

THE POOR MAN'S TELESCOPE

by

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Part 1.

Ownership of a telescope is the amateur astronomer's pet ambition, but the cost of a really fine commercially made telescope is far beyond the purse of a large percentage of the star-gazing fraternity. To purchase a telescope, even of small aperture, together with the necessary mounting and accessories, involves an expenditure of several months salary for Mr. Average Wage-earner.

The amateur who is possessed of the necessary patience and is able to use a few ordinary tools can overcome these obstacles by making a telescope and mounting in his spare time. A newton reflecting telescope of five or six inch aperture is, when carefully made, an instrument of real value to anyone interested in exploring the heavens. Such a telescope can be made at a cost of twenty to twenty-five dollars in a few weeks spare time.

The Newtonian reflecting telescope consists primarily of a mirror, a prism or diagonal mirror to deflect the light rays out to the side of the tube, and an eye-piece to examine the object under observation. The principal mirror is the most difficult part to make, and the making of such a mirror will be discussed in a later article. Some kind of tube is required to hold the optical parts in proper relation to one another, and modern thin plywood offers an excellent medium for this.

An equatorial mounting presents very few difficulties to the city where pipe and pipe-fittings are easily and cheaply obtained. Further refinements, such as a finder, extra eye-pieces of various sizes, etc. can be added when funds become available or as interest in the use of the telescope increases.

With a telescope of this type and size, magnification of from 50x to 200x can be used and a great deal of useful work is possible. Lunar occultations and variable star observations are only two of the fields in which worthwhile observations can be carried out.

Such an instrument will give its owner and friends pleasure out of all proportion to the cost in money and effort, revealing as it does the beauties of star clusters, double stars and much planetary detail, including Saturn's rings, Jupiter's bands and satellites, and the Martian polar caps. For those interested in our nearest neighbour in space, many pleasant hours may be spent in the study of the lunar mountains, craters and other detail.

Part 2.

After last week's introduction to the "Poor Man's Telescope", perhaps I should title this week's article - in accordance with the current trend - "So you're going to make a telescope". Well, maybe you are. Here is the first step toward that goal.

Let us appreciate before we start that making a telescope is not extremely difficult or beyond the ability of the average man, and it can be an instrument that will give real results and pleasure - but it is an instrument, not a toy to be tossed together on the spur of the moment.

First, the principles. In the ordinary refracting telescope, spy-

glass, field-glass, etc., all the light that falls on the front lens passes through it and in so doing is bent or refracted and concentrated to a point or focus. This focus is magnified by the eye lens and passes into the eye. So, if our field-glass has an outer lens $1\frac{1}{2}$ " diameter, all the light that falls on it is passes into the eye whereas without it only the light that falls on the natural opening of the eye - about $1/5$ " diameter - passes in to register on the retina. The instrument gathers for us a larger supply of light with which to see fainter objects or more detail on objects we already see.

In a reflecting telescope the same end is achieved by reflecting to a focus all the light that falls on a large concave mirror - instead of passing it through a large object lens - magnifying it with an eye-piece and passing it into the eye as before.

Second, a couple of simple technical terms. A lens or a concave mirror brings the light falling on it to a "focus" or, as a boy with a simple magnifying glass calls it, a burning point. The distance from the glass to the focus is the "focal length". On cameras you have perhaps noticed such mystic figures around the lens as f4.5 or f7.7, etc. This is simply the ratio between the diameter of the lens and its focal length. In a telescope we have the same relation. If our concave mirror is 6" in diameter (an ideal size for a first effort) and it focuses 48 inches from the mirror, it is f8.

Now a concave mirror when it is ground has a curved surface. Across the diameter of the glass the curve will be a very small arc of a very large circle. The radius of such a circle is twice the focal length of the mirror we want to make. It is called the "radius of curvature".

Finally, for this week, how much of a curve will we have on our glass? Imagining our glass to be ground concave, lay a ruler across the diameter and you will see that the curve is nil at the edges where the ruler rests and deepest at the centre. How deep? $r^2/2R$, where "r" is the radius of our disc of glass and "R" is the radius of curvature of our mirror. On a 6" disc the radius r of the disc is 3 inches, and to make our mirror f8, the radius of curvature R will be twice the focal length, or 96 inches. So we get $r^2/2R$ equals $3 \times 3 / 2 \times 96$, or $9/192$, which equals 0.046". Our curve will be 46 thousandths of an inch deep at the centre.

Next to be considered will be materials and grinding.

Part 3.

Last week we considered the principles of the telescope and applied them in particular to the amateur's ideal instrument - a 6" reflector.

Let us assume that you are going to try your hand on a reflecting telescope, 6" diameter, 48" focal length, being an f8, with a concave mirror as its principal part.

Your materials: Two circular discs of good quality plate glass, $\frac{3}{4}$ " to 1" thick, edges ground and slightly bevelled. These can be obtained from any reputable glass company. Carborundum powder, one pound each of No.80 and No.120, half a pound each of Nos.220,400 and 600, and half a pound of No.600 Aloxite. The coarser sizes may be obtained through large hardware dealers but Nos. 400 and 600 are better obtained direct from the manufacturers - Canadian Carborundum Co., Toronto, - as it then comes in the original containers and uncontaminated with other sizes. Then, a good solid bench on which to work, or, better still, a barrel weighted with rock, coal or ashes.

Having these things, select the best piece of glass - the one having the best edge grind, fewest chips, etc. - and put it aside for the mirror.

The other piece of glass is the Tool. Lay it flat on the corner of the bench or on the top of the barrel and fasten it into position with three wooden cleats cut to fit the circumference and nailed down around the glass. They should fit quite snugly and hold the glass fairly tightly and they should not project above the surface of the glass. Quarter of an inch below the surface is better.

All set? Sprinkle a little #80 Carborundum on the surface of the tool - $\frac{1}{4}$ to $\frac{1}{2}$ a teaspoonful, or better still, use an old saltshaker to sprinkle your carbo. Add about $\frac{1}{2}$ teaspoon of water to the top of the tool, place the other disc of glass on top of the tool, carbo and water, and, using both hands, one on each edge, push and pull the top disc back and forth across the tool, centre over centre. Apply some shoulder pressure to the top of the glass as you push it back and forth and obtain a nice loud gr-gr-grinding noise.

The length of the stroke should result in the top disc overhanging about an inch, or inch and a half, at each end of the stroke, not more, but make no attempt to keep every stroke the same length.

Every half dozen strokes rotate the mirror under your hands about 30 degrees, and every 40 or 50 strokes move your position around the barrel or corner of the bench by a short step. The combination of the movements will result in every part of the two surfaces getting an even grind, and the automatic changing of the location of pressure due to the overhang of the stroke will result in the mirror grinding concave and the tool going convex to match it.

At first a lot of your carborandum will be lost over the edge of the tool. Never mind it. Grind until the grinding noise fades out, add fresh carborundum and grind again. Each dose of carbo and water is called a "wet". About every six wets wash the tool and mirror free of mud and go at it again. After 45 minutes to an hour of this treatment, wash and dry the mirror, hold it at eye level with the ground side up, lay a ruler across the diameter, and you should be able to see daylight under the ruler, sufficient to know that your mirror is grinding concave.

You will remember from last week's article that the finished mirror is to be .046" deep at the centre. Use the #80 carbo until the depth under the ruler at the centre of the glass is from .040" to .044". Use a set of feeler gauges or a small piece of wire of measured thickness to measure the depth of the curve.

Continue the grinding. Remember that it is a hobby and not a labor. Don't work too long at a time. It will take several hours grinding to get the required depth. Don't make your strokes too rapid. Don't let the mud get too thick or too dry.

Part 4.

Having hollowed out our mirror to within two thousandths of an inch of the required depth, we now change to finer grinding powders. The object of this is to remove the coarse pits caused by the abrasive action of the larger size carborundum. This is done by stages, and if each grade of carborundum is used thoroughly, a smooth surface free of all large pits will result, saving many hours on the next stage of mirror making.

First, wash the mirror, tool and stand thoroughly to get rid of all stray grains of the coarse carbo. Throw away any rags or other materials used in cleaning during the coarse grinding. As an added precaution, brush off the clothing you are wearing, and when all traces of rough carbo are disposed of, go to work with No. 120 grain.

Using the same stroke, grind four or five wets with the mirror on top. Then reverse the position of the two pieces of glass and grind three or four wets in this position. Reverse the glass again and continue for another three or four wets. A "wet" is the time taken to grind each change of carborundum until it is of no further use, usually about five to seven minutes.

At this stage the mirror should be tested for contact. Wash the mirror and tool, and, with a medium soft pencil, draw a line across the face of the tool. Place the mirror on top and vibrate for a few seconds using no pressure. If the mirror and tool are in good contact, the line will be transferred to the mirror. If the line does not show right across the face of the mirror when tested, continue grinding until it does.

When contact is evidenced by the transfer of a pencil mark in several directions, we may continue with the finer grades. Nos. 220, 280, 400 and 600 are used in succession, care being taken to wash up thoroughly before starting with a finer grade, and the pencil test being made before changing. Nos 400 and 600 should be mixed with water before applying and stirred thoroughly before each application.

The final stage of fine grinding is done with No. 600 Aloxite, and this, too, must be kept in suspension in either water or alcohol for the best results. In this final stage of grinding great care must be taken to avoid scratches and also to keep the working surfaces wet as the small amount of abrasive between the glasses, if allowed to become dry, will cause the two pieces of glass to grab and stick together.

Not less than an hour and a half, or better still, two hours, should be spent on this final grinding. The result should be a satin-like finish through which large print can be read at three inches distance. It is absolutely essential that the mirror and tool be in perfect contact at the finish as it is useless to start to polish if contact is out by more than the thickness of a pencil line.

Part 5.

By now you have a fine-ground surface of the required curve, and many seeming mysteries have become "old stuff". The next step is to polish your mirror. Polishing is very similar to grinding - it is done with an abrasive, though a very fine grade, it removes glass but an extremely small quantity, and it is done with the same old stroke. The essential difference is that it is done on a "lap" of soft material instead of on the glass tool.

Many materials have been tried for a lap but there are two which are satisfactory for our purpose. They are pitch and beeswax. The simplest to handle, and readily available in the city, is beeswax. This material for our purpose is in the form of sheets rolled and impressed with an hexagonal pattern and sold by dealers in "beekeeper's supplies" under the name of "Medium Brood Foundation". Get a few sheets of this material. It comes 8"x16", 7 sheets to the pound, for about a dollar. Our abrasive is optician's rouge. This is a powder, and a quarter of a pound, either red or white, from some working optical shop will be sufficient.

So much for supplies. Now, wash up everything you have used during grinding - mirror, tool, bench or barrel - everything that might have a trace of carborundum on it, and put all your carborundum safely out of the way. Don't use anything you have used before unless it has been thoroughly cleaned.

Having cleaned up, set up the glass tool again on your bench as before. Then take a sheet of beeswax, or as it is called by the amateur, H.C.F.

(Honeycomb Foundation), lay it over the tool, put the mirror face down on top concentric with the tool and cut round it with a razor blade, cutting out a disc of H.C.F. the same size as the tool and mirror. Remove the mirror and disc of H.C.F. from the tool and take a small piece of H.C.F. - a corner left over after cutting out the disc - roll it into a wad and rub it vigorously all over the surface of the tool until it has a coating and feels slightly sticky.

Mix up, in a clean glass, about a teaspoon of rouge in half a glass of water, lay the disc of H.C.F. on the sticky tool. This is the lap. Pour on a couple of spoonfuls of the rouge soup. (It will be difficult to get it evenly on the lap when the lap is new but after it has been used a while the soup will work all over it.) Place the mirror face down on the lap and work it around a few times without pressure until you can see through the back that every part of the lap is wet with soup. Then bring the mirror concentric with the tool and place a weight on it for 15 or 20 minutes. An electric iron makes a good weight. Let it press and after twenty minutes remove the weight but without lifting the mirror commence to polish by the same stroke as in grinding.

You will find one charge of rouge lasts much longer than a charge of carbo. In fact, it may last as long as you want to work at one stretch. Polishing will take several hours. When you finish one spell of work, take the tool off the barrel and wash the lap under running water without removing it from the tool. Put it back in position and cover with clean cloth or paper. Do not leave the mirror on lap overnight.

Part 6.

After polishing for three hours or so, the mirror should be polished out to the edge and look reasonably clear when light is passed through. It is now time to start testing, and the beginner would be well advised to contact a fellow amateur who has had experience in Foucault testing and obtain his advice and assistance in this important phase of mirror making.

If the focal ratio chosen is f10 or over, the mirror may be left spherical, but if the conventional f8 has been made, it is absolutely necessary to parabolize the mirror. This is done by deepening the curve in the centre of the mirror. There are several ways of accomplishing this - lengthening the stroke, using the "side stroke" or removing part of the lap so that the outer zones of the mirror receive less polishing. Here again time and effort will be saved by obtaining advice from someone who has made one or more mirrors. If your library has "Amateur Telescope Making", full details of testing and parabolizing will be found in this volume, together with descriptions of easily made testing apparatus.

When the mirror shows a satisfactory curve it only requires silvering or aluminizing, and the principal part of your telescope is ready for use.

In addition to the mirror, a small flat mirror or a prism is required to reflect the beam of light to a position where it can be examined by an eyepiece. The prism and eyepiece cost very little and it is more economical to purchase these items than to try to make them. A tube to carry the parts and maintain them in proper optical alignment is very easily made from plywood, and the matter of mounting is up to the individual. By all means make a rigid mount and make an equatorial head of some kind as this enables the amateur to follow a star with motion in one direction.

For further information, contact the Montreal Centre of the Royal Astronomical Society of Canada.

