

Building a Spectrograph and Telescope

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Yield: 1 Spectrometer and 1 telescope

Diagrams shown on next page

These were developed for a "Space Camp" class I taught for summer students at the Discovery Montessori Academy in Plano, TX. One session had middle school age students and the other had intermediate school age students. It seemed to work well for both those ages.

Material:

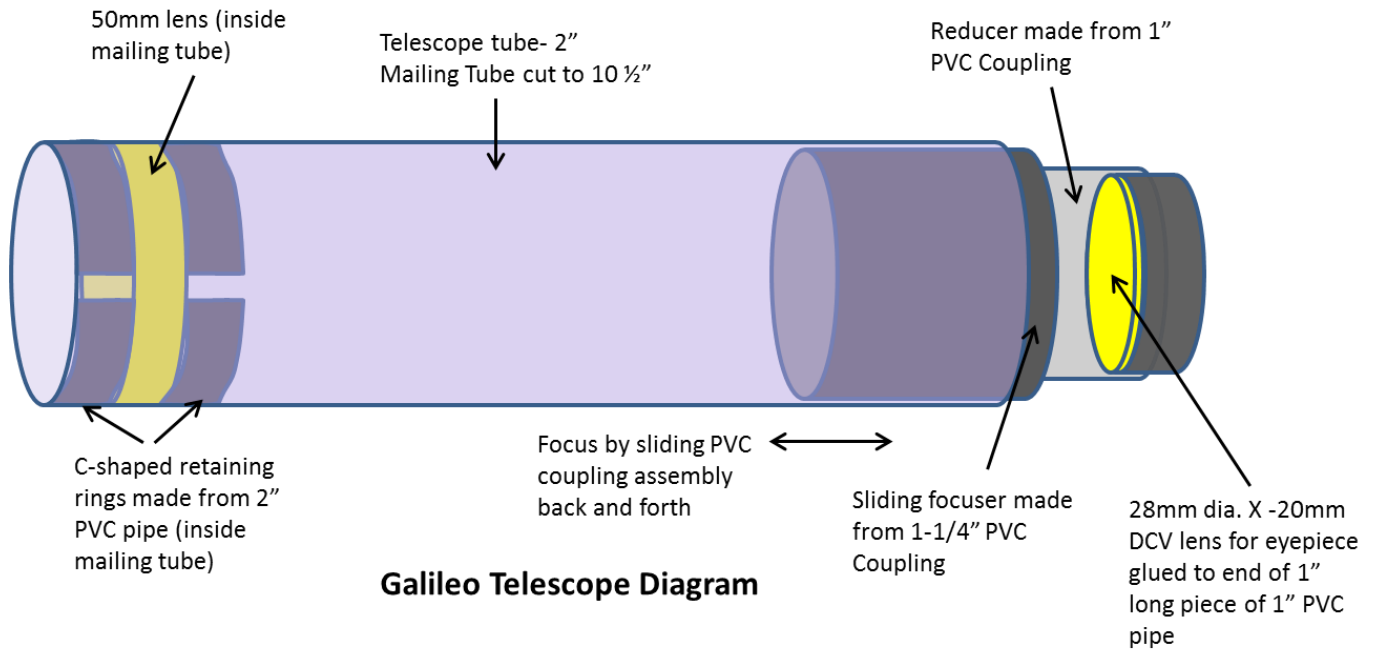
Qty	Material	Price
1	Staples Mailing Tube, White, 2 1/2" x 24", Each (468298) (similar tubes can be substituted, but I know this one works.) Note that the length is really 25"	\$1.59
1	One quarter portion of a Recordable CD with label removed. Some CD's are easier to remove the top label. I used a Memorex Recordable CD.	\$0.05
1	50mm x 300mm FL lens surplusshed.com Part # L1916D	\$1.35
1	DCV LENS 27.9MM DIA BY -20MM FL CTD surplusshed.com Part # L14721 . Makes a 15 power telescope but non inverted image.	\$3.50
2	3/8" thick rings cut from 2" PVC pipe (cut from 2 ft. pipe, Lowes Item # 256099 Model # PVC 07200 0200) (Optional- see instructions below)	\$0.07
1	1 inch long tube cut from 1 Inch PVC pipe (cut from 2 ft. pipe, Lowes Item # 351124 Model # PVC 04010 0200)	\$0.11
1	1-1/4 inch Lasco PVC Coupling (Lowes Item # 23854 Model # 429012RMC)	\$0.73
1	1 inch Lasco PVC Coupling (Lowes Item # 23852 Model # 429010RMC)	\$0.46
2	1-1/2 inch by 1" rectangles cut from 3x5 index card	\$0.01
	Total cost per student	\$7.97
1	Used to cut tubing-IRWIN Classic 10-in Circular Saw Blade (Lowes Item # 23213 Model # 1826439)	\$12.98

Note 1: Cutting Tubing

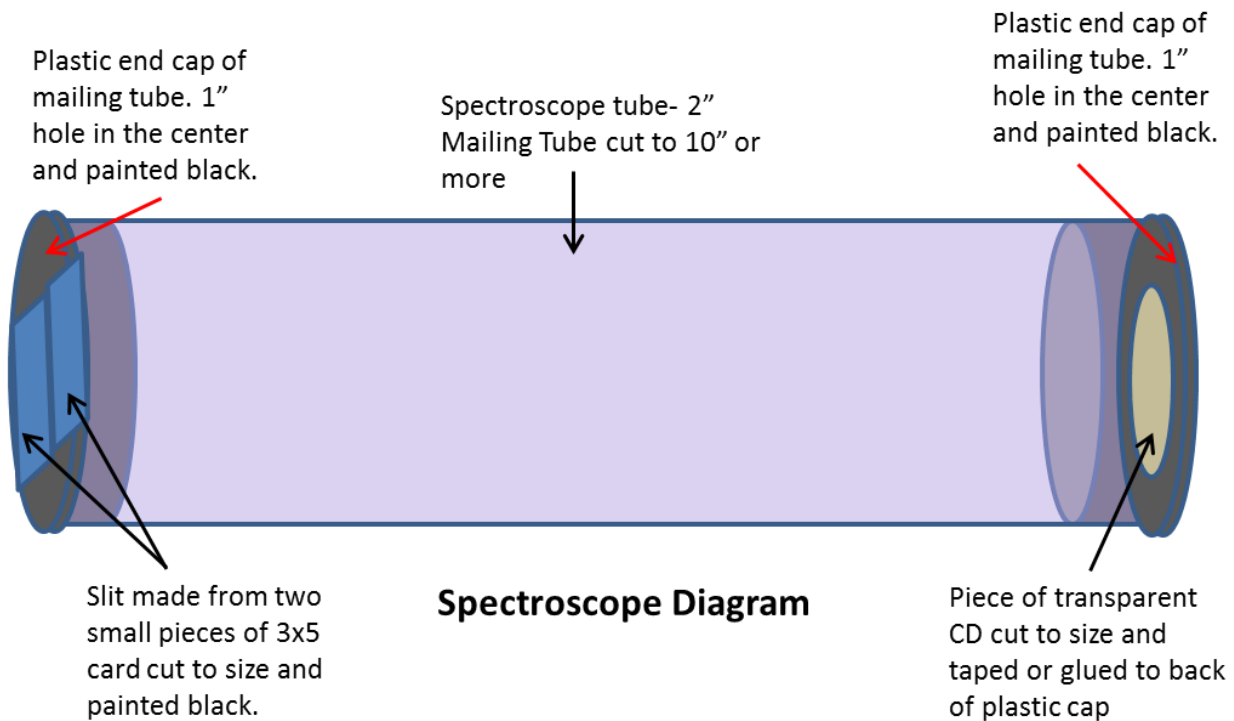
I found that the easiest way to cut the tubing (both the cardboard mailing tube and the PVC tube) was to use a Radial Arm Saw with the above mentioned IRWIN Classic 10" blade. I also used a table saw to cut the notches for the 3/8" Rings as described below. I also used a drill press to cut the holes in the plastic ends of the mailing tube, though workable square holes can be cut with a box knife. There may be other ways to cut the tubing (and I tried several tubing cutters), but I found this method to be the quickest and easiest. If you don't own these tools perhaps you can find a friend who can do it. In major cities there are Makerspace (for instance <https://dallasmakerspace.org/>) where you might find someone to help cut the tubing, or perhaps enlist the help of a local high school shop teacher.

BE VERY CAREFUL, POWER TOOLS CAN BE DANGEROUS. TAKE PROPER PRECAUTIONS AND WEAR EYE PROTECTION!

WARNING!: Tell the students to NEVER, EVER, EVER, NEVER, EVER, EVER, NEVER LOOK AT THE SUN WITH EITHER THE TELESCOPE OR THE SPECTROSCOPE. PERMANENT EYE DAMAGE CAN RESULT. I usually repeat this several times during the building phase.



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Making the Galileo Telescope:

Step 1: Cut an 11 inch section from the Mailing Tube for the telescope tube. (See Figure 1) I typically keep the plastic endcaps in the tube when cutting. The other section (about 14 inches long) will be used for the spectrograph. You can cut a few inches off of the Spectrograph section if you like, but I would not make it shorter than 10". Remove the plastic end caps from the each tube; these will be used for the Spectroscope.



Figure 1: Cutting the Mailing tube

Making C-Rings using Option 2



Figure 2a: Cut a slot in the 2" PVC pipe.



Figure 2b: Slot cut out of the PVC



Figure 2c: Carefully cut C shaped rings from the PVC.

Figure 2d: Completed C-Rings. PVC on left, Cardboard on right.



Step 2: Make 2 C-Rings to hold the lens in. You have two options: make them from the cardboard mailing tube or from the 2" PVC tube. The cardboard retaining rings are easier to make, but often the cardboard delaminates. Also, they must be glued in as they do not hold well against the side of the tube. The PVC tubes are much harder to make, but don't need to be glued in and hold the lens better. I have the equipment to make the PVC ones so that is what I use.

Option 1 is to cut them from the Mailing Tube

Cut two ½ inch rings from the mailing tube using the same method you used to cut the main tube (Figure 1). Then use scissors to cut about a ¼" section out of the ring to make a C shape. Figure 2d (right)

Option 2 is to cut them from the 2" PVC pipe

Step 1: Cut a 1-1/4 inch section out of the length of the 2" PVC pipe, Figure 2b. Start by marking a spot on the end of the PVC with a sharpie, then measure 1-1/4" around the circumference from this spot and mark another spot. I used a table saw with the blade set just high enough above the table to cut through one side of the PVC pipe. To make this cut you will probably need to remove the blade guard from the table saw. This is VERY DANGEROUS so be careful! I didn't saw all the way, but kept the last 8" or so of the PVC as a handle. See Figure 2a. Rotate to the other spot you marked and make another cut. I then used a hand saw to cut out the slot, see Figure 2b.

Step 2: Using the Radial arm saw cut out ¼" to 3/8" C shaped rings from the section of PVC you just cut. Figure 2c. You need two C-Rings per telescope. You can cut several C-Rings from the 2 foot piece of 2 inch PVC.

Make the eyepiece tube:



Figure 3: 1 inch section of 1 inch diameter PVC pipe

Using the Radial arm saw cut a 1" long section from the 1 inch PVC pipe. This will be your eyepiece barrel. Figure 3. You can cut several from a single piece of the 2 foot long section.

Make the Focuser assembly:

Put the 1" coupler into the 1-1/4" coupler and glue all the way around the seam with hot melt glue. You can also put some

hot melt glue on the bottom of the 1" coupler before putting into the 1-1/4" coupler. (Figure 4)



Figure 4: Assemble focuser and glue with hot melt glue.



Figure 5: Paint all the plastic parts flat black

You should now have the C-Rings, the glued focuser, and the eyepiece tube. You should paint all surfaces of the plastic pieces flat black, Figure 5. You should also paint the inside of the Mailing Tube flat black as well.

This is optional, but makes the telescope perform better. Be careful not to paint the outside.

Once they are dry you are ready for assembly.

Assemble the Galileo Telescope (Done by student):

Assembly is fairly easy. If you are using cardboard C-Rings, use a Q-Tip to put white glue around the inside inch or so of the mailing tube. If you are using PVC-Rings do not put glue in the tube. Squeeze the ends of one of the C-Rings and inserting it into the end of the mailing tube. Push it in so that about 3/8" or so of the mailing tube is showing. Figure 6a. Then insert the 50mm diameter 300mm focal length lens into the tube followed by the other C-Ring on top. Make sure the C-Ring is inside the tube but sticking up a small amount. Then invert the tube assemble and push it down on a table top to seat the lens assembly.

Carefully glue the 20mm fl. concave lens to the 1" PVC eyepiece tube, Figure 6c. Use hot melt glue, super glue or similar adhesive. When it is dry put it into the focuser assembly with the lens side down. It should look like Figure 6d.

Just slide the focuser assembly into the end of the telescope opposite the 50mm lens and you are done.

Final Assembly



Figure 6a: Put a C-Ring into the tube.



Figure 6b: Put Lens into tube followed with the final C-Ring on top.



Figure 6c: Carefully glue concave lens to eyepiece tube.

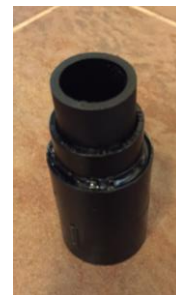


Figure 6d: Insert eyepiece into focuser tube.



Finished Telescope



Look through the eyepiece and move the focuser back and forth to focus the image.

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Making the Spectroscope:



Figure 7: Drilling a 1" hole in the plastic endcaps.

Step 1: Remove the plastic end tubes and cut a 1 inch hole in the each cap. (Figure 7) I use a 1 inch hole saw in a drill press to cut these holes. Note that I use a pair of slip-joint pliers to hold the end while drilling. The shape of the hole doesn't matter so you can cut a 1 inch square hole using a box knife or X-Acto knife. Once again, be very careful.

Paint the top and bottom of the endcap Flat Black, Figure 5 above. You need to paint the inside of the cardboard tube flat black, not optional. Be careful not to paint the outside of the tube.

Take a 3x5 note card and paint it black on both sides to make it opaque. Then cut two 1-1/4" x 3/4" rectangles from the card.

Tape the two rectangles onto the inside part of the end cap leaving a 1/16" or smaller slit between them. Figure 8a. Turn the cap over and use hot melt glue to glue the cards to the hole in the endcap. Then trim the tape and ends of the rectangles to be flush with the endcap. Figure 8b.

Remove the label from the CD by carefully cutting halfway around the label's outside edge with a sharp knife. Then cover the top with Duct Tape (Figure 9a). Then pull the tape off starting at the side you cut and the label should come right off (Figure 9b).

Cut the now clear CD into 4 sections then trim each section to fit on the inside of the other end cap. Hot melt glue it to the end cap with what was the label side facing the endcap. Usually it is easy to tell which side this is as some of the color film remains.

Put the endcap with the slit into one end of the mailing tube you cut earlier. You will need to adjust the position of the CD endcap before inserting it. Hand hold it against the end of the tube opposite the slit. Look at a bright light or the sky (NOT THE SUN!) and rotate the endcap until you see a rainbow spectrum both to the right and left of the bright slit.

Now push the endcap in and you are done!



Figure 9a: Duct Tape used to remove CD Label



Figure 9b: CD Label removed

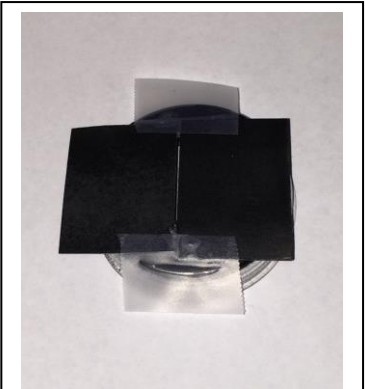


Figure 8a: Slit formed by 2 card rectangles

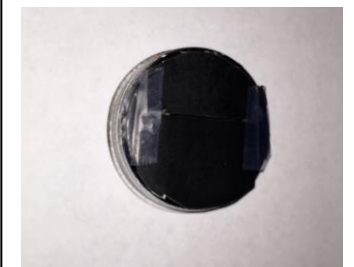


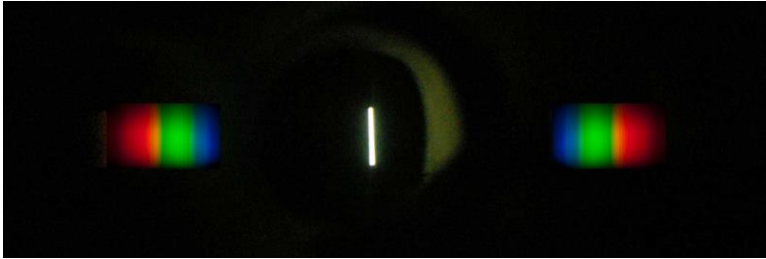
Figure 8b: Trim the tape and rectangles flush.



Figure 10: Hot Melt Glue the CD to the other end cap (inside).

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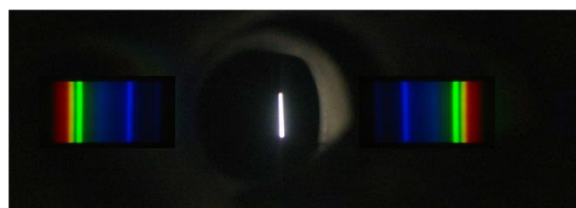
Spectra of an incandescent bulb as seen by the spectroscope:



Other Emission Spectra as seen by the spectroscope:



Compact Fluorescent Bulb



Mercury Vapor Street Light

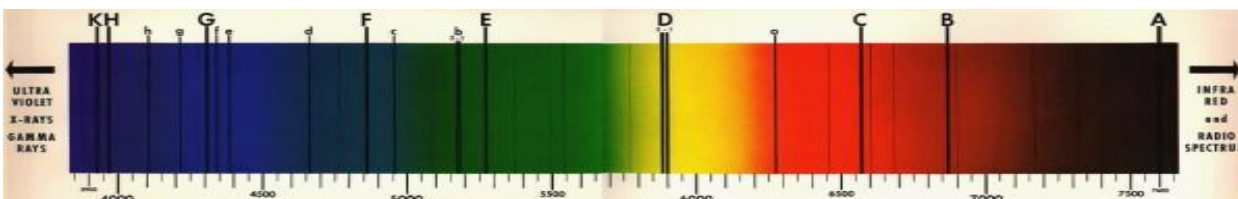


White LED



High Pressure Sodium Street Light

Absorption Spectrum- This is an expanded view of the spectra of the sky. See if you can see the Spectral lines shown:



Legend of Absorption Lines in the Visible Solar Spectrum

Letter	Wavelength (nm)	Chemical Origin	Colour Range
A	759.37	atmospheric O2	dark red
B	686.72	atmospheric O2	red
C	656.28	hydrogen alpha	red orange
D1	589.59	neutral sodium	yellow
D2	589.00	neutral sodium	yellow orange
E	526.96	neutral iron	green
F	486.13	hydrogen beta	cyan
G	431.42	CH molecule	blue
H	396.85	ionized calcium	dark violet
K	393.37	ionized calcium	dark violet