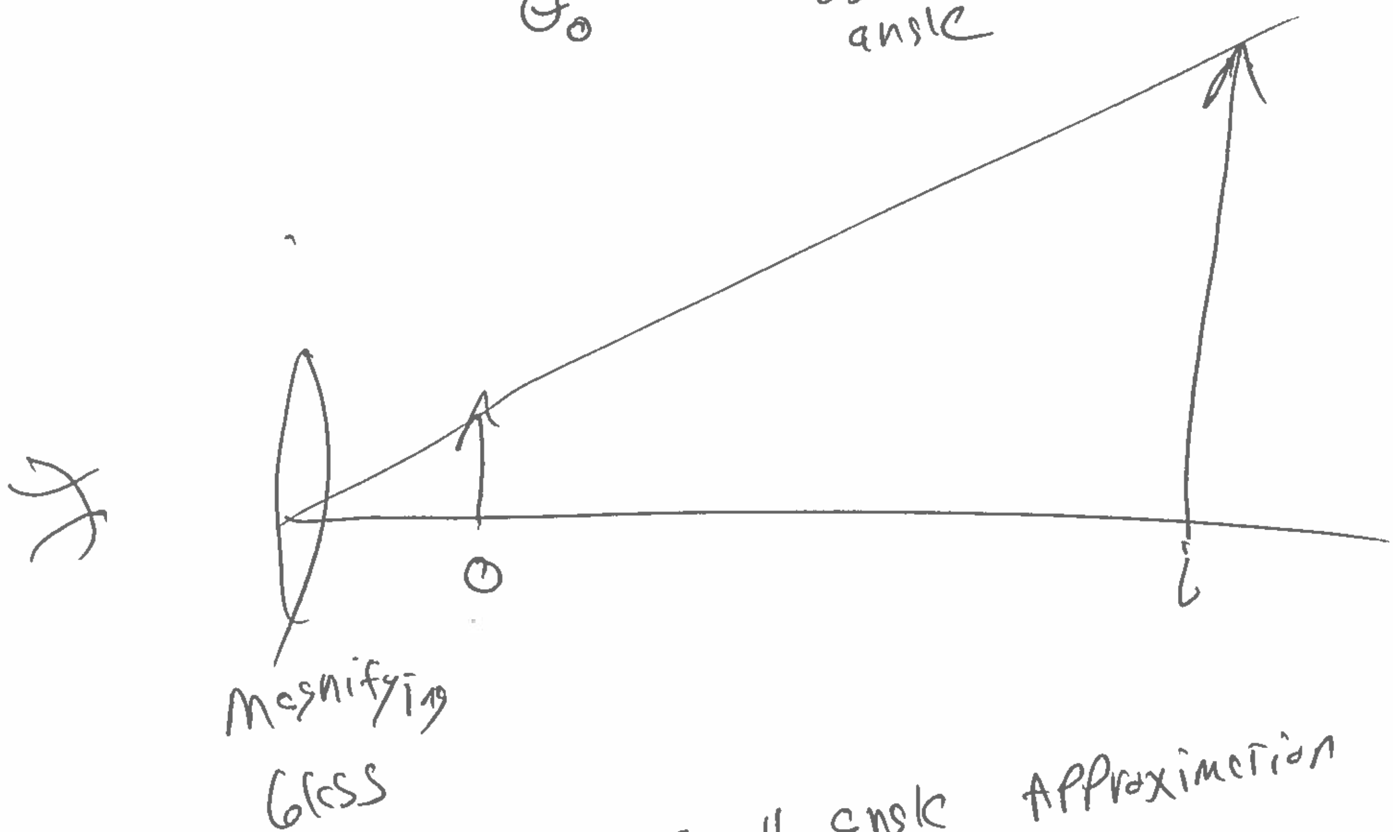
Angular Magnification and Optical Instruments.

$$M = \frac{h_i}{h_o} = \frac{-i}{o}$$ Linear Magnification

$$M_\theta = \frac{\theta_i}{\theta_o} = \frac{\text{image angle}}{\text{object angle}}$$



Use small angle Approximation

if $\theta << 1$ radian

$$\tan\theta \approx \theta \Rightarrow \tan\theta = \frac{\text{Opp}}{\text{Adj}}$$

$$\theta \approx \frac{\text{height}}{\text{distance}}$$

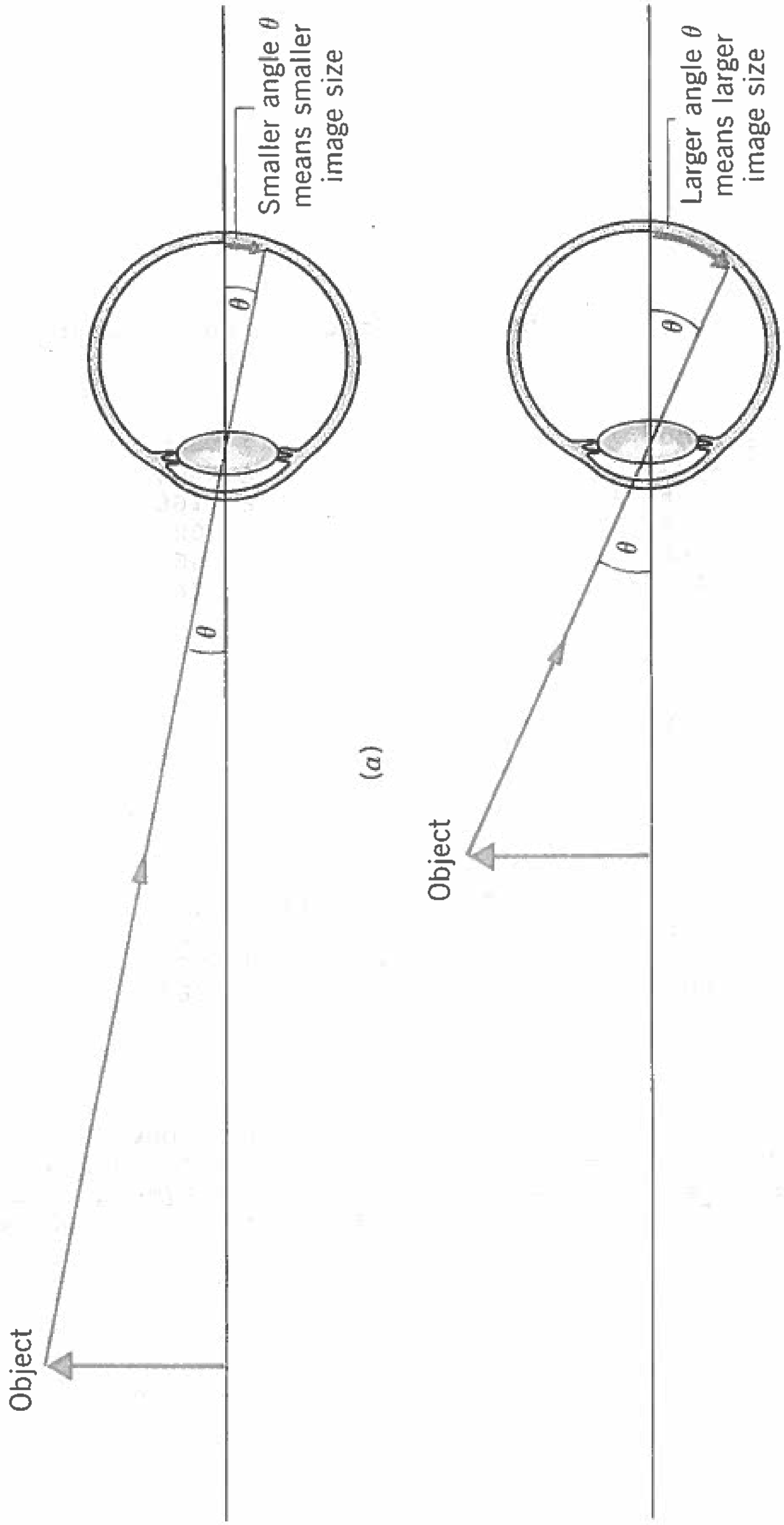


FIGURE 26.31 a, b

To create largest object angle we put object at Near Point of the eye

$$\theta_{object} = \theta_{ref} = \frac{h_o}{D} = \frac{h_o}{N}$$

$$\boxed{\theta_{ref} = \frac{h_o}{N}}$$

N is near point of eye

$$\theta_i = \frac{h_i}{i}$$

Linear Magnification

$$h_i = h_o\left(\frac{-i}{o}\right)$$

$$\theta_i = \frac{h_o(i/o)}{i}$$

drop − sign because it is dealing with upright or inverted

$$\theta_i = \frac{h_o}{o}$$

$$M_\theta = \frac{\theta_i}{\theta_{ref}} = \frac{h_o/o}{h_o/N} = \frac{N}{O}$$

$$M_\theta = \frac{N}{o} = N\left(\frac{1}{f} - \frac{1}{i}\right)$$

simple magnifier

Two cases

1) want image as close as possible

$i = -N$ virtual image close to Near point

$$M_\theta = N\left(\frac{1}{f} - \frac{1}{-N}\right) = \frac{N}{f} + 1$$

$$M_\theta = \frac{N}{f} + 1$$

eg/ $f = 25.0\ \text{cm}$ $N = 25.0\ \text{cm}$

$$M_\theta = \frac{25\text{cm}}{25\text{cm}} + 1 = 2X$$

2) minimum eye strain case

our eyes are most relaxed when we see at a Great distance.

so $i = -\infty$ (virtual image)

$$M_\theta = N\left(\frac{1}{f} - \frac{1}{-\infty}\right) =$$

$$\boxed{M_\theta = \frac{N}{f}}$$

eg/ Let $f = 2.5\,cm$

$$M_\theta = \frac{N}{f} = \frac{25.0\,cm}{2.5\,cm} = \boxed{10X}$$

26-83

$N = 72\ cm$

$O = 4.0\ cm$ $\quad M_\theta = ?$

$$M = \frac{N}{O} = \frac{72\ cm}{4.0\ cm} = \boxed{18\times}$$

26-84

$h_{o_f} = 1.9\ m$ $\quad d = 75\ m$ $\quad \theta_f = ?$

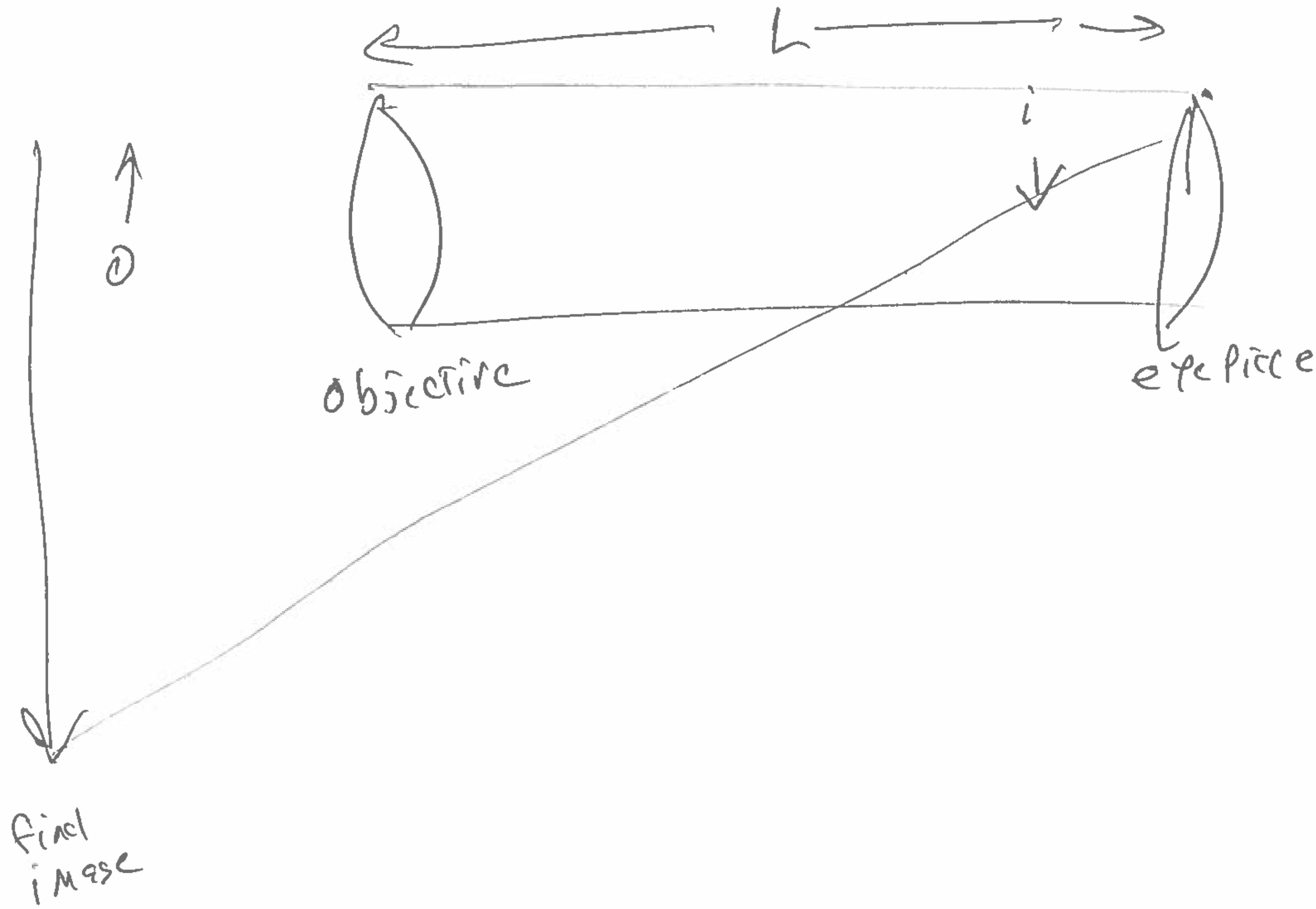
$h_{o_T} = 0.12\ m$ $\quad d = 3.0\ m$ $\quad \theta_T = ?$

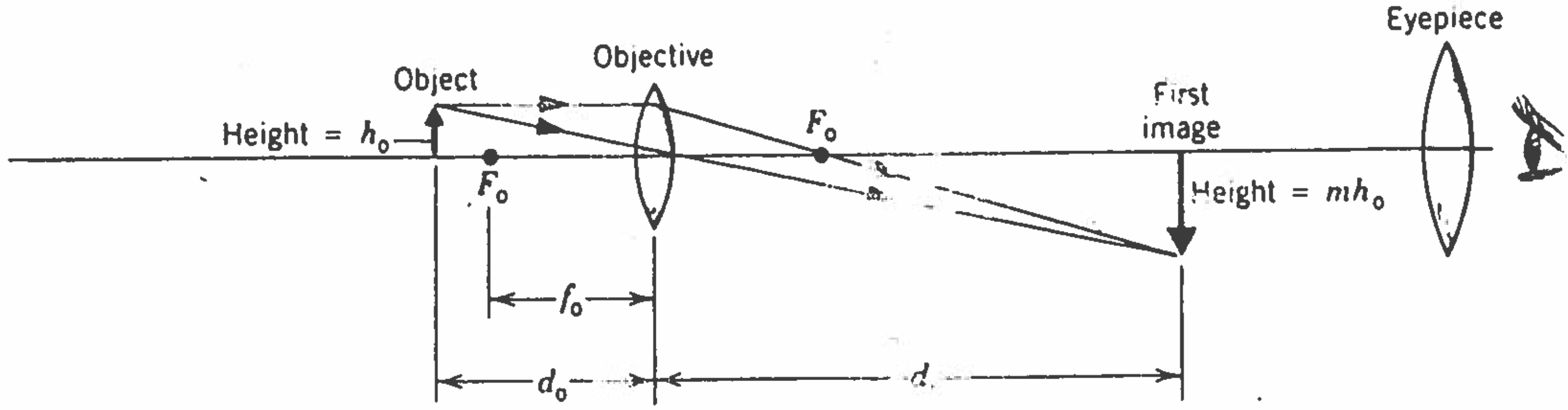
$$\theta_f = \frac{\text{height}}{\text{dist}} = \frac{1.9\ m}{75\ m} = \underline{0.025\ rad}$$

$$\theta_T = \frac{.12\ m}{3.0\ m} = \underline{0.040\ rad}$$

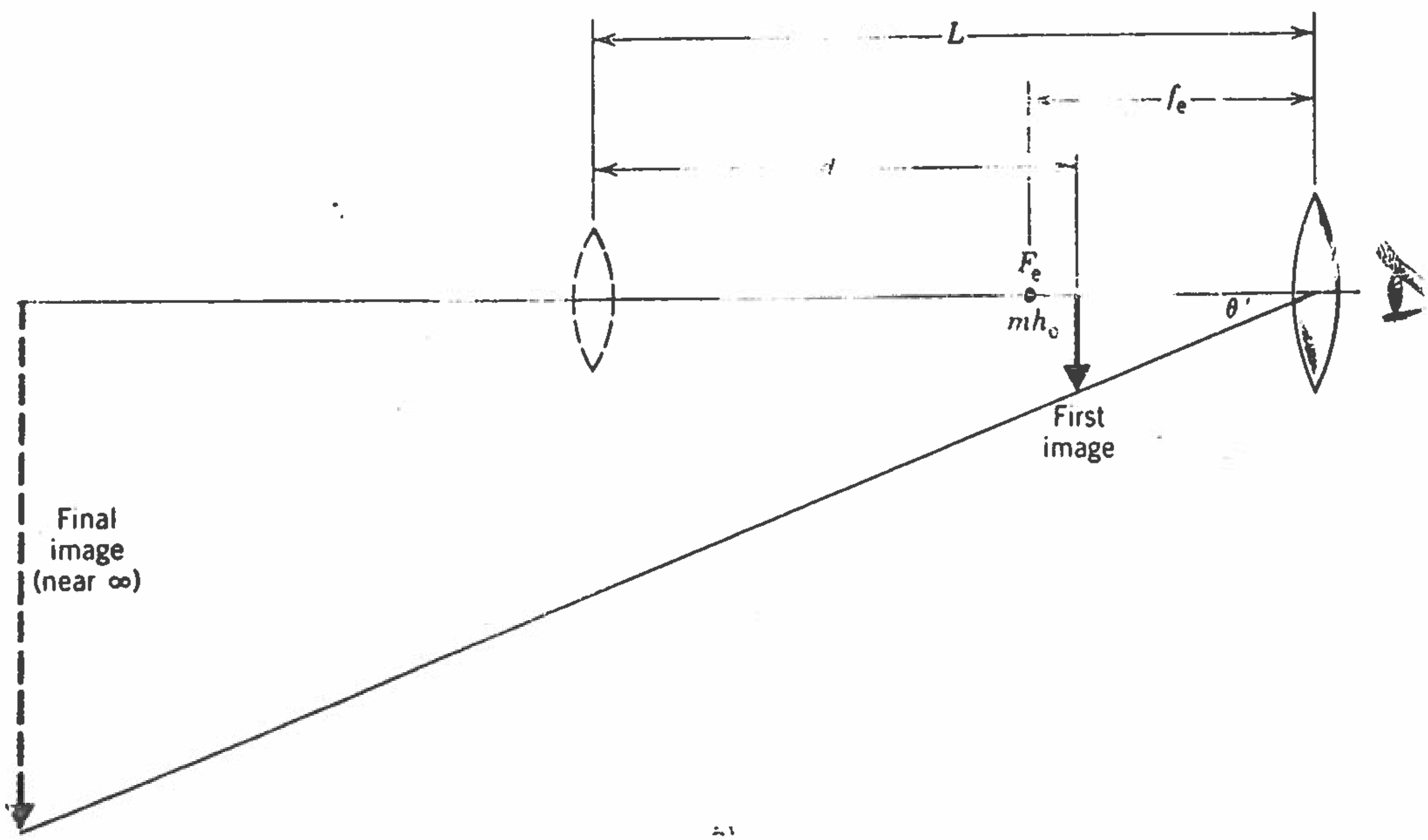
Compound Microscope

Two lenses Objective and an eyepiece




Object
Objective
Eyepiece
Height = h_o
F_o
F_o
First
image
Height = mh_o
f_o
d_o
d_i

(a)


L
f_e
d_i
F_e
mh_o
θ'
First
image
Final
image
(near ∞)

$$M_\theta = \frac{\theta_i}{\theta_{ref}} \qquad \theta_{ref} = \frac{h_o}{N}$$

$$h_i = h_o M.$$

$$\theta_i = \frac{h_i}{f_e}$$

$$m = -\frac{i}{o} = -\frac{d_i}{d_o} = \frac{-(L-f_e)}{f_o}$$

$$\theta_i = \frac{h_o m}{f_e} = \frac{h_o\left(\frac{-(L-f_e)}{f_o}\right)}{f_e}$$

$$\theta_i = -\frac{(L-f_e)h_o}{f_o f_e}$$

$$M_\theta = \frac{\theta_i}{\theta_{ref}} = \frac{-\frac{(L-f_e)h_o}{f_o f_e}}{\frac{h_o}{N}}$$

$$\boxed{M_\theta = -\frac{(L-f_e)N}{f_o f_e}}$$

compound microscope

e) $f_o = 0.40\ cm$ $L = 20.0\ cm$

$f_e = 3.00\ cm$ $N = 25.0\ cm$

what's $M_\theta = ?$

$$M_\theta = -\frac{(L - f_e)N}{f_o f_e} = -\frac{(20.0\ cm - 3.00\ cm)(25.0\ cm)}{(0.40\ cm)(3.00\ cm)}$$

$$\boxed{M_\theta = -354X}$$

26-91

$L = 16.0\ cm \qquad f_e = 1.4\ cm$

$N = 25.0\ cm \qquad f_o = ?$

$M_\theta = -320\times$

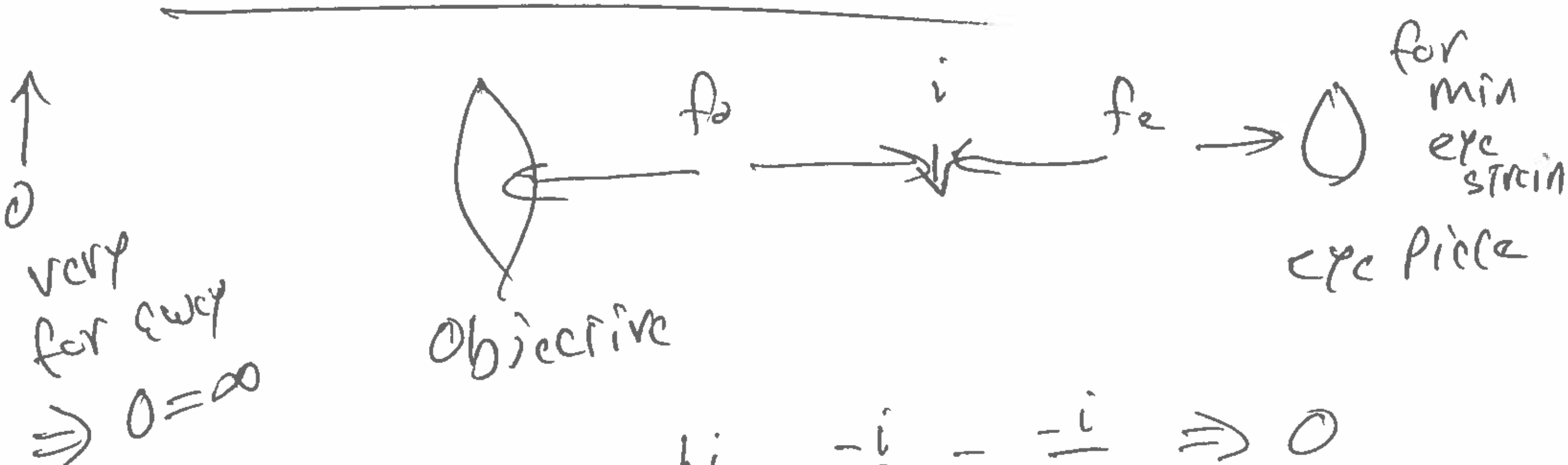
$$M_\theta = -\frac{(L - f_e)N}{f_o f_e}$$

$$f_o = \frac{-(L - f_e)N}{M_\theta f_e}$$

$$f_o = -\frac{((16.0\ cm) - 1.4\ cm)(25.0\ cm)}{(-320)(1.4\ cm)}$$

$$\boxed{f_o = 0.81\ cm}$$

Telescopes

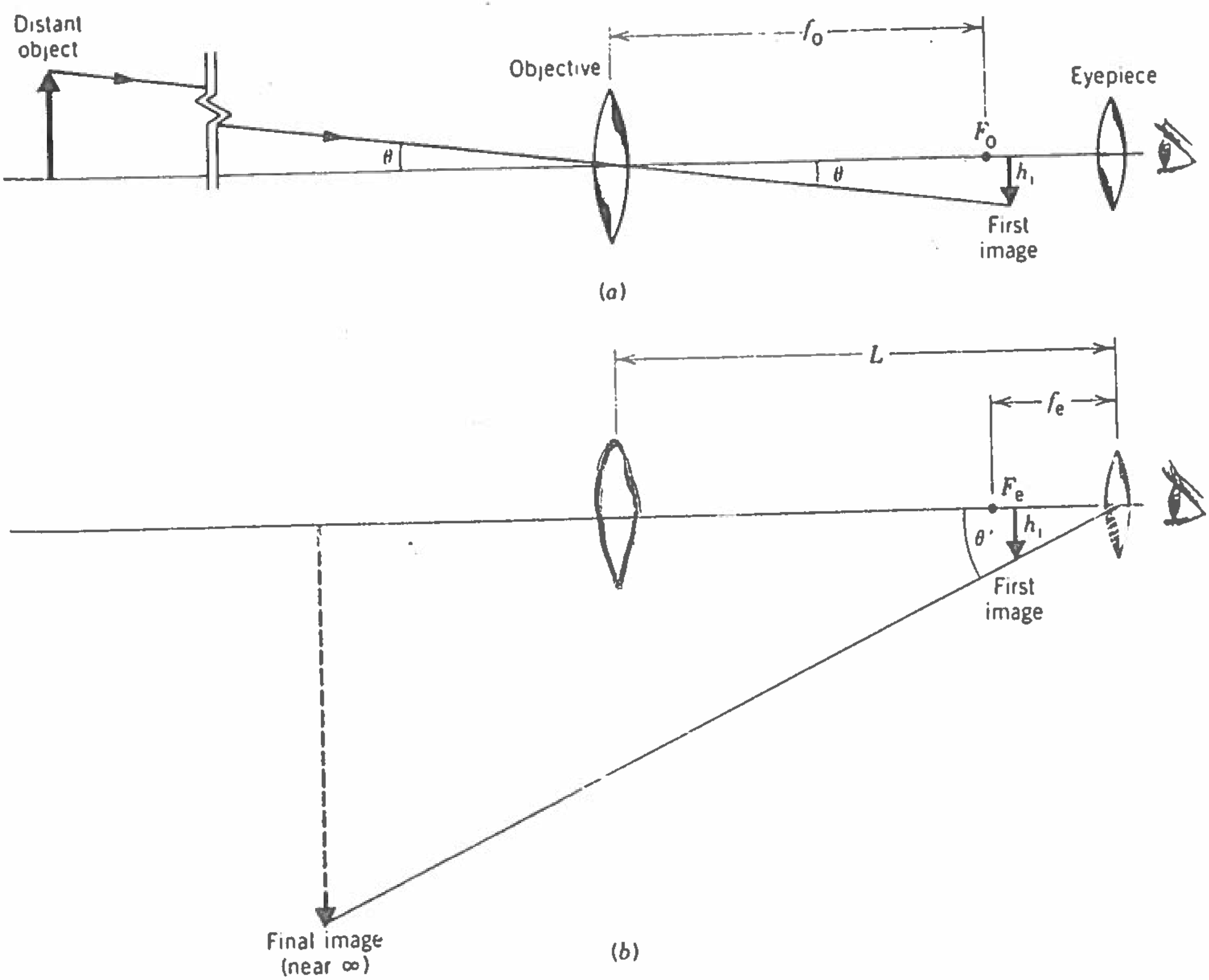


$$M = \frac{h_i}{h_o} = \frac{-i}{o} = \frac{-i}{\infty} \Rightarrow 0$$

$$\boxed{L = f_o + f_e}$$

$$M_\theta = \frac{\theta_i}{\theta_{ref}} = \frac{h_i/f_e}{h_i/f_o}$$

$$\boxed{M_\theta = -\frac{f_o}{f_e}}$$



Distant object
Objective
f_o
Eyepiece
F_o
θ
θ
h_1
First image
(a)
L
f_e
F_e
θ'
h_1
First image
Final image (near ∞)
(b)

c9/

$70.0\ cm = f_o$ $f_e = 0.20 cm$

how far apart should lenses be?

$L = f_o + f_e = 70.0\ cm + 0.20\ cm$

$L = 70.20\ cm$

$M_\theta = ?$

$$M_\theta = \frac{f_o}{f_e} = \frac{70.0\ cm}{0.20\ cm}$$

$M_\theta = 350\ X$

26-97

Mars subtends an angle 8.0×10^{-5} rad $f_e = 0.032$ m

$\theta_{Tel} = 2.8 \times 10^{-3}$ rad $f_o = ?$

$$M_\theta = \frac{\theta_i}{\theta_o} = \frac{f_o}{f_e}$$

$$f_o = f_e \left(\frac{\theta_i}{\theta_o}\right) = (0.032\ \text{m}) \left(\frac{2.8 \times 10^{-3}\ \text{rad}}{8.0 \times 10^{-5}\ \text{rad}}\right)$$

$$\boxed{f_o = 1.12\ \text{m}}$$