VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE
http://studentorgs.vanderbilt.edu/vsvs

Properties of Waves

2018-2019 VINSE/VSVS Rural

Goal: To investigate properties waves by studying reflection, diffraction and refraction of light.
TN State standards: GLE 0707.11

VSVSer LESSON OUTLINE:

______ **I. Introduction**
Students discuss the properties of waves.
II. Wave Behavior
______ **A. Scattering**
A laser beam is shone through a stream of flour to illustrate scattering.
B.. Reflection
a. Using a Mirror - Students use a laser pointer, a mirror, and a finger to trace the path of the reflected laser beam. Students observe that the angle of reflection is the same as the angle of incidence.
b. Demonstration: Using a Light Pipe - A VSVS member shines a red laser through a light pipe to demonstrate total internal reflection.
______ **C. Refraction**
Refraction will be demonstrated using a jar of water and a straw.
______ **D. Diffraction**
a. Diffraction Gratings - Students hold up what looks like a blank slide and look at room lights or outdoor light through a window and see separation of white light into several rainbows.
b. CDs - Students hold the CD in a way that produces "rainbow" patterns. CDs have many parallel grooves, so the CD acts like a diffraction grating.
______ **E. The Appearing Coin**
Students will learn a "magic" trick using the concept of refraction.

LOOK AT THE VIDEO BEFORE YOU GO OUT TO YOUR CLASSROOM
https://studentorg.vanderbilt.edu/vsvs/lessons/
USE THE PPT AND VIDEO TO VISUALIZE THE MATERIALS USED IN EACH SECTION.

1. In the car ride, read through this quiz together as a team. Make sure each team member has read the lesson and has a fundamental understanding of the material.

1) State the definition of a wave.
2) Which four behaviors do all waves exhibit?
3) State the law of reflection applicable to all waves.
4) What is the significance of the critical angle of a substance?
5) What are the two conditions for refraction of a wave to occur?
6) Why does a CD appear to have a rainbow pattern in white light?

2. Use these fun facts during the lesson

- There are lots of waves surrounding us, such as sound waves, light waves, and water waves.
- Electromagnetic Spectrum: This is the name given to all the different kinds of waves that can move through a vacuum (empty space). They include radio waves, microwaves, infra-red radiation, visible

light, ultra-violet (UV), x-rays, and gamma rays. The only ones that we can see make up visible light. However, we still use many of the invisible ones in everyday life, such as microwaves for heating up food and x-rays to see bones.

- Sound Waves: The loud noise created by cracking a whip occurs because the tip is moving faster than the speed of a sound wave. Similarly, when an aircraft moves faster than the speed of sound, a sonic boom is heard!
- Lightning and Thunder: Why is it that thunder is always heard after the lightening is seen? The speed of a light wave, which is 186,000 miles per second, is much faster than the speed of a sound wave which is 770 miles per hour.
- Earthquakes: These are caused by waves that transport the energy stored in rocks deep inside the Earth to the Earth's surface. They are called seismic shock waves.

Unpacking the Kit:

VSVSers do this while 1 person is giving the Introduction. Note that students are put into pairs and should have their pencils ready.

For Part I. Introduction

32 Observation sheets
16 Instruction sheets (in page protectors)

For Part II: Wave Behavior

For IIA. **Scattering**

Use the red laser, plate and flour container

For IIB**. Reflection**

a. Using a Mirror 16 bags containing: 1 mirror mounted on a block of wood**,** 1 red laser pointer

b. Demonstration: Using a Light Pipe

1 acrylic light pipe and laser pointer

For IIBC Refraction

8 4oz jars containing water and a straw

For IID. Diffraction

32 CDs, 32 diffraction gratings

For IIDE Optional: The Appearing Coin

8 cups with a penny taped in the center, 8 bottles of water

I. Introduction

Learning Goals: By the end of the lesson, students should know the following:
What is a wave? How do waves behave?

Why is the science in this lesson important?

Light and other electromagnetic radiation are waves, and scientists are able to manipulate classical properties of waves, such as refraction or reflection. Solar thermal farms in the Mojave Desert use 170,000 giant mirrors to reflect sunlight onto water towers to heat the water over 1000 degrees Fahrenheit. The water then turns into steam and turns turbines, providing a renewable source of energy to reduce our carbon footprint.

Write the following vocabulary words on the board: **wave**, **reflection, diffraction, refraction, laser**
Ask students to tell what they know about waves.

Your Notes:

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These points may come up in the discussion or you may choose to add them to the discussion. Remember to keep this discussion short.

- "A wave is a disturbance that transfers energy from one place to another without transferring "matter". (From Glencoe text.)
- All waves exhibit the same behavior – reflection, refraction, diffraction, and interference.

Learning Goals: Students will learn how waves behave by studying reflection, refraction and diffraction. Students will know what "laser" stands for and how a laser is used safely.

II. Wave Behavior

A. Scattering

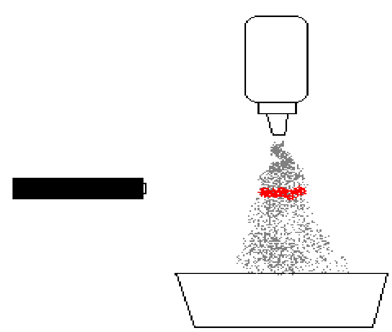
A. Laser Light

Materials for Demonstration:
1 laser pen
1 pie pan
1 2oz dropper bottle of flour

Safety Note: CAUTION – Be careful not to point the laser at anyone and to keep it pointed away from your eyes.

Tell students they are going to investigate how waves behave, by studying light waves. The term "laser" is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation (l.a.s.e.r). Lasers emit a single wavelength of light. The wavelength of light emitted by the red laser pointer is 670 nanometers.

- Shine the laser perpendicular to the direction the students are facing. Ask them whether or not they can see the path of the laser beam. *The answer should be no, but they will be able to see the red dot on a wall at the end of the beam.*
- Tell the students that you are going to use the flour to help you see the beam.
- Using the pie pan to catch the flour, continue to shine the laser perpendicular to the students and squirt the flour in small portions onto the beam from above. If you watch carefully, you should be able to see the path of the laser light before it reaches its final destination.



- Ask the students why you are able to see the beam with the flour, but cannot see the beam without it.
- This phenomenon can be very useful. For example, some home security and protection systems operate on the concept of invisible laser beams, such as in the movie Mission: Impossible. The use of a powder or a fine mist of liquid can allow you to see the path of the laser.

Your Notes:

B. Reflection

a. Using a Mirror - Divide the class into pairs.

Materials – each pair needs:

2 Observation sheets

1 Instruction sheet

> **Safety Note:** Tell the students that they will be using lasers to study some properties of light waves, and that there are several rules that **must** be followed**:**
>
> Be **very careful** with the laser pointer.
>
> **Never** aim it at anyone.
>
> When turning it on, always have it **pointed away from your eyes and from other persons**. Eye damage can occur with direct eye exposure to some laser beams.

1 Mirror mounted on a wooden block

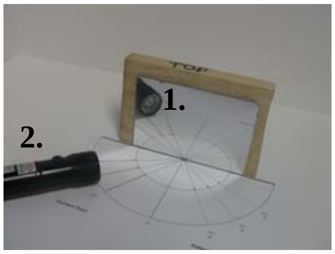
1 laser pointer

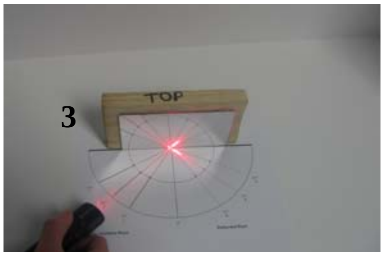
Ask students what happens to light when it strikes a surface.

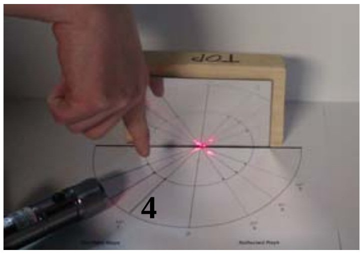
- When light strikes an object, it is either **transmitted** (allowed to pass through the object), or **reflected** (bounced back to your eyes so that you can see the object) or absorbed.
- When light hits a smooth surface, such as a mirror, regular reflection occurs. Ask students what we call the image that we see in the mirror. *A reflection.*
- Tell students that they are going to experiment with reflecting light in a mirror.

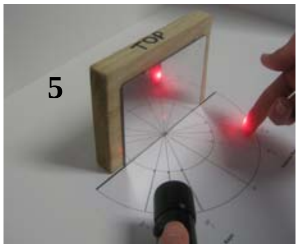
Tell the students to:

1. Place the block of wood with the mirror on the marked line on the observation sheet.
2. Designate one student to hold the laser pointer. Remind the students to NEVER look directly into a laser beam.
3. Shine the laser along the **solid 45° line** and toward the **"X".**
4. Angle the laser so that you can see it travelling along the 45° incident line and out along its reflected beam.
5. "Trace" the laser beam with a finger along the 45° line in towards the mirror.
6. Now tell the students to trace the **reflected** beam with a finger and to note which line the finger moves along. (It should be close to the dotted 45° line.)









7. Tell the students that the light from the laser to the mirror is called the <u>incident ray</u> and the light from the mirror is the <u>reflected ray</u>.
8. Explain that when light goes in at an angle on one side (left or right), it comes out at the same angle on the other side. (It is helpful to some students if you draw this on the board or relate it to a billiard table.)

Your Notes:

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Note: The concept the students should learn is that light can bounce or reflect. Light goes in at one angle and comes out on the opposite side at an equal angle.

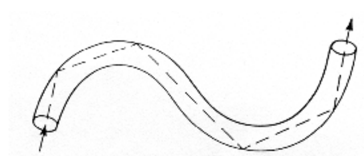
9. Allow the students to try other angles (moving the ruler and laser) to see what happens. Remind students to aim for the "X" in the center.
10. After a brief time of experimentation with other angles, ask the students what they can conclude about the reflection of light.
    - Light can be reflected by using a mirror.
    - When you shine a light straight into a mirror, it comes straight back.
    - When you shine a light into a mirror at an angle, it will come out at an equal angle on the opposite side of the mirror.
    - Incoming light is reflected at the same angle as the outgoing light.

10. Ask students how other waves show reflective behavior.
    Sound waves can echo, water waves bounce back from a barrier.

b. Demonstration: Using a Light Pipe.

Materials:
1 acrylic light pipe
1 laser pointer
Show the students the acrylic light pipe.

- Hold the light pipe so that the long part is vertical and the small horizontal part is pointing towards the class (but not directly at any person's eyes).
- Shine the red laser beam up towards the ceiling and have the students notice the red color on the ceiling.
- Turn off the classroom lights, and ask students what they think they will see when the red laser is shone through the long end of the pipe. If the room is not dark, take the light pipe to each group.
- Shine the laser through the long horizontal end of the pipe.
- Show students that the red light can be seen at the other end, but that no light escapes along the pipe
- If the room is dark enough, the red light can be seen traveling around the tube.



Explanation: When the angle of incidence is high enough (above a critical angle characteristic of the substance; 42° for glass), the incident light is totally reflected inside the medium. Because of total internal reflection, light can be "piped" from one location to another in glass, plastic rods, or other fiber optic material. On entering the "light pipe" at an angle greater than the critical angle of pipe material, the light undergoes repeated internal reflections and follows the contour of the pipe.

C. Refraction

Materials - 8 4oz jars with straw and water

Water Refracts Light

1. Distribute the 8 jars containing water and a straw to students – 1 per 3 or 4 students.

Your Notes:

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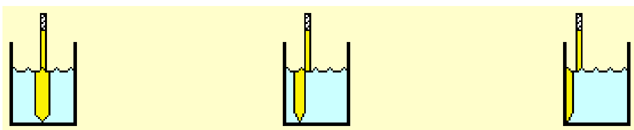
2. Tell the students to rotate the jar while looking at the straw, which should be lying at an angle in the jar. Ask them what they observe. *The straw will appear to be bent at the point where it emerges from the water.*
3. Tell the students to unscrew the lid and to hold the straw vertically in the center of the jar so that half is in the water and half is out of the water. Look at the straw "straight on" at the center point, and then slowly move it to the side of the glass (do not move your head with the straw). Ask them what they observe.
4. Tell students to hold their observation sheet behind the jar and shine the laser through the water in the jar. Note where the red beam is on the paper.
5. Tell students to move the laser up so that the beam now shines through the air in the jar. Note where the beam moves to on the observation sheet.

Explanation:

- The bending of light **- refraction -** occurs when light waves pass from one medium (or substance) to another.
- The speed of a wave depends on the substance that it is traveling through. Since light is a wave, its speed changes when it changes medium. In this example, the speed of light is slower in water than in air.
- As the wave slows down, it also changes its direction. So the light wave "bends" as it enters the water.
- **Refraction only occurs when light waves pass into a different medium, at an angle**.
- The straw did not appear to be "broken" when viewed in the center of the jar. (When you look at it "straight-on".)
- The straw becomes more "broken" as it moves across the jar. (When you look at it from different angles.)



Reference: http://www.physicsclassroom.com/mmedia/optics/bp.html

Important. Collect **all** laser pointers and count them to make sure you have them all. **Do not continue with the lesson until you have placed the laser pointers in the VSVS box**. Also, make sure the laser pointers are not left on.

D. Diffraction

Materials:
32 CDs
32 diffraction gratings

Ask students if they know what diffraction is.

- All waves can be bent when they move around a barrier or through an opening, this is called **diffraction**.
- For light to be diffracted, it must pass through a slit that is very narrow.

a. Looking Through a Diffraction Grating

A VSVS volunteer should show students how to hold the diffraction grating.

- o Hold the slide by the cardboard only.
- o Do not touch the clear film in the cardboard holder.

Your Notes:

- Hold the diffraction grating close to (but not touching) the eye, and look at any lights or windows in the room.
- Several rainbows should appear.

Hand out a diffraction grating and CD to each student.

CAUTION: Do not look directly at the sun with a diffraction grating.

Explanation:

- Diffraction grating slides consist of many equally spaced parallel grooves -- typically about 1500 lines per centimeter.
- Each space between two grooves acts as a slit through which light can pass.
- The light bends around the edges of the grooves.
- When illuminated with white light, the diffraction grating has the same effect as a prism in that it separates white light into a spectrum of colors.
- The order of the colors, however, is opposite from that seen in a spectrum made by a prism. A diffraction grating will also split a laser beam.

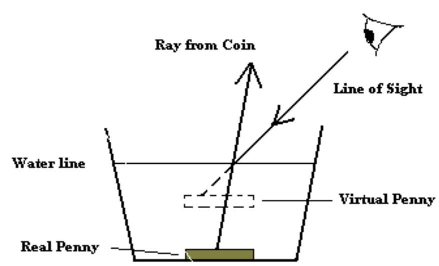
b. CDs

Tell the students to pick up the CD and notice the "rainbow" pattern from the room lights.

- CDs have many parallel grooves so the CD acts as a diffraction grating.
- The different colors in white light are bent different amounts, so a full spectrum of color can be seen when light is shone onto a CD.
- All wavelengths are diffracted at different rates, so diffracted visible light is split into a rainbow of colors.

Sound waves diffract around buildings – you can hear sounds that are made around "corners".
Light waves cannot diffract around buildings – you cannot see around corners if a building is in the way.

E. The Appearing Coin



Materials:

8 cups with a penny taped in the center
8 bottles of water

Tell students that the next activity involves the property of refraction and may be used as a magic trick to try on their family.

Have students in each group do the following:

1. Place the Styrofoam cup with the penny on the desk.
2. Select one student in each group to pour the water.
3. Have the students in the group stand so that they can easily see the coin.
4. Now have the students back up slowly and stop when the coin has just disappeared from sight. (Tell the students that they may not stop at the same point as other students because they are different heights and have different lines of vision. They should stop just as soon as the coin disappears from sight and should not go back too far.)
5. Tell the designated student to slowly pour water in the cup. The other students should raise their hands as soon as they can see the coin again.
6. Continue to pour the water into the cup until all the students raise their hands. (If they cannot see the coin, they went back too far.)

Your Notes:

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Explanation: **Refraction** causes this effect. When water is added, the light is bent so that the coin becomes visible. This experiment shows that light is bent as it travels at an angle through one medium (water) into another (air). As light rays from the coin cross the water/air boundary, they speed up and bend. Our brains are programmed to assume that light rays travel straight from an object to our eyes. Therefore we see the coin straight in front of our eyes.

III. Review

Review the properties of waves that have been discussed today, and ask students if they can tell you some examples seen or heard in everyday life.

1. Reflection – Images can be seen in dark sunglasses, Echoes are an example of reflected sound waves. Some animals depend on echoes to locate food.
2. Refraction – Rainbows are created when light is refracted when it travels through water droplets or prisms.
3. Diffraction - Sound can be heard in different rooms because its waves can be diffracted around solid objects.

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Your Notes:

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<u>Properties of Waves Instruction sheet</u>

NEVER AIM THE LASER POINTER AT ANYONE.

1. Introduction

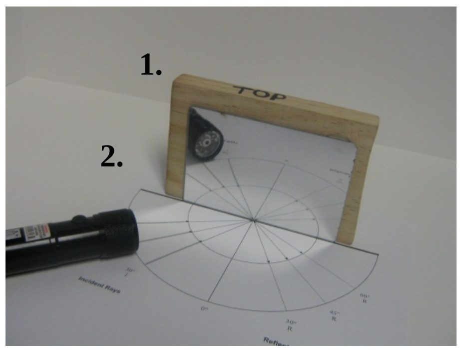
2. Wave Behavior

A. Watch Demonstration on Scattering

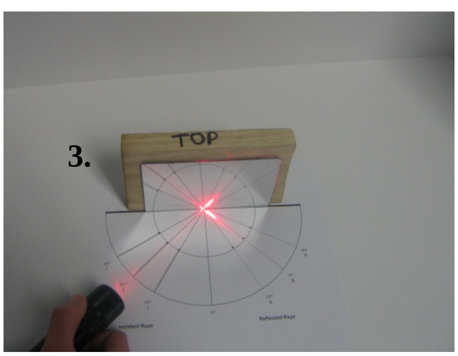
B. Reflection

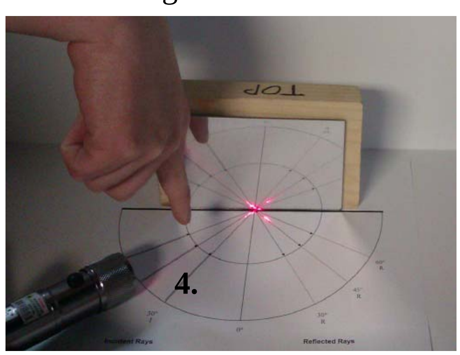
a. Using a Mirror

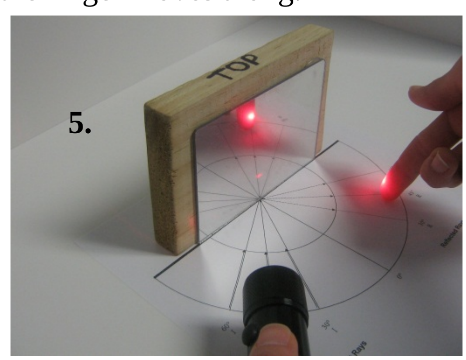
1. Place the block of wood with the mirror on the bolded marked line on the observation sheet.
2. Designate one student to hold the laser pointer. Follow directions #3-5 using the pictures for reference.



3. Shine the laser along the **solid 45° line** and toward the **"X"**. The light from the laser to the mirror is called the incident ray, and the light from the mirror on the dotted line is the reflected ray.
4. Angle the laser so its reflected beam lands on the paper within the semi-circle. "Trace" the **incident** laser beam with a finger along the 45° line in towards the mirror. Adjust the position of the laser if necessary.
5. Now trace the **reflected** beam with a finger and note which line the finger moves along.





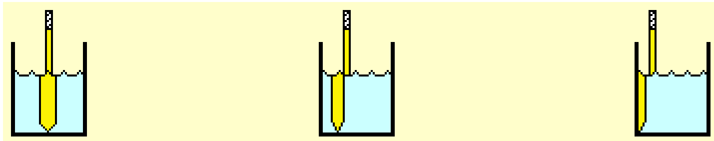


6. A VSVS member will now explain the relationship between the incident angle and reflected angle. Listen. Then go on to step #7.
7. Now try other angles (moving the ruler and laser) to see what happens. REMEMBER, always aim for the "X" in the center. Record what happens.

b. Demonstration: Using a Light Pipe

C. Refraction

1. Rotate the jar while looking at the straw. What appears to happen to the straw?
2. Unscrew the lid and hold the straw vertically in the center of the jar, so that half is in the water and half is out of the water.
3. Look at the straw "straight on" at the center point, and then slowly move it to the side of the glass (do not move your head with the straw). What do you observe?
4. Hold your observation sheet behind the jar and shine the laser through the water in the jar. Note where the red beam is on the paper.
5. Move the laser up so that the beam now shines through the air in the jar. Note where the beam moves to on the observation sheet.



D. Diffraction

a. Diffraction Gratings

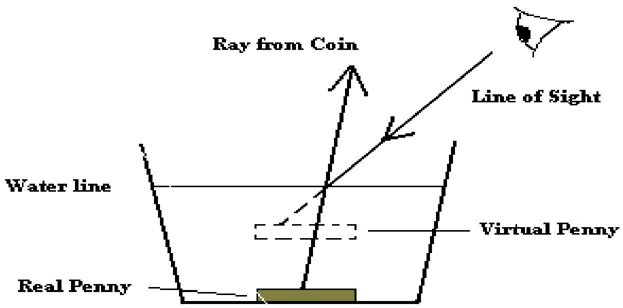
1. Hold the slide by the cardboard only.
2. Do not touch the clear film in the cardboard holder
3. Hold the diffraction grating close to (but not touching) your eye, and look at any lights or windows in the room.
4. A rainbow should appear.

b. CD

- Pick up the CD and notice the rainbow pattern from the lights.

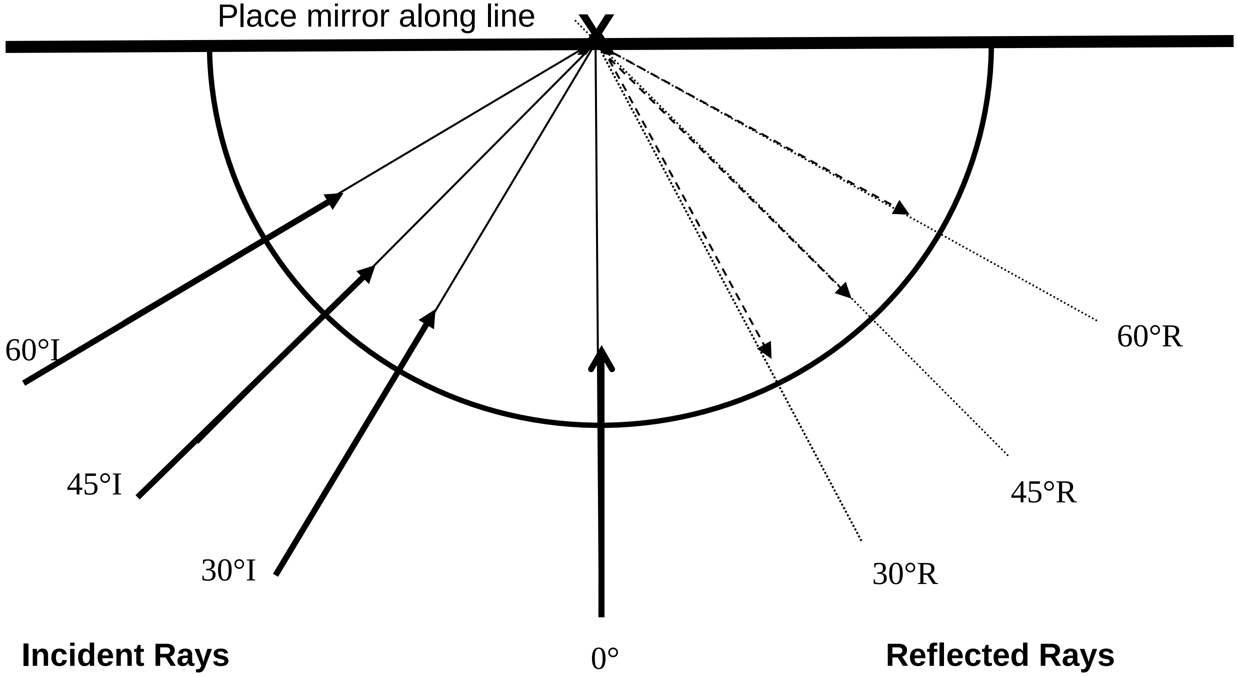
E The Appearing Coin (Optional, if time permits)

1. Place the Styrofoam cup with the penny on the desk.
2. Stand so you can easily see the coin.
3. Select one person in your group to pour the water (but do not pour water until step 5).
4. Back up slowly and stop when the coin has just disappeared from sight. (Taller students will have to back up further. Water pourer does not move.)
5. Slowly pour water in the cup. The other group members should raise their hands as soon as they see the coin again.
6. Continue to pour the water into the cup until all group members raise their hands.



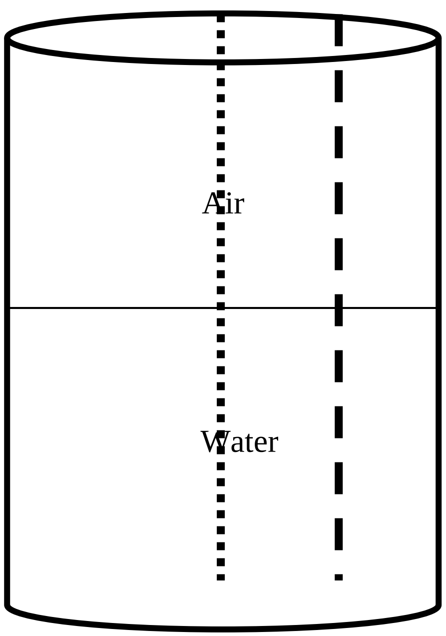
Your Notes:

OBSERVATION SHEET



1. Reflection

Incident Angle	Angle of Reflection
45°	



2. Refraction

Draw what the straw looks like when it has has been moved to the side of the jar.

Hold this observation sheet behind the jar.

Mark the position of the red dot from the laser when it is shone thru air and then water, along dashed line and then the dotted line. Explain___________________________________

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3. Diffraction

What colors do you see through the diffraction grating?____________________

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From the CD?________________________

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