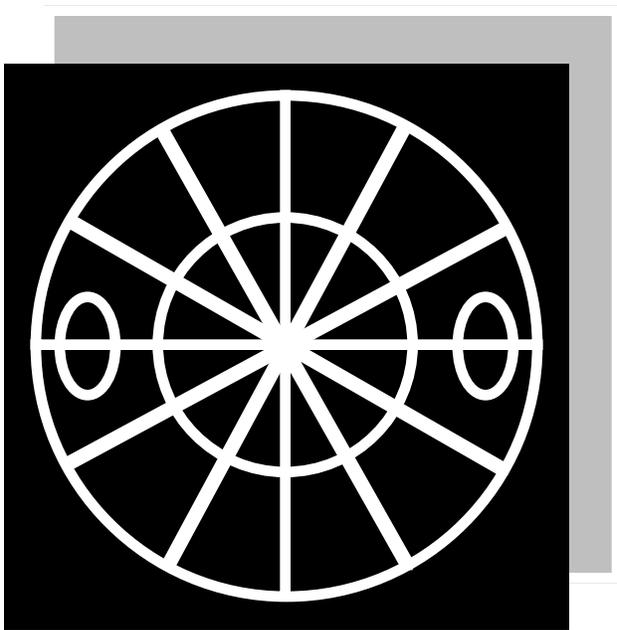


LOW VISION AIDS

Optical Characteristics of the Low Vision Patient

The definition of visual loss includes two components and limited resolving power or acuity, a blur that can't be eliminated with a simple spectacle lens. This blurring can be due to distortions of the optics of the cornea, lens, or the quality of the retinal receptors. Usually field constriction and limited resolving power come together. Most low vision therapy treats blur primarily via magnification.



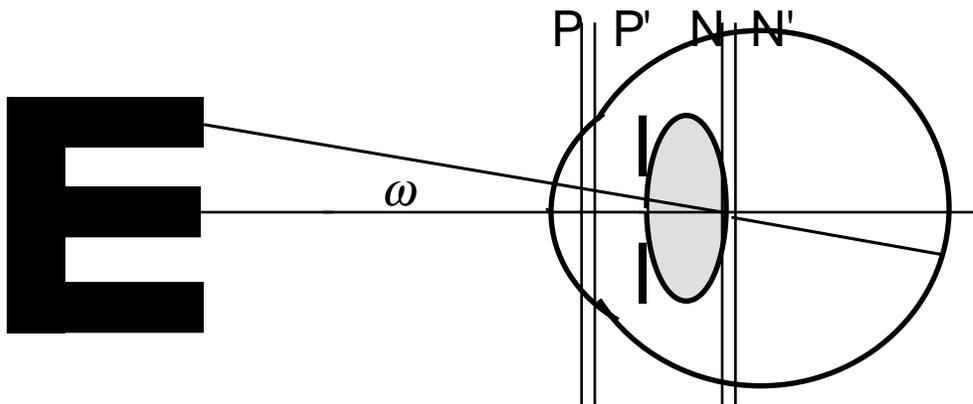
visual acuity chart

tangent screen to measure
visual field losses

Magnification Devices

Angular Resolution

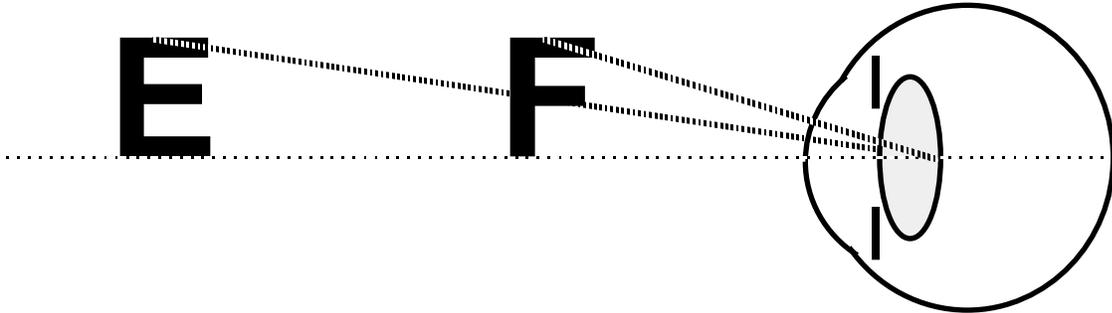
The resolving power of the eye is the ability to distinguish two proximal but separate sources such as the legs of the **E** in the diagram below. The two sources are moved together until the subject is just barely able to distinguish them. In practice the resolving power of the eye is measured by having a patient read down an acuity chart until the details of the letters are too small to read them.



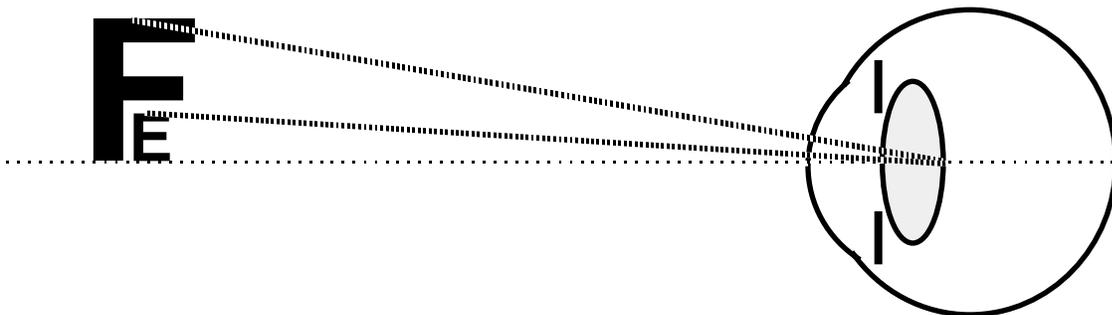
The angle ω characterizes the resolving power of the eye, the smaller ω the better the resolution. if ω is 1' we say clinically the patient is 20/20(6/6). We measure resolution with the familiar acuity chart. For low vision, patients ω is large so we compensate by increasing angular subtense of object or of an image of the object.

Non-Optical Magnification

Non optical magnification is usually achieved by holding material closer to the eye. In the diagram below the **F** is magnified with respect to the **E** because of its relative position. This assumes, however, that the patient can accommodate sufficiently to clear the image. Even if he can, this is tiring.

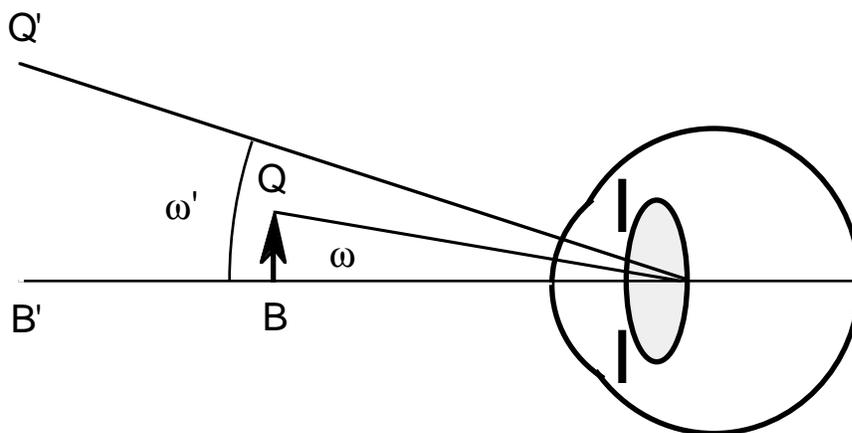


Another approach is to make the object bigger, just as the **F** subtends a larger angle than the **E** in the diagram below. Large print reading materials increase letter size with no increase in accommodative demand. The patient is, of course, limited in his choice of reading matter. The space age version of this is the CCTV.



Reading Loupes

In discussing conjugate imagery we discussed lateral magnification, m . The kind of magnification appropriate to a discussion of low vision aids is angular magnification, M . Suppose we have a device that forms an image $B'Q'$ of object BQ , as below:



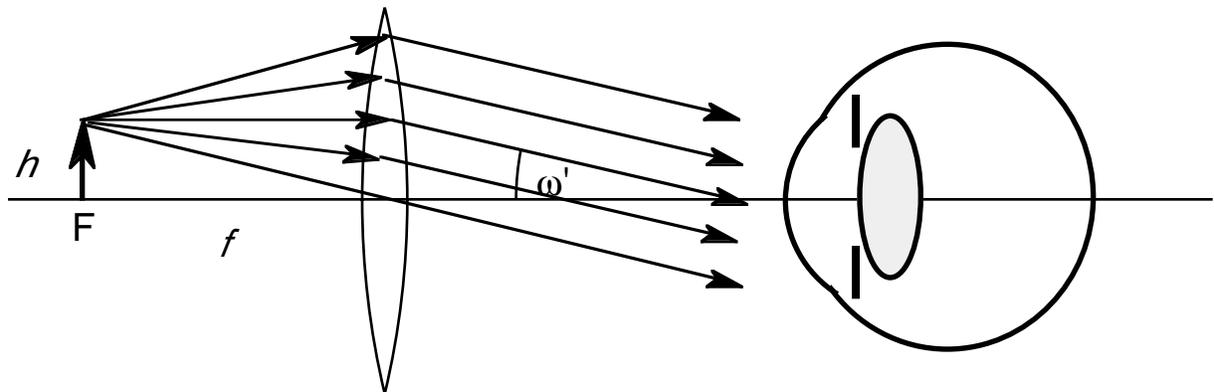
The image is viewed by an observer. If the object subtends angle ω at the observer and the image subtends angle ω' at the observer, then

$$\text{angular magnification} = M = \omega' / \omega.$$

Suppose the observer holds an object of height h a distance q in front of his unaided eye. The angular subtense of the object is $\omega = h / (-q)$. Now suppose he places the object at the primary focus of a simple lens of focal length f' . The image now subtends angle $\omega' = h / f'$. The angular magnification is $M = -q / f'$. By convention, $-q$ is taken to be 25cm so

$$M = -q / f' = 0.25 / f' = F/4.$$

This is the famous $F/4$ formula.



Example: What is the power of a 10X magnifier?

Solution: $F=4M=4 \times 10=+40D$.

Note that the power in the $F/4$ equation is the **equivalent power** of the system, not the front or back vertex power.

Many kinds of positive powered optical systems are used in low vision work including hand held magnifiers, stand magnifiers, and magnifying spectacles. While their forms differ, the power of any of these devices may be related to the visual acuity of the patient by the equation

$$F=1.25/\nu$$

where F is the magnifier appropriate for a patient with decimal acuity ν when viewing an acuity chart held at 40cm.

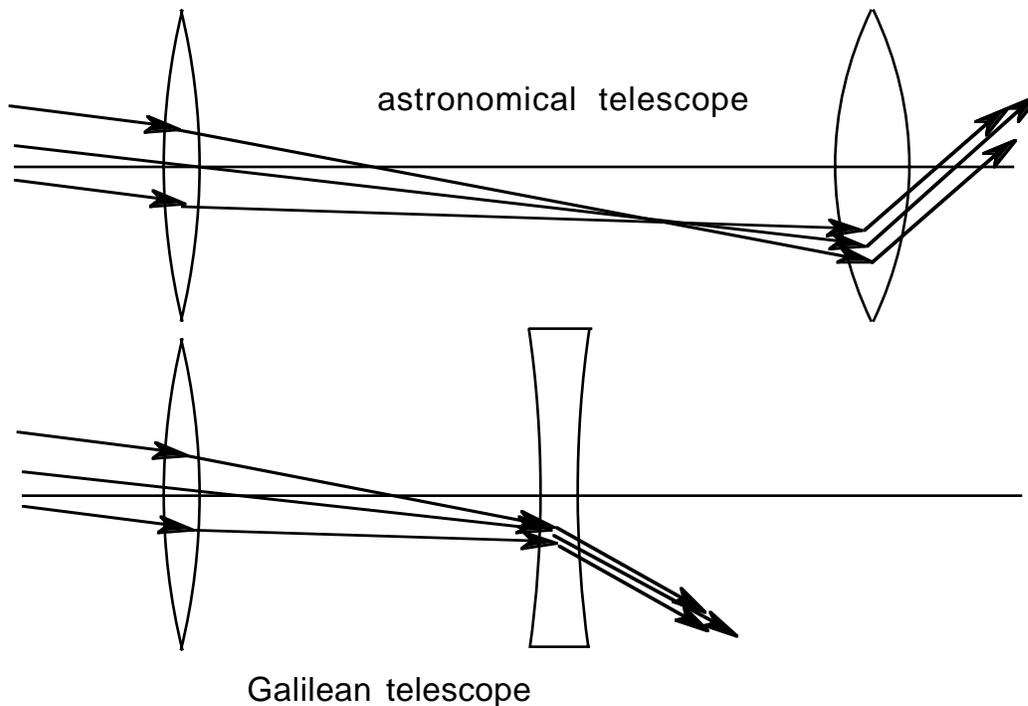
Example: What power magnifier would be appropriate for a patient with 20/60 acuity measured with a chart held at 40cm?

Solution: The patient's decimal acuity is $\nu=20 \div 60=1/3$, so the magnifier power is $F=1.25/(1/3)=+3.75D$. This could be given as a high add, hand magnifier, or stand magnifier.

Besides magnification, clinicians should know something about the optical quality, field of view, accommodative demand, weight, and working distance of the device.

Telescopes

While microscopes give angular magnification of near objects, telescopes give angular magnification of distant objects. Telescopes consist of two lenses (in practice two optical systems) mounted such that the secondary focal point of the objective coincides with the primary focal point of the ocular. The objective lens is a converging lens and the ocular lens can be positive or negative. If the ocular is positive it is a Keplerian or astronomical telescope, if it is negative it is a Galilean telescope. Astronomical telescopes produce inverted images and Galilean telescopes produce erect images. Image formation is shown in the diagrams below.



The angular magnification of either kind of telescope can be calculated from the equation

$$M = -F_{\text{ocular}}/F_{\text{objective}} = \rho_E/\rho_{E'}$$

where F_{ocular} and $F_{\text{objective}}$ are the powers of the ocular and objective lenses and ρ_E and $\rho_{E'}$ are the radii of the telescope's entrance and exit pupils.

Example: A telescope has objective of +5.00D power and ocular of -10.00D power. What is its magnification?

Solution: $M = -(-10)/(5) = +2$. The telescope is Galilean with 2X magnification.

Example: A telescope has entrance pupil 9mm in diameter and exit pupil 6mm in diameter. What is its magnification?

Solution: $M = (9\text{mm})/(6\text{mm}) = 1.5X$.

Taking the ratio of the entrance pupil to exit pupil diameter is, incidentally, a useful way to measure the power of clinically used telescopes.

In practical systems the thin lenses of the diagrams are replaced by optical systems designed to improve image quality.

Many different forms of telescopes are used in low vision including spectacle mounted telescopes like the sportscope, bioptic mirror spectacles, contact lens telescope, as well as a variety of hand held telescopes.

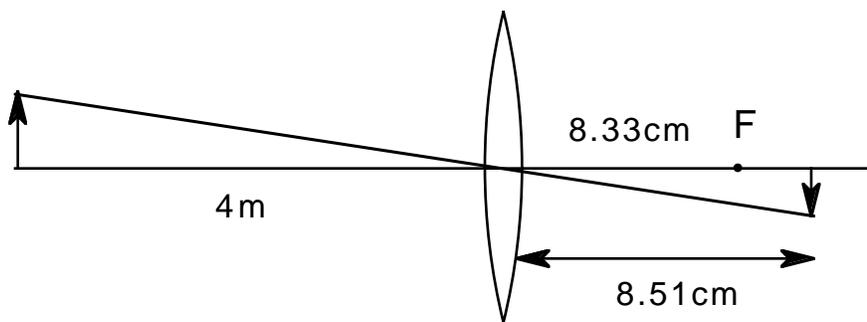
If a telescope of magnification M focused for a remote object is used to view a near object, the accommodation necessary to focus the image is M^2A where A is the accommodation that would have been necessary without the telescope. With a 3X telescope, for example, accommodation demand is multiplied by $3^2 = 9$ times! Clearly some means of focusing must be employed to see objects at near or intermediate distances with a telescope. Telescopes may be focused for near objects by changing the distance between ocular and objective lenses or by means of a reading cap, a positive lens placed over the objective, on the ocular or objective. A telescope with a reading cap has a long, more comfortable working distance than a loupe, but more limited field of view.

Example: A 4X telescope with a 12D objective lens is used to look at an object 4 meters from the telescope. How much accommodation would be necessary to see the object clearly through the telescope if it were focused for a remote object and how much would the ocular have to be moved from its infinity focus position to focus the image for the unaccommodated eye?

Solution: The accommodation necessary to see an object 2 meters from the eye is simply $A=1/4m=0.25D$. The accommodation with the 4X telescope would be

$$4 \times 0.50 = 8D.$$

For a remote object, the image falls at the secondary focal point of the objective, a distance $f' = 1/12D = 8.33\text{cm}$ behind the objective. For an object 4m from the lens, adjust the distance from objective to ocular so that the image formed by the objective **still** falls on the primary focal point of the ocular. The position of that image can be calculated from the fundamental paraxial equation, $L' = L + F$ where $L = 1/(-2m) = -0.50D$ and $F = 12D$ so that $L' = -0.50D + 12D = +11.50D$. The distance of the image from the lens is $f' = 1/L' = 1/11.50D = 8.70\text{cm}$. The ocular and objective must, then be separated by an additional $8.70\text{cm} - 8.33\text{cm} = 3.7\text{mm}$.

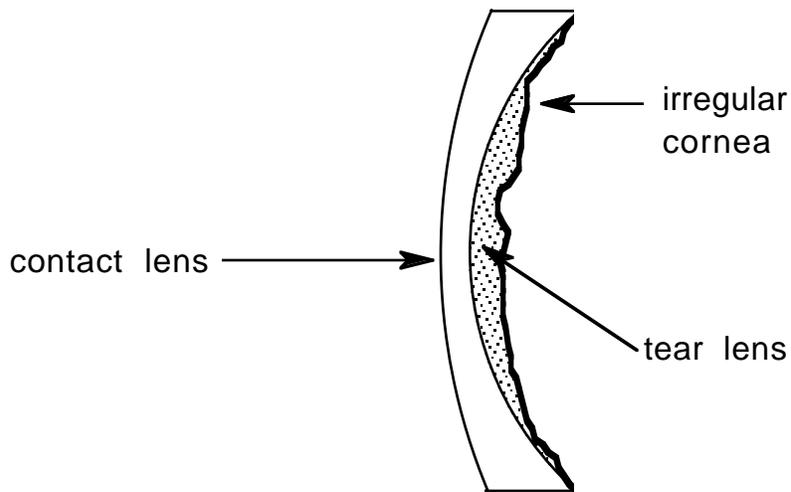


Note that there is the same increase in separation for either a Galilean or Keplerian telescope.

Contact Lenses

In low vision work there are two main uses for contact lenses: irregular corneas and aphakia.

With an irregular cornea, the contact lens replaces optically the roughened cornea with a smooth one.



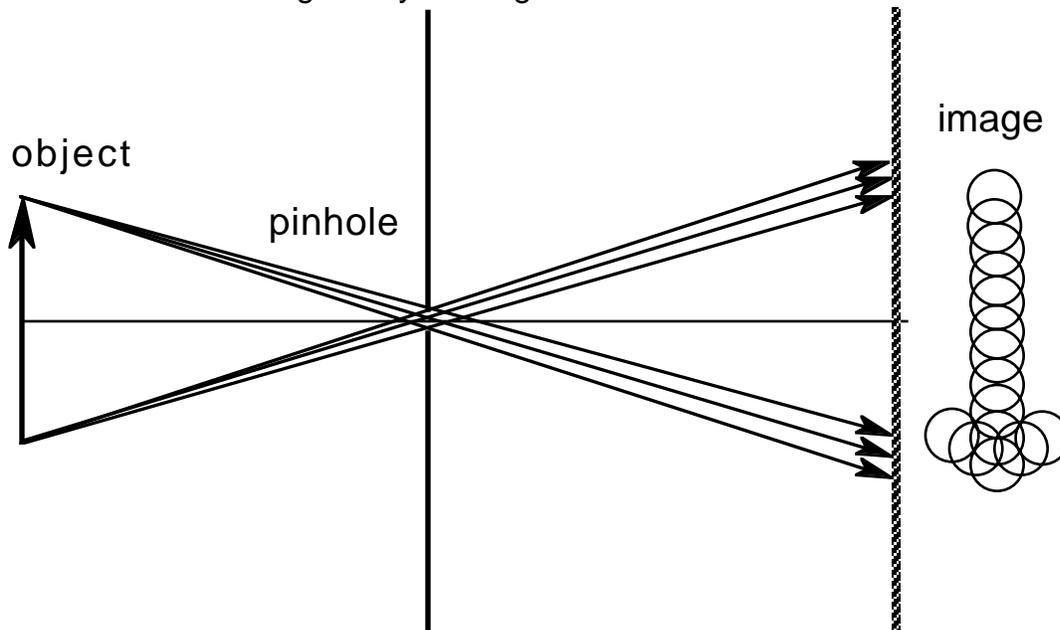
For the aphakic, a contact lens produces a more normal, smaller image. But if low vision is involved we're actually better off with spectacles which give higher magnification.

Contact lenses are sometimes used with nystagmus. Some authors claim they slow the rate of oscillation, improving acuity. It's not clear if this is so or, if so, why.

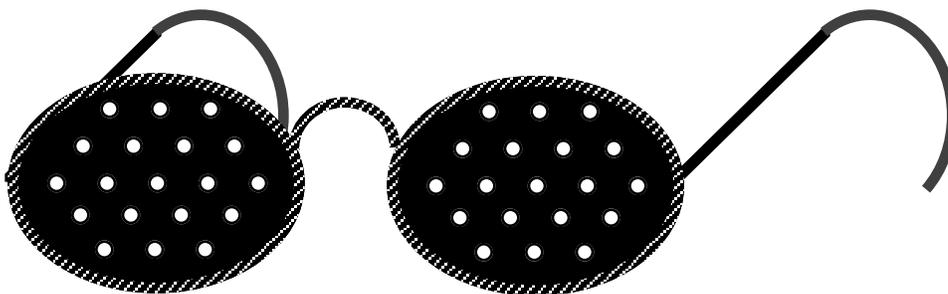
Contact lens telescopes have been advocated from time to time. In these telescopes a contact lens becomes the ocular and a spectacle lens the objective.

Pinhole Optics

Pinholes form "images" by cutting down blur circle size.



Placed before the eye a pinhole effectively shunts the optics of the eye producing an improved, if rather dim image. Multiple pinhole glasses are made that are prescribed occasionally.



Pinholes placed in contact lenses have a greater field of view than those in glasses.

Field Expanders

There are two main approaches. The first is the reverse Galilean telescope. Just look the wrong way down a telescope. Minification gives more field

Mirror and prism arrangements have also been tried in the form of hemioptic spectacles, etc.

Conclusions

Although this discussion doesn't exhaust the possibilities of optical aids for the partially sighted, it has reviewed the main aids used, as well as several obscure ones. Each aid discussed has advantages and drawbacks. The clinical art of lower vision care is in picking the device or devices which meet the needs of a patient best.