Refractor and Reflector Telescopes

Overview: Telescopes aren't nearly as complicated as they seem. We're going to build two different kinds of telescopes: the refractor (which has only lenses) and the reflector (which has lenses and mirrors) telescopes.

What to Learn: Your lenses are curved pieces of glass or plastic designed to bend (refract) light. A simple lens is just one piece, and a compound lens is when you stack two or more together, like inside a camera. You can arrange your lenses in different ways to get different types of magnification.

Do not use this telescope to look at the Sun! *This telescope is for looking at the moon, distant terrestrial objects, and flashlights with their light intensity stepped down and passed through a wax filter.*

Materials

- index card
- 3 clothespins
- popsicle sticks
- 2 meter sticks
- bright light source
- two double-convex lenses
- concave mirror
- small flat mirror (like a mosaic mirror)
- large paper clip
- black garbage bag
- rubber band
- wax paper
- masking tape
- hot glue gun
- scissors

Experiment

1. The video for these labs is longer than usual. You'll want to make sure to complete the optical bench experiment first which includes complete instructions for mounting lenses and mirrors to the rail.
2. To make a moon light source, stretch a section of a garbage bag over the head of the flashlight. You can cut out a crescent moon and line the cut section with wax paper on the inside. Attach the garbage bag to the flashlight with a rubber band with the wax paper on the inside.
3. Mount a double-convex lens to a clothespin as shown in the Optical Bench video. You need two of these for the refractor telescope. Make sure your two lenses magnify about the same amount.
4. Make an optical rail and mount one of the lenses near one end of the rail. You'll adjust it soon when you bring the moon shape into focus.
5. Place an index card near the middle of the optical rail. Don't attach it to the meter stick itself.
6. Place your flashlight about six feet away from the table so it shines through the lens and onto the index card.
7. Adjust the distance the lens is from the index card and bring the moon into focus.
8. At this point, if you have different-sized lenses, you can hold the second one near the first so you have two moons on the card. Do you notice the difference in brightness in moons? If your lenses are different sizes but magnify the lenses, the larger lens will make a brighter image because it's got more light-gathering ability. Remove the second lens - we were just demonstrating this concept with it.
9. Slide the optical rail around so that the moon on the index card is right over the meter stick.
10. Take the second lens and insert it into the rail on the *other side* of the index card.
11. Look through the second lens and bring the moon that shines through the card into focus.

12. As you still look through the second lens, remove the card and look through both lenses. Make any tiny adjustments, if needed. You're looking for the moon to be in focus and magnified. You just made a refractor telescope, exactly like Galileo did 400 years ago!
13. Draw a diagram of your telescope and include the following:
    a. Label the two lenses
    b. Label the light source
    c. Measure the distance between the light source and the first lens and draw it in your diagram
    d. Measure the distance between the first and second lens and draw it in your diagram
    e. Title your image – what kind of telescope is it?
    f. What is the magnification of your telescope? Add this to your drawing under the title.

14. Now, we're going to replace one of the lenses with a curved mirror to make a reflector telescope.
15. Mount the mirror at the far end of the optical rail. The light source is still at the opposite end.
16. Move the index card into position to catch the reflection of the moon. Adjust the mirror so that the moon is right over the rail and in focus. Make sure the index card is not attached to the optical rail.
17. Pick up your double-convex lens and place it on the opposite side of the card from the mirror and look through it to focus the image as we did before.
18. Uh-oh! Did you find a problem? That's right – your *head* got in the way of the light source, didn't it?
19. What if we use a tiny mirror to change the direction of the light and then we can focus it?
20. Open up the paperclip into an L-shape and hot glue or tape one side of the L to the back of your mirror.
21. The other end of the paperclip attaches to the popsicle stick so you can insert it into the optical rail.
22. Hold the popsicle stick and paper clip junction as you rotate the mirror into position. You need to flip it 90 degrees down and over at 45 degrees.
23. Insert the secondary mirror (the tiny one we just mounted on a popsicle stick) into the optical rail.
24. Adjust your rail so that the moon is right over the rail and at the edge of the index card.
25. Adjust the image of the moon by moving the mirror so that the moon is the same height as the tiny mirror.
26. When you've got it, remove the card and the image should be right on your card. Look right at the tiny mirror with your eye and see if you can spot the crescent moon.
27. Take your magnifier and hold it up to your eye to see if you can make that focused image even larger. The magnifier is your *eyepiece*. The curved mirror is your *primary mirror*. The tiny flat mirror is your *secondary mirror.*
28. Draw a diagram of your telescope and include the following:
    a. Label the two mirrors
    b. Label the lens (what kind is it?)
    c. Label the light source
    d. Measure the distance between the light source and the first (primary) mirror and draw it in your diagram
    e. Measure the distance between the first and second mirrors and draw it in your diagram
    f. Measure the distance between the second mirror and your magnifier and draw it in your diagram
    g. Title your image – what kind of telescope is it?
    h. What is the magnification of your telescope? Add this to your drawing under the title.

Reading

The word *telescope* came about in 1611 when a Greek mathematician was presented with one of Galileo's instruments. Back then, a telescope was a couple of lenses spaced apart carefully in order to observe distant objects. The first known telescopes were used to look at objects in the distance on land, not the stars.

The earliest telescopes were refractor telescopes. While Galileo is often credited with the first telescope, it was actually first constructed in 1608 individuals in the Netherlands. Galileo was the first person to take the telescope and point it at the stars.

There are different types of astronomers, some of whom have never looked through a telescope. For example, radio astronomers use satellite dishes to "view" the sky while backyard astronomers use optical telescopes armed with cameras. Professional observational astronomers use computers and specialized camera equipment to look through their X-ray scopes and determine what's out there. And the kid down the street uses a new set of binoculars he got for his birthday. They are all doing astronomy, just in different ways.

Amateur astronomers usually have smaller telescopes, typically 4" to 20" in diameter. They generally don't get paid to do astronomy. They just do it for the love of it, and they are the ones you'll find on sidewalks and sharing views of the sky with the general public during local stargazing events. Many amateur astronomers have discovered new objects based on their raw knowledge of the sky.

Professional astronomers come in two varieties: observational and theoretical. Professional observational astronomers mostly use expensive scientific instruments to look through their massive telescopes for them. They spend a lot of time measuring things, taking data, and crunching the numbers. They are very good at designing and performing experiments that answer the big questions to which no one knows the answers.

Professional theoretical astronomers think up new ideas and new models for fitting the data so that it makes sense in the field of physics. They are great at asking the big questions in the first place. Albert Einstein was a theoretical astronomer, as he hated to do experiments of any kind. Instead, he preferred to sit back and *think* about what might happen in the laboratory of his mind.