

# Guide for Building a Telescope

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## Under The Same Sky

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# Introduction

This booklet was prepared to provide information for high school students and teachers who are interested in making telescopes. This book was prepared with the information that was obtained as a result of Astrophotography studies and trainings of the astronomy themed project named Erasmus + Under the same sky. Under the same sky project partnership was carried out between Eczacı Bahattin Sevinç Erdiñç Fen Lisesi (Türkiye), Itis Ettore Majorana (Italy), Colegiul Tehnic Edmond Nicolau Focsani (Romania), Akademickie Liceum Ogólnokształcące Politechniki Śląskiej Gliwicach (Poland) schools. Project started in December 2020 and ended in December 2023. You can use and share this booklet.

Sincerely

## 2. Refracting Telescopes

The telescope was first used for sky object observation purposes by Galileo Galilei. In 1610, Galileo built a telescope with a magnification of 30 times and discovered the four largest moons of Jupiter.

The telescope used by Galileo was a simple refracting telescope. And there are two types of refracting telescopes called Galilean type and Keplerian type.

### Galilean Telescope

This telescope was built by Galileo in 1609. That telescope only had a magnification of 10 times. It used a convergent (plano-convex) objective lens and a divergent (plano-concave) eyepiece lens. A Galilean telescope, because the design has no intermediary focus, results in a non-inverted and, with the help of some devices, an upright image



Galileo Galilei (1564–1642)

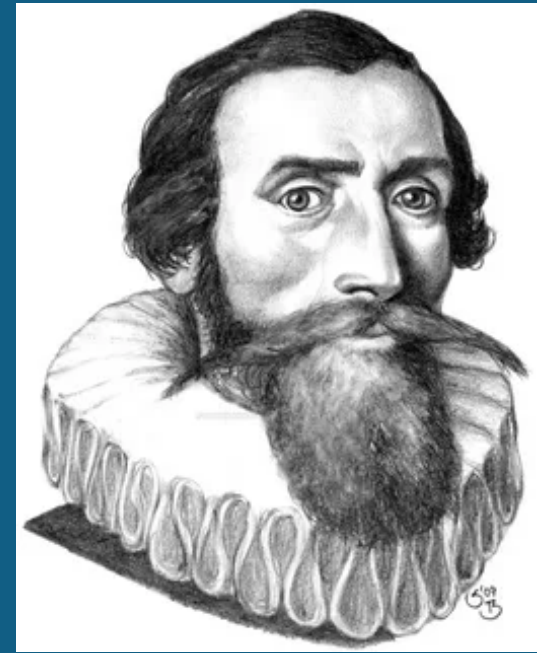


Galileo telescope (1609)

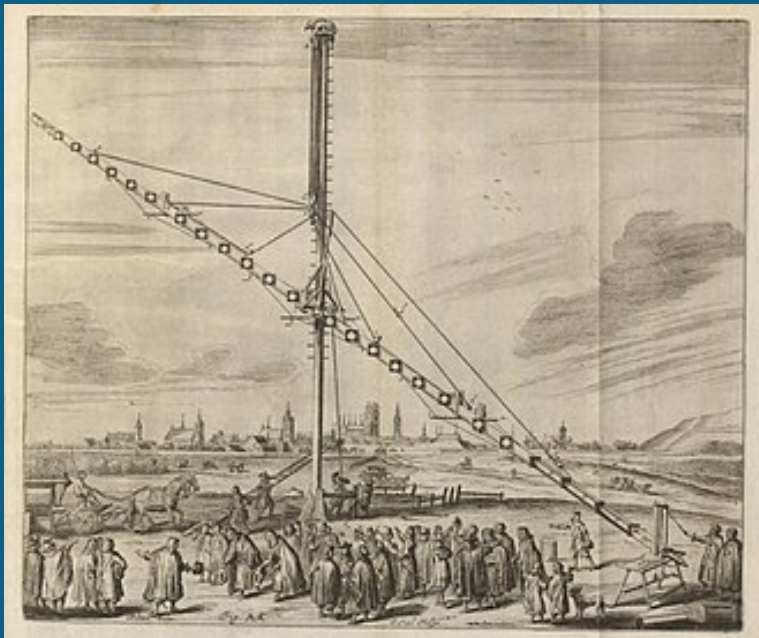
## Keplerian telescope

The Keplerian telescope, invented by Johannes Kepler in 1611, is an improvement on Galileo's design.

It uses a convex lens as the eyepiece instead of Galileo's concave one. The advantage of this arrangement is that the rays of light emerging from the eyepiece are converging. This allows for a much wider field of view and greater eye relief, but the image for the viewer is inverted.



Johannes Kepler (1570–1630), drawing



Drawing of the 46 m (150 ft) focal length Kepler astronomical refracting telescope built by Johannes Hevelius.

In Keplerian type telescopes, lenses with very large focal lengths were used to obtain better images. Tubes were not used in the first telescopes produced.

# Making Galilean Telescope

## Materials:

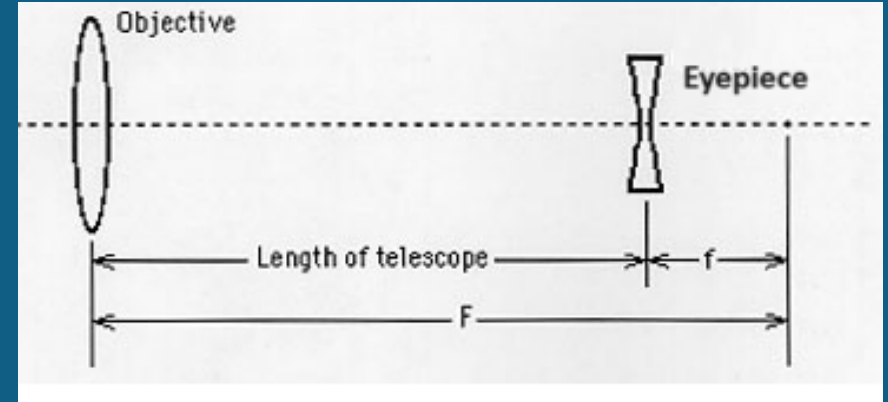
- 1 concave lens (eyepiece)
- 1 convex lens (objective)
- Black cardboard or PVC pipe
- Scissors
- Ruler
- Glue or hot glue gun
- Compasses

Focal Length of convex lens (F) = 1350mm  
diameter = 49mm

Focal Length of Concave Lens (f) = -152mm  
Diameter = 49mm

## Fabrication:

Black cardboard can be used for tube making. If you use ready-made tubes or such as PVC pipes the inside of tube must be black if not you can paint it with black color. To create the front part of the tube, roll the cardboard into a roll with a 60mm diameter. Let the length of the tube to be 70 cm. To create the second part of the tube, roll the cardboard into a roll with a diameter of 56 mm and glue it. Let the length of the tube to be 70 cm.



Model of Galilean telescope



Telescope tube

To place the lenses cut 60 mm diameter two circle cardboard for manila frame. Cut the middle of the manila frame, you created, with a diameter of 49 mm and glue the lens inside them. Glue frames to tube with glue or hot silicone. Place the tubes inside each others so that the lenses are on the outside. Your telescope is ready. Move the tubes back and forward to focus the telescope.

Power of Magnification (M) can be calculated with this equation

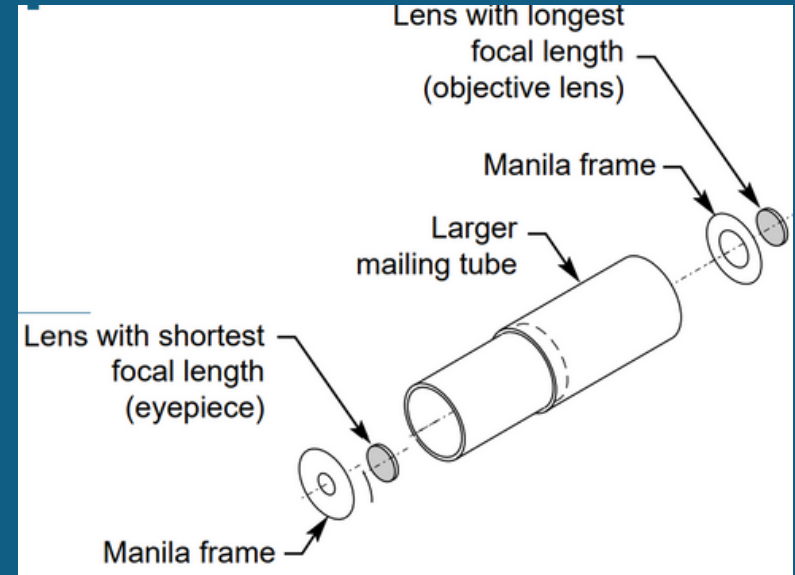
**M** = power or magnification

**F<sub>e</sub>** = focal length of the eyepiece

**F<sub>o</sub>** = focal length of the objective

$$M = \frac{F_o}{F_e}$$

For used lenses the M = 8.9



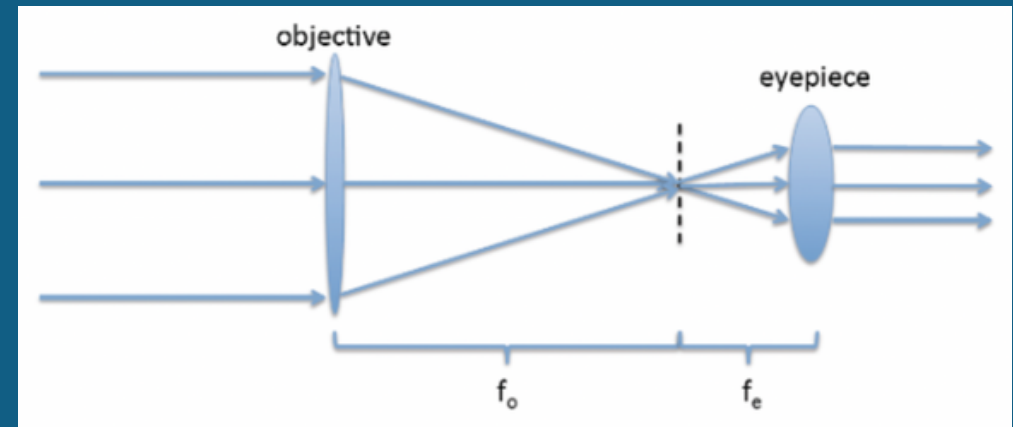
Parts of Galilean telescope

The useful magnification of a telescope is limited by diffraction. This diffraction limit is about 10 times magnification per inch of diameter of the objective lens. So our telescope has around 20 times magnification power.

# Making Keplerian Teleskop.

## Materials:

- 2 concave lenses
- Black cardboard or PVC pipe
- Scissors
- Ruler
- Glue or hot glue gun
- Compasses



Model of Keplerian telescope

The focal length of the lenses must be different. For example, the objective lens can be selected with 60 cm focal length and 5 cm diameter. The eyepiece lens can be chosen as a lens with a diameter of 2 cm and a focal point of 20 cm. In this case, the length of the tube must be at least 80 cm. Black cardboard can be used for tube making. If you use ready-made tubes or such as PVC pipes the inside of tube must be black if not you can paint it with black colour.

## Fabrication:

To create the front part of the tube, roll the cardboard into a roll with a diameter equal to the diameter of the front lens (50mm) and glue it. Let the length of the tube to be 50 cm. To create the second part of the tube, roll the cardboard into a roll with a diameter of 46 mm and glue it. Let the length of the tube to be 50 cm.

Glue the objective lens to the front of the first tube, you created, with glue or hot silicone..



To place the rear lens, cut a circle of cardboard equal in size to the diameter (46mm) of the rear tube. Cut the middle of the circle you created with a diameter of 2 cm and glue the rear lens. Glue the circle to the back tube with glue or hot silicone. Place the tubes inside each others so that the lenses are on the outside. Your telescope is ready. Move the tubes back and forward to focus the telescope

Power of Magnification (M) can be calculated with this equation

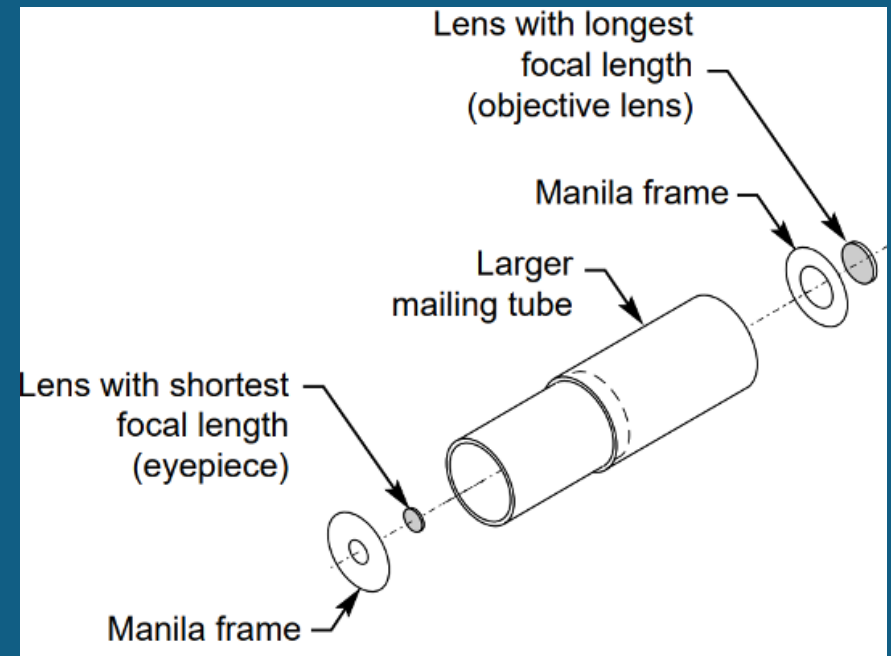
**M** = power or magnification

**F<sub>e</sub>** = focal length of the eyepiece

**F<sub>o</sub>** = focal length of the objective

$$M = \frac{F_o}{F_e}$$

For used lenses the M = 3

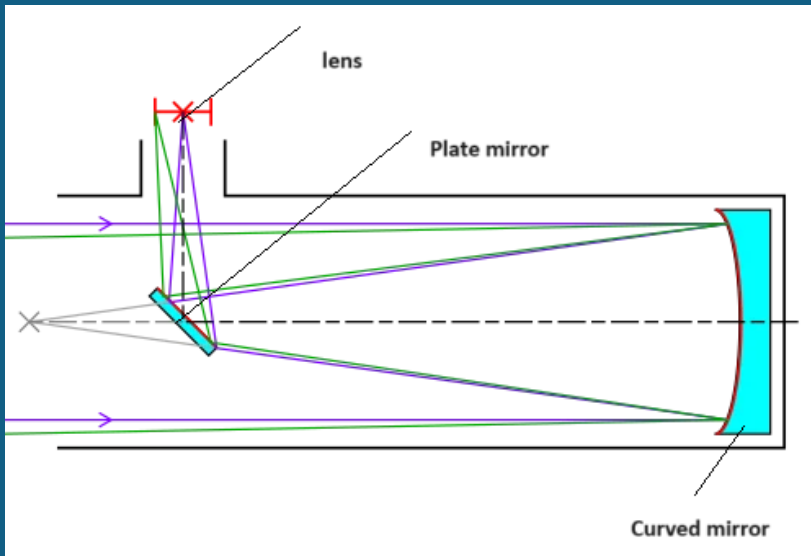


Parts of Galilean telescope

The useful magnification of a telescope is limited by diffraction. This diffraction limit is about 10 times magnification per inch of diameter of the objective lens. So our telescope has around 25 times magnification power. It should be noted that this calculated value depends on the quality of the lenses and many other factors. Therefore, the telescope you obtain can provide magnification at the calculated rate.

### 3. Newtonian Reflector Telescope

In this design, successfully established by Newton in 1668, the secondary mirror is a flat mirror, positioned close to the open ends of the tube and at an angle of approximately 45 degrees. The function of the secondary mirror is to reflect the light reflected from the primary curved mirror to the eye lens. The eyepiece is placed in the hole opened in the tube at the level of the secondary mirror.



Model of Newton telescope



A replica of Newton's second reflecting telescope, presented to the Royal Society in 1672

Advantages of Newtonian design:  
It does not contain chromatic aberration found in eyepiece telescopes. Newtonian telescopes are generally less expensive than other types of telescopes of comparable quality for any given objective diameter (or aperture). A short focal ratio can be achieved more easily, resulting in a wider field of view.

### Designing Newtonian Telescope

#### Materials

Concave mirror, Flat mirror, Tube, Focus adjustment, Cardboard, Lens, Glue, hot glue thin stick or wire, knife, Scissors

You can buy the concave mirror that produced specifically for telescopes, or you can make it yourself by knapping method. Since making a concave mirror using the knapping method is quite time-consuming and requires experience, we recommend beginners to use ready-made mirrors.

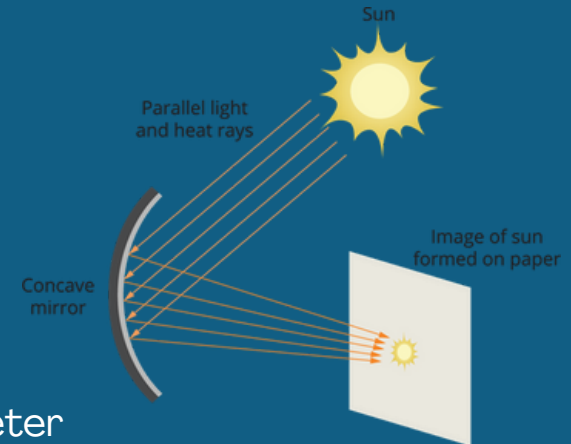
You can buy the concave mirror from vendors that produce it specifically for telescopes, or you can make it yourself by etching method. Since making a concave mirror using the etching method is quite time-consuming and requires experience, we recommend beginners to use ready-made mirrors.



Curved mirror

However, those who want to make their own mirror can use this link. (<http://www.ikizler.org/index.php/2018/03/28/amator-teleskop-aynasi-yapimi/>)

It is sufficient that the diameter of the mirror you purchase is 10 cm. If you do not know the focal point of your mirror, you can determine the focal point of your mirror by going outside on a sunny day and measuring the distance from the point where the sun rays collect to the mirror.



Finding curved mirror focus

You can use durable hard cardboard or wood to make the tube of your telescope. Instead, you can use a PVC wastewater pipe suitable for the diameter of your mirror. We recommend using a PVC wastewater pipe with a diameter of 15 cm for ease and durability.



PVC pipe for telescope tube

If the inside of the pipe is not black, it must be painted black. You can paint the inside of your pipe with spray paint. The length of the pipe should be slightly larger than the focal length of the mirror.

For the reflective mirror, you can use a plane mirror measuring 3x4.5 cm. You can cut this mirror into a rectangular or oval shape.

To place the focuser piece at a focal distance from the concave mirror, drill a hole on the tube the size of the diameter of your focuser.

You can use thin rod or wire to fix the mirror to the tube. You can make a spacer from cardboard to stick the stick to the mirror and capture the 45 degree angle. We used the part we printed from the 3D printer for the intermediate part.

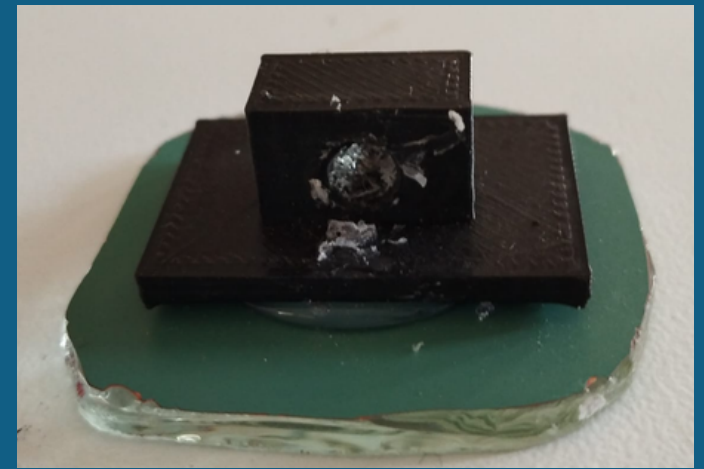
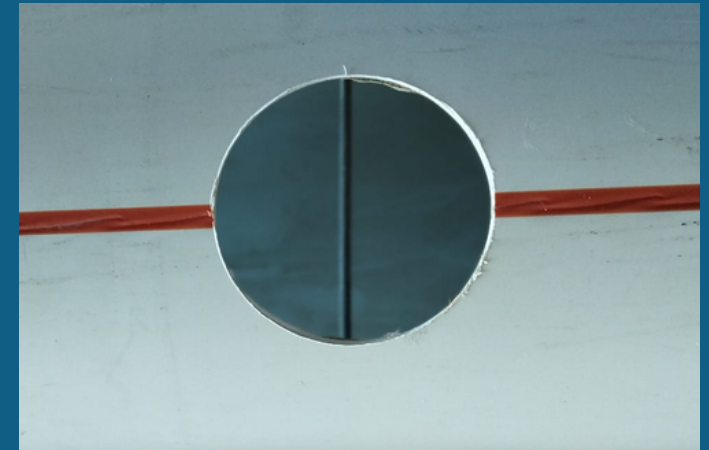


plate mirror with its fitting part



Hole for focuser



A plate is prepared from wood or cardboard to fix the concave mirror to the tube. We printed parts from a 3D printer to fix the concave mirror to the tube.

A tool for fix the concave mirror to tube

You can buy the focuser ready-made or create it by designing it yourself using a 3D printer. We used a 3D printer to print the focuser we designed ourselves.

After mounting the focuser on the tube, attach the lens you want to use on the focuser. Your telescope is now ready for use. However, you will need a telescope mount to easily point the telescope at the celestial object you will be looking at.



Focuser for telescope

## 4. Telescope Mount

To a large extent, a telescope is only as good as its tripod and mounting. A telescope is used to magnify the sky, but unfortunately it also magnifies vibrations. A telescope mount has two primary functions:

1. Support the telescope firmly so that objects can be viewed and photographed without vibrations
2. Provide a system for smooth controlled movement to point and guide the instrument

There are two major types of mounts for astronomical telescopes: Altazimuth and Equatorial.

### Altazimuth

Altazimuth (sometimes called alt-az) is the simplest type of mount with two motions, altitude (vertical) and azimuth (horizontal): thus the name Altazimuth. Good Altazimuth mounts have slow-motion knobs for making precise adjustments, aiding smooth tracking across the sky. These type mounts are generally good for terrestrial observing and for scanning the sky at lower power but not for deep sky photography. Some Altazimuth mounts are now computer driven and allow a telescope to track the sky more accurately. This is generally good for visual use but can lose tracking on longer exposure astrophotography.



Altazimimuth mount

# Equatorial

Equatorial mounts are superior to non-computerized Altazimuth mounts for astronomical observing over long periods of time and absolutely necessary for astrophotography. As the earth rotates around its axis, the stationary stars appear to move across the sky. If you are observing them using an Altazimuth mount, they will quickly float out of view in both axes. A telescope on a properly aligned equatorial mount can be aimed at a celestial object and easily guided either by either manual slow-motion controls or by an electric motor.

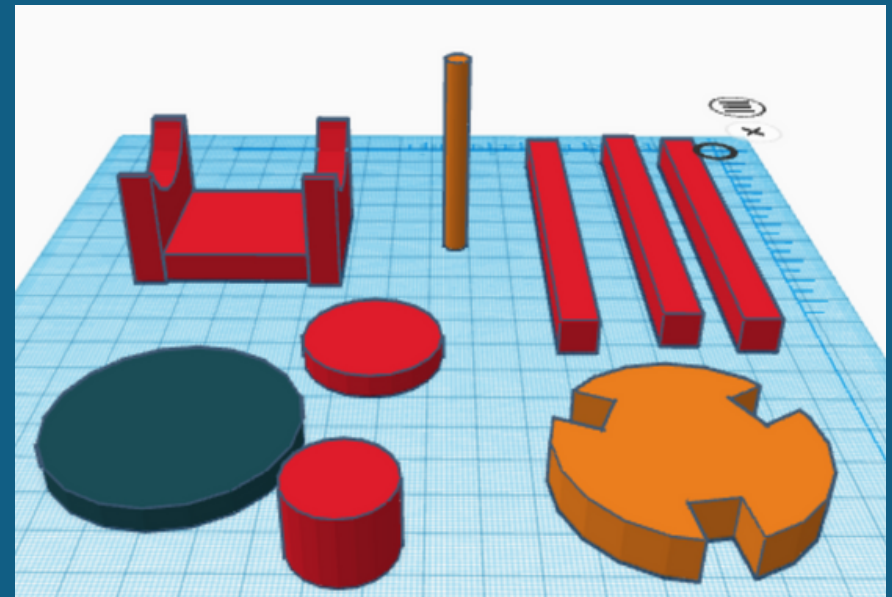


Equatorial mount

Since it is easier to make an Altazimuth mount to start with, we will prepare an Altazimuth type mount for our telescope.

We will use wood to make the mount. You can use hinges and bolts to open and close the legs.

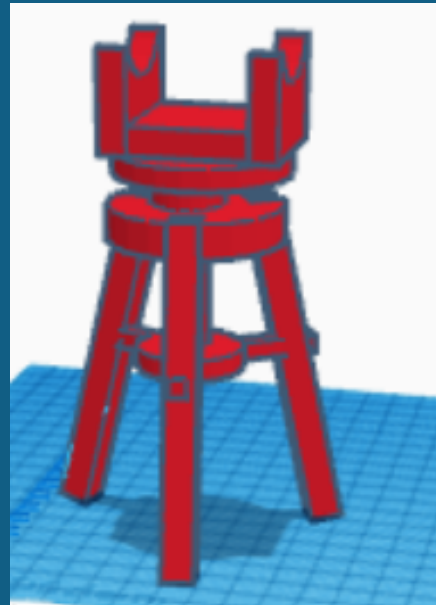
First, we made a 3D design of the stock we would make. Thus, the necessary parts and the shape and size of these parts were determined.



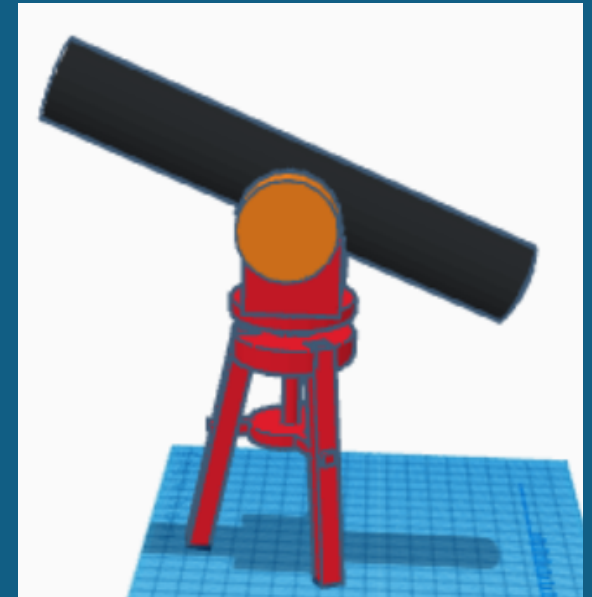
the parts of designed mount

After determining the shape and dimensions of the wooden pieces to be used in making the swaddle, you can cut them yourself if you have the tools to cut them. However, if you do not have enough tools, you can have it cut in a carpentry workshop.

After the parts are prepared, you can proceed with the screwing process and finally place the telescope on the mount as shown at figure.



designed 3D model of mount



placing telescope on mount

If you have completed your telescope, we wish you good sky observations. Your next goal may be to make the concave mirror yourself. Additionally from this, you can make an equatorial mount and use DC motors and Arduino for orient the telescope.

## References

[GalileanKeplerianTelescopes \(ymaws.com\)](http://ymaws.com)

[Teleskoplar I: Temel Bilgiler ve Amatör Teleskoplar – İTÜ Astronomi Kulübü \(itu.edu.tr\)](http://itu.edu.tr)

[Making a Galilean Telescope \(rice.edu\)](http://rice.edu) [Amatör Teleskop Yapımı – ikizler.org](http://ikizler.org) – Uğur İkizler

[GalileanKeplerianTelescopes \(ymaws.com\)](http://ymaws.com)