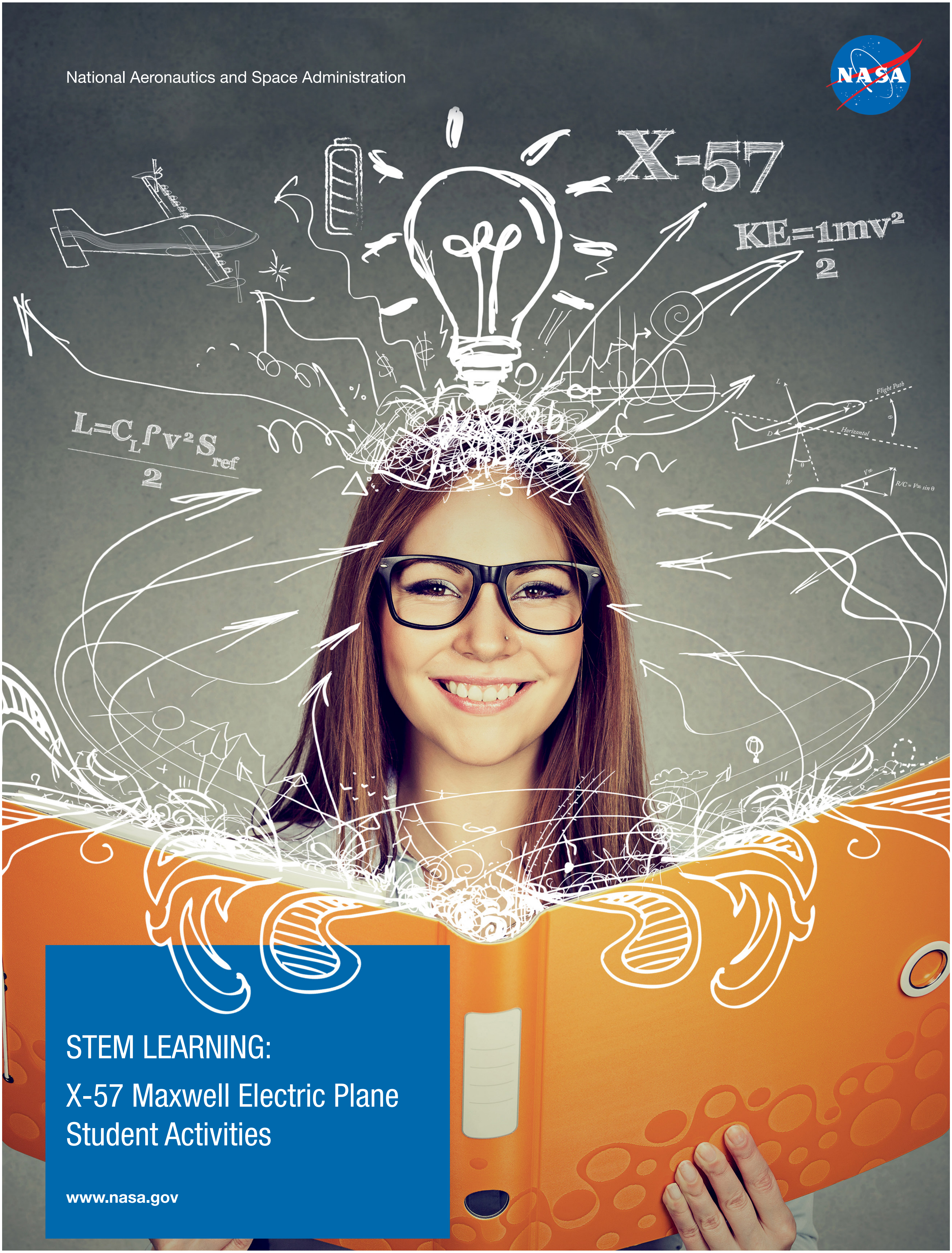
National Aeronautics and Space Administration



STEM LEARNING:

X-57 Maxwell Electric Plane Student Activities

www.nasa.gov

STEM LEARNING STUDENT ACTIVITIES: BE A NASA AERONAUTICS SCIENTIST!

Learn about NASA's X-plane, the X-57 Maxwell by watching NASA animations, completing hands-on activities, and completing digital challenges. The X-57 uses alternative energy and innovative design to fly without aviation fuel with wings that provide five time as much lift as expected.

START HERE!
About Electric Airplanes

What is NASA's new X-57 Maxwell plane?

Navigate the X-57 presentation. https://www.nasa.gov/specials/X57/index.html

Read carefully and take notes. Then answer these X-57 questions.

1. Why is NASA developing this technology?
2. What is unique about this aircraft?
3. Why is it called the Maxwell?
4. What are the two kinds of motors, and when are they used?
5. What kind of batteries will be used, and how are they tested?
6. How is the wing "tricked" into behaving as if it had a larger area?
7. What was the first real-world test of this technology?
8. What are the environmental benefits of this technology?
9. What is "thermal runaway?"
10. To increase the X-57's energy efficiency, the force we need to increase is _________, and the force we need to decrease is ___________.

START LEARNING ABOUT BATTERY POWER HERE!

NASA NOTES

The X-57 gets all the energy needed to power the airplane from batteries. NASA scientists researched many different kinds of batteries and many different arrangements of batteries to find a combination with enough long-lasting power. Now it's your turn!

Watch this animation about batteries.

https://www.youtube.com/watch?v=jgfceqwqUec&list=PLiuUQ9asub3TogGec4FJsGaXWjeGK5Ff8&index=2

Fill in the blanks.

All batteries convert ________________________ energy to ________________________ energy through a ______________________ reaction. When batteries are used to power an electrical device, the stored ________________________ energy is converted to ____________________. The X-57 Maxwell uses _____________________ - __________ batteries.

LESSON 1: BUILD A WORKING BATTERY

TASK

Build a basic battery from pennies and a salt/vinegar solution, and test battery voltage using LED lights and a voltmeter.

Coin Battery Lab Instructions

Watch this video demonstrating the coin battery lab instructions.

https://www.youtube.com/watch?v=7UrsO9QBFXA&index=3&list=PLiuUQ9asub3TogGec4FJsGaXWjeGK5Ff8

Any Questions?

The written directions are on page 5.

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 sanded penny copper side down, and then place a piece of damp cardboard 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.

10. **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 you 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? What did you do to try to improve its performance?

If your LED did not light up check the battery output with the voltmeter. What did it read?

11. **Answer the following questions:**
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?

BACKGROUND INFORMATION ABOUT BATTERIES (READ AFTER LAB)

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, called electrodes, that either releases or uses electrons. When these electrodes are connected by a wire, electrons will move from one surface to the other, creating an electric current.

Pennies that were made after 1982 have zinc cores that are plated 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 cardboards and sanded pennies, you've 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 they 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.

What's the Difference Between Batteries?

With a voltmeter, you can compare the storage capacity and battery life of different types of batteries. Each student group can test a set of different size batteries (AAA, AA, D, etc.- **DO NOT** use car or marine batteries). Predict how much voltage each battery will measure, and then take readings. Do this for several days, or over two different weeks, to see how batteries lose stored energy over time.

Another experiment would be to use the battery in a battery-operated device like a flashlight, and then see how much electrical charge was lost. Use your voltmeter to record before and after readings of a rechargeable battery to see if the battery is able to continue to hold the same charge over time.

Extension Questions:

Why did pennies change after 1982?

How did the appearance of the pennies change after using it? Why?

Why are batteries created in so many different sizes and shapes?

LESSON 2: HOVERBOARD BATTERIES—PORTABLE ELECTRIC POWER WITH EXPLORLABS

TASK

Explore how batteries store and release energy, and what causes thermal runaway in lithium ion batteries.

NASA NOTES

Since the X-57 gets all of its energy from electricity stored in batteries, it's important to understand how batteries work. Batteries are vulnerable to damage from temperature and pressure changes, impact (like being dropped) or punctures. NASA scientists needed to find batteries that are already commercially available, store large amounts of energy and are completely safe. Batteries that are currently on the market have a known history of operations, are built to fairly exact standards and are often cheaper that building new batteries.

When a large number of battery cells are used in combination, they are vulnerable to overheating, and can sometimes lead to fire or explosion. This phenomenon is called "thermal runaway." In the X-57, this meant packaging the batteries in specific materials and configurations so that overheating cells would be contained and the rest of the battery pack would be minimally affected. When a large number of battery cells are used in combination, they are vulnerable to overheating, and can sometimes lead to fire or explosion. This phenomenon is called "thermal runaway." In the X-57, this meant packaging the batteries in specific materials and configurations so that overheating cells would be contained and the rest of the battery pack would be minimally affected.

Since testing batteries for overheating and thermal runaway is not an activity that can be conducted safely outside of a specialized lab setting, an all-digital module was created by, and is presented with the consent of UL Xplorlabs. It focuses on how portable electric power works, how batteries can be tested, and engineering design for hover boards.

Once the digital testing is complete, investigators can select from one or more of three hands-on investigations. They also can enter into two innovation challenges to be posted on the Xplorlabs website!

Go to: https://ulxplorlabs.org/portable-electrical-power

Here is the direct link to the Teacher Guide.

LESSON 3: FOUR FORCES BERNOUILLI WATER GUNS AND WIND TUNNELS! LIVING IN A PHYSICAL WORLD

ACTIVITY 1

Understanding the Forces: Four stations with an activity for each of the forces.

https://www.nasa.gov/sites/default/files/atoms/files/four_forces_5_8.pdf

Learn about motions and forces, and transfer of energy as you explore the basics behind the four forces of flight. Witness the effects of gravity on a tennis ball, the thrust provided by an inflated balloon, the drag created by air resistance and the lift produced by your hands in a stream of air.

ACTIVITY 2

Using Bernoulli's Principle: math-oriented lesson

https://www.teachengineering.org/lessons/view/cub_bernoulli_lesson01

Bernoulli's principle relates the pressure of a fluid to its elevation and its speed. Bernoulli's equation can be used to approximate these parameters in water, air or any fluid that has very low viscosity. Learn about the relationships between the components of the Bernoulli equation through real-life engineering examples and practice problems.

ACTIVITY 3

A Shot Under Pressure: Using Super soaker-type devices

https://www.teachengineering.org/activities/view/cub_bernoulli_lesson01_activity1

Learn about projectile physics and fluid dynamics to find the water pressure in water guns. By measuring the range of the water jets, you can calculate the theoretical pressure. Create graphs to analyze how the predicted pressure relates to the number of times we pump the water gun before shooting.

ACTIVITY 4

Build and test a wind tunnel

http://tryengineering.org/lesson-plans/wind-tunnel-testing

Engineers in many industries use wind tunnel tests to aide in the development of products such as airplanes, cars, and even buildings. Build your own model car out of everyday products and test your design in a wind tunnel made of a fan blowing through a long cardboard box.

LESSON 4: TEAMWORK: HOW TO BE SUCCESSFUL WORKING IN A GROUP USING NASA EXPEDITIONARY SKILLS FOR LIFE

Expeditions are experiences made by people who share a definite purpose and specific experiences. Although the examples in the unit focus on space exploration, they are equally applicable to aeronautics missions, or any kind of group project that requires teamwork!

To make their expeditions successful, NASA works to prepare mission team members to work together during missions. These same skills are useful in all team activities. *This module was developed in cooperation with 4-H, USDA, and the National Institute of Food and Agriculture.*

As you learn about X-57 and battery power, learn skills to make your groupwork a success by completing all four expeditionary skills nodules.

These skills are organized in four main categories:

1. **Self-Care/Team Care: Preparing for the Voyage**

   "Before you can contribute to a team, you must first be able to take responsibility for yourself. This ability includes being mentally, physically and emotionally ready to go on the voyage. Everyone has the occasional difficult day, so knowing how to support your team members is also important. This section will strengthen your ability to care for yourself and your team."

2. **Cultural Competency: Embarking on Pilgrimages**

   "Pilgrimages are searches that help people understand their personal beliefs and recognize how and why they have those beliefs. The activities in this section take you beyond your own beliefs and teach you how to understand, appreciate and value the beliefs of others. Only in creating paths that allow the team to work together can you move forward in your expeditions."

3. **Leadership/Followship: The Challenge of the Quest**

   "Lots of people like to be the leader, but leaders need a team to follow them. Different quests require different skills, which means different types of leaders are needed throughout an expedition. Understanding when to lead and when to follow, and the importance of both roles, will be explored in this section."

4. **Teamwork Communication: Launching into Orbit**

   "This section takes everything you've learned and puts it into action. To launch your expedition into orbit, everyone on the team needs to do their part. Of course, that begins with knowing what each person's part is, making sure team members are ready to perform their part and that they get it done, and dealing with any unexpected challenges that develop along the way. Launching an expedition, like teamwork, takes practice and patience."

Student Activity Wrap Up:

1. Return to the unanswered questions poster and discuss what is now known and still unknown. Record what you Learned on the K-W-L poster.
2. Retake the X-57 quiz
3. Identify any new questions or area that students would like to follow up on. Students can visit https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-109.html for the X-57 Fact Sheet.
4. Reflect on what you learned as you completed these activities. Write a one-page summary of your learning experiences.
5. Want to know more about NASA Aeronautics? Check in at www.nasa.gov/aeroresearch and what NASA Aeronautics is working on!

National Aeronautics and Space Administration

Headquarters
300 E. Street, SW
Washington, DC 20546

www.nasa.gov

NP-2018-07-2604 HQ