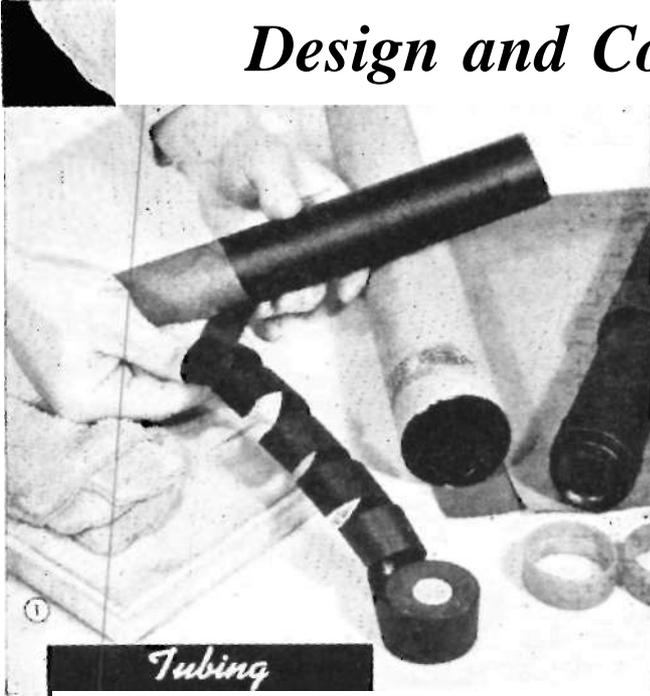


Design and Construction of

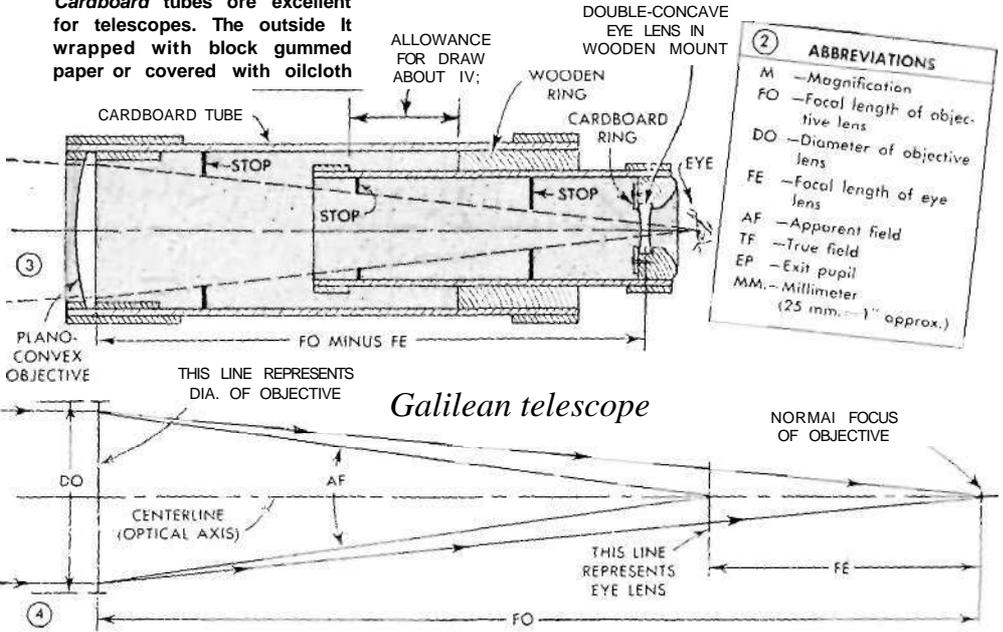
PART I



TV/TAKING distant objects appear close by looking through pieces of curved glass is always thrilling, but the enjoyment is increased when you peer through a telescope that you yourself have made. The cost of making a telescope is especially low now because war-surplus stocks of perfect and chipped-edge lenses and prisms are available at low prices. You can make a good scope for as little as one dollar, and a really good terrestrial telescope for only three to five dollars for lenses.

Kinds of telescopes: Telescopes are divided into two

Cardboard tubes are excellent for telescopes. The outside is wrapped with block gummed paper or covered with oilcloth

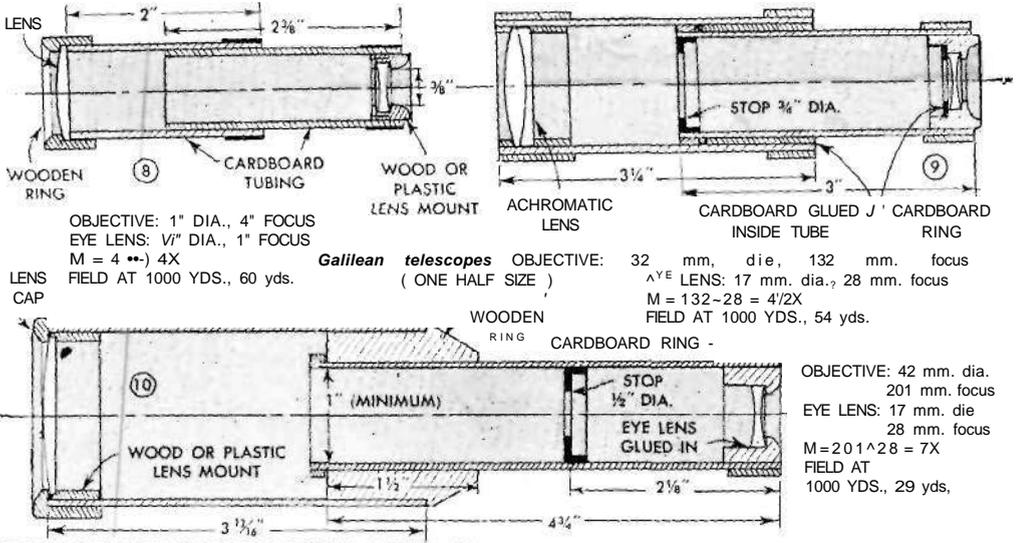


ABBREVIATIONS	
M	-Magnification
FO	-Focal length of objective lens
DO	-Diameter of objective lens
FE	-Focal length of eye lens
AF	-Apparent field
TF	-True field
EP	-Exit pupil
MM.	-Millimeter (25 mm. = 1" approx.)

Galilean telescope

NORMAL VALUES
 M—4 to 7X, top limit about 12X
 DO and FO—Value of f/4 to 1/6
 FO—5" to 10" (127 to 254 mm.)
 DO—1" to 2 1/2" (25 to 64 mm.)
 AF—About 16° TF—2° to 4°
 FE—1" to 2" (25 to 50 mm.)
 DIA. OF EYE LENS—Any small size
 EP—Galilean telescope has no exit pupil

CALCULATIONS
 $M = FO / FE$
 AF—Measure angle on layout
 $TF = AF \times M$
 f/number of objective = FO / DO
 $FE = FO / \text{Desired } M$
 Field in yards = $\frac{DO \times 1000}{FO \times M}$
 at 1000 yards



Typical Galilean telescopes

These designs show general construction. An achromatic objective lens is always an improvement. The scopes here are drawn as focused on an object at 18 ft. distance



00 GLARE-STOPS PREVENT INTERNAL REFLECTIONS

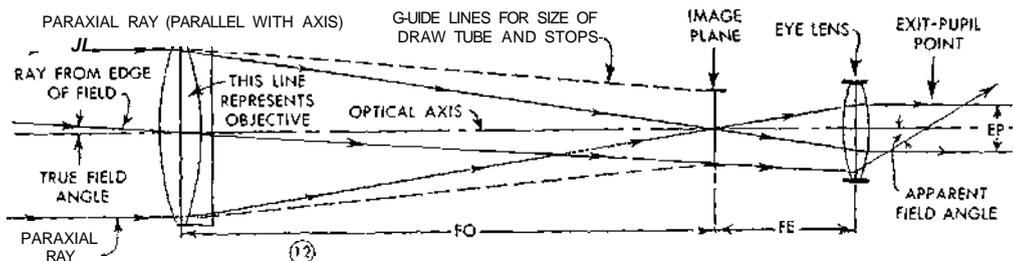
you study this, learn the abbreviations given in Fig. 2, and always read the symbols as full words. It is best to use normal values as given in Fig. 4 when designing your scope, particularly where the f/value of the objective lens is concerned. You will understand quickly that to get a large field with a Galileian telescope you would need a large-diameter objective. Specific instruments are diagrammed in Figs. 8, 9 and 10. "1" shown set up at about an 18-ft. focus, whereas Fig. 4 shows a focus at infinity. Focused at infinity means focused for a distant object, usually 300 to 400 yards away. Your telescope is at its shortest draw when focused at infinity. You will have to allow an extra half-inch or so on the draw so that you can focus on near objects. The whole range of focusing

from near to far objects is about $M \times$ in. with the average objective, as most of the draw-tube travel is simply a matter of making the telescope as compact as possible. Glare stops prevent internal reflections. You can determine the diameter of these at any point from the AF lines, Fig. 4. One glare stop is enough for the Galileian. This can be made from cardboard with tabs turned over as in Fig. 11, pushed inside the draw-tube and fastened with a dab of glue.

Optical bench: An optical bench is handy for checking any lens system and almost a "must" when you get into five and six-lens systems. The design shown in Figs. 5 and 6 is simple and satisfactory. If you want to make a simpler setup, use a plain board and mount the lenses with modeling clay or wax on small blocks of wood. Test setups can be made indoors at about 18 ft. focusing on printed matter. Have a good light on the copy, but avoid light on the optical bench.

Tubing: Cardboard tubing is satisfactory for all telescopes. Select sturdy tubes of good wall thickness. Use a black water stain or flat black lacquer to blacken the inside of the tubes as in Fig. 7. Cover the outside with black gummed tape, spiral-wound as in Fig. 1. Oilcloth, canvas or imitation leather in plain wrap-around style also makes a neat outer covering. A metallic-silver or bronze paper makes an ideal covering for the draw tube.

Astronomical telescope: The astronomical is different from the Galileian in that it has a real image inside the telescope, and the eye lens is positive instead of negative. The layout for the astronomical telescope, and the table giving normal values and simple calculations, are shown in Fig. 12.



NORMAL VALUES

- DO: 1/i" and up. f/10 to f/15
- FO: 20" and up
- FO: 10 to 15 times DO
- M: 15 to 60 times DO
- EP: VV to Va"
- FE: Vt" to 1"
- AF: 40°
- TF: Vt° to 2°

CALCULATIONS

- $M = FO \div DO$
- $M = DO - EP$
- $EP = DO - M$
- $FE = FO \div M$
- $TF = 40^\circ - M$
- f/VALUE OF OBJECTIVE = $FO - DO$
- FIELD IN YDS. 1 Read two right fig
- AT 1000 YDS. f ures from table

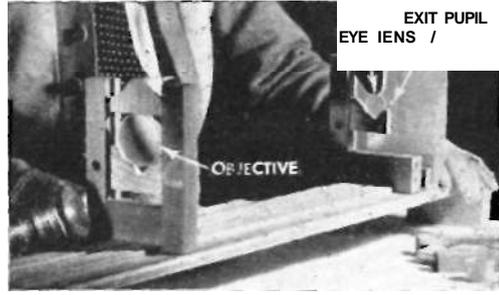
Adi>u>+uwucal teleAaoft.*

@ SIZE OF IMAGE					
Find Figure opposite magnification and multiply this factor by focal length of objective lens					
M	Factor	M	Factor	M	Factor
20X	.035	35X	.020	50X	.014
25X	.028	40X	.017	60X	.012
30X	.023	45X	.015	70X	.010

Select your lenses and make a layout as in Fig. 12, checking this directly from the actual setup as made on the optical bench. Determine the image size from table Fig. 13. The pair of paraxial rays will pass through the center of the image and continue until they strike the eye lens, from which they emerge parallel, as shown. The ray from the edge of the field will pass through the center of the objective and the edge of the image and continue until it strikes the eye lens. This is the most important ray to consider. If you can get this through the telescope, the hundreds of other rays from the object viewed will automatically get through. Note that the eye lens must be big enough to catch this ray.

Exit pupil: Stand back about a foot from the eye lens and look at it. You will see a round dot of light in the center. This is the exit pupil of the telescope. Actually, it is an image of the objective lens. Now put a piece of paper or ground glass behind the eye lens and move it back and forth until you get the smallest and sharpest circle of light, Fig. 14. This location is the exit-pupil point and it marks the proper location of the eye. Noting its position from the eye lens, complete your layout drawing as in Fig. 12, continuing the ray from the edge of field through the exit-pupil point. Look again at your test setup and note how large the exit pupil is. A big exit pupil means good illumination; a small exit pupil, poor illumination. Since the astronomical telescope is used, for viewing a light source, the matter of illumination is not so important, and the exit pupil can be as small as Vu in.

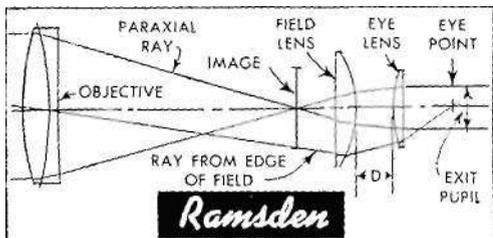
Experiments: While you have the astronomical telescope set up on the optical bench, make a few experiments. Remove the eye lens. Put a piece of ground glass or



@ CHECKING EXIT-PUPIL SIZE AND POSITION

waxed paper at about the position of the image plane and move it back and forth until you get a sharp image. The image received in this manner covers a very wide field, much more than you can see through the eye lens. Now, in place of the ground glass put a piece of printed matter in the image plane. Place the eye lens in position and move it back and forth until the copy is sharp. The image is just the same as a solid piece of copy, and the purpose of the eye lens is to magnify it.

Eyepieces: There are better eyepieces than the single lens. The three common styles in use are shown in Figs. 15 to 19 inclusive. The Ramsden is the easiest to calculate and make; at the same time it is one of the best types of construction, giving a good field without distortion or other faults. The Kellner, Fig. 17, is a slight improvement on the Ramsden. The Huygenian, Fig. 18, is an old reliable, still popular. It differs from the Ramsden in that the image plane is behind the field lens. This style cannot be used directly as a magnifier. It has shorter eye relief (distance from eye point to eye lens) than the Ramsden, a point worth remembering when you are trying to get shorter or longer eye re-



15) CONSISTS OF TWO PLANO-CONVEX LENSES OF SAME FOCAL LENGTH, SPACED APART AT DISTANCE D, WITH CURVED SURFACES FACING .

CALCULATIONS

D = TWO-THIRDS OF FOCAL LENGTH OF INDIVIDUAL LENS

EXAMPLES

33 MM. FOCUS 33 MM. FOCUS

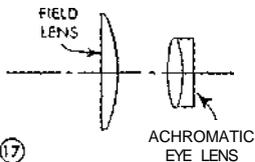
$$y \ 3 \ ^ \ .$$

COMBINED FOCUS OF BOTH LENSES

$$\frac{33 \times 33}{-33 + 33-22} = 44 \text{ "}$$

Keilitt&i

SAME AS RAMSDEN EXCEPT IT HAS A CEMENTED DOUBLET ACHROMAT AS EYE LENS. CALCULATIONS ARE SAME AS FOR RAMSDEN



PARAXIAL RAY ^ FIELD LENS IMAGE i EYE POINT

EYE LENS

JtuuaetUcut

CONSISTS OF TWO PLANO-CONVEX LENSES WITH CURVED SURFACES FACING OBJECTIVE. FOCAL LENGTH OF FIELD LENS IS TWO TO THREE TIMES FOCAL LENGTH OF EYE LENS

CALCULATIONS

D = ONE-HALF OF COMBINED FOCAL LENGTHS

EXAMPLES

60 MM. FOCUS 20 MM. FOCUS

$$60 + 20 = 80 .$$



COMBINED FOCUS CALCULATED SAME AS RAMSDEN

$$\frac{60 \times 20}{60 + 20 - 40} = 20P$$

Two lenses combined form an eyepiece and give better results than a single lens. Most popular style is the Ramsden although the Huygenian is an old favorite, especially for astronomical telescopes. The mounting can be wood, metal or plastic, turned to shape

lief. Of the two lenses in any eyepiece, the eye lens is the most important as it controls distortion and magnification much more than the field lens. The prime purpose of the field lens is to pick up the light rays from the edge of the field.

The combined focus of the two lenses in the eyepiece is determined by the calculations given in Fig. 16. The example in Fig. 16 shows that a 33-mm. field lens and a 33-mm. eye lens spaced 22 mm. apart will have a focal length of approximately 24 mm. This is not quite the same thing as a single 24-mm. focus lens. When you hold the single 24-mm. focus lens to your eye, you are sharply focused on any image or copy when the lens is 24 mm. away from the image or copy. In the combined lenses you will find the focal plane just a little ahead of the field lens because the 24-mm. focal length is measured from a point between the two lenses. As a matter of fact, the best correction of the combined lenses is obtained when the focal plane is exactly in the plane of the field lens. This means, however, that the field lens is sharply in focus; hence, you can see every speck of dust on it. When you note this condition, your lenses are spaced too far apart. Close them up until the dust specks disappear,

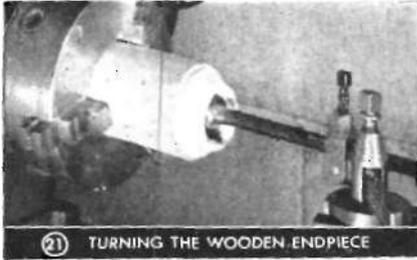
The image stop: The image stop is a round disk of cardboard placed in the image plane. The size of the hole is determined from Fig. 13; also, you can get a good idea of size by viewing a ruled piece of paper through the eyepiece. The image plane formed by the objective and the focal plane of the eyepiece always indicate the same plane when the telescope is focused. This stop is important because it clearly defines the field of view, cutting out weak edge rays and giving a sharp, clean-cut image. It is commonly made a part of the eyepiece, being located between the lenses in the Huygenian and ahead of the field lens in the Ramsden or KeHner. It should be dead sharp as viewed through the eye lens and, when the telescope is focused, it will always coincide with the image plane.

A typical astronomical telescope: Typical construction of a simple astronomical telescope is shown in Figs. 20, 21 and 22. This has a 2%-in. diameter objective (2h in. clear) and the focal length is 36 in. A draw tube is used for rough focusing; critical focusing is done with a 40-pitch threaded eyepiece. The eyepiece is a Ramsden and can be of Vi to 1-in. focus. With a %-in. eyupiv^, tkf. magnification would be 72X; with a 22-mm. eyepiece, ine lou^sr-; .^; ^ would be 41X. Magnification could be pushed up to 144X with a %-in. eyepiece. The exit pupil then would be about %4 in., representing about the limit for astronomical use.

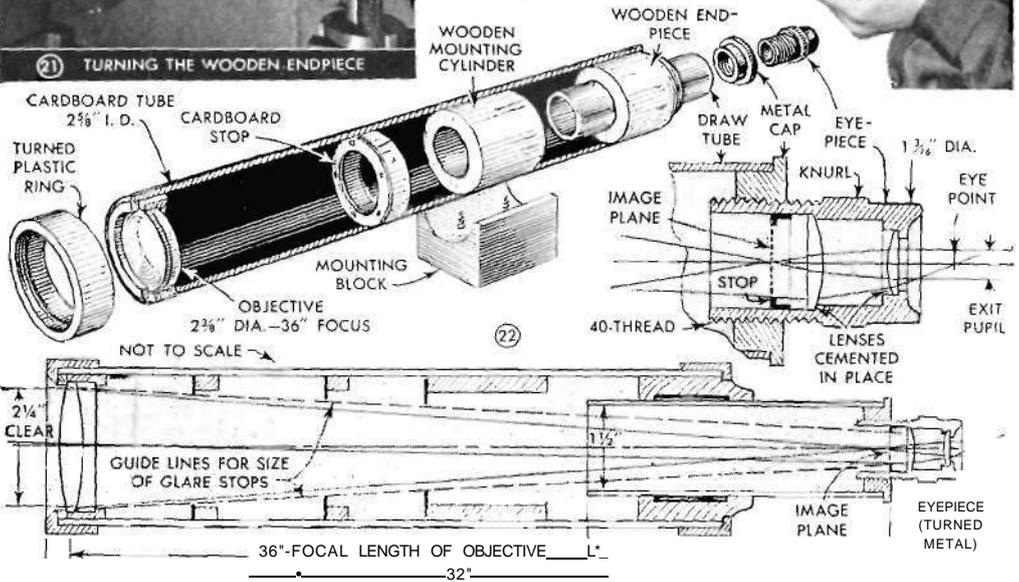
>L || ISii LO UUIICI cHI d^L! I-
 nomical telescope, carefully study the drawings and text covering this subject as they are the basis for all terrestrial telescopes. You will need all this data in order to make the popular hand telescope or .spy glass.



This one will magnify up to 144X.
 It can be fitted with prismatic eyepiece and used at 40X for viewing objects on land

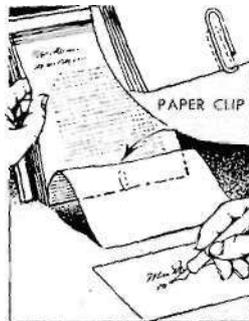


21 TURNING THE WOODEN ENDPiece



Clipping Sheets for Fast Copying

When addressing envelopes from mailing lists or sheets, each of which contains only one name, if you fasten the sheets together at the lower edge with a paper clip they will fall forward easily as you turn each one after doing your copying. This method is much faster than picking each sheet off a pile in order to copy one name and address. —N. Campbell, Boston, Mass.



Pencil Erasers Quiet Rattling Door

Rattling of a door caused by a loose fit of the latch in the strike plate can be silenced by inserting two pencil erasers in the door stop. The erasers are forced tightly into holes drilled in the stop, after which the tips are shaved off with a knife until the door will close properly, with the erasers keeping the latch firmly pressed against the strike plate. —Axel E. Ogren, Chicago.

