figure 34-18*a* shows a jalapeño seed O_1 that is placed in front of two thin symmetrical coaxial lenses 1 and 2, with focal lengths $f_1 = +24$ cm and $f_2 = +9.0$ cm, respectively, and with lens separation $L = 10$ cm. The seed is 6.0 cm from lens 1. Where does the system of two lenses produce an image of the seed?



Lens 1: Ignoring lens 2, we locate the image I_1 produced by lens 1 by applying Eq. 34-9 to lens 1 alone:

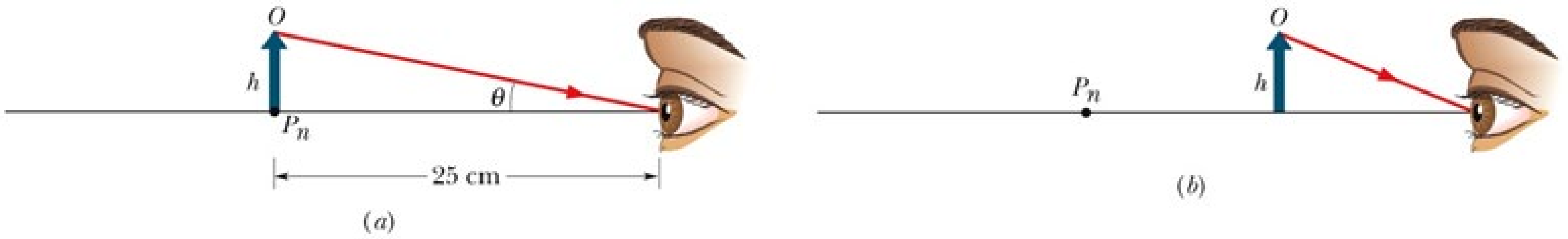
$$\frac{1}{p_1} + \frac{1}{i_1} = \frac{1}{f_1}. \qquad \frac{1}{+6.0\text{ cm}} + \frac{1}{i_1} = \frac{1}{+24\text{ cm}},$$

yields $i_1 = -8.0$ cm. and virtual.

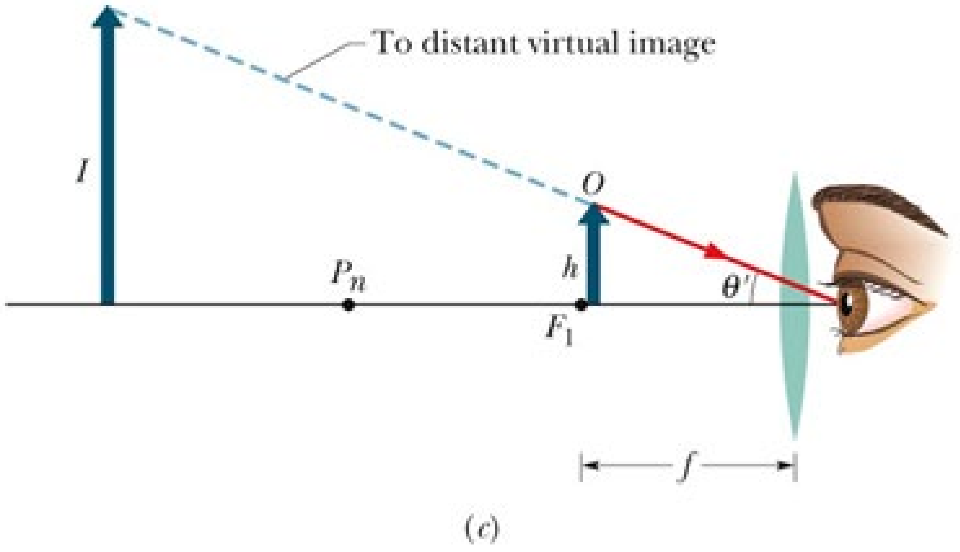
Lens 2: $p_2 = L + |i_1| = 10\text{ cm} + 8.0\text{ cm} = 18\text{ cm}$

$$\frac{1}{+18\text{ cm}} + \frac{1}{i_2} = \frac{1}{+9.0\text{ cm}}. \quad i_2 = +18\text{ cm, real}$$

34-5 Optical Instruments (4 of 10)

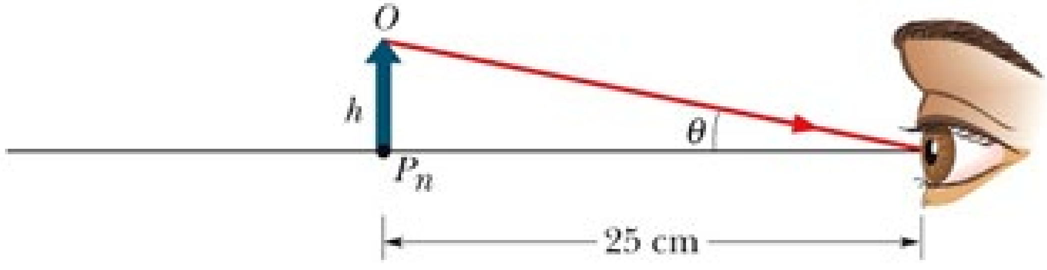


(a) An object O of height h placed at the near point of a human eye occupies angle θ in the eye's view.
(b) The object is moved closer to increase the angle, but now the observer cannot bring the object into focus.
(c) A converging lens is placed between the object and the eye, with the object just inside the focal point F_1 of the lens.
The image produced by the lens is then far enough away to be focused by the eye, and the image occupies a larger angle θ' than object O does in (a).



34-5 Optical Instruments (4 of 10)

Simple Magnifying Lens



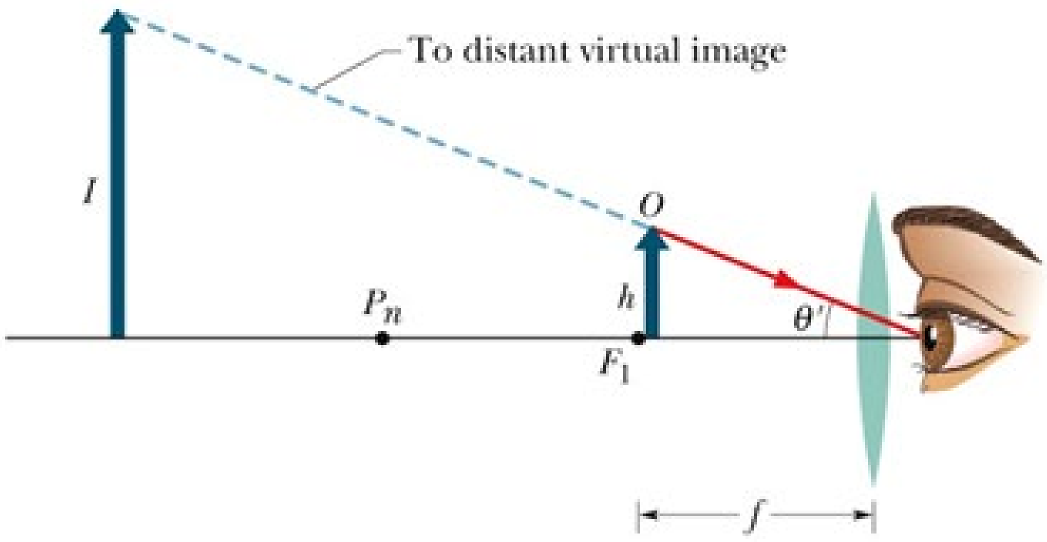
(a)

(b)

$$m_\theta = \theta'/\theta$$

$\vartheta \approx h/25$ cm and $\vartheta' \approx h/f$.

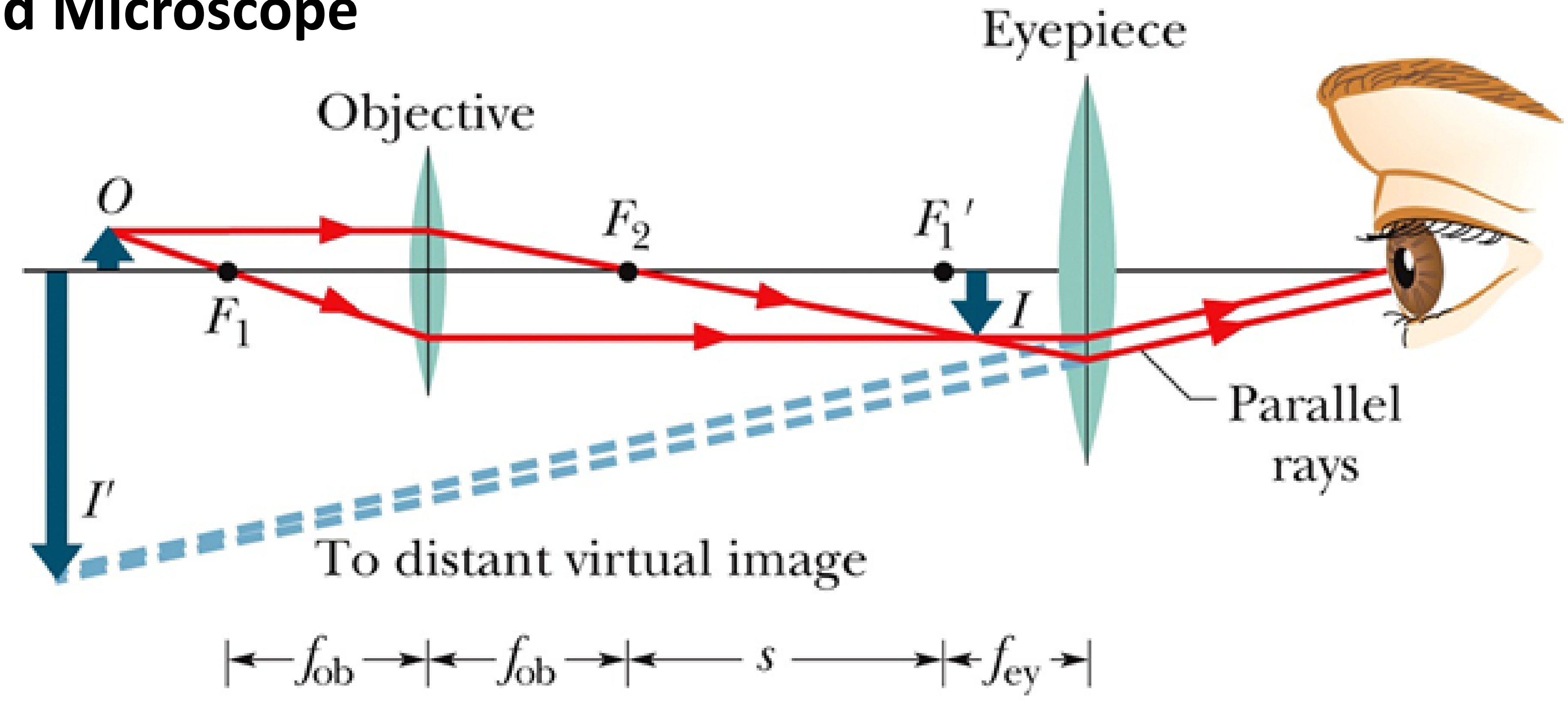
$$m_\theta \approx \frac{25\ cm}{f}$$



(c)

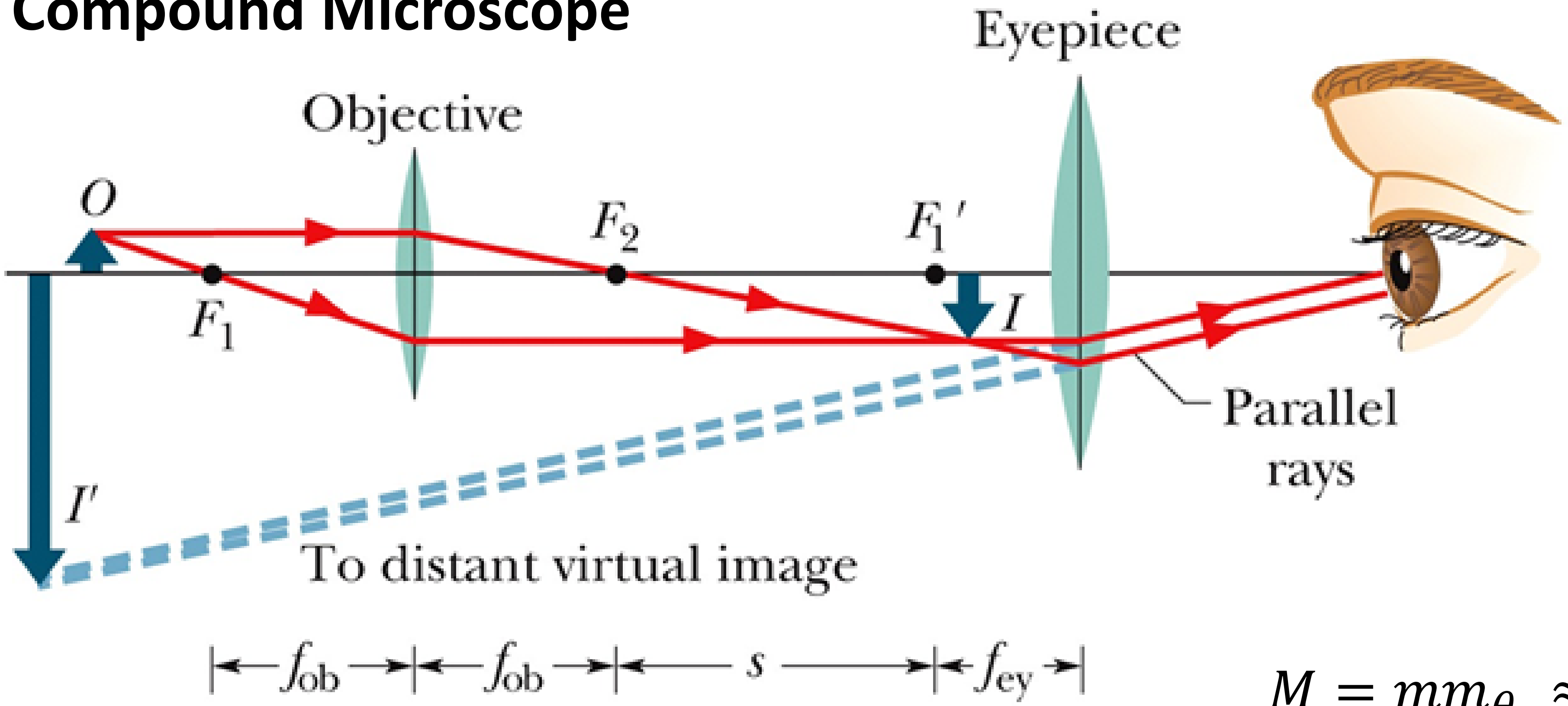
34-5 Optical Instruments (7 of 10)

Compound Microscope



34-5 Optical Instruments

Compound Microscope



$$s \gg f_{ob}$$

lateral magnification

$$m = -\frac{i}{p} = \frac{s}{f_{ob}}$$

$$m_\theta \approx \frac{25\ cm}{f_{ey}}$$

$$M = m m_\theta \approx -\frac{s}{f_{ob}}\frac{25\ cm}{f_{ey}}$$

34-5 Optical Instruments

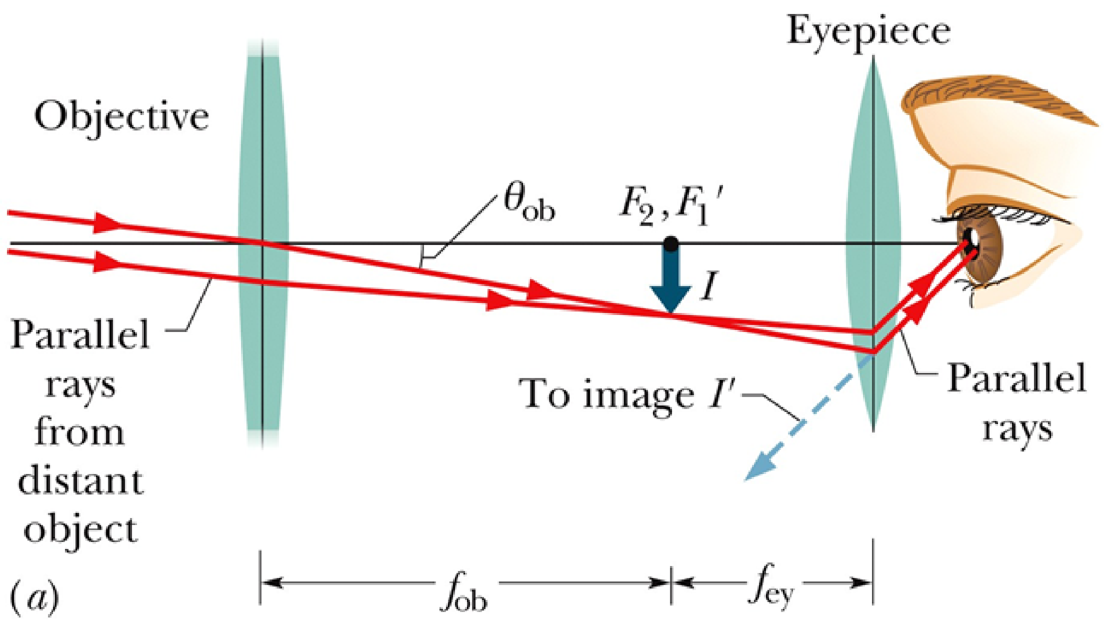
Refracting Telescope

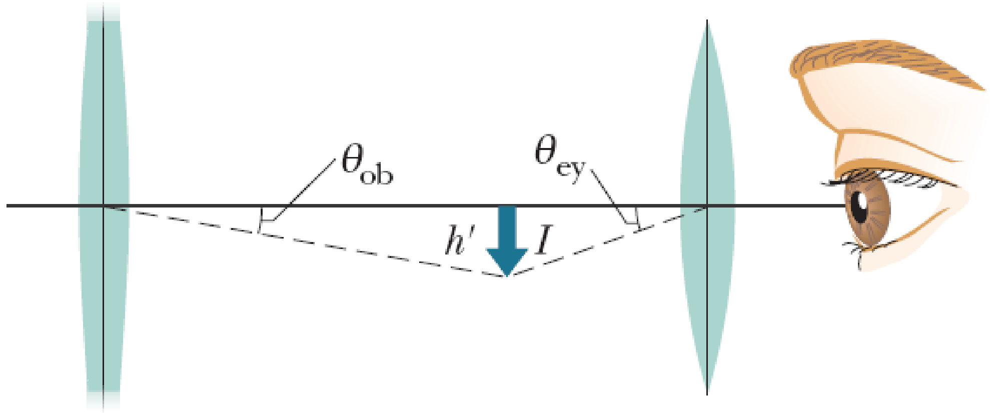
The angular magnification of a refracting telescope is

$$m_\theta = -\frac{f_{\text{ob}}}{f_{\text{ey}}}.$$

$$\theta_{\text{ob}} = h'/f_{\text{ob}} \quad \theta_{\text{ey}} \approx h'/f_{\text{ey}},$$

$$m_\theta = \theta'/\theta$$





Summary (1 of 5)

Real and Virtual Images

- If the image can form on a surface, it is a real image and can exist even if no observer is present. If the image requires the visual system of an observer, it is a virtual image.

Image Formation

- Spherical mirrors, spherical refracting surfaces, and thin lenses can form images of a source of light—the object — by redirecting rays emerging from the source.

Summary (2 of 5)

- **Spherical Mirror:**

$$\frac{1}{p}+\frac{1}{i}=\frac{1}{f}=\frac{2}{r},$$

Equation 34-3& 4

- **Spherical Refracting Surface:**

$$\frac{n_1}{p}+\frac{n_2}{i}=\frac{n_2-n_1}{r}$$

Equation 34-8

Summary (3 of 5)

- **Thin Lens:**

$$\frac{1}{p}+\frac{1}{i}=\frac{1}{f}=(n-1)\left(\frac{1}{r_1}-\frac{1}{r_2}\right), \qquad \textbf{Equation 34-9\& 4}$$

Optical Instruments

- Three optical instruments that extend human vision are:

Summary (4 of 5)

1. The simple magnifying lens, which produces an angular magnification m_θ given by

$$m_\theta = \frac{25\,\text{cm}}{f}$$

Equation 34-12

2. The compound microscope, which produces an overall magnification M given by

$$M = m m_0 = -\frac{s}{f_{\text{ob}}}\frac{25\,\text{cm}}{f_{\text{ey}}}$$

Equation 34-14

Summary (5 of 5)

3. The refracting telescope, which produces an angular magnification mu given by

$$m_\theta = -\frac{f_{\mathrm{ob}}}{f_{\mathrm{ey}}}$$

Equation 34-15