VOLUNTEER INFORMATION
Team Member Contact Information

Name: ____________________________ Phone Number: _____________________

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 Director: Pat Tellinghuisen
patricia.c.tellinghuisen@vanderbilt.edu

VSVS Office: Stevenson Center 5234

615-343-4379 (W), 615-297-5809 (H)

Co-Presidents: Christine Wang christina.e.wang@vanderbilt.edu
Arunabh Singh arunabh.singh@vanderbilt.edu

Secretaries: Gabriela Gallego gabriela.l.gallego@vanderbilt.edu
Sabeen Rehman sabeen.rehman@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://studentorgs.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 Pat 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!
### FEBRUARY

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- **Team Leader Training**
- **Team Training Mini Lesson for Tues, Wed, Thurs Teams**
- **Week 1 for Tues, Wed, Thurs Teams**
- **Week 1 for Tues, Wed, Thurs Teams**
- **Week 2 for all teams**
- **Week 3 for all teams**
- **Week 4 for all teams**
- **Make Up Week**
- **Mon Team Training**
- **Mon Teams Teach**

### MARCH

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- **Team Training for Tues, Wed, Thurs Teams**
- **Week 2 for all teams**
- **Week 3 for all teams**
- **Week 4 for all teams**

### APRIL

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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:

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.
  - 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: 417 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 LITERATURE MAGNET SCHOOL: 110 GALLATIN AVE 615-262-6947
Going down Gallatin Avenue, East Literature Magnet School is on the left.

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.
Goal: To demonstrate the concept of density using saltwater, and to share some information about the salinity of oceans.

Fits Tennessee standards GLE 0607.8.2

VSVSer Lesson Outline:

I. Introduction - Saltwater in the Ocean:
The VSVS team will share some information about oceans with the students.

II. Density Information and Activities
A. Density Background Information: VSVS team members will explain the concept of density.
B. Polydensity bottle
C. Floating Solids Demonstration: Students will observe two vials: one with saltwater and one with freshwater. A plastic bead will float in the saltwater but not in the freshwater, this illustrates the concept of floating.

III. Separation Challenge: Students will separate a mixture of beads using the concept of density. There are four types of beads with differing densities. As students add salt to the water, the density changes, the beads will float according to their densities.

IV. Review

LOOK AT THE VIDEO BEFORE YOU GO OUT TO YOUR CLASSROOM (https://studentorgs.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. What’s the difference between density and mass?
   2. What region of the globe is home to densest salt water?

2. During the Lesson:
   Here are some Fun Facts for the lesson
   Density of salt water: 1020 kg/m³
   Density of the human body: 1062 kg/m³
   Density of the Dead Sea: 1240 kg/m³
   Least dense? The universe: estimated at 10^{-27} kg/m³
   Most dense? A black hole; “infinitely” dense

   Draw an analogy to a pinhole and a football field. If you compress a football field into the size of a pinhole, the football field would have a very high density. If you shrunk the football field into a tiny, tiny space, just a little more than nothing, you’d have the density of the singularity of a black hole. A singularity of a black hole is a one-dimensional point that contains infinite mass

Your Notes:

________________________________________________________________________
in an infinitely small space (this example may be too advanced for the class, so share accordingly).

Refer to Disney’s Despicable Me. In Despicable Me: when Gru shrank the moon, he decreased the volume, without altering the composition of the moon (i.e. the mass did not change). So the density would have increased. So it would be impossible for Gru or a spaceship to lift the moon.

**Unpacking the Kit – What you will need for each section:**

**For Part I: Introduction - Saltwater in the Ocean**
32 Observation Sheets, 16 Instruction Sheets, 16 World Maps with Ocean Salinity and Density Graphs

**For Part II. Density Information and Activities**
A. Density Activity
B. 1 Polydensity bottle
C. Floating/Sinking Beads
16 bags with 1 vial of saltwater and a plastic bead (#1), 1 vial of regular water and a plastic bead (#2)

**For Part III: Separation Challenge – Changing the Density of Water to Make Beads Float**
16 containers of kosher salt, 2L bottle of water, 16 100 mL plastic jars containing several beads of 4 different colors/shapes filled with water.
16 Ziploc bags containing: 1 measuring spoon, 1 coffee stirrer, 16 plates

**I. Introduction - Saltwater in the Ocean**

**Learning Goals: Students learn about salinity differences in the ocean.**

**Why is the science in this lesson important?**
The density of saltwater can impact global currents that wildlife use to migrate around the ocean. Thus an understanding of saltwater density is relevant to oceanologists, fishermen, and anyone who relies on the sea for a living.

Tell students that:
- Oceans and seas contain considerably more salt than freshwater.
- Ask students why they think the sea contains so much salt but lakes, streams, and rivers have very little.
- The salt in the ocean comes from the gradual process of weathering and erosion of the Earth’s crust, as well as the wearing down of mountains.

Salinity is the amount of dissolved salts in water.
- Have students look at the map of the world handout.
- As students can tell from the map, the oceans vary widely in salt concentration.
  The numbers in the key (at the bottom) are measures of salinity. 35 means there are 35 grams of salt per 1000 grams (1 kilogram) of water. The higher the

Your Notes:
number, the more salt that ocean contains. http://en.wikipedia.org/wiki/Salinity

- Ask students if they can point to the saltiest area. The saltiest water occurs in the Red Sea and the Persian Gulf.
- The average salinity of water in the ocean is 35 PSU.

II. Density Information and Activities

Learning Goals:
Students learn the definition of density, and that density is a physical property of matter.
- Students observe that solids (beads) of different densities float or sink depending on the density of the liquid they are in.

A. Density Background Information

- Ask the students to explain the property of density.
  - Density is a physical property of matter.
  - Each element and compound has a unique density associated with it.
- Ask students to give you some examples of high density objects and low density objects.
  Some examples might be:
  - Regular coke can vs. Diet coke (diet floats in water, regular sinks)
  - Oil (less dense) vs. water (more dense)
  - 1 golf ball (more dense) vs. 1 cotton ball (less)
- Sum up the difference between high density and low density with these generalizations:
  - High density means there is a lot of material in a given space (volume)
  - Low density means there is little material in a given space (volume).
- Have students look at the pictures on their Instruction Sheet. The circles represent material. Both pictures have the same space (area), but the high density picture has much more material (circles).

Since \( D = \frac{m}{V} \), more mass (circles) in a given volume increase in density.

B. Polydensity Bottle Demonstration

- Have students observe the polydensity bottle. Shake the bottle gently and let the students observe what happens (the 2 liquids gradually separate).
- Ask students what happened? First the white beads moved to the top and the blue beads moved to the bottom of the liquid (refer to background information). Then the white beads floated down and the blue beads floated up and met in the middle.
- Ask students why they think this happened?
  - The two liquids have different densities.
  - One of the liquids is denser salt water (lies below the beads on the bottom).
  - The other liquid is less dense rubbing alcohol (lies above the beads on the top).
  - These 2 liquids do not mix, they form layers (salt water on the bottom & rubbing alcohol on the top)

Your Notes:
The beads also have different densities:

- The blue beads are denser than the white beads and less dense than the salt water (they float on the salt water).
- The white beads are less dense than the salt water and blue beads, but denser than the rubbing alcohol (they float on the blue beads but not on the rubbing alcohol).

For VSVS background information only: The bottle contains a mixture of isopropyl alcohol and saltwater. All of the liquids and beads have different densities. The rubbing alcohol is the least dense followed by the white beads, then the blue beads, with salt water being the densest. When the two liquids are forced to temporarily mix by shaking, the liquid formed has a density somewhere between those of rubbing alcohol and saltwater. As the two liquids separate once more (due to their different densities), the initial layering reoccurs: the blue beads float to the top of the saltwater layer because they are less dense than saltwater, and the white beads float to the bottom of the isopropyl alcohol layer because they are more dense than the isopropyl alcohol.

C. Floating/Sinking Beads

| Learning Goals: Students observe how density of a liquid impacts beads’ ability to float. |

Materials:
16 bags containing
1 vial with saltwater and a plastic bead (#1)
1 vial with regular water and a plastic bead (#2)

Pass out the bags containing the vials with the beads to pairs of students. **Make sure that students do not remove the tops of the vials.** Tell students that the 2 liquids have different densities.

Explain to students that:
- solids that are less dense than a liquid will float in that liquid.
- solids that are denser than a liquid will sink in that liquid.

**Tell students that the beads in all of the vials have the same density.**

Ask students why the bead floats in vial 1 but not in vial 2.
- Vial #1 has a liquid that is denser than the bead.
- Vial #2 has a liquid that is less dense than the bead.
- Tell students that the liquid in vial #1 is salt water and in vial #2 is distilled water.

Point to the facts on the board:
- Pure water has a density of 1g/ml.
- Ocean water at the sea surface has a density of about 1.027 g/ml.
- Saturated salt solution has a density of 1.202 g/ml.

Ask students why they think saltwater is denser than regular water.
- Saltwater has a higher mass because of the added salt but still occupies the same amount of space in a container that regular water would, and hence is denser.

Ask students if the bead is more or less dense than regular water. **More**
Ask students if the bead is more or less dense than saltwater. **Less**

Your Notes:
III. Separation Challenge – Changing the Density of Water to Make Beads Float

Learning Goals: Students observe how density of a liquid impacts beads’ ability to float.

Distribute to each pair of students:
1. plate
1. 100mL jar containing water and several colored beads
1. measuring spoon (pink 1/4tsp)
1. Coffee Stirrer
1. container of salt
32 Density Graphs (Handouts)

Tell students to:
1. Observe that there are 4 different beads. Tell students that the beads have different densities. They are (see student handout):

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<tr>
<th>Bead</th>
<th>Approximate Density</th>
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<tr>
<td>#1, white, oval</td>
<td>&lt; 1.00g/mL</td>
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<tr>
<td>#2, blue, cylindrical</td>
<td>1.05-1.07g/mL</td>
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<tr>
<td>#3, yellow, cylindrical</td>
<td>1.13-1.16g/mL</td>
</tr>
<tr>
<td>#4, clear, cylindrical</td>
<td>&gt; 1.276g/mL</td>
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</tbody>
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2. Pure water has a density of 1g/mL
3. A saturated salt solution has a density of 1.202 g/ml
4. Ask students to explain why the white oval beads are floating? Their density is less than that of pure water.

Tell students that we can gradually change the density of the water by adding salt to it.
5. Tell students to look at the Density of Salt Water graph and explain that the density of water increases as more salt is added.
6. Ask students: What do you think will happen to the beads when salt is added to the water?
    Since the beads have different densities, they will float in different densities of salt water.
7. Ask students to predict the order that the beads will float.

For VSVS Information: The density of the salt water has been calculated using a mass of 1.63 g for one ¼ teaspoon of salt and 100mL for volume.
The density of regular (fresh) water is 1g/mL. 100mL = 100g
(Since D = m/V, the density of water is 100g/100mL, = 1g/mL.)
The density of the saltwater is calculated using:
100g of water + (1.63 grams X # of 1/4-teaspoons of salt added) / 100mL

Tell students to:
1. Stir the beads and water, using the coffee stirrer.
2. Tap all of the floating beads gently to see which ones float and which beads sink to the bottom.

Share the following explanation with the students: some of the beads float initially because water has a high surface tension. This surface tension is mostly due to the high intermolecular forces between water molecules making it possible for some things that would normally sink to float.

Your Notes:
Tapping the bead exerts enough force to break the surface tension. Stirring the water may also break the surface tension.

3. Record on their observation sheets, which beads are floating and which are at the bottom of the cup. *The round whitish beads should be the only ones floating at this point.*

4. Fill the spoon with salt (do not overfill).
5. Add one level spoon of salt and then stir the water until they can no longer see salt particles.
6. Record what happens. Are any more beads floating on top? *There shouldn’t be any beads floating on top.*
7. Have students repeat this step. Record what happens after each spoon is added.
8. Students can add several more spoons; but tell them not to go higher than 10 spoons of salt total.
9. After 10 spoons, have students screw lid on jar. Make sure it cannot leak. Place jars in kit box so that NO water will leak into box – ie upright!

**Note:** In the lab, 3 or 4 1/4- teaspoons of salt were required for the blue beads to float and 7-9 spoons were necessary for the yellow beads to float. This may vary depending on students’ “level teaspoons”. The clear beads will not float at all. Their density is greater than that of a saturated salt solution. Students can add several more spoons; tell them not to go higher than 10 spoons of salt total. The salt solution eventually becomes saturated and no more salt will dissolve.

### V. Results

Ask students if their predictions were correct.

- The white beads floated initially, because their density is less than one.
- The beads floated in the order of their densities, white, then blue, then yellow.
- The clear beads never floated. The students should have noticed that salt stops dissolving in the water. This is called a saturated solution.

- Ask students if they can think of a way to make the clear beads float.
  - **We could use liquids more dense than saltwater for the clear beads.**

Tell students to look at the Density Table for Recyclable Plastics (on their Handout) and determine what kinds of plastics might have been used in this lesson.

### IV. Review

- **Ask students:** If a solid floats in a liquid, is it denser or less dense than the liquid? – *Less* If it sinks -more
- **Ask students why saltwater is more dense than freshwater?** *Saltwater has a higher mass than the same volume of freshwater.*
- **Ask students:** what is one way to separate mixtures? *Density*

**References:** Educational Innovations Mixture Separation Challenge, and Polydensity Bottle.

**Lesson written by:** Patricia Tellinghuisen, Director of VSVS, Vanderbilt University
Michael Gootee, VSVS Lab Assistant

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**Your Notes:**

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Observation Sheet - Saltwater Density

IIC. Floating Solids in Vials
Is the bead more or less dense than freshwater? __________
Is the bead more or less dense than saltwater? __________

III. Separation Challenge
Look at the table of bead densities and predict the order in which they will float as spoons of salt are added to the water.
1. ___________________________________________________________________________
2. ___________________________________________________________________________
3. ___________________________________________________________________________
4. ___________________________________________________________________________

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<thead>
<tr>
<th>Bead</th>
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</tr>
<tr>
<td>#3, yellow, cylindrical</td>
<td>1.13-1.16g/mL</td>
</tr>
<tr>
<td>#4, clear, cylindrical</td>
<td>&gt; 1.276g/mL</td>
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Write down what happens to the beads after each addition.

<table>
<thead>
<tr>
<th>Number of Spoons Added</th>
<th>Density salt water</th>
<th>What Happened to the Beads?</th>
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</table>

Look at the Density Table for Recyclable Plastics (on your Handout) and determine what kinds of plastics might have been used in this lesson.
white, oval = ________________  blue, cylindrical = ________________
yellow, cylindrical = ________________  clear, cylindrical = ________________
Observation Sheet Answers - Saltwater Density

IC. Floating Solids
Is the bead in the vial more or less dense than freshwater? More
Is the bead in the vial more or less dense than saltwater? Less

III. Separation Challenge
Look at the table of bead densities and predict the order in which they will float as spoons of salt are added to the water.
1. white, oval will float in pure water, since its density is less than the density of water
2. blue, cylindrical
3. , yellow, cylindrical
4. clear, cylindrical

<table>
<thead>
<tr>
<th>Bead</th>
<th>Approximate Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1, white, oval</td>
<td>&lt; 1.00g/mL</td>
</tr>
<tr>
<td>#2, blue, cylindrical</td>
<td>1.05-1.07g/mL</td>
</tr>
<tr>
<td>#3, yellow, cylindrical</td>
<td>1.13-1.16g/mL</td>
</tr>
<tr>
<td>#4, clear, cylindrical</td>
<td>&gt; 1.276g/mL</td>
</tr>
</tbody>
</table>

Write down what happens to the beads after each addition.

<table>
<thead>
<tr>
<th>Number of Spoons Added</th>
<th>Density salt water</th>
<th>What Happened to the Beads?</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.0163</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.0326</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1.0489</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1.0652</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1.0815</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1.0978</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1.114</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1.1304</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1.1467</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1.163</td>
<td></td>
</tr>
</tbody>
</table>

Look at the Density Table for Recyclable Plastics (on your Handout) and determine what kinds of plastics might have been used in this lesson.
white, oval = HDPE, LDPE, PP    blue, cylindrical = PS
yellow, cylindrical = PVC      clear, cylindrical = PETE, PVC
Goal: To help students understand the energy conversions from chemical to light, sound, mechanical and thermal energy.

**TN Curriculum Alignment: SPI 0607.10.3** Recognize that energy can be transformed from one type to another.

**VSVOs**

**Lesson Outline**

______ I. Introduction.
Discuss different forms of energy and note that energy can be neither created nor destroyed.

______ II. Chemical Energy → Thermal, Light, Sound, Mechanical Energy
Spray flammable Lycopodium powder into a can with a lit tea candle. There are many energy conversions taking place. Students are told that this demonstration will be repeated at the end of the lesson, when they will be asked to name the conversions.

______ III. Chemical Energy → Light energy
The conversion of chemical energy to light energy is demonstrated with a lightstick.

______ IV. A. Chemical Energy → Thermal Energy.
The Recyclable Hand Warmer contains a supersaturated solution of sodium acetate that crystallizes when disturbed, demonstrating the conversion of chemical energy to thermal energy.

______ V. Thermal Energy → Chemical Energy.
Potassium chloride is dissolved in water – students will observe a decrease in temperature. Thermal energy in the water provides the energy needed to dissolve potassium chloride. Show students the cold pack and explain that ammonium nitrate is the chemical in commercial cold packs.

______ VI. Chemical Energy → Thermal, Light, Sound, Mechanical Energy
The dust can explosion is repeated, and students will name all the conversions taking place.

______ VII. Review Questions

**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) What forms of energy are discussed in the lesson?
   2) How is chemical energy stored?
   3) What energy conversions are part of the “dust can” experiment?
   4) How is energy converted in the lightstick demonstration?
   5) In which demonstration(s) is a phase change used to give off heat?
   6) Why does water become cooler when potassium chloride is added to it?
2. Use these fun facts during the lesson:
   - If a person yelled for 8 years, 7 months, and 6 days, he or she would produce enough energy to heat one cup of coffee.
   - A hurricane releases 50 trillion to 200 trillion watts of heat energy. This is as much energy as a 10-megaton nuclear bomb exploding every 20 minutes.
   - Just 1/3 of the energy in burning coal reaches the consumer as electricity. The rest is converted to unusable forms of energy, e.g. heat, chemical, light energy.
   - Heating and cooling rooms is the greatest source of energy usage in American homes today.
   - The amount of energy produced by the sun in 2 weeks equals the combined stored energy of all the coal, iron, and natural gas reserves known to man.

During the lesson, use this diagram to emphasize the energy conversions taking place.

Unpacking the Kit:
VSVSers do this while one person is giving the Introduction and another is writing the following on the board: Note that students are put into 8 groups of 3-4 and should have their pencils ready.

For Part I. Introduction
Give each student an observation sheet and goggles.
Give each pair an instruction sheet (inside a page protector).

For Part II. Introducing Chemical Energy Conversions: Dust Can Explosion
1 plastic bag containing materials for exploding can demonstration:
1 aluminum pie plate, 1 coffee can with hole in side and lid lined with foil, 1 tea candle, 1 box matches and 1 lighter
1 container lycopodium powder and 1 pipette

For Part III. Chemical energy → Light energy: Lightstick Demonstration
1 large lightstick

For Part IV. Chemical Energy → Thermal Energy: Hand warmer demonstration
8 Recyclable hand warmers (plastic pouch maybe green, blue or colorless, and contains a liquid inside)

For Part V. Thermal Energy → Chemical Energy: Dissolving Potassium Chloride in Water
Students do this activity in pairs. Two pairs will share the potassium chloride and water.
   16 Styrofoam cups, 16 thermometers, 16 50 mL measuring cylinders, 8 water bottles (shared by two pairs), 1 instruction sheet in a protector

For Part VI. Chemical Energy to Thermal, Light, Sound, and Mechanical Energy: Dust Can Explosion Same as Part II.

Your Notes:
I. Introduction

**Learning Goals:** Students understand that chemical energy is a form of potential energy that is stored in the bonds of molecules

**Why is the science in this lesson important?**
One popular field in engineering is petroleum engineering, where scientists work to turn simple resources like oil and gas into usable energy.

Hydrogen is a very efficient energy carrier and is often produced through the means of biological, thermochemical, and electrolytic processes. The challenge is to be able to obtain hydrogen from renewable energy sources instead of fossil fuels. Hydrogen has great potential to be a clean and efficient power - a fuel cell that turns the chemical energy of hydrogen into electricity combined with an electric motor could be very successful in transportation applications.

**Ask students:** What are the different forms of energy?
*Possibilities include: electrical, chemical, mechanical, thermal, light (electromagnetic), sound, and nuclear. (Note that Potential Energy and Kinetic Energy are states of energy, not forms.)*

Tell the students that this lesson will be emphasizing chemical energy and conversions of this form to and from other energy forms. Students can use the depiction that you drew on the board as a reference in determining what chemical energy is converted to in each experiment.

Explain to students that chemical energy is a type of potential energy, in that it is energy stored in the chemical bonds that hold the chemical together.

When the atoms or molecules in a chemical are rearranged, chemical energy is released or absorbed. Point out that several types of energy may be produced in a chemical energy conversion; for example, when wood burns, chemical energy is converted to thermal, light, and sound energy.

**Ask students:** What are some other examples of chemical energy being converted to other forms?
- Food being eaten (chemical to thermal and mechanical).
- Batteries used in flashlights (chemical to light and thermal).

**Ask students:** What happens to energy when we use it? Be sure to include the following points in the discussion.
- **Energy is neither created nor destroyed.**
- The total amount of energy stays the same. It only changes from one form to another.

In this lesson, students will study the following energy conversions

- chemical energy → light energy
- chemical energy → thermal energy
- thermal energy → chemical energy
- chemical energy → sound energy
- chemical energy → mechanical energy

**Organize students into eight groups of three or four students.**
- Give each student an observation sheet.
- Give each pair an instruction sheet (inside a page protector).
II. Introducing Chemical Energy Conversions: Dust Can Explosion

Learning Goal: Students observe at least 4 chemical energy conversions.

Caution: This experiment is loud and sometimes propels the lid of the coffee can in the air. Be sure the can is some distance away from the nearest students before you do this experiment!
Note: If the explosion does not happen on the first try, please try again. Some groups have to try this several times to achieve the desired results. The students love to see this more than once, and it shows them that perseverance pays off.

Tell students that the next demonstration will illustrate at least 4 chemical energy conversions. Students will observe so that they can name the conversions at the end of the lesson.

Put on Goggles
- Show students the "dust can".
- Light the tea light candle and place it in the coffee can. Do not place it too far away from the hole in the side of the can.
- Load the pipette with enough lycopodium powder to fill the tip. DO NOT turn the pipette upside down, it will fall out of the pipette. There must be a good amount of powder at the tip of the pipette for this to work.
- Show the students the hole in the side of the can.
- Holding the pipette at an angle (aiming down with about a 30° angle from the horizontal), place the pipette in the hole (make sure the pipette is snug) and angle it toward the flame.
- Place the lid on the can. Wait until now to do this, as the flame will quickly go out after the lid is secured.
- Immediately after securing the lid, firmly squeeze the pipette. Leave the pipette in the hole after squeezing.
- There will be a flash of fire and a loud explosion, and the lid will blow off the can.
- Tell students that you will do this again at the end of the lesson and that they will need to name the different chemical reactions taking place
- The large volume of combustion gases created (carbon dioxide and water vapor) causes the lid of the can to blow off.

Background Information for VSVS members only: The dust can explosion is a dramatic illustration of the effect of surface area on the rate of reaction. The chemical reaction is the same as any combustion reaction of an organic fuel - wood, coal, gasoline, natural gas. These fuels all contain carbon which can react with oxygen to create water and carbon dioxide. If these gases are confined, an explosion will occur because the gases take up a larger volume than the fuel. Explosions can be useful. For example, the internal combustion engine in a car works by small explosions set off by sparks from the spark plugs in each cylinder which drives the pistons. Other explosions can be disastrous. The dust can explosion is a safe, small scale illustration of what happens in a flour mill explosion. The dust can explosion illustrates why workers in grain elevators, saw mills, and flour mills have to be very careful about sparks. A spark can ignite flammable dust in the air to produce a large explosion.

Your Notes:
III. Chemical energy → Light energy: Lightstick Demonstration

**Learning Goals:** Students can observe the release of light energy to determine that a chemical energy conversion has occurred

**Lightstick Demonstration**
- Hold up the lightstick.
- Ask the teacher if it’s fine to turn off the lights for the demonstration. If not, continue with lights on.
- Bend the plastic tube to break the thin vial inside. The lightstick may need to be bent using the edge of a table.
- Shake the lightstick.
- Hold the lightstick up and walk around the room to give the students a closer look at the lightstick.

**Explanation:**
- There are two chemicals in the lightstick, one encased in a vial. When the lightstick is bent, the vial breaks and two chemicals mix and react.
- Ask them what kind of energy they think chemical energy was converted to in this demonstration: Light Energy
- **Ask students** if they know of any other energy conversions from chemical energy to light energy. *Some examples are burning wood in fireplaces, a lit match, and fireworks. Another example in nature is the glow of the firefly or lightning bug (light is produced through the action of an enzyme, luciferase, on luciferin). This is called bioluminescence.*
- Tell students to answer question #1 on their observation sheet.

**For VSVS information only:** The lightstick is an example of a chemiluminescent reaction. **Chemiluminescence** occurs when a chemical reaction produces a molecule in an excited state. When this excited molecule changes to a more stable form, it emits light. **Bioluminescence** is an example of chemiluminescence in a biological system, generally an animal or bacterium.

IV. Chemical Energy → Thermal Energy: Hand Warmer Demonstration

**Learning Goals:**
- Students can observe the release of thermal energy to determine that a chemical energy conversion has occurred.
- Students can explain how the recyclable hand warmer illustrates the law of conservation of energy.

**Materials:** 8 Recyclable hand warmers (plastic pouch maybe green, blue or colorless, and contains a liquid inside)

**Recyclable Hand-Warmer** - Show the class a hand warmer and explain that it contains a supersaturated sodium acetate solution.
- Give each group a hand warmer.
- One student in each group should use a fingertip to firmly press and release the metal activation button. Some handwarmers have a piece of metal that needs to be bent.
- Students should see white solid beginning to form around the button/metal disc. If they don’t, they need to press the button again/bend metal disc. (Try using the tip of a finger to press down on the button.)
- Ask the students what they observed. A *change of state from liquid to a solid has occurred, and the pouch felt warmer.*

**When finished, collect all hand warmers and return them to the kit box. They are rejuvenated by heating in boiling water.**

**Explanation:** Tell the students that there is more chemical energy in the bonds of liquids than in solids. When liquids change to solids, excess chemical energy is given off. This energy can be converted to another form. **This is an excellent reminder that energy is not lost; it merely changes form.**

**Ask the students** what form of energy they think the chemical energy was converted to:

- **Thermal Energy (because heat was released in the reaction)**

  - Tell students to answer question #2 on their observation sheet.

  - Point out that the hand warmer can be recycled by placing it in a pan of hot water for several minutes (directions are given on the hand warmer). This returns the energy that was lost during crystallization.

  - Ask the students to explain how the recyclable hand warmer illustrates the **law of conservation of energy.**

    - Pushing the button causes the solution to turn to a solid and thermal energy to be released. The opposite reaction occurs when the pouch is placed in hot water. This input of thermal energy restores the sodium acetate solid to its original liquid state.

**For VSVS Information only:**

1. **Saturated solutions** contain the maximum amount of solid that can be dissolved in a liquid at a given temperature. Usually, more solid can be dissolved if the solution is heated to a higher temperature; however, when this solution is cooled, the excess solid crystallizes. This is the normal process for purifying a solid (by recrystallizing it from solution).

2. **Supersaturated solutions** are unstable because they contain more dissolved solid than normally can be dissolved at that temperature. The difference between a supersaturated solution and a saturated solution is that the excess solid doesn’t crystallize when the solution is cooled. The excess solid will only crystallize with the addition of a seed crystal of the same substance, or in the case of the recyclable hand warmer, when the solution is disturbed by pressing the activation button. Only a few solids are capable of forming supersaturated solutions. Sodium acetate trihydrate is one of them.

**Everyday Applications:**

1. **Liquid to Solid Phase change gives off thermal energy:**

   Tell students to look at the picture of ice on oranges hanging from a branch of an orange tree on their handouts. Explain that farmers spray water on fruit trees when a light freeze is expected. The water freezes on the outside of the fruit. When it freezes, it releases enough heat to keep the fruit from freezing. (This is another phase change from liquid to solid that releases thermal energy, it just happens more slowly than in the hand warmer). This only works if the temperature doesn't drop below 28°F.

**Your Notes:**
2. **Liquid to Gas uses thermal energy (Thermal to chemical)**
   This is especially important for humans – when we sweat, the evaporation of water from our skin absorbs heat from our skin. This helps maintain our body temperature. This is why a fan feels so cool after running around outside (it is a phenomenon called evaporative cooling).

**V. Thermal Energy → Chemical Energy: Dissolving KCl in Water**

<table>
<thead>
<tr>
<th>Learning Goals:</th>
<th>Students can observe the conversion of thermal energy to chemical energy.</th>
</tr>
</thead>
</table>

**Materials:** *(Students do this activity in pairs.)* Two pairs will share the potassium chloride and water.

Give each pair the following:

- 1 Styrofoam cup
- 1 thermometer
- 1 50 mL measuring cylinder
- 1 water bottle (shared by two pairs)
- 1 instruction sheet in a protector

- Distribute one jar of potassium chloride and 2 plastic spoons to each group of two pairs.
- Give each student safety goggles and instruct them to wear them while they are doing this experiment.
- Tell the students that in each activity thus far, chemical energy has been converted to another form of energy.
- Let them know that in this activity, the opposite will occur. One form of energy will be converted to chemical energy.

**Background:** When dissolving a solid in a liquid, energy is required to break the bonds that hold the solid together. This energy is supplied by thermal energy from the liquid, and thus when most solids dissolve, the temperature of the liquid drops.

In this experiment, potassium chloride is dissolved in water, and thermal energy from the water is absorbed. The temperature change will be measured to show that thermal energy is used. *The water will be cooler.*

**Make sure students know how to read a thermometer:**
- Ask students to look at the diagram of the thermometer on their Observation Sheet.
- Explain that:
  - This diagram is a copy of their thermometer.
  - Each line represents a temperature degree.
  - The temperature is read by observing where the top of the red liquid is.
- Find the lines that represent 20°C and 30°C (the temperature will be between these 2 values).
- Mark on their diagram, the height to which the red liquid has reached on the thermometer.

**Note:** While students are starting the experiment, VSVS members should circulate among the students and check their observations to see if their reading is about 24°C.

**Note:** The instruction sheet also tells the students to mark the thermometer diagram when they measure the temperature of the water and the temperature of the potassium chloride solution. Continue checking their Observation Sheets throughout the activity to make sure they have recorded temperatures which correspond to their marks on the thermometer diagram.

**Your Notes:**

________________________________________

________________________________________

________________________________________
Tell students to:

- Determine which black line it matches up with on the thermometer diagram. The degree that the black line represents is the temperature the thermometer senses. Record this temperature.
- The temperature represented by their mark should be about 24°C. (Answer question #4 on the Observation Sheet).
- Students and VSVS members should put on their safety goggles.
- The following instructions are given on their instruction sheet – make sure they are following this procedure while you are circulating and checking Observation Sheets.

Tell each pair to:

1. Fill the 50 mL cylinders to the mark with water and add it to the Styrofoam cup.
2. Place the thermometer in the water make sure it rests on the bottom of the cup) and (after about 1 minute) measure the temperature of the water.
3. They should mark the temperature they think the water is and answer question #5A on the observation sheet.
4. Add two spoonfuls of potassium chloride and stir with the thermometer. It takes about two minutes for the solid to dissolve.
5. Find where the red liquid has moved to, read the temperature, mark the temperature on the thermometer diagram, and write in the temperature on the blank for #5B (water plus potassium chloride).
6. Subtract the two temperatures and record this value.

- Ask the students what they noticed after they added potassium chloride to the water: *The water got colder.*
- Ask students: What was the temperature difference they observed? Write these values on the board. *Students should observe a decrease in the range of 10-14 degrees.*
- Ask students what type of energy was converted to chemical energy in the experiment: *Thermal Energy*
- It is often difficult for students to see this. Remind them that in the activities with hand warmers, chemical energy was converted to thermal energy, so heat was released. In this activity, heat was used (the solution got colder), so it is a thermal energy to chemical energy reaction/conversion.
- Ask students if they know what a cold pack is. When is it used? Show the students a cold pack. Activate it and pass it around the room for the students to feel. (Make sure it is returned to the VSVS lab.)

Share the following information with the students:

*Commercial cold packs contain separate bags of ammonium nitrate and water. The cold pack is activated by squeezing to break the plastic divider between the water and ammonium nitrate so ammonium nitrate mixes with the water. Just as in the experiment above, when ammonium nitrate is dissolved in water, thermal energy from the water is absorbed.*

Disposal: All the chemicals in this lesson are OK to pour down the sink. Pour the solutions from the Styrofoam cups down a sink or, using the large funnel, into the waste bottle provided. Make sure the waste bottle lid is screwed on tightly and placed UPRIGHT in the kit box. **Put used Styrofoam cups in the trash bag before putting them back in the kit box. Return all cups etc to VSVS lab.**

Your Notes:

**Learning Goals:** Students can identify the chemical energy conversions to thermal, mechanical, light, and sound energy.

**A. Dust Can Explosion: Flame Demonstration**

Materials needed for the Dust in a Flame Demonstration are in the Coffee Can which contains:

1. box of matches
2. container of lycopodium "dust" powder
3. pipette (jumbo size)
4. tea light candle
5. aluminum pan

- Show the students the lycopodium "dust" powder.
- Light the tea candle and place it on the aluminum pan.
- Load the pipette with enough dust powder to fill the tip. **Do not turn the pipette upside down.** There must be powder at the **tip** of the pipette for this to work.
- Hold the pipette so the tip is about 10 inches above the flame and squeeze the pipette bulb to release the lycopodium powder into the flame.
- There will be a flash of fire.

**Ask students:** Why was there a flash of fire? It was caused by the rapid burning (combustion) of the lycopodium powder.

**Ask the students** if they can name the chemical energy conversion involved? *Burning involves chemical energy to light and thermal energy.*

**Explanation for VSVS members:** If the powder is put in a pile, it will not light. Oxygen cannot get inside the pile to react with enough particles of powder; it can only react with the particles on the outside of the pile. When the powder is suspended in the air, it has more surface area than when it was in a pile. This is because the particles are extremely small. When they are sprayed into the air near the flame, the particles are spread out so the oxygen in the air reaches more particles at the same instant – hence more particles are burning at the same time, and you see a big flash of flame. (Lycopodium powder is a dried-up moss. It is used for this type of demonstration because the powder has extremely small particles.)

**B. Dust Can Explosion: Whole Demonstration**

The dust can explosion is repeated (see Part 1 for instructions). Students will need to observe and name the conversions.

**Ask students:** What chemical energy conversions are involved? Write the answers on the board and tell them to then complete question #6 on their observation sheets.

- Chemical to thermal
- Chemical to light
- Chemical to mechanical
- Chemical to sound

**Your Notes:**

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________
VII. Review Questions

**Learning Goals:** students review the different forms of energy and the Law of Conservation of Energy.

Go over the observation sheet with the students, and ask them to answer the review questions. Discuss the review questions, including reference to vocabulary words whenever possible.

**What are the different forms of energy?** Different forms of energy covered in this lesson include chemical, light, and thermal, mechanical. Other forms include, electrical, nuclear.

**Can energy ever be created or destroyed?**
No, energy is always conserved. It only changes form. *This is the Law of Conservation of Energy*

**What type of energy conversions does the following represent?**
- Turning on a flashlight: chemical energy to electrical energy to light energy

**What are some other types of energy conversions that we have not discussed today?**
*Examples include:* nuclear to electrical, electrical to thermal, electrical to mechanical (electric cars).

Lesson written by
Dr. Melvin Joesten, Chemistry Department, Vanderbilt University
Pat Tellinghuisen, Coordinator of VSVS, Vanderbilt University
Susan Clendenen, Teacher Consultant, Vanderbilt University
Circle the correct energy conversion for the following questions:

1. When the light stick was activated, chemical energy was converted to:
   a. thermal energy  
   b. light energy  
   c. electrical energy

   What evidence do you have for this conversion? __________________________

2. When the button was pushed (or disc bent) in the recyclable hand warmer, chemical energy was converted to:
   a. electrical energy  
   b. thermal energy  
   c. light energy

   What evidence do you have for this energy conversion? ____________________

3. Activity: Reading the Thermometer

   Look at your thermometer. Mark the height to which the red liquid has reached. This is the temperature the thermometer senses. Record this temperature below.

   Initial temperature reading of the thermometer diagram: ______ °C

4. Potassium Chloride Activity

   Repeat temperature reading after the thermometer has been in the water. Determine what the temperature the water is and record below:

   Temperature of water (A): _____ °C

   Repeat temperature reading after potassium chloride has been added and dissolved, and record below:

   Temperature of water + potassium chloride (B): _____ °C
   Temperature change (A-B): _____ °C

   In this activity, _____________energy was converted to chemical energy

5. Exploding Can Demonstration.

   When the powder was ignited in the coffee can, chemical energy was converted to several other forms. Circle all the conversions and give the evidence for the conversion:

   Chemical to light  
   Chemical to sound  
   Chemical to mechanical  
   Chemical to nuclear  
   Chemical to thermal  
   Chemical to electrical

   Where did the chemical energy come from?

   ____________________________________________________________________
ANSWER SHEET

CHEMICAL ENERGY CONVERSIONS OBSERVATION SHEET

1. When the light stick was activated, chemical energy was converted to:
   a. thermal energy  b. light energy  c. electrical energy
What evidence do you have for this conversion?  lightstick lit up

2. When the button was pushed/disc bent in the recyclable hand warmer, chemical energy was converted to:
   a. electrical energy  b. thermal energy  c. light energy
What evidence do you have for this energy conversion?  It felt warmer

3. Activity: Reading the Thermometer
   Put a mark next to the line on the thermometer diagram that is even with the top of the black line in the middle of the thermometer. Record the temperature represented by this mark on the blank below.
   Temperature reading of the thermometer diagram: 24 °C

4. Potassium Chloride Activity
   Draw a line on the picture of the thermometer that matches where the top of the red line is on your thermometer in the water. Determine what the temperature the water is and record below:
   Temperature of water (A): 21 (varies) °C
   Temperature of water + potassium chloride (B): 14 (varies) °C
   Temperature change (A-B): -10 to -14 °C
   In this activity, thermal energy was converted to chemical energy

5. When the powder was ignited in the coffee can, chemical energy was converted to several other forms. Circle all the conversions and give the evidence for the conversion:
   Chemical to light  Observed a yellow flame
   Chemical to sound  Heard a loud noise
   Chemical to mechanical  The lid blew off.
   Chemical to nuclear  none
   Chemical to thermal  The lid and can felt warm
   Chemical to electrical  none

   Where did the chemical energy come from?  Stored in the chemical bonds of the powder. The energy was released when the powder burned.
VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE
http://studentorgs.vanderbilt.edu/vsvs

Deep Ocean Currents
Spring 2018

Goal: To teach students about deep ocean currents by allowing them to visualize and understand how and why the currents form. To introduce students to convection in liquids.
Fits Tennessee standards GLE 0607.8.1 and GLE 0607.8.2

VSVS Lesson Outline:

I. Introduction to Ocean Currents
II. Density Background Information:
   a. Density Demonstration: VSVS volunteers will show students how salt packs around water molecules using a jar of marbles and salt.
   b. Demonstration – students will observe that a liquid with lower density will float on water.

III A. Saltwater in the Ocean:
   a. The VSVS team will share some information about oceans with the students.
   b. Saltwater demonstration: Students will add colored salt water to one side of a partitioned rectangular container and fresh water to the other side. Plugs in the partition will be removed and students will watch the flow of water. Pepper will be added to the surface of the water on both sides and students will observe the circulation.

B. Cold Water in the Ocean
Students will observe the flow of cold water into warm water.

IV. Where Are The Deep Ocean Currents?
   a. Students look at a map of deep ocean currents.

V. Review

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.

Deep Ocean Currents & Air Convection Currents Lesson Quiz
   1) Which ocean current is driven by the temperature and density of the water?
   2) Which is denser? Pure water or salt water?
   3) Why does the sea contain so much salt, but lakes, streams, and rivers do not have much salt at all?
   4) True or False? With time, the seas have gotten less salty.
   5) Why was pepper used in one of the experiments?
   6) Where does deep water formation occur?
   7) True or False? When ocean water freezes into icebergs and ice sheets, the ice is made up of water with no salt.
   8) Which is denser? Cold water or warm water?

2. During the lesson:
   Here are some Fun Facts
   • A well-known density-driven current occurs where the saltier Mediterranean Sea empties into the Atlantic Ocean. During World War II, submarines used this current to enter and leave the Mediterranean without even turning on their engines! (http://science.howstuffworks.com/)
• If the salt in all of the earth’s seas could be removed and spread evenly over the Earth’s surface, it would form a layer more than 500 feet thick – that’s about as tall as 2.5 Batman Buildings!
• The oceans move 1.4 trillion cubic kilometers of water each day!
• Radioactive tritium is used to trace the world’s currents because it is easily detected and it travels at the same speed as the water carrying it.
• It takes a minimum of 500 years and up to 1,000 years for the oceans’ water to cycle itself globally.

Unpacking the Kit– What you will need for each section:
Divide the class into 10 groups (of 3).

For Part II. Density Background Information and Demonstrations
1 6oz container of salt, 1 6oz jar containing marbles , 32 Observation Sheets, 16Instruction Sheets, 10 oil/salt water jars

For Part III. Movement of Saltwater in the Ocean
10 containers of salt, 10 spoons, 10 rectangular containers, 10 16oz/500 mL bottles water
20 16oz cups with marked water level [~250mL]
2 blue food coloring dropper bottle
1 pair plastic gloves (for VSVS members to wear when using food coloring)
2 pepper container
10 oval plates

For Part IIIIB. Cold Water in the Ocean
20 2oz jars with holes in lids
2 16oz cups styrofoam Ice
2 L water
Food Coloring from Part III
10 plastic plates
10 Clear plastic squares

Set-up:
VSVSers will put 2 drops of blue food coloring in 10 of the jars and then pack with ice.
(Just before the students do this experiment, VSVSers will pour room temperature water into all containers so they are FULL.)

For Part IV. Where Are The Deep Ocean Currents?
32 World Maps with Ocean Salinity

I. Introduction to Ocean Currents

| Learning Goals: Students understand the two types of ocean currents |

Why is the science in this lesson important?
The movement of deep ocean currents are partly responsible for global temperatures, as they cycle cold water to different areas of the globe. Changes in deep ocean currents due to climate change can alter ecosystems around the world.

Your Notes:
Ask students if they know the names of the 2 types of ocean currents?
Ocean currents are divided into 2 types - surface and deep.

Surface currents are driven by the wind blowing over the ocean, the earth’s rotation, and large land masses.
Surface currents occur at the surface of the ocean.
They are only about 400m (1300ft) deep (occur in the top 400m of the ocean).
That’s about that the height of two Batman Buildings! (192m (630.5ft))

Deep ocean currents are driven by the temperature and density of the water.
Sometimes they are called submarine rivers.
90% of the ocean water is moved by deep ocean currents.

Tell students they will investigate the behavior of dense salt water, which is similar to that found in the deep ocean waters AND the behavior of cold water compared with room temperature water

II. Density Background Information

Learning Goals: Students observe how manipulations of mass and volume affect density.

- Ask the students if they know what density is. Tell them that they can think of density as how much mass there is in a given fixed volume. A good example would be the different densities of a golf ball and ping pong ball. They have the same volume but different mass.

A. Demonstration
Materials:
1 6oz container of salt
1 6oz jar containing marbles
- Show students the jar with marbles in it.
- Tell the students that the marbles represent water molecules.
- Pour the container of salt into the jar.
- Explain to the students that the salt packs around the marbles like it does around water in salt water.
- Ask students why they think saltwater is denser than regular water. Saltwater has a higher mass because of the added salt, and hence is denser.

B. Density of Liquids - Demonstration

Learning Goals:
- Students investigate solutions with different densities and find that a lower density solution layers on top of a solution with higher density.

Materials
10 oil/salt water bottles (1 per 3-4 students)
Pass out the oil/salt water bottles. Tell students that the water was colored blue to make the layers easier to see.
Share that density is a property of solids, liquids, and gases.
- Ask students: what do you notice? There are two separate layers, the saltwater is on the bottom and the oil is on the top.
- Ask students: why do you think the two liquids layer? *Saltwater is more dense than oil, so the oil floats on top of the saltwater.*

Write these facts on the board:
- Pure water has a density of 1 g/cm$^3$.
- Ocean water at the sea surface has a density of about 1.027 g/cm$^3$.
- Oil has a density of 0.83 g/cm$^3$ (depends on type of oil – we used baby oil).

Tell students that a liquid with low density will float on top of a liquid with a high density.

### III. Saltwater in the Ocean

| Learning Goals: Students understand and observe how density drives deep ocean currents. |

**Why does Ocean Water have a higher Salinity?**
- Ocean water is saltier than fresh water.
- Ask students why they think the sea contains so much salt but lakes, streams, and rivers do not have much at all.
  - The salt in the ocean comes from the gradual process of weathering and erosion of the Earth’s crust, as well as the wearing down of mountains.
  - Rain and streams then transport the salt to the sea.
- Some salts may have come from volcanic emissions when earth was being formed.
- Some salts also come from the magma at the mid-ocean ridges.
- As time has passed, the seas have actually gotten saltier. Evaporation of water from the ocean leaves salts in the ocean while weathering continues to add salts.

**What kind of salts are in the ocean?**
- Seawater is actually very complex and contains salts made up of combinations of at least 72 elements, most in very small amounts. Salts of sodium, chloride, magnesium, sulfate and calcium are the most abundant.

**Divide the class into 10 groups (of 3).**
Tell students they will make their own salt water and observe what happens when it “meets” fresh water.
Pass out the following materials to each group:
- 1 16oz bottle water
- 2 16 oz cups
- 1 2 oz container of salt
- 1 spoon
- 1 plastic container with divider in middle and holes punched at bottom & top with plugs inserted
- 1 oval plate

1. Tell students to add 3 full spoons of salt to the water in ONLY ONE of the cups (labeled salt water).
2. A VSVS member will add 15 drops (or one squirt) of blue food coloring to the SAME salted water cup until the solution is **dark blue**.

3. Make sure the students understand the differences between the 2 waters. *The salt water (blue) is denser than the “fresh” water (clear).*

**Your Notes:**
4. Draw a sketch of the container with the divider on the board. Tell students they will be adding the salt water to the LEFT side and fresh water to the right side BUT NOT YET! (point out that the sides of the container are labeled & make sure they have it turned the correct way)

<table>
<thead>
<tr>
<th>Salt Water (Blue)</th>
<th>Fresh Water (Clear)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>Right</td>
</tr>
</tbody>
</table>

5. Ask the students to predict what will happen when the 2 waters are added and plugs are removed. Accept all answers and write them on the board. Students may not have the correct answer at this time! **Do not correct them.**

6. Have one student per group be responsible for the salt water and another responsible for the fresh water. Tell these students to pour their water solutions into the correct sides AT THE SAME TIME. **Check that the water level on both sides is above the top nail.**

7. Tell the students that they are going to be removing the plugs and that they ALL need to be ready to observe the water from the sides of the container once the plugs have been removed.

   Have one student in charge of the top plug on the salt water side and another student in charge of the bottom plug on the fresh water side.

   Tell them they will remove both plugs on the count of 3. **Count to 3 loudly, so everyone can hear.**

8. Have one VSVS member go to each group to sprinkle pepper on the top of the water on BOTH sides. Once this is done, the students should also observe the water from the top. **The other VSVS members should be circulating the room helping students.**

9. Students should make their observations through of the sides and from the top of the container for about 5 minutes and record their observations on their observation sheet.

10. Ask students what happens to the salt water.  
    *It moves through the bottom hole underneath the clear fresh water.*

11. Ask the students what happens to the fresh water.  
    *It moves through the upper hole and layers on top of the blue salt water.*

12. Ask the students what they noticed when the pepper was added.  
    *The pepper/water on the right (originally just clear water) seemed not to move much, but the pepper/water on the left side (originally blue salt water) is moving away from the hole and is circling around that side.*

**Explain to the students they have just created currents, similar to those in the ocean.** The blue salt water is more dense than the fresh water, so it acts like the colder, saltier water of the ocean while the fresh water acts like the warmer, less salty water of the ocean. **Deep ocean currents are formed when denser water sinks/flows beneath less dense water, which in turn flows on top of the denser water, as they observed in their experiment.**

**Your Notes:**
You can also mention that when the pepper water hits the side of the container and circles around the left side, the effect is similar to that of water hitting large landmass – one of the causes of surface currents.

Set aside the model – the students can refer to it as they look at the map of ocean currents. They will observe the model again before the end of class to see that there are 2 distinct layers that do not seem to be mixing.

IIIB. Movement of Cold Water in the Ocean

| **Learning Goals:** Students understand and observe how temperature drives deep ocean currents. |
|

**Materials**
- 20 2oz jars with holes in lids
- Ice
- Water
- Food Coloring
- Plates
- Plastic squares

**Set-up:**
VSVSers will have already put 2 drops of blue food coloring in 10 of the jars packed with ice.
Now pour room temperature water into all containers so they are FULL.
Tell students that the blued water tells them that the water is COLD.

**Students must do the following in this order:**

1. Take one bottle of cold and one of room temperature. Place the plastic square on top of the ROOM TEMPERATURE bottle. Hold the square securely to keep water from pouring out, turn it upside down and place on top of a bottle of blue cold water. Once in place, have one member of the group (or VSVSer) hold the 2 bottles securely and slide the plastic square out. Observe what happens. Not much! There may be some initial movement of water due to the disturbance created when the plastic is removed.

2. Separate the 2 bottles (a little water will spill, so keep on the plate. “Top” up the bottles with water if needed. (It is important to have both bottles full to the top.)

3. Place the plastic square on top of the COLD bottle, turn it upside down and place on top of the room temperature water bottle. Once in place, have one member of the group (or VSVSer if needed) hold the bottles securely and slide the plastic square out. Observe what happens. The cold water will flow, and continue to flow, into the bottom warmer bottle.

**Explanation:** Cold water is denser than warm water and so will sink to the bottom. Warm water will rise up through cold water. Cold water will sink below warmer water.

**Your Notes:**

______________________________________________________________________________
______________________________________________________________________________
IV. Where Are The Deep Ocean Currents?

Tell students to look at the map of ocean currents (pass this out if you haven’t already). Have the students notice where deep water formation occurs (3 areas in the Arctic & Antarctic).

[Image of ocean currents map]

Robert Simmon, NASA
http://earthobservatory.nasa.gov/Features/Paleoclimatology_Evidence/paleoclimatology_evidence_2.php

Explanation:

- The biggest source of deep water is highly saline surface water from the Gulf Stream in the North Atlantic. This water is cooled by the polar air and sinks to the bottom. It flows south to Antarctica.

- The densest water is in the Weddell Sea of Antarctica. It forms in the southern winter when sea ice forms, leaving more salt in the water below the ice. This water sinks to the bottom of the ocean and flows north.

- The average temp of surface sea water is 17.5 °C (63.5 °F).

  75% of all ocean water has a temperature of between 0 °C (32 °F) and 5 °C (41 °F). So most of the water that fills the oceans is much colder than surface water.

- When ocean water freezes into icebergs and ice sheets, the ice is made of pure water with no salt. That salt is left in the water, so the ocean becomes saltier and denser. (This can be related to the marble demonstration - if all of the salt remained but a few marbles were removed, (became ice) then there would be more salt per marble).

- Have them trace the paths of the current with their fingers, following the arrows. Start at the northern-most point.
  - Tell students that the entire trip for the current to return to its starting point can take over 1000 years!

- Have students look at where the water appears to warm up (blue changes to red).
  - This happens in warm areas of the world, near Hawaii and off the coast of Africa.
  - When the blue line turns red, the water has become less dense by warming up and/or becoming less salty, and hence rises above the denser water.

Have students look once more at their water experiment to notice the layering effect of the salt water and fresh water. Explain to them that these layers will remain separated for several hours.

V. Review

- Ask students why saltwater is more dense than freshwater? Saltwater has a higher mass but the same volume of freshwater.

- Ask students: What can we say about cold water versus warm water?
  - Cold water sinks.
  - Warm water rises.

Lesson written by: Patricia Tellinghuisen, Director of VSVS, Vanderbilt University
Courtney Luckabaugh, VSVS Lab Assistant, Undergraduate, Vanderbilt University

Your Notes:
Deep Ocean Currents Answer Sheet

Name __________________________

1. Draw arrows on the diagram below showing the movement of the blue salt water and the clear fresh water.

What happens to the salt water? *Moves through the bottom hole and stays below the fresh water*

What happens to the fresh water? *Moves through the top hole and stays above the salt water*

What happens to the pepper? *The pepper/water on the right (originally just clear water) does not move much, but the pepper/water on the left side (originally blue salt water) moves away from the hole and is circling around on that side.*

2. Draw arrows on the diagram to show the movement of blue cold water and the clear room temperature water.

Look at the map of ocean currents to answer the following questions.

In what parts of the Earth does deep water formation occur? *3 areas in the Arctic & Antarctic*

Why does deep water formation occur in these regions? *Cold temperatures and salty water.*
Deep Ocean Currents Observation Sheet

Name ___________________________

1. Draw arrows on the diagram below showing the movement of the blue salt water and the clear fresh water.

   ![Diagram showing movement of salt and fresh water]

   What happens to the salt water? ____________________________________________
   What happens to the fresh water? ___________________________________________
   What happens to the pepper? ______________________________________________

2. Draw arrows on the diagram to show the movement of blue cold water and the clear room temperature water.

   ![Diagram showing movement of cold and warm water]

3. Look at the map of ocean currents to answer the following questions.

   In what parts of the Earth does deep water formation occur? ____________________
   Why does deep water formation occur in these regions? _________________________
GOALS:
To show how gravitational potential energy is related to the height and mass of an object.
To investigate different forms of potential energy.

Fits TN State standards:
GLE 0507.10.1: Design an experiment to illustrate the difference between potential and kinetic energy
GLE 0607.10.1: Compare and contrast the three forms of potential energy.

VSVSer LESSON OUTLINE
I. Introduction - Energy Definitions
Definitions of energy are discussed with the students.

II. Demonstrations: Potential Energy/Kinetic Energy Conversions
The conversion of potential energy to kinetic energy and the law of conservation of energy are illustrated by three demonstrations.

III. Demonstration: Potential Energy
Students are shown the activity they will do in part IV.

IV. Gravitational Potential Energy (PE) is related to Mass and Height
Students learn how potential energy is related to the height and mass of an object by observing the distance a wooden block moves.

1. PE is related to height (mass held constant)
A ball is rolled down a ramp and collides with a small block of wood. The students will repeat this multiple times, each time changing the height (and thus potential energy) at which the ball is dropped on the ramp. Students record and graph the distance the block moves and then predict what will happen when a fourth ramp support is added.

2. PE is related to mass (height held constant)
Students use two balls of different mass and measure the distance traveled by the wood block after it has collided with each ball.

LOOK AT THE VIDEO BEFORE YOU GO OUT TO YOUR CLASSROOM
(https://studentorgs.vanderbilt.edu/vs/vs/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. What is the definition of mechanical energy? Which energy types contribute to total mechanical energy?
2. At what height must you drop the astroblaster from?
3. How can one tell when the ball in demonstration #3 has the most potential energy?
4. What is the difference between mass and weight?
5. Where do the balls in Newton’s cradle have the most potential energy?
6. When should safety eyewear be worn during this lab?
7. Are the supports laid under the track on their large or thin side?
8. What is the maximum number of supports a student should place underneath the track?
2. During the Lesson:
Here are some fun facts about the lesson:

- Most rollercoasters only have motors to get you to the top of the first hill; the rest of the ride is entirely dependent on gravitational potential energy
- When you pull back the arrow in a bow-and-arrow, you are increasing the potential energy of the system and when you let go, that is converted into kinetic energy as it flies toward the target

Unpacking the Kit – What you will need for each section:
While one team member starts the introduction, another should write the following vocabulary words on the board:
Mechanical energy, Kinetic energy, Potential energy, Conservation of Energy, Elastic Potential Energy

Another member should assemble ten tracks - one track for each group.
Be sure to assemble the pieces in the correct sequence. They are numbered 1, 2, 3 on the topside and are labeled to show you how to put them together (see training Powerpoint, slide 4). Each 3-piece track requires 2 plastic joiners.

For Part II. Demonstrations: Potential Energy/Kinetic Energy Conversions
1 Newton’s Cradle, 1 Tennis ball, 1 Dropper Popper, 1 Astroblaster

For Part III. Demonstration: Potential Energy
Use a student set of: 3 pieces of track with 2 plastic connectors, 32 Observation sheets, 10 Instruction sheets, 1 plastic bag containing: 1 golf ball, 1 small block of wood (approximately 0.75”x 1.5”) and 1 track support (9x6x2cm piece of wood)

For Part IV. Gravitational Potential Energy Is Related To Mass and Height
10 sets of 3 pieces of track (joined) with 2 plastic connectors
10 Ziploc bags containing 1 golf ball, 4 pieces of wood (track supports), 1 small block of wood, 1 tape measure

I. Introduction – Energy Definitions

Learning Goals: Students identify examples of potential and kinetic energy in the real world.

Why is the science in this lesson important?
Engineers often work on projects that explore new ways to convert one type of energy to another. Dams are one example of such a project: they convert the potential energy in stored water to mechanical energy. Engineers are responsible for calculating the size of the dam and how it must be built to hold back the pressure of the water.

Your Notes:
Ask students: What is energy?

Energy is the ability to do work (like applying a force to move an object) and cause change.

Tell students they are going to investigate Mechanical Energy.

Mechanical Energy is the total energy of an object due to its motion and position.

Ask students: What is potential energy?

Potential energy is the energy of an object has due to its position or shape.

Ask students to give examples of potential energy.

Elastic potential energy: a stretched rubber band, a wound-up spring.

Gravitational potential energy: a boulder at the top of a hill, water in a lake at the top of a mountain.

Ask students: What is kinetic energy?

Background information for VSVS members:

The Law of Conservation of Energy states that:

- Energy can be neither created nor destroyed.
- Energy can only be converted from one form to another.
- During a collision, energy is transferred from one object to another.

Kinetic energy is the energy of an object due to its motion.

As students to give some examples of kinetic energy.

- All moving objects: a swinging hammer, a wrecking ball, a moving car.

Explain to students that under ideal conditions, energy is never lost.

- It is just changed from one form or state to another.
- This is the law of conservation of energy.

II. Demonstrations: Potential Energy/Kinetic Energy Conversions

Learning Goals: Students understand conservation of energy and how energy can be converted between potential and kinetic.

The following demonstrations are designed to get the students thinking about different types of potential energy.

Materials:
1. Newton’s Cradle
1. Tennis ball
1. Dropper Popper
1. Astroblaster

A. Comparing a Dropper Popper and Tennis Ball
   - Drop the tennis ball from shoulder height and tell students to pay attention to the height the ball reaches after one bounce.
   - Now invert the dropper popper (rubber half-dome), hold it at the same shoulder height and let it drop. Tell the students to pay attention to where the popper reaches after one bounce. (Catch it!)

Your Notes:
Ask the students: **what forms of mechanical energy are illustrated by dropping the tennis ball and the dropper popper?**

1. **Tennis ball:** gravitational potential energy (when the tennis ball is lifted) and kinetic energy (when the ball is moving).
2. **Dropper Popper:** gravitational potential energy (when the dropper popper is lifted) AND elastic potential energy (work is done to invert popper) and kinetic energy (when the popper is moving).

Ask the students **what energy transformations occurred in each transformation?**

1. **Tennis ball:** gravitational potential energy is transformed to kinetic energy (as the object falls from a stationary position) then transformed back to potential (kinetic energy used to lift ball).
2. **Dropper Popper:** gravitational plus elastic PE is transformed to kinetic then back to potential.

**Explanation and Discussion:**

Ask the students which of the two bounced back higher. Ask them if they know why.

By lifting the tennis ball, work was done to the ball. This work was converted to gravitational potential energy as it was raised. When the ball was dropped, the potential energy was converted to kinetic energy, which was then converted to potential energy as it bounced back.

The popper had the same gravitational potential energy as the ball (assume equal masses—do not bring this up at this point) PLUS elastic potential energy, which it got when it was turned inside out. The work that was done to invert it was converted into elastic potential energy. Thus, the popper started off with more potential energy and bounced higher.

**IMPORTANT:** The demonstrator must wear the safety goggles. Other members must watch and retrieve the ball. Make sure to drop the “Astroblaster so that the small ball will shoot straight up and will come back down again. **This demonstration must be done on a table so that all students can see it.**

**IMPORTANT:** DO NOT drop the astroblaster from shoulder height. The small ball will fly off the rod at an uncontrollable speed and direction, and could cause injury to students.

**B. Astroblaster** (rod with multicolored balls)

- Take the red ball off the rod. Hold the ball 4 inches above table level and let it drop. Point out the height it reaches after one bounce. **Catch it!**
- Place the ball back on the rod, hold the “Astroblaster” by the tip of the rod at the same height above the table, make sure it is pointed directly down, and let the entire rod drop.
- Point out the height the small ball now reaches. **Retrieve the ball.**

Ask the students **what forms of energy are illustrated by the demonstration?**

**Answer** - Gravitational potential (lifting) and kinetic (moving).

Ask the students **what do they think is happening?**

**Explanation:**

Ask students if they think they know what is happening. Point out that the astroblaster starts out with gravitational potential energy gained from its height from the floor and the total mass of all balls. As it falls, its potential energy is converted to kinetic energy until it reaches the floor. There, the four balls

Your Notes:
collide with the ground, **but three cannot bounce upward.** All their energy is transferred to the red ball in the form of kinetic energy, causing the ball to fly off the rod and reaching a higher height than before (because of the extra energy).

**C. Newton’s Cradle – Conservation of Energy**

Show the students Newton’s Cradle. Tell them that this is a common toy that can be used to demonstrate the Law of Conservation of Energy.

- Lift up the first ball about 3 inches above from the other 4 balls. Let it go and have the students observe what happens. (When the first ball hits the 4 stationary balls, only one ball at the other end will be moved.)
- Ask students if they noticed how high the last ball reached. *Some may have noticed that it rose to nearly the same height as the first ball.*
- Repeat, lifting the ball to the same position, and have another VSVS member point to the position the last ball rises to.
- Repeat again, this time raising the first ball to the highest level possible. Ask students what happens to the height reached by the last ball. *It increases because raising the first ball higher increases its energy. This energy is transferred to the last ball.*

Remind students: *Energy can be converted between potential and kinetic energy.*

**Follow-up Questions:**

Refer back to the Newton’s Cradle:

Ask students the following questions:

Where does the first ball have the most potential energy? *When it was held at the highest position*

Where does the first ball have the least potential energy? *Just before it collided with the other 4 balls.*

What happened to the potential energy? *It was converted to kinetic energy.*

Where does the first ball have the most kinetic energy? *Just before it collided with the other 4 balls.*

Where does the first ball have the least kinetic energy? *When it was not moving.*

**III. Demonstration: Potential Energy**

**Learning Goals:** Students use a ramp to understand how height and mass are related to potential energy.

Materials 3 pieces of track with 2 plastic connectors
1 plastic bag containing: 1 golf ball, 1 small block of wood (approximately 0.75”x 1.5”)
1 track support

Write the formula for gravitational potential energy on the board:

**Gravitational Potential Energy = mgh** *(m=mass, g is a constant, h=height)*

Emphasize that the potential Energy of an object can be changed by changing mass or height. If you increase mass you increase potential energy. Explain that in the following demonstrations, you will be testing the effect of each of these variables.

1. **Demonstration**
   a. Place the 3-piece track on a flat surface so that all students can see the demonstration.
   b. Put the track support under the start end of the track.
   c. Place the ball at the beginning of the track and release it.
d. Point out to the students that the ball has gravitational potential energy at the start of the track, which is converted to kinetic energy as it rolls down the slope.

2. Changing Potential Energy
   a. Tell students that they will observe how potential energy changes as you change the height of an object, or as you change the mass of an object.
   b. Tell them they will determine the relative potential energy of a ball by measuring the work done by it as it rolls and collides with a stationary object, which will be moved a certain distance. Remind students that this was what was happening in the Newton’s Cradle experiment.
   c. Place the red end of the small wooden block on the black line on the track. (This is the 0 cm mark).
   d. Place the ball back at the top of the track and release it so that it collides with the small block.
   e. Measure how far the block moved (in cm).

Ask students if the block will move farther if the ball is given more potential energy by placing it at a higher position (Yes)

Tell them they are going to test this and other hypotheses.

Organize students into 10 groups. Students should take turns performing tasks.

Note: These activities require good classroom control. Tell students that they must stay on task and under control in order to do these activities. If they cannot maintain control, VSVS members may do all of the activities in small groups (3-4) as demonstrations.

IV. Gravitational Potential Energy Is Related To Mass and Height
A. Potential Energy Is Related to Height (mass held constant)

Learning Goals: Students use a ramp to understand how height and mass are related to potential energy.

Materials per group
1 3-piece track set
1 golf ball
4 9x6x2cm wood supports
1 small block of wood
1 tape measure
4 observation sheets (graphs) – 1 per student
1 Instruction sheet in sheet protectors

Tell groups to follow directions on the instruction sheets. VSVS members should each monitor 1-2 groups and guide them through the procedures, making sure they understand the instructions.

Tell students that in the next experiment the track will be elevated first on one wood support, then on two supports, and finally on three supports. Each wooden support measures 9 x 6 x 2 cm, so the height will be increased by 2 cm each trial run.

Your Notes:

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
Make sure the students understand that the **mass** of the golf ball does not change. **The only variable is height.**

Refer to the equation for potential energy and ask students to predict which stack of supports (1, 2 or 3) will give the ball the most potential energy. Record the predictions on the board (Correct answer = 3).

**Trial Run #1**

Have each group look at the first picture on the instruction sheet and set up their materials in the same way.

1. Place one of the supports so that its large flat area is lying on the desk or floor surface, and the black line is facing up.
2. Rest the "START" end of the track on the surface of the support so that the track edge lines up with the line on the support.
3. Place the small block of wood on the track so that its red end is on the black "0 cm" mark.
4. Hold the golf ball on the track at the starting point and release it.
5. Use the measuring tape to measure the distance the block moved from its starting "0 cm" mark. Make sure that the tape measure starts at the "0" mark, and is pulled out taught, and that the distance to the red end of the block is measured.
6. Have all students record this value on their graph at the 2cm (one support) line by using their pencil to make a small, filled-in circle.

**Trial Run #2**

Have each group do the following:

1. Add another support under the "START" end of the track.
2. Repeat steps 1-6 from Trial Run #1. Be careful! Make sure that:
   - Students line up the track with the black line on the wood support
   - That they start the ball from the beginning ("START") of the track each time
   - That the small block is at the black "0 cm" line at the beginning for each run.
3. Have all students record the new distance traveled on their graph at the 4cm (two support) line.

**Trial Run #3**

Have each group do the following.

1. Add another support under the "START" end of the track.
2. Repeat steps 1-6 from Trial Run #1.
3. Have all students record the new distance traveled on their graph at the 6cm (three support) line.

**Follow-Up Questions:** Ask students the following questions:

1. What state of energy did the ball have at the top of the track? *(potential energy)*
2. Did the ball have more potential energy when it was resting on one, two, or three supports? *(three)*
3. How can you tell the ball had more potential energy when it was resting on three supports? *(The ball moved the small block farther than it did when it was released from one support.)*

**Your Notes:**

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
4. How is the height of an object related to its potential energy?  (*the higher an object, the greater the potential energy of that object*)

**Investigative Run**

1. Ask students to look at the graph and see how the distance the ball and block of wood traveled increased as the height of the supports increased.

2. Have students draw a line through the dots on their graph (students will need to use a ruler or straight edge) and extend the line so that it goes through the “8cm” line.  **Students will need help drawing the line, especially if the dots do not line up exactly.** A ‘line of best fit” is appropriate. Explain: sometimes, we care more about the general trend than about connecting the dots precisely.

3. Ask students to predict how far the ball will travel (using their graph) if a 4th support (8cm) is added?

4. Have the students write down their prediction and test it.  **The graphs should look like the one at the right.**

5. Ask the students if their prediction was correct.

6. Ask students if they were accurate in their prediction. Explain that errors occur in all science experiments, even to the best scientists.

7. Ask students what factors might influence the measurement (friction, some energy lost and converted to heat)

**B. Potential Energy Is Related to Mass (height held constant)**

**Materials per group** (same as above plus 1 squash ball (29 gm))

<table>
<thead>
<tr>
<th>Height (cm)</th>
<th>Distance Traveled (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>25</td>
<td>10</td>
</tr>
</tbody>
</table>

**Note:** Explain to students that the term "weight” is often used in place of "mass.” Weight and mass are not the same. The mass of a body is constant, but its weight is the force exerted upon it by gravitational attraction (usually earth’s gravity). For example, your mass would be the same on the moon as it is on the earth, but your weight on the moon would be much less.

1. Tell a student in each group to hold the golf ball in one hand and the squash ball in the other. Ask a student which ball has more mass? (*the golf ball*)

2. Tell students that the squash ball has a mass around 29 grams, while the golf ball has a mass of about 45 grams.  **(The masses are recorded on the balls.)**

3. Tell them that the height will be changed to 6cm (3 supports).

4. Ask students to predict what effect increasing the ball’s mass will have on the distance the block travels.  (Refer back to the formula, PE = mgh, where m = mass.)

5. Tell students they will now conduct the experiment to see if their predictions are correct.
**Trial Run #1**

1. Rest the "Start" end of the track on 3 supports so that the track edge lines up with the black line on the block.
2. Place the red end of the small block on the 0cm black line drawn on the track.
3. Hold the squash (lighter) ball on the starting point of the track.
4. Release the squash ball and measure the distance the small block was moved (from the "0 cm" mark to the red end of the block).
5. Have students record the measurement on their graph at the line that corresponds with the mass of the squash ball. **Students will need help doing this.**

**Trial Run #2**

1. Use the heavier golf ball.
2. Tell the students that care should be taken that the “start” end of the track rests at the same position as in Trial #1, and that the ball starts from the same position on the track.
3. Repeat steps 1 - 5 from Trial Run #1, but for the golf ball.

The graphs should look like the one at the right. All graphs will vary depending on the ball and small block of wood used.

**Follow-Up Questions:**

1. Ask students what effect did the larger mass have on the distance the block moved? (The greater the mass; the farther the block moved.)
2. Ask students why did the ball have more gravitational potential energy? (It had more mass.)

**V. Questions and Information for Review**

<table>
<thead>
<tr>
<th>What is energy?</th>
<th>The ability to do work</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is kinetic energy?</td>
<td>Energy of motion</td>
</tr>
<tr>
<td>What is potential energy?</td>
<td>Energy of position</td>
</tr>
</tbody>
</table>

Mechanical energy can be separated into kinetic and potential energy. Potential energy is changed to kinetic energy as an object falls or gets closer to the earth.

**Clean-up:** Make sure that the correct number of balls is returned - please count them before you leave the room.

Lesson written by Pat Tellinghuisen, Director of VSVS, Vanderbilt University  
Dr. Melvin Joesten, Chemistry Department, Vanderbilt University  
Susan Clendenen, ENCORE Teacher, Metro Nashville Public Schools  
We gratefully acknowledge the assistance of Claire Ivanov, Metro Nashville Public Schools Science Teacher

Your Notes:
Potential Energy Observation Sheet

Data Collection For Potential Energy Related To Height (Mass Held Constant)

1. Distance block moved when 1 block (2cm height) under track _______

2. Distance block moved when 2 blocks (4cm height) under track _______

3. Distance block moved when 3 blocks (6cm height) under track _______

4. Make a line graph showing results.

5. Predict (from the line graph) the distance block will move with 4 blocks (8 cm) under track _______

6. Test prediction:
   Distance block moved when 4 blocks (8cm height) under track _______

Data Collection For Potential Energy Is Related To Mass (Height Held Constant)

Use 3 blocks (6 cm height) for all trials.

Which ball has more mass?
Predict which ball will make the block move a greater distance?

1. Distance block moved when squash ball is used. _______

2. Distance block moved when golf ball is used. _______

3. Make a bar graph showing results.
Potential Energy - Answer Sheet

Data Collection for Potential Energy related to height (mass held constant)

1. Distance block moved when 1 block (2cm height) under track ________________
2. Distance block moved when 2 blocks (4cm height) under track ________________
3. Distance block moved when 3 blocks (6cm height) under track ________________
4. Predict the distance block will move with 4 blocks (8 cm) under track __________
5. Test prediction: 
   Distance block moved when 4 blocks (8cm height) under track ________________

Data Collection for Potential Energy is related to mass (height held constant)

Use 3 blocks (6 cm height) for all trials.

Which ball has more mass?  The golf ball

Predict which ball will make the block move a greater distance?  The golf ball

4. Distance block moved when squash ball is used. ________________
5. Distance block moved when golf ball is used. ________________