

Introduction

Telescope making is a vital part of astronomy. Early astronomers starting with Galileo had to design and build the instrument that revolutionized the science of astronomy. Isaac Newton, among his great accomplishments, designed and built the venerable telescope that now bears his name. In today's world of space exploration there are scientists and astronauts that explore the universe, and there are engineers that design and build the fabulous machines that make that exploration possible. As amateurs we can share the best of both worlds.

First of all let's not deceive ourselves. Modern technology has made it possible to produce excellent, relatively low cost telescopes and accessory devices that make the life of the amateur astronomer rewarding and full of awe. I believe that some of the astronomical images produced by amateurs today rival those of the state-of-the art professional astronomer just two decades ago. It is much easier, and most likely less expensive to purchase a telescope today as opposed to building your own.

Telescope making is a declining skill among amateurs. As a high school student I experienced the thrill of "first light" of my very own 8-inch reflector. I know what the experience has done for me. I would hope that it can be a similar experience for our club members and to the members of the future generations that we can inspire.

I will be producing a number of introductory "papers" explaining the mirror making process. I do not intend to be very theoretical or mathematical; just enough information to get the job done.

Some Initial Requirements

- Work Area

Requirement #1 is the work area. You will need a clean area and a stable "stand" on which to work. The simplest grinding technique involves walking around the stand as you grind and polish. I salvaged an old microwave cart that I believe will work well for mirrors up to 8". I can weight it down for more stability and move it out of the way when I'm not working. It is small enough to walk around. I am looking into using sand-filled garbage as an alternative.

- Materials

A mirror grinding "kit" includes a mirror blank, tool, abrasives, polishing compounds, and optical pitch. Traditionally the mirror blank is made of Pyrex or some other low expansion glass. The tool is made up of plate glass or ceramic material the same size as the mirror. Abrasives range from a coarse #80 grit to a fine emery #305. Polishing compounds include cerium oxide and jeweler's rouge. An optical pitch is used to create a polishing lap.

A small flashlight, a simple mirror testing stand, and a knife edge tester completes your suite of tools.

Choosing the Project

There are a number of factors that will help determine the type of telescope you would like to construct.

- Purpose

I will try to make things simple by describing three different categories of telescopes by purpose:

1. Moon and planets (f/10)¹
This telescope is of a longer focal length resulting in a narrower field of view. Longer length and weight, and the anticipated use of higher magnification will require a sturdy mounting assembly.
2. Deep sky and comets (f/6)
This telescope is of shorter focal length, lower magnification, and wider field of view. Less weight and lower magnification reduces the requirements for mounting. There will be a little more grinding and some additional time and care in final figuring.
3. General Purpose (f/8)
This telescope is a compromise of some performance to achieve some benefits in all worlds.

Performance

There are some traditional parameters to evaluate performance:

1. Resolving Power

In simple terms this is the ability of a telescope to distinguish small or closely arranged objects. Often an amateur will test the resolving capability of his/her telescope by “splitting” a pair of double stars. The distance between double stars is expressed in “arc seconds”². The image of Jupiter’s disk is on the order of 30 to 45 arc seconds. The components of the popular double star Albireo has a separation of 34 arc seconds. Expectations for several apertures look something like this table.

Aperture (inches)	4.25	6.0	8.0
Resolution (arc sec)	1.0	0.8	0.6

2. Limiting Magnitude

Limiting magnitude is the faintest star that you can expect to see. There are many factors such as sky conditions, condition of the mirror surfaces, and the

¹ f/ or f-number is the ratio of the focal length to the diameter.

² 1 degree(1°) is equal to 60 minutes of arc (60′) and 1minute of arc is equal to 60 seconds of arc (60″).

eyesight of the observer. Given all this here is another chart that can establish some expectations.

Aperture (inches)	4.25	6.0	8.0
Limiting Magnitude	12.0	13.3	13.6

3. Field of View

Field of view is determined by the apparent field of view of the eyepiece and the magnification of the telescope. The magnification of the telescope is in turn determined by the focal lengths of the eyepiece and mirror. Here are more tables.

Wide Field (35mm and 40mm eyepieces)

Aperture	f/	Focal length	35mm/50°	35mm/60°	40mm/50°	40mm/60°
4.25	6	25.5"/648mm	19x/2.7°	19x/3.1°	16x/2.7°	16x/3.1°
	8	34"/864mm	25x/2.0°	25x/2.4°	22x/2.3°	22x/2.7°
	10	42.5"/1080mm	31x/1.6°	31x/1.9°	27x/1.9°	27x/2.2°
6.0	6	36"/914mm	26x/1.9°	26x/2.3°	23x/2.2°	23x/2.6°
	8	48"/1219mm	35x/1.4°	35x/1.7°	30x/1.7°	30x/2.0°
	10	60"/1524mm	44x/1.1°	44x/1.4°	38x/1.3°	38x/1.6°
8.0	6	48"/1219mm	35x/1.4°	35x/1.7°	30x/1.7°	30x/2.0°
	8	64"/1626mm	46x/1.1°	46x/1.3°	41x/1.2°	41x/1.5°
	10	80"/2032mm	58x/0.9°	58x/1.0°	51x/1.0°	51x/1.2°

Moon and Planets (10mm eyepiece)

Aperture	f/	Focal length	10mm/50°
4.25	6	25.5"/648mm	65x/0.8°
	8	34"/864mm	86x/0.6°
	10	42.5"/1080mm	108x/0.5°
6.0	6	36"/914mm	91x/0.5°
	8	48"/1219mm	122x/0.4°
	10	60"/1524mm	152x/0.3°
8.0	6	48"/1219mm	122x/0.4°
	8	64"/1626mm	163x/0.3°
	10	80"/2032mm	203x/0.25°

Mirror Fabrication

- Grinding

The first stage of grinding is rough grinding. This creates the correct depth or sagitta. Some mirror kits provide a pre-curved blank and tool. The second stage of grinding is to reduce the size of the “pits” created by the previous stage. The focal length of the mirror may be effected slightly. The third and final stage of grinding is fine grinding. This process smoothes the surface in preparation for polishing.

I am always reluctant to assign actual time values for mirror fabrication because of personal work habits and technique. Longer focal length mirrors require less rough grinding. For f/6 4-1/4” and 6” mirrors the extra time is really not very significant. An 8” will take a little longer.

- Polishing

Polishing transforms the diffuse surface to a clear, smooth spherical surface. Polishing is accomplished through the use of a polishing compound (Cerium Oxide) and a pitch lap tool. The entire polishing process may require 10 to 15 hours. Cleanliness is a major concern beginning with this stage.

After several minutes it may be possible to use the Foucault knife edge test to make an initial assessment of the “figure” of the mirror. During this stage the surface is brought to a spherical shape.

- Final Figuring

The final stage of polishing employs a finer polish called Jewelers Rouge. In addition to producing a very high polish this stage transforms the spherical surface to a parabolic surface. . This may take 2 to 3 hours. The knife edge test is used to measure the accuracy of the mirror surface. The knife edge, or Foucault test a very simple and very effective test will be explained later.

The mirror is then ready for its optical reflective coating.