6th Grade

Spring 2016 Lesson Plans

Vanderbilt Student Volunteers for Science

http://studentorgs.vanderbilt.edu/vsvs/

VOLUNTEER INFORMATION

Team Member Contact Information

Name:____ Phone Number:________________________

Name:____ Phone Number:________________________

Name:____ Phone Number:________________________

Name:____ Phone Number:________________________

Name:____ Phone Number:________________________

Teacher/School Contact Information

School Name: ____ Time in Classroom: _______________________

Teacher's Name: ______________________________________ Phone Number: __________________________

VSVS INFORMATION

VSVS Director: Pat Tellinghuisen 615-343-4379 (W), 615-297-5809 (H)

patricia.c.tellinghuisen@vanderbilt.edu **VSVS Office:** Stevenson Center 5233

Co-Presidents:	Arulita Gupta	arulita.gupta@vanderbilt.edu
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Vanderbilt Protection of Minors Policy: http://www.vanderbilt.edu/meetatvanderbilt/wp-content/uploads/Minors-Policy-Risk-management.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 5233.
- The VSVS Lab is open 8:30am – 4:00pm (earlier if you need dry ice or liquid N_2).
- 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

SUN	MON	TUES	WED	THU	FRI	SAT
	1	2	3	4	5 Team Leader Training	6
7 Team Leader Training	8 ← Training (Grades 6, 7, 8) →	9	10	11	12	13
14	15 Some Teams Go Out ← Training (Grades 5 & 6) →	16	17	18	19	20
21	22 All Teams Go Out	23	24	25	26	27
28	29 All Teams Go Out					

MARCH

SUN	MON	TUES	WED	THU	FRI	SAT
		1	2	3	4	5
6	7 (X)	8 (X)	9 (X)	10 (X)	11 (X)	12
13	14	15	16 ← Training →	17	18	19
20	21 ← Training →	22	23	24	25	26
27	28 (X)	29	30	31		

APRIL

SUN	MON	TUES	WED	THU	FRI	SAT
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

CLASSROOM ETIQUETTE

Follow Metro Schools' Dress Code!

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

Metro student standard attire guideline:
http://jtmoorems.mnps.org/pages/JohnTrotwoodMooreMiddle/About_Our_School/8998762518461552450/Dress_Code

COLLEGE Q&A SESSION

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

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

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

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

DIRECTIONS TO SCHOOLS

H.G. HILL MIDDLE SCHOOL: 150 DAVIDSON RD **615-353-2020**
HG Hill School will be on the right across the railroad lines.

HEAD MAGNET SCHOOL: 1830 JO JOHNSON AVE **615-329-8160**
The parking lot on the left to the Johnston Ave.

JOHN EARLY MIDDLE SCHOOL: 1000 CASS STREET **615-291-6369**
Going down the Cass Street, the school is on the right.

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.

WRIGHT MIDDLE SCHOOL: 180 MCCALL STREET **615- 333-5189**
Going down Mccall Street, Wright Middle School is on the left.

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

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

Chemical Energy Conversions

Spring 2016

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.

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

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

Lesson Quiz

1) What 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.

Your Notes:

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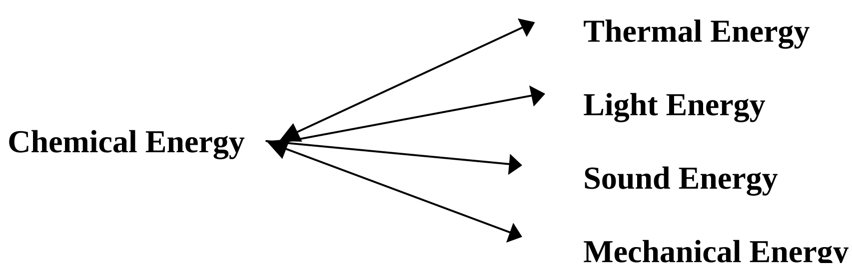
- A hurricane releases 50 trillion to 200 trillion watts of heat energy. This is as much energy as a 10-megaton nuclear bomb exploding every 20 minutes.
- Just 1/3 of the energy in burning coal reaches the consumer as electricity. The rest is converted to unusable forms of energy, e.g. heat, chemical, 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.

Materials

1 large lightstick
8 small lightsticks
16 plates
8 4 oz jars of potassium chloride
16 thermometers
8 recyclable hand warmers (sodium acetate solution in plastic pouch)
1 Cold pack
16 50 mL measuring cylinders
16 spoons
16 8 oz Styrofoam cups
1 trash bag for used Styrofoam cups
1 large funnel
1 waste container (64 oz)
8 bottles filled with water
32 observation sheets
16 <u>instruction sheets</u> backed with picture of oranges with ice on them in sheet protectors
10 paper towels in plastic bag
1 box of goggles
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
 1 pipette

<u>Unpacking the Kit:</u>

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.



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

Your Notes:

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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

8 small lightsticks, 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.

I. Introduction

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 the energy stored in the chemical bonds that hold the chemical together.

Since it is a stored energy, it is a type of potential energy.

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.

Your Notes:

- 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 <u>instruction sheet</u> (inside a page protector).

II. Introducing Chemical Energy Conversions: Dust Can Explosion

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.

<u>Put on Goggles</u>

- 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. **<u>Wait until now to do this, as the flame will quickly go out after the lid is secured.</u>**
- **<u>Immediately</u>** 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.



Your Notes:

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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.

III. Chemical energy → Light energy: Lightstick Demonstration

Materials
8 small lightsticks, 1 large lightstick

Lightstick Demonstration

- Give groups a lightstick to do the experiment along with you.
- 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.
- Tell the students to do the same.
- 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.***
- The students can now answer question #1 on their observation sheet.

Note: 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.

Your Notes:

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IV. Chemical Energy → Thermal Energy: Hand Warmer Demonstration

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 became 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)

- In this activity, the liquid to solid change occurs when the sodium acetate crystallizes (precipitates) out of solution. Thermal energy is given off.
- Students can now 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 crystallize (turn 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.

Your Notes:

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^{o} F.

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

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**.
Ask students how they will be able to tell if thermal energy is being 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.

Your Notes:

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Tell them to:

- 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.
- 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).*

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.

- 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 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

Your Notes:

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: 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.**

VI. Chemical Energy to Thermal, Light, Sound, and Mechanical Energy (The Return of the Dust Can Explosion).

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	1 container of lycopodium "dust" powder
1 pipette (jumbo size)	1 tea light candle
1 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.

Your Notes:

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

VII. Review Questions

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

Your Notes:

CHEMICAL ENERGY CONVERSIONS OBSERVATION SHEET

Name ____

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/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?

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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

After potassium chloride has been added and dissolved, measure the temperature of the water using the same method as before and record below:

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

6. 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.

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Electrical Circuits

Spring 2016

Series and Parallel Circuits

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

Acknowledgement: We want to thank NASA and the Tennessee Space Consortium for funds to purchase the electric circuit kits.

Goal: To learn about series and parallel circuits and their properties through the use of Elenco Snap Circuit™ kits.
Fits Tennessee standards SPI 0607.12.1

Lesson Outline

I. Introduction
Discuss electric circuits (series and parallel circuits) and write the vocabulary on the board. Show students the Energy stick and how to complete a "human circuit".

II. Activity – Making a Simple Circuit
Students work in pairs and build a simple circuit.

III. Activity– Using a Switch
Students place a switch in the circuit in part II.

IV. Activity – Measuring Current
Students test the simple circuit with a meter.

V. Activity – Building Series and Parallel Circuits
One pair of students in the group builds a series circuit while the other pair builds a parallel circuit. Then they compare brightness of bulbs and current measurements to see what happens when one light is unscrewed in each circuit. After they have finished, students review series and parallel circuits.

VI. Discussion
Review the results of the lesson and the vocabulary words**.** Discuss electrical energy conversions illustrated by a hand generator.

Materials

4	"Energy Sticks" in SEPARATE plastic bags
2	Hand Generators
14	ziploc bags containing materials for assembling series and parallel circuits
14	sets of Instruction Sheets
30	observation sheets
1	demonstration simple circuit grid for VSVS members to use
1	Extra bag of 5 light bulbs
1	Extra bag of 5 batteries

Unpacking the Kit:

VSVSers do this while 1 person is giving the Introduction.

> **Important Note:** Divide students into groups of four so that there are **8 groups**. There are sixteen sets of materials for pairs of students within groups to do the activities. Students will be working in pairs, so that one pair of the group will build the series circuit while the other pair of the group builds the parallel circuit. This will allow them to look at both circuits to see the difference in brightness of bulbs and meter measurements.

For Part I. Introduction
4 “Energy Sticks” in SEPARATE plastic bags

For Parts II, III and IV Activities
16 ziploc bags containing circuit boards and materials,
16 sets of instruction sheets for building simple, series, and parallel circuits
32 observation sheets. Students have their own pencils.

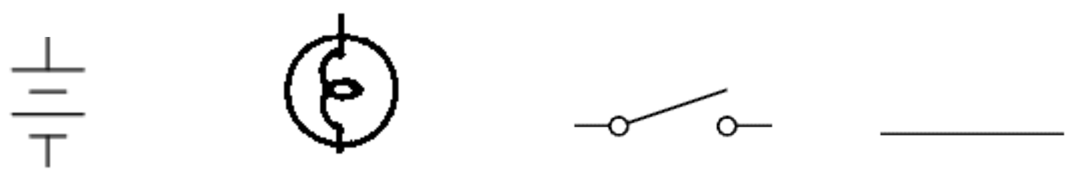
For Parts V. Activity: Building Series and Parallel Circuits
Same as above, with Extra circuit for Demonstration

For Parts VI.
2 hand generators

I. Introduction

Do not hand out materials until you have discussed the following background information.
Write the following vocabulary words on the board: **electricity, current, simple circuit, series circuit, parallel circuit**

Draw the following symbols on the board.



2 1.5V batteries   bulb   switch   wire

Ask students to tell you what they know about static electricity and current electricity:

Make sure the following is included in the responses:

There are 2 types of electricity, **static** and **current.**

Static electricity is the build-up of electrical charge. It does not flow. It can make your hair stand on end, or “zap” you when it is discharged. Lightning is an excellent example of static electricity being discharged.

Current electricity is moving electrical charge, usually electrons.

Current electricity flows through a **<u>circuit</u>**.

The electrons can flow only if the circuit is complete.
Show students one of the Energy sticks. Put a hand on each of the foil ends of the Energy Stick. The stick will flash lights and buzz.
Tell students that the stick is activated only when an electrical circuit has been completed.
Remove one hand to show the students note that the stick no longer flashes or buzzes. The Energy Stick contains a small battery, and has a circuit that is highly sensitive. It can detect very small amounts of electricity that travel through the moisture on your skin.
Now have 2 or more VSVS members form a connected circle (by holding hands). Have 2 VSVSers each hold the foil at the opposite ends of the stick to complete a human chain of

Your Notes:

electricity. Show them a "human switch" by having one member drop a hand and break the circle, and then rejoin.
Tell students to look at their Observation sheet and ask them if they can name some energy conversions when the stick is activated. Tell them to circle the correct answers – chemical to electrical (battery to electrical) and the electrical to sound and light.
If time permits at the end of the lesson, see how many students can form a circle and activate the Energy stick. Or do this with smaller groups and a VSVS member.

Tell students they will be following diagrams on their instruction sheets to build a simple circuit.

IIA. Activity: Making a Simple Circuit

Materials

16 ziploc bags containing materials for series or parallel circuits
16 sets of instruction sheets for building simple, series, and parallel circuits
32 observation sheets

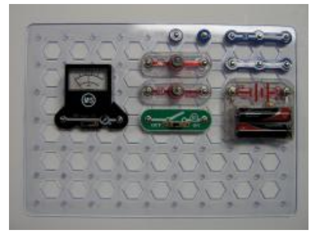


Diagram #1

1) Hand out one bag containing circuit materials to each pair.
2) Tell the students to look at the grid and its components, and compare it with **Diagram #1** on their Instruction sheets. Tell them they will need to replace the components in the same way when they are finished with the activities.
3) Tell the students that the **snap circuits** we will use today contain flattened wires. Tell them to remove one of the **#3 connectors** and look at its underside. Point out the flattened wire connecting the two snaps. This wire carries the electrical current.
4) **Review the correct way to unscrew a light bulb – demonstrate the "righty tighty, lefty loosey" concept.**
5) Have **all pairs** of students follow Diagram #2 to build the simple circuit on their board.
6) Tell them **not** to connect one of the **#3 snaps** until they are **told to do so**.
7) Ask the students if the circuit is complete. *No*.
8) How can they tell? *The light bulb does not come on*. *No electrical flow*

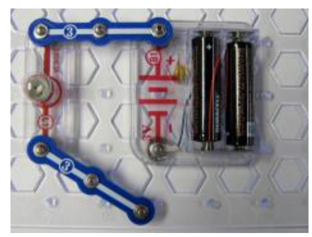


Diagram #2

9) What does it take to complete the circuit? *Connect the last snap, as seen in Diagram #2*.
10) Tell the students to do this, and to note that the bulb now glows.
11) This is called **a closed circuit.** Once the circuit is closed, electrons can flow through the circuit.
12) Ask the students which way the electricity is flowing. *Electrons flow from the negative end (the "flat" end of a battery) to the positive end (the end with the "knob").*
13) Ask the students: What happens if you unscrew the light bulb? *The light goes out because the circuit has been broken.*

Your Notes:

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III. Activity: Using a Switch

Tell the students to replace one of the #3 snaps with the switch **(Diagram #3)**.
Sliding the switch to the "on" position is the same as completing the circuit – the light bulb then glows. Sliding the switch to the "off" position is the same as breaking the circuit—the light bulb no longer glows. Tell the students this is a simple way to control flow through the circuit.

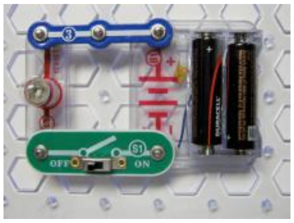
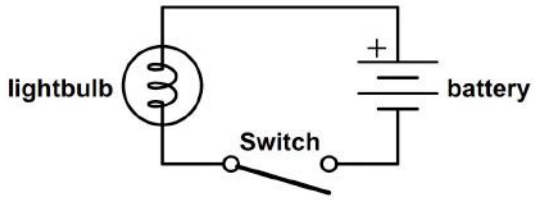


Diagram 3.



Simple Circuit

Draw the Simple circuit (above) on the board and point out the relationship between the symbols and the electrical parts.

IV. Activity: Measuring Current

Show the students the meter and tell them it can measure both current and voltage. Briefly explain that voltage is a measure of electrical potential energy between two points.

Show the students that the meter has 3 positions.

Move switch to:	You are measuring:	You read the scale located at:
All the way to the left (the 5V setting)	Voltage (V)	Upper scale reads between 0-5 volts
All the way to the right (the 1A setting)	Current (A)	Upper scale reads between 0-5 amps)
In the middle (1mA setting)	Very small current	Lower. Reads in milliamps

Diagram # 4

Measuring Current:
Tell the students:

1. That the meter must be in the circuit for it to be able to measure current.
2. Move the switch to the 1A setting.
3. Look at **Diagram #4** on the Instruction sheet. Remove the remaining #3 snap and replace it with the meter, as shown.
4. Turn the switch on and measure the current.
5. Point out the relationship between the symbols and the electrical parts.
6. Record the measurement in Part B on the Observation Sheet.

Your Notes:

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V. Activity: Building Series and Parallel Circuits

Series and Parallel Circuits

Tell students that there are two ways that a circuit can be connected: **series** and **parallel**.

- The difference between the two is how their parts are connected
- Each has properties that are unique to it.
- A normal circuit may have both series and parallel elements..
- The behavior of light bulbs in a circuit can be used to observe the differences between the types of circuits.

Diagram #5

Diagram 6

The instruction sheet also includes some questions under the diagrams for the series and parallel circuits to guide their observations of the difference between the two circuits.

1. Tell **one** pair in the group to build the **series circuit (Diagram #5)** while the **other pair** of the group builds the **parallel circuit (Diagram #6) -** point out that a #1 connector is placed on top of lamp holder on the left before a #3 is used to connect to the switch).
2. Tell the pairs within the group to compare the brightness of the bulbs in the two different circuits.
3. Measure the current flowing and record the data in Part B on the observation sheet.

Note: Students will observe the lights are dimmer in the series circuit but not in the parallel circuit. They will observe that the current in the series circuit is less that that in the parallel circuit. See Answer Sheet.

4. Tell the pairs within the group to show each other what happens when the one bulb is unscrewed.
5. Point out the relationship between the symbols and the electrical parts.

Note: Students will observe the other bulb goes out in the series circuit but not in the parallel circuit. (See Answer Sheet.)

Tell students to respond to the questions in Section A on the observation sheet for the circuits they have just tested.

Demonstration: One VSVS team member should take the demonstration simple circuit bag out, screw in the light bulb, and connect #3 snap to complete the simple circuit (from IIA). Go around the room and show them the bulb brightness in the simple circuit so they can compare brightness to that as well. (It's the same as the parallel circuit.)

Your Notes:

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If students are curious, help them to set up the parallel circuit as in **Diagram #7** and measure the current going through only 1 bulb in the parallel circuit. *It is about the same current as in the simple circuit.*

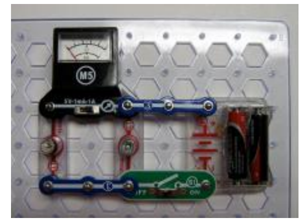

Diagram #7

VI. Discussion of Series and Parallel Circuits

After students have finished responding to the questions about the series and parallel circuits they built, take a few minutes to review the differences that they observed. Make sure to include the following in your discussion:

- A series circuit only has one pathway for the electric current – a break in the circuit stops all flow of electric current.
- A parallel circuit has multiple pathways for the electric current to travel
    - a break in one pathway will still allow the current to go through the other pathways.

Review the responses for what happened with the light bulbs in their series and parallel circuits in terms of these concepts.

<u>**Electrical Energy Conversions – Use the handgenerator**</u>

Ask students what energy conversions are taking place in their circuits?

Answers should include:

1. Electrical to Light.
2. Electrical to thermal (feel the light bulb while the circuit is closed).

Ask the students what other electrical energy conversions could be possible?

Answers could include electrical to mechanical, electrical to sound, electrical to chemical.

Show students the hand generator. Rotate the handle to activate it.

Ask students what energy conversions are taking place in this device. Have them circle all the conversions on their observation sheet.

Lesson modifications by:

Dr. Mel Joesten, Professor Emeritus, Vanderbilt University
Pat Tellinghuisen, VSVS Program Coordinator, Vanderbilt University
Matt Majeika, NSF Undergraduate Teaching Fellow, Vanderbilt University
By Matt Jackson, NSF Undergraduate Teaching Fellow, Vanderbilt University and
David Harris, VSVS Co-President, Spring 2010

Your Notes:

Observation Sheet
Electric Circuits

Name ____

Introduction – Energy Stick

Circle the energy conversions when the stick is activated.

chemical to electrical
chemical to nuclear
electrical to sound
electrical to light
electrical to mechanical

A. Series and Parallel Circuits – Circle your answer.

1. The light bulbs in the series circuit were (brighter, dimmer, the same brightness) as those in the parallel circuit.

2. When one light bulb was unscrewed, the other light went out in the (series, parallel) circuit.

3. When one light bulb was unscrewed, the other light remained on in the (series, parallel) circuit.

4. The light bulb in the simple circuit was (brighter, dimmer, the same brightness) as the light bulb in the parallel circuit.

B. Current Measurements

Current in the Simple Circuit: ___________________________________

Series Circuit: ___________________________________

Parallel Circuit: ___________________________________

Circle the energy conversions that occur when the hand generator is activated.

chemical to electrical
mechanical to nuclear
mechanical to sound
mechanical to electrical to light
mechanical to electrical

Observation Sheet
Electric Circuits

Name ____

Introduction – Energy Stick

Circle the energy conversions when the stick is activated.

chemical to electrical
~~chemical to nuclear~~
electrical to sound
electrical to light
~~electrical to mechanical~~

A. Series and Parallel Circuits – Circle your answer.

5. The light bulbs in the series circuit were (brighter, **dimmer**, the same brightness) as those in the parallel circuit.

6. When one light bulb was unscrewed, the other light went out in the (**series**, parallel) circuit.

7. When one light bulb was unscrewed, the other light remained on in the (series, **parallel**) circuit.

8. The light bulb in the simple circuit was (brighter, dimmer, **the same brightness**) as the light in the parallel circuit.

B. Current Measurements

Current in the Simple Circuit: **~1 A**

Series Circuit: **~0.5 A**

Parallel Circuit: **~2 A**

Circle the energy conversions that occur when the hand generator is activated.

~~chemical to electrical~~
~~mechanical to nuclear~~
mechanical to sound
mechanical to electrical to light
mechanical to electrical

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Electrical Conductivity

Spring 2016

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

Acknowledgement: We want to thank NASA and the Tennessee Space Consortium for funds to purchase the Elenco Snap Circuit™ kits.

Goal: To measure the conductivity of solids and solutions using an LED in a circuit.

TN Curriculum Alignment:

GLE 0607.12.1 Describe how simple circuits are associated with the transfer of electrical energy.

GLE 0607.12.2 Explain how simple electrical circuits can be used to determine which materials conduct electricity.

Lesson Outline

I. Introduction

Explain Static and Current electricity. Write the vocabulary words on the board and explain conductors and nonconductors. Explain that all materials can be described as conductors, insulators, or semi-conductors.

II. Explaining the Circuit – Demonstration

Explain the circuit and LED and demonstrate how the students will use the red and black lead wires to test conductivity.

III. Conductivity of Solids

Students will work in pairs. Hand out one grid and one bag of solids to each pair. Make sure all groups have a correctly assembled the circuit by having them touch the ends of the black and red lead wires together and noting the red LED glows brightly. Explain what conductors and insulators are. Students then test the solids and record their results on the Observation Sheet.

IV. Conductivity of Solutions

Explain that some solutions are conductors while others are nonconductors. Students will test a number of solutions. Make sure they understand the importance of rinsing off the metal leads of the red and black wires in distilled water between each conductivity test.

V. Optional Activity

If time permits, have students test one of the solutions: (the bag may contain Gatorade, Sprite, rubbing alcohol, lemon juice, bottled water).

VI. Optional Activity #2 - Demonstration

Why use LED's?

VII. Review

Review the results of the lesson and the vocabulary words.

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

Lesson Quiz

1. What is the difference between static electricity and current electricity?
2. How can you tell the difference between a good conductor and a poor conductor through a conductivity test?
3. Will an electrolyte solution or a non-electrolyte solution conduct electricity? Why?
4. Is sugar solution a conductor? Why or why not?

5. At the conclusion of the lesson should the leads be snapped together before they are placed back in the kit?

2. Use these fun facts during the lesson:

- Copper is commonly used as a conductor for electrical wiring but silver is actually a better conductor. Silver is not widely used in industrial applications because it is too expensive.
- Damp wood is a better conductor than dry wood. Although wood is generally considered to be an insulator, it is able to conduct sufficiently strong currents, which is why it is not recommended to stand under a tree during a thunderstorm.
- In the food service/production industry, cooking equipment may be sanitized with harsh chemicals that have high concentrations of ions. A conductivity test can be used to determine if the cleaning agent has been sufficiently rinsed away. If there is still significant conductivity when pure water is in contact with the equipment, then the equipment should be further rinsed to remove the cleaning agent.
- Public water facilities often monitor the conductivity of their output water to determine how much material is dissolved in the water (total dissolved solids). It is important to note that this test only accounts for the dissolved solids that are conductive. However, this method would be useful to determine if water has been demineralized, that is, if hard water has been effectively treated to remove some of the contaminating ions. As another example, conductivity tests can be used to determine if desalination processes have removed all of the salt from ocean water so that it becomes fit for human consumption.

Materials

1	conductivity demonstration grid with assembled circuit, plus a bag with a nail and a bottle cap.
16	sets of grids with assembled circuit
16	bags of solid materials for checking conductivity (paper clip, aluminum foil, copper strip, golf pencil sharpened on both ends, paper
1 plastic box containing:	
	6 jars labeled and containing: distilled water, tap water, vinegar, 0.1 M hydrochloric acid, distilled water for sugar to be added, distilled water for salt to be added.
8	bags containing: 1oz wide-mouth bottle of sugar 1oz wide-mouth bottle of salt 2 taster spoon 1 chemwipe tissue 2 toothpicks
1	bag containing wide mouth bottles of Gatorade, Sprite, rubbing alcohol, bottled water, and lemon juice
1	quart distilled water
16	6oz cups for distilled water for rinsing leads
16	sets of Instruction Sheets
32	observation sheets
1	bag of 5 AA batteries (extras)
1	light bulb holder plus bulb

Your Notes:

Unpacking the Kit:

Do not hand out materials until you have discussed the following background information.

For Part I. Introduction
While 1 person is giving the Introduction, another VSVS member writes the following vocabulary words on the board: **conductors, insulators (liquids are referred to as nonconductors), semiconductors.**

For Part II. Explaining the Circuit – Demonstration
1 grid with assembled circuit, plus a bag with a nail and a bottle cap for demonstrating conductivity.

For Part III: Conductivity Tests of Solids
Students will do this activity in pairs.

16 sets of grids with assembled circuit, 16 bags of solids (paper clip, aluminum foil, copper strip, golf pencil sharpened on both ends, paper), 16 sets of instruction sheets, 32 observation sheets

For Part IV. Conductivity of Solutions
16 6oz cups for distilled water for rinsing leads, 8 set of jars labeled and containing: distilled water, tap water, vinegar, 0.1 M hydrochloric acid, distilled water for sugar to be added, distilled water for salt to be added.

8 bags containing: 1oz wide-mouth bottle of sugar, 1oz wide-mouth bottle of salt, 2 taster spoons, 1 chemwipe tissue, 2 toothpicks

For Part V: Optional Activity #1
1 container with wide mouth bottles of Gatorade, Sprite, rubbing alcohol, bottled water and lemon juice

I. Introduction

Materials

1 grid with assembled circuit, plus a bag with a nail and a bottle cap for demonstrating conductivity.

Ask students if they know what the 2 types of electricity are.

1. **Static electricity** is the build-up of electrical charge. It does not flow. Lightning is an example of static electricity being "discharged" after having been built up.
2. **Current electricity** is moving electrical charge, usually electrons. Some materials have more "free" electrons than others. Current electricity flows through a completed circuit.

Tell the students that electricity flows through some materials better than others. All materials can be classified as <u>conductors</u>, <u>insulators / nonconductors</u> or <u>semiconductors</u>.

- **Conductors** are materials that allow the movement of electrons through them. Metals have many "free" electrons that can easily move, and therefore are *good* <u>conductors</u>. "Free" electrons are those not strongly held by the atom's nucleus. Since they are not strongly held, they are able to "jump" from one atom to another. Wires used for electric circuits are usually made out copper wire, but other materials also conduct electricity.
- **Insulators** resist the flow of electricity, meaning electrons do not flow through them. Some examples of <u>insulators</u> are Styrofoam, plastic (e.g., the casing around electrical wires), and glass.

Your Notes:

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- **Semiconductors** allow small currents to flow. Sometimes they are conductors and sometimes they are insulators. Silicon is the material most often used in making semiconductors.

Background information for VSVS members:
Insulators generally cause static charge to build up. Insulators do not allow the flow of electricity so the charge that builds up is not able to dissipate; it is only able to discharge. An example of discharge would be when a person rubs their feet on a carpet while wearing socks and then touches another person causing a small shock.

Tell the students that the **snap circuits** we will use today contain flattened wires. Remove one of the **#2 connectors** (blue bar with a 2 on it) and hold it up so that the students can see the metal underside. Tell the students that this metal is a good conductor of electricity.

II. Explaining the Circuit – Demonstration

VSVS team members should hold up the demonstration circuit to show the students.
Tell the students to look at **Diagram 1** and tell them it is a picture of this circuit. Point out the different parts – batteries, circuit connectors, black and red leads, resistor and LED light.

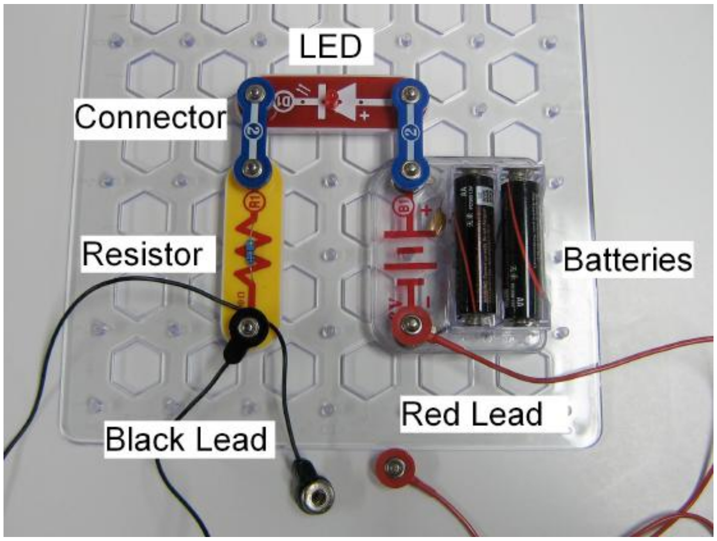

Diagram 1

Explain LED's to the students: LED's (Light Emitting Diodes) are more sensitive than light bulbs and glow brightly with small currents. They are made from semiconductors. They can be damaged by high currents and so are used with resistors to limit the current. Do NOT allow the students to remove the resistor.

Your Notes:

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Ask the students what you should do to make the LED glow. *Touch the black and red lead together to complete the circuit.*
Show the students that this is correct and that the LED emits light. **Tell the students that the circuit is closed when the red and black leads are touching.**
Now touch the end of one lead wire to the head of the nail and the end of the other lead to the point of the nail. The LED again lights up indicating that the circuit is closed. The metal nail is a *good* conductor of electricity and completes the circuit.
Repeat with the bottle cap, putting the ends of the leads on opposite sides of the bottle cap. The LED will not light up, indicating the plastic bottle cap is not a conductor, it is an insulator.
Tell the students that in the first activity they will determine whether a solid is a conductor by testing whether it completes the circuit and causes the LED to light up.

III. Conductivity Tests of Solids

Students will do this activity in pairs.

Materials

16 sets of grids with assembled circuit
16 bags of solid materials for checking conductivity (paper clip, aluminum foil, copper strip, golf pencil sharpened on both ends, paper)
16 sets of instruction sheets
32 observation sheets

- Hand out one grid and one bag of solid conductivity materials to each pair.
- Tell them they will be testing several materials to see if they are conductors.
    - A *good* conductor will complete the circuit and the LED will glow brightly.
    - An insulator will prevent completion of the circuit, and the LED will not glow at all.
    - A *poor* conductor will make the LED light glow dimly.
- Have them assemble the circuit as demonstrated in Diagram 1. Make sure all groups have a correctly assembled circuit by having them touch the ends of the black and red wires together and noting the brightness of the LED.
- Tell the students to follow the instruction sheet and to record their results.

> Explain that although pencils are referred to as "lead" pencils, the core of the pencil is actually graphite. In ancient Rome, the scribes wrote with a stylus made from lead. A large deposit of graphite was discovered in the 16^{th} century in England, and found to be very useful for marking sheep! The early chemists mistook it for lead.

IV. Conductivity of Solutions

Materials per pair

1 6oz cup for distilled water for rinsing leads
1 set of jars labeled and containing: distilled water, tap water, vinegar, 0.1 M hydrochloric acid, distilled water for sugar to be added, distilled water for salt to be added.
8 bags containing:
  1oz wide-mouth bottle of sugar
  1oz wide-mouth bottle of salt

Your Notes:

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2 taster spoons
1 chemwipe tissue
2 toothpicks

Note: One VSVS member should fill 6oz cups about 1/3 full of distilled water. Each pair will use one of these to rinse the metal ends of lead wires.

Hand out the jars of solutions, salt and sugar containers etc, and a cup with distilled water to each group. The pairs will share the jars. Make sure that only 1 jar is open at a time to avoid contamination.

Background Information to tell the students:
Solids are not the only materials that can conduct electricity. In fact, liquids have electrical properties as well. Some liquids are conductors while other liquids are nonconductors.

Background information for VSVS members only:
Conducting liquids are called **electrolytes.** An **electrolyte** contains electrically charged ions that can conduct electricity. Some examples of electrolytic solutions are acids and bases and salt solutions such as sodium chloride (table salt) in water.
A **non-electrolyte** does not allow the flow of electric current because it does not have electrically charged ions that can conduct electricity. Some examples of non-electrolytic solutions are distilled water, sugar water.
Electrolytes are important to humans because they are necessary for proper cellular function, muscle function, and neurological function. A greater level of electrolytes is needed during strenuous muscular activity because more electrolytes are lost due to increased sweating. This is the reason why Gatorade and other sports drinks advertise that they replenish electrolytes.

Tell students to:

- Rinse the metal ends of the black and red lead wires by dipping them into the cup of distilled water. Tell the students they will need to do this in between each test, to avoid contaminating the next test sample with the one just tested (make sure that the students know what contamination means). They should then place the leads into the first jar containing distilled water to check that the leads are clean. The LED will not light up if the leads are clean. Note the rinse water will be contaminated enough after the HCl is tested so that the LED will be dimly lit. However, the test in the distilled water well should give a negative result (no glow).
- Place the labeled jars on top of the diagram on the instruction sheet. Make sure that the students have the order correct. Students must remove only 1 lid at a time, and replace it after both pairs have tested the liquid.
- Students MUST test the solutions in the order given, 1-6. The non-conducting solutions are tested first, followed by conducting solutions.

1. Testing distilled water:

Remove the lid of the first jar (contains distilled water).
Put the metal ends of both lead wires in the jar, as far apart as possible, and note if the LED is glowing. (It should not).
Remove the leads.
The lid can remain off, since this jar will be used again in steps 4 and 5.

Your Notes:

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2. **Testing sugar water:**

Use the tissue to wipe off the small spoon.
Remove the lid of the 2nd jar (distilled water) and add a small amount of sugar (just a little on the tip of the spoon is enough). Stir with a toothpick. Break toothpick so that it will not be used again.
Repeat the conductivity test. Record your results.
Rinse the metal ends of the lead wires in the rinse cup.
Replace the lid.

3. Testing tap water:

Remove the lid of the 3rd jar (tap water). Repeat the conductivity test. Record your results. Rinse the metal ends of the lead wires in the rinse cup. Replace the lid.

4. Testing vinegar:

Remove the lid of the 4th jar (vinegar) and repeat the conductivity test. Record your results. Rinse the metal ends of the lead wires in the rinse cup. Test that the leads are clean by putting them in the distilled water in jar 1. The LED should not glow. Replace the lid.

5. **Testing hydrochloric acid**:

Remove the lid of the 5th jar (hydrochloric acid, HCl) and repeat the conductivity test. Record your results. Rinse the metal ends of the lead wires in the rinse cup.
Test that the leads are clean by putting them in the distilled water in jar 1. The LED should not glow. If it does, rinse the leads in distilled water again. Replace the lid

6. Testing salt solution

Remove the lid of jar 6 (distilled water).
Use the small spoon to add a small amount of the salt into the same well (just a little salt on the tip of the spoon is enough). Stir with a toothpick. Break toothpick so that it will not be used again. Repeat the conductivity test Record your results. Rinse the metal ends of the lead wires in the rinse cup. Replace the lid.

Explanation of results:

1. **Distilled water** does not contain ions and thus does not conduct electrical currents.
2. **Sugar molecules** do not dissociate (split up) into ions in water, and so is a nonconductor.
3. **Tap water** comes from wells, lakes, or rivers, and so it often contains small amounts of dissolved mineral compounds that can be ionic. The LED did not light up very brightly, but tap water can conduct enough current to stop a person's heart.
4. **Vinegar** is a *weak* conductor of electric current– the LED glows dimly. Only a few of the vinegar molecules ionize.
5. **Hydrochloric acid** is a conductor of electric current **-** the LED glows brightly. All of the molecules ionize to H^+ and Cl^- ions.
6. **Solid salt** will not conduct electricity because the sodium and chloride ions are not free to move around. However, when salt is dissolved in water, it dissociates completely into ions, and so is a *strong* conductor of electric current.

Your Notes:

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V. Optional Activity #1

Materials:

1 bag containing wide mouth bottles of Gatorade, Sprite, rubbing alcohol, bottled water and lemon juice

If time permits, ask the students to choose one of the solutions.
Ask the students to predict if they think the solution will conduct an electrical current. Test it.

1. Gatorade caused the light to shine very brightly indicating that it is a *strong* conductor. The ingredients list citric acid, salt, sodium citrate, potassium phosphate.
2. Sprite contains citric acid, potassium citrate and other salts which make it a good conductor.
3. Rubbing alcohol does not conduct electricity.
4. Bottled water may or may not contain minerals, depending on how it is "processed".
5. Lemon juice contains citric acid which conducts electricity.

VI. Optional Activity #2 - Demonstration

Why use LED's?

In a light bulb, electricity is converted into light energy. The brightness depends on the amount of electricity flowing through it. Regular light bulbs need a high current to be bright. Repeat Experiment III using the nail and using a regular light bulb instead of the LED in the circuit. It will not light up.
LED's Light Emitting Diodes are more sensitive than light bulbs and glow brightly with small currents. They are made from semiconductors and can be damaged by high currents and so are used with resistors to limit the current. **Do NOT** allow the students to remove the resistor.

Electrical current can flow through them in one direction only.

Ask the students which way the electricity is flowing. Show the students the direction of flow.

Current flows from the positive end ("knob") of the battery to the negative ("flat") end.

Demonstration only: change the direction of the LED piece by unsnapping it, turning it around and snapping it back in to place.
What happens? *The LED does not light up.*

VII. Review

1. Go over the observation sheet with the students. Make sure they understand the chemistry behind conductivity and non-conductivity.

Lesson modifications by:

Dr. Mel Joesten, Emeritus Professor of Chemistry, Vanderbilt University
Pat Tellinghuisen, VSVS Director, Vanderbilt University
Michael Gootee, Undergraduate student, Vanderbilt University

Your Notes:

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Conductivity Observation Sheet

Name ____

A. Testing the Circuit.
What happens when you touch the ends of the red and black lead wires together?
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Explain____

B. Conductivity Tests with Solids
Which of the following materials makes the LED glow brightly, dimly, or not at all? Circle your answer.

1. copper strip	no light,	dim light,	bright light
2. paper clip	no light,	dim light,	bright light
3. paper	no light,	dim light,	bright light
4. pencil wood (only)	no light,	dim light,	bright light
5. "lead" in pencil	no light,	dim light,	bright light
6. aluminum foil	no light,	dim light,	bright light

On the basis of your tests, which ones are conductors of electricity?

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C. Conductivity Tests with Solutions
Which of the following solutions makes the LED glow brightly, dimly, or not at all? Circle your answer.

1. distilled water	no light,	dim light,	bright light
2. sugar water	no light,	dim light,	bright light
3. tap water	no light,	dim light,	bright light
4. vinegar	no light,	dim light,	bright light
5. hydrochloric acid	no light,	dim light,	bright light
6. salt water	no light,	dim light,	bright light

D. Optional Activity

Which solution did you test? ________________

Circle your answer.	no light,	dim light,	bright light

Conductivity Answer Sheet

A. Testing the Circuit.

1. What happens when you touch the ends of the jumper cables together?

The LED lights up.

Explain: **Touching the ends of the leads together completes the circuit.**

B. Conductivity Tests with Solids

Which of the following materials cause the speaker to produce sound?
Circle your answer.

1. copper strip	bright light
2. paper clip	bright light
3. paper	no light
4. pencil wood(only)	no light
5. “lead” in pencil	bright light
6. aluminum foil	bright light

On the basis of your tests, which ones conduct electricity?

Copper strip, paper clip, “lead” in golf pencil, aluminum foil

C. Conductivity Tests with Solutions

Which of the following solutions makes the LED glow brightly, dimly, or not at all?
Circle your answer.

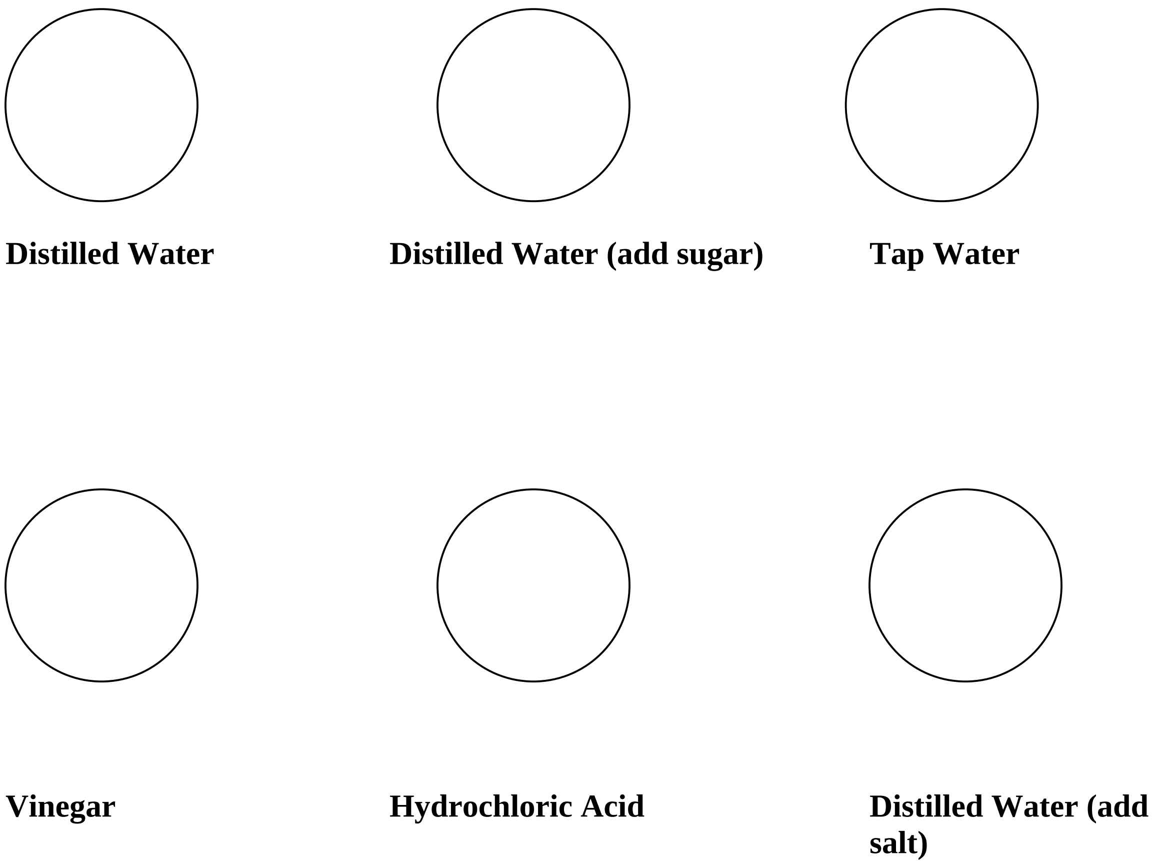
1. distilled water	no light
2. sugar water	no light
3. tap water	dim light
4. vinegar	dim light
5. hydrochloric acid	bright light
6. salt water	bright light

D, Optional Activity

The following are good conductors: Gatorade, Sprite, and lemon juice.
Rubbing alcohol does not conduct electricity. Bottled water may.

Electrical Conductivity Instruction Sheet

Place the jars on top of the diagram. Make sure that the labels match. Do not remove lids until you are ready to test the liquid.



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

Electrolysis of Water and Fuel Cells

Mini Lesson for Spring 2016

Goal: To learn about the energy conversion from electrical energy to chemical energy through the electrolysis of water and to become familiar with fuel cells.

I. Introduction

Discuss different forms of energy.

II. Electrolysis of Water: Electrical Energy → Chemical Energy

A. Distilled Water Experiment

Students use two nichrome electrodes and a 9-volt battery to test whether any reaction occurs in distilled water. Nothing happens because distilled water doesn't conduct electricity.

B. Salt Water Experiment

Students then add a small scoop of sodium sulfate to the distilled water, stir with a toothpick, and then place the nichrome electrodes in the water. This time they should see bubbles - more at one electrode than the other (approximately twice as many hydrogen bubbles)

C. Fuel Cell Experiment

Students will work with a VSVS member. There are 4 sets of materials, so divide the class accordingly

A. Examining the Fuel Cell

Students examine the various parts of the fuel cell, and identify what they are used for.

B. Hydrogen Production

Students use the hand crank to produce hydrogen and oxygen gas, and observe the different volume each gas holds.

C. Fuel Cell Car

Students learn how the fuel cell car operates, and observe how the hydrogen is converted back to water.

Fun Facts

1. Electrolysis was first studied in 1833 by the English physicist and chemist Michael Faraday.
2. Hydrogen fuel for hydrogen fuel cells can be made from many sources like wind energy, solar energy, and even garbage.
3. A fuel cell for a hydrogen fuel cell car lasts up to 150,000 miles before it needs to be replaced.
4. Fuel cells were discovered in 1838 by two European physicists.
5. Iceland has committed to eventually having every vehicle in the country hydrogen fuel cell-based.
6. Fuel cell are generally considered better for the environment than most commercial vehicles.

<u>**Complete teacher/school information on first page of manual.**</u>

1. Make sure the teacher knows the VSVS Director's (Pat Tellinghuisen) home and office numbers (in front of manual).
2. Exchange/agree on lesson dates and tell the teacher the lesson order (**any changes from the given schedule need to be given to Pat in writing (email)**).
3. Since this is your first visit to the class, take a few minutes to introduce yourselves. Mention you will be coming three more times to teach them a science lesson.
4. Do the experiment with the classroom, and leave 10 minutes at the end to discuss aspects of college life with them. Some topics that could be included are on page 5 of the manual.

Unpacking the Kit

For Part II. Electrolysis of Water

Students will work in pairs for this part. There are 16 sets of materials, so divide the class into enough groups to use all the materials.

1 Demonstration ziploc bag containing:
- 1 9-volt battery with wire leads
- 1 set of nichrome electrodes mounted in Styrofoam

1 plastic container with 16 sets of nichrome electrodes mounted in Styrofoam
16 ziploc bags containing the following items:
- 1 9-volt battery with wire leads clipped to popsicle stick
- 1 small container of sodium sulfate
- 1 small plastic scoop
- 1 toothpick
- 1 hand magnifying lens

1 plastic container with 17 2oz. jars of distilled water
10 paper towels in plastic bag
16 plates

For Part III. Fuel Cells These are distributed to VSVS members only, who will conduct the experiment with the students (the class needs to be divided into as many groups as there are VSVS team members)

4 plastic containers with
- 1 reversible fuel cell
- 1 model car
- 1 3oz. bottle of distilled water
- 1 hand crank with built in patch cables

4 6 oz cups
4 plastic plates
16 student handouts showing fuel cell car and handcrank
4 VSVS handouts

I. Introduction

Ask students if they can name any conversions of electrical energy to other forms of energy. Ask for examples for each conversion.

Your Notes:

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Answers should include:

1. Electrical to Mechanical – motors
2. Electrical to Thermal (heat) – heaters, toasters, ovens
3. Electrical to Light - light bulbs
4. Electrical to Chemical – electrolysis of water
5. Electrical to Sound – doorbells

Ask students if they know the formula for water? ***H_2O*.**

Write this formula on the board. Explain that this formula shows that water is made up of two parts hydrogen and one part oxygen.

Ask students if they know what will happen if an electrical current is passed through water?

The water decomposes into 2 gases, oxygen and hydrogen.

Write the formula for these gases on the board – **O_2 and H_2**.

Tell students that they are going to use electrical current from a 9-volt battery to decompose (break down) water.

II. Electrolysis of Water: Electrical Energy → Chemical Energy

Materials

1 Demonstration ziploc bag containing:
- 1 9-volt battery with wire leads
- 1 set of nichrome electrodes mounted in Styrofoam

1 plastic container with 16 sets of nichrome electrodes mounted in Styrofoam

16 ziploc bags containing the following items:
- 1 9-volt battery with wire leads
- 1 small container of sodium sulfate
- 1 small plastic scoop
- 1 toothpick
- 1 hand magnifying lens

1 plastic container with 17 2oz. jars of distilled water

10 paper towels in plastic bag

16 plates

Perform the following demonstration before you pass out materials:

1. Take the 9-volt battery, wire leads, and the set of nichrome electrodes from the demonstration bag.
2. Take one of the jars with distilled water from the plastic container.
3. Follow the diagram below and show the students how to hook up the set of nichrome electrodes to each wire by attaching the alligator clip to the short end of the electrode. **Explain that the nichrome is an electrode because nichrome conducts electricity.**
4. Show them how the electrodes are placed in the jar. Emphasize to students that the **nichrome electrodes and their mount should be handled with care**. Refer them to the picture on the instruction sheet (also given below) for the correct hookup and placement of the nichrome electrodes. **Note that the alligator clips are connected to the short end of the nichrome electrodes.**

Your Notes:

Give each group a bag of materials, a jar with distilled water, and a set of nichrome electrodes.

A. Distilled Water Experiment

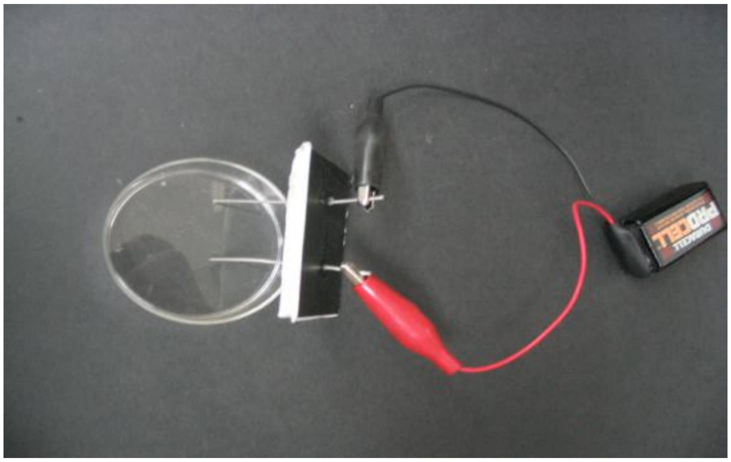
1. Have students place the electrodes connected to the 9-volt battery in the jar that contains distilled water so that the electrodes are in the water.
2. Tell the students to see if any bubbles are forming around the end of the electrodes in the water.
3. Record observations on the board. (Students should observe that nothing happens.)

For the next experiment, students should remove the electrodes from the water before adding salt.

B. Salt Water Experiment

1. Tell students to use the small plastic scoop to get a small amount of sodium sulfate from the container.
2. Add one scoop of sodium sulfate to the distilled water in the jar.
3. Stir the water and sodium sulfate with the toothpick.
4. Follow the same procedure as before and place the electrodes back into the jar.
4. Tell students to look through the side of the jar to see if any bubbles are forming around the end of the electrodes in the water. They may have to use the hand lens.
5. Record observations on the board.
6. Ask students to notice which electrode (black connection or red connection) has the most bubbles. *Answer: Black connection*.

Note: Students should observe tiny bubbles of gas at both electrodes.
One electrode should have twice as many bubbles as the other. This is the negative electrode (the black wire). The students may have difficulty seeing this because this is where the hydrogen bubbles are emitted. Hydrogen bubbles are smaller than the oxygen bubbles.



Your Notes:

Ask the students the following questions:

1. Where is the electrical energy coming from? *The battery.*
2. What kind of bubbles are forming in the jar? *Hydrogen and Oxygen gas*
3. Which electrodes had the most bubbles? *The electrode connected to the black (negative) alligator clip. It may be difficult to notice, but the ratio is 2:1.*
4. Based on the formula for water, which bubbles are being produced in larger amounts: hydrogen or oxygen? *The formula for water shows that water has twice as many hydrogen atoms as oxygen atoms. There are more bubbles around one electrode. Those are the hydrogen bubbles.*

Explanation:

Important point - the electrical energy in the battery was converted to chemical energy when water (H_2O) was broken into hydrogen and oxygen gas.

The decomposition of water is a chemical change.

The decomposition of water requires energy, and this case, electrical energy is being used to cause the reaction to occur.

The electrolytic solution contains a small amount of sodium sulfate, which conducted the electric current through the solution. Pure water does not conduct electricity so water was not broken down in the pure or distilled water.

For VSVS Information only:

In the water at the negatively charged cathode, a reduction reaction takes place, with electrons (e^-) from the cathode being given to hydrogen cations to form hydrogen gas

Cathode (reduction): $4\ H_2O(l) + 4e^- \rightarrow 2H_2(g) + 4\ OH^-(aq)$

At the positively charged anode, an oxidation reaction occurs, generating oxygen gas and giving electrons to the cathode to complete the circuit:

Anode (oxidation): $2\ H_2O(l) \rightarrow O_2(g) + 4\ H^+(aq) + 4e^-$

Overall reaction: $2\ H_2O(l) \rightarrow 2\ H_2(g) + O_2(g)$The number of hydrogen molecules produced is thus twice the number of oxygen molecules.

Clean – up:

Tell students to clip the alligator clips back on to the popsicle stick. This is to prevent the clips touching each other, which could create a short-circuit and drain the battery or cause the battery to become very hot.

Collect the nichrome electrode sets; place them back in their plastic container.

Collect the jars and make sure the lids are screwed on tightly. Return them to their plastic container.

Have students put the other materials in their bag.

VSVS volunteers should collect the bags of materials and place them back in

Your Notes:

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III. Fuel Cells

Materials

4 reversible fuel cells
4 model cars
1 plastic container with 4 3oz. bottles of distilled water
4 hand cranks with built in patch cables
4 6 oz cups
4 plastic plates
10 paper towels in plastic bag
16 student handouts showing fuel cell car and handcrank
4 VSVS handouts showing fuel cell

Give each <u>VSVS member</u> a fuel cell and a jar with distilled water

A. Examining the fuel cell

1. Pass out the provided handout.
2. Have students look at the fuel cell and the handout. Help students identify all parts of the cell.***There is a student version of the handout and a volunteer version. The volunteer version has descriptions of what each component does. The student version merely has them numbered, but not described***
3. Place the fuel cell upside down (number facing down) on a plastic plate placed on a flat surface.
4. Remove the stoppers on fuel cell (two).
5. Pour distilled water into both storage cylinders (be careful to pour it around the outside of the cylinder, not into the small tube in the middle) until the water reaches the tops of the small tubes in the center of the cylinders.
6. Tap the fuel cell lightly to help water flow into the area surrounding the membrane and metal current-collecting plates.
7. Add more water until it starts to overflow into the tubes in the cylinders.
8. Place the stoppers back onto the cylinders. Make sure no air is trapped inside the cylinder. Small air bubbles will not cause problems.
9. Turn the fuel cell right side up.

Give each group a hand crank.

B. Hydrogen production

1. Attach the red patch cable from the hand crank to the banana jack positive terminal (red) (2 in the following diagram). Then attach the black patch cable from the hand crank to the banana jack negative terminal (black) (1 in the following diagram).
2. Begin to turn the hand crank to cause the water to begin being converted to hydrogen. Students should observe water displacing out of the outlet tube and into the open container above as gas bubbles form and collect in the storage cylinders. *Water is displaced because the gas coming into the storage cylinders takes up more volume than the water which was there to begin with, and so the water must go into the overflow channel.*
3. Turn the hand crank in complete circles, about 50 times. Students should now see a small bubble in the hydrogen tank.

Your Notes:

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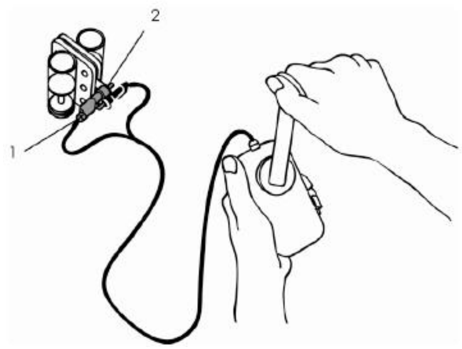


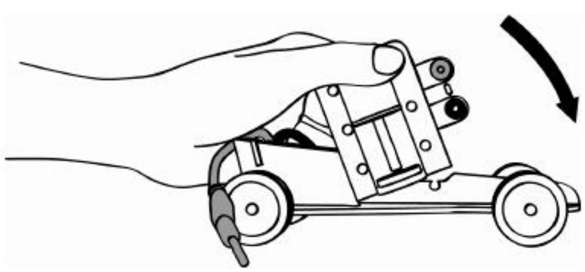
Ask the students the following questions:

1. Ask students to notice which side (O_2 side or H_2 side) has the greater volume of gas. *Answer: Hydrogen side*
2. Based on the formula for water, which bubbles are being produced in larger amounts: hydrogen or oxygen? *The formula for water shows that water has twice as many hydrogen atoms as oxygen atoms. There is a larger bubble in the hydrogen tank, so it is hydrogen.*
3. Where is the electrical energy coming from? *The hand crank is turned by the student, turning an electromagnet inside of a wire coil which generates electricity. The electrical energy is used to put a current through the membrane in the fuel cell, which is used to split water into hydrogen and oxygen. Splitting it in this way converts the electrical energy into chemical energy, since the stored hydrogen acts as a battery. So, the final energy pathway is mechanical energy going to electrical energy going to chemical energy. When the car runs, this pathway reverses. The gas is consumed into electricity, which powers the fuel cell car.*

Give each group a fuel cell car and a 6 oz cup

C. Fuel Cell Car

1. Detach the patch cables from the fuel cell.
2. Being careful not to spill the overflow water, clip the fuel cell into the notches on the car.



3. Place the car on the cup so that the wheels are touching neither the cup nor the ground.

Your Notes:

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4. Plug the patch cables from the car into the cell (red cable to red banana jack and black cable to black banana jack). The car will begin running as soon as both cables are plugged in.
5. Let the car run all the way down until it runs out of the H_2/O_2 gases.
6. Once the energy is discharged, have the students examine the two water storage tanks.
7. Did the water return to the original level?

Explanation:
Important point - the energy from the hand crank (mechanical) was converted immediately to electrical energy before travelling through the wires to the electrolyzer, where the electrical energy was converted to chemical energy when water (H_2O) was broken into hydrogen and oxygen gas.

In the case of the Fuel Cell, only distilled water was used. The electrolyzer is a plastic-like film (called a polymer) which has tiny amounts of platinum and iridium (another metal) imbedded in it. This allows the water to be split without salt or other electrolytes needing to be added.

The hydrogen was stored and therefore became a sort of battery, and the energy stored was able to be used to power the car.

Discuss the importance of going to College and answer students' questions.

Lesson written by
Kristen Engerer, Vanderbilt University Graduate Student
Pat Tellinghuisen, VSVS Program Coordinator

Your Notes:

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The reversible fuel cell is the central device of the Model Car. It serves as an electrolyzer to produce hydrogen and oxygen (chemical power) and store them in the storage cylinders.

The reversible fuel cell generates (electrical) power when it consumes the hydrogen and oxygen from the storage cylinders.

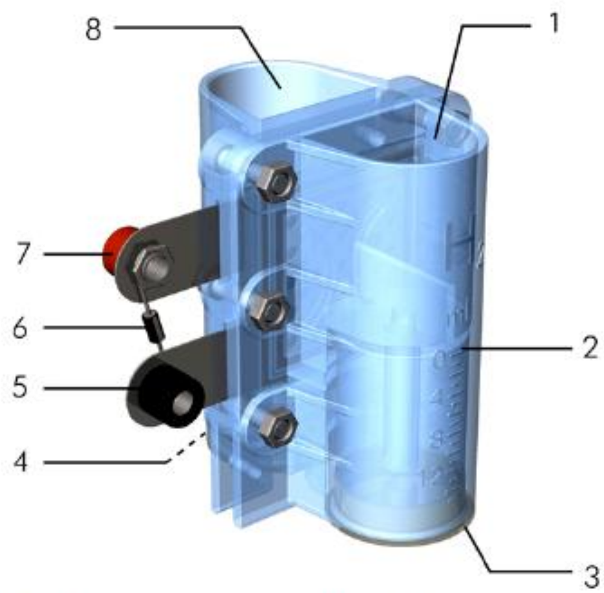

Fig. 3-4 Proton Exchange Membrane reversible fuel cell

1	Overflow compartment hydrogen side	5	Banana jack negative terminal
2	Hydrogen storage	6	Protective diode
3	Hydrogen side stopper	7	Banana jack positive terminal
4	Storage cylinder oxygen side (hidden)	8	Overflow compartment oxygen side

1. Overflow compartments are needed to compensate for the increase in volume when the water undergoes electrolysis. Since the gases take up more volume, some of the water is displaced into this compartment.
2. The tank that holds water that is electrolyzed into hydrogen gas.
3. The stopper used to hold the gas and water in the cell.
4. The tank that holds water that is electrolyzed into oxygen gas.
5. The negative terminal used to connect the patch cables to provide electricity for the reaction.
6. The diode used to prevent high current levels from damaging the fuel cell membranes.
7. The positive terminal used to connect the patch cables to provide electricity for the reaction.
8. See point 1

Not shown: Electrolyzer membrane. This is a plastic-like film (called a polymer) which has tiny amounts of platinum and iridium (another metal) imbedded in it. This allows the water to be split without the addition of salt or other electrolytes.

The motor of the car is powered by the fuel cell, or the solar panel, or both.

The car is steerable; it can run straight or a circle.

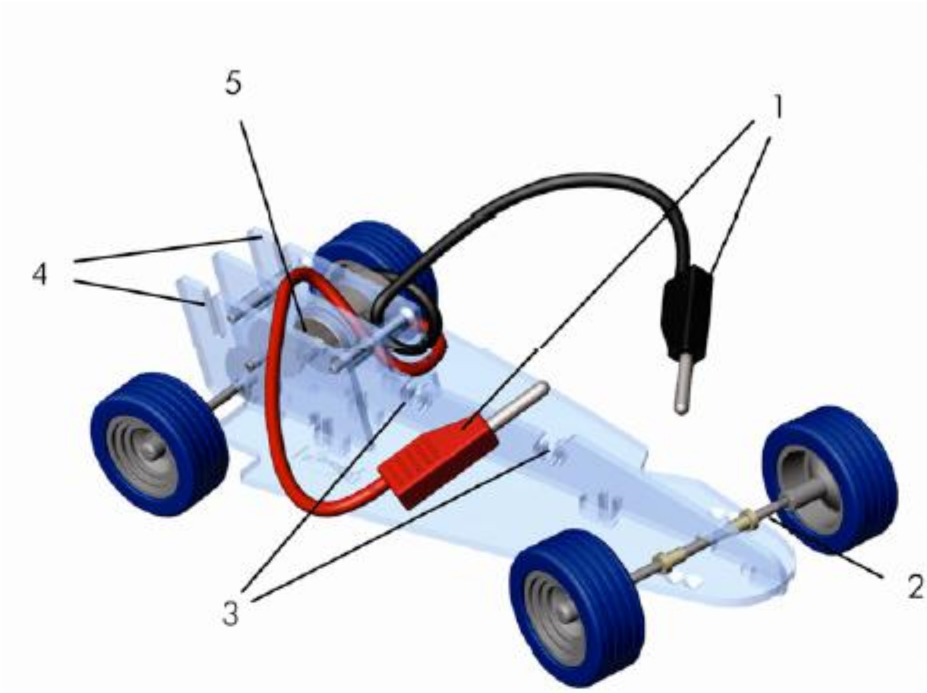

Fig. 3-5 Car chassis

1	Banana jacks (positive / negative)	4	Slots for attaching solar panel
2	Steerable front axle	5	Rear-engine with rear-wheel drive
3	Notches for attaching reversible fuel cell		

1. Cables used to connect the car to the fuel cell supplying the car with power
2. Allows the car to be set to drive straight or in a circle
3. Place where the fuel cell can attach securely
4. Place to have the solar panel attached to the car to allow for continuous energy generation and car running, rather than using stored energy from the fuel cell. This will not be used in this lesson
5. Uses the energy provided to drive the car