ACTIVITY 14-1
GLASS FRACTURE PATTERNS

Objectives:

By the end of this activity, you will be able to:

1. Use glass fracture patterns to explain how to sequence events that occurred to form the broken glass.
2. Analyze glass fracture patterns and determine the order of the breaks in the glass.
3. Distinguish the differences between fractures formed in tempered or safety glass and the fractures formed in window glass.

Time Required to Complete Activity: 45 minutes

Materials:

(per group of two students)
diagrams included with lab
pencil
ruler
piece of broken window glass (demonstration table)
piece of broken tempered glass or safety glass (demonstration table)

Safety Precautions:

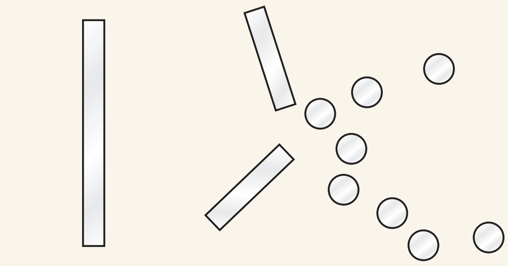
This activity involves paper exercises only. If your teacher chooses to include additional hands-on work with fractured glass, wear gloves and goggles while handling glass. Spread newspaper or construction paper in your work area. Dispose of all materials as directed by your teacher.

Background:

Forensic examiners need to be able to look at evidence left at a crime scene and try to determine what happened. If witnesses or suspects are at the crime scene, they may describe their version of what happened. Evidence can either corroborate their story or present a new version of what actually occurred. In this activity, you will examine glass fracture patterns to determine the sequence of events that lead to the breaking of the glass. The fracture patterns may also indicate where force was applied to break the window, and if there are a series of impacts, which impact occurred first.

Procedure:

1. Examine the diagrams to the right, which show a side view of a window both before and after impact. Determine the point of impact and direction of force.



side view of window before impact *side view of window after impact*

2. Draw an arrow showing the direction in which the force was applied to the window. Explain your answer using the terms *tension* and *compression*.
3. Tempered glass is also known as safety glass. One of the main uses of this type of glass is for car windshields. When impacted, safety glass fractures differently than window glass. Analyze the pictures of safety and window glass. (If you have actual pieces of broken safety glass and window glass, refer to them.)
   a. Record some of the differences you observed between the two types of glass.
   b. Explain how safety glass is better suited for windshield glass than window glass.

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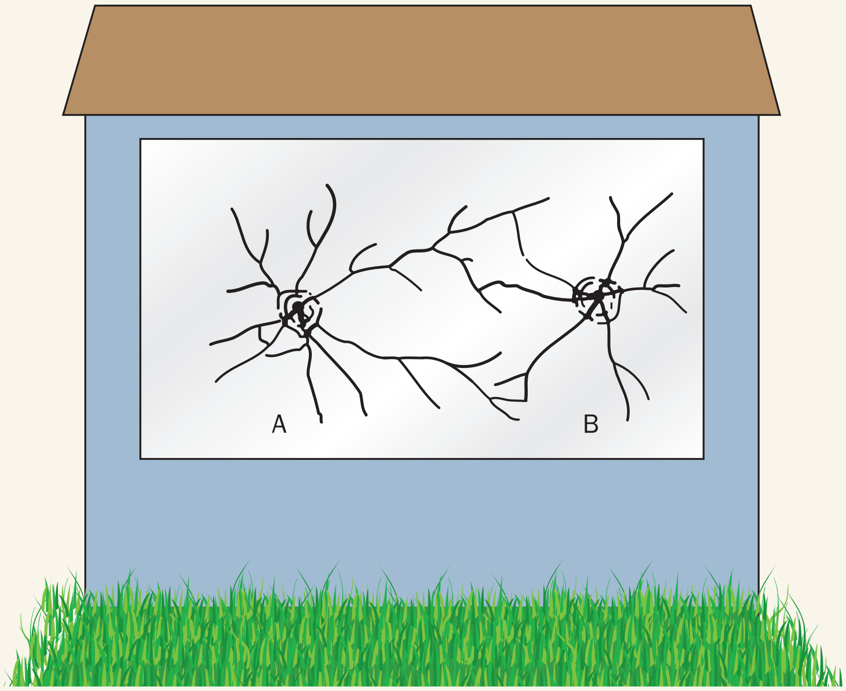
(a) Safety glass

©Stock4B/Jupiter Images

(b) Window glass

4. Police responded to an incident involving gunshots. When they arrived at the scene, they found two men arguing. One man named Henry was inside the home, and the other man, Ralph, was outside near a shed. Two bullets went through the large living-room window. The police did not recover the bullets. Henry claimed that he was firing in self-defense and that Ralph had fired the first shot noted by A in the diagram. In self-defense, Henry shot the second bullet from inside the house, noted by letter B in the diagram. Ralph claimed that he did not fire any guns and that the man in the house fired both bullets at him. You have been called in as a glass expert to analyze the glass. Based on the glass fracture patterns, can you determine if either of the two men is telling the truth or if both men are lying.

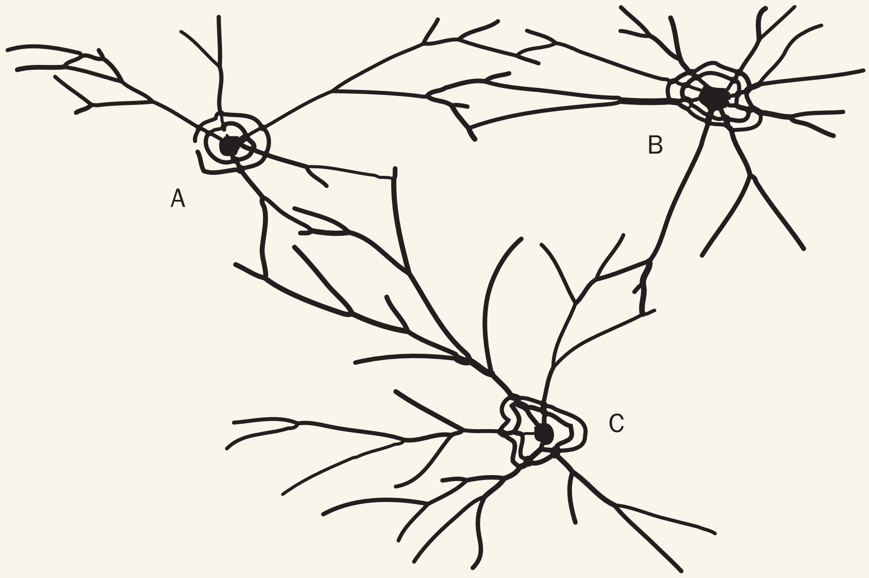


   a. On diagram B, label the primary and secondary fracture lines. Explain your answer.
   b. Based on the fracture lines, which impact, A or B, occurred first? Explain your answer.

c. As a glass expert, you told the police that if you could examine the actual broken glass, it would be possible for you to determine the direction in which the bullets were fired. You explain that it is possible to determine if they were fired from inside the house or from the outside. Explain two different methods you could use to determine the direction of the bullets based on glass analysis.

d. If you examined the actual glass, could you determine who was telling the truth: Henry or Ralph? Explain your answer.

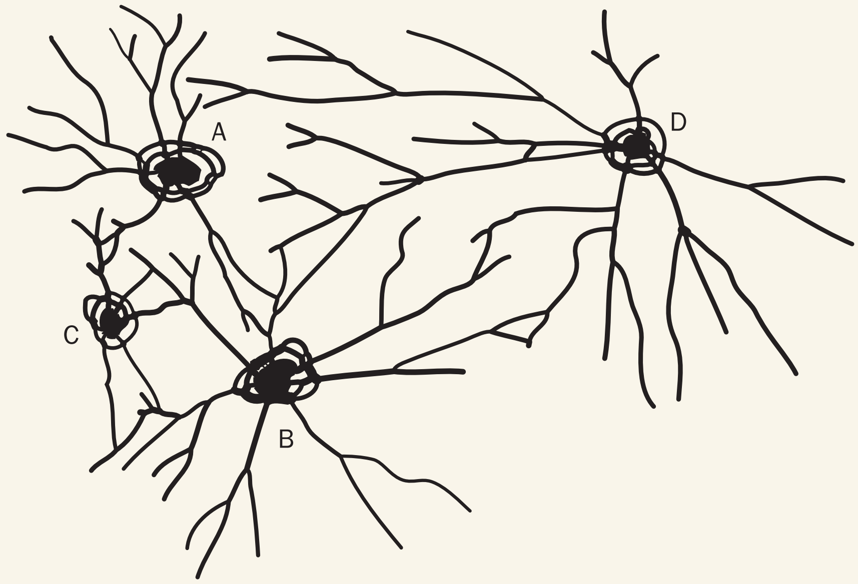
5. Examine the diagram of the glass fracture patterns. Three different impacts resulted in the breaking of the glass. Which impact occurred first, second, and third? Justify your answer in writing and by labeling the diagram using words like "boundary" and "radial fracture."



6. Review the diagram showing four different impacts from four different rocks striking glass.

a. What is the sequence?

b. Justify your answer.



ACTIVITY 14-2
GLASS DENSITY

Objectives:

By the end of this activity, you will be able to:

1. Describe how density is determined using a water displacement method.
2. Calculate the density of various samples of glass.
3. Determine if any of the glass evidence obtained from the four suspects has the same density as the glass found at the crime scene.
4. Maintain the proper chain of evidence when collecting and examining glass evidence.

Time Required to Complete Activity: 45 minutes

Materials:

(per group of three students)
evidence bags containing glass labeled Suspects 1, 2, 3, and 4
evidence bag containing crime-scene evidence labeled CS
displacement containers *or* 10 mL graduated cylinders
beaker (250 mL)
water
dropper bottle of water containing 50 mL of water
balance (accurate to at least .01 gram)
forceps
newspaper or construction paper
labeling tape
permanent marker pen

Safety Precautions:

Wear gloves and goggles while handling glass. Spread newspaper or construction paper in your work area. Dispose of all materials as directed by your teacher. Immediately report any accidents with glass to the teacher.

Background:

The density of glass fragments found at a crime scene can be compared to the glass fragments found on suspects. Keep in mind that if the densities do match, this does not prove that the suspect is guilty, because glass would be considered class evidence.

Glass fragments from a crime scene need to be matched with any glass fragments associated with the four suspects.

In this activity, you will be asked to determine the density of glass fragments found at the crime scene and the densities of glass fragments found on any of the suspects. If the densities do not match, you may be able to disqualify a suspect. If you find that the densities do match, then you will need to collect further evidence to help prove that a particular suspect was at the crime scene.

Procedure:

1. Obtain the evidence envelopes labeled:
   Suspect 1
   Suspect 2
   Suspect 3
   Suspect 4
   Crime Scene
2. Using Suspect #1 evidence bag, record your name, date, and time on the Chain of Possession form.
3. Open the envelope labeled Suspect #1. Do not disturb the signatures on the evidence envelope. Open it from a different side.
4. Remove two pieces of glass fragments from suspect's evidence bag #1. Using a balance, determine the combined mass of both pieces. Record the mass on Table 1. Leave the two pieces of glass on the balance for further testing.
5. Reseal the evidence bag. Place a piece of tape over the opened edge. Write your signature or initials across the interface of the tape and the bag to maintain chain of custody. At this point, there should be two taped areas on the bag, both containing signatures or initials on top of the tape. Refer to proper chain of command described in Chapter 2.
6. Set up a 250 mL beaker of water filled to overflowing. You may need to add the last few drops with a dropper.
7. Position a clean, dry, 10 mL graduated cylinder to receive overflow water. Several books may have to be placed under the beaker to adjust the height of the beaker.
8. Slowly add your two glass fragments of glass Sample 1 into the beaker one at a time. Water will spill over into your graduated cylinder.
9. Measure the volume of water displaced by the addition of the two glass fragments. This is determined by reading the amount of water that has overflowed into the graduated cylinder.
10. Record the combined volume for the two glass fragments in Data Table 1.
11. Calculate the density of the glass fragments from Suspect 1 evidence bag and record your answer on the data table.
12. Remove the two glass fragments from the beaker and handle as described by your teacher.
13. Refill the beaker to just overflowing.
14. Repeat the process with glass from (Suspect) 2. Be sure to properly open and reseal the evidence bag. Record your name, date, and time on the Chain of Possession form. Record all information for Suspect 2 in the Data Table.
15. Repeat the process until you have recorded all the information for the glass found on suspects 3 and 4, and the crime-scene evidence envelope.

Data Table: Density of Glass Samples

Sample	Combined Mass of Two Fragments (mass)	Combined Volume of Two Fragments (milliliters)	Density (M/V) (grams/ml)
Suspect 1			
Suspect 2			
Suspect 3			
Suspect 4			
Crime Scene			

Questions:

1. Did the density of the glass found on any of the four suspects match the density of the glass found at the crime scene? Explain your answer.
2. Check your results with your classmates. How did your results compare to those of the rest of the class?
3. Describe how you could improve your experiment to have more reliable results.
4. Based on your results, are you able to link any of the suspects to the crime scene based on your glass analysis?
5. Explain why glass is considered to be a form of class evidence.
6. If you did find that the glass density of fragments found at the crime scene matched those found on one or more of the suspects, what other additional tests could be done on the glass evidence to further link the suspect(s) to the crime scene?
7. In checking the density of the glass fragments, why did you use only two fragments of glass and not all of the glass fragments found in the evidence bag?

ACTIVITY 14-3

DETERMINING THE REFRACTIVE INDEX OF LIQUIDS USING SNELL'S LAW

Objectives:

By the end of this activity, you will be able to:
Determine the refractive index of three liquids.

Time Required to Complete Activity: 45 minutes

Materials:

(per group of two to three students)
laser pointer (that can be turned on without having to keep pressing down on a button)
paper (8 × 11)
protractor
calculator with sine function or Sine Table
three different liquids (Samples 1, 2, and 3)
ruler (mm or inches)
three semicircle plastic dishes
pencil

Safety Precautions:

Students should not look directly at the laser light.
Students should be careful when handling glass to avoid being cut. Immediately report any injuries to the teacher.

Background:

Light travels through different mediums at different velocities. There is a relationship between the density of a medium and the speed of light: the higher the density of the medium, the slower the velocity of light through that medium. When light passes between two different mediums of different densities, the velocity of the light will be altered. The change in the velocity of light results in a bending of the light wave as it passes through this medium. This bending is known as *refraction*.

As a means of comparison, a ratio of the speed of light through a vacuum (186,000 ft/sec or 56,693 m/sec) is compared to the speed of light through a different medium. This ratio is referred to as a *refraction index* (RI). For example:

Refraction index for water
speed of light in a vacuum = 186,000 ft/sec (56,693 m/sec)
speed of light through water = 140,000 ft/sec (42,672 m/sec)

$$= \frac{186{,}000 \text{ ft/sec}}{140{,}000 \text{ ft/sec}}$$

$$= 1.33$$

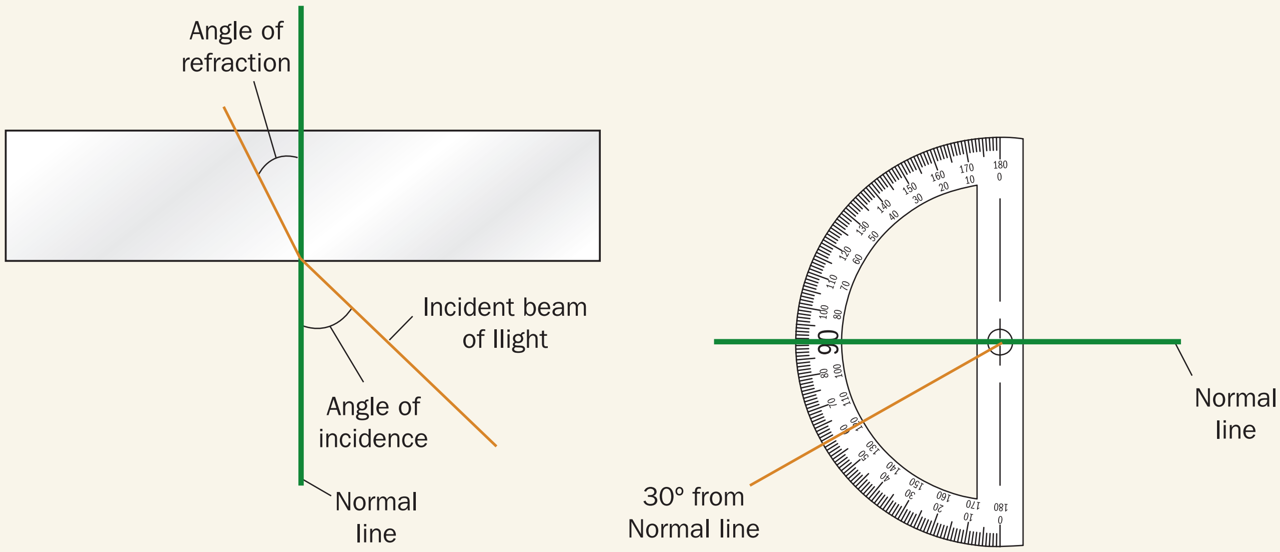
Snell's Law:
Mathematically, the relationship between the refractive indices and the angle of incidence and angle of refraction is expressed as Snell's Law.

n_1 (sine angle of incidence) = n_2 (sine angle of refraction)

n_1 = refractive index of medium 1

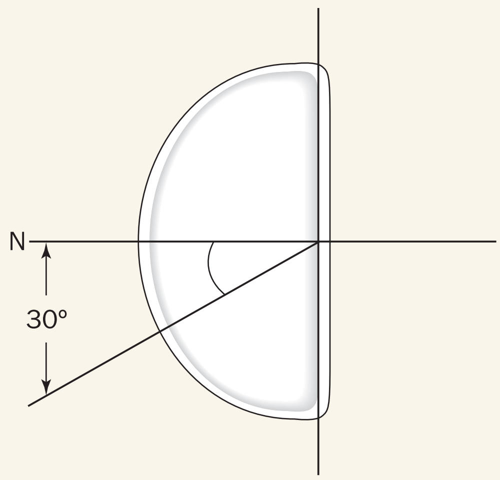
n_2 = refractive index of medium 2

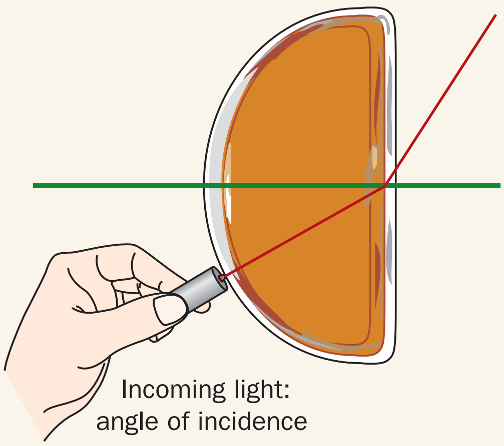
Comparison of Angle of Incidence and Angle of Refraction as light passes between two different mediums.



Procedure:

1. Place a piece of white paper on the table and draw a straight line down the center of the paper. Draw a second line that is perpendicular (90°) to the first line. This second line is called a normal (N).
2. Using a protractor, draw a line on the paper at 30° from the normal as shown in the diagram. This line will also be at a 60° angle from the first line you drew.
3. Obtain a semicircular plastic dish filled with Sample 1 and arrange the dish as pictured in the diagram. Position the center of the protractor at the point where the normal and 30° line meet.





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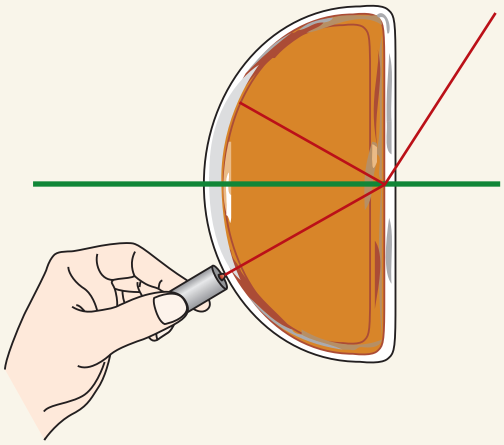

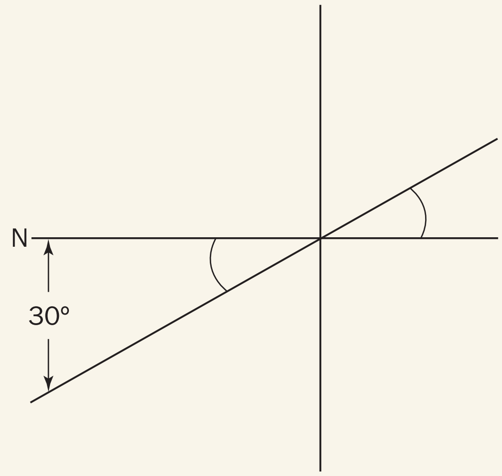

4. Position the laser pointer so that its beam lies on top of the 30° line you just drew.
5. All angles are measured from the normal line. It is called the *angle of incidence.* This is the angle of the incoming beam of light and is equal to 30°. Record 30 degrees as your angle of incidence on your data table. Use a calculator to determine the sine value of 30 degrees and record the sine on your data table.
6. Notice how the beam of light is bent as it passes through the container or liquid and then through the second medium of air. Note where the light shines on the paper on the other side of the liquid. Using a pencil and a dotted line, trace the line of refracted projected light as it exits the plastic dish and passes through the air. Label the line Sample 1.
7. Using this dotted line and the normal line and a protractor, determine R, the *angle of refraction*. Record the angle of refraction on your data table.
8. Using a calculator, determine the sine value of your angle of refraction. Alternatively, a sine table can be used and is found in the appendix at the back of your textbook.
9. Calculate the refractive index for Sample 1 using Snell's Law. Note: the angle of refraction was determined after the laser light was shown through the plastic dish.

   n_1 (sine of angle of incidence) = n_2 (sine of angle of refraction)
   angle of incidence = 30 degrees for all samples
   n_2 = 1 (recall that the refractive index of air is approximately 1)
   n_1 is unknown
   n_1 (sine of angle of incidence) = n_2 (sine of angle of refraction)
   n_1 (sine of 30 degrees) = 1 (sine of angle of refraction)
   n_1 (0.5000) = (sine of angle of refraction)
   n_1 = (sine of angle of refraction)/(0.5000)

Another way to look at this relationship is:

n_1 (sine of angle of incidence) = n_2 (sine of angle of refraction)
n_1 = n_2 (sine of angle of refraction)/(sine or angle of incidence)

10. Label two new sheets of paper, Sample 2 and Sample 3. Repeat this procedure for each of the Samples 2 and 3. Use 30 degrees as your angle of impact for each sample, and calculate the refractive index of each of the liquids. Record all information in the data table.

Refractive Index of Three Liquid Samples

Liquid Sample	Angle of Incidence (I)	Sine of Angle I	Angle of Refraction	Sine of Angle R	Refractive Index of Liquid
1	30°				
2	30°				
3	30°				

1. Compare the refractive indices of each of the three liquids. Which liquid had the highest refractive index and which one had the lowest refractive index?
2. Describe any visual correlation you can make about the refractive index and the appearance of the three different liquids.
3. Suppose you set your angle of impact at 45 degrees instead of at 30 degrees. Would you have obtained a different refractive index using the 45-degree angle of incidence instead of the 30-degree angle of incidence? Explain your answer.
4. Your two different mediums through which light passed in this experiment were the liquids and the air. In terms of density, air is less dense than any of the liquids. Would you expect the velocity of light to be faster or slower moving through the liquids than the air? Explain your answer.
5. If we assume that air is less dense than the liquids, did the angle of refraction move toward the normal, or did it move away from the normal as the light traveled from the liquid (more dense) through the air (less dense)? Support your answer with data from your table.
6. Suggest other liquids to test for refractive index that you think might give you a higher refractive index than any of the liquids selected in this experiment.
7. As the thickness of the liquid increases, what effect might that have on the bending of light? Will the bending become more pronounced or less pronounced? Explain.

ACTIVITY 14-4

DETERMINING REFRACTIVE INDEX OF GLASS USING LIQUID COMPARISONS IN A SUBMERSION TEST

Objectives:

By the end of this activity, you will be able to:

1. Perform a submersion test on glass fragments to estimate the refractive index of the glass fragment.
2. Explain how to do a submersion test on glass fragments.
3. Compare the refractive indices of the evidence glass pieces to the refractive index of the crime-scene glass.
4. Determine if the suspects can be linked to the crime scene based on the refractive indices of the evidence glass and the refractive index of the crime-scene glass.

Time Required to Complete Activity: 45 minutes

Materials

(per group of four students)
3 samples of glass fragments contained in evidence bags labeled Crime Scene, Suspect #1, Suspect #2
1 pair forceps
1 beaker of 250 mL detergent solution
250 mL of tap water
permanent marker
1 test tube rack
labeling tape
paper toweling
set of 7 small test tubes half filled with
- methanol
- water
- isopropyl alcohol
- olive oil
- cinnamon oil*
- castor oil
- clove oil*

*Because of expense and odor, these two tubes may be set up by your teacher as a demonstration for the entire class to use.

Safety Precautions:

Spread newspaper or construction paper in the work area to capture small fragments of glass. Handle glass with forceps.

Scenario:

Students at a local high school decided to steal the basketball trophy in the locked display case near the gym. They planned to steal the trophy after 7 p.m., when only a few janitors would be in the building. Once the glass case was broken, they thought they could easily run out of the back door by the gym. What they didn't plan on was that the coach came back to his office just as he heard the glass breaking and saw the two boys running out of the gym.

The coach thought he recognized one of the boys by his coat that held numerous old snowboard lift tickets from the past four years. He reported the incident and gave a description to the police, who quickly located both boys at the pizza place across the street from the school.

Did they break into the display case and steal the trophy? The police brought the boys to the police station, where they examined the bottom of their sneakers. As expected, small particles of glass were embedded in the soles of their sneakers. Did the glass in their sneakers match the glass found in the display window where the trophy case was removed? What type of testing can be used to match the glass in their sneakers to the glass found in the display case?

Background:

In this activity, we will try to match the glass found in the sneakers on the two suspects to the glass found in the broken display case. Refractive indices of the glass found in their sneakers will be compared to the refractive index of the glass in the display case.

Liquids of known refractive indices can be used to visually estimate the refractive index of glass samples. In order to estimate the refractive index of a piece of glass, submerge individual pieces of the glass in a series of different liquids. If the glass appears to disappear when submerged, then the glass has a refractive index similar to the solution. If the refractive index of the glass differs from the refractive index of the solution in which it is immersed, you will be able to see an outline of the glass. This is known as a submersion test for refractive index.

After testing the evidence glass from the sneakers and determining the refractive indices of the glass, you will test the crime-scene glass for its refractive index. If the glass from the crime scene has the same refractive index as the glass from the suspects' sneakers, it can place the suspects at the crime scene.

Procedure:

1. Obtain a test tube rack with five test tubes. Label the tops of the five test tubes in the following order:
    - methanol
    - water
    - isopropyl alcohol
    - olive oil
    - castor oil
2. Half fill each test tube with the five different liquids as numbered in the table. They are arranged in increasing order of refractive index. The table provides the refractive index of each liquid.

Data Table 1: Refractive Indices of Liquids

Liquid	Refractive Index
1. Methanol	1.33
2. Water	1.33
3. Isopropyl alcohol	1.37
4. Olive oil	1.47
5. Castor oil	1.48
6. Clove oil (teacher display)	1.54
7. Cinnamon oil (teacher display)	1.62

3. You need to maintain proper chain of custody when opening and resealing each of the evidence envelopes. Remember to:
   a. Cut open the bag in an area that does not disrupt the signature of the person who had the evidence bag before you.
   b. Sign and date the Chain of Possession form on the front of the evidence bag.
   c. When resealing the bag, tape each bag and sign your name or initials across the interface of the tape and the package.
4. Starting with the crime-scene glass, submerge a fragment of the glass into test tube 1. Hold the glass fragment with a forceps. Do not let go of the glass fragment.
5. View the submerged glass at eye level. Is the glass invisible, or can you see the glass fragment? Record your results on Table 2. Remember: If the glass and the liquid have the same refractive index, the glass will seem to disappear in the solution. The test tube containing the liquid that results in the disappearance of the glass fragment best approximates the refractive index of the glass.
6. Remove the piece of glass from test tube 1 using the forceps. Wash the glass and forceps in the soap solution, rinse the glass and forceps in a beaker of water, and dry them on the paper towel.
7. Submerge the *same piece* or a new piece of glass in test tube 2 and observe. Is the glass visible, slightly visible, or invisible? Record the information on Data Table 2.
8. Rinse the glass piece and forceps in the soapy water followed by tap water and dry before continuing with the same procedure until you have tested the crime-scene glass on all seven solutions (your five solutions and the two solutions set up by your teacher).
9. Repeat the procedure for the submersion test on a glass fragment found on Suspect #1 and Suspect #2 and record your results in Data Table 2.

Data Table 2: Submersion Test Results

Test Tube #	Refractive Index of Liquid	Visibility: Visible / Slightly visible / Invisible		
		Crime Scene	Suspect 1	Suspect 2
1. Methanol	1.33			
2. Water	1.33			
3. Isopropyl alcohol	1.37			
4. Olive oil	1.47			
5. Castor oil	1.48			
6. Clove oil (teacher display)	1.54			
7. Cinnamon oil (teacher display)	1.62			

Questions:

1. Based on the results of your submersion test, record the estimated refractive indices for each of the glass fragments.
   The Refractive Index (RI) of the Crime Scene glass = ________
   The Refractive Index (RI) of the glass from Suspect #1 = ________
   The Refractive Index (RI) of the glass from Suspect #2 = ________
2. What would you consider to be the experimental errors in using this technique?
3. What could you do to improve the reliability of this experiment?
4. Is your match conclusive? Why or why not?
5. Why would the match of glass from a crime scene and a suspect be considered to be class evidence?
6. Explain refraction of light. Include in your answer the following:
   - two different mediums
   - light velocity
   - density
7. A refractive index of olive oil is equal to 1.47. It is calculated as a ratio between what two numbers?