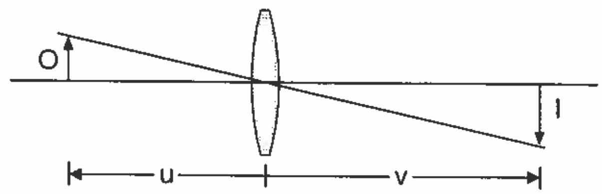
Magnification

Transverse magnification (linear, lateral)

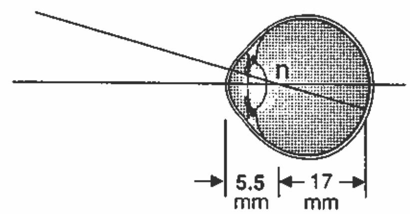
Central ray forms similar triangles:

$$\text{Mag} = \frac{I}{O} = \frac{v}{u}$$



See:
p69, prob 21

Central ray for the eye passes through "the nodal point"

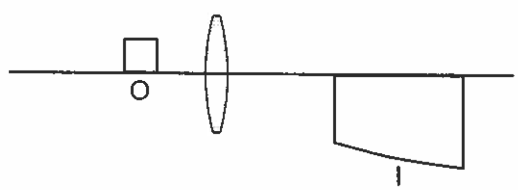


See:
p63, prob 14

Axial magnification

Magnification **along** the axis.

Is always the square of the transverse magnification (between any given pair of conjugate planes).



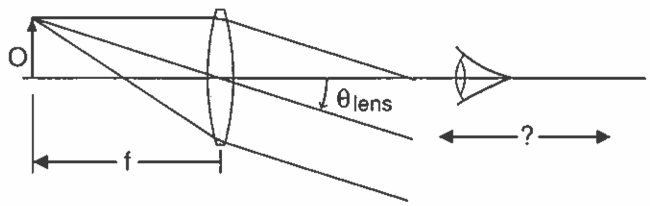
Causes **distortion** in 3-D images, as in indirect ophthalmoscopy or when using fundus viewing lenses with the slit lamp (see page 109).

Angular magnification

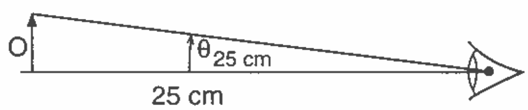
Used:

1. **With objects and images at infinity** (although they are infinitely large, they have a finite angular size).

2. **When viewing with an eye** (because of different powers and lengths of eyes, we cannot know the size or distance of the retinal image; we must rely on angles).



How should the magnification produced by this lens be expressed?



By comparing the angular size produced (Θ_{lens}) to a reference angle ($\Theta_{25\ cm}$)

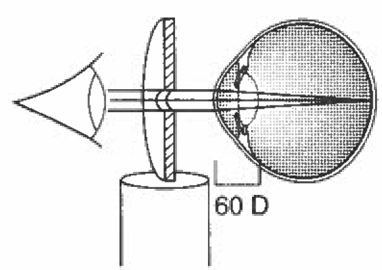
$$\text{Mag} = \frac{\Theta_{lens}}{\Theta_{25\ cm}} = \frac{\tan^{-1}(O/f)}{\tan^{-1}(O/25)} \approx \frac{25\text{ cm}}{f} = \frac{\mathbf{D}}{\mathbf{4}}$$

Magnification of a **simple magnifier**

Direct ophthalmoscope magnification:

The examiner uses the optics of the patient's eye as a simple magnifier to examine the patient's retina.

$$\text{Mag} = \frac{60\text{ D}}{4} = 15\text{ X}$$



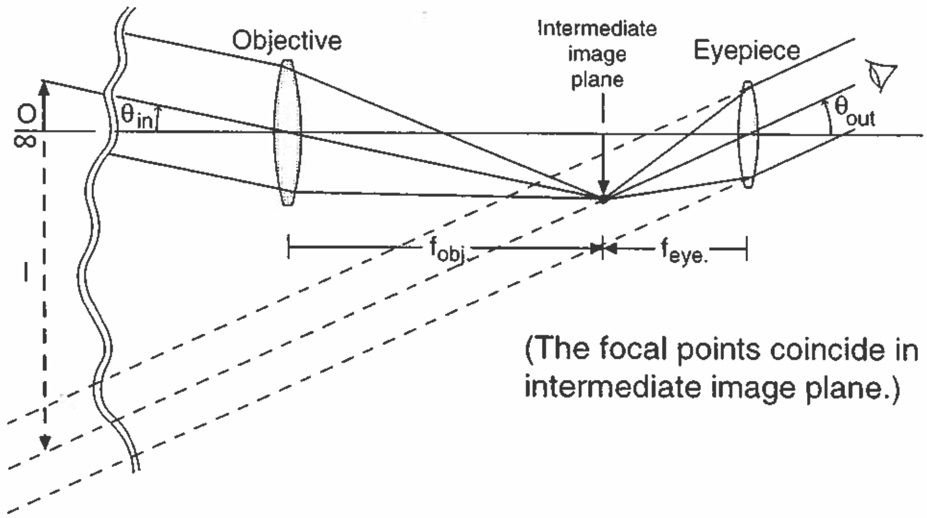
This indicates that the patient's retina appears 15 times larger than if it were cut out of the eye and held at 25 cm.

See:
p69, prob 22

Angular magnification, continued

Astronomical telescope

Forms an inverted image and has few uses in ophthalmic optics.



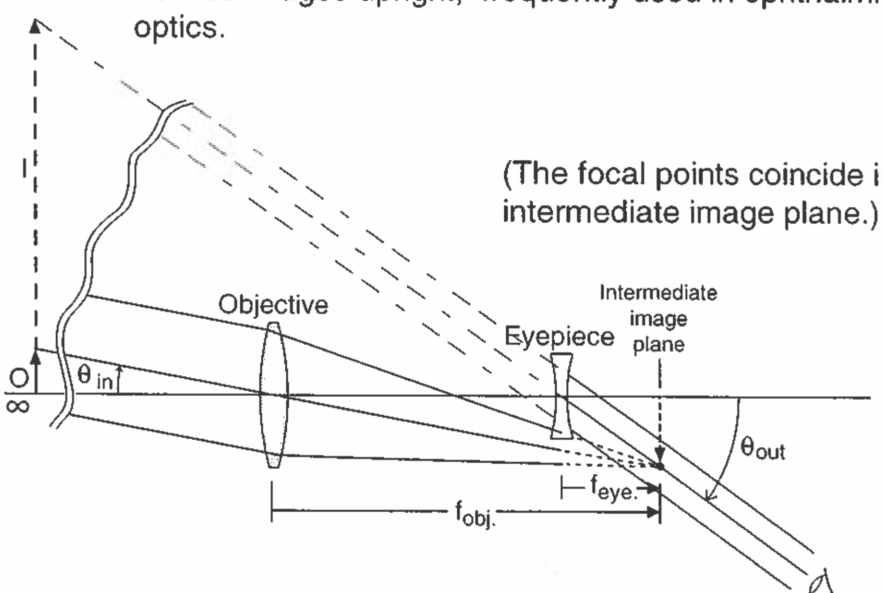
(The focal points coincide in the intermediate image plane.)

$$Mag = \frac{\Theta_{out}}{\Theta_{in}} \approx \frac{f_{obj}}{f_{eye}} = \frac{D_{eyepiece}}{D_{objective}}$$

Galilean telescope

Leaves images upright; frequently used in ophthalmic optics.

(The focal points coincide in the intermediate image plane.)



$$Mag = \frac{\Theta_{out}}{\Theta_{in}} \approx \frac{f_{obj}}{f_{eye}} = \frac{D_{eyepiece}}{D_{objective}}$$

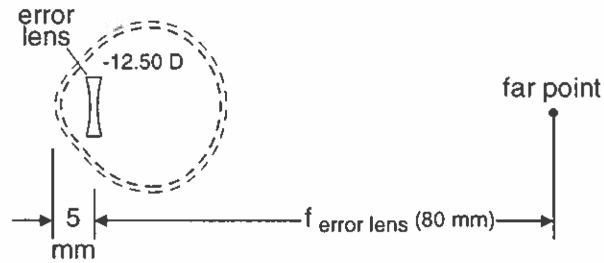
See:
p89, prob 38
p91, prob 39

NOTE for all telescopes: zero vergence **in** gives zero vergence **out**

Angular magnification, continued

Corrected aphakic eye (magnification considerations)

The refractive error of an aphakic eye can be thought of as a single -12.50 D lens **in air** acting at the seat of ametropia, 5 mm behind the cornea. The primary focal point of the -12.50 D lens is the far point of the eye.



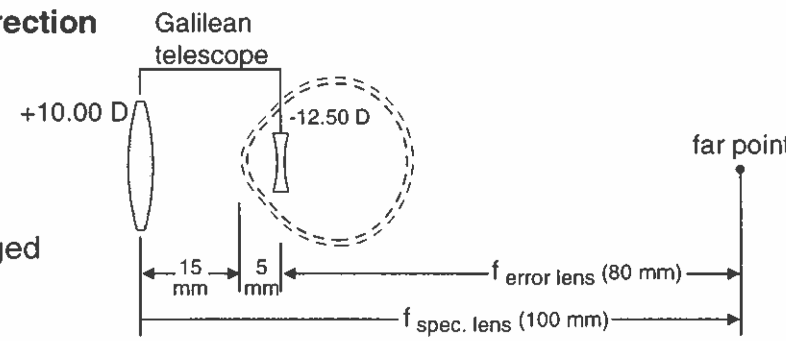
The secondary focal point of the corrective lens must coincide with the far point, thereby creating a Galilean telescope with magnification determined by the ratio of the eyepiece power to the objective power, as shown below:

Spectacle lens correction

$$\text{Mag} = \frac{12.50}{10.00}$$

$= 1.25$ X

$= 25\%$ enlarged

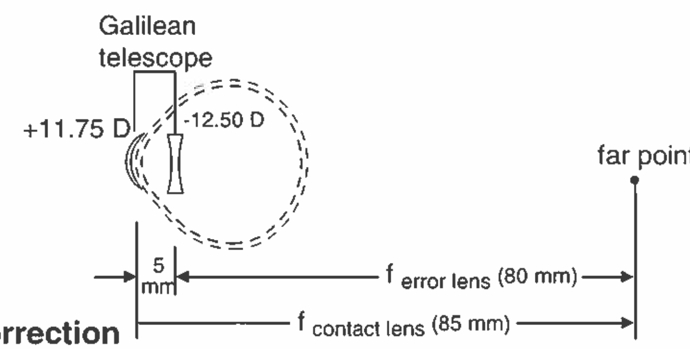


Contact lens correction

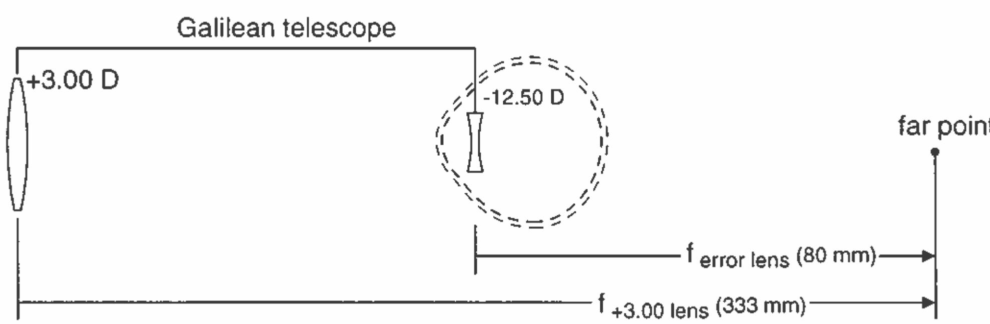
$$\text{Mag} = \frac{12.50}{11.75}$$

$= 1.06$ X

$= 6\%$ enlarged



Hand-held +3.00 D lens correction



$$\text{Mag} = \frac{12.50}{3.00} = 4.2 \text{ X, or } 320\% \text{ enlarged}$$

See:
p71, prob 23

Angular magnification, continued

Ordinary spectacle lenses

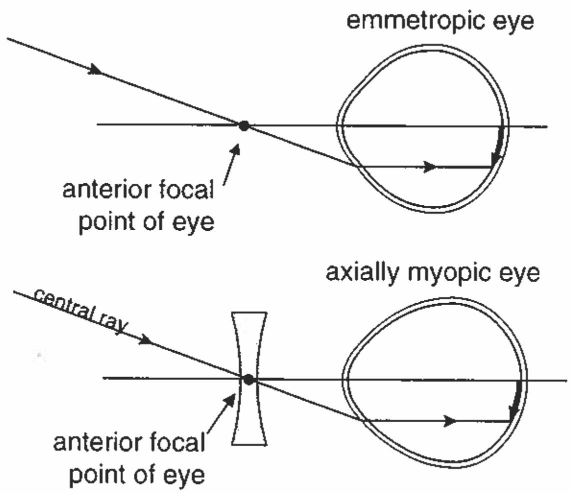
A spectacle lens at a vertex distance of 12 to 13 mm changes the retinal image size by about 2% per diopter of power, with respect to the retinal image size in the uncorrected state.

	type of telescope	example	% change	Mag
Plus lenses magnify	Galilean	+ 4 D	8% larger	1.08 X
Minus lenses minify	reverse Galilean	- 4 D	8% smaller	0.92 X

Up to 6 to 7% overall image size difference (aniseikonia) between the two eyes can usually be tolerated. This corresponds to a spectacle-lens-corrected **refractive** anisometropia of 3 to 4 diopters of sphere. Children are very tolerant of aniseikonia and adapt partially, or fully, automatically. DO NOT undercorrect children for fear of aniseikonia, for you risk amblyopia and permanent visual loss.

Knapp's rule

In **axial** anisometropia (i.e. unilateral high myopia), equal image sizes on the two retinas are obtained by correcting the refractive error by a spectacle lens placed at the anterior focal point of the eye, approximately 16-17 mm in front of the cornea. (In **axial** ametropia, the **optical power** of the eye is normal, and the anterior focal point is in the normal position 16-17 mm in front of the cornea.)



Same image height as in the emmetropic eye, **whatever** the necessary power of the minus lens

Highly myopic eyes may have stretched-apart photoreceptors, however, and a **larger** retinal image in the highly myopic eye may be desirable. It is impossible to determine this in young unilateral high myopes who cannot respond to special aniseikonia tests, and many practitioners use contact lens correction instead of glasses. Contact lens correction avoids the anisophoria that glasses correction produces in such cases.

Low vision aids

Prerequisites for optimal determination and demonstration:

Assessment of patient's needs
Visual acuity known (linear or reading acuity is more useful than single optotype acuity)
Visual field status
Assortment of aids

Available aids for near – Plus lens*		
	Advantages	**Disadvantages**
High add in bifocal		
+ 4 to +20 D	Large field of view.	Short reading distance, expensive.
High power single vision lens		
+ 4 to +20 D, full frame or half-eye. Monocular or binocular (with base-in prism)	Large field of view.	Short reading distance, expensive.
Hand-held magnifier		
usually +5 to +20 D	Variable eye-to-lens distance. Easy to carry. High rate of acceptability.	Small field of view with lens held away. Difficult to manipulate by patients with tremors, arthritis, etc.
Stand magnifier		
About +4 to +50 D. Fixed focus (requires accommodation or a reading add in addition) or focusable (can adjust for refractive errors or presbyopia).	Greater eye-to-lens distance than spectacle. Easy to manipulate. Favorite of older patients.	Smaller field of view than spectacle. Bulky, especially if light source is built in.

* see next page

Low vision aids, continued

***Kestenbaum's rule** — (estimation of strength of plus lens necessary to read ordinary newspaper print (without accommodation))

At a normal reading distance of 40 cm (16 in), newspaper print (8 point, Jaeger 5, 1 M) requires a linear (not single letter) visual acuity of approximately **20/50**. This reading distance also requires plus power of +2.50 D for proper focus. Coincidentally, **the reciprocal of the Snellen acuity is equal to the plus dioptric power required**.

A patient with 20/100 distance visual acuity would have to hold the newspaper print at 20 cm so that it would appear twice as large as at 40 cm. This reading distance of 20 cm would require plus power of +5.00 D, either from accommodation or from a plus lens reading aid. Again, the plus power required is equal to the reciprocal of the Snellen acuity (100/20 = 5), illustrating the generality of this relationship.

If reading vision is measured in terms of M units with the Sloan reading cards at 40 cm, the plus lens power necessary for reading 1 M print (newspaper print) is equal to M x 2.5 D.

Available aids for near – loupes

Loupes (close-focus telescopes)	Advantages	Disadvantages
Prefocused (e.g. surgical loupes). An "add" (lens cap) over a distance telescope brings working distance in from infinity.	Long working distance, leaves hands free.	Small field of view. Limited depth of field, especially with higher powers. Requires precise head positioning without tremor. Expensive.

Available aids for near – electronic displays for reading

	Advantages	Disadvantages
Closed circuit television (CCTV)		
Reading material is moved about in the field of the camera and is displayed at a magnification as high as 40 X.	Contrast reversal (white on black) possible for less glare.	Non-portable.
View-Scan®		
Linear sensor is moved over reading material, painting magnified image on screen.	High magnification. Contrast reversal possible. Manual dexterity required.	Expensive.
Magni-Cam®		
Hand-held (cigarette-pack-sized) video camera is scanned across material to be viewed.	Relatively inexpensive. Contrast reversal simple. Can view uneven surfaces. Camera is PORTABLE and can be battery powered.	Limited field of view. Requires television and some manual dexterity.
Large print computer display programs		
Fixed size or variable. Can reverse contrast.	Built-in rectilinear orientation.	Reading material must be available on disc or stored in computer. Large monitors are more expensive. Difficult to scan at high magnification.
Mentor Horizon®		
Text is scanned into device and is automatically displayed as a continuous line-of-text format (like Times Square).	Black on white or reverse contrast. Variable size and speed of display. Good for patients who are avid readers (e.g., students and lawyers).	Expensive. Not portable. Separate scanning step is time-consuming.

Available aids for near – Non-optical aids

	Advantages	Disadvantages
Large-type watches / talking clocks		
	Readily available. Inexpensive models available.	Talking models conspicuous.
Large numeral calculators		
	Inexpensive.	
Large numeral telephone dials		
	Inexpensive. Readily available.	Conspicuous.
Large print books and periodicals		
	Available through libraries.	Not all titles available. News is out of date in large print periodicals.
Black ink marking pens		
	Inexpensive. Readily available.	Conspicuous.
Signature guides		
	Inexpensive.	Conspicuous.
Masking devices for reading (e.g. "Typoscope")		
	Inexpensive	Conspicuous.
Illumination control		
Patients usually need increased contrast: halogen lamps.	High contrast. Readily available. Inconspicuous.	Some models expensive.

Distance low vision aids		
	Advantages	**Disadvantages**
Telescope		
Monocular or binocular. Hand-held or spectacle mounted. Fixed- or adjustable-focus.	The only magnifying distance aid available. Portable. Some states allow driver's license with telescopic aid, despite poor acuity.	Restricted field of view. Limited to about 8X because of difficulty in finding object, and swimming of field with movement. Cosmetically obvious.
Absorptive lenses		
For glare control in presence of media opacities or albinism.	Relatively inexpensive.	Cosmetically obvious.
For partial dark adaptation in patients with congenital achromatopsia and in some cases of age-related maculopathy.	Relatively inexpensive.	Cosmetically obvious.
Night vision telescopes		
For patients with poor scotopic vision (e.g. Retinitis pigmentosa)	Aids mobility during scotopic conditions.	Cosmetically obvious. Limited field of view. Bulky. Expensive.