REFRACTION AND REPAIR

COMMON CORE STANDARDS
CCSS.MATH.PRACTICE.MP1: Make sense of problems and persevere in solving them.
CCSS.MATH.PRACTICE.MP4: Model with mathematics.
CCSS.ELA-LITERACY.RST.6-8.8: Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.
CCSS.ELA-LITERACY.RST.6-8.9: Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

OVERVIEW
In this lesson, students will practice using protractors to measure the angle of refraction of light as it passes through possible repair materials. Students will then choose a material that would best replace missing glass in the damaged 700-year-old original beaker. This brief lesson can be used in conjunction with the Integrating the Arts Islamic Glass Beakers Activity.

MATERIALS NEEDED
- Clear glasses, half filled with water
- Straws
- Copies of Glass Beakers (47.17 and 47.18)
- Copies of Material Reflection Analysis Worksheet
- Protractors
- (Optional) Access to Integrating the Arts Islamic Glass Beakers Activity

ACTIVITY
1. Place a straw in a clear glass filled halfway with water. Ask students to notice that the straw appears to shift position after it enters the liquid. When light travels from air through glass, it is bent, or refracted, at a measurable angle. This is called the angle of refraction. Because the light is refracted at one angle in the air and a second angle in liquid, the straw looks like it is in different positions in each medium: air and liquid.

2. To repair ancient glass, conservators compare the angles of refraction between light passing through the ancient glass with that of potential repair materials. The closer the angle of refraction, the more similar the repair will look to the ancient glass. Allow students to examine and discuss the repairs on Glass Beakers (47.17 and 47.18). Are the repairs apparent? Do they detract from the overall appearance of the objects?

3. Have students complete Material Reflection Analysis Worksheet to determine a compatible repair material.

4. Discuss: Why is important for museum conservators to find a repair material with a similar refraction angle as the original glass?
Glass Beakers (47.17 and 47.18)
Believe it or not, light can also be a rather destructive force. Conservators and curators in a museum are very aware of the affect of light on objects on display. When choosing material to use to repair broken pieces or replace missing sections, conservators have to choose material that will look the same as the original. But how will they determine which material is best?

When light travels from air through glass, it is bent, or refracted, at a measurable angle. We call this the angle of refraction. To repair ancient glass, conservators must compare the angles of refraction between light passing through the ancient glass with that of the potential repair materials. The closer both angles are, the more similar the repair will look to the original glass.

Every transparent material bends light in a different way. This is called the angle of refraction. The materials examined are molded in the shape of a semicircle, because that makes it easier to measure the angle of refraction. In a semicircle, a beam of light is refracted only once. When a beam of light is pointed at the center of the flat part of the semicircle, it is refracted when it enters the material.

But because any radius of a semicircle is perpendicular to its surface, the light passes through without being bent or refracted again when it exits the material (fig. 1). This is not true if the beam of light exits a surface at any angle other than 90 degrees (see fig. 2).

In this activity you will:

1. Measure and record the angle of refraction of light entering the 700-year-old glass.
2. Measure and record the angle of refraction of light entering four different repair materials.
3. Select the repair material with an angle of reflection closest to that of the 700-year-old glass beakers.

As the laser light hits the glass, it should follow the green dotted line. Instead, the orange light is bent, or refracted. Measuring the angle of refraction of light entering the glass, we can see that it measures 35 degrees.

Glass Beaker

Angle of refraction: ___________
DIRECTIONS: Using a protractor, measure the angle of refraction for four different possible repair materials. Record those angles of refraction next to the images.

Material #1: Diamond
Angle of refraction: 

Material #2: Wax
Angle of refraction: 

Material #3: Casting Resin
Angle of refraction: 

Material #4: Wax
Angle of refraction: 

The light shining through our 700-year-old beaker was refracted, or bent, to an angle of 35 degrees. Remember, the repair material that bends light closest to 35 degrees will look most similar to our ancient glass.

Which material would you choose? 