Telescope Eyepiece Experimenter Kit

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Introduction

Many amateur astronomers build their own telescopes, but very few build their own eyepieces…at least until now! This kit is designed as an introduction to the fascinating hobby of telescope eyepiece construction. Included in this Experimenter Kit is everything you need to get started: an eyepiece body, an assortment of lenses, mounting hardware and instructions.

How the Eyepiece Kit Works

The Eyepiece Experimenter Kit contains one eyepiece body. It is machined from Delrin plastic, a hard and durable material with low moisture absorption. The eyepiece body fits into any telescope with a standard 1.25" eyepiece holder. The eyepiece body accepts lenses up to 1.00" (25.4 mm) diameter. The maximum clear bore exit aperture of the eyepiece body is .75" (19.1 mm).

The Eyepiece Experimenter Kit also contains an assortment of black washers and elastic rings, as

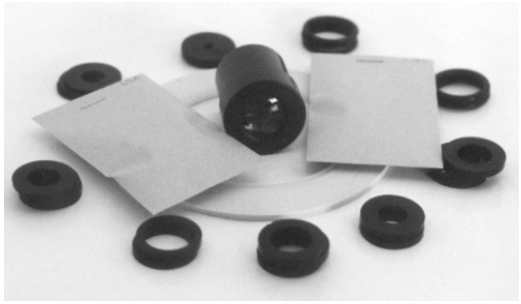

Figure 1. The Eyepiece Experimenter Kit.

detailed in Table 1. The washers are used to center and space lenses inside the eyepiece body. The washers provide a useful range of dimensions for accommodating different size lenses. The elastic rings are slightly oversized, and are used to snugly hold the optics inside the eyepiece body. The elastic rings (which can be inserted and removed) allow for fast design changes and quick experiments with different lenses and spacings.

Component	ID x OD	Thickness
Washer A	4.0x25.4	1.6 mm
Washer B	10.3x25.4	1.6 mm
Washer C	11.4x25.4	3.2 mm
Washer D	14.3x25.4	3.2 mm
Washer E	16.0x25.4	3.2 mm
Washer F	19.5x25.4	3.2 mm
Spacer A	23.2x25.4	6.4 mm
Elastic A	22.2x27.0	2.4 mm
Elastic B	20.6x27.0	3.2 mm

Table 1. Lens Mounting Parts List, 3 pieces of each component are included in the kit.

Mounting Lenses for Perfect Fits

Although some lenses fit inside the eyepiece body (or assorted washers) perfectly, it is more common that a lens will not fit precisely. Experimenters have several options for mounting the off-sized lenses.

The best approach is building up the lens diameter by using a narrow piece of the masking tape. If necessary, slit the masking tape to size by using a sharp blade, a straight edge and a firm surface, such as a cutting board. Always prepare a single piece of tape that is longer than necessary. Wrap the tape on the edge of the lens, and methodically remove tape (in small lengths) to achieve a perfect fit. This method is quick and provides very satisfactory results.

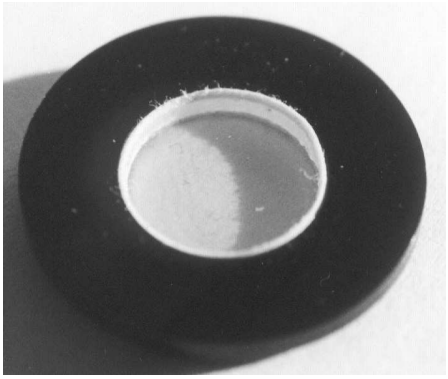

Figure 2. Masking tape around the edges of a small lens makes for a perfect fit.

Another option is enlarging the washer's hole. This should be done on a hobby lathe or in a drill press with suitable clamping. *Note: Attempting to enlarge washers using a hand drill produces unsatisfactory results and is dangerous.* The inside edges of a modified washer can be darkened using a black permanent marker.

Specific Eyepiece Designs

This section explains the basics of eyepiece design. Detailed descriptions of several eyepiece designs are presented which use the specific optics supplied in this kit. See the resource list (at the end) for additional design information and optical suppliers.

A small refracting telescope is very useful when experimenting with eyepieces. The telescope can be used during daytime to quickly evaluate design changes. It is helpful to select a distant object, such as a telephone pole, and use it as a standard object for judging performance.

Eyepieces are generally referred to by name and focal length. Some common eyepiece types are Simple, Ramsden and Plossl. The focal length of an eyepiece is usually measured in mm (millimeters). A common eyepiece focal length is 25 mm. The magnification of an eyepiece

used with a telescope is calculated by dividing the telescope's focal length by the eyepiece focal length. For example, a 1000 mm focal length telescope used with a 25 mm eyepiece magnifies 40X.

A Simple eyepiece uses a single lens. The focal length of the lens is the focal length of the eyepiece. The lens may have a positive or a negative focal length. As viewed, the image is upside down (inverted) using a positive lens, and erect using a negative lens. The telescope eyepiece used by Galileo was a single negative lens, hence the name Galilean eyepiece.

The focal length of a positive lens can be measured by focusing sunlight on a card. The distance from the lens to the card (in mm) is the focal length.

The principal advantage of a single lens eyepiece design is economy of construction. The principal disadvantages are narrow field of view and optical distortion.

The assorted packet of small lenses included with the Eyepiece Kit is ideal for experimenting with single lens eyepiece designs. Don't dismiss the idea of using a single lens eyepiece too quickly! A few hours spent experimenting with single lens eyepieces is time well spent. And later, when two lenses are used, you will recognize the performance differences.

A large single-lens eyepiece may not present sharp image definition at the outer edges. Worse yet, it is difficult "not to look" at the blurred edges. A simple and effective solution is installing a smaller diameter washer, inside the eyepiece body, to reduce the visible area down to the clear image. This is called a Field Stop.

Multi-Lens Eyepieces

The discussion of multi-lens eyepieces begins with some definitions. By convention, the optic nearest the eye in a two-lens eyepiece is called the Eye Lens. The optic furthest from the eye is called the Field Lens. If a third lens is used between the Eye Lens and Field Lens, it is called the Middle Lens.

The effective focal length of two lenses in proximity to each other is calculated using the following formula:

$$\text{Effective FL} = \frac{F1 \times F2}{F1 + F2 - D}$$

Where,
F1 = Focal length of first lens
F2 = Focal length of second lens
D = Distance between the lenses

For example, two identical 50 mm focal length lenses, spaced 33 mm apart, exhibit an effective focal length of 37 mm.

A nice example of a two-lens eyepiece is the Ramsden. The symmetrical Ramsden eyepiece consists of two identical plano-convex lenses. The distance between lenses is generally 2/3 the focal length of a single lens. The convex lens surfaces face together.

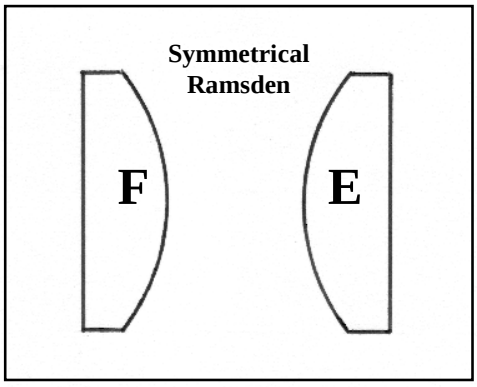

Figure 3. The Symmetrical Ramsden eyepiece is made using two identical plano-convex lenses, as provided in the kit.

The Eyepiece Kit includes two plano-convex lenses for building a symmetrical Ramsden eyepiece. The lenses are 25mm diameter with a 50mm focal length. Figure 4 is a sectional view of the assembly. The spacing between the lenses can be adjusted for modified performance.

Another good example of a two-lens eyepiece is the Plossl. The

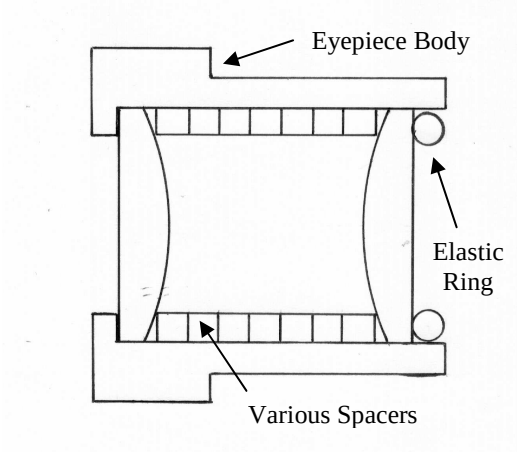

Figure 4. Assembly details for building a symmetrical Ramsden eyepiece.

symmetrical Plossl is made with two identical achromatic lenses spaced close together, with the crown elements facing each other (e.g. flints external). Note: In a crown and flint achromat, the crown usually has the thinner lens edge.

The Plossl eyepiece is well known for effective field correction. Amateur eyepiece builders report great results experimenting with surplus achromats and the Plossl design.

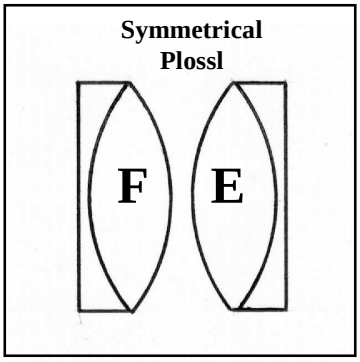

Figure 5. The Symmetrical Plossl eyepiece is made using two achromat lenses.

There are many other types of eyepiece designs: For example, Kellner, Huygens (or Huygenian), Super Plossl, Orthoscopic and Erfle…to name just a few! Specific designs, using specific lenses are available on the Internet: Check the links given in the resource list.

One note about adding more lenses to an eyepiece design: Lenses do not transmit 100% of the incoming light. The reflected light reduces image contrast, and may create "ghost" images. Anti-reflection coatings on the lenses greatly reduce the problem. If given a choice, purchase optics with the anti-reflection coatings for optimum performance.

Also, it is reported that darkening the edges of eyepiece lenses with a black permanent marker reduces reflections, and improves contrast.

Things to Try

In addition to building the basic types of telescope eyepieces, it is also possible to build several specialty types. One option is adding crosshairs to a spacer washer, between the eye lens and field lens, to create a finder or guider eyepiece. Experiment with the location of the crosshairs to obtain best results.

Another useful variation is mounting a small LED in the eyepiece body to create an illuminated crosshair eyepiece. The plastic eyepiece body can be drilled with ordinary hand tools.

For experimenters on a budget, it is possible to build acceptable eyepieces using salvaged optics. For example, microfiche readers contain a fairly high quality optic for enlarging the microfilm. Some of these microfiche magnifiers fit quite nicely inside the eyepiece body, making it easy to assemble a budget eyepiece. Wrap black electrical tape around the assembly to create a perfect fit.

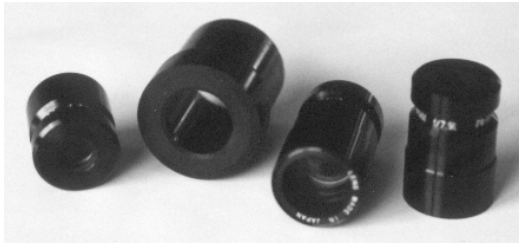

Figure 6. Microfiche reader optics can be adapted into budget eyepieces.

The Eyepiece Kit contains a surplus optical assembly salvaged from a toy projector. Careful examination will reveal the optics are fairly high quality. Try mounting the assembly inside the eyepiece body and evaluate its performance. The eye relief is surprisingly good.

Once you start looking, you will find optics suitable for eyepieces in old movie cameras, toys, binoculars and office equipment. Usually at low cost, and often free for the asking!

The Barlow lens is well known in for increasing eyepiece magnification. The Barlow lens is a special name given to a negative lens. The lens is placed in the optical path, ahead of the eyepiece. The negative lens effectively increases the focal length of the telescope, and hence the magnification. Several negative lenses are included in the surplus assortment for experimenting.

Here's an idea: Eyepiece builders may want to consider *making* their own lenses. As odd as that might sound at first, there actually is a wealth of information available on the topic… and it takes the idea of a homebuilt telescope to a whole new level!

Safety

Never look at the sun with a telescope. Permanent blindness may result.

Do not leave optical elements in a location where the sun may shine on them. The focused sunlight could start a fire.

Optical elements are essentially glass, and as such, can shatter or break. Please handle accordingly.

Resource List: Building Eyepieces

Here is a list of design information and parts sources for building eyepieces. Although the Internet resources change constantly, they provide some of the best information, including specific design details.

The Astronomy Daily website has a great introductory tutorial on eyepiece fundamentals. This is a "must read" item, and it features many useful formulas. Go to:
http://www.astronomydaily.com/atm/ep.asp

Peter Smith, in Australia, has an excellent website on eyepiece design. The information presented is especially useful for advanced experimenters. Go to:
http://www.users.bigpond.com/PJIFL/

Jim L. has created a very useful eyepiece website. The main topic is adapting plastic pipe fittings for eyepieces, but it also contains tabulated design information for specific eyepieces types. Go to:
http://earth.vol.com/~lifedata/eibasic.htm

Larry Brown has published a useful website for eyepiece builders. It's an excellent "what I did, and how I did it" for several

different eyepieces. Go to:
http://home.fuse.net/astronomy/eyepieces.html

Apogee Inc. offers small lenses and achromats suitable for building eyepieces. This link goes directly to the lens page. Go to:
http://www.apogeeinc.com/scopeoptics.html

SurpluShed offers a selection of small lenses and also sells inexpensive "Eyepiece Optics Kits". Nice printed catalog. Go to:
http://www.surplushed.com

American Science & Surplus sells small lenses for experimenting. The Optics Catalog is available by mail, for a fee. They also offer small, medium and large lens "grab bags", which are an excellent value. Go to:
http://www.sciplus.com

C & H Sales Company offers surplus optical items, including a great selection of inexpensive microfiche lenses. Go to:
http://www.candhsales.com

Sky and Telescope Magazine, February 2000 issue, has an excellent article titled “Budget Eyepieces & Barlow Lenses” by Chuck Hards.

Book 3 of the series “Amateur Telescope Making” published by Scientific American contains design information about eyepieces.

Final note

You may decide to build up one of your experimental eyepieces into a permanent design. For that purpose, MTM Scientific, Inc offers the Mechanical Kit. It is identical to the Experimenter’s Kit, but without the optics. “Super Glue” or silicone sealant bonds the parts together permanently.