STEM in the lab

Inspiring Idaho's future STEM workforce

POWERING PERSEVERANCE

GRADE LEVELS

This activity is appropriate for grades 3-5.

MISSION

Build your own MMRTG.

VOCABULARY

ENCAPSULATED: to enclose in or as if in a capsule.

INSULATOR: a substance which does not readily allow the passage of heat or sound.

IRIDIUM: a chemical element with the symbol Ir and atomic number 77. A very hard, brittle, silvery-white transition metal of the platinum group, iridium is considered to be the second-densest metal.

PLUTONIUM: radioactive chemical element with the symbol Pu and atomic number 94. It is an actinide metal of silvery-gray appearance that tarnishes when exposed to air and forms a dull coating when oxidized.

MATERIALS

- 1 black crayon
- 1 red crayon
- 1 white crayon
- Ruler
- Inner/outer cardboard tubes
- Glue
- Scissors
- Plastic gloves
- 2-4 x 6 index cards

ABOUT THIS ACTIVITY

Idaho National Laboratory's Space Nuclear Power and Isotope Technologies Division assembles and tests Radioisotope Power Systems. What they make is then delivered for use in remote, harsh environments, such as space. INL recently assembled, tested, and delivered to Kennedy Space Center, the Multi Mission Radioisotope Thermoelectric Generator (MMRTG). The MMRTG will power NASA's Mars Perseverance Rover.

The MMRTG's are ideal for space missions because they are compact, durable, and reliable. They provide continuous power over long periods of time. The MMRTG will power Perseverance's movement, instruments and help keep it warm while exploring the chilly Red Planet. RTG's are devices that turn the heat from the decay of radioactive Plutonium 238 directly into electricity. In this activity, you will use the supplies provided to build your own MMRTG.

INSTRUCTIONS

PREP WORK

Gather your supplies and materials. Learn about INL's role in NASA's Mars Perseverance Rover: Watch Prepping the Perseverance Fuel Source.

SAFETY MEASURES

Scientists working with nuclear material have to do so in a very protective environment called a glove box. Radiation protection is the science and practice of protecting people and the environment from the harmful effects of ionizing radiation. For the same reason we need to be careful around open flames, toxic chemicals, or knives, we also need to be careful and respect radiation. Radiation protection uses three ways to protect people from identified radiation sources-shielding, distance, and limited time. All three ways are used daily at Idaho National Laboratory. Safety is the number one priority because there are many different types of research projects that are being done at Idaho National Laboratory.

For this engineering design process activity, we will practice being safe by wearing the gloves that are in your kit. Find them and put them on. With your gloves on, remove the inner cardboard tube from the outer tube. In the video, experts placed fueled clads into a graphite housing called a general purpose heat source. The General Purpose Heat Source module, or GPHS, is the essential building block for the radioisotope generators used by NASA. These modules contain and protect the plutonium-238 (or Pu-238) fuel that gives off heat for producing electricity. The inner cardboard tube represents the GPHS. The fuel is made of ceramic pellets of plutonium-238 dioxide (238PuO2) and encapsulated in a protective casing of iridium, forming a fueled clad. The red crayons represent the Plutonium fueled clads. As we learned from the video, four fueled clads go into each heat source.

INSTRUCTIONS

1. Using a ruler, measure 3/4 of an inch from the flat end of the black crayon. Place a mark at this point. From that point measure another 3/4 (1 ½) and place another mark. Using your scissors, cut the black crayon at the 3/4 and 1 ½ marks. Then glue one of the black crayon pieces in the end of the inner cardboard tube. This black crayon represents the end cap that will keep the fueled clads from falling out. Save the second black crayon piece for later. Place the rest of the crayon off to the side.

2. Using a ruler measure ¾ of inch from the end of the red crayon. Place a mark at this point. Then measure another ¾ (1 ½) and place another mark, measure another ¾ (2 ¼) and make a mark, measure another ¾ (3) and make a mark. Using your scissors, cut the red crayon at the ¾, 1 ½, 2 ¼, and 3-inch marks. You should have four red crayon pieces that are each ¾ inch long.

3. Put one of the fueled clads (red crayon) in the inner tube.

4. Using a ruler, measure ½ from the end of the white crayon, place a mark at this point, from that point measure another ½ (1 inch), make a mark, from that point measure another ½ (1 ½ inch), make another mark. Then cut each of the pieces. You should have 3 white pieces that are ½ inch long.

5. Place one insulator (white crayon) into the inner cardboard tube. The white crayon acts as an insulator to regulate the heat source.

6. Finish filling the inner cardboard tube, next put in a red crayon, then white crayons, then a red crayon, white crayon, then the last red crayon.

7. When all the crayons are in the tube, install the other black crayon. Glue it in as the final end cap.

8. The complete pattern is BRWRWRWRB, where B is black crayon, W is white crayon, and R is red crayon.

9. Even though we learned that the RTG requires 8 general purpose heat sources, for our example we are going to only have 1 general purpose heat source.

10. Fold the 4x6 index cards in half on the long edge (hotdog style). Cut on the fold, so that there are 2 pieces. Then fold each of the 2 pieces in half on the long edge again. Cut on the fold of these pieces. Now there are 4 long, skinny pieces. Follow these directions for the other card. So that we can glue the index cards onto the outer cardboard tube, fold up the bottoms of the cards. Evenly place the fins around the outer cardboard tube. Once they are evenly spaced, place glue on the bottom of the fin and attach it to the cardboard tube.

11. Once the fins are dry, carefully place glue around the GPHS (inner cardboard tube) and place it into the RTG (outer cardboard tube).

12. The RTG is now ready to be attached to a Mars Rover and provide the power needed for the rover to explore the surface of Mars.

Nice work engineers! Now let's learn the nuclear science behind the space batteries to understand how they generate electricity for the Mars Rover, Perseverance.

THE SCIENCE BEHIND IT

MMRTGs work by converting heat from the natural decay of radioisotope materials into electricity. The generators consist of two major elements: a heat source that contains Plutonium 238 and thermocouples that convert the plutonium's decay heat energy and the cold of space into electricity. The MMRTG is designed to produce about 110 watts of electrical power. This is about how much power is needed to run a computer. The system has a design life of 17 years, but can be expected to produce power much long than that.

EXTENSIONS

- Build a rover. Then attach your RTG to the rover to provide the energy needed to explore. https://inl.gov/wp-content/uploads/2019/12/Roving-on-the-Moon-Lesson-Plan.pdf
- Learn more about the three ways to protect people from radiation sources. Purchase UV beads-use them to demonstrate the following:
- **Limiting Time.** The amount of radiation exposure depends directly on the time people spend near the source of radiation. The dose can be reduced by limiting exposure time. Take the UV beads outside. Time how long it takes for the beads to change color when they are directly exposed to the sun. What could you do to limit the exposure of the beads to the sun?
- **Distance:** The amount of radiation exposure depends on the distance from the source of radiation. Similarly to a heat from a fire, if you are too close, the intensity of heat radiation is high and you can get burned. If you are at the right distance, you can withstand being there without any problems. Since the sun is so far away, this is harder one to test. To test out distance use a black light or a UV nail light. Place the beads at various distances from the UV or black light.

» **Shielding.** Radiation shielding simply means having some material between the source of radiation and you (or some device) that will absorb the radiation. If the source is too intensive and the time or distance does not provide sufficient radiation protection, shielding must be used. Radiation shielding usually consist of barriers of lead, concrete or water. Place different transparent filters between a UV light source and the beads. Try sunglasses, water, sunscreen or a UV absorbing window film. You will find that the front windshield of most automobiles absorbs UV radiation. Usually the side windows do not have this built-in protection.

» **Shielding #2:** Are hats are an effective method of protection from ultraviolet rays? Find a few of your favorite hats. What criteria for judging can you make to decide which hat will give the best protection from UV rays. Put the UV beads on the ground and cover the beads with the different hats. The test can be performed on an overcast/cloudy day, a sunny day or both.

RESOURCES

» **Beginner's Guide to Rockets**
https://www.nasa.gov/stem-ed-resources/beginners-guide-to-rockets.html

» **Rocket Fun Facts**
https://www.ulalaunch.com/explore/rocket-science/fun-facts

» **NASA Knows! What is a Rocket?**
https://www.nasa.gov/audience/forstudents/k-4/stories/nasa-knows/what-is-a-rocket-k4.html

» **Propulsion with Foam Rockets**
https://nextgenstem.battelle.org/propulsion-with-foam-rockets

» **Build a Foam Rocket**
https://https/www.jpl.nasa.gov/edu/teach/activity/foam-rocket/

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