Lenses and Telescopes

Takeaway lessons:

- Lenses work by refraction. Convex lenses focus light and concave ones disperse it.
- Convex lenses have a focal point, a point where all light from far away gets focused. This is how camera lenses work. The focal point determines where a magnifying glass switches from an upright image to an inverted image.
- With two convex lenses, you can make a telescope that magnifies objects, but also turns images upside-down. With a convex lens and a concave lens, you can make a telescope that keeps the image right side up.

Focal Length:

Materials:
- Flashlight
- Magnifying glass
- Rulers
- Paper

Lenses are in many everyday objects like cameras, microscopes and magnifying glasses. Can your students name any others? (glasses/contact lenses, some flashlights, telescopes, etc.) Lenses are curved pieces of glass that work through refraction, just like how the glass of water in the previous lesson bent the light coming from the pencil and the coins.

Convex lenses are also called focusing lenses because they focus light. In this activity, we will trace out the shape of light as it goes through the lens. If the ceiling light doesn't provide enough light, have one student (or yourself) hold the flashlight high above the magnifying glass instead. Neither should be able to burn even when focused. Have each student do this for their own magnifying glass in case they are different.

1. Place the paper directly below a ceiling light (or flashlight). Place the magnifying glass on top of the paper.
2. Slowly move the magnifying glass away from the paper. A bright region under the lens where the light is focused should be brighter than the other areas of the lens. Watch this spot as the magnifying lens is raised.
3. At some point the size of the bright spot should be at a minimum. Stop once you get to this point. The distance where far away light is the most focused is called the *focal distance*. Measure the focal distance of the magnifying lens.

4. In the first drawing on the worksheet, show how the lens is bending the light so that all of the light from the far away light source is going through the focal point. In these kinds of drawings, we can draw light coming from a far away source as parallel lines. (Hint: light moves in straight lines except at the lens.)
5. Extend the lines you drew beyond the focal spot. What does this mean will happen to the size of the bright spot if you move the magnifying lens further away from the paper? Try it and see if you're right.

Images:

Magnifying glasses are used to magnify images. But how does that work? In this lesson, we find out.

Materials:

- Magnifying glass
- Paper with letters on it.
- Ruler

1. On the worksheet, there are some letters of different sizes. The first letter is half the size of the second letter and a third the size of the third letter.
2. See if you can use the magnifying glass to make the first letter the same size as the other letters. How far did you have to raise the magnifying glass above the paper for this to happen? Is that less or more than the focal length of this lens? Does it matter where your eye is when you're looking?
3. What happens if you hold the magnifying glass further from the paper than the focal length? Are you still able to see the letters? Are they still right side up? If you put your eye next to the lens, do you still see the letter?
4. What's happening here is the bending of the light is creating images of these letters. When the magnifying glass is close to the paper, the image of the letter appears to be upright and behind the paper. When the magnifying glass is far from the paper, the image appears to be inverted and in front of the magnifying glass.
5. To test this, you can move your head left and right and look at how the letter moves in the lens. An object behind the lens will move to the right of the lens as you move your head to the right. An object in front of the lens will move to the left of the lens as you move your head to the right. (Try this with a finger in front of the lens to convince yourself this is right!)

Camera:

Materials:

- Magnifying glass
- Ruler
- Paper
- Light blocking material

Camera lenses are convex lenses like the magnifying glass. They project an image onto a piece of film (or a chip) to record an image.

1. Find something bright to look at the image of. Windows can work well for this. Ceiling lights can as well. Position your paper perpendicular to the direction of the object you're looking at. Try to block as much outside light as you can from your paper.
2. Put your magnifying glass between the bright object and your paper. Move the magnifying glass towards or away from your paper until you can see a clear image. Is the image right side up or upside down?
3. How far away from the paper does your lens need to be

Telescope:

Materials:

- Magnifying glass
- Concave lens
- Cardboard tube
- Tape

Telescopes let you see far away by combining lenses. A convex and concave lens will produce an upright image. Do not look at any lights through the telescope!

1. The convex lens is the eyepiece and the magnifying glass is the objective. To start, we'll take the convex lens and tape it to the end of the tube without the slit cut in it. The lens is smaller than the tube, so you may want to have a ring of cardboard to tape it to.
2. Hold the eyepiece to your eye and slide the magnifying glass into the slot. Try moving it at different distances from the eyepiece and see how the image through the telescope changes in size.
3. The focal length of the concave lens is 10 mm. Take the focal length you measured for your magnifying lens in the first part and subtract 10 mm from it. Move the magnifying glass that far away from the eyepiece. The image through the telescope should be clear and magnified. (It may be distorted because the magnifying glasses are not the best.)
4. Once you have a good place for your objective, tape it in place.

5. How magnified are objects through the telescope? One good way to estimate this is to look at an object through the telescope in one eye and not through it in the other. You should see two images of the same thing on top of each other and can estimate the magnification that way. If you place the objective at the position in part 3, the magnification should be the focal length of your magnifying glass divided by 10 mm. Is this about right? (It may not be, again due to the magnifying glass).