

Mirror, mirror - Teacher Guide

Introduction

In this activity, test the Law of Reflection based on experimental evidence. However, the back-silvered glass mirrors present a twist. As light travels from air into glass, it changes direction (refracts), reflects off the shiny metal back coating, then changes direction again upon emerging from the glass. The reflected ray may not match up with students' expectations, and offers them a challenge to work out what happened as the light traveled into and out of the mirror. Mirrors are everywhere: in our cars, bathrooms, shiny metal surfaces, water, and windows. Large astronomical telescopes use curved mirrors (a rigid glass or polymer coated with a metal) to focus starlight on to electronic detectors.

Objective

Students produce raw data and explanations based on their data. Their raw data are their pencil tracings of incident and reflection rays.

Texas Essential Knowledge and Skills, Grades 9-12:

Astronomy

112.33(c)-2(I) use astronomical technology such as telescopes, binoculars, sextants, computers, and software.

Integrated Physics and Chemistry

112.38(c)-5(G) explore the characteristics and behaviors of energy transferred by waves, including acoustic, seismic, light, and waves on water as they superpose on one another, bend around corners, reflect off surfaces, are absorbed by materials, and change direction when entering new materials.

Physics

§112.39.(c)- 1A: demonstrate safe practices during laboratory and field investigations.

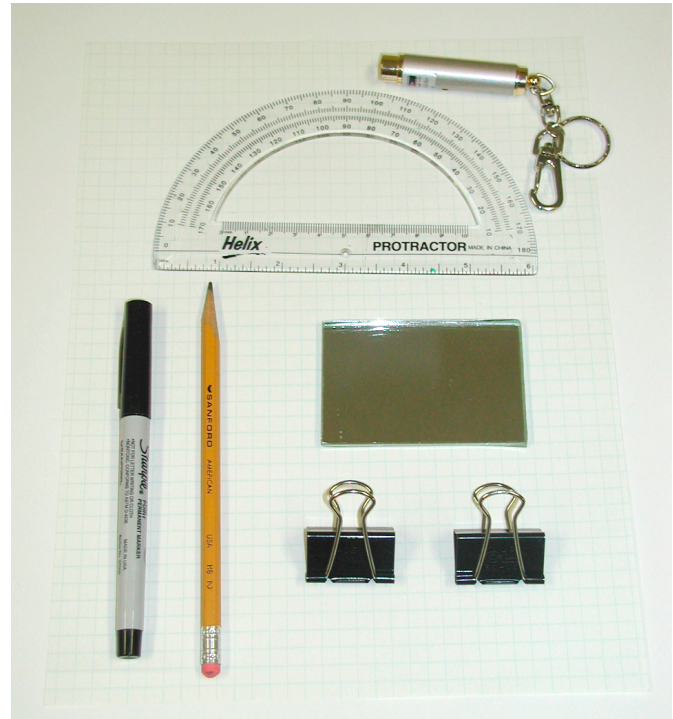
§112.39.(c)- 2E: design and implement investigative procedures, including making observations, asking well-defined questions, formulating testable hypotheses, identifying variables, selecting appropriate equipment and technology, and evaluating numerical answers for reasonableness.

112.39(c)-7D: investigate behaviors of waves, including reflection, refraction, diffraction, interference, resonance, and the Doppler effect.

Materials:

Each student team needs:

- pen and pencil
- Laser pointer
(Scientific Laser Connection:
<http://www.slclasers.com>)
- 2 Binder clips (office supply store)
- 1 Flat back-silvered mirror, 1/4 inch thick
(Wal-Mart, Target)
- Letter size (8.5 x 11 inches) graph paper
- 1 Protractor



Activity:

Preparation

Test the lasers, and make sure that the binder clips can hold them horizontally while keeping the laser "on".

Break students up into teams of 2 to 4. Ask a member from each team to pick up tools and materials for their team.

Engage

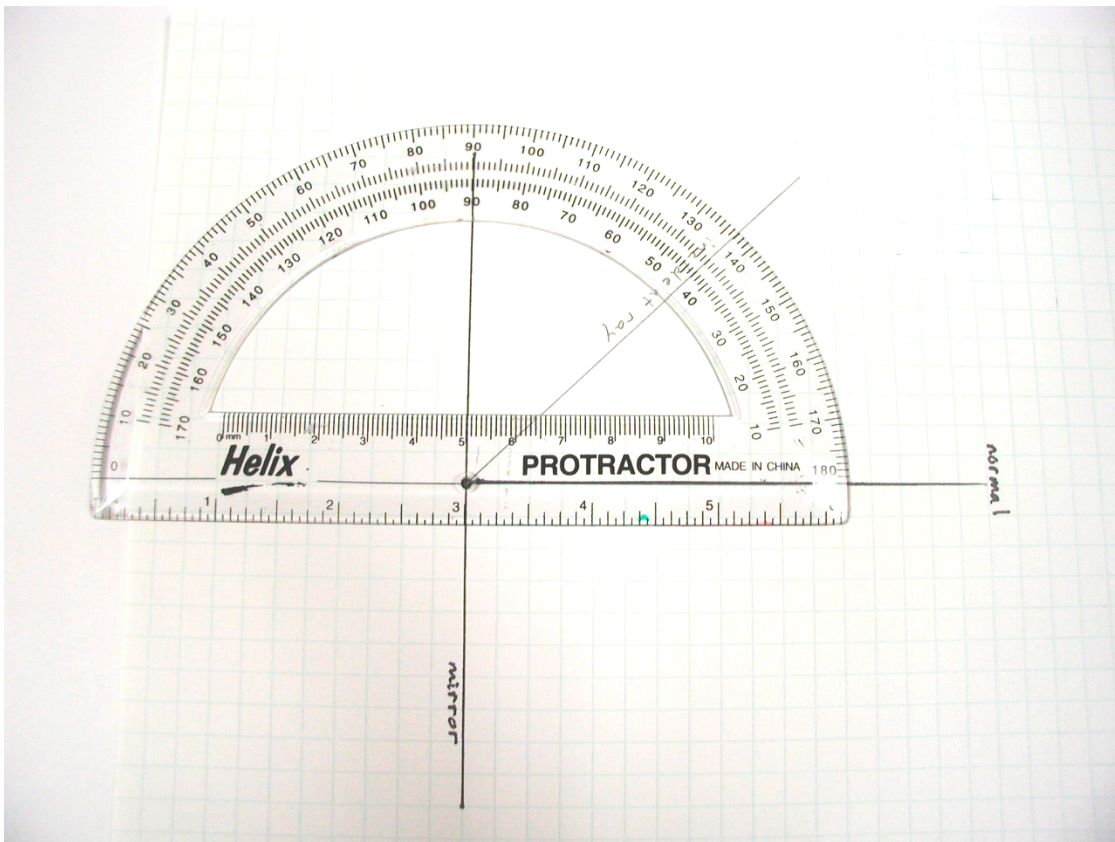
Begin by asking student name mirrors they have encountered today. For instance, they may say "bathroom mirror", "rear-view mirror", "make-up compact mirror", etc. Show them a variety of examples of mirrors, from shiny aluminum foil, to typical back-silvered on glass mirrors. Make a list of these mirrors, so that students can reexamine them after exploring mirrors.

Explore

Ask students to follow the procedure on their instruction sheet:

1. Using a pen, draw a straight line on your graph paper. Label it "mirror".
2. Mark a central point on the line where the graph paper's grid intersects your line, and label it "reflection point".

- Using your pen and protractor, draw the normal line. The normal should be perpendicular to the "mirror" line. Label the normal line "normal".
- Using the protractor and pencil, draw an incoming angle to your "reflection point". You may choose an angle between 20 and 50 degrees from the normal. Label this new line "incident ray".
- Using the protractor, measure the angle between the "incident ray" and the "normal". Write the angle measurement on your graph paper.



- What do you think will happen when the laser's incident ray strikes the mirror? Draw a dotted line to represent your "hypothesis ray".

Most likely, students will draw a "hypothesis ray" that begins at the point on the "mirror" line, and goes straight out at an angle from the normal equal to the incident angle.

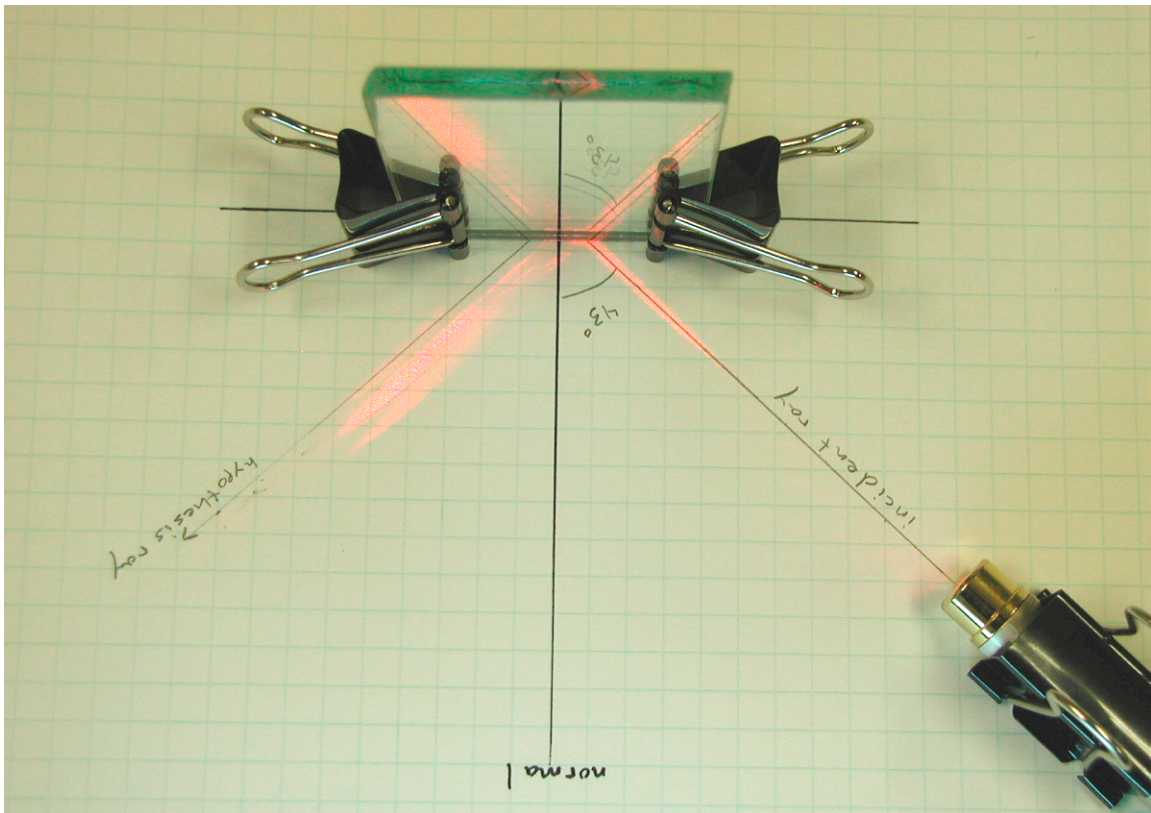
- Place the flat mirror so the back of the mirror is on the "mirror" line. On the graph paper, carefully trace a pencil line along the front side of the mirror. This line marks the edge of the glass surface.

The shiny reflective surface is on at the back of the mirror, behind the glass. It will reflect most of the light and produce the brightest reflection ray. The glass surface will reflect some light, and make dim reflection rays. The glass edge line is critical for helping students make sense of their reflection ray observations in the next steps.

8. Turn the laser pointer on. **Never look directly at the laser beam or allow it to shine in someone's eyes.** Use the binder clip to maintain the laser pointer in the ON position. If you need help seeing the laser beam, ask your teacher for assistance. Make sure that the laser beam follows the "incident" line, and clearly shows a reflected beam on the other side of the normal line.

*The bright reflection ray shows up well if you angle the laser pointer so that the incident and reflected beam "skims" the surface of the graph paper. Once students get the laser pointer adjusted, they should not disturb it until they have recorded **all** their data on their graph paper.*

9. Mark the reflected laser ray in several places (at least 3) along the laser's reflected beam. Do not disturb the laser pointer's position. Turn the laser pointer off when you are done.

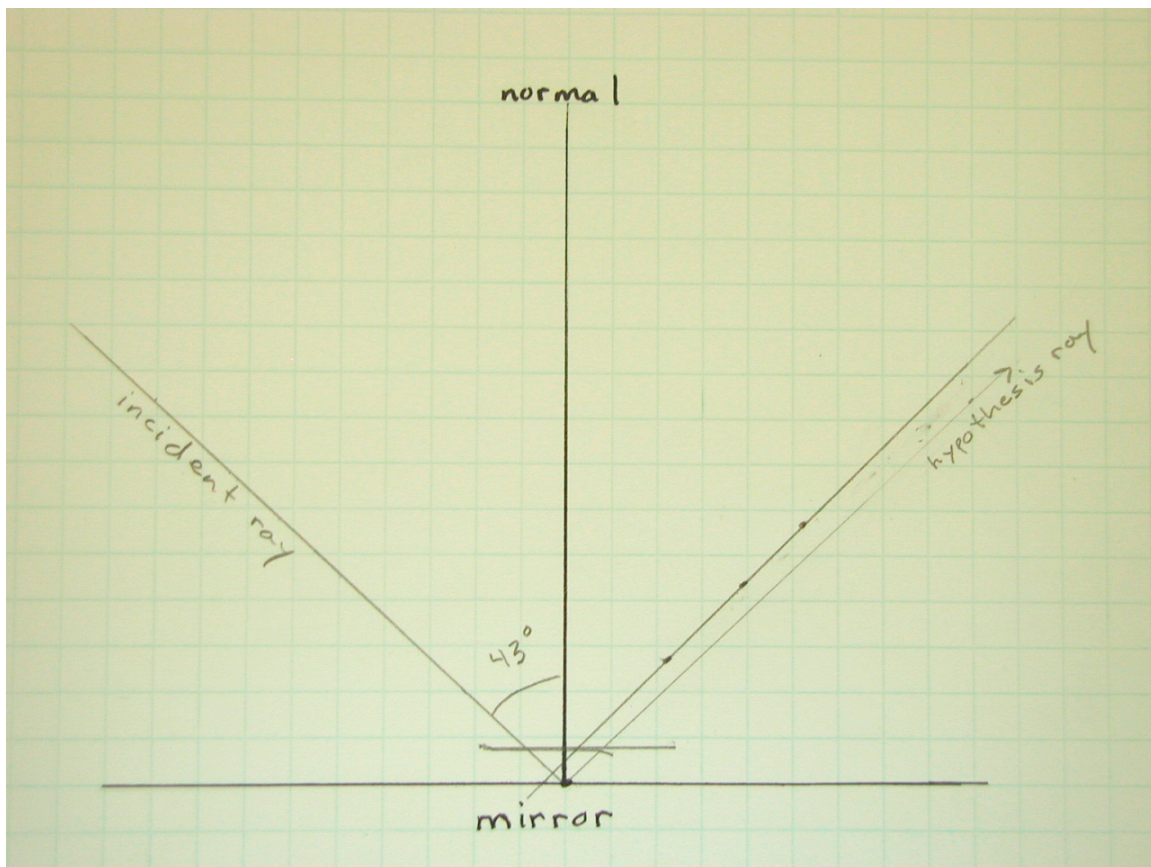


10. Using your protractor, line up the reflected ray's marks, and draw a straight line that intersects the "mirror" line. Measure the angle between the reflected ray and the normal.

At this point, your students should sense something is "wrong" (the observations do not match their expectations):

a. The laser reflected ray does not line up with a hypothesis ray that starts at the mirror line point (where the incident ray pencil line intersects with the mirror line). Double check that students line up the laser's incident ray with their pencil drawn incident ray.

b. Students will probably notice that if they extend the reflected ray toward the mirror, it intersects the normal line. They might be confused about where or how to measure the reflected ray with respect to the normal. Place the protractor eye at the intersection of the normal and reflected ray, and align the protractor to the normal – the reflection ray angle will equal (or very nearly equal) the incident ray angle, even though it is shifted.



Explain

1. Did the law of reflection work with the glass mirror? Explain.

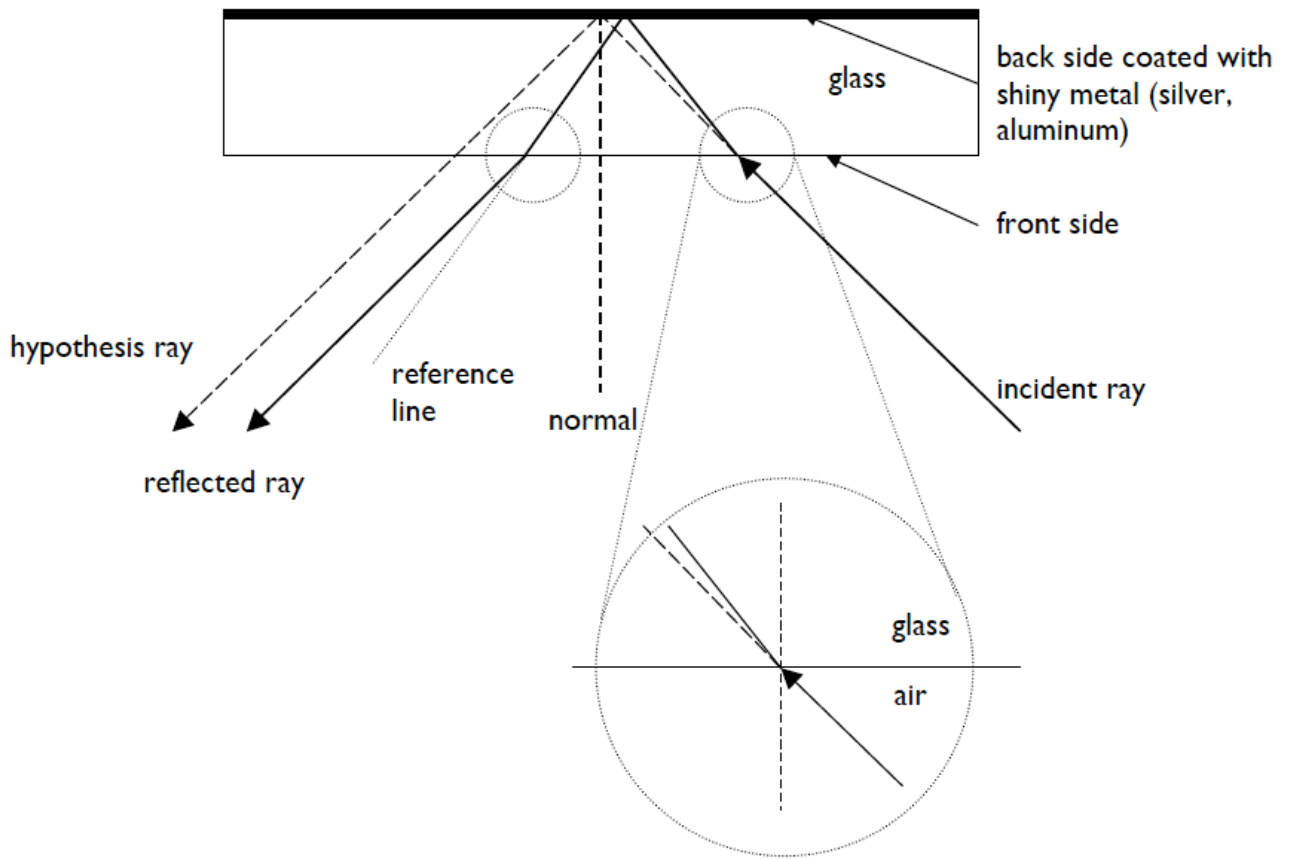
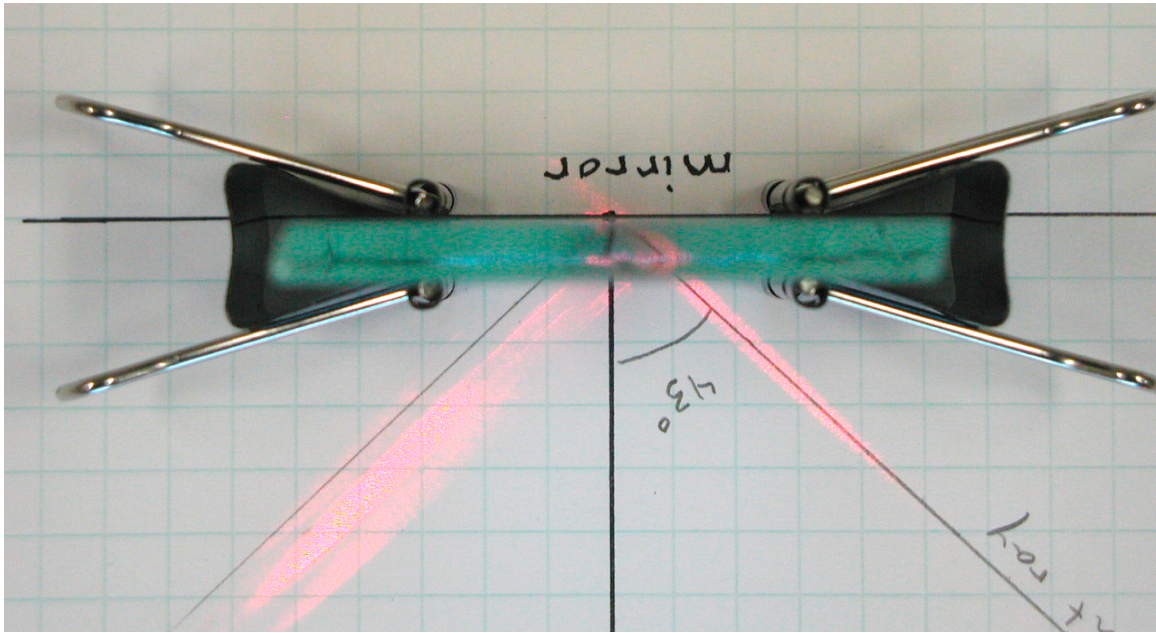
Yes. But reflection is not the only way that the light and matter (air, glass, and shiny reflective metal on the back side of the glass) are interacting. The laser light refracts and changes direction between the air and glass mediums.

2. Based on your data, where do you think the actual reflection point lies on the "mirror" line?

The actual reflection point, where the laser incident ray strikes the metal reflective surface on the back of the mirror, lies just a bit toward the incident ray side of the normal line.

3. What do you think happened to the incident laser beam inside the glass based on your observation data?

As light travels from air into the glass medium, it changes direction (refraction), reflected off the metal reflective back coating, then changed direction again as it traveled from glass to air.



Elaborate

Pick the "Elaborate" activity you think is best for your students.

1. StarDate: "William Parsons" June 17, 2000 and "Return of the Leviathan" June 18, 2000;

"McDonald's 107-inch Telescope" November 26, 2003 and "Staying Busy" November 27, 2003.

Students read or listen to the above StarDate radio shows. Ask students how these scripts relate to their investigation of reflection.

2. What Are Astronomers Doing? Telescopes
(<http://mcdonaldobservatory.org/research/telescopes/>)

Explore the telescopes at McDonald Observatory.

2a. Where are the telescope mirrors?

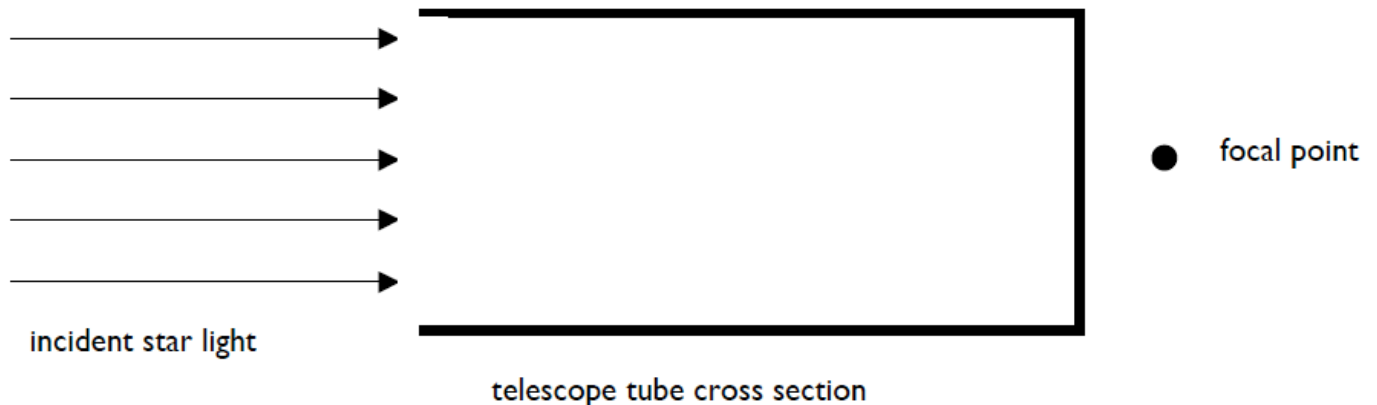
2b. Based on your mirror experiment, where do you think the reflective coating is on the telescope's primary mirror – front or back side? Explain why.

Creative problem solving:

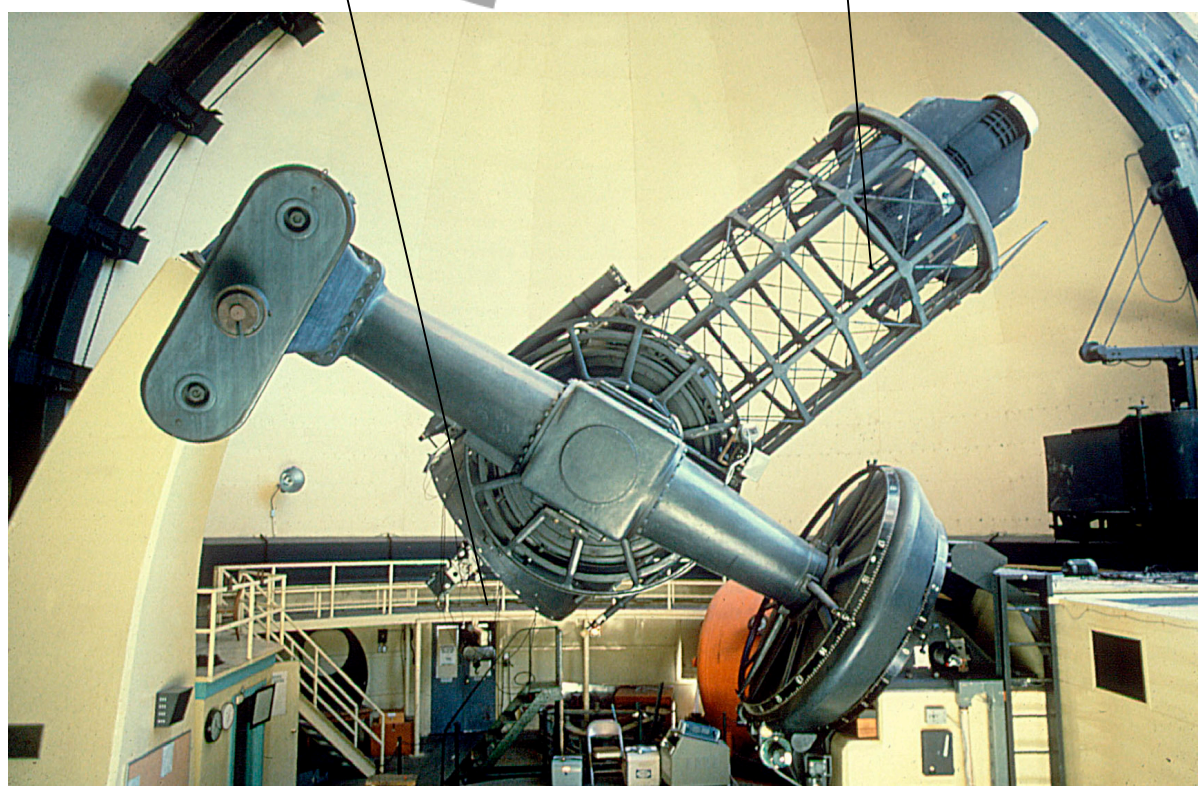
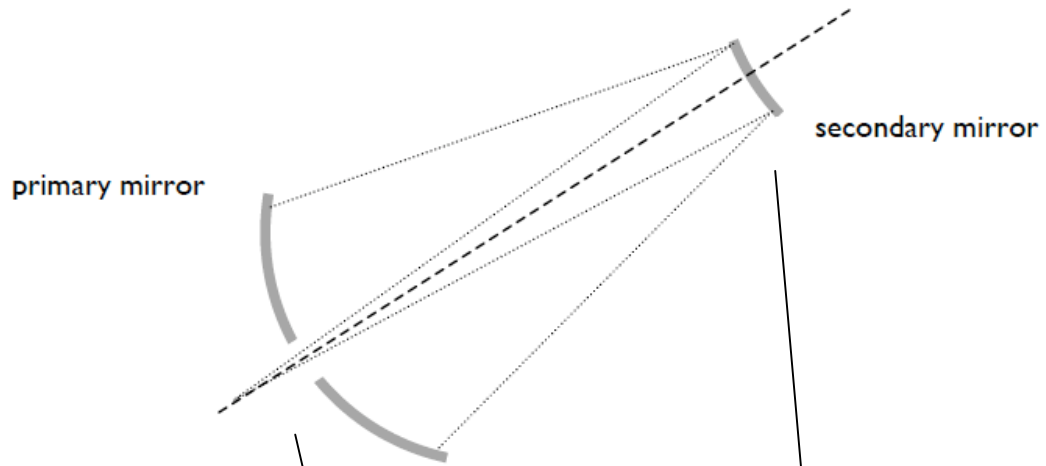
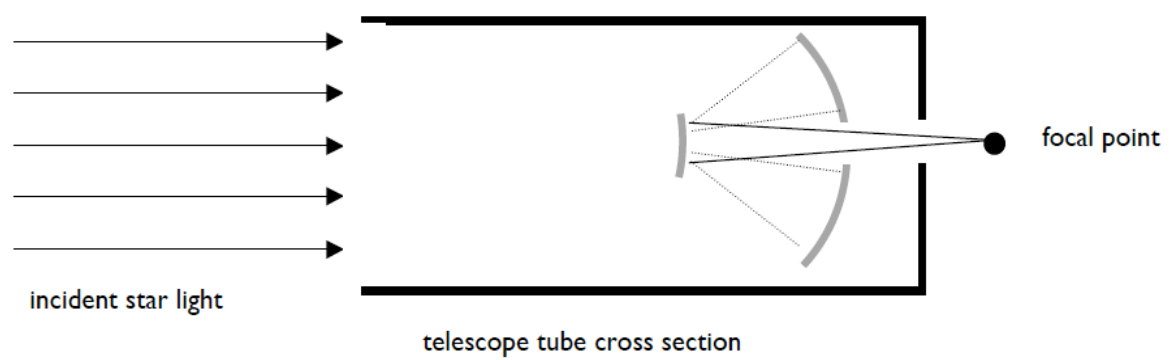
3. Make a reflecting telescope work: Where should you place 2 mirrors in order to direct all the incident star light to the focal point?

Hints:

- You may shape the two mirrors any way you like.
- You may cut holes wherever you think you should.



Elaborate: One possible solution

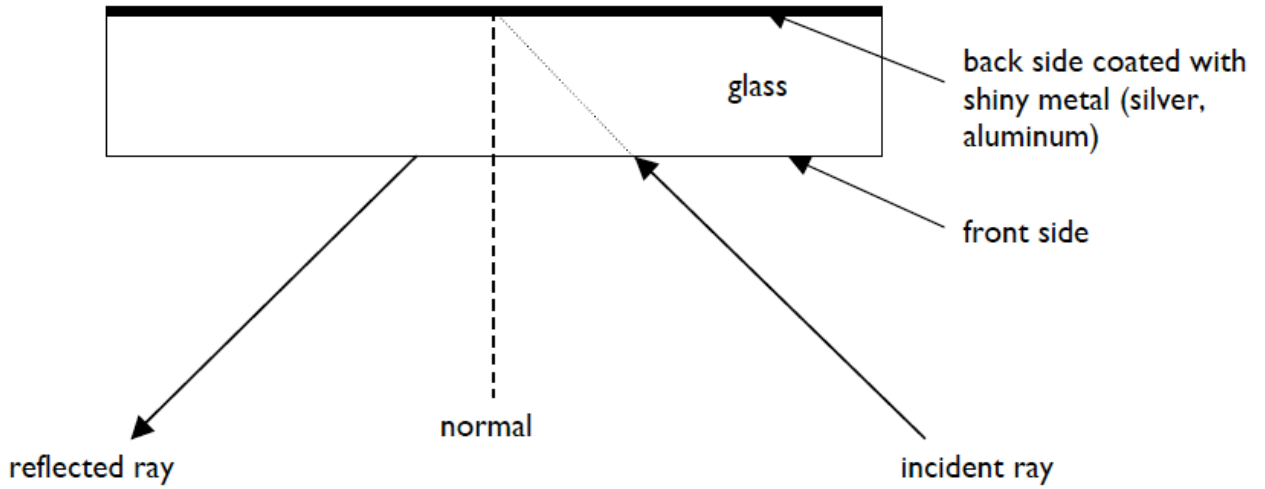


2.1-meter Struve telescope inside its dome at McDonald Observatory

Evaluate

The reflective coating is on the front side of the glass. In your experiment you used a back-silvered mirror, where the glass protected the reflective coating.

Back silvered mirror experiment:



Front-silvered mirror experiment:

