The Lemon Battery Challenge

Grade Level

3rd through 8th

Materials

- 4 D-size batteries
- 4 Lemons
- 4 Copper electrodes - in shape of a spike, 3-5 cm. long
- 4 Zinc electrodes - in shape of a spike, 3-5 cm long
- Multimeter for measuring DC voltage and low (-.0001 A) current

Objectives of this activity

• Learn how a chemical reaction can produce electricity

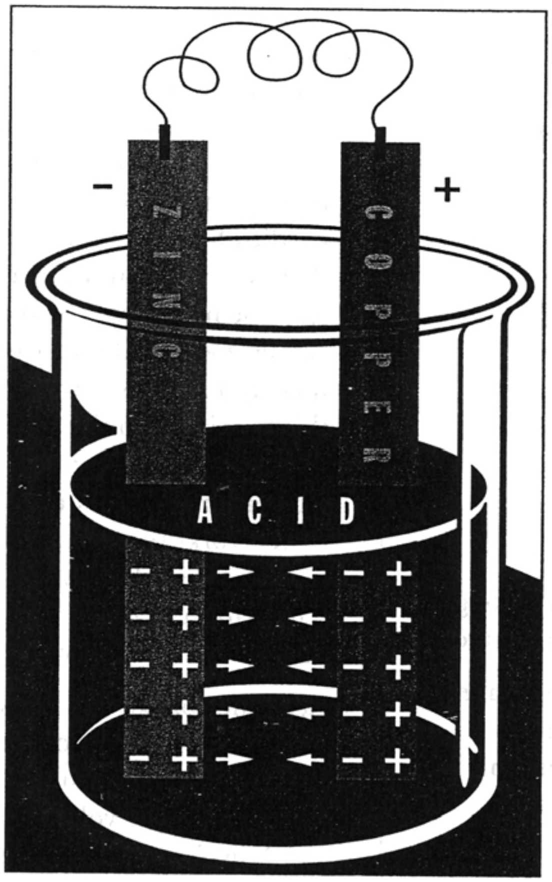
• Create a wet-cell battery

• Understand how much power it takes to run an electric car

Background

The power behind electricity comes from one of the smallest things known to science -- electrons. Electrons are tiny particles within atoms that have a minute electric charge. If a million million (1,000,000,000,000 -- write this number on the chalkboard or white board!) electrons were lined up, they would barely reach across the head of a pin. When electric current flows through a wire, these tiny particles actually surge through the metal of the wire -- just like water flows through a pipe. It takes an unbelievably large number of electrons flowing through a wire to light a bulb -- approximately 6 million million million (6,000,000,000,000,000,000) electrons flow through the bulb each second (write this number on the board). The flow of electrons is called an electrical current and is measured in Amperes --- when 6 million million million electrons flow through an electrical circuit in one second, the current is approximately 1 Ampere (6,000,000,000,000,000,000 electrons = 1 Ampere).

Electricity is used for many important things in our lives: light, heat in our homes, computers, etc. In order for electrons to move (and for us to get electrical current to power our favorite devices), a source of energy is needed. This energy may exist in various forms: mechanical motion, light, heat, or a chemical reaction.



Chemical energy is the source of power in batteries. The simplest batteries consist of two different metals (electrodes) floating in a bath of acid. Atoms from one metal travel through the acid to the other metal releasing electrons. Eventually, when all the mobile atoms have been transferred, no additional electrons may be released, and the battery is dead

Engineers make measurements when they are working with electricity. They measure voltage, current, resistance and power. By considering a simple circuit, a battery connected to a light bulb, one can see how engineers use these measurements:

In an analogy to water flow, a battery is like a paddle wheel that raises water up to a height --this is voltage.

As water flows through a pipe, electrons flow through the filament of the light bulb this is current.

As water flowing downhill through a pipe encounters friction, electrons flowing through the filament of the light bulb encounter friction and release energy -- this is electrical resistance.

The entire process converts electrical energy to light energy and heat energy.

Engineers abbreviate these electrical quantities as V (voltage), I (current), R (resistance). These are related to each other as follows: V = I x R. Electrical power (P) is related to voltage and current as follows: P = I x V.

Activity

- Explain the goal of the exercise: To calculate how many lemons it would take to run an electric car.
- Explain that electric cars run on very large batteries and not internal combustion engines like regular

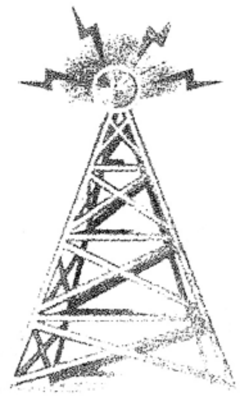
cars. So what are batteries?

- Show the students a typical alkaline battery. Ask them how it works.

- Explain that, within a battery, a chemical reaction takes place between an electrolyte and electrodes. An electrolyte can be a liquid acid or a dry chemical. The electrodes are two different conducting materials, such as metals. Show the theory diagram of the electrodes in an acid bath.

- The chemical reaction causes electrons to be displaced, and these electrons have the potential to do work. The potential energy stored in the electrons is known as voltage (V). The flow of electrons through a wire is known as current (I). The power (P) delivered by a battery is measured by multiplying its voltage times the current. On a chalkboard or whiteboard, write P=V x I.

- Batteries come in two categories: dry cell and wet cell. Dry cells (such as flashlight batteries) are the alkaline batteries that use a powder chemical for an electrolyte; wet cells (such as car batteries) use acids as the electrolyte. The



students will create a wet cell battery using the juice of a lemon, which is a mild acid, as the electrolyte.

- The voltage (V) and current (I) delivered by the lemon battery will be measured using a multimeter. Show the multimeter and the model diagram depicting the circuit through the lemon and the multimeter.

- Divide the class into smaller groups. Give each group a D-size battery, a lemon, a copper electrode and a zinc electrode.

- Ask one student to be a designated recorder and stand by the chalkboard or whiteboard to record the results as they are called out.

- From the front of the room direct each group to first press down on the lemon and roll it on the table to get the juices flowing inside.

- Have the students insert the zinc electrode into the lemon so that approximately half of the electrode is still protruding out.

- Instruct them to do the same with the copper electrode. Have them space the electrodes about 3 or 4 cm apart.

- Go around to each group with the multimeter. Set the multimeter to read DC voltage, and measure the voltage (V) of the battery. Hold the display or needle of the multimeter so that everyone can see and read the numbers. The battery voltage (V) should read approximately 1.5 Volts -- show that this is written on the side of the battery, confirming in the students' minds that the multimeter works properly. If the reading is less than 1.5 Volts, tell them the battery is old and has lost some of its energy.

- Read the voltage (V) across the electrodes of the lemon battery. The multimeter should read approximately I volt. Digital LCD displays might show 0.997 Volts or 0.989 Volts. Have the designated recorder put this under a column labeled "V' on the chalkboard. The readings will be averaged.

- Set the meter to read DC current, and take the reading across the electrodes of the lemon battery. The reading will be approximately 0.0001 Amperes. Ask the recorder to put this reading in a separate column labeled "I" on the board. Again, the readings will be averaged.

- After taking readings from each small group, look at the recorded results. Take the average of the readings.

- Multiply the average voltage (V- 1. 0 Volt) times the average current (1-0.0001 ampere) to find the average power (P- 0.0001 watt) delivered by the battery.

- Explain how it takes 100 watts to power a 100 watt light bulb. The more the wattage, the greater the power consumption. Ask the students to calculate how many lemon batteries would be required to power the 100 watt light bulb [Answer: 100 watt / 0.0001 watt = I million (1,000,000) lemon batteries].

- An electric car requires 6000 W of power to run. Ask the students to calculate how many lemon batteries would be required to power the electric car. [Answer: 60 million (60,000,000) lemon batteries, employing 60 million lemons!] Let, them think about that for a minute.

- Ask if it makes sense to use lemons to power a car. What are some of the pros and cons?

Pros - does not pollute, renewable energy source, electric cars are quiet etc.

Cons - cannot recharge lemons, heavy, expensive (25 cents per lemon = $15 million)

- Explain that the point was to actually see if lemons should be used to power cars, but rather to explain the principles of batteries and electricity; that a simple lemon could be made into a battery by creating a chemical reaction, and that we can apply simple mathematical formulas and determine how much power we can generate and how much it would take to run the car.

Conclusion

These are the problems engineers and scientists face. They ask questions, develop a theory or a model, test out their ideas and draw conclusions. In order to do this however you need a strong background in math and science.

Credits

This activity was provided by IBM research engineers who invite you to see what's going on at www.research.ibm.com.