5.2 Optical Instruments

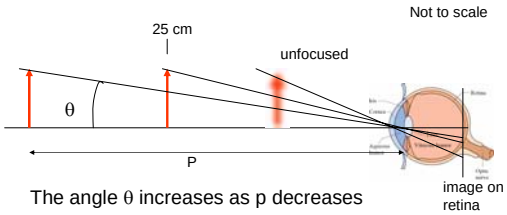
- Simple magnifier
- Compound microscope
- Telescope

Magnifiers

How do we image small objects?

- We can image a small object by bringing it close to our eye.
- But we cannot bring it closer than the near point. (we can't focus on it).
- A magnifier can produce a larger image of the object at the near point (or farther away) that can be focused on by the eye.

Angular size

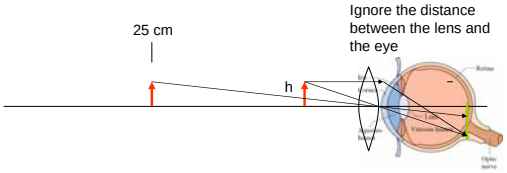


The angle θ increases as p decreases

But is limited by the near point of the eye. Objects closer than the near point are not in focus.

Simple Magnifier

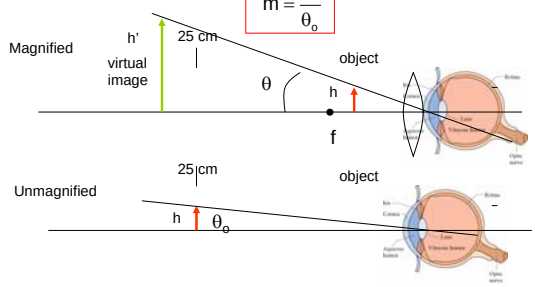
A converging lens in combination with the lens of the eye forms an image on the retina from an object closer than the near point of the eye.



Angular Magnification

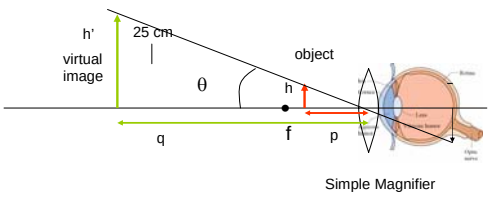
The angular magnification is the ratio of θ for the magnified image compared to value of θ_o for the object at the near point of the eye. (25 cm)

$$m = \frac{\theta}{\theta_o}$$



Simple Magnifier

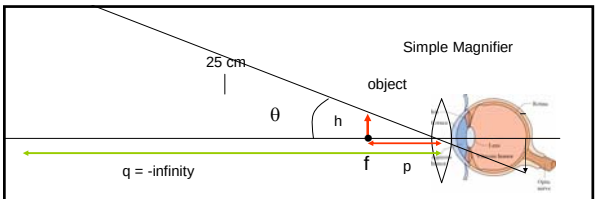
Produces an enlarged virtual image at a distance from the eye (from 25 cm to infinity) that the eye can focus on.



Angular magnification

The angular magnification can have a range of values because the focal length of the eye can vary due to accommodation.

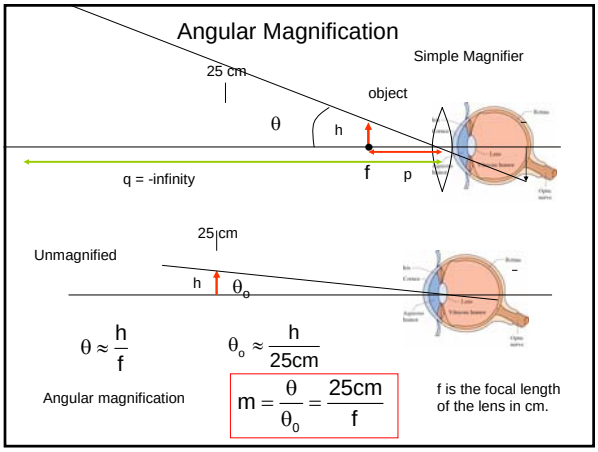
The simplest case is the magnification for the relaxed eye. (focused at infinity)



Object at the focal point.
Image at - infinity

The linear magnification is infinite (not useful) but the angular size is well defined.

$$\tan\theta = \frac{h}{f} \qquad \text{for small angles} \qquad \theta \approx \frac{h}{f}$$



$$\theta \approx \frac{h}{f} \qquad \theta_o \approx \frac{h}{25cm}$$

Angular magnification

$$m = \frac{\theta}{\theta_0} = \frac{25cm}{f}$$

f is the focal length of the lens in cm.

Simple magnifier question

A simple magnifier with a focal length of 5.0 cm is used to view an insect. What is the angular magnification for a relaxed eye?

Simple magnifiers.

The angular magnification for a single lens is limited by aberration to about 4. Combination lenses can have magnification to about 20.

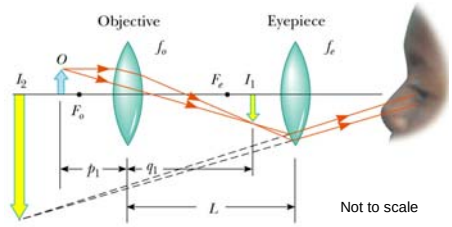
Compound Microscopes.

Magnification by 2 lenses.

- Objective lens – Produces an enlarged real image of the object.
- Eyepiece – Used like a simple magnifier to view the image.

The net angular magnification of the product of the two magnifications.

Compound microscope

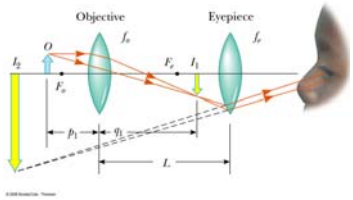


Not to scale

The objective lens produces a magnified real image I_1
The image is viewed through the eyepiece.

$M_o = \frac{M}{a} = -\frac{q_1}{p_1} \approx -\frac{L}{f_o}$ $\quad m_e = \frac{25cm}{f_e}$ For relaxed eye

Magnification of a compound microscope



Overall angular magnification

$$m = M_1 m_e = -\frac{L}{f_o}\frac{(25cm)}{f_e}$$

Microscope question

A compound microscope has an objective lens and eyepiece with a focal lengths of 2.0 cm and 4.0 cm respectively. The microscope is 20 cm long. Find the angular magnification

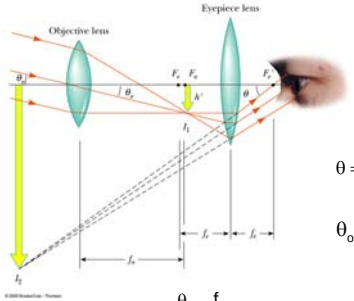
Refracting Telescope

Two lenses

Objective lens – produces a reduced image of a distant object near the focal point.

Eyepiece – used to magnify the image.

telescope



$\theta = \frac{h'}{f_e}$

$\theta_o = \frac{h'}{f_o}$

Angular magnification $\quad m = \frac{\theta}{\theta_o} = \frac{f_o}{f_e}$

Telescope Question

A telescope has an objective and eyepiece with focal lengths of 50 cm and 1.2 cm respectively. What is the angular magnification?