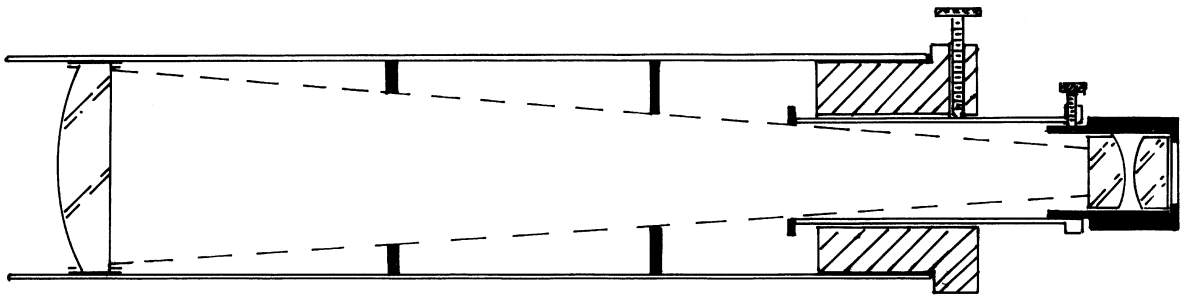
HOW TO MAKE YOUR OWN TELESCOPES

This part of our web site gives you lots of information about designing and building your own telescope. The principles are the same whether you are just building a small telescope, say for your GCSE project, or a really ambitious telescope.

This diagram shows the layout of an astronomical refracting telescope. The **objective lens** of the telescope is shown at the left, while the pair of lenses that form the **eyepiece** are shown at the extreme left. The only other thing that is inside the telescope is, well, fresh air.



The **ASTRONOMICAL TELESCOPE** consists of an **OBJECTIVE LENS**, whose job is to gather the light from the distant object of interest and to produce a sharply focussed image, and an **EYEPIECE**, which can be just one lens, but is more usually a couple of lenses. The purpose of the eyepiece is to magnify the image produced by the objective lens.

The astronomical telescope, then, is particularly simple. It produces an image that is inverted i.e. everything looks upside-down when viewed through such a telescope. Obviously that doesn't matter when you are looking at the Moon, stars or planets, but it can be a nuisance if you wish to observe heavenly bodies of a quite different nature.

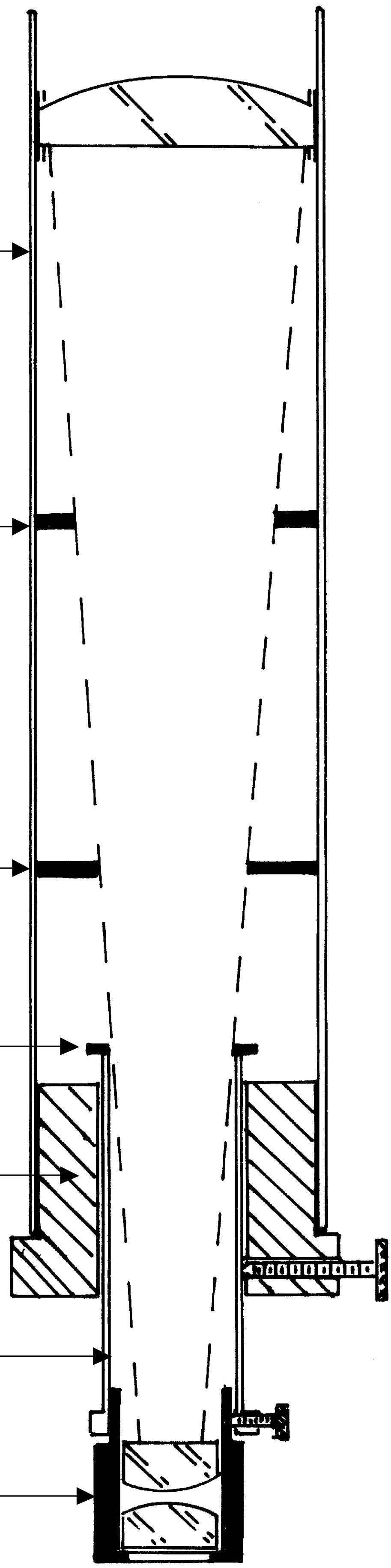
The terrestrial telescope produces an erect image. Traditionally the image was turned up the right way by an extra set of lenses called the **RELAY LENS SYSTEM**. That made the telescope rather longer, because room had to be left for the extra lenses. However, the positioning of the relay lenses allowed the magnification of the telescope to be varied, so that was useful.

Nowadays the image is turned up the right way by means of a roof prism, also called an Amici prism, either the straight-through version (PR.8 in our catalogue) or the right-angle version (PR. 6 in our catalogue) and we will show you later how this is done. The advantage of using an Amici prism, instead of the relay lens system, is that the length of the telescope is reduced. Again, we will explain this later.

The next diagram shows the components of the telescope.

An astronomical telescope

For the objective lens you could use, say, our lens 9530, 5900, 9613, 5001, 5003 or 5004.



For the eyepiece you could use a pair of lens 5293 or any of our shorter focal length lenses.

The eyepiece (‘e’) is fitted into the end of the drawtube ‘d’. Usually the end of the drawtube has a small clamp-screw to hold the eyepiece safely in place. The drawtube should protrude about 150mm beyond the end of the main tube (‘m’) of the telescope. The entire drawtube needs to be about 230mm (9inches) long, because the plug ‘p’ needs to be about 75mm long.

The drawtube needs to be a neat, sliding fit inside the plug ‘p’. You can line the plug with baize to help the drawtube glide smoothly. You can cut a suitable piece of baize from the middle of a friend’s billiard table.

You may wish to provide the plug with a clamp screw also, so you can hold the draw-tube in a fixed position once you have focussed the telescope by sliding the draw tube to the position that gives the best image, seen through the eyepiece.

It is a good idea to do a scale drawing of the proposed telescope, even a full-size drawing, once you know the focal length of the objective lens that you are going to use. Remember that the total length of the telescope will be the focal length of the objective lens, plus the thickness of the eyepiece lenses.

Light baffles

The purpose of light baffles is to prevent stray light, reflected off the inside of the telescope, spoiling the contrast of the image. You can have as many baffles as you like, but two or three is usually sufficient. In the diagram they are labelled ‘a’, ‘b’ and ‘c’.

On the scale drawing mark the extreme edges of the path of light from the edges of the objective lens to the edges of the eyepiece lenses. These extremities are shown in the diagram by dotted lines. The holes in the baffles should just come to the edges of this cone of light, so you can use your scale drawing to MEASURE the size holes you have to cut in your baffles.

Position the baffles inside you telescope in the same locations as you chose on the scale drawing. Do make sure that the baffles cannot be hit by the drawtube when it is pushed right in!

The last job is to paint the inside of the telescope, including the baffles, with matt black paint.

Before you rush off to get started, here are a couple of pieces of important information:

1. Choosing the right sort of lens

In the science books used in schools you will find diagrams that show the layout of lenses in a telescope. These textbooks always show the lenses as single pieces of curved glass. Such lenses will work, after a fashion, but the optical quality of the telescope will be miserable, because rainbow colours will surround the view that it produces and it will be impossible to obtain sharply focussed images.

In real telescopes the lenses are **ACHROMATIC** lenses, which means they are made from two layers of glass. The types of glass used in the two layers, and their curvatures, are chosen so that there are no rainbow colours around the image to spoil its crispness.

When you choose the lenses for your telescope, especially the **objective lens** (the big lens at the front of the telescope) you need to be sure it is an achromatic lens. All the objective lenses we sell are achromatic lenses.

2. Finding the focal length of a lens

When you use a lens you need to know something about the way it performs. One of the most important measurements is the distance from the lens to the point where it produces a sharply focussed **image**. That distance is called the **FOCAL LENGTH** of the lens. The focal length depends on the curvature of the glass surfaces - a chubby lens with highly curved surfaces, for example, will bring the light to a focus a short distance from the lens. A lens that has a very shallow curvature will bring the light to a focus a greater distance from the lens. The focal length of the **objective lens** in a telescope is important because it is the deciding factor in the length of the telescope – the total length of the telescope will be just a little bit greater than the focal length of its objective lens.

The other important factor that is decided by the focal length of the objective lens of the telescope is the **magnification** that the telescope produces. The longer the focal length of the objective lens, the greater will be the magnification that the telescope will produce. Later we will show you how to measure the focal length of a lens, and how to work-out the magnification of the telescope.

Building a prismatic telescope

Now we are going to give you details of how to construct a telescope where the eyepiece is set at **right angles** to the body of the telescope.

The advantage of an angled telescope is that you do not have to get your head under the telescope when you are observing objects that are at a high angle, such as the stars that are nearly overhead. There is another advantage: the telescope is more compact.

The way to turn the light path from the objective lens through 90^o is to use a right-angle prism. You will find them listed in our catalogue. You need to realize, however, that the view seen through this telescope will be the right way up, but the wrong way round. Such a telescope is fine for astronomy, but it is not much use in the daytime.

The prism will need to be held in place. The best method is to glue the triangular side of the prism, which is usually frosted glass, to a support that protrudes from the rear plate of the telescope. You can telephone us if you need some help with this idea.

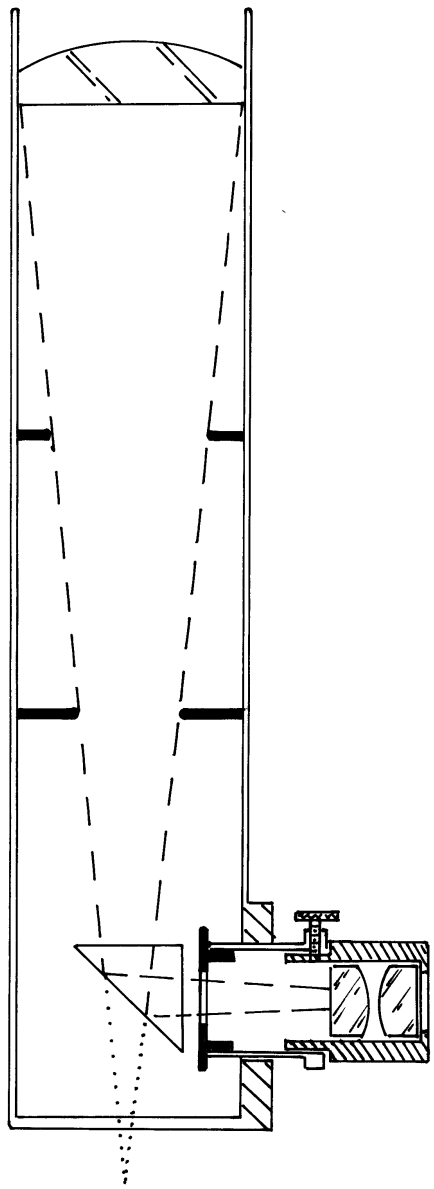
The diagram shows how the components are positioned. The distance from the objective lens to the eyepiece is still the same as if the prism were not there and you were making a 'straight-through' telescope. That distance is now being bent round a corner, so the front to back length of the telescope will be less.

When you make such a telescope you still need to have some means of altering the focus. The choices are EITHER to fit the instrument with a stubby draw-tube OR to dispense with the draw-tube and alter the focus by moving the objective lens instead. Either method will work well.

If you want to make a telescope like this, but for terrestrial observation, such as bird watching, you just need to use an **amici** prism, such as the lovely **PR.6** listed in our catalogue.

If you are a serious astronomer and are worried about light-loss through the glass prism, you can replace it with a small, front aluminised mirror. We sell such items and we list them on a separate data sheet that we will happily send you on request.

A prismatic telescope



You can select a suitable objective lens for this project from our lists of lenses that appear in our catalogue (page 8 et seq.)

For an astronomical telescope you could use our prism PR.2 OR pentaprism PR.8

For a terrestrial / astronomical telescope you need to use our amici prism PR.6

You can find suitable eyepiece lenses for this project listed in the catalogue.

(For the telescope shown in the photograph below we chose a pair of lens 5293.)

And here is one we made earlier!

Finally, a few words of encouragement: making a telescope for the first time is always a daunting task, because you are not sure which components to choose – there seems such a huge variety. Then there is the problem of finding the tubing necessary to make the body of the telescope. Do not worry, we can help! If you need to talk to someone about the project, just call us, we may even be able to supply some tube.

It is a fact that the telescope that you make yourself will probably perform better than those that you can buy ready-made. After all, you are likely to take much more care in its construction because you are working for your own benefit. If you do make a few wrong moves along the way its worth remembering that the person who never made a mistake probably never made anything.

Good luck, enjoy your telescope building and don't be afraid to seek our advice if you get stuck..

Here is some technical information if you need it:

You can measure the focal length of a lens by the following method:

In daytime stand indoors, opposite a window. Hold the lens against the wall opposite the window and move the lens away from the wall until it produces, on the wall, a sharply focussed image of the outside world. Measure the distance from the lens to the wall. That distance is the focal length (approximately) of the lens.

The magnification of the telescope depends upon the focal lengths of the objective lens and the eyepiece. The magnification is calculated by DIVIDING the focal length of the objective lens by the focal length of the eyepiece.

Magnification = Focal length of objective lens ? Focal length of eyepiece

Another way to find the magnification of a telescope (or a pair of binoculars) is as follows:
(1) Measure the diameter of the objective lens.
(2) Hold the telescope or binoculars a few inches from your face, with the instrument pointed towards the bright sky (NOT THE SUN!). Look at the eyepiece(s) and measure the diameter of the bright circle of light that you see in the centre of the eyepiece(s).
(3) Divide the diameter of the objective lens by the diameter of the circle of light in the eyepiece. The answer will be the magnification of the instrument.

Example:
The objective lens of a certain pair of binoculars has a diameter of **30mm**
The circle of light seen in the eyepieces is about **5mm**

The magnification produced by the pair of binoculars will be **30mm** ? **5mm** = 6

So this pair of binoculars will give a magnification of **6 times.**

You can use this method to find the focal length of an eyepiece. First you find the magnification of the telescope by the method we have just described. Then you find the focal length of the objective lens by the method given at the top of the page.

Focal length of eyepiece = Focal length of objective lens ? magnification

MAKING EYEPIECES

Now that you have got the gist of what objective lenses look like and how they work, the next thing you need to understand is how to make the **eyepiece** of the telescope. Eyepieces are seldom just one lens, usually they are several lenses grouped together to make the eyepiece easier and more comfortable to use than would have been possible with a single lens.

The Plossl Eyepiece.

This is one of the commonest eyepieces used in astronomy, and certainly the easiest to make. It consists of two identical achromatic lenses, placed with their most curved surfaces facing each other. The lenses are positioned so that these surfaces are almost (but not quite!) touching. The same design is also called the **Symmetrical** or **Dial Sight** eyepiece. It is obvious why it is called a symmetrical eyepiece when you look at a diagram of its construction.

This type of eyepiece is also called a Dial Sight eyepiece because it was commonly used in the dial sight (the aiming instrument) on artillery pieces.

The focal length of the Plossl eyepiece is just over HALF of the focal length of each of its lenses. **Example** If two of our lens 5293 were used, the eyepiece would have a focal length of about 35mm., because each of its lenses has a focal length of just over 50mm.

Building the Plossl Eyepiece

The next diagrams show the components of the Plossl eyepiece.

First make the spacer ring ‘c’ the same diameter as the lenses. This ring keeps the two lenses from touching. The spacing of the lenses is not critical but try to get them as close as possible.

Assemble the two lenses and the spacer ring and hold them together by a twist of adhesive tape. (This is shown as ‘f’ in the lower diagram.) The body of the eyepiece (‘e’) should be bored out to such a size that the lens assembly slides in smoothly.

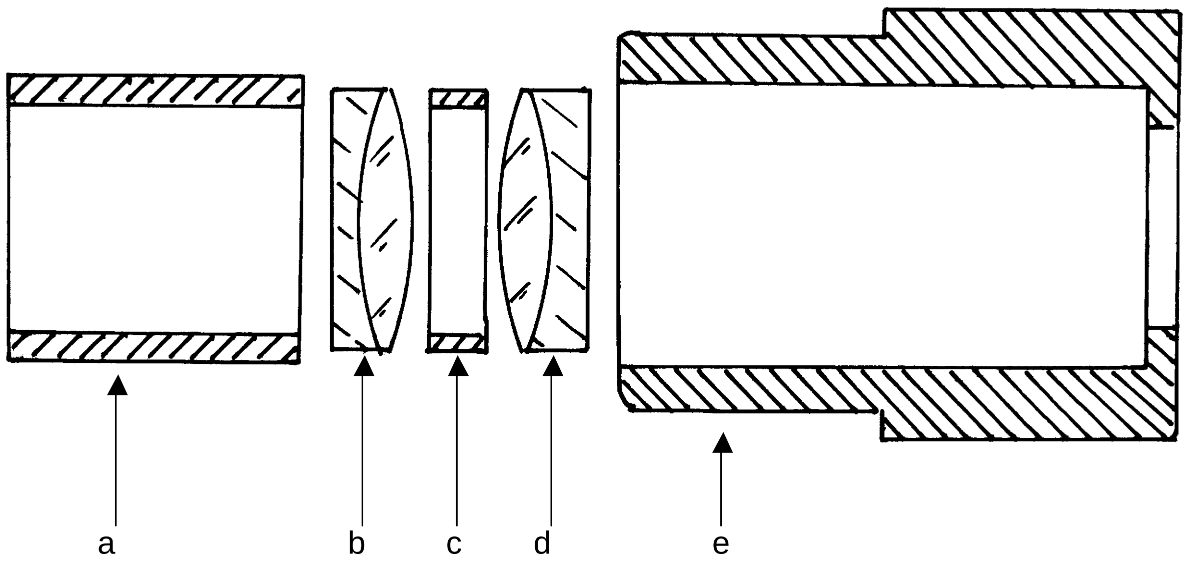
Make a retaining sleeve ‘a’ that is a tight fit in the eyepiece body. Push this sleeve into the body of the eyepiece to stop the lenses from falling out. The lower diagram shows the complete eyepiece. Simple!

If you are a more advanced metal worker you can make the components of the eyepiece so that they screw together. This photograph shows such a Plossl eyepiece that we made, using a pair of our lens 1401.

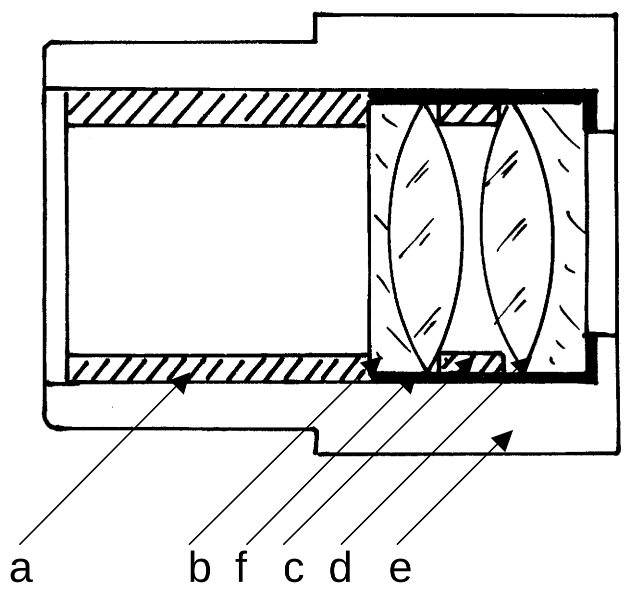
It is most important that the exposed metal parts inside the eyepiece are painted matt black to minimize reflected light within the eyepiece.

The Ramsden eyepiece is made from two identical plano-convex lenses, spaced apart by about 75% of their focal length. Again, the focal length of the finished eyepiece is just over half of the focal length of the lenses from which it is made. The lenses have their curved surfaces facing each other. Again, the lens arrangement is symmetrical. **Example:** If two of our lens 20 were used they would be spaced about an inch or so apart.

<u>How to make a Plossl eyepiece</u>



We suggest that you can use any of our achromatic doublet lenses. The focal length of the eyepiece will be about HALF the focal length of the lens that you chose.



This diagram shows the assembled eyepiece