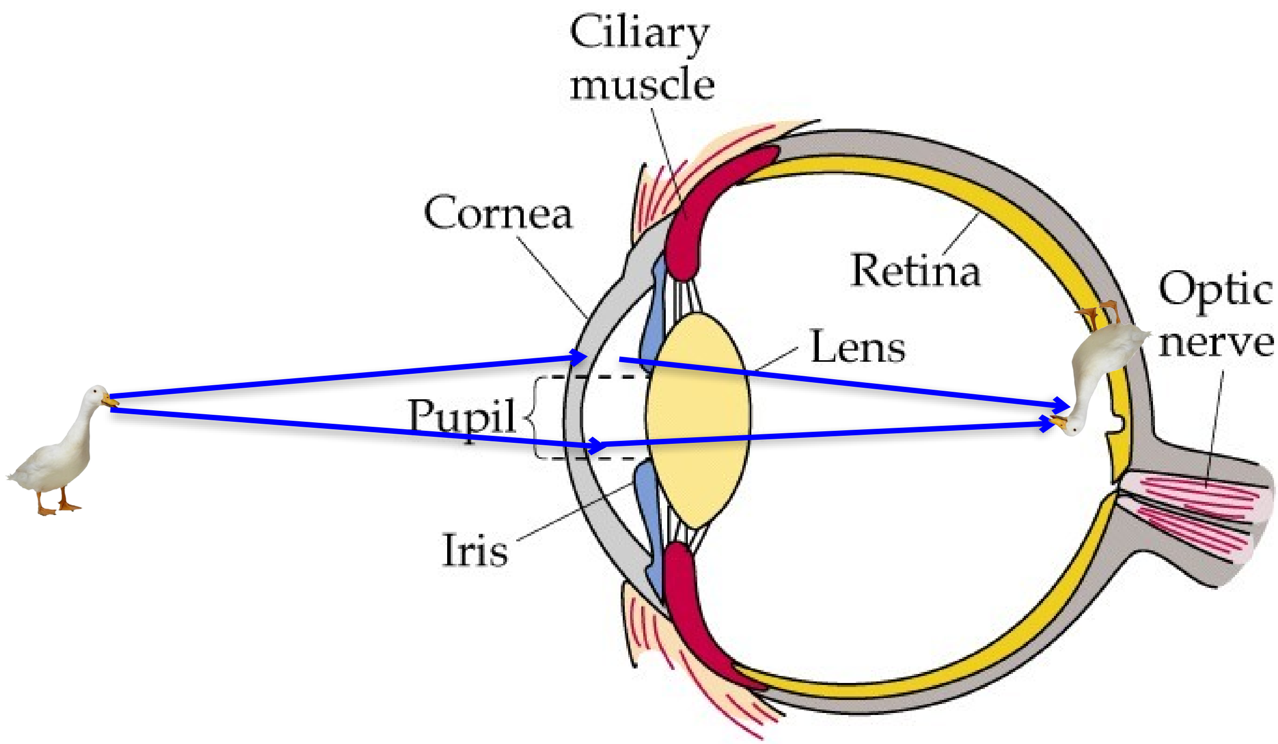
Optics and Waves

Lecture 18

Optical instruments

Y&F 34.6-34.8 p1142-1151

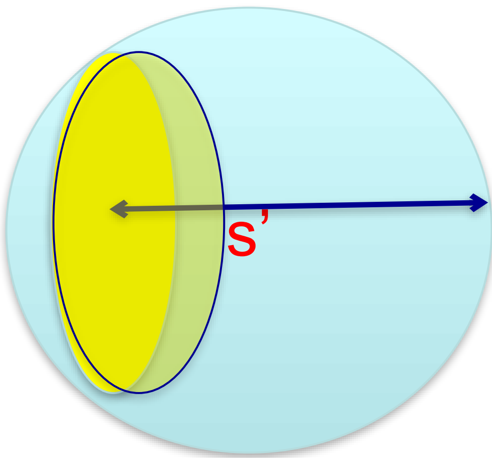
The eye



The far point is at infinity
The near point is 25 cm.

The near point is the closest distance for which the eye can form a sharp image (usually about 25 cm) – this changes with age!

Image distance is fixed at s'= 1.8 cm



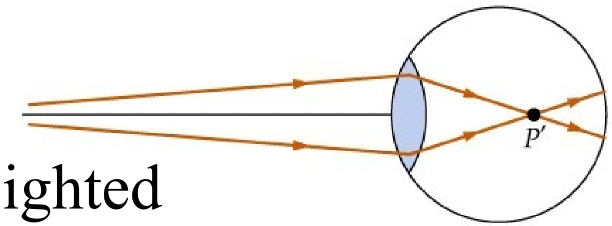
The eye changes its focal length to accommodate the varying object distance.

Object distance	Focal length
0.25 m	1.68 cm
1 m	1.77 cm
3 m	1.79 cm
100 m	1.80 cm
Infinity	1.80 cm

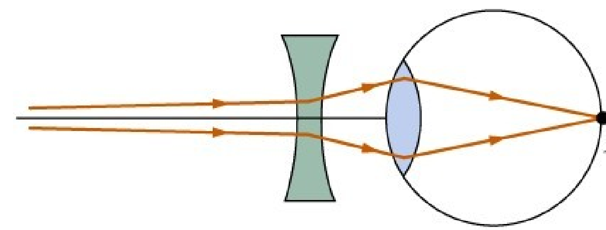
When two lenses are added together (no spacing) the focal length is

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

Near sighted



(a)

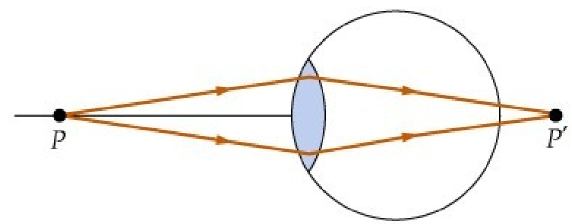


(b)

$$\frac{1}{f} = \frac{1}{f_{eye}} + \frac{1}{f_L} = \frac{f_{eye} + f_L}{f_{eye} f_L},$$

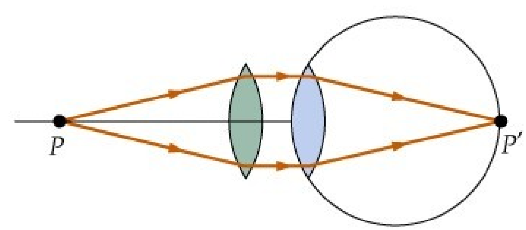
$$f = \frac{f_{eye} f_L}{f_{eye} + f_L} = \frac{f_{eye}}{\frac{f_{eye}}{f_L} + 1} > f_{eye}, \quad \text{if } f_L \text{ negative}$$

Far sighted



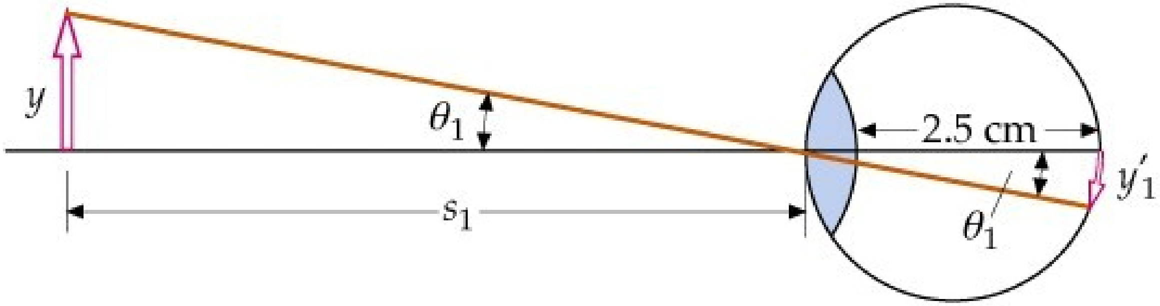
(a)

$$f = \frac{f_{eye} f_L}{f_{eye} + f_L} = \frac{f_{eye}}{\frac{f_{eye}}{f_L} + 1} < f_{eye}, \quad \text{if } f_L \textit{ positive}$$

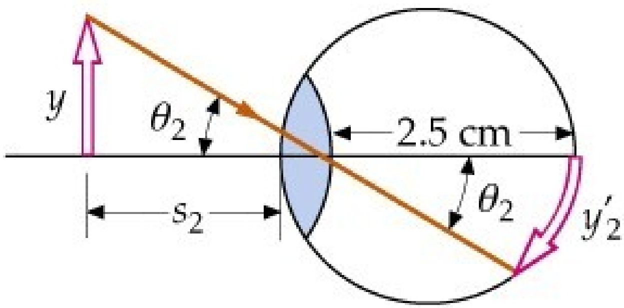


(b)

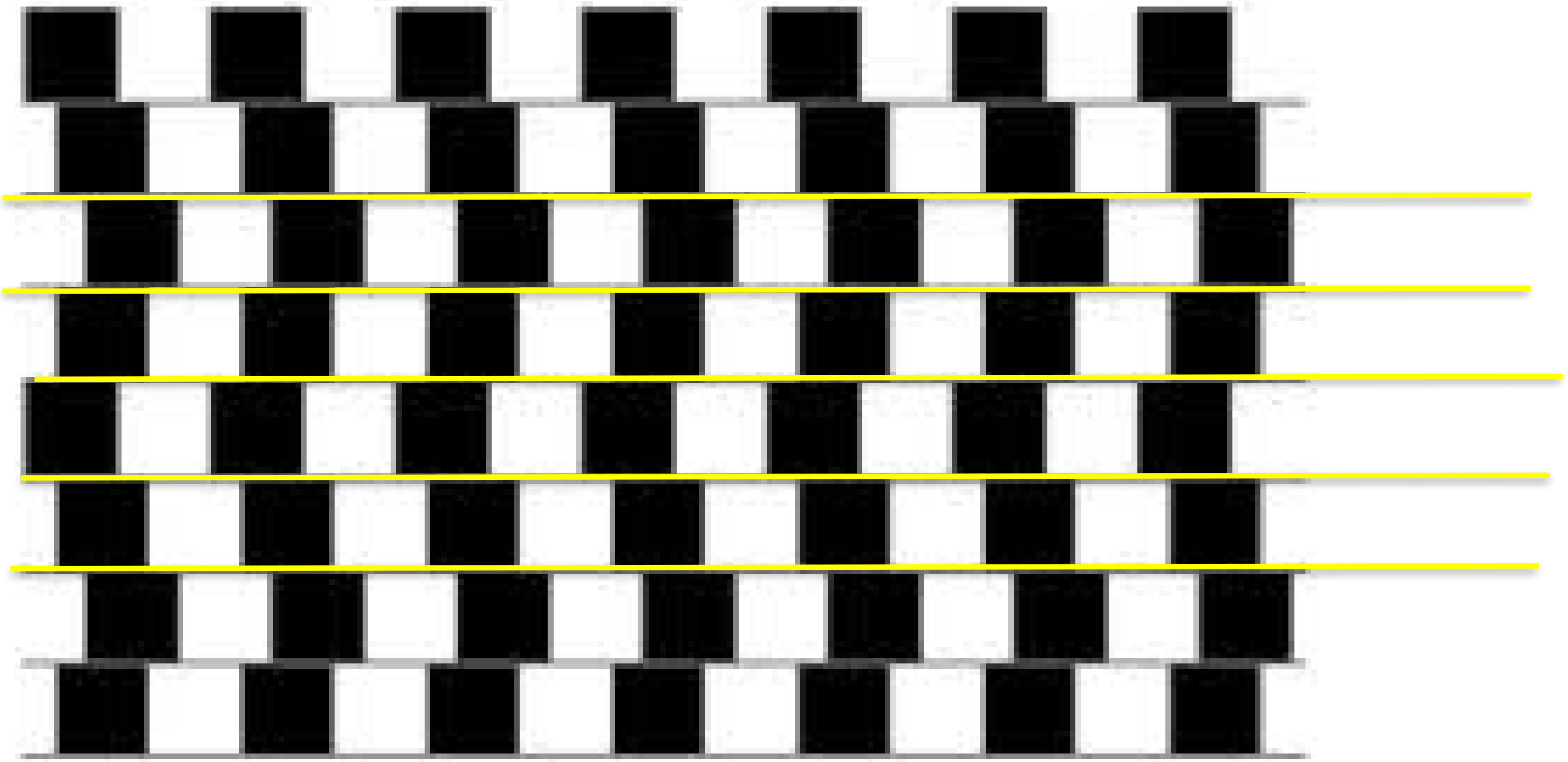
Apparent size of an object



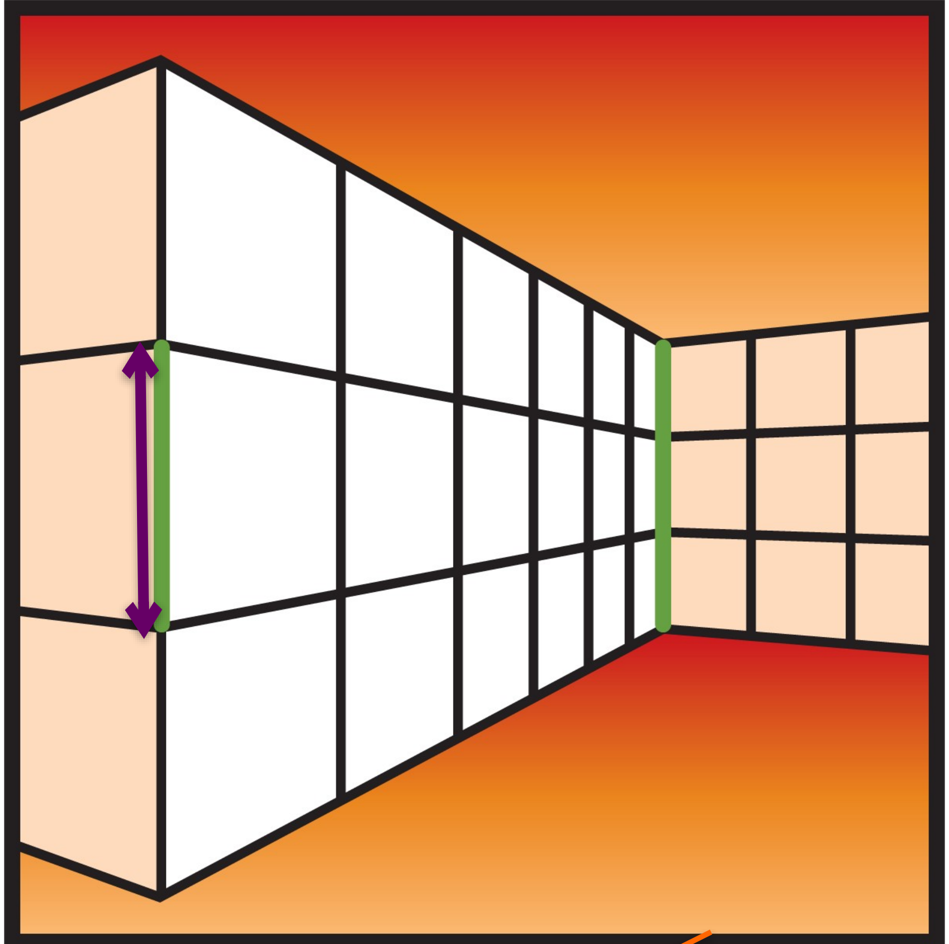
(a)

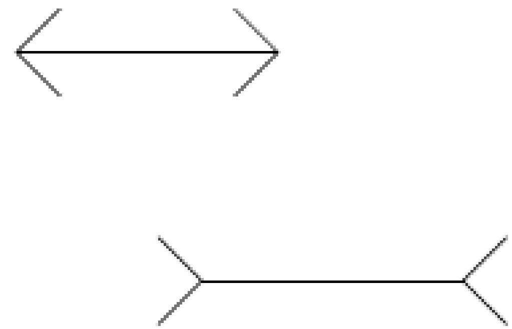


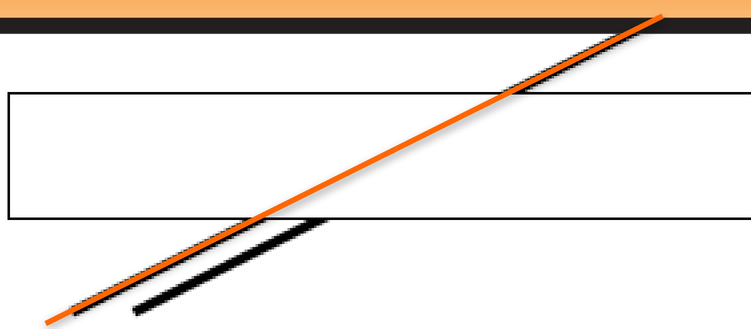
(b)

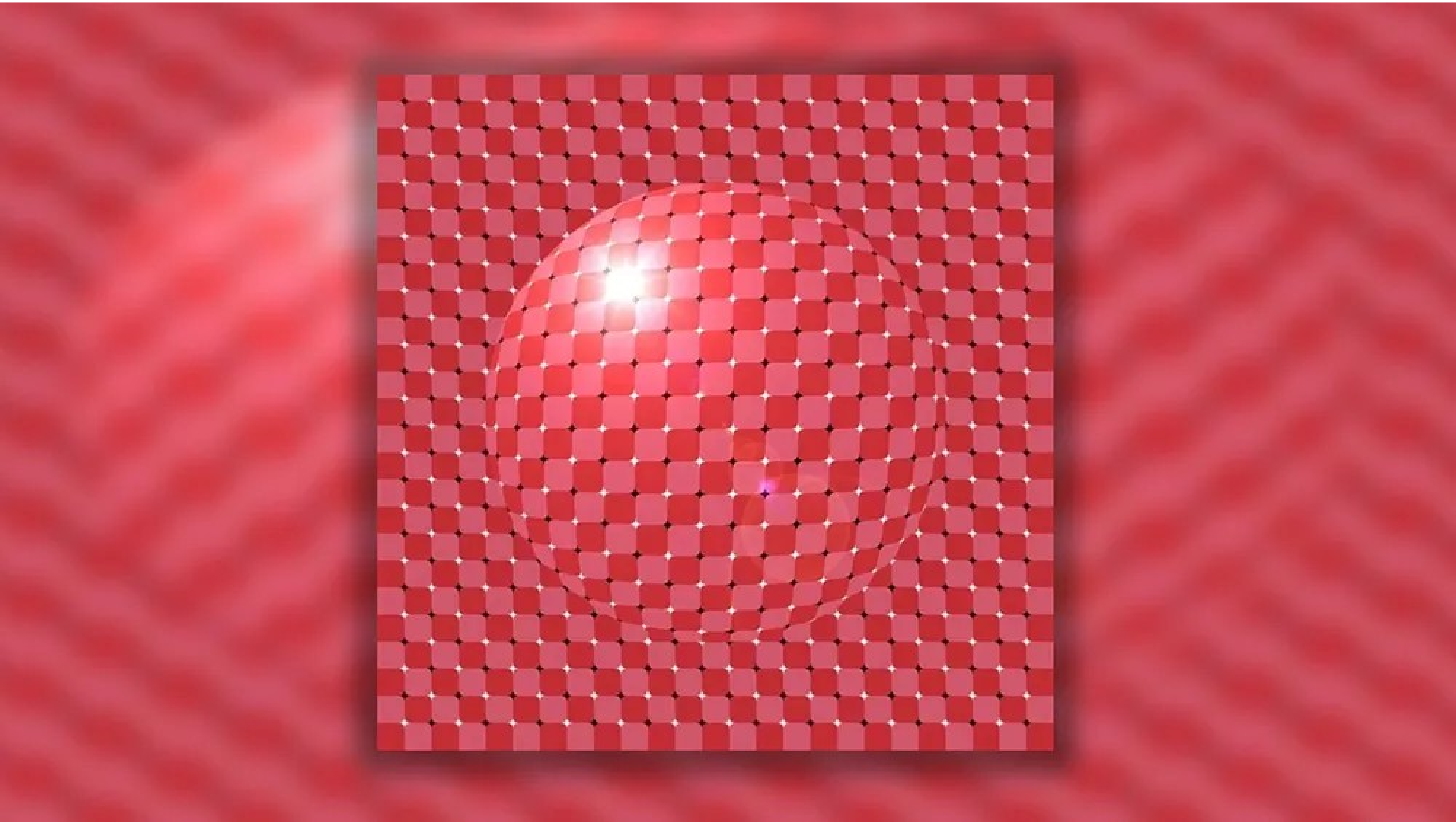


Are the horizontal lines parallel or do they slope?









The microscope

Object just outside F_{o1}

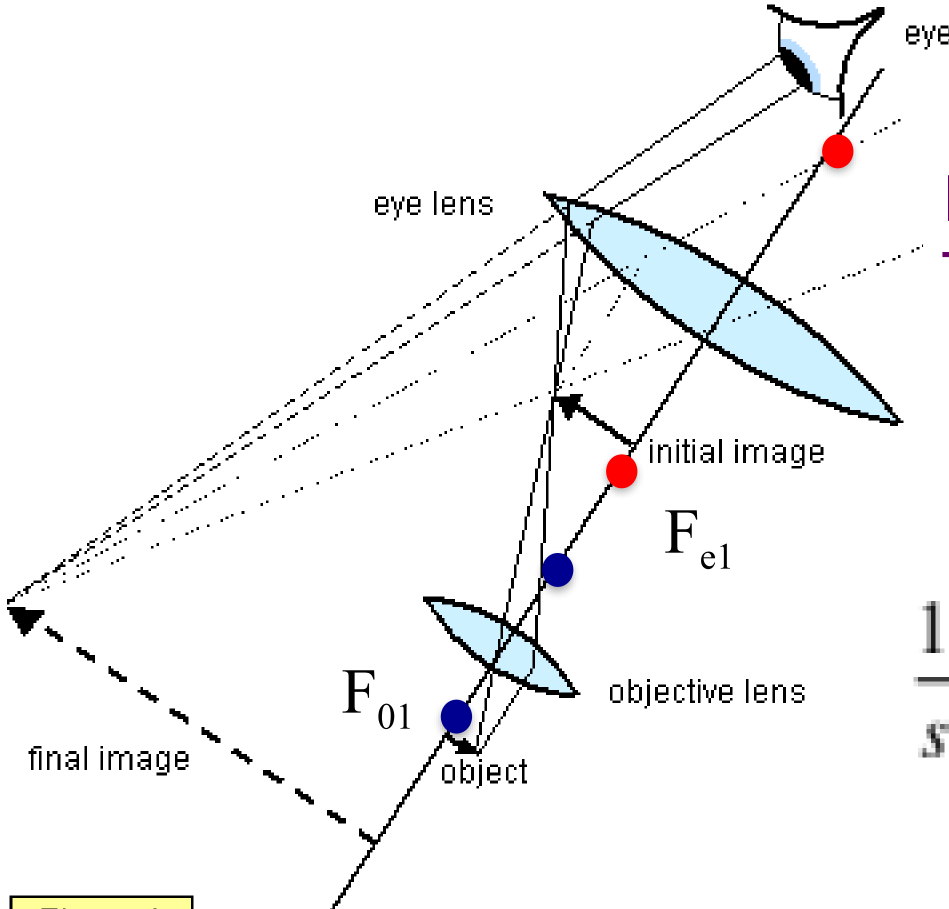


Figure 1

Initial image just inside F_{e1}

Final image 25 cm from The eye.

Shorter focal length gives higher magnification.

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

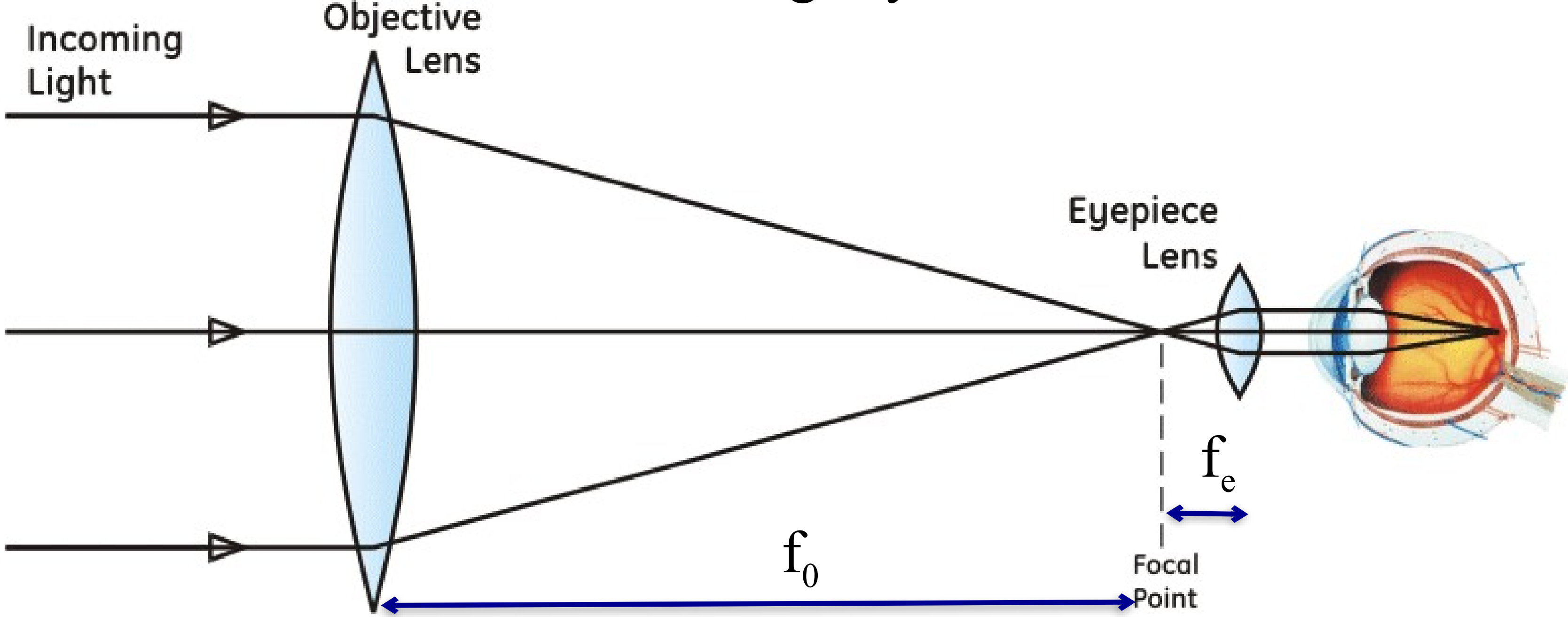
$$m=-\frac{s'}{s}\sim-\frac{s'}{f}$$

Magnification of a microscope?

http://www.schoolphysics.co.uk/age11-14/g

The Telescope

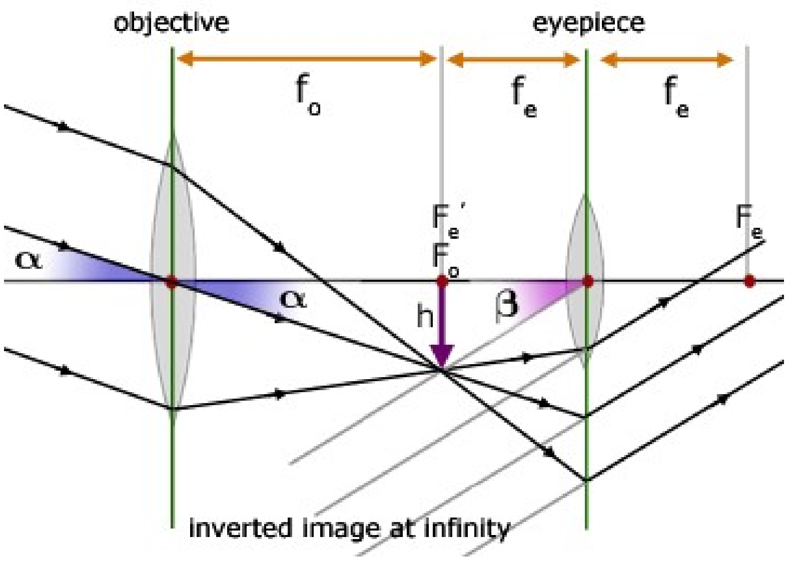
Job of telescope is to make objects which are far away appear close - and magnify them!



Large diameter of the objective: to collect more light, so faint objects can be seen.

10 cm diameter lens, 0.7 cm pupil $\dfrac{10^2}{0.7^2} = 204$

Magnifying power of a telescope



The distant object subtends an angle α

$$\alpha \approx -\frac{h}{f_o},$$

The final image subtends an angle β

$$\beta \approx \frac{h}{f_e} \qquad M = \frac{\beta}{\alpha} = -\frac{f_o}{f_e}$$

1 m objective focal length and 5mm eyepiece focal length: M=200

Suppose two stars, one above and one below the optic axis, the angle between the two objects is 2α, the angle between the two images is 2β. The angular spread of the two objects has been stretched. Hence angular magnification.

For high M, needs long focal length of the objective. Hence long telescope tubes.