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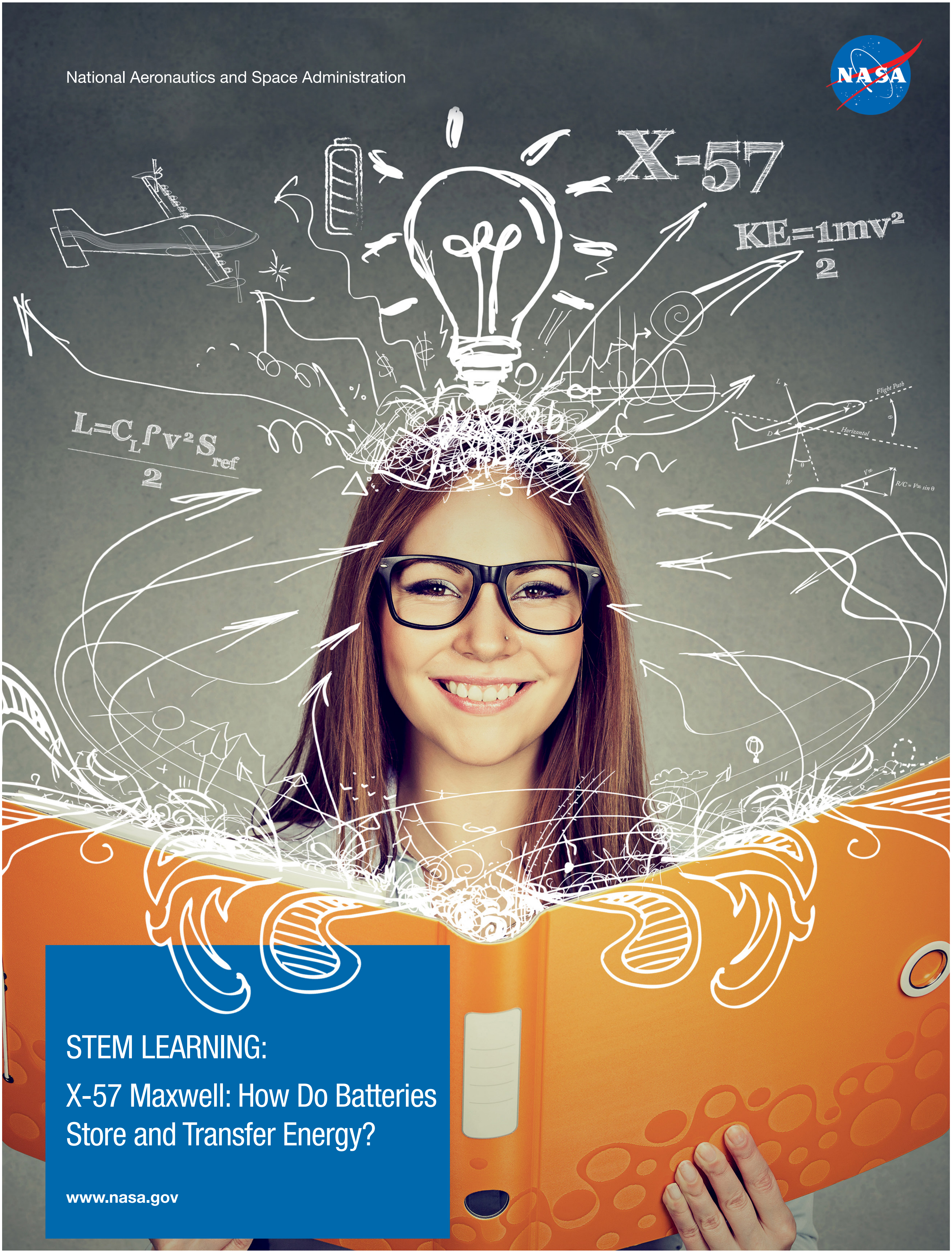

STEM LEARNING:

X-57 Maxwell: How Do Batteries Store and Transfer Energy?

www.nasa.gov

ACTIVITY OVERVIEW

In this activity, participants will build basic batteries from pennies and a salt/vinegar solution and test their batteries using LED lights and voltmeters. This activity provides foundational knowledge about batteries, which are used for NASA's X-57 Maxwell, an all-electric aircraft.

WHAT IS THE X-57?

NASA's X-57 Maxwell is a small, experimental aircraft powered completely by batteries. It is NASA's first full-sized all-electric experimental aircraft, or X-plane. Compared to standard fuel-powered airplanes, the X-57 is designed to have increased high-speed cruise efficiency, zero in-flight carbon emissions, and flight that is much quieter for the community on the ground.

One of the primary goals of the X-57 project is to develop all-electric technology that will make flying cleaner, quieter, and more sustainable. The technologies and verification and testing processes created for the X-57 will be an important part of future projects that work towards more sustainable aviation.

In order to generate enough lift for the X-57 to fly, it has 14 propellers, a large one on each wingtip and 6 smaller ones along each wing. To generate enough power for the 14 motors, as well as the control systems for the plane, the X-57 has two 400-pound packs of lithium-ion batteries.

Figure 1. This artist's rendering shows the X-57 in flight. Credit: NASA

HOW DOES A LITHIUM-ION BATTERY WORK?

Lithium-ion batteries are rechargeable batteries used in many different types of electronics. Like most batteries, they have a positive terminal called a cathode and a negative terminal called an anode. In lithium-ion batteries, the cathode is made of a form of a metal called lithium while the anode is made of a form of carbon. They are separated by a material called an electrolyte.

Atoms like lithium, are made up of positively charged protons, negatively charged electrons, and neutrally charged neutrons. If an atom has more protons than electrons, it is a positively charged ion. And, if it has more electrons than protons, it is a negatively charged ion.

When a lithium-ion battery is charged, electrons enter the battery and flow to the anode. This attracts positively charged ions which move though the electrolyte and are stored at the anode.

When the battery is used, electrons move from the anode to the cathode. They cannot go through the electrolyte, so they travel through whatever electrical circuit is attached to the battery. This provides power to the circuit. Once all the electrons have moved, the battery needs to be recharged.

Student Activity

Each group needs:

- 5-10 pennies made after 1982
- 100-grit sandpaper
- Mat board or cardboard
- Vinegar
- Salt
- High intensity red and blue LED lights
- Voltmeter
- Electrical Tape
- Scissors
- Paper Towel
- Mixing cup
- Paper towel

Each group will:

1. Fill a plastic mixing cup with a cup of water. Add 5 tablespoons of salt and stir until dissolved. Add 3 tablespoons of vinegar and then stir the solution until well mixed.
2. Cut the cardboard or mat board into 4 squares measuring approximately ½ inch on each side. Soak them thoroughly in the saltwater solution. Once they are fully soaked, take them out and set them on the paper towel. They will need to be damp but not dripping with liquid.
3. Each group will receive a stack of five pennies. Sand off the copper from one side of four of the pennies until all that is seen is the silver-colored zinc. An easy way to do this is to lay the sandpaper flat on the table, gritty side up, and energetically rub the tails-side of the pennies on the sandpaper. Remember to do this carefully so you don’t hurt your fingers. The goal is to have 4 pennies that are copper on one side and zinc on the other, and a fifth penny that is copper on both sides.
4. Start assembling the battery. Place a penny, copper side down, and then place the damp piece of cardboard or mat board on top of it. Repeat three times until all that is left is the unsanded penny. Place it on the top of the stack. Students will have a stack of pennies and damp cardboard with all copper sides facing down, all zinc sides facing up, except that the top penny will have copper on both sides. No pennies should touch, and no damp cardboard should touch.

5. Next, you will test your battery. Pick up the red LED and look at the leads (wires) coming out of it. One is longer than the other. Touch the longer lead to the top of the penny stack and the shorter lead to the bottom of the stack. Don't let the leads touch each other.

6. The LED should light up! If it doesn't, make sure all pennies are facing in the correct direction but not touching each other, and that the cardboards squares are damp but not dripping. Then try again. When the LED lights up, the battery is working. It sometimes takes a few minutes to reach maximum power.

7. How can you tell how much voltage your battery is producing? Take the voltmeter and touch its leads to the top and bottom of the coin battery. Record the measurement. Then use the electrical tape to attach the LED to the battery. You can watch as the light gets fainter over time, as the cardboard dries out. Take a second measurement if the LED is still lit after one day.

8. To recharge the battery, simply soak the cardboard squares in the liquid again and put the battery back together.

9. Want to try some variations on this activity? Try making the battery with more than 5 pennies. Try a liquid solution using other liquids like lemon-lime soft drink or mild hydrochloric acid. A blue LED requires more electricity. Try making a battery that will light up a blue LED.

Answer the following questions:

- Did the battery work with 5 pennies? If yes, what voltage did it read?
- How long did the battery stay lighted? What was the voltage on the second day?
- If students tried a different liquid, what was it, and did the LED light up?
- What was the voltage on the first and second reading? What conclusions can be drawn from this information?
- If the battery did not work, why?

10. Combine class data:
    - For the 5-penny battery, record the voltage reading for all groups.
    - Calculate the mean value (add together all values and divide by the number of values), median (middle) value and the mode (most frequent value).
    - Discuss your findings.
    - Was there a wide range of values?
    - Were the measurements similar?
    - Why do you think this occurred?
    - What could you do differently?

HOW DOES THIS WORK?

- Batteries are devices that convert chemical energy into electrical energy. When two different metals are connected by an electrolyte, a chemical reaction occurs at each metal surface that either releases or uses electrons. When these surfaces are connected by a wire, electrons will move from one surface to the other, creating an electric current.

- Pennies made after 1982 have zinc cores that are plated, or covered, with copper. By sanding off one face of a penny, you create a zinc electrode that can pair with the copper electrode on the face of the next penny. The cardboard soaked in salty vinegar water serves as the electrolyte between the two terminals.

- Each zinc-cardboard-copper stack represents one individual cell. By stacking additional pieces of cardboard and sanded pennies, you have created a battery, which is a series of electrochemical cells. This is also called a voltaic pile, which is named after Alessandro Volta, who created the first battery in 1800 by alternating zinc and copper electrodes with sulfuric acid between them.

- In Volta's battery and the penny battery, an oxidation reaction occurs at the zinc electrode that releases electrons, and a reduction reaction occurs at the copper electrode that uses them.

- With a voltmeter, you can see that each cell can generate over 0.6 volts. The penny battery you created for this stack has four cells. A stack of three cells should generate enough voltage to light a red LED, which usually requires around 1.7 volts.

ADDITIONAL RESOURCES

NASA XPLANE-ations: How to Build a Coin Battery video:
https://www.youtube.com/watch?v=7UrsO9QBFXA&list=PLiuUQ9asub3TogGec4FJsGaXWjeGK5Ff8&index=4

X-57 STEM Learning Module:
https://www.nasa.gov/aeroresearch/stem/X57

X-57 Mini Posters (in English and in Spanish):
https://www.nasa.gov/sites/default/files/atoms/files/x-57-litho-print-v4.pdf
https://www.nasa.gov/sites/default/files/atoms/files/corrected-color-x-57-litho-print-v5-spanish.pdf

X-57 Bookmark:
https://www.nasa.gov/sites/default/files/atoms/files/x-57-bookmark.pdf

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