Be a Laser Scientist

Physics Question: How can we change the direction light energy travels in?

MATERIALS:

- Large balls (1 per 3–4 students)
- Small balls (1 per 3–4 students)
- Laser pointers (1 per 3–4 students)
- Wooden blocks (1 per 3–4 students)
- Mirrors (4 per 3–4 students)
- Binder clips (4 per 3–4 students)
- White cardstock sheets (1 per 3–4 students)
- Metal rings (1 per 3–4 students)
- Pencils
- Lab notebooks
- Laser Scientist Career Card
- Masking tape
- Red permanent marker
- Optional materials:
  - Pump for inflating balls
  - Extra batteries for laser pointers
  - Images or videos of space probes or satellites
  - Rulers

Prepare

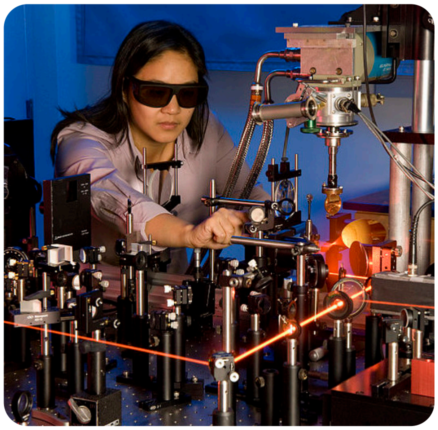
1. If necessary, inflate the small and large balls.
2. Use the red marker to make an "X" or large dot on each of the large balls to mark the location of the "receiving station." Depending on the type of ball you use, you could either draw directly on the ball, or draw on a piece of tape and place the tape on the ball.
3. Use tape to securely attach each laser pointer to a wooden block. Make sure that the laser's power button is accessible and that the laser is aligned as straight as possible on the block.
4. Attach a binder clip to the side of each mirror to create a stand that will hold the mirror upright.
5. Check that the laser pointers are working and replace batteries as needed.
6. (Optional) Create a materials kit for each pair of students containing a large ball, a small ball, a laser block, four mirrors with stands, and a white cardstock sheet.
7. Before beginning the activity, hang the "Research Lab" sign in a visible location. Have one laser and one mirror available to use for demonstration.

SAFETY NOTE:

Lasers can cause eye damage if used improperly. However, the red lasers used in this activity are unlikely to cause damage unless they are shined directly in the eye for long periods. To avoid this, provide students with clear safety guidelines for handling the lasers, and do not allow them to use the lasers without adult supervision.

Engage

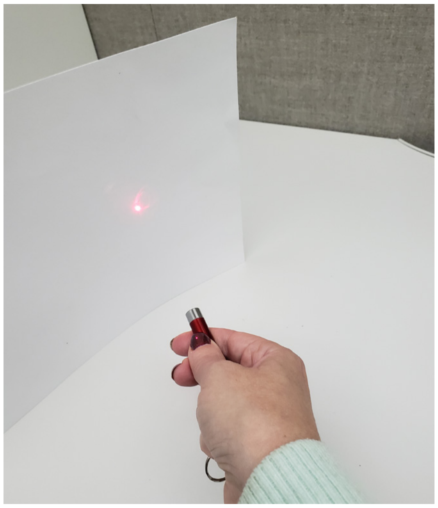
1. Introduce the laser scientist career by showing the group the career card and asking questions to encourage students to think about what a laser scientist might do:
   - *What do you notice about this picture? What do you think this person is doing?*
   - *Have you ever heard the word "laser" before?*
   - *What do you think a laser scientist might do or study?*



2. Explain that **lasers** are machines that make a very narrow beam of light. The beam doesn't spread out or get weaker like other lights so it can travel long distances. Laser scientists study how lasers work and develop devices that use lasers.
   - *What machines or other objects have you heard of that might use lasers?*
3. Introduce the storyline of the activity like this:
   - Imagine we're a team of laser scientists and this room is now our research lab. What does our lab look like?
   - We work for an organization that is building a **space exploration system**: we'll send a probe out to explore outer space, and it will send back information via laser. Equipment here in our lab will receive the laser signal and decode the information.
   - Our job is to make sure the laser signal can reach our lab here on Earth no matter where the probe goes.

To help younger students visualize the space exploration storyline, use the large ball and laser as props to show the probe moving out into space and sending signals back to the "receiving station." You could also use the photos of space probes and satellites in the student lab notebooks to introduce those vocabulary words and what they mean.

4. Explain that you'll need to think about how light energy travels. Introduce the laser pointer and use it to demonstrate. Choose a wall visible to students, but away from anyone's eyes, as a target for the laser beam.
   - *Have you seen something like this before? What part does the light energy come from?*
   - *If I point it in this direction, where will the light go?*
   - *Was your prediction correct? How can you tell?*
   - *We can see where the light ended up, but how did it get there? Is it going straight, or up-and-down, or wobbling? How could we find out?*



5. Invite a volunteer to help you test where the light is going by using a white cardstock sheet. Ask them to hold the sheet in different locations between the laser pointer and the wall to track where the light beam is.
   - *What did the test show us about how the light beam traveled?*

6. Ask **questions** to help the group to think about how to redirect the light. Choose a new target location, such as the ceiling, or a different wall.
   - *What if I want the light energy to end up over there instead? What could I do?*
   - *What if I couldn't move the laser? How could we make the light beam change direction?*
7. Introduce the mirror. Ask the group to help you use the mirror to reflect the light toward your new target location.
   - *What have you used mirrors for? How could we use a mirror to help us get the light onto the ceiling?*
   - *Where is the light beam going now? What could I do to try to get it onto the ceiling?*
8. Connect the mirror demonstration back to the space probe storyline. Point out that the probe might not always be in a straight line from our receiving station on Earth. Use one of the large balls along with the laser to model how the Earth rotates, moving the receiving station (red mark) away from the laser.
   - *What could we do to make sure the laser signal can always get to our receiving station?*
9. Explain that your team has decided to send some **relay satellites** into space that can act like mirrors and bounce the signal in a new direction until it gets to our lab.
   - *Where in space should we put the satellites, so the signal always gets to our station? Let's go to our research lab to figure it out!*

Explore

1. Point out that sending satellites and probes into space is complicated and expensive, so your team can't just send up a whole bunch of them and see what happens! When scientists need to study something that's too big or complicated, they use a **model**—a simpler or smaller version that can help them understand the real thing. You will use a model to figure out where to place the satellites.
2. Introduce the parts of the model system: large ball, laser, mirrors, and small ball. Ask the group to **make connections** between the model and the real-life situation:
   - *If this large ball is the Earth, what do you think the red dot stands for?*
   - *What do you think this smaller ball could represent?*
   - *How do you think we could use these parts to help us figure out where in space our satellites should go?*
3. Demonstrate how to set up the Earth ball on the ring, place the laser block about one foot away, and rotate the ball until the laser light hits the red dot that represents the receiving station.
4. Before distributing materials, discuss the importance of safety when using science tools. Explain that these lasers can't cut or burn skin, but they could damage eyes if someone looked directly at it for too long. Give **three rules for laser safety**:
   - **Laser doesn't move**. Once it is set up, the block with the laser won't move from the table or surface it sits on. Don't pick it up or point it at anyone—even if it's turned off!
   - **Keep your face above the laser**. Use the white sheet to check where the laser beam is, don't put your face down to look!
   - **Turn on the laser only when testing**. Laser beams can travel a long distance – keeping it on when you don't need it means a better chance someone across the room could accidentally get in the way of it!

5. Divide the group into research groups of 3–4 students. Give each group a set of materials and ask them to set up their model Earth and laser satellite so the laser beam aligns with the receiving station.
6. Ask students to look at the first diagram on p. 9 of their lab notebooks. Explain that the diagram is a bird's-eye view of their model (looking down from above). Help them **make connections** between the diagram and their model system:
   - *If the big circle is the Earth ball, what is the red dot?*
   - *Where is the Moon in the diagram? Where should you put your model Moon so it matches this diagram?*

Set-up Tips:

- If you don't have rulers available, students can set the distance between the ball and laser by using the length of their arms from elbow to fingertips.
- Use tape to secure the laser block on the work surface, to remind students not to pick it up or move it.

7. Remind the group that the Earth and Moon are always moving. Explain that the diagrams on p. 10 of the notebook show different arrangements they will have. Your team's job is to figure out where the relay satellites need to be in each arrangement to bounce the signal to the station. Suggest this basic procedure:
   - Set up the Earth and Moon according to one of the diagrams.
   - Place mirrors to direct the laser beam to the receiving station.
   - Use the white sheet to track where the beam is going.
   - Draw the final satellite (mirror) locations on the diagram.

8. As students work on their mirror placements, **encourage scientific thinking** by asking them to make predictions, solve problems, and draw conclusions:
   - Which direction should you turn the mirror to move the beam more to the right?
   - If you've run out of mirrors, how could you change the arrangement to use fewer mirrors?
   - How does this satellite set-up compare to the one you found for the first Earth position?

FOR YOUNGER GROUPS:

- Focus on just one or two of the Earth/Moon arrangements.
- Introduce the arrangements one at a time. Help students set up their models according to one diagram and figure out the best mirror placement for that arrangement.
- Move on to a second arrangement if there is time and interest.

Reflect

1. Gather the whole group together. **Cultivate rich dialogue** by inviting pairs to share their satellite placement solutions.
    - *How did you decide on this satellite placement?*
    - *What things did you try that didn't work?*
2. Discuss the results of the team's research:
    - *What did our satellite solutions have in common? What were some differences?*
    - *What did we find out about the best satellite placements to get the signal to Earth?*
    - *Which arrangement was the hardest? How many satellites did you need?*
    - *What should we tell our organization about the best places to put satellites around the Earth?*
3. Encourage the group to reflect on how they were like scientists during the activity. You may want to show the laser scientist career card again, or refer to the science skills stickers in their notebooks:
    - *What are some of the things we did today as laser scientists?*
    - *How did we think like scientists? What science skills did we use?*
    - *What did you do today that made you feel like a scientist?*
4. Allow time for students to draw or write their reflections in their lab notebooks. Invite them to choose a science skills sticker that reflects a skill they used and add it to their notebooks.

Extend

Ask students to consider additional challenges the satellite system might encounter and adapt their model to find solutions:

- What other Earth/Moon configurations might be a challenge for getting the laser signal to the station? Try more arrangements of Earth, Moon, and space probe and find the mirror placement that works for each of them.
- Satellites are expensive! Find the solution for each arrangement that uses the fewest possible mirrors.
- Once the satellites are in space, it's hard to move them around to new locations. Find a mirror placement that will work for all three of the original Earth/Moon arrangements without moving the mirrors. (The mirrors can turn or tilt but can't change position relative to the Earth or each other.) How many mirrors does it take?

Background

- **Light is electromagnetic energy, a type of energy that also includes radio waves, microwaves, and x-rays**. Light energy travels in waves, and the waves travel in a straight line, unless something happens to change their direction. Light can be bent when it passes from one kind of material into another (for example from air into water) or it can be reflected by a surface and bounce off in a new direction.
- **A laser is an instrument that creates a narrow, concentrated beam of light** of one particular energy or wavelength. The name "laser" is an acronym for *Light Amplification by Stimulated Emission of Radiation*, which describes the process used to create the beam. Most light sources give off light waves that spread out and get weaker as they move away from the source. Laser beams stay visible at much longer distances because the light waves stay tightly focused.
- **Lasers are useful for many purposes**, because they produce specific wavelengths of light and focus a lot of energy into a small area. The kinds of laser weapons shown in sci-fi movies don't exist (yet), but there are lasers in bar code scanners, laser printers, and DVD players. Lasers are used to transmit information in TVs, internet, and mobile phones. They are also used instead of scalpels for delicate eye surgeries, and as cutting tools for making complicated machinery parts. **Laser scientists** work on developing new kinds of lasers, solving problems with existing lasers, and creating new technologies that use lasers.

- **Most space exploration probes in real life use radio waves, not visible light lasers, to transmit and receive information**. These waves are often very weak by the time they reach Earth, so space agencies like NASA use a network of large radio receivers to gather the signals. Like the model used in this activity, the receivers must be very precisely aimed to pick up transmissions from the probe or send new instructions. NASA is currently researching laser technology for space communication, since it could carry information much more efficiently.
- **Relay satellites** are spacecraft that are stationed around the Earth in space to receive signals from further away spacecraft and pass them on to receiving stations on Earth. NASA has a network of ten relay satellites that allow the Hubble Space Telescope, the International Space Station, and other spacecraft to send and receive information even when they're not in line with a receiving station. Unlike the model in this activity, satellites aren't stationary; they are orbiting around the Earth, usually at the same rate that the Earth is rotating, so that they stay above the same spot on the Earth as the Earth turns. A satellite's orbit is difficult to change once it is in place, however, so it's important to figure out where to position all the satellites before launching them!
- For more information about space communication, visit NASA's Space Communications page.

Laser Scientist Quick Guide

ACTIVITY SECTION	DO	ASK
Engage	Use career card to discuss career Introduce story: • Building a space exploration system • Make sure probe's laser signal gets to the station on Earth Demonstrate laser, checking beam location with white sheet, reflecting with mirror	*What do you think this person is doing?* *Have you heard the word "laser" before?* *What do you think a laser scientist does?* *What did the test show us about how the light beam traveled?* *How could we make the light beam change direction?*
Explore	Introduce model system Give laser safety rules Test 3 Earth/Moon arrangements; place mirrors to relay the light beam to the station	*If this large ball is the Earth, what do you think the red dot stands for?* *Where should you put your model Moon so it matches this diagram?* *How could you change the arrangement to use fewer mirrors?* *How does this satellite set-up compare to the one you found for the first Earth position?*
Reflect	Share group results Report conclusions Reflect on career connections Use stickers & notebook to draw/write reflections	*How did you decide on this satellite placement?* *What did our satellite solutions have in common?* *What recommendations should we give about the best places to put satellites around the Earth?* *How were we like laser scientists today?* *What science skills did you use?*