



8th Grade

Fall 2019 Lesson Plans

Vanderbilt Student Volunteers for Science

<http://studentorg.vanderbilt.edu/vsvs/>

VOLUNTEER INFORMATION

Team Member Contact Information

Name: _____ Phone Number: _____

Name: _____ Phone Number: _____

Name: _____ Phone Number: _____

Name: _____ Phone Number: _____

Name: _____ Phone Number: _____

Teacher/School Contact Information

School Name: _____ Time in Classroom: _____

Teacher's Name: _____ Phone Number: _____

VSVS INFORMATION

VSVS Educational Coordinator:

Paige Ellenberger
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615-343-4379
VSVS Office: Stevenson 5234

| | | |
|-----------------------|------------------|--|
| Co-Presidents: | Eric Zhang | eric.zhang@vanderbilt.edu |
| | Vineet Desai | vineet.desai@vanderbilt.edu |
| Secretaries: | Gabriela Gallego | gabriela.l.gallego@vanderbilt.edu |
| | Emily Chuang | emily.a.chuang@vanderbilt.edu |

Vanderbilt Protection of Minors Policy: As required by the Protection of Minors Policy, VSVS will keep track of the attendance – who goes out when and where.

https://www4.vanderbilt.edu/riskmanagement/Policy_FINAL%20-%20risk%20management%20v2.pdf

Before You Go:

- The lessons are online at: <http://studentorg.vanderbilt.edu/vsvs/>
- Email the teacher prior to the first lesson.
- Set a deadline time for your team. This means if a team member doesn't show up by this time, you will have to leave them behind to get to the school on time.
- Don't drop out from your group. If you have problems, email Paige or one of the co-presidents, and we will work to help you. Don't let down the kids or the group!
- If your group has any problems, let us know ASAP.

Picking up the Kit:

- Kits are picked up and dropped off in the VSVS Lab, Stevenson Center 5234.
- The VSVS Lab is open 8:30am – 4:00pm (earlier if you need dry ice or liquid N₂).
- Assign at least one member of your team to pick up the kit each week.
- Kits should be picked up at least 30 minutes before your classroom time.
- If you are scheduled to teach at 8am, pick up the kit the day before.
- There are two 20 minute parking spots in the loading dock behind Stevenson Center. Please do not use the handicap spaces – you will get a ticket.

While you're there – Just relax and have fun!

| September | | | | | | |
|---|---|------|---|-----|------------------------------------|-----|
| SUN | MON | TUES | WED | THU | FRI | SAT |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 Team Leader Training 6-8 pm | 26 | 27 VSVS Day of Service 3-5pm | 28 |
| 29 Team Leader Training 6-8pm | 30 Team Training 5 th & 7 th Grade (come during your normal lesson time) | | | | | |

| October | | | | | | |
|----------------|---|---|---|--|--|---|
| SUN | MON | TUES | WED | THU | FRI | SAT |
| | | 1 Team Training 5 th & 7 th Grade (come during your normal lesson time) | 2 Team Training 5 th & 7 th Grade (come during your normal lesson time) | 3 Team Training 5 th & 7 th Grade (come during your normal lesson time) | 4 Team Training 5 th & 7 th Grade (come during your normal lesson time) | 5 |
| 6 | 7 Team Training 6 th & 8 th Grade (come during your normal lesson time) | 8 Team Training 6 th & 8 th Grade (come during your normal lesson time) | 9 Team Training 6 th & 8 th Grade (come during your normal lesson time) | 10 Team Training 6 th & 8 th Grade (come during your normal lesson time) | 11 Team Training 6 th & 8 th Grade (come during your normal lesson time) | 12 |
| 13 | 14 Lessons, Week 1 | 15 Lessons, Week 1 | 16 Lessons, Week 1 | 17 Lessons, Week 1 | 18 | 19 Mega Microbe 9am-2pm |
| 20 | 21 Lessons, Week 2 | 22 Lessons, Week 2 | 23 Lessons, Week 2 | 24 Fall Break (lessons scheduled 10/24 will be moved to the week of 11/14) | 25 Fall Break | 26 |
| 27 | 28 Lessons, Week 3 | 29 Lessons, Week 3 | 30 Lessons, Week 3 | 31 Lessons, Week 3 | | |

| November | | | | | | |
|-----------------|---|----------------------------------|----------------------------------|----------------------------------|-----------|-----------|
| SUN | MON | TUES | WED | THU | FRI | SAT |
| | | | | | 1 | 2 |
| 3 | 4 Lessons, Week 4 | 5 Lessons, Week 4 | 6 Lessons, Week 4 | 7 Lessons, Week 4 | 8 | 9 |
| 10 | 11 Veterans Day, Metro Schools Closed | 12 Make ups, Week 1 | 13 Make ups, Week 1 | 14 Make ups, Week 1 | 15 | 16 |
| 17 | 18 Make ups, Week 2 | 19 Make ups, Week 2 | 20 Make ups, Week 2 | 21 Make ups, Week 2 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 |

CLASSROOM ETIQUETTE

Follow Metro Schools' Dress Code!

- No miniskirts, shorts, or tank tops.
- Tuck in shirts if you can.
- Please dress appropriately.

Metro student standard attire guideline:

http://jtmoores.mnps.org/pages/JohnTrotwoodMooreMiddle/About_Our_School/8998762518461552450/Dress_Code

COLLEGE Q&A SESSION

VSVS members should be candid about their experiences and emphasize the role of hard work and a solid body of coursework in high school as a means to get to college.

- Email the teacher prior to the first lesson.
 - They may want to have the students write down questions prior to your lesson.
 - They may also want to have a role in facilitating the discussion.
- Finish the experiment of the day and open up the floor to the students.
- Remind them of your years and majors and ask if they have specific questions about college life.
- If they are shy, start by explaining things that are different in college.
 - Choosing your own schedule, dorm life, extracurricular activities, etc.
 - Emphasize the hardworking attitude.

The following are some sample questions (posed by students):

- When is bedtime in college? Does your mom still have to wake you up in college?
- How much does college cost?
- What do you eat in college and can you eat in class in college?
- How much homework do you have in college?

DIRECTIONS TO SCHOOLS

H.G. HILL MIDDLE SCHOOL: 150 DAVIDSON RD

615-353-2020

HG Hill School will be on the right across the railroad lines.

HEAD MAGNET SCHOOL: 1830 JO JOHNSON AVE

615-329-8160

The parking lot on the left to the Johnston Ave.

J.T. MOORE MIDDLE SCHOOL: 4425 GRANNY WHITE PIKE

615-298-8095

From Lone Oak, the parking lot is on the right, and the entrance into the school faces Lone Oak, but is closer to Granny White.

MEIGS MIDDLE SCHOOL: 713 RAMSEY STREET

615-271-3222

Going down Ramsey Street, Meigs is on the left.

ROSE PARK MAGNET SCHOOL: 1025 9th AVE SOUTH

615-291-6405

The school is located on the left and the parking is opposite the school, or behind it (preferred).

WEST END MIDDLE SCHOOL: 3529 WEST END AVE

615-298-8425

Parking is beside the soccer field, or anywhere you can find a place. Enter through the side door.

EAST NASHVILLE MAGNET MIDDLE SCHOOL: 2000 GREENWOOD AVE

615-262-6670

MARGARET ALLEN MIDDLE SCHOOL: 500 SPENCE LN

615- 291- 6385

From West End down Broadway, take 1-40E to exit 212 Rundle Ave. Left on Elm Hill to Spence Lane.

Electromagnetism

(Adapted from Student Guide for Electric Snap Circuits by Elenco Electronic Inc.)

Goals: To produce an electromagnet using a bar magnet and a wire coil.

To experiment with an electromagnet to determine how to vary its strength.

Fits Tennessee standards: 8.PS2.1

VSVS Lesson Outline

I. Introduction

Discussion of magnets and electromagnets

II. Making an Electromagnet Using Batteries, a Nail and Copper Wire.

Students make an electromagnet using different # coils around a nail

III. Comparing Properties of Magnets and Electromagnet

Students Test the Magnetic attractiveness of the magnet and electromagnet

IV. Applications of Electromagnets - Using Electricity and an Electromagnet to make a Motor.

Students identify parts of a motor and make it work

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. Before the lesson:

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. Why does the needle of a compass point North?
2. How is an electromagnet different from a regular magnet?
3. How can we make a current to flow using magnets and no battery?
4. Explain how a motor works.

2. During the Lesson:

Here are some Fun Facts for the lesson

Wind turbines generate electricity by using the wind to turn their blades. These drive magnets around inside coils of electric wire

Electromagnets are used in junk yards to pick up cars and other heavy metal objects

Electromagnets are used in home circuit breakers, doorbells, magnetic door locks, amplifiers, telephones, loudspeakers, PCs, medical imaging, tape recorders

Magnetic levitation trains use very strong electromagnets to carry the train on a cushion of magnetic repulsion. Floating reduces friction and allows the train to run more efficiently.

Unpacking the Kit - What you will need for each section:

II. Making an Electromagnet Using Batteries, a Nail and Copper Wire.

10 sets (of 2) D-batteries in holder,

10 bags containing sets (of 2) nails wrapped with copper wire (1 nail has 50 coils and the other 10 coils), 1 bag of 10 paper clips, 2 single alligator clips, 1 double alligator clip, 1 push switch

36 Observation sheet

III. Comparing Properties of Magnets and Electromagnet

10 bags containing: 2 paper clips (paired),

10 magnets

10 circuit boards with: 4 # 2 snaps, 1 # 1snap, 1 # 3 snaps. 1 electromagnet, 1 battery holder with batteries, 1 switch

1 red and 1 black lead, Iron rod

20 circuit diagrams (2 per group)

IV. Applications of Electromagnets - Using Electricity and an Electromagnet to make a Motor

10 simple motors

V. Making Electricity with Magnets and Coil

10 transparent generators.

I Introduction

Learning Goals: Students understand the main ideas about magnets and electromagnets.

A. What is a Magnet?

Ask students to tell you what they know about **magnets**. Make sure the following information is included:

All magnets have the same properties:

All magnets have 2 magnetic poles.

The poles in the bar magnet are at the ends. One pole is labeled **N** (for north)

The poles are the places where its magnetism is strongest.

Same poles repel each other:

If the **N** pole is brought close to the **N** pole of a second magnet they will repel each other, the same is true for 2 **S** (for south) poles brought together.

Opposite poles attract each other.

If the **N** pole of one magnet is brought close to the **S** pole of another magnet, they will attract each other.

All magnets have a magnetic field, which can be visualized using iron filings.

Your Notes:

B. What is an electromagnet?

Ask students if they know what an electromagnet is and accept answers.

An electromagnet is made by wrapping copper (the metallic reddish-colored) wire into a coil. It generates a magnetic field when an electric current passes through the wire.

- An iron rod placed inside the coil will increase the magnetic force.
- Magnetic fields are produced by **moving** electrical charges
- Explain that an electromagnet is a magnet that works only when an electrical current passes through it (e.g. when it is connected to a battery).
- Electromagnets differ from permanent magnets in that they have an inducible or **temporary magnetic** field. Their magnetic field can be turned off by removing the electric current.

Divide class into 10 groups.

II. Making an Electromagnet Using Batteries, a Nail and Copper Wire.

Learning Goals: Students understand the components necessary for making an electromagnet and the steps needed to do so.

Materials

10 bags containing:

- 1 set of 2 nails wrapped with copper wire (1 nail has 50 coils and the other 10 coils)
- 1 bag of 10 paper clips
- 2 single alligator clips,
- 1 double alligator clip,
- 1 push switch

Tell students to:

1. Look at the 2 nails – one has 50 coils of copper wire, and the other has only 10. Tell students that they will be testing the strength of the 2 electromagnets by finding out how many paper clips each one can hold.
2. Take the nail with the 50 coils and test the nail to make sure it is not magnetic by attempting to pick up a paperclip with the nail. If the nail does pick up the paper clip, have the students carefully tap it on the table until it becomes demagnetized and no longer picks up the paper clip.
3. Have students look at the diagram on the Instruction Sheet and make the circuit by:
 - a. Snapping the 2 wires containing snaps onto the switch.
 - b. Clipping one of these wires to the metal bar protruding from the battery holder, using the alligator clip.
 - c. Clipping the other wire to one of the ends of the copper coil on the nail, using the alligator clip.



Your Notes:

- d. Take the 3rd wire (with alligator clips on **both** ends) and clip one end onto the other metal bar on the battery holder and the remaining end of the copper wire coil.
- e. Ask students what they need to do to complete the circuit (press and hold the switch).
- f. Tell students to press the switch and to try to pick up a paper clip with the tip of the nail.
- g. **Warn students not to hold switch too long as the batteries can become very hot and drained.**
- h. Tell students to see how many paper clips they can hang from the nail while the circuit is complete.
- i. What happens when the circuit is broken?
- j. Repeat the test with the nail with 50 coils.



Collect all battery holders, etc.

III. Comparing Properties of Magnets and Electromagnet

Learning Goals:

- Students understand the components necessary for making an electromagnet and the steps needed to do so.
- Students explore how electromagnets' magnetic properties can be modified

Materials

- 10 paired paper clips
- 10 circuit boards with:
 - 4 # 2 snaps, 1 # 1snap, 1 # 3 snaps, 1 battery holder with batteries,
 - 1 electromagnet, 1 switch, 1 red and 1 black lead, Iron rod
- 10 bar magnets



Give each group one electromagnetism circuit board kit, one bar magnet, paired paper clips. Have students connect battery holder, switch, and electromagnet using black and red jumper wires and insert iron core rod into the center of the electromagnet.

Explanation:

Tell students to examine the electromagnet from the kit and notice that this commercial electromagnet has copper wire that is coiled many more times compared with the nail used in the previous experiment.

The iron core rod replaces the nail in the previous experiment.

Ask students to predict if this electromagnet will be stronger or weaker than the one they made with the nail and wire? Why?

The snap circuit electromagnet should be stronger, since it has more coils.

Testing the Magnetic attractiveness of the magnet and electromagnet

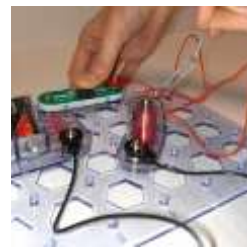
1. Move the **magnet** towards the paper clip. Is the paper clip attracted to the magnet? – yes
2. Testing the **electromagnet**:



Your Notes:

Dangle the paired paper clips close to the top of the iron rod in the electromagnet. Is there any attraction? *No.*

3. Press and hold the switch **down** and repeat step 3. Is there any magnetic attraction? *Yes, the paper clip is attracted to the electromagnet.*
4. Release the switch to **OFF** and notice what happens. *The paper clip is no longer attracted.*
5. Place the paper clip near the rod **under** the electromagnet and notice what happens when the switch is turned **ON**. *The paper clip is attracted to the electromagnet when the switch is on.*



Explanation:

Explain to students that all materials have tiny particles with magnetic charges, which are usually so well balanced that you do not notice them. Remind students, from the nanotechnology and magnetism lesson, that magnets are made up of smaller magnets called domains.

A **magnet** is a material that concentrates the magnetic charges at opposite ends (the poles).

In an **electromagnet**, the electric current that flows in the wire has a tiny magnetic field. By looping a long wire into a coil the tiny magnetic field is concentrated into a large one.

The strength of the magnetic field depends on how much current is flowing in the wire and how many loops of wire are present.

IV. Applications of Electromagnets - Using Electricity and an Electromagnet to make a Motor.

Learning Goals: In a motor, electric energy is converted to kinetic energy.

Pass out the assembled motors.

In an electric motor, a magnetic field turns electricity into motion.

Tell students to look at the motor and identify the following parts: a permanent magnet, copper wire, and a battery.

Point out that the electrical current is produced by the battery

Point out the copper supports that connect the battery to the coil.

Point out that the copper wire is covered with an enamel coating for insulation. Tell students to look closely at the 2 straight ends of the copper coil. Both ends have had the enamel coating stripped from one side of the wire (it does not have the same shiny copper color as the other side). The coated side will not conduct electricity, whereas the stripped side will allow a current to flow through the coil.

Tell students to:

1. Place the straightened wires from the coil into the U of the copper supports. The shiny (insulated) side must be facing UP.
2. Give the coil a gentle tap. If it spins continuously, the student has succeeded in making a motor.
3. If the coil does not spin, have the student tap it in the other direction.

Optional:

4. Flip the magnet over (a different pole will now be facing up). Repeat steps 1-3. What happens?



Your Notes:

Explanation:

We know that an electromagnet has a magnetic field when an electrical current flows through it. Magnets also have permanent magnetic fields. The 2 magnetic fields can attract or repel each other. The motor works because electricity flows through the coil and a magnetic field is formed. The magnetic fields from the magnet and electromagnet repel each other and the coil pushes away from the magnet with enough force to turn it around. As the coil rotates around, the coated side makes contact with the copper supports and breaks the electrical circuit. Momentum carries the coil around to its starting position, where the stripped wire now comes back into contact with the copper supports. The circuit is again completed, so the magnetic field in the electromagnet is created again, and the coil continues to spin.

V. Making Electricity with Magnets and Coil

Learning Goals: Students know that an electric current can be induced by using a magnet and a wire.

Pass out a generator to each group
Tell students to identify the different parts – a coil, a magnet (inside), a light bulb and moving spindle.



Ask students to identify what happens when the spindle moves (it rotates the magnet). Students should twirl the spindle with a finger,. Do not let them run the wheel on the desk.

What happens when you turned the spindle of the transparent generator SLOWLY? (nothing)

What happens when you turned the spindle of the transparent generator FASTER? (the LED lights up)

Explain that a generator uses a magnetic field to turn motion into electricity.

What kind of energy are you using when you turn the spindle? (mechanical energy)

What kind of energy is it being converted to (electrical).



What devices use generators to convert energy to electricity? Windmills, steam/water turbines, alternator of a car

Lesson written by Pat Tellinghuisen, Coordinator of VSVS, Vanderbilt University
Leandra Fernandez, VSVS Lab Worker, Vanderbilt University

Your Notes:

Electromagnetism Observation Sheet

Name _____

1. How many paper clips can you pick up with the nail plus 50 coils?

 2. What happens when the circuit is broken (the switch no longer pressed)?

 3. How many paper clips can you pick up with the nail plus 10 coils?

 4. What materials are necessary to make an electromagnet?

 5. What makes an electromagnet stronger?

 6. Is the magnetic field around the electromagnet similar or different to that around a magnet?
How?

 7. What happens when you move the magnet over the coil plus the iron rod?

 8. What materials are necessary to make a motor?

 9. What does the LED lighting up tell us?

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VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE

Properties of Waves

Goal: To investigate properties waves by studying reflection, diffraction and refraction of light.

TN State standards: 8PS4.1, 8PS4.2

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 lightning 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: 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.

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

Your Notes:

- “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:

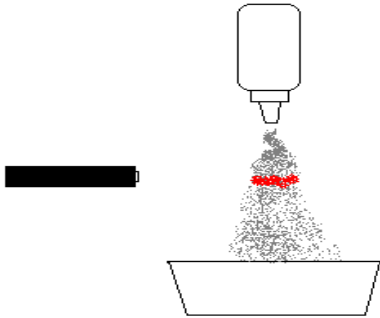
1 laser pen

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.

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.

B. Reflection

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

Materials – each pair needs

2 Observation sheets

1 Instruction sheet

1 Mirror mounted on a wooden block

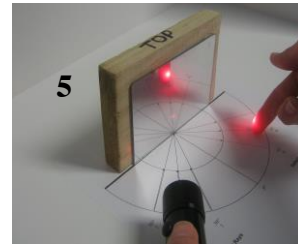
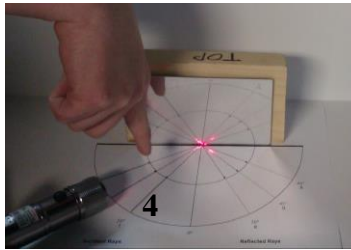
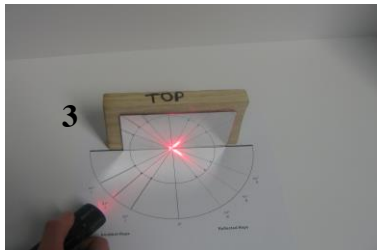
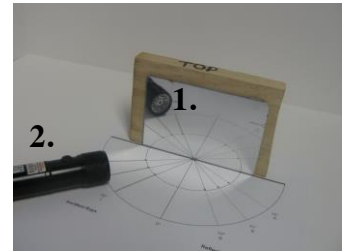
1 laser pointer

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 incident ray and the light from the mirror is the reflected ray.
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.)

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.

Your Notes:

- 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.

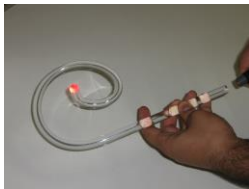
b. Demonstration: Using a Light Pipe.

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

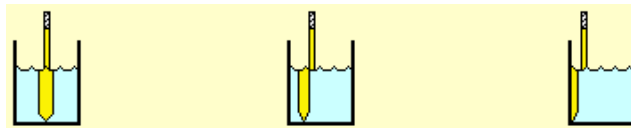
1. Distribute the 8 jars containing water and a straw to students – 1 per 3 or 4 students.
2. Tell the students to rotate the jar while looking at the straw, which should be lying at an angle in the jar. Ask them what they observe. *The straw will appear to be bent at the point where it emerges from 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.

Your Notes:

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.

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

Your Notes:

- 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.

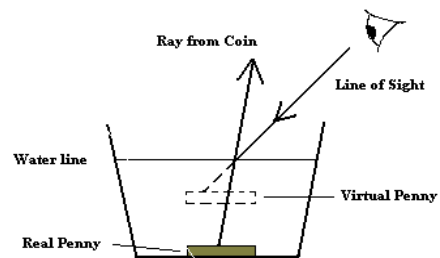
Sound waves diffract around buildings – you can hear sounds that are made around “corners”.
 Light waves cannot diffract around buildings – you cannot see around corners if a building is in the way.

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.)

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.

Your Notes:

III. Review

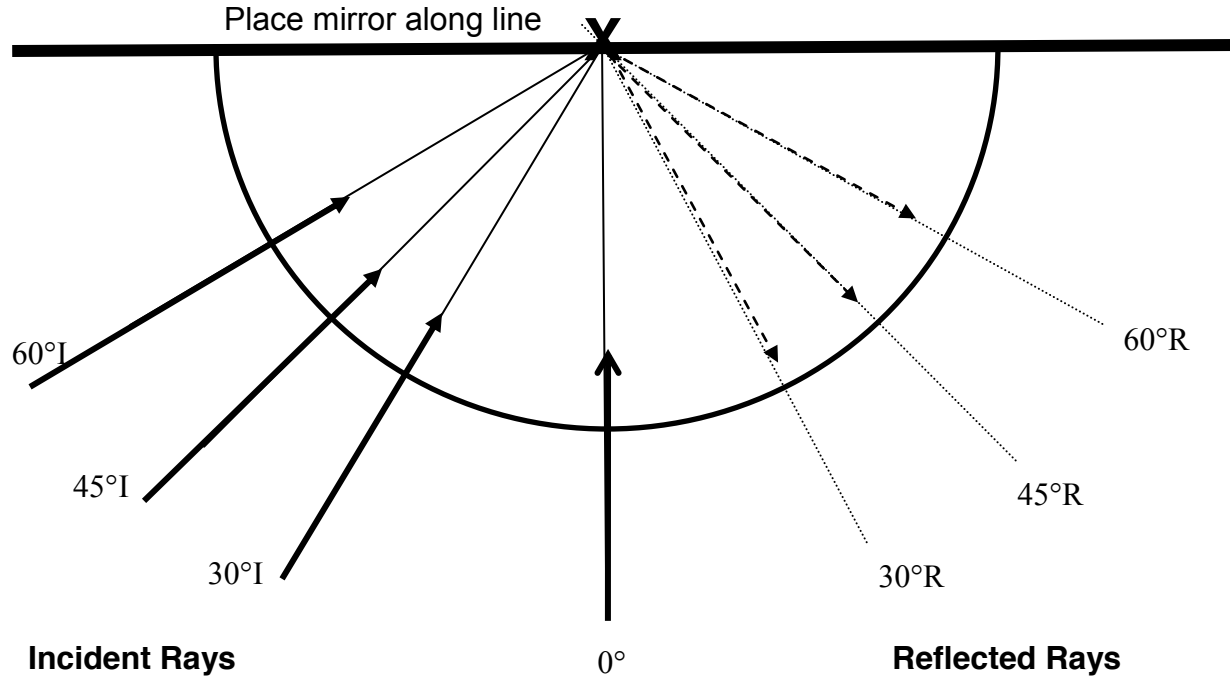
Review the properties of waves that have been discussed today, and ask students if they can tell you some examples seen or heard in everyday life.

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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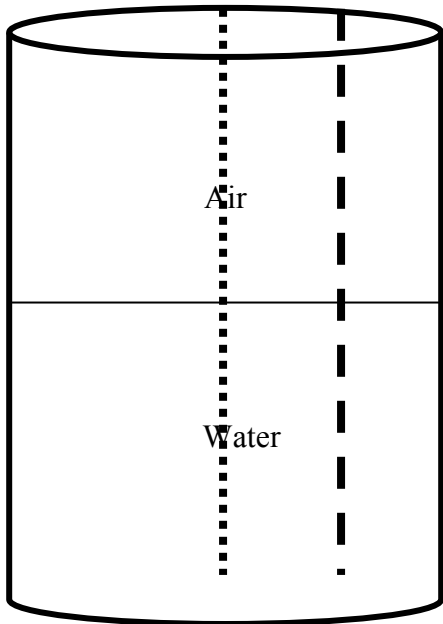
Your Notes:

OBSERVATION SHEET



1. Reflection

| Incident Angle | Angle of Reflection |
|----------------|---------------------|
| 45° | |
| | |
| | |
| | |



2. Refraction

Draw what the straw looks like when it 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 _____

3. Diffraction

What colors do you see through the diffraction grating? _____

From the CD? _____

VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE

Nanotechnology and Magnetism

Goal: To introduce students to nanotechnology and new magnetic products.

TN state standards:8.ETS1.1, 8.ETS1.2, 8PS2.1

Complete teacher/school information on first page of manual.

1. Make sure the teacher knows Paige's office number and email (front of manual).
2. Exchange/agree on lesson dates and lesson order (any changes from the given schedule need to be given to Paige in writing via email).
3. Since this is your first visit to the class, take a few minutes to introduce yourselves. Mention you will be coming three more times to teach them a science lesson.

VSVSer Lesson Outline:

_____ **I. Introduction**

- A. Reviewing Magnetism
- B. Magnets Have Poles
- C. Magnets can be Permanent or Temporary
- D. Magnets have fields (shown by iron filings).

_____ **II. Magnetism and Nanotechnology**

_____ **III. Nanoscience**

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. Before the lesson:

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.

Nanotechnology and Magnetism Lesson Quiz

1. What is a magnetic field?
2. How is ferrofluid a unique material?
3. What is nanoscience?
4. What is the difference between permanent and temporary magnets?

2. During the Lesson:

Here are some Fun Facts for the lesson:

The Earth has a magnetic field because there is iron and nickel in the Earth's core.

Earth's magnetic field switches direction every 450,000 years on average. This means that a compass would someday point towards the South Pole.

The iron in our blood cannot be magnetized because it's attached to a protein in your blood cells.

Jupiter's magnetic field is the largest single structure in our solar system besides the Sun.

Many scientists believe birds use Earth's magnetic field as a kind of GPS when they migrate.

Unpacking the Kit

For Part I. Introduction

B. Magnets have Poles, Activity 1: 16 wand magnets, 16 ring magnets on a pole

C. Magnets can be permanent or temporary, Activity 2

16 wand magnets from above, 16 bags containing 5 large paper clips

16 handouts showing temporary and permanent magnets (in sheet protectors)

D. Magnets have fields (shown by iron filings), Activity 3

16 wand magnets (from above), 16 petri dishes of iron filings, 8 pieces of lodestone

16 vials containing iron oxide powder,

8 plastic 3-dimensional magnetic field generators - **Remove bar magnet from plastic container and place on top of red lid before handing out to students.**

For Part II. Magnetism and Nanotechnology

16 Handouts - "How Big Is Your Hand?" and Nanosized objects on reverse size.

Activity 4: 16 vials of iron oxide powder in liquid, 8 vials of ferrofluid, 16 magnetic wands (from above)

I. Introduction

Learning Goals: Students can identify the main magnetic properties and know what permanent, temporary, and induced magnets are.

Vocabulary words: magnetism, lodestone, ferromagnetic, permanent magnet, temporary magnet, magnetic induction, magnetic field, ferrofluid, macroscale, nanoscale, nanotechnology

These words are on the handout, and can be referred to during the lesson.

Why is the science in this lesson important?

Nanotech and Magnetism: Ferrofluids can be currently being researched for utilization in precise satellite movements in space. The fluid is being shot through needles for extremely specific control. This research is currently in computer simulation stages.

In ophthalmology, ferrofluid is starting to be used in research regarding retinal detachment, the leading cause of blindness. Because of ferrofluids nanoproperties, the fluid has the potential to seal tiny retinal holes that otherwise cause surgeries to be extremely meticulous and delicate.

To address the BP oil spill of 2010, oil companies have begun to develop new methods for cleaning up offshore oil spills. When oil mixes with water-repellent nanoparticles containing iron, it can be separated from water. The magnetic fluids attach to the oil particles, and the mixture of oil and water can then be filtered with magnets. This way, the water can be returned to the ocean and the oil can be returned to an oil refinery and reused.

Man has been fascinated by magnetic properties since 600 B.C. (One story tells of a Greek shepherd boy called Magnes who discovered that the iron tip on his staff was mysteriously attracted to a rock.) **This rock was a naturally occurring magnetic rock called lodestone.** Lodestone is also called magnetite and is a mineral containing the compound iron oxide, chemical formula Fe_3O_4 . NOTE: Fe_3O_4 is not the same as red "rust," which is Fe_2O_3 .

Up until about 30 years ago, magnetic materials were known only in the solid form. Tell students that they are going to investigate a new magnetic liquid called ferrofluid and compare its properties with regular magnets.

A. Reviewing Magnetism

Ask students to tell you what they know about magnets.

Your Notes:

Students should know:

- Magnets have north and south poles.
- The south poles on 2 magnets will repel each other. The north poles on 2 magnets will repel each other.
- The north and south pole on 2 magnets will attract each other.
- Magnets have invisible “force” fields extending around them. These “force” fields allow attractions and repulsions to occur without the magnets actually touching.
- This attraction and repulsion is called **magnetism**.
- Some magnets are permanently magnetic, and some magnets are just temporarily magnetic.

B. Magnets have Poles

Materials for each group of 4:

- 2 wand magnets
- 1 floating ring magnets set

Activity 1

Divide the class into groups of 4 – each pair in the group will do the 2 activities.

- a) Tell 2 members of the group to look at the **wand magnets** and find the labeled north (N) and south (S) poles. Each student will take turns holding the two magnets, one in each hand. Tell students to observe what happens when the two N-poles are brought together (they will repel each other) and when an N-pole and an S-pole are brought together (they will attract each other).
- b) Tell the other 2 members of the group to use the disc magnets on a pole and arrange them so that they all float (repel each other). They will start with the magnet in the base having its N pole facing up.
- c) Pairs then exchange tasks.
- d) Write the observations on the board.

Collect floating ring magnets but leave the wand magnets with the group.

C. Magnets can be permanent or temporary.

Materials per group of 4: 2 wand magnets, 2 bags containing 5 large paper clips,
16 handouts showing temporary and permanent magnets

Activity 2

1. Ask students if they think that the paper clips are attracted to each other, like the 2 magnetic wands. Tell students to test their hypothesis (they should not be).
2. Tell students to use the magnet to pick up a paper clip.
Ask the students if they know why the paper clip is attracted to the magnet.
*Only materials containing metals iron, cobalt or nickel are attracted to magnets. These 3 elements are called **ferromagnetic** (which means they are attracted to a magnet). Most metals (aluminum, copper, lead, silver, gold, etc.) are **NOT** attracted to a magnet. The prefix **ferro** comes from the Latin word for iron.*
3. Adjust the first paper clip so that it hangs down from the end of the wand. Tell students to keep the paper clip attracted to the magnet and to pick up another paper clip so that it hangs from the first. Tell students that the first paper clip is now magnetic **by induction**.
4. Try adding a 3rd and 4th paper clip, one at a time, to the bottom clip.
5. Remove the paper clips from the magnet and place on the desk top.

Your Notes:

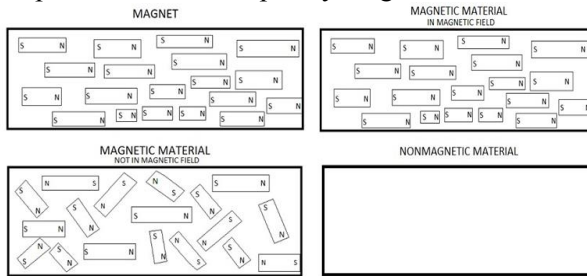
- Ask students if the paper clips are still magnetic. Tell students to use one of the paper clips and try to pick up other paper clips (without using the magnet).
- Tell students that some magnets are permanently magnetic and some magnets are just temporarily magnetic.

The wand magnet is a permanent magnet. The paper clips are temporary magnets. Temporary magnets become magnetized in a strong magnetic field but quickly lose their magnetism when the field is removed.

Activity 2b

Use several paperclips to make a chain and hang it from the wand magnet. Ask students what they think will happen when you remove the wand magnet. Holding onto the first paperclip, slowly remove the wand magnet. Some paperclips may remain attracted to each other. Eventually they will fall. The wand magnet (permanent magnet) is strong enough to magnetize the paperclips by aligning the dipoles, or tiny magnets within the paperclip, as shown below. They will remain aligned for a short period until jolted.

Tell students to look at the diagrams on their handout and give a grade-appropriate explanation for permanent and temporary magnetism.



VSVS Background information: Permanent or temporary magnetism is determined by whether the **domains** are arranged. A domain is just a tiny cluster of atoms within the magnet. Under certain circumstances which cause a material (such as iron) to become magnetic, the domains are all aligned and pointing in the same direction. Permanent magnets are materials that have all their domains permanently aligned. Temporary magnets can temporarily align domains as long as they are in something else's magnetic field.

D. Activity 3: Magnets have fields (shown by iron filings).

Materials:

- 16 wand magnets
- 16 petri dishes of iron filings
- 8 pieces of lodestone
- 16 vials containing iron oxide powder
- 8 plastic 3-dimensional magnetic field generators

Remove bar magnet from plastic container and place on top of red lid before handing out to students.

Pass out lodestone, iron oxide powder and petri dishes.

- Tell students to move the wand magnet around the petri dish of iron filings.

Your Notes:

Ask students to describe what is happening.

Answers might include: the wand magnet makes the iron filings follow it, spikes may form, the filings are attracted to the magnet, etc.

Iron filings can be used to study the pattern formed by the lines of force in the magnetic field around a magnet. The iron filings have been magnetized by induction. They organize themselves into little magnets that point north and south.

2. Tell students to shake iron filings gently so that they cover the bottom of the petri dish in a thin layer.

Place the wand magnet underneath the petri dish and observe the pattern formed. Tell students to twist the wand magnet around in a circle and watch how the positions of the iron filings change. Tell students that there is an invisible pattern of force around every magnet. This force is called a **magnetic field**. The patterns that can be seen with the iron filings are called **lines of force**.

3. Tell students to move the lodestone around the petri dish. What happens? Place the lodestone underneath the dish and observe if there are lines of force patterns.

Is lodestone a permanent or temporary magnet? *Permanent.*

4. What happens when the vial containing iron oxide is placed underneath the petri dish?

Nothing happens – the powder is not a magnet.

What happens when the wand magnet is placed near the vial of iron oxide?

The iron oxide moves to align with the magnetic field.

Which items are permanent magnets and which are temporary?

The wand magnet and lodestone are permanent magnets. The iron filings, paper clips and iron oxide powder (in the vial) are temporary magnets.

Tell students that the iron oxide powder has the same formula as the lodestone (Fe_3O_4).

On the **macroscale**, magnetite, in the form of lodestone, is permanently magnetic.

On the **nanoscale**, magnetite powder is *paramagnetic*, meaning that it's magnetic only in the presence of a magnet.

5. Pass out the plastic 3-dimensional magnetic field generators. **Make sure the bar magnets are sitting on top of the plastic container instead of inside it. Students need to keep the inner tube inside the outer casing.**

Tell students that the plastic containers are filled with iron filings, just like the petri dishes.

Tell the students to gently insert the bar magnet into the center of the plastic container, put the lid on and gently rotate the container. What happens?

The iron filings will be attracted to the bar magnet and should form spikes around the ends.

The accumulation of the iron filings follows the magnetic field lines in 3 dimensions.

II. Magnetism and Nanotechnology

| |
|---|
| <p>Learning Goals: Students understand what ferrofluid is and why it is different from the powdered iron oxide .</p> |
|---|

Ask students if they have ever seen a **liquid** that is magnetic.

Tell students that magnetizing a fluid is impossible, because the molecules in liquids have a lot of freedom to move around.

Your Notes:

Tell students that **nanotechnology** takes advantage of special properties at the nanoscale to create new materials and devices.

Hold a vial of the **ferrofluid** up so that students can see it. Tell them that the black material is called ferrofluid and that ferrofluid is a unique material that **acts like a magnetic solid and like a liquid.**

VSVS Background information only: Ferrofluid is made of tiny (about 10 nm), nanometer-sized particles of coated magnetite (iron oxide) **suspended** in liquid. Ferrofluids were developed by NASA as a way to control the flow of liquid fuels in space. (How could you keep a liquid in place in outer space where there is no gravity?)

Important Idea: At the nanoscale, many ordinary materials have different and unusual properties, compared with the same material at the macro level.

III. Nanoscience

Learning Goals: Students understand the difference between the macro, micro, and nanoscale and can classify different objects as belonging to one of the categories.

Ask students if they know what nanoscience is.

Nanoscale science, or **nanoscience**, focuses on things that are measured in nanometers, including atoms and molecules. In the field of nanotechnology, scientists and engineers make new materials and tiny devices.

Hand out the “How Big Is Your Hand?” worksheet and Nanosized objects (1 per pair).

Tell students to:

1. Look at the scale.
2. Place their hand against the ruler and read off how many nanometers your hand measures.

One meter is a billion nanometers. (A meter is a little longer than a yard.)

Or, **a nanometer is a billionth of a meter.** That’s really tiny! Nanometers are used to measure things that are too small to see.

So a person who is a little over three feet tall measures one billion nanometers. A person 6 feet tall is nearly 2 billion nanometers.

Tell students to look at the reverse side, showing the sizes of different objects, measured in nanometers. The pictures are designed to show students ways to think about how small a nanometer is.

There are 3 categories:

1. **Macroscale objects – objects we can see with our eyes.**
2. **Microscale objects – we need tools like microscopes**
3. **Nanoscale objects – we cant see them with just our eyes. We need special tools to make images of them.**

Why is nanoscience important?

Nanoscience has begun changing products that we use in everyday life, like sunscreen, household appliances, tennis balls, paints, video game consoles, and bandages.

Your Notes:

Background Information on Ferrofluids: Lodestone, the black iron oxide powder and ferrofluid are all made from magnetite (Fe_3O_4). But the lodestone and the powder do not have ferrofluid's unusual properties.

Ferrofluids are unique in that they have the magnetic properties of a solid but also the fluid properties of a liquid. The nanoparticles are not affected by gravity, which means they will not settle out. They also become denser in the presence of a magnetic field.

When there is no magnet around, ferrofluid acts like a liquid. The magnetite particles move freely in the fluid. When there's a magnet nearby, the particles are temporarily magnetized. They form structures within the fluid, causing the ferrofluid to act more like a solid.

When the magnet is removed, the particles are demagnetized and ferrofluid acts like a liquid again.

Activity 4:

CAUTION: DO NOT OPEN VIAL. DO NOT SHAKE THE VIAL.

Pass out the vials of ferrofluid and iron oxide in liquid. The wand magnets will be used again. Tell them to investigate the magnetic properties of the iron oxide in the liquid (lodestone powder in liquid).

1. Ask students if the black material is like a solid or liquid.
2. Hold the vial horizontally and place the wand magnet above the vial. Describe what happens. *The ferrofluid should form spikes. . Some of the black liquid moves. The powder clumps.*
3. Move the magnet around the vial, including on top of it. Describe what happens. *The liquid should move around the vial with the magnet.*
4. Put the flat side of the magnet on top of the vial so that spikes appear. Gradually move the magnet up and away from the vial. What happens? *Gravity finally takes over.*
5. Ask students what the spikes are showing. *The spikes are a result of the ferrofluid trying to follow the magnetic lines of force.* Tell students to turn the magnet onto its side – what happens to the spikes?

Ask students:

1. Does the ferrofluid behave in the same way as the iron oxide powder in the liquid?
In both, something in the vial was attracted to the magnet, but in the vial with iron oxide and liquid, some of the solid did not move. The iron oxide clumps more than the ferrofluid.
The magnetite particles in the ferrofluid do not clump together because of the smaller size of the particles and because a surfactant has been added.
2. What is considered to be “nano” about ferrofluid? *The size of the magnetic particles is on the nanoscale (10nm), which allows ferrofluid to have its unique properties.*

Uses for Ferrofluids

Ferrofluid is used in seals in computer hard drives and other rotating shaft motors and in loudspeakers to dampen vibrations. Ferrofluids are also used in developing MRI images and in experimental cancer treatments. In the future, ferrofluids may be used to carry medications to specific locations in the body.

Lesson written by Pat Tellinghuisen, Coordinator of VSVS, Vanderbilt University
Jen Ruddock, VSVS Lab Worker, Vanderbilt University

Your Notes:

VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE

SOUND AND RESONANCE

Goal: To introduce students to sound waves, resonance, and the speed of sound.

Fits TN Standards: 8.PS4.1., 8PS4.2

LESSON OUTLINE

1. Wave Demonstration

VSVS volunteers demonstrate compressional and transverse waves with a slinky, an air blaster and wave machine.

2. Sound is produced by vibrations.

Students spin a hex nut inside an inflated balloon and observe that they can feel the balloon vibrating when there is a sound being produced.

3. Natural Frequency

A. Student Activity

Students are introduced to resonance by having them listen to the pitches created in tubes of different lengths.

4. Introducing Tuning Forks

Students are introduced to tuning forks. They note the frequency and corresponding keynote on each fork.

5. Finding the length of a tube at which resonance is heard

Students hit a tuning fork with a mallet and place it at the opening of the shortest of 4 tubes. They listen closely to hear if the volume of the sound has increased. They move the tuning fork to the openings of the other tubes and discover which tube produces resonance. VSVS members will collect the data and write it on the board. The class will learn that longer tubes are needed for the tuning fork with the lower frequency, shorter tubes are needed for the tuning fork with higher frequency and that the same length tube is needed for tuning forks with the same frequency.

Optional

Students can exchange tuning forks so that they have one that has a different frequency, and repeat the above activity.

6. Play “Twinkle Twinkle Little Star” with tubes. Students take one numbered sound tube (Not #0 or # 1) and play a tune by hitting the tubes on their thighs or hands .

7. Optional: Calculation of the speed of sound

Students use the formula, $v = f \times \lambda$, to calculate the speed of sound. The wavelength is calculated by measuring the length (x 2) of the tube that resonates with the tuning fork.

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.

Lesson Quiz

- 1) What are the two kinds of waves? Which category do sound waves fall under?
- 2) How does the frequency affect the pitch of the sound produced?
- 3) How does wavelength affect the pitch of the sound produced?
- 4) What happens when two waves of the same wavelength are in phase with each other? What is this called?

5) The vibration of what causes human eardrums to mimic the movements and allows us to perceive sound?

2. Use these fun facts during the lesson:

- The scientific study of sound waves is known as acoustics.
- Since sound is produced by the vibration of air molecules, sound cannot travel through a vacuum (an area empty of matter). Thus, there is no sound in space.
- A violinist produces different notes by pressing down on strings with his/her fingers, thus changing the frequency at which the strings vibrate. A flute player changes pitch by opening and closing holes along the flute, essentially changing the length of a tube.
- Resonance can produce vibrations powerful enough to destroy objects.
 - A singer can break glass by singing a note at the same frequency as the natural frequency at which the glass vibrates. Energy transfers from the sound to the glass until its vibrations become so strong it shatters.
 - Soldiers marching over a bridge can set up extreme vibrations at the bridge's natural frequency and shake it apart. This is why soldiers break step to cross a bridge.
 - In 1940, the Tacoma Narrows Suspension Bridge collapsed after strong wind gusts caused the bridge to vibrate at its natural frequency.
- Sound travels at different speeds through different media. Old western movies show characters putting their ear to steel tracks in order to hear for an oncoming train. This is because sound travels faster through solid objects than through air. Sound travels through water about four times faster than it does through air.
- The human range of hearing is on average from 20 to 20,000 Hertz. The ability to hear sounds at the highest frequencies decreases with age. The Mosquito alarm is a device used to deter loitering by emitting a sound at high enough frequency that only younger people can hear it.
- Some animals, like dogs, have eardrums that can vibrate at higher frequencies than human eardrums, allowing them to hear higher pitches that we can't, such as training whistles.
- Any frequency that is below the human range is known as infrasound. Ultrasound is any frequency above the range of the human ear. Bats, whales, and dolphins use ultrasound for navigation by emitting sounds and listening for the echoes, a process known as echolocation.

Materials (for 8 groups)

- 16 9" balloons with hex nut inserted
- 3 garbage bags for inflated balloons with hex nuts inserted
- 1 slinky
- 1 Air Blaster
- 1 Wave machine
- 6 10 oz cups
- 8 tuning forks (4 "A"s and 4 "G"s)
- 8 mallets
- 8 sets of plastic tubing (Each set has 4 different lengths, numbered 0-7. The sets are color coded.)
- 2 balloon inflators
- 16 Instruction sheets
- 16 Observation sheets

Warning: This lesson can be **noisy**. Tell the students that they must stop this activity at a certain signal, e.g. when you turn the lights out, or some other strategy that the teacher uses.

Your Notes:

Pre-lesson set-up:

- Inflate enough balloons (use the balloon pumps) so that each **pair** of students can share a balloon. Use the balloon clips to tie-off the balloons (or hand tie). **Do this during Part I., preferably outside the classroom. It is too distracting for the students to see it being done in the room!**
- Put the following vocabulary words on the board: **vibration, pitch, frequency, natural frequency, resonance**
- Refer to these words as you introduce them during the lesson.

I. Sound Waves: Demonstrations

A. Comparing transverse and compressional waves

Materials: slinky

Two VSVS volunteers need to perform this demonstration.

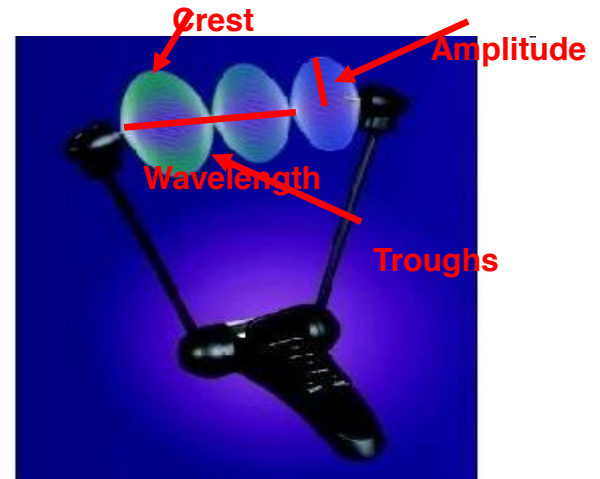
- Hold the slinky so that there is no slack between the two ends.
- Have one volunteer slowly move the slinky up and down (the other volunteer should hold it steady).
 - This is an example of a **transverse wave**. Light waves are transverse waves.
- For the **compressional wave**, have one volunteer pull back on the slinky (as if cocking a spring) and release it. This should result in a pulse traveling down the length of the slinky.
 - Tell students that this is an example of a compressional wave. Sound waves are compressional waves.



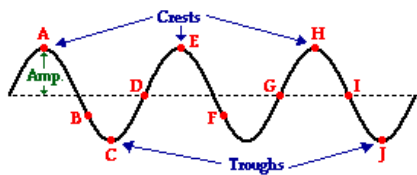
Slinky waves can be made by vibrating the first coil back and forth in either a horizontal or a vertical direction.

Tell students to look at the diagram on their observation sheet. Turn the wave machine on and adjust it so that it has 2 standing waves (see training presentation).

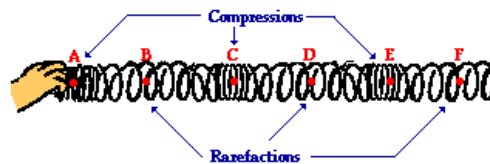
- Point out the crest, trough, amplitude and wavelength



A transverse wave has an alternating pattern of crests and troughs, For a **transverse wave**, the wavelength is determined by measuring from crest to crest..



Transverse wave



Compressional wave

<http://www.physicsclassroom.com/class/waves/Lesson-2/The-Anatomy-of-a-Wave>

Tell students that because the coils of the slinky are vibrating longitudinally, there are regions that become pressed together and other regions where they are spread apart.

Your Notes:

A region where the coils are pressed together in a small amount of space is known as a compression. Points A, C and E on the diagram above represent compressions

A region where the coils are spread apart, thus maximizing the distance between coils, is known as a rarefaction. Points B, D, and F represent rarefactions.

A compressional wave has an alternating pattern of compressions and rarefactions.

For a compressional **wave**, a wavelength measurement is made by measuring the distance from a compression to the next compression or from a rarefaction to the next rarefaction. On the diagram above, the distance from point A to point C or from point B to point D would be representative of the wavelength.

B. Using an Air Blaster:

Materials: Air Blaster and 3 10 oz cups.

- Use the air blaster to demonstrate how a compressional (sound) wave travels.
 - Stack the cups upside in a pyramid on a table. Aim the Air Blaster at them and knock the cups over.
 - The changing air pressure within the compressional wave knocks over the cups

II. How is Sound Produced

Materials

16 balloons with hex nut inserted

- Give each pair an inflated balloon with a hex nut inside. Tell the pairs that each student will do this activity once, and then pass the balloon to the next student.
- Show the students how to make the hex nut start spinning (by making a circular motion with the balloon). Tell the students to start spinning slowly, then faster, and observe what happens. The student should:
 - be able to feel the vibrations
 - feel that the vibrations and sound stop at the same time
 - hear that a higher pitch is made when the hex nut is moving fast
 - hear that the pitch gets lower as the hex nut slows down
- Ask the students what this experiment tells them about sound. Some answers should be:
 - Sound is produced by vibrations.
 - The faster the vibrations occur, the higher the pitch.

Collect all the balloons. The hex nuts are reused. Remove the balloon clip, deflate balloons, and return them to the kit box.

III. What is Natural Frequency?

Materials

8 sets of plastic tubing (each set has 4 different lengths, numbered 1, 3, 5, 7 or 0, 2, 4, 6).

Student Activity

Ask the students if they have ever held a seashell to their ear to “hear the ocean”? Tell them that they are not hearing the ocean, but are hearing the air vibrating inside the shell, at the **natural frequency** of the shell.

Tell the students they must be quiet so that they can hear the pitch of the sound in their tubes.

Your Notes:

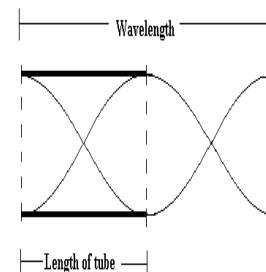
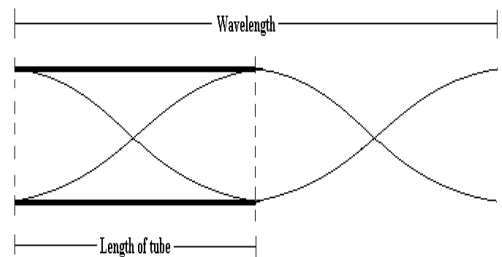
- Give each group one set of the plastic tubes.
- Tell each student to hold one of the tubes to an ear and listen.
- Then have pairs of students exchange tubes so that they can listen to a different length of tubing.
- Ask the students what they hear:
 - The pitch of the sound changes with the length of the tube.
 - The shorter tube produces a higher pitch.
 - The longer tube produces a lower pitch.
- Have the students look at the diagram on their Instruction Sheet, and explain to them that **lower** frequencies have **longer** wavelengths. Resonance occurs when the wavelength “fits” the tube’s length.

For VSVS members only: The length of the tube is actually half the wavelength.

Demonstration:

Look to make sure you won’t hit anything.
Slowly twirl the longer tube so that a *constant* low pitch is heard.

- Twirling the tube forces air up the tube.
- The ridges in the tube makes the tube and its air **vibrate**.
- Since the tube always produces the same **pitch**, the **frequency** of the wave produced by the tube is always the same.
- This frequency that the tube vibrates at is called its **natural frequency**.



Explain to the students that the sound is produced in the following manner:

- The tube always produces the same **pitch**, and the **frequency** of the wave produced by the tube is always the same.
- The frequency that the tube vibrates at is called its **natural frequency**.

- Explain that the tubes have different **natural frequencies**.
- Each tube vibrates at its **natural frequency**.
- This **natural frequency** is determined by the **length** of the tube.
- When the frequency of sound in the air matches the **natural frequency** of the tube, it gets reinforced many times so that the sound is magnified and can be heard above the rest of the sound mixture. This is called **resonance**.

Ask the students if they can tell you some other simple examples of **resonance**.

Some examples include:

- A window will vibrate and buzz when a particular note comes from a radio or stereo.
- A swing will go much higher if the person on it pumps at just the right time. The timing is more important than the force of the pump. Small pumps or pushes, done in rhythm with the natural frequency of the swing, will make the swing go higher than strong pumps at the wrong time.

Your Notes:

- Buildings can be severely damaged in an earthquake if their natural frequency matches the frequency of the waves created by the earthquake.

To reinforce the fact that each tube produces a different pitch, have all students holding tube #0 hit the tube on the palm of their hand. Then tell all students holding tube #1 to hit the tube on the palm of their hand. Continue with all tubes so that the students can hear a complete scale.

IV. How Do Tuning Forks Work?

Do not pass out the tuning forks and mallets until you have discussed the properties of tuning forks and how to use them.

Materials

8 mallets

8 sets of plastic tubing (each set has 4 different lengths, numbered 1, 3, 5, 7 or 0, 2, 4, 6).

8 tuning forks (4 of one frequency and 4 of another)

Ask the students what they know about tuning forks. Be sure to include the following information in the discussion.

- Tuning forks are usually made of metal.
- They have a handle and two tines that can vibrate when struck.
- These vibrations are so fast that they are impossible or very difficult to see.
- Each tuning fork is made to vibrate at **one frequency**, which is written on the fork. This frequency is its natural or resonant frequency.
- The number of times the tines vibrate in one second is called the **frequency**. **Frequency** is directly related to **pitch**.

The faster the vibrations occur, the higher the frequency and the higher the pitch.

Show the students how to hold the tuning fork at the **handle** and to hit the **tines** of the fork with the black rubber side of the mallet so that the fork produces a sound.

Show them that the sound is stopped as soon as the tines stop vibrating (do this by touching both tines).

Caution the students NOT to hit the tuning forks on a hard surface.

Give each group a mallet and the tuning fork that corresponds to the set of tubes that each group was given.

Set 0,2,4,6, (orange numbers) needs the “A” tuning fork

Set 1,3,5,7 (green numbers) needs the “G” tuning fork

Note: There are 4 different lengths of tubing in each set. Make sure the groups have kept the sets labeled 0,2,4,6 or 1,3,5,7 along with the correct tuning fork.

Note: The class will use 2 different tuning forks, so the students should be aware that different groups will get different results!

- Tell the students to look for the **frequency** number on the fork. Tell them to look for a **letter** as well.

Your Notes:

- Tell the students to record the letter and number on their observation sheets. The letter and number will correspond to one of the sets in the table below (and on their instruction sheets). Tell them that the **letters** correspond to only 1 note on the piano, the **pitch**.

Table of tuning fork frequencies and corresponding notes

| Frequency | Keynote |
|-----------|---------|
| 440 | A |
| 392 | G |

- Have ONE student in the group strike the **tines** of the fork with the black rubber side of the mallet so that the fork produces a sound and have the rest of the group listen for the sound.

This may have to be done a few times for everyone to hear it. Caution the students to avoid touching the vibrating tines unless they want to deliberately stop the sound.

- Remind the students that a tuning fork vibrates at a frequency that produces a special pitch.
- Ask the students if they can anticipate what will happen to the sound from a tuning fork if we match the natural frequency of the tuning fork with the natural frequency of a tube?
*The sound will become **louder** when the tuning fork and tube have matching frequencies because of resonance.*
- Tell the students that this is what they need to be listening for in the next experiment.

V. Finding the Length of a Tube at Which Resonance is Heard

Tell the students that they are going to find the length of tubing that will resonate with their tuning fork, and that these lengths will depend on the fork they are using. Tell the students to be quiet during this demonstration or the resonance will not be heard.

Tell the students to do the following:

- Place the set of tubes on the table in their **numbered order**. Leave about 3” between each tube.
- Place the tines of the tuning fork at the opening of the shortest tube.
- Hit the tuning fork to start it vibrating and listen for the resonance.
- Move the tines to the opening of the next tube and repeat. Continue doing this until the resonant sound increases to its loudest level.
- Continue moving the fork to the openings of the remaining longer tubes to show that the volume of the sound is no longer loud.
- Record the number of the tube that gives the loudest resonance.

Have one VSVS member record the results on the board, including the number and corresponding length of tube.

Ask the students what observations they can make about these measurements. They should observe that:

- **Longer** tubes are needed for the tuning fork with the **lower** frequency.
- **Shorter** tubes are needed for the tuning fork with **higher** frequency.
- The **same** length tube is needed for tuning forks with the **same** frequency.

Your Notes:

Optional (time permitting): Have the students exchange tuning forks **and** tubes so that they now have a tuning fork with a different frequency. Repeat the experiment with the second tuning fork, and record the results.

VI. Play “Twinkle Twinkle Little Star” with the Tubes

All students can do this, with one tube each. If the class is noisy have three VSVS volunteers do it.

- Have each person take one numbered sound tubes (2&3, 4&5, 6&7). Note that #'s 0 and 1 do not play
- To play a note, just whack the tube (that corresponds to the correct note) on your thigh or hand (NOT a table).

This tune is taped to the inside of the kit lid.

Twinkle Twinkle, Little Star

7 – 7 – 3 – 3 – 2 – 2 – 3

4 – 4 – 5 – 5 – 6 – 6 – 7

3 – 3 – 4 – 4 – 5 – 5 – 6

3 – 3 – 4 – 4 – 5 – 5 – 6

7 – 7 – 3 – 3 – 2 – 2 – 3

4 – 4 – 5 – 5 – 6 – 6 – 7

VII. Calculating the Speed of Sound

Do this if you you have time. Otherwise, leave it for the teacher to do.

- The speed of sound in air at 68°F is 344m/s (meters per second).
- The speed of sound can be calculated using the following formula:

$$v = f \times \lambda$$

Speed (**v**) = frequency (**f**) x wavelength (**λ**)

- The speed can be calculated by using an **open-ended** tube.
- The frequency is obtained from the inscription on the tuning fork (or the Table).
- The wavelength is found by measuring the length of the tube that the tuning fork resonates in and multiplying this by **2**. This measurement must be converted to **meters**.

Tell the students to enter their measurements and observations on the observation sheet and to follow the steps to complete the calculation.

Lesson written by: Pat Tellinghuisen, VSVS Director

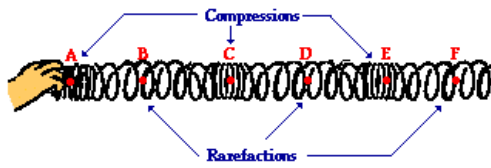
Walter Saba, Undergraduate Teaching Fellow, Vanderbilt University

Your Notes:

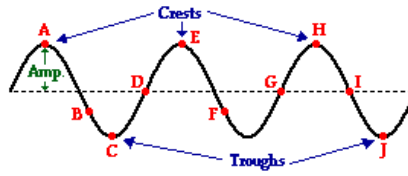
SOUND AND RESONANCE

Observation Sheet

Names _____



Compressional wave



Transverse wave

<http://www.physicsclassroom.com/class/waves/Lesson-2/The-Anatomy-of-a-Wave>

| Tuning fork frequency | Keynote | Which tube (#) produced the loudest resonance? |
|-----------------------|---------|--|
| | | |
| | | |

Length of tube

| Tube number | Length of tube |
|-------------|----------------|
| 0 | 30.6cm = .306m |
| 1 | 32.2cm = .322m |
| 2 | 36.5cm = .365m |
| 3 | 41.1cm = .411m |
| 4 | 46.5cm = .46m |
| 5 | 49.3cm = .493m |
| 6 | 55.1cm = .551m |
| 7 | 63.5cm = .635m |

Calculation of Speed of Sound (Optional)

$$v = f \times \lambda$$

Speed (v) = frequency (f) x wavelength (λ)

- The **FREQUENCY (f)** of the tuning fork = _____ Hz
(Shown on the fork)
- Number on tube that resonates with tuning fork = _____
- Length of this tube = _____ meters
(Look at the "Length of Tube" **Table above.**)
- The **WAVELENGTH (λ)** of sound = length of tube x 2 = _____ meters
- Speed of sound = wavelength x frequency = value in #4 x value in #1. = _____ m/se

Observation Sheet - Answers

| Tuning fork frequency | Keynote | Which tube (#) produced the loudest resonance? |
|-----------------------|---------|--|
| 440 | A | #2 |
| 392 | G | #3 |

Length of tube

| Tube number | Length of tube |
|-------------|----------------|
| 0 | 30.6cm = .306m |
| 1 | 32.2cm = .322m |
| 2 | 36.5cm = .365m |
| 3 | 41.1cm = .411m |
| 4 | 46.5cm = .46m |
| 5 | 49.3cm = .493m |
| 6 | 55.1cm = .551m |
| 7 | 63.5cm = .635m |

Calculation of Speed of Sound (Optional)

| | | |
|---|-----------------------------|-----------------------------|
| 1. The frequency (f) of the tuning fork (shown on the fork) | = 440 Hz | = 392 Hz |
| 2. Number on tube that resonates with tuning fork | = #2 | = #3 |
| 3. Length of this tube (Look at the Length of Tube Table above.) | = .365 meters | = .411 meters |
| 4. The wavelength (λ) of sound = length of tube x 2 | = .73 meters | = .822 meters |
| 5. Speed of sound = wavelength x frequency = value in #4 x value in #1. | = .73 x 440 =321.1 m/sec | =.822 x 392 =322.2 m/sec |