Title: “Electrochemistry-From Food to Fuel”			
Course: Physical Science, Earth Science, Chemistry, Physics **Grade:** 6-12		**Duration:** 45 minutes	
Objective: Investigate how a lemon can be used as a source of electrical energy to power a small electronic device.			
Arkansas State Standards:			
SUBJECT:	**GRADE LEVELS:**	**CODE:**	**STANDARD:**
Physical Science	**6-8**	**6-PS-3-4** **6-PS-3-5** **8-PS-2-5**	Plan an investigation to determine the relationships among the energy transferred, the type of matter, themass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
Earth Science	**9-12**	**ES-ESS3-2**	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios
Physics		**P-PS2-5**	Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
Chemistry	**9-12**	**CI-PS1-8**	Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

Instructional Strategies and Practices:
Provide background knowledge on necessary vocabulary, followed by student design and testing of materials with application of concepts

Bloom’s Level: Application and Evaluation

Materials and Resources:
- 2 ripe lemons/potatoes
- low-voltage digital clock (one that takes one AA battery or a 1.5 volt button cell one)
- one AA battery
- 2 copper pennies (older the penny, pre-1982 when they were made with more copper the better)

- three 8″ lengths of copper wire
- 2 galvanized nails
- knife
- scissors
- alligator clips (optional)

Formative Assessment:
Collect data on efficiency of electrical charge transfer between the food objects
Determine strength of charge
Discuss how this could apply to real-world situations where power is limited

Notes to Teacher:
This activity requires background knowledge on how electrical currents are transferred from one energy source to another. That energy is neither created nor destroyed, just transferred. Understanding of positive and negative charges needed for conduction.

Student Activity:
Batteries are small devices that store energy, which can be converted to electrical energy in the form of electricity. This method of storing energy allows us to utilize portable devices outside of the home or office. Of the many types of batteries in the world, each of them have a different capacity for storing energy. The chemical reaction typically occurs between two pieces of metal, called electrodes, and a liquid, called an electrolyte. It turns out that the movement of positive ions through the water inside a lemon works as a galvanic cell. When you add metal electrodes, you create a battery.

Basic concepts and vocabulary about electricity. The flow of electricity is called an electrical current. It is measured by a unit called amperes (A) (also called amps for short). Voltage, measured in volts (V) is what pushes electrical current through wires. Then you have electrical resistance, measured in ohms (Ω) (the capital Greek letter Omega) is a measure of the difficulty of electricity to flow through a certain material. The type and size of the wire determines the ease or difficulty of the current to travel.

Student Handout:

Materials:

2 ripe lemons

Low-voltage digital clock (one that takes one AA battery or a 1.5 volt button cell one)

1 AA battery

2 copper pennies (older the penny, pre-1982 when they were made with more copper the better)

3 of 8″ lengths of copper wire

2 galvanized nails

Knife

Scissors

Alligator clips (optional)

Safety Considerations:

- Wear safety glasses
- Use gloves when handling metals
- Work under adult supervision
- Do not consume the experimental materials

Directions for Activity:

1. Wrap one end of a wire around a penny and the other around the end of a nail. (These will be used to connect the lemons together.)

2. Connect a second wire to a penny and leave the other end bare.

3. Wrap the third wire around a nail and leave the other end bare. (Connecting lemons with metal wires adds the voltage from each lemon. The more lemons you connect together, the higher the voltage.)

4. Now roll the lemons on a hard surface, being careful not to break the skin. The reason we do this is it will loosen the pulp, make the lemons juicy and help the electrons move through the lemons. Cut a slit in each lemon just large enough to insert the pennies.

5. Insert the penny connected to the wire in the slit you made.

6. Insert the other end of the wire with the nail into the next lemon. If you are connecting more than two lemons for more voltage, do so by linking them together with more penny to nail connections. Now on your first lemon attach the nail wrapped wire and empty other side to connect to the clock. On the last lemon in your chain insert the penny wrapped wire with the empty wire on the other side to connect to the clock. Each lemon should have only and exactly – one penny and one lemon leading in/out of the circuit. HINT: Make sure the copper wire has good contact with both the pennies and nails, and make sure the pennies and the nails make good contact

7. Remove the battery from the clock. You don't need this as you are going to power it with your lemon battery. Have an adult carefully touch the wires to the positive and negative terminals in the clock. If your clock doesn't work, try switching the wires. with the lemon pulp and juice.

Assessment:

So how does the lemon clock work?

Explain the chemical process that allows a lemon to generate electrical energy:

- Identify the chemical reaction

- Describe the role of the copper and zinc

- Explain how the acidic lemon juice facilitates electron flow

Analysis Questions:

1. Did your lemon battery successfully power the clock?

2. What challenges did you encounter during the experiment?

3. How does the chemical reaction in the lemon create electrical energy?

4. Compare the performance of different types of lemons or metals.

Extension:
Test other types of fruits and vegetables to compare their effectiveness.

Answer key:

So how does the lemon clock work?

When the copper pennies and zinc nails are inserted into the lemon, a chemical reaction takes place. The electrons move from the zinc plates to the copper plates to form a circuit with a current which activates the clock. The lemon juice helps to conduct electricity.

Explain the chemical process that allows a lemon to generate electrical energy:

- Identify the chemical reaction-

Anode (Negative Electrode): The zinc (or other metal) reacts with the citric acid in the lemon juice. This reaction causes the zinc to lose electrons, becoming positively charged zinc ions. The electrons move away from the zinc.

Cathode (Positive Electrode): The copper (or other metal) attracts the electrons. The electrons are added to the copper, and it becomes negatively charged

- Describe the role of the copper and zinc-Copper (Cathode):

. **Copper is more electronegative than zinc, meaning it has a stronger attraction for electrons. When the copper and zinc electrodes are connected in the lemon battery circuit, the copper pulls electrons from the zinc.**

Zinc (Anode): Zinc readily reacts with the lemon's citric acid, losing electrons (oxidizing). These electrons then flow from the zinc towards the copper.

Lemon Juice (Electrolyte): The lemon juice acts as an electrolyte, facilitating the flow of ions (charged particles) and completing the electrical circuit. It provides the medium for the chemical reaction to occur between the metals.

- Explain how the acidic lemon juice facilitates electron flow-

When electrolytes like citric acid are dissolved in a solvent like water, they can conduct electricity because they break down into ions, which are charged particles. Citric acid, it dissociates into hydrogen ions (H^+) and other ions. These H^+ ions act as the charge carriers, allowing electrical current to flow.

Analysis Questions:

Answers will vary

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