Simple PVC-pipe Telescope

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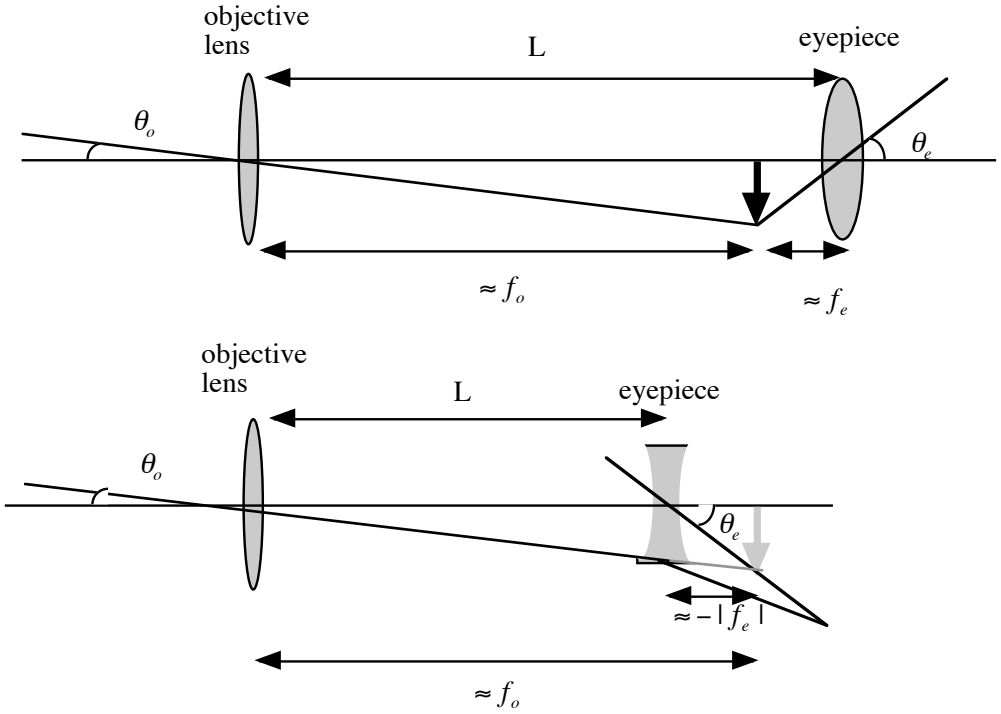
Basic principles: A simple telescope can be made with two lenses:

Objective lens = a convex (converging) lens with "long" focal length ($f_o \approx 50cm$)
Eye-piece = either a "short" focal length convex lens ($f_e \approx 5cm$, image will be inverted)
Or a "short" focal length concave lens ($f_e \approx -7.5cm$, image will be upright)

Angular Magnification : $M \approx -\frac{f_o}{f_e}$
Total length of telescope: $L \approx f_o + f_e$

Image formation of a far away object



I suggest that the students construct both types of eyepieces for comparison. If you use the same telescope body to accommodate both eyepieces then the telescope must be capable of varying its length from 50-7.5=42.5cm to 50+5=55 cm. These are approximate lengths because the lenses that we use are of "educational" quality so their focal lengths may not be accurate. I have chosen a shorter focal length for the convex eyepiece so that I can accommodate both eyepieces into one telescope.

Material List:

1. Objective lens – 50 cm f.l., 50mm dia, DCX lens (DCX=Double-convex)
2. Eyepiece 1 – 5 cm f.l., 38 mm dia, DCX lens
3. Eyepiece 2 – - 7.5 cm f.l., 38 mm dia, DCV lens (DCV=Double-concave)
4. Objective lens holder – An open-ended threaded cap which fits over a 2" PVC pipe (see picture in pictorial instruction; Home Depot stock No: C5801-7, 2")

5. Eyepiece lens holder – A 1-12" to 1-1/4" reducer, with a thread cap, it couples a 1-1/2" PVC pipe to a 1-1/4" PVC pipe (see picture in pictorial instruction; Home Depot stock No: C5801-7, 1 ½ x 1 ¼)
6. Telescope body – 2" SCH 40 PVC pipe (black color), length ~ 30 cm. Note: 2" is the inner dia., the outer dia ~ 2-3/8". (Home Depot sales it in 2 foot length or 10 foot length)
7. Eyepiece extension – 1-1/2" SCH 40 PVC pipe (black color), length ~ 26 cm (must be shorter than the telescope body). Note: 1-1/2" is the inner dia., the outer dia ~ 1-7/8". (Home Depot sales it in 2 foot length or 10 foot length)
8. Friction pad & Velcro pad. (Also sold at Home Depot)

Suggested Vendors and Approximate Cost:

Lenses can be ordered on-line from "Surplus Shed" at www.surplusshed.com
Look under the category of Educational Optics.
Lens ~ $1.20- $1.50 , discount for a set of 10
These are pretty good lenses, individually package, but don't thrust the stated f.l.

The rest of materials can be obtained from any hardware store such as Home Depot.

The total cost per telescope is under $10 (if you make more than one).

Construction Steps:

1. Prepare objective lens holder (see pictorial instruction 1), place lens in holder
2. Prepare eyepiece holder(s) (see pictorial instruction 2), place lens in holder
3. Determine the length of the telescope (see pictorial instruction 3).
   Hold the objective lens in one hand and the eyepiece in the orther. Adjust distance between hands to bring a far object into focus. Have your partner measure the distance between the lens and record the measurement. Make measurements for both eyepieces. From your measurements, determine the length of the telescope body and the eyepiece extension to accommodate both eyepieces.
4. Cut PVC pipes (telescope body & eyepiece extension) to desired lengths
5. Attach objective lens holder to telescope body; attach eyepiece holder to eyepiece extension
6. Mount friction pad to interior of telescope body
7. Insert eyepiece extension into telescope body – ALL DONE!

Tools:

1. Hacksaw to cut PVC pipe.
2. Utility knife or "Exacto" knife to cut paper gasket and modify PCV cap.

Pictorial Instructions:

1. **Objective lens holder**

Since the 50 mm dia. objective lens is just a little bit smaller than the opening of the PVC cap, a home-made paper gasket is needed. Also a thick tape in the interior of the cap is needed to prevent the lens to fall through (I used self-adhesive friction pad for furniture, see the grey color pad).

a. Screw cap, b. paper gasket (1.8" inner dia, 2.2" outer dia.), c. objective lens, d. cap fits over a 2" PVC pipe.

2. **Eyepiece lens holder**

The eyepiece lens holder is easier, it fits perfectly into the standard PVC housing. However, one needs to trim off the plastic "lips" in the interior of the cap; a utility knife works fine.

a. A 1-1/2" to 1-1/4" reducer, b. eyepiece lens, c. screw cap

3. **Determine lengths of the telescope**

Hold the objective and eyepiece to view a distant object, adjust the distance between them to get a sharp image. Ask another person to measure the distance between the objective lens and eyepiece.

Note 1: The distance between the objective and eyepiece is longer when viewing closer objects. Decide approximately what viewing distance you intent to use this telescope before determine the telescope length.

Note 2: If you want to accommodate both convex and concave eyepieces in one telescope, you need to determine the length of telescope for both cases. You will need to cut the PVC pipe for the telescope body and eyepiece extension to accommodate both lengths, see next instruction.

4. **Cut PVC pipes (telescope body & eyepiece extension) to desired lengths**
5. **Mount friction pad to interior of telescope body**

Telescope body ~ 29 cm.

Put four piece of Velcro pad for friction

Insert eyepiece extension into telescope body

Eyepiece extension ~ 26 cm.

Velcro for providing friction when sliding eyepiece extension inside the telescope body, see Step 5.

Friction pad for furniture, used here to support the objective lens, see Step 1.

6. **Finished product**

Further topics:

1. Field of view

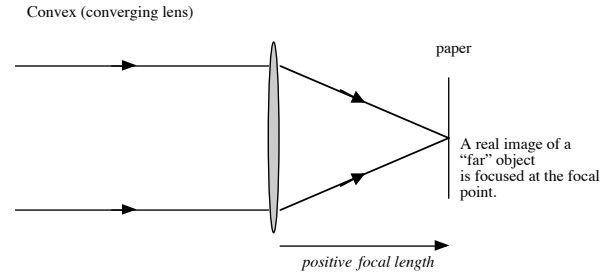
You may notice that your telescope has a rather narrow "field of view" (you can see only a small area at a time). The field of view is related to the angle subtended by the objective lens, hence it is related to diameter divided by the focal length

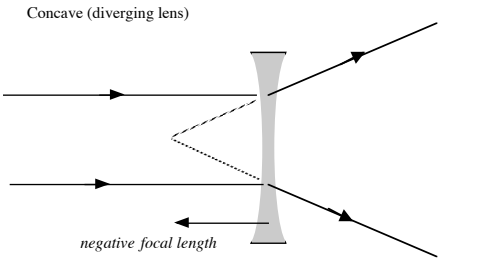
$$\text{Viewing angle (in radian)} \approx \frac{D}{f_o}$$

You can increase the field of view by increasing the diameter of the objective lens or decreasing the focal length. Increasing the diameter is the preferred way but the cost of the lens goes up rapidly with increasing diameter. In our case, the diameter is also restricted by the diameter of the PVC cap. I have included a shorter focal length objective lens - 25 cm f.l., 50mm dia, DCX lens (the problem with reducing the objective focal length is the decrease in angular magnification).

Pre-exercise:

Before you have your students making the telescope, you may want to get to learn a little bit about convex and concave lens, such as measuring the focal length of the objective lens (convex). Focus a far object (distance > 100 x focal length), onto a piece of paper, see figure below, and measure the focal length. Compare this measurement with the manufacture value. This method cannot be used to find the focal length of a concave lens because the image is "virtual", see figure below.





Your brain interprets that the the diverging rays came from a focal point. This is a "virtual image"

Review Questions:

1. You make a magnifying telescope with a

(a) Convex objective lens
(b) Concave objective lens
(c) Either convex or concave

2. You make a magnifying telescope with a

(a) Convex eyepiece lens
(b) Concave eyepiece lens
(c) Either convex or concave

3. Given the focal length of the objective lens is 50 cm and the focal length of the eyepiece is 5 cm. What is the magnification of the telescope?

4. Refer to Q.3. Is the image upright or inverted?