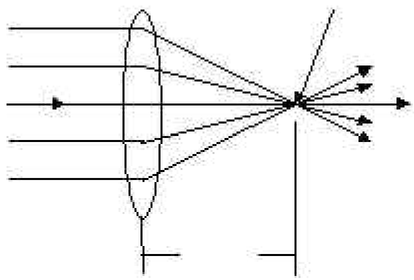
Lab 3: Lenses

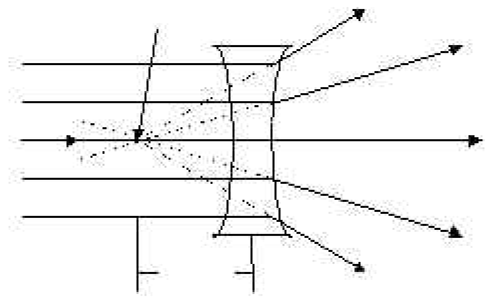
1. The two figures below illustrate how light bends for convex and concave lenses.

Positive Convex Lens



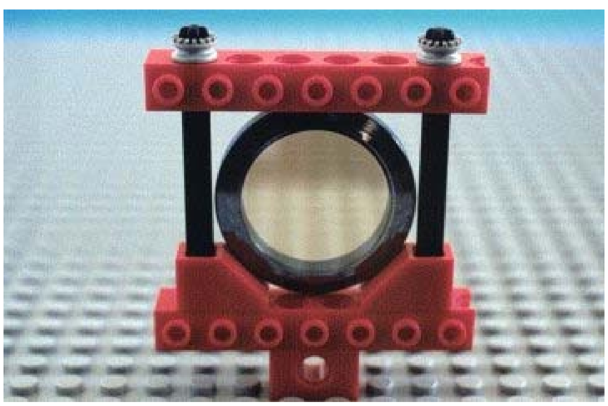
Focal Point Length

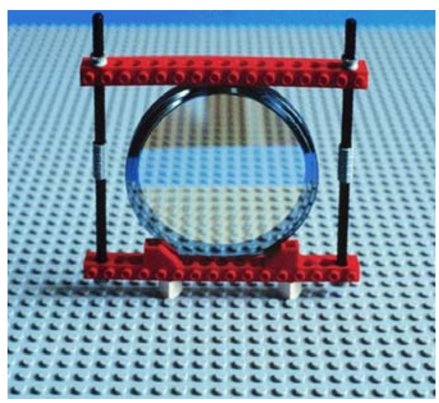
Negative Concave Lens



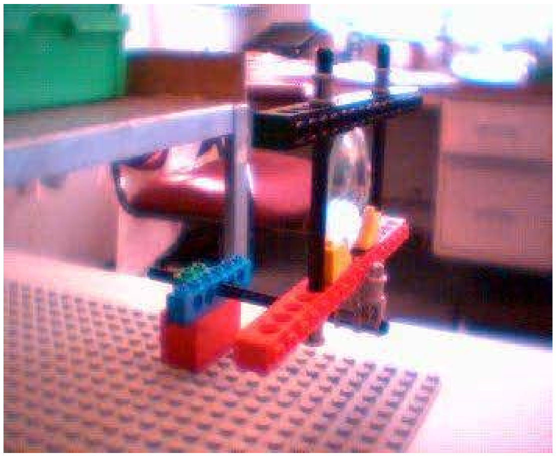
Focal Point Length

2. In this lab, you will explore how lenses form images. You will first need to build a LEGO rail and lens mounts. The images below indicate a simple way to secure a large and a small lens using LEGOs. Secure the 17cm and 50mm focal length convex lenses as shown below.





3. Build a rail system for each lens (see images below). When you place the rail on the project board, you can adjust its position by sliding it along the rail.



4. Measure the focal length f_{pos} of the two positive lenses (+17cm and +50mm) by focusing the light from the ceiling lights onto plain paper.

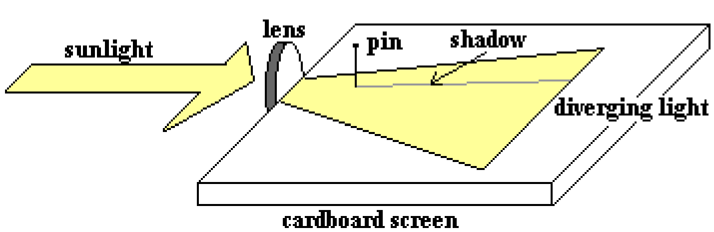
17cm f_{pos} = distance between the lens and the paper = ___________cm

50 mm f_{pos} = distance between the lens and the paper = ___________cm

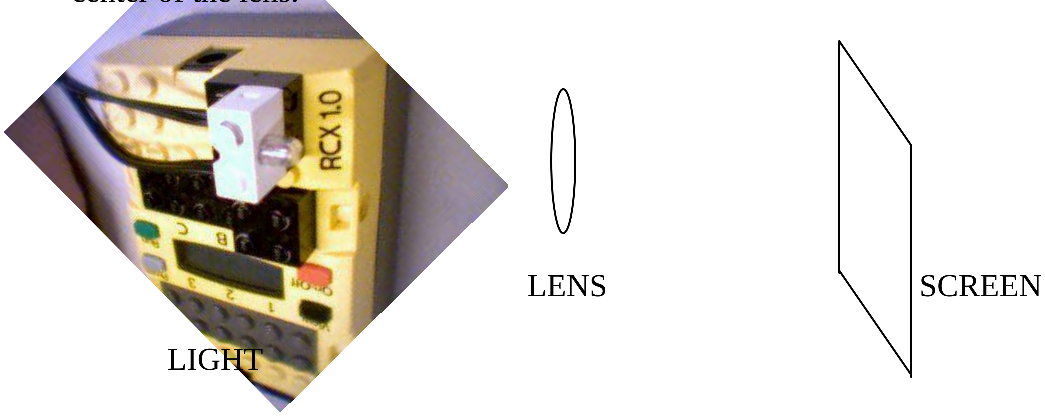
Does your measurement agree with the focal length written on the lens box?

5. Measure the focal length f_{neg} of the negative lens (-17cm). Place the lens perpendicular to a plain paper and shine a light through the lens. Place a pin at two different locations on the paper and trace the shadow. When you retrace the two shadow lines towards the lens, the distance between the point of intersection of the two lines and the lens is the focal length. The image below shows an example setup.

f_{neg} = ___________cm



6. Use the +50mm lens to test image formation of a light source. We went through ray tracing principles in class. A very useful expression to remember is: $\mathbf{(1/f)= (1/s_o)+(1/s_i)}$**,** where f is the focal length of the lens, $\mathbf{s_o}$ is the distance of the object (your light source in our case) to the lens, $\mathbf{s_i}$ and is the distance of the image to the lens. This expression is an approximation. Because your light source is fairly week you need to work in the dark to see images. If you don't like working with the lego light source, you can just use a small object and shine light onto it with a flash light or a bright lamp so that you have enough light to see an image on your screen.
   You will have to place the light at several locations (indicated below) and then place a white paper as a screen on the opposite side of the lens. You get better images when the light source is more or less on the axis that goes through the center of the lens.



   The light will be a LEGO light that connects to port A on the RCX. You should be able turn the light on by any program that runs the motor on port A. If you cannot get the light to turn on, program the RCX to run a motor on port A continuously.

   Once you have the light on and positioned at the right distance from the lens, modify the distance of the screen until an image forms (you can use the equation above to estimate where your image should be). Record your findings below.

   What happens to the image at each of the following locations of the light?

Object Distance	Image Distance	Image Orientation
10cm		
5cm (focal length)		
2.5cm		

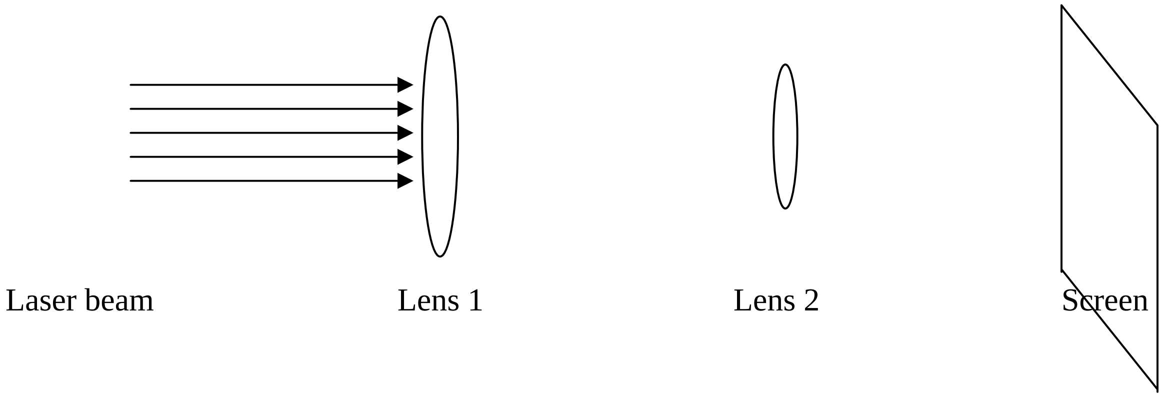
   In the last case, you have a virtual image. Do you remember how you see virtual images?

7. Mount two convex lenses on the track, one small (+50mm) and other large (+17cm). Place your diode laser on one side and plain paper on the other side of the set up. The centers of your lenses and the diode laser should be located along the same axis.

Set the distance between the lenses to be 50mm+17cm = 22cm.

What is the size of the laser beam on the screen compared to the original size of the beam when the 17 cm lens is positioned closer to the laser diode?

Illustrate how the laser beam is affected by the two lenses.

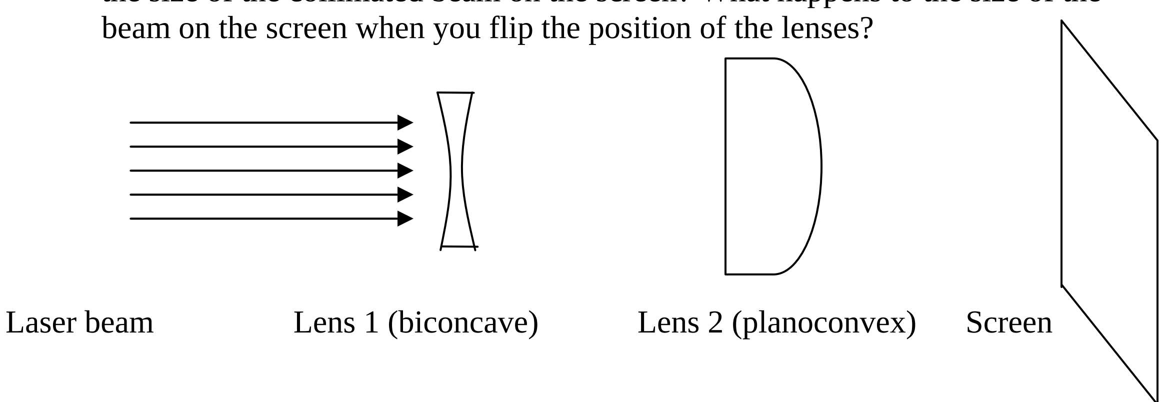


8. In principle the ratio of the beam size on the screen to the original beam size equals the ratio of the focal lengths of the two lenses. This is the magnification *M* of the two lens system. You have built a Keplerian telescope.

$$M = \frac{f_{Lens2}}{f_{Lens1}}$$

9. Now examine what happens if you reverse the order of the lenses.

10. Now use the -17 cm biconcave lens and the +35 cm plano convex lens. Place the concave lens closest to the laser beam. Can you figure out what should the distance be between your two lenses to get a collimated (i.e. a beam whose beam size doesn't change noticeably) on the other side of the concave lens? What is the size of the collimated beam on the screen? What happens to the size of the beam on the screen when you flip the position of the lenses?

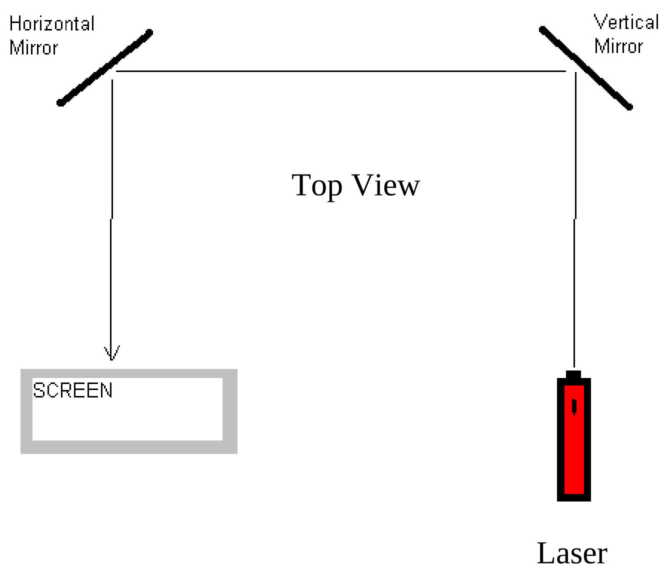


11. This is a Galilean telescope. The magnification is still given by the relationship

$$M = \frac{f_{Lens2}}{f_{Lens1}}$$

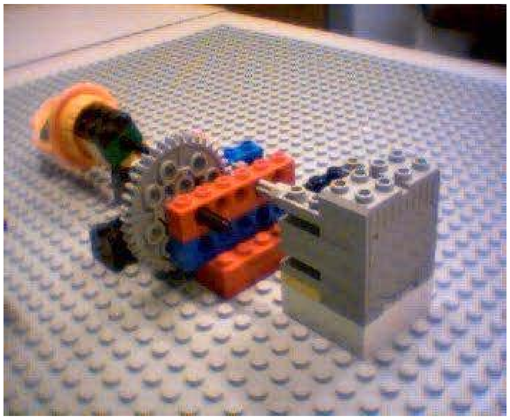
Are your results consistent with this magnification expression?

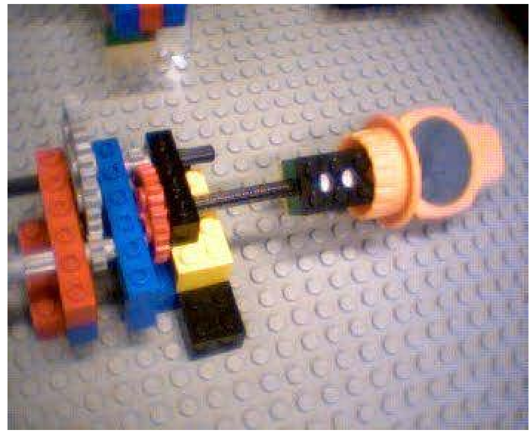
12. You will also need to set up a beam scanning system that is controlled by the software. **In the next lecture, you will have to demonstrate that your beam scanning system works.** You will scan a small $1cm^2$ area using a laser beam. The schematic below illustrates how you will set up the system.



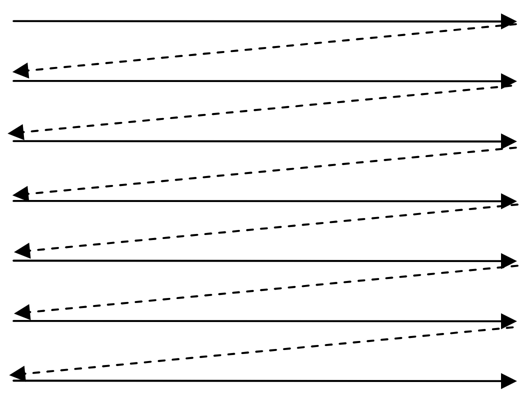
Be careful not to shine the laser into your eyes. You have to also mount the laser so that it is stationary. Mount one mirror on one motor and position it to scan horizontally. Mount another mirror on the second motor and position it to scan vertically. You will need to gear the motors down in order to get precision in scanning. When you gear down the motor, the final speed of rotation will be reduced. The image below (right) illustrates one possible way of gearing.

Gearing: The motor is attached to the smallest gear, which then turns the largest gear. The largest gear turns another smallest gear on the right side, which turns the medium gear. The axle of the medium gear turns the mirror. You may have to use more gears to get even higher precision.





When one mirror scans a line, the other mirror is stationary. Incrementing the position of the second mirror will allow you to scan another line. One mirror should follow a sawtooth pattern, while the second scan one line at a time. In the end, you should scan a pattern on the screen that looks like the one below.



NOTE: Do not disassemble your lens and gearing setups. You will need them for your final project.