A comparison of part (a) of Fig. 25–16 with part (b), in which the same object is viewed at the near point with the unaided eye, reveals that the angle the object subtends at the eye is much larger when the magnifier is used. The **angular magnification** or **magnifying power**, M, of the lens is defined as the ratio of the angle subtended by an object when using the lens, to the angle subtended using the unaided eye, with the object at the near point N of the eye ($N = 25\text{ cm}$ for a normal eye):

$$M = \frac{\theta'}{\theta}, \tag{25–1}$$

where θ and θ' are shown in Fig. 25–16. We can write M in terms of the focal length by noting that $\theta = h/N$ (Fig. 25–16b) and $\theta' = h/d_o$ (Fig. 25–16a), where h is the height of the object and we assume the angles are small so θ and θ' equal their sines and tangents. If the eye is relaxed (for least eye strain), the image will be at infinity and the object will be precisely at the focal point; see Fig. 25–17. Then $d_o = f$ and $\theta' = h/f$. Thus

Small angles assumed, so $\sin\theta \approx \tan\theta \approx \theta$ (in radians)

$$M = \frac{\theta'}{\theta} = \frac{h/f}{h/N} = \frac{N}{f}. \qquad \left[\begin{array}{c}\text{eye focused at }\infty;\\ N = 25\text{ cm for normal eye}\end{array}\right] \tag{25–2a}$$

Magnification of a simple magnifier

We see that the shorter the focal length of the lens, the greater the magnification.[†]

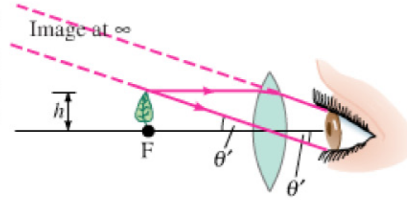

FIGURE 25–17 With the eye relaxed, the object is placed at the focal point, and the image is at infinity. Compare to Fig. 25–16a where the image is at the eye's near point.

The magnification of a given lens can be increased a bit by moving the lens and adjusting your eye so it focuses on the image at the eye's near point. In this case, $d_i = -N$ (see Fig. 25–16a) if your eye is very near the magnifier. Then the object distance d_o is given by

$$\frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i} = \frac{1}{f} + \frac{1}{N}.$$

We see from this equation that $d_o = fN/(f + N) < f$, as shown in Fig. 25–16a, since $N/(f + N)$ must be less than 1. With $\theta' = h/d_o$ the magnification is

$$M = \frac{\theta'}{\theta} = \frac{h/d_o}{h/N} = \frac{N}{d_o} = N\left(\frac{1}{f} + \frac{1}{N}\right)$$

or

$$M = \frac{N}{f} + 1. \qquad \left[\begin{array}{c}\text{eye focused at near point, }N;\\ N = 25\text{ cm for normal eye}\end{array}\right] \tag{25–2b}$$

We see that the magnification is slightly greater when the eye is focused at its near point, rather than relaxed.

EXAMPLE 25–7 ESTIMATE A jeweler's "loupe." An 8-cm-focal-length converging lens is used as a "jeweler's loupe," which is a magnifying glass. Estimate (*a*) the magnification when the eye is relaxed, and (*b*) the magnification if the eye is focused at its near point $N = 25\text{ cm}$.

APPROACH The magnification when the eye is relaxed is given by Eq. 25–2a. When the eye is focused at its near point, we use Eq. 25–2b and we assume the lens is near the eye.

SOLUTION (*a*) With the relaxed eye focused at infinity,

$$M = \frac{N}{f} = \frac{25\text{ cm}}{8\text{ cm}} \approx 3\times.$$

(*b*) The magnification when the eye is focused at its near point ($N = 25\text{ cm}$), and the lens is near the eye, is

$$M = 1 + \frac{N}{f} = 1 + \frac{25}{8} \approx 4\times.$$

[†] Simple single-lens magnifiers are limited to about 2 or 3× because of distortion due to spherical aberration (Section 25–6).