OpticsInternational
Performance Optics

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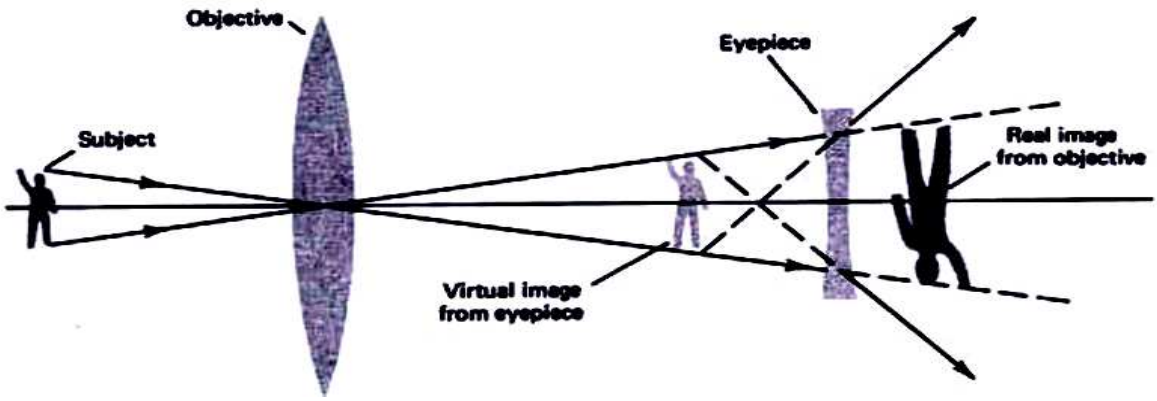
ABOUT BINOCULARS

Binoculars are a pair of identical telescopes mounted side-by-side and aligned to point accurately in the same direction, allowing the viewer to use both eyes (binocular vision) when viewing distant objects. Most are sized to be held using both hands, although sizes vary widely from opera glasses to large pedestal mounted military models.

Unlike a (monocular) telescope, binoculars give users a three-dimensional image: for nearer objects the two views, presented to each of the viewer's eyes from slightly different viewpoints, produce a merged view with an impression of depth. There is no need to close or obstruct one eye to avoid confusion, as is common with monocular telescopes. The use of both eyes also significantly increases the perceived visual acuity (resolution), even at greater distances where depth perception is not apparent.

Galilean binoculars

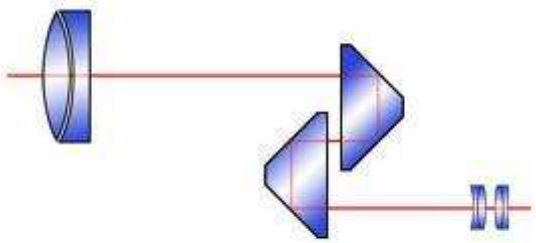
Most early binoculars used Galilean optics; that is they used a convex objective and a concave eyepiece lens. The Galilean design has the advantage of presenting an erect image but has a narrow field of view and is not capable of very high magnification. This type of construction is not widely used anymore, but is still used in certain low cost models and in opera - or theater glasses. Below see a pair of Galilean binoculars and the path of light travelling through lenses.



Prism binoculars

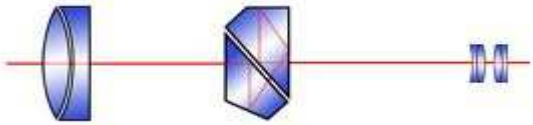
An improved image and higher magnification can be achieved in a construction binoculars employing **Keplerian optics**, where the image formed by the objective lens is viewed through a positive eyepiece lens (ocular). This configuration has the disadvantage that the image is inverted. There are different ways of correcting these disadvantages.

Porro prism binoculars are named after Italian optician Ignazio Porro who patented this image erecting system in 1854 and later refined by makers like Carl Zeiss in the 1890s. Binoculars of this type use a Porro prism in a double prism Z-shaped configuration to erect the image. This feature results in binoculars that are wide, with objective lenses that are well separated but offset from the eyepieces. Porro prism designs have the added benefit of folding the optical path so that the physical length of the binoculars is less than the focal length of the objective and wider spacing of the objectives gives a better sensation of depth. Below see a typical porro prism binoculars and also the light path through lenses and prisms.



Binoculars using **roof prisms** may have appeared as early as the 1870s in a design by Achille Victor Emile Daubresse. Most roof prism binoculars use either the Abbe-Koenig prism (named after Ernst Karl Abbe and Albert Koenig and patented by Carl Zeiss in 1905) or Schmidt-Pechan prism (invented in 1899) designs to erect the image and fold the optical path. They have objective lenses that are approximately in line with the eyepieces.

Roof-prisms designs create an instrument that is narrower and more compact than Porro prisms. Traditionally, porro prism binoculars offered better quality viewing as the layout of the internal prisms allowed more light through and therefore provided a brighter image. Over the years, advances in lens and prism coatings mean that there is now little discernible difference between porro and roof prisms in terms of the light transmission. This combined with the more compact nature of roof prism binoculars means that it is this design which is favoured by most binocular users and manufacturers. Below see a typical pair of roof prism binoculars and also the path of light through lenses and prisms.



Optical Parameters

When selecting optics, it is important to understand the optical parameters of the instrument.

Parameters listed on the prism cover plate describing 7 power magnification binoculars with a 50 mm Objective diameter and a 372-foot Field of view at 1000 yards

Binoculars are usually designed for the specific application for which they are intended. Those different designs create certain optical parameters (some of which may be listed on the prism cover plate of the binocular). Those parameters are:

- **Magnification:** A magnification of factor X, produces an image as if one were X times closer to the object. The amount of magnification depends upon the application the binoculars are designed for. A larger magnification leads to a smaller field of view.
- **Objective diameter:** The second number in the binocular number represents the objective diameter in millimetres. The diameter of the objective lens determines how much light can be gathered to form an image. This number directly affects performance. When magnification and quality is equal, the larger objective diameter, the brighter the image as well as the sharper the image. An 8x40, then, will produce a brighter and sharper image than an 8x25, even though both enlarge the image an identical eight times.

- **Field of view:** The field of view of a pair of binoculars is determined by its optical design. It is usually notated in a linear value, such as how many feet (meters) in width will be seen at 1,000 yards (or 1,000 m), or in an angular value of how many degrees can be viewed.
- **Exit pupil:** Binoculars concentrate the light gathered by the objective into a beam, the exit pupil, whose diameter is the objective diameter in millimetres, divided by the magnifying power. For maximum effective light-gathering and brightest image, the exit pupil should equal the diameter of the fully dilated iris of the human eye— about 7 mm, reducing with age. If the cone of light streaming out of the binoculars is larger than the pupil it is going into, any light larger than the pupil is wasted in terms of providing information to the eye. In daytime use the human pupil is typically dilated about 3 mm, which is about the exit pupil of a 7x21 binocular. Much larger 7x50 binoculars will produce a cone of light bigger than the pupil it is entering, and this light will, in the day, be wasted. It is therefore seemingly pointless to carry around a larger instrument. However, a larger exit pupil makes it easier to put the eye where it can receive the light: anywhere in the large exit pupil cone of light will do. This ease of placement helps avoid vignetting, which is a darkened or obscured view that occurs when the light path is partially blocked. The image can also be quickly found, which is important when looking at birds or game animals that move rapidly. Finally, many people use their binoculars at dusk, in overcast conditions, and at night, when their pupils are larger. For comfort, ease of use, and flexibility in applications, larger binoculars with larger exit pupils are satisfying choices even if their capability is not fully used by day.
- **Eye relief:** Eye relief is the distance from the rear eyepiece lens to the exit pupil or eye point. It is the distance the observer must position his or her eye behind the eyepiece in order to see an unvignetted image. The longer the focal length of the eyepiece, the greater the eye relief. Binoculars may have eye relief ranging from a few millimetres to 25 millimetres or more. Eye relief are particularly significant for eyeglass wearers. The eye of an eyeglass wearer is typically further from the eye piece which necessitates a longer eye relief in order to still see the entire field of view. Binoculars with short eye relief can also be hard to use in instances where it is difficult to hold them steady.
- **Close focus distance:** Close focus distance is the closest distance to an object that the binocular can focus on. This distance varies from about 1m to 30m, depending on the design of the binoculars.

We trust that the above gave you some background on binoculars.

With compliments

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