Girls of Energy

Come explore, learn, and change our world.

Table of Contents

Girls of Energy

Hi!

The world of energy is a beautiful place, brimming with cutting-edge innovations and brilliant minds. The only thing missing is YOU!

For decades, women educated in science, technology, engineering, and math (STEM) have been making a HUGE difference in our country. Like you, these women come from diverse backgrounds and have unique interests. . . and we LOVE them for that! Also like you, these women are passionate about improving the world around them. Their diversity of thought and experience have afforded us an opportunity to take advantage of innovative science and energy technology solutions.

To keep this movement going, now we need YOU! Who knows? You could be the one to make the next big scientific discovery to help all of humanity. So as you read this book, remember...

Be fearless.
Be creative.
Be empowered!

Let's get STARTED!

This is just a taste of what's to come. WANT MORE? Visit **energy.gov/girlsofenergy** to:

- Download our new ebook
- Explore exciting activities
- Meet our amazing scientists

Dear Educator and Student,

Girls of Energy is designed to ignite curiosity and engage young minds across the globe, and we are thrilled to bring it to you. It showcases exceptional women who are conquering today's energy challenges and creating tomorrow's technology solutions.

Comprised of lesson plans, activities, and an engaging website, **Girls of Energy** highlights the importance of energy and how it improves the lives of our friends, neighbors, and family members. Exploring the cutting-edge energy research and technology being developed at the U.S. Department of Energy's National Laboratories, **Girls of Energy** allows young women to see just how amazing a STEM career can be.

Our nation's economy and security depend on the next generation of Energy leaders. Simply put, STEM professions help every American, as well as our global community. Therefore, it is paramount that teachers earnestly expose young people of all backgrounds to STEM disciplines. **Girls of Energy** is a rallying cry for young women of all ages, demonstrating emphatically that they have a place in STEM and Energy fields.

We are committed to spearheading diversity in STEM education. As we prepare for a more technologically advanced world and to ensure America's leadership in creativity and innovation remains unquestioned, the Girls of Energy must be a priority for all.

U.S. Department of Energy
Office of Economic Impact and Diversity
energy.gov/girlsofenergy

MINORITIES IN ENERGY INITIATIVE
U.S. DEPARTMENT OF ENERGY

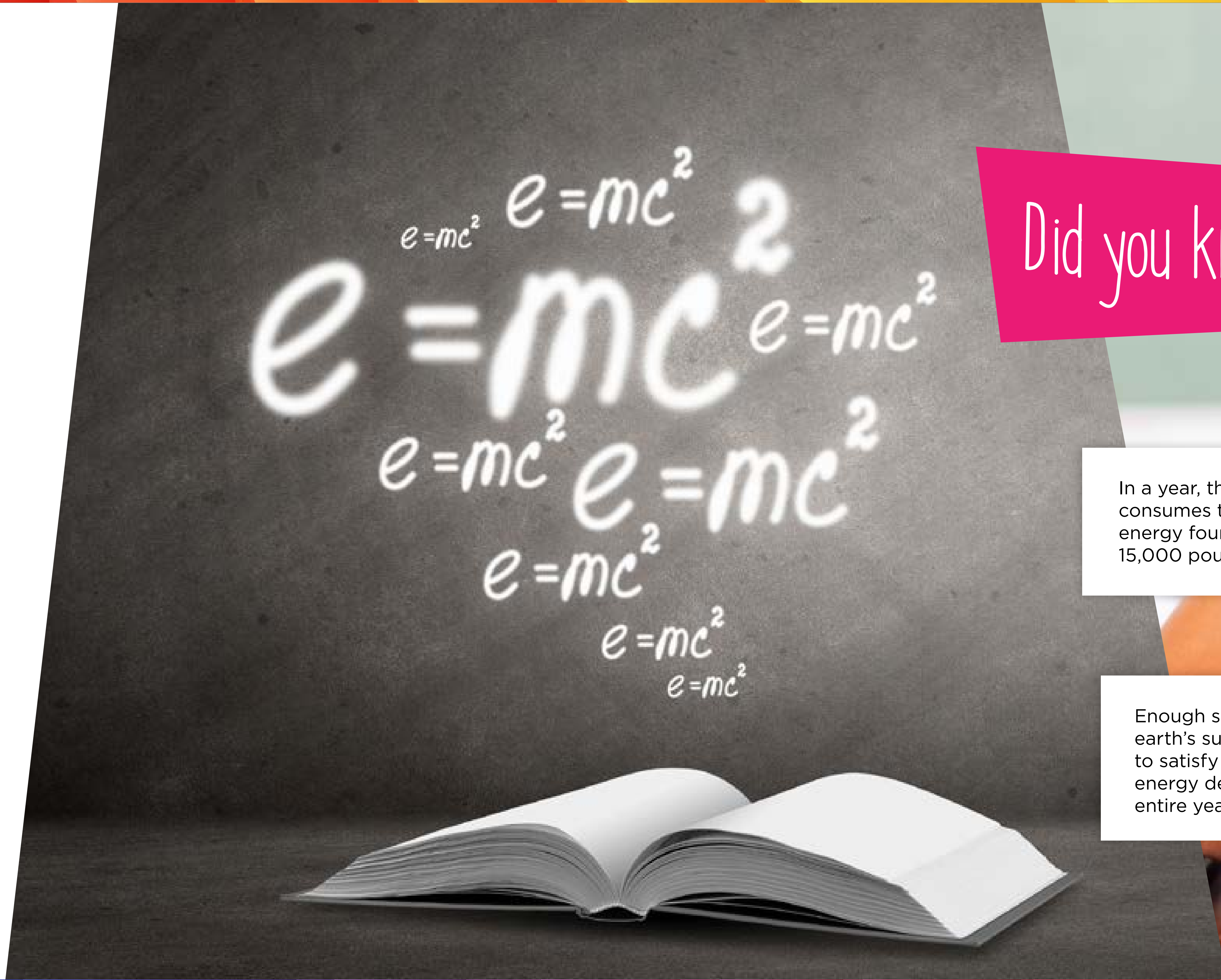
Know who you are!
Be who you are!
Bring who you are!

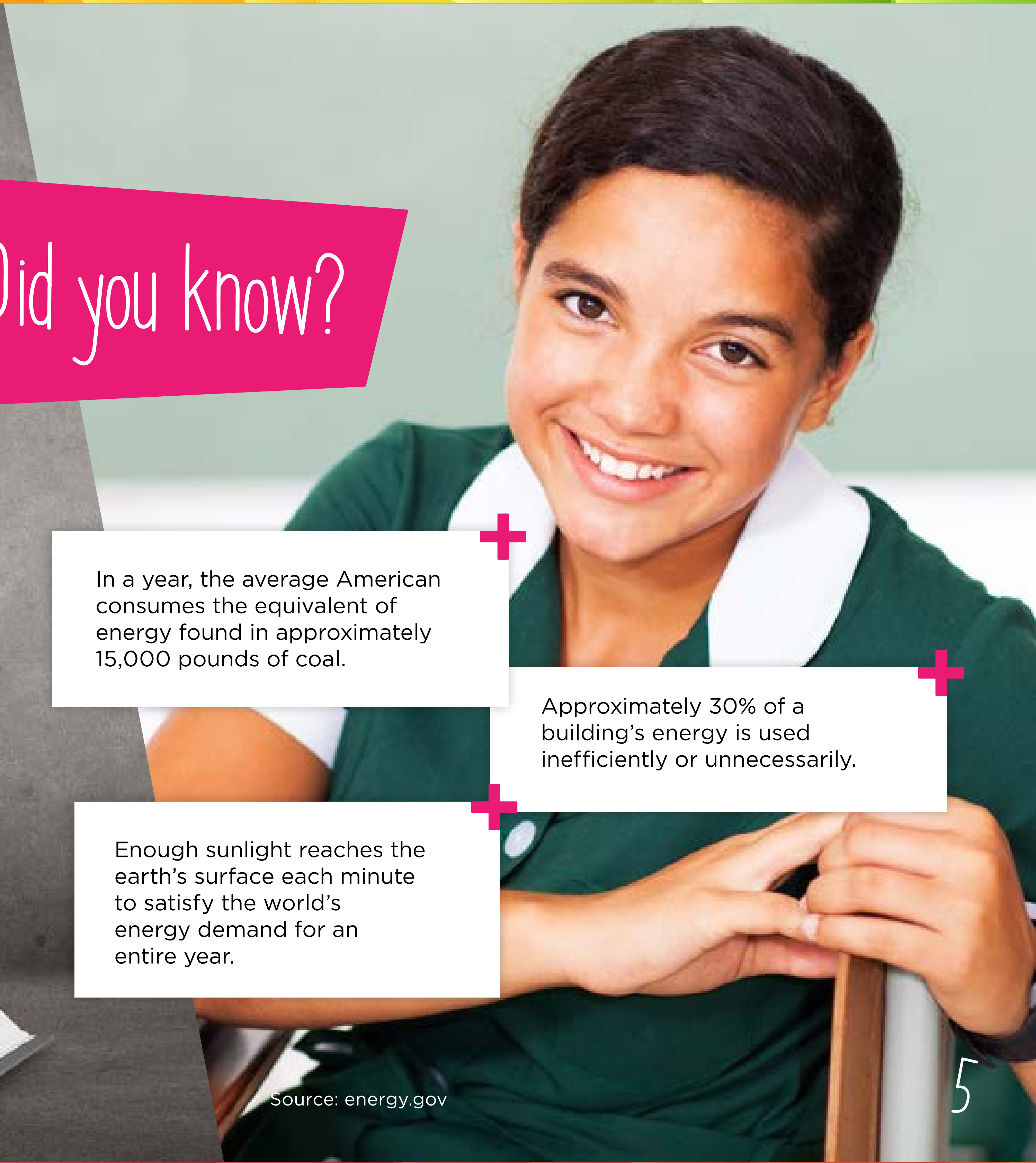
Importance of Energy

Energy is a part of everything you do and plays an important role in everyday life! Powering our homes, schools, and hospitals are just a few ways energy is used. When you plug in your phone or turn on your television, have you ever thought about where that energy comes from?

Some energy comes from burning oil, coal, and natural gas from the earth. Light from the sun, energy from plants, gusts of wind, and water are used to generate sustainable sources of power. There is also nuclear energy that uses the energy stored in atoms. No matter the source, energy is eventually converted to electricity.

Through their endeavors in world-class science and engineering, the U.S. Department of Energy ensures our nation's security and prosperity. Today, the U.S. Department of Energy's goal is to transform our nation's energy system and lead the world in clean energy technologies.





Did you know?

In a year, the average American consumes the equivalent of energy found in approximately 15,000 pounds of coal.

Approximately 30% of a building's energy is used inefficiently or unnecessarily.

Enough sunlight reaches the earth's surface each minute to satisfy the world's energy demand for an entire year.

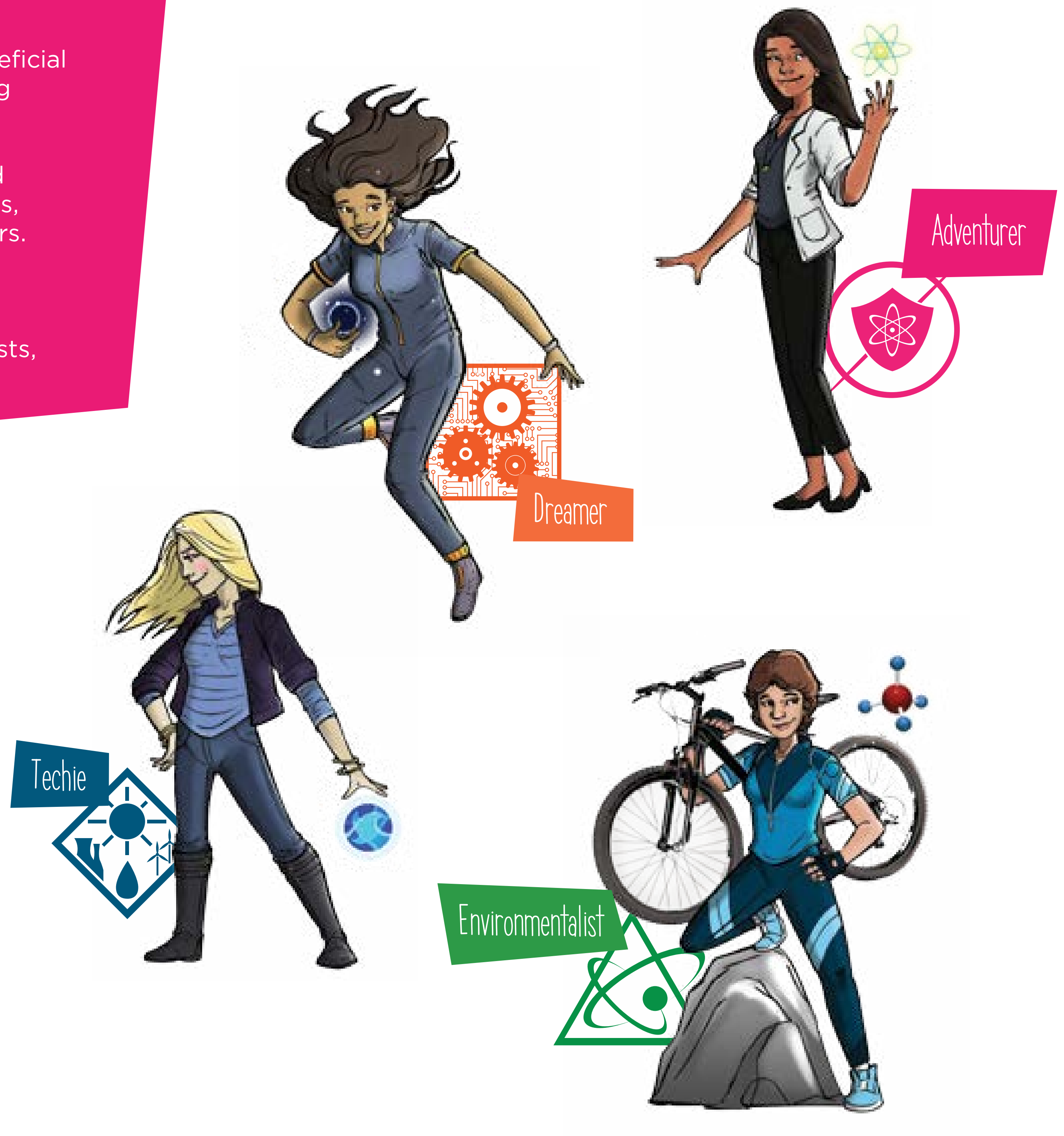
Source: energy.gov

Energy Challenges

The world is changing. An energy revolution is taking place across the globe! Scientists and engineers are working towards finding solutions to the world's four biggest energy challenges. They are discovering cleaner and more sustainable power sources, maximizing the efficiency of energy, maintaining energy safety and security, and creating innovative technology to meet the growing energy demand.

Everyone's creativity and ideas can contribute in a tremendous and beneficial way. Scientists who focus on solving these four energy challenges come from different backgrounds, with different interests, skills, talents and personalities. Some are adventurers, animal lovers, artists, or astronomers. Others are athletes, book lovers, dancers, dreamers, engineers, environmentalists, fashionistas, mathematicians, musicians, scientists, and techies.

As you learn about the four energy challenges, we encourage you to realize how your individuality and uniqueness can play an important role in the future of our planet. Which of the qualities do you identify with?



Girls of Energy

Power Sources

We have energy challenges that require us to think cleverly about power sources we currently use and those we must incorporate in the future. This means we should prioritize using more renewable (or clean) energy. Nature has an abundance of it: the sun rises, the wind blows, and rivers low.

The U.S. Department of Energy depends on scientists and engineers who are passionately working to improve existing energy sources and discover new ones. They go to work just like everybody else; but as part of their jobs, they get to be energy pioneers who think of things that have never been thought of before. Their work takes them wherever they are needed, from helping millions in big cities to providing access to solar panels for people in remote communities.

THE TECHIE

Researchers in the Los Alamos and Sandia National Laboratories are widening research opportunities for tracking stem cell evolution, trying to understand how spiders vary the quality of the silk they spin, and even transforming everyday windows into solar panels.

"Humans are allergic to change. They love to say, "We've always done it this way." I try to fight that. That's why I have a clock on my wall that runs counter-clockwise."

Grace Murray Hopper

Hopper was recruited by Harvard in 1943 to work on the first computer in the United States. She built the first compiler to translate mathematical notion into machine code.

Images on the left/right: STEM professionals at the U.S. Department of Energy

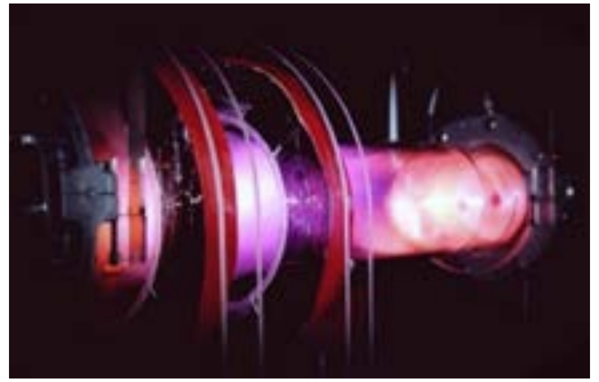
POWER SOURCES CHALLENGE

HOW CAN YOU MAKE A PLASMA BALL?

Summary: What is plasma? When you think of plasma, where do you think you can find it? How does plasma relate to energy?

How cool would it be if you could make your own plasma ball from the comfort of your home or school?! Princeton Plasma Physics Laboratory (PPPL), a Department of Energy National Laboratory, has devised a way for students of all ages to experience plasma physics—all you need is a computer with internet access. The Remote Glow Discharge Experiment (RGDX) allows remote access and control of the entire experiment including the gas pressure inside the tube, the voltage produced by the power supply that makes the plasma, and the strength of an electromagnet surrounding the plasma.

Did you know that plasma is used to make magnetic fusion energy? Get excited to learn more about how you can actually make your own plasma!



Background: The Department of Energy (DOE) has 17 National Laboratories across the United States, including the PPPL. The RGDX was developed as a way to fill a tremendous gap in online science education, allowing students anywhere in the world to participate in a plasma lab experiment. This development offers a unique opportunity to bring the laboratory to the students. Students can manipulate the three variables that control the creation of the plasma and then watch as the plasma product streams online. This allows students to witness how the changes in conditions of each of the variables changes the product in the glass tube. (https://pppl.princeton.edu/RGDX)

Learning Objectives - After this activity, students should be able to:

- Name and describe the four phases of matter;
- Demonstrate, using magnets, opposite charge attraction and repulsion;
- Participate in a virtual online laboratory experiment creating plasma;
- Understand how gas pressure, electrode voltage and electromagnets affect the physics of plasmas

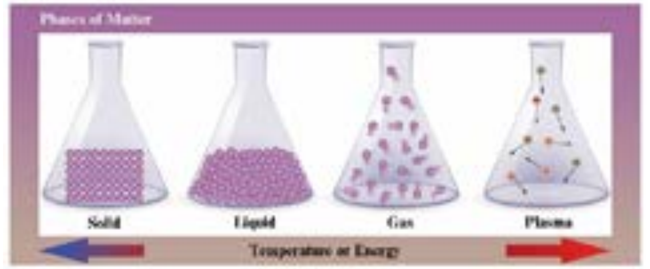
Introduction: The four physical states of matter are solid, liquid, gas, and plasma; a substance can transform its state with an increase in energy.

Solids
- Solids have the lowest energy and are arranged in a regular, repeating pattern with vibrational movement.
- Solids have a definite shape and a definite volume.

Liquids
- Liquids have a definite volume and an indefinite shape.
- Liquids have attractive forces between them that allow them to flow past one another.

Gases
- Gas atoms and molecules (neutral substances) gain enough energy to break free of the attractive forces between them
- Gases have an indefinite shape and an indefinite volume.

Plasma
- Plasma is formed as the energy increases in gaseous atoms to the point of stripping electrons from the neutral gases, and the hot, charged gas becomes a plasma.



- Plasma is produced naturally in the stars and the sun where there is intense heat and a large density enabling fusion reactions to occur.
  - Magnetic nuclear fusion is a clean and abundant energy alternative used to generate electricity.
- In order to create plasma, you must have gases with enough energy, movement of electrons, and a force that enables them to come in close contact with one another.

In order to make the plasma in the virtual experiment, there are three variables that you can control: gas pressure, voltage and electromagnets. We will examine each of the variables before you begin the experiment.

Pressure: Gas pressure is measured as force per unit area. The gas molecules collide with one another and the walls of the container. If you think about pressure in your bicycle tires, what happens when they go flat? You need to add more air and thus more pressure to fill them back to normal. Since temperature is a measure of the average kinetic energy of the molecules, how is gas pressure affected by an increase in temperature? When it gets cold and you leave your bicycle outside, how do the tires feel when you first start to ride your bike?

The air we breathe is actually a mixture of gases, but nitrogen gas (N_2) is the most abundant. What other gases might be in the air? The gas used to create plasma in the RGDX is air comprised of nitrogen, oxygen, carbon dioxide and other small amounts of different gases.

By manipulating the controls of the RGDX, you can increase the amount of gas pressure in the tube. How do you think this might affect the creation of plasma?

You can learn more about gas pressure and how it is measured by using the "Gas Pressure Realities" power-up activity.

Voltage: A positively-charged substance (+) and a negatively- charged (-) substance are attracted to one another. This attraction, due to the difference in charge, is called electrostatic attraction. You can explore this attraction the "Smacking Electrons" power-up activity.

At the end of the glass tube are two metal plates called electrodes. Electrodes make contact with a nonmetallic part of a circuit. The higher the voltage, the more opportunity there can be for the electrons to be stripped from the neutral gas and the gas now becomes plasma.

If you look at the power outlet in your home or school, you might see the value 110v or 120v.Voltage is measured in volts (v) and these two amounts are the most common for household electrical outlets. When you go outside and look at the power lines that provide electricity to homes and businesses, keep in mind that those lines provide 1000 times more voltage than your normal outlet. The voltage for power lines start at 110,000v or 110 kilovolts (kv).

Electromagnets: Electromagnets are used to create a magnetic field inside of the glass tube. A magnetic field helps align charged particles and keep them in closer proximity to one another. How do you think the electromagnets will change what you see inside of the tube?

You can feel the force of magnets by experimenting with individual magnets. How are they attracted and repulsed? What types of things are magnets attracted to?

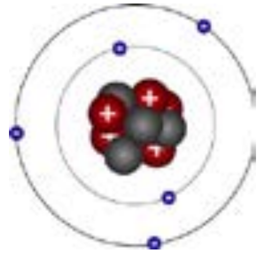
Materials Needed for an Activity:

- Computer with internet access
- Notebook for making predictions and testing hypotheses.

Now that you are a little more familiar with how you will interact with this website, go to the Remote Glow Discharge Experiment (RGDX) http://scied-web.pppl.gov/rgdx/ and click on the "What is Plasma?" tab. This tab contains information about the structure of an atom and how plasma is made.

The following information is provided by PPPL RGDX website (1).

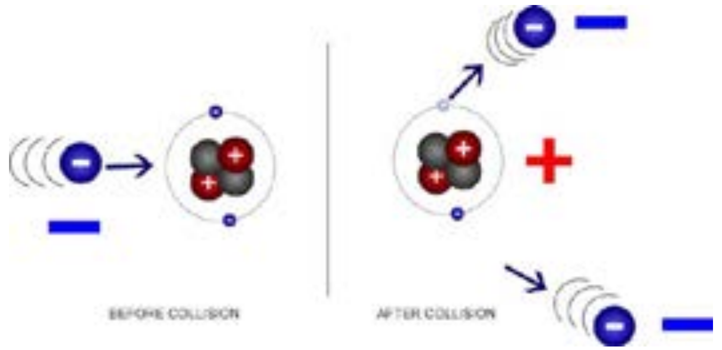
What is Plasma?



All matter is made out of atoms which are composed of a nucleus and electrons. The nucleus has protons and neutrons. Around the nucleus, are the electrons.

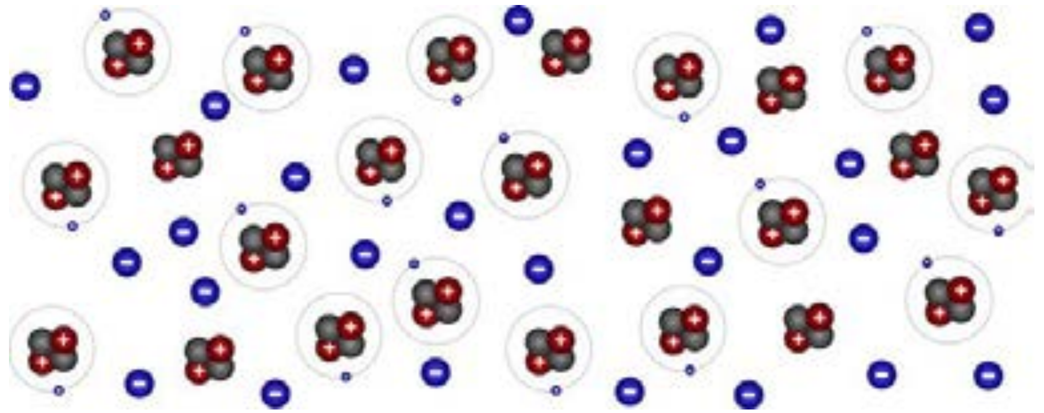
The **protons** are charged POSITIVELY, the **electrons** are charged NEGATIVELY and the **neutrons** are neutral. Most of the matter around us, solids, liquids and gases, are made out of neutral atoms and molecules (collection of atoms), that is, there are the SAME number of protons and electrons.

If for some reason, like collisions with a fast electron, an atom ejects an electron, then the neutral atom will now be POSITIVE and the free electron is NEGATIVE (for simplicity, we'll use Helium (He) atom, with 2 protons, 2 neutrons, 2 electrons, as the gas. Helium is very commonly used in laboratory plasma experiments):



The positively charged atom is called an ION. The more electrons are ejected, the more positively charged it is. This process is called **ionization**.

Plasma is the state of matter made out of ionized atoms (i.e. ions) and free electrons:



Since the particles need to be energetic enough to undergo ionizing collisions, and energetic particles simply means that they're hot, plasma is the hottest of the 4 states of matter.

While most of the matter we come in contact with is solid, liquid, or gas, the visible universe is more than 99% plasma.

Here are some examples of plasmas:

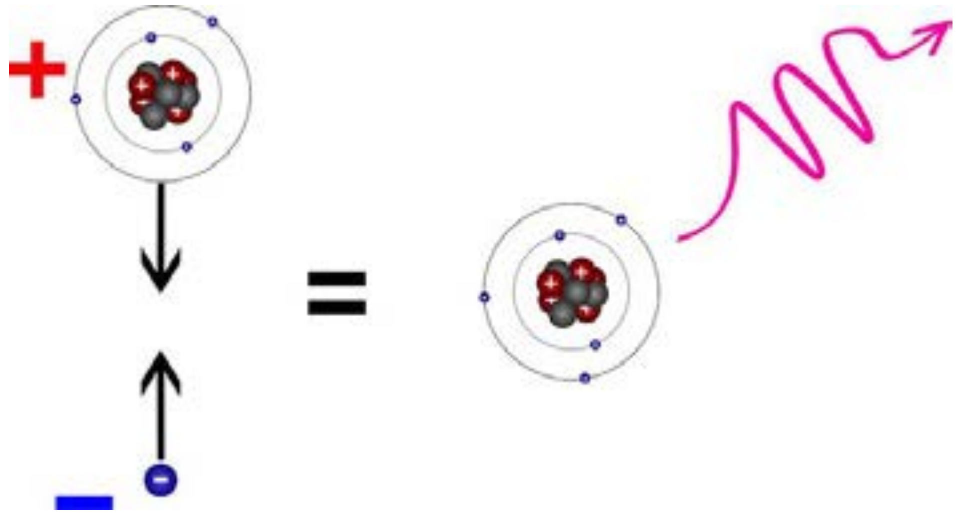
Next, click on the tab that states "Why does a plasma glow?" This illustrated page will help you understand how light is given off when the electrons move to a lower energy level. Remember the 1st Law of Thermodynamics states that energy cannot be created or destroyed, but it can change form. Energy can be given off in the form of light when an electron moves from a higher energy level to a lower energy level.

The following information is provided by PPPL RGDX website (1):

Why does the plasma glow?

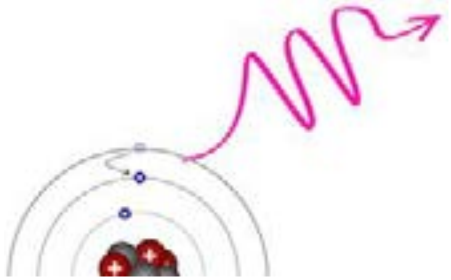
From the "What is Plasma?" page, we saw that the glow is actually plasma, a lot of positively charged ions and negatively charged electrons held at high temperatures.

Sometimes (very often), the electrons RECOMBINE with the ions:

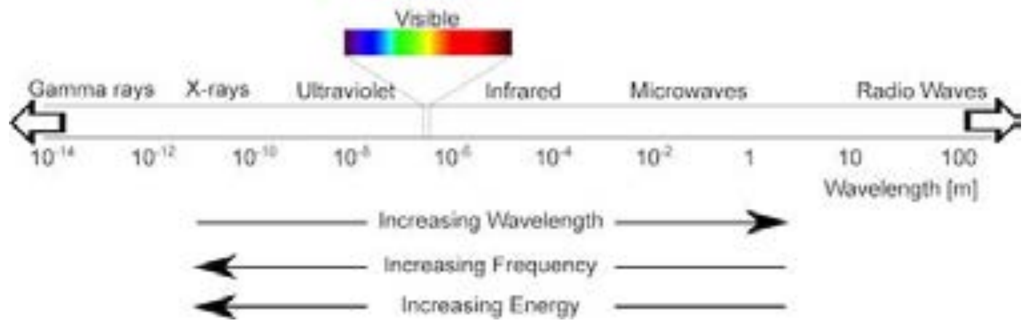


The recombination leads to a neutral (or less ionized) atom. But, in order to conserve energy, the atom releases a photon, which is just light.

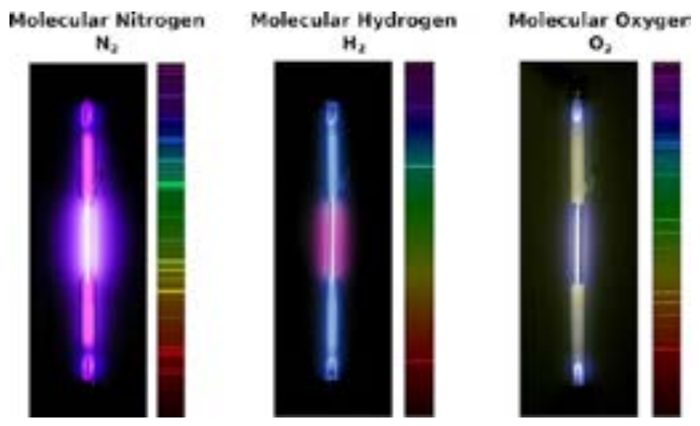
Another way light is emitted is when an electron is at a high energy level (that is, further away from the nucleus) and then transitions to a more favorable, lower energy level:



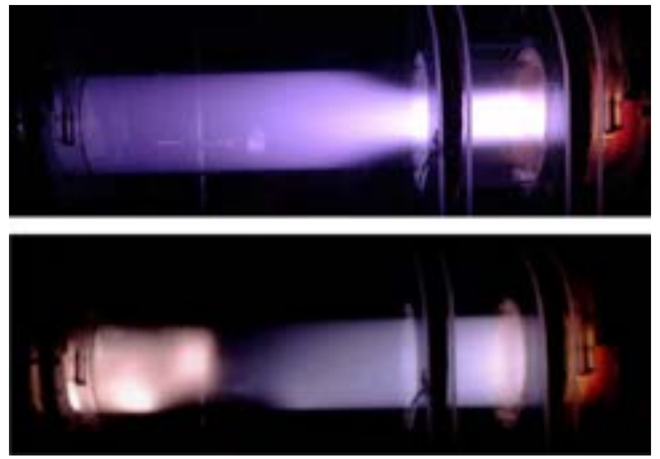
The higher the drop the more energy the photon has to have. The energy of the photon determines its color:



Since each atom and molecule has its own preferred transitions (given by their electronic configuration), each one has an emission fingerprint. You can see a few examples on the right.



Because air is mostly composed of N_2 (nitrogen), O_2 (oxygen) and water vapor, the spectra shown above are the main ones observed in the RGDX, primarily the N_2, as seen here on the right.

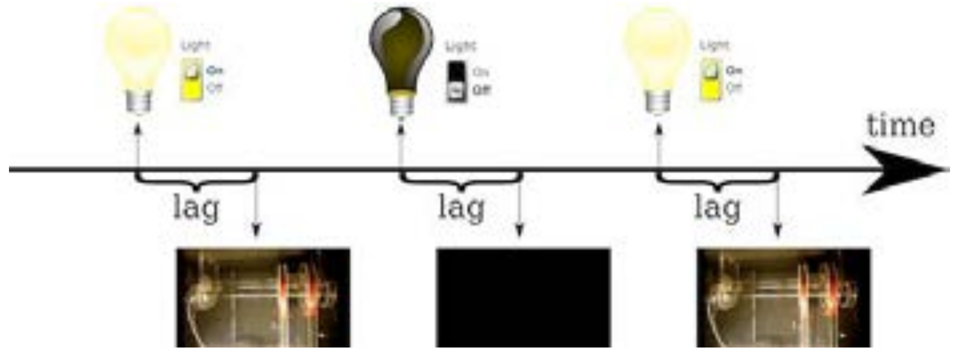


Now you are ready to make the Plasma GLOW! You will proceed to the tab that states "How do I make it Glow?" Read the important information about lag time and settings.

The following information is provided by PPPL RGDX (1):

How can I make it glow?

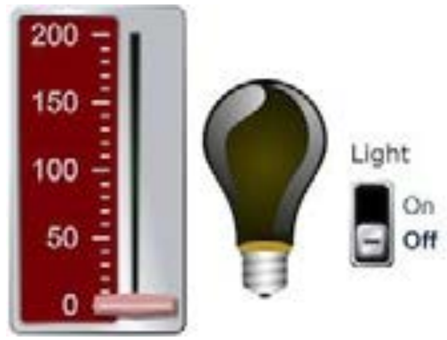
Before we begin, get a feel for the lag time: the video streaming has a few seconds of lag time which you should take into account. By turning the auxiliary light on and off and observing the streaming, you can get a feel for this lag.



If the lag is too long (more than 4 seconds) reload the page. While it may take a little time to get used to this lag, it will not be too much of a problem for the RGDX experience.

To start out, let's make it glow:

Make sure the electromagnet is set to 0 Gauss and the auxiliary light is turned off



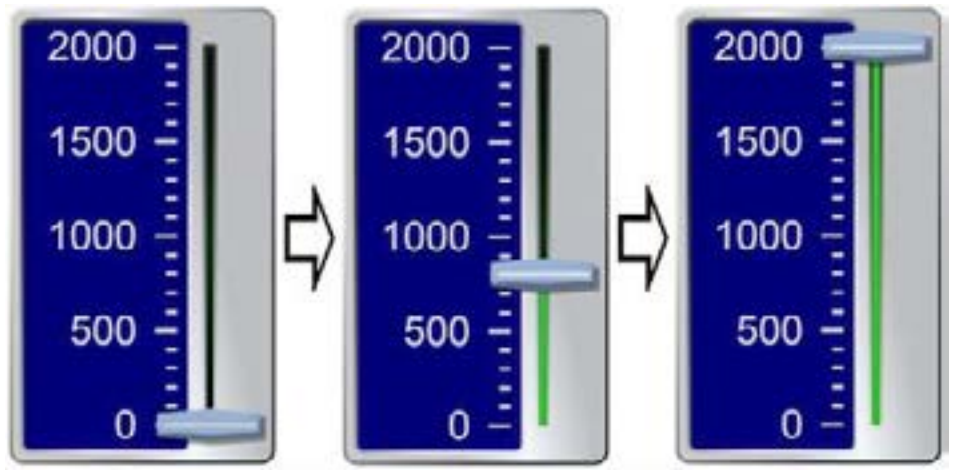
Set the pressure in the tube to about 40mTorr (if not already set)

Wait a few seconds for the pressure to stabilize (between 30mTorr and 50mTorr is fine)

Turn up the voltage between the electrodes

At approximately 800V, a glow discharge will appear.

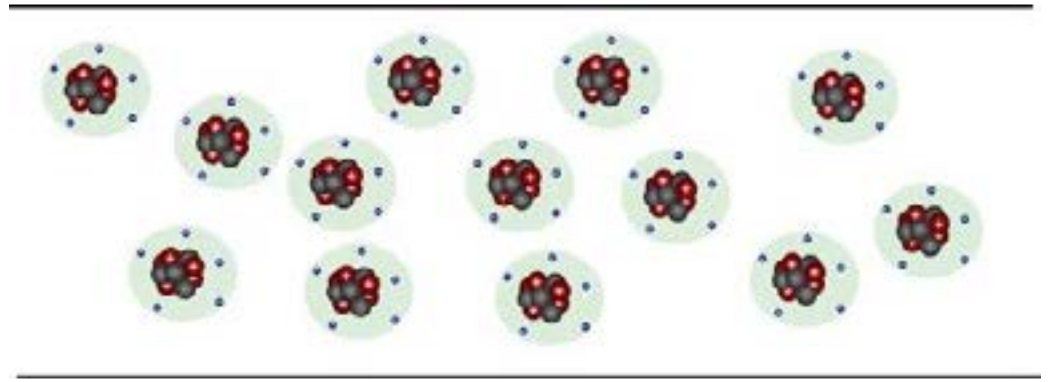
Raise the voltage to 2000V.



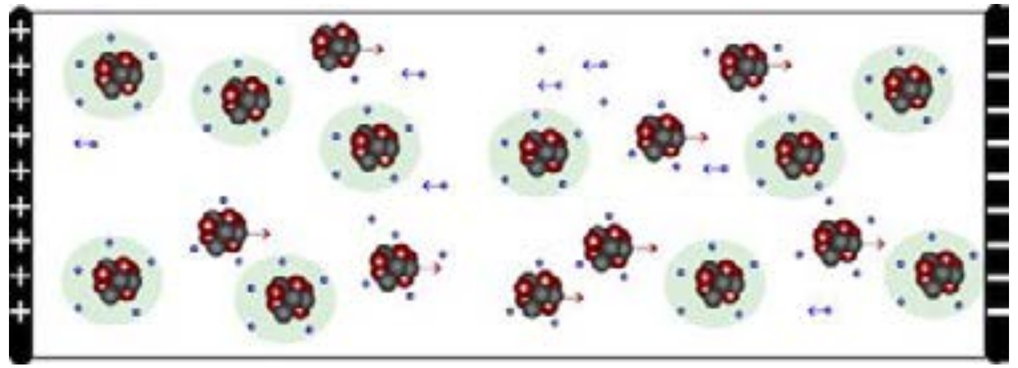
A glow discharge similar to the one below should appear.

What are we looking at?

Before the voltage is high enough, almost all the air is neutral atoms and molecules. In the drawing below the neutral atoms are highlighted just to identify them as neutral.



When the voltage is high enough, the air conducts electricity and the atoms and molecules start to lose electrons...some of the neutral atoms and molecules turn into **plasma**.



Plasma, sometimes referred to as the 4th state of matter, is gas that has positive and negative charged particles.

Once you use the settings provided, take time to experiment with the three variables to see how they make the plasma in the tube change. Think about how each of the different variables, pressure, voltage and electromagnets might change what happens in the tube and change what you see.

Can you predict what might happen? Write down your predictions and then test. Were you correct? If not, how might you change your thoughts about what should happen?

The following information is provided by the PPPL RGDX website (1).

What does the electromagnet do to the plasma?

Have you tried turning on the electromagnet while the plasma's on?

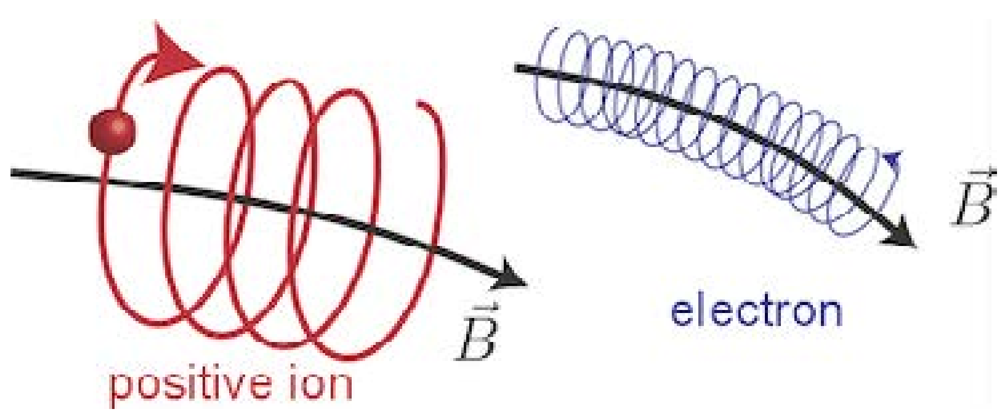
- Set the pressure to 40 mTorr
- Set the electrode voltage to 2000 Volts
- Turn the electromagnet on to 200 Gauss

Do you see something like what's shown below?

We have already seen that plasma responds to the voltage across the electrodes, just turn the electrode voltage up and down and see the changes in the plasma.

Now we see that the plasma also reacts to magnetic fields!

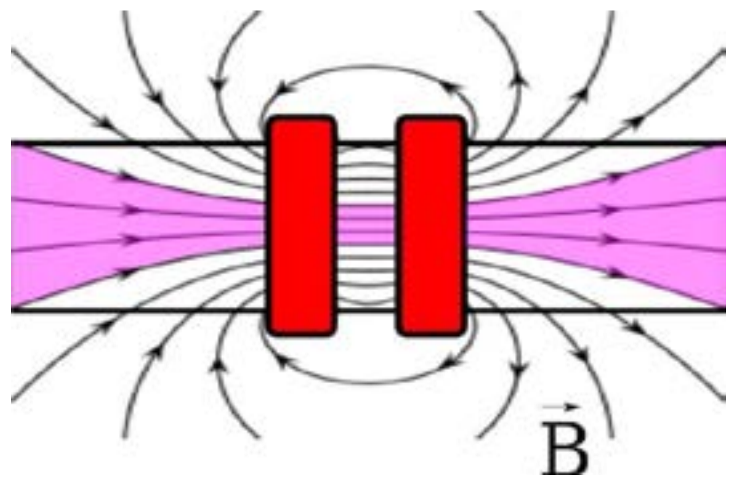
As seen in the figure below, when a negatively or positively charged particle sees a magnetic field, the particle starts spiraling around it.



Now, the radii of these spirals are known as the electron and ion gyroradii and depend on the magnetic field and on the temperature of the plasma.

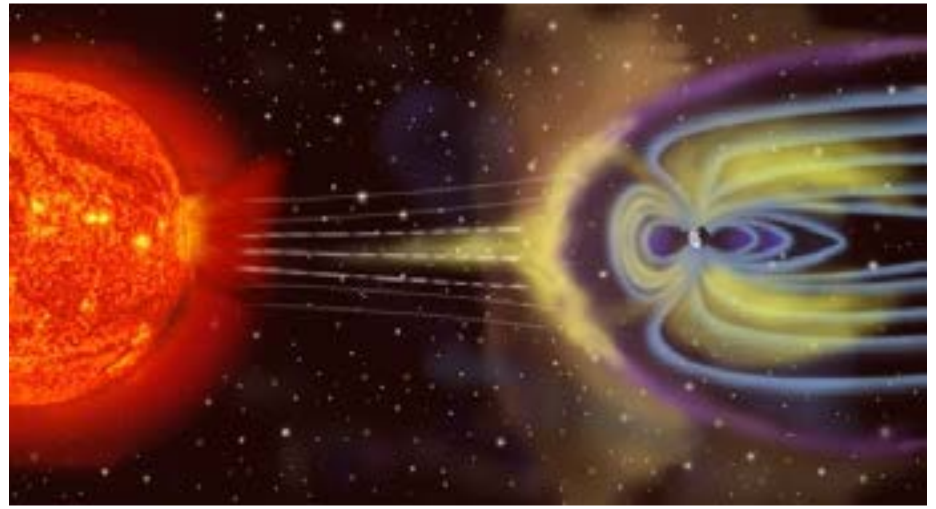
For our case, the sizes are of the order of an inch.

If we now look at the picture of the magnetic field of the Helmholtz coil, the squeezing of the plasma makes sense! As the plasma spirals around the field lines, it gets redirected due to the curvature of the fields.



You can see that the plasma is kept away from the glass between the coils. This fact is critical to one of the main missions of the Princeton Plasma Physics Lab and other plasma labs around the world: **Magnetically Confined Fusion.**

We mentioned in "What is plasma" that the northern lights are also plasma. Now you can understand why we only see them in the poles:



As solar winds (made out of plasma) reach the earth's magnetic fields, they follow the fields towards the north and south poles. The northern (and southern) lights are seen when the plasma interacts with the atmosphere.

Next Generation Science Standards (4):

Energy:

- Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents. (4-PS3-2)
- Ask questions and predict outcomes about the changes in energy that occur when objects collide. (4-PS3-3)

Science and Engineering Practices:

- Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. (4-PS3-3)
- Use evidence (e.g., measurements, observations, patterns) to construct an explanation. (4-PS3-1)
- Make observations to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. (4-PS3-2)

Disciplinary Core Ideas:

- Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (4-PS3-2), (4-PS3-3)
- Light also transfers energy from place to place. (4-PS3-2)
- The faster a given object is moving, the more energy it possesses. (4-PS3-1)

- Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. (4-PS3-2),(4-PS3-4)
- When objects collide, the contact forces transfer energy so as to change the objects' motions. (4-PS3- 3)

Cross-cutting Concepts:
- Energy can be transferred in various ways and between objects. (4-PS3-1), (4-PS3-2), (4-PS3-3), (4-PS3-4)
- Science affects everyday life. (4-PS3-4)

Structure and Properties of Matter - Students who demonstrate understanding can:
- Develop a model to describe that matter is made of particles too small to be seen. (5-PS1-1)
- Make observations and measurements to identify materials based on their properties. (5-PS1-3)

Science and Engineering Practices:
- Use models to describe phenomena. (5-PS1-1)

Disciplinary Core Ideas:
- Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects. (5-PS1-1)

Cross-cutting Concepts:
- Cause and effect relationships are routinely identified and used to explain change. (5-PS1-4)
- Natural objects exist from the very small to the immensely large. (5-PS1-1)
- Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume. (5-PS1-2),(5-PS1-3)

MS. Structure and Properties of Matter

Disciplinary Core Ideas:
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4)
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (MS-PS1-4)
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4)
- The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material. (secondary to MS-PS1-4)

MS. Forces and Interactions
- Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. (MS-PS2-3)
- Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. (MS-PS2-5)

Disciplinary Core Ideas:
- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3)
- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)

Cross-cutting Concepts:
- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3), (MS-PS2-5)

MS. Energy
- Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. (MS-PS3-2)

Disciplinary Core Ideas:
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (MS-PS3-3), (MS-PS3-4)
- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (MS-PS3-2)

Sources:

1. Princeton Plasma Physics Laboratory Remote Glow Discharge Experiment (RGDX): http://scied-web.pppl.gov/rgdx/
2. Next Generation Science Standards http://www.nextgenscience.org/

POWER SOURCES CHALLENGE

POWER UP ACTIVITIES – PLASMA BALL LESSON

ACTIVITY ONE:

FEEL THE FORCE

Students will study electron movement using adhesive tape and demonstrate how negative charge and positive charge are affected by movement of electrons.

Question:

What causes attraction between molecules?

Explore:

Tear off two small pieces of adhesive tape. Place the tape pieces' sticky-side down onto a table, allowing 1 inch of overlap hanging off of the table. Now, quickly rip the tape pieces off of the table and bring the two pieces within close proximity of one another.

What do you notice? How do they move? Can you feel a force?

Explain:

Electrons move all of the time, and it is this movement that causes a difference in charge. As electrons move away from an object, it becomes positively charged. If an object gains electrons, it becomes negatively charged. This attraction is called electrostatic attraction and accounts for objects with opposite charges being attracted to one another. When you pulled the tape off of the table, electrons were displaced, so one end of the tape had a positive charge and the other end had a negative charge.

Here is an example of what you might see—make sure you manipulate until you FEEL the force.

ACTIVITY TWO:

ARE YOU BONDED?

Students will use a kinesthetic activity to simulate the movement of particles and their bonds through the four different phases of matter.

Question:

How do particles bond in the different phases of matter?

Explore:

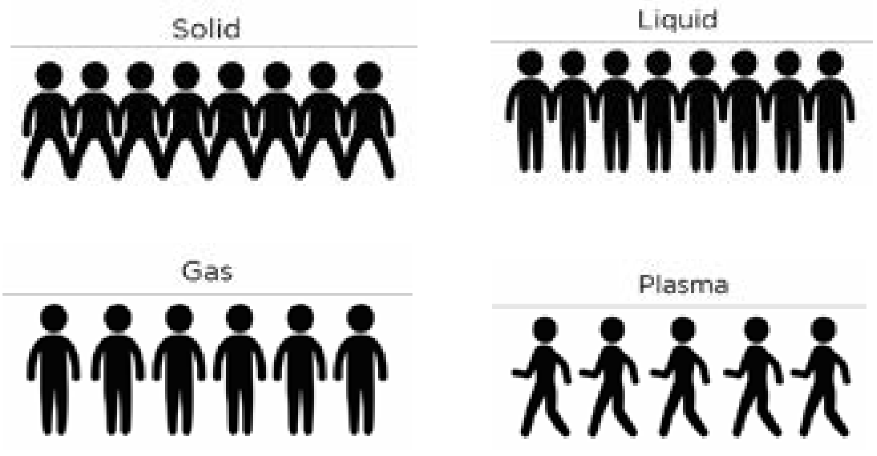
This works best with at least two other people. To simulate the bonding of a solid, stand shoulder to shoulder in a straight line and link arms and cross your feet with the feet of the person on each side of you. Now try to move—and note your range of movement. For a liquid, uncross your feet with the two people standing next to you, keeping your arms linked. How has your range of motion changed? Has it increased or decreased?

To understand the gaseous phase, release your arms and stand all by yourself. Move at a walking and running pace and notice your range of mobility. Now, you will turn into plasma! Plasma is a gas that has lost its electrons and is positively charged. Take the two electrons (a piece of paper with "e- "written on it and place one in each hand). Run as fast as you can and lose your electrons somewhere along the way!

Explain:

Solids move at the slowest pace, they have the least kinetic energy (energy of movement). Liquids do not have as many bonds between molecules, so they can move freely and have more kinetic energy. Gases have no bonds, (they are neutral) so gas molecules can move about independently; they have a higher kinetic energy than solids and liquids. Plasma has the highest kinetic energy, and it has a charge since it loses electrons. Plasma moves at an increased speed and can combine with other things once it loses its electrons.

Here is a visual way to demonstrate using stick figures.



ACTIVITY THREE:

GAS PRESSURE REALITIES

Students will learn what gas pressure is and how it affects the plasma in the tube.

Question:

What is gas pressure and how does it affect plasma?

Explore:

Because some gases are invisible to the naked eye, we will look at the effects of a gas (carbon dioxide- CO_2) in water to understand how concentration affects gas pressure. Take a bottle of sparkling water and go to a place that can get wet (maybe outside or in your bathtub).

Look at the bottle—do you see any bubbles?

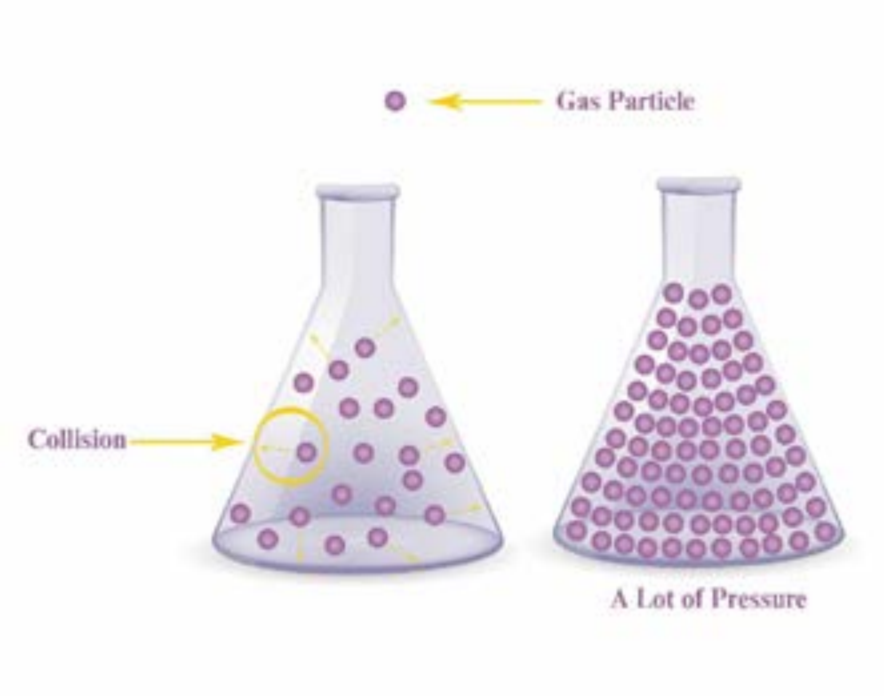
Those bubbles create gas pressure when they collide with the interior surface of the bottle. Now shake the bottle gently—what do you see?

Carefully point the bottle away from you and uncap. What happened?

Now let the bottle remain unopened overnight. Come back the next day, replace the top and shake again. What happened? What did you see? How does it compare to the result you experienced the day before?

Explain:

Gas pressure is defined as the force produced by the gas per unit area. Many different variables can affect gas pressure but we will focus on the concentration or amount of gas. If we think about the force of the gas bubbles on the sides of the container, they exert a certain pressure. The more bubbles that are present, the higher the gas pressure. In order to form plasma, there must be a certain amount of gas that is present in the tube. The more gas that is present in the tube, the higher the probability that the reaction will take place.



ACTIVITY FOUR:

VOLTAGE AND ELECTROMAGNETS

Students will be able to answer the question--how do these two variables help make plasma?

Question:

How do voltage and electromagnets affect the synthesis of plasma?

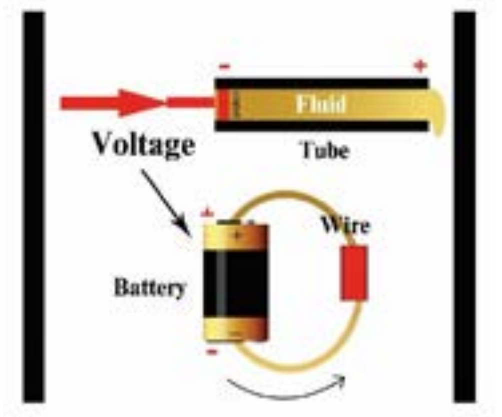
Explore:

You can think about voltage in terms of the flow of a water stream. Take an open bottle or glass of water and tilt at a slight angle. As you begin to pour the water out, when does it flow out with the greatest speed? Try it again and turn it upside down rather than pouring slowly. What did you observe?

Now take 10 paperclips and place them on the table. Using a magnet, pick up the paperclips that are randomly scattered about. What happened? How are they ordered differently?

Explain:

Voltage helps electrons move from one electrode at one end of the tube to another electrode at the far end of the tube. It is this movement of electrons that helps charge the gas to produce plasma. Electromagnets concentrate the charged particles to a confined space so more of the charged particles can interact.



Girls of Energy

POWER SOURCES CHALLENGE

FUSION PHYSICS! A CLEAN ENERGY

Summary: What if we could harness the power of the Sun for energy here on Earth? What would it take to accomplish this feat? Is it possible?

Many researchers including our Department of Energy scientists and engineers are taking on this challenge! In fact, there is one DOE Laboratory devoted to fusion physics and is committed to being at the forefront of the science of magnetic fusion energy.

In order to understand a little more about fusion energy, you will learn about the atom and how reactions at the atomic level produce energy.

Background: It all starts with plasma! If you need to learn more about plasma physics, visit the Power Sources Challenge plasma activities.

The Fusion Reaction that happens in the SUN looks like this:

Photo by Department of Energy

Fusion reactions occur when two nuclei come together to form one atom. The reaction that happens in the sun fuses two Hydrogen atoms together to produce Helium. It looks like this in a very simplified way: H + H → He + ENERGY. This energy can be calculated by the famous Einstein equation, $E = mc^2$.

Each of the colliding hydrogen atoms is a different isotope of hydrogen, one deuterium and one tritium. The difference in these isotopes is simply one neutron. Deuterium has one proton and one neutron, tritium has one proton and two neutrons. Look at the illustration—do you see how the mass of the products is less than the mass of the reactants? That is called a mass deficit and that difference in mass is converted into energy. A really important note is that for a very small change in mass, an enormous amount of energy is produced. How can scientists and researchers simulate this reaction that happens in the sun here on earth to produce energy?

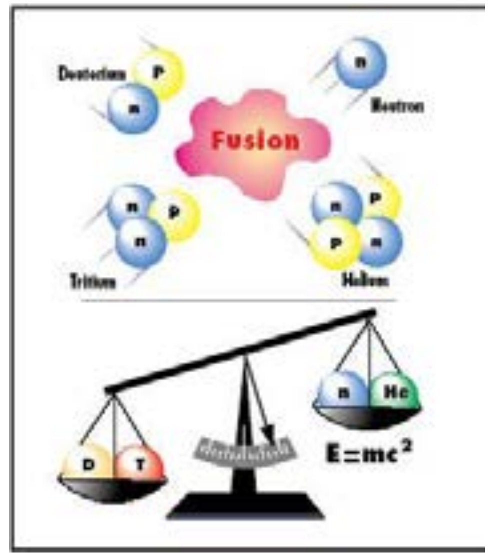


Illustration by U.S. Department of Energy

From a small change in mass, an enormous amount of energy is produced, and has the potential to be an inexhaustible source of energy.

Learning Objectives - After this activity, students should be able to:

- Describe atomic structure including sub-atomic particles and their charges
- Define fusion reactions
- Understand the differences in the isotopes of hydrogen
- Model a fusion reaction to understand how nuclei come together and how that affects energy
- Using the mass deficit to understand nuclear energy
- Design a project to explain fusion using art and/or media

Introduction: Fusion is the process that powers the sun and the stars. In one example of this type of reaction, two atoms of hydrogen combine together to form an atom of helium. In the process, some of the mass of the hydrogen is converted into energy. The easiest fusion reaction to make happen combines deuterium with tritium to make an atom of helium. Nuclear fusion depends on three things; high density of particles, close proximity of the particles to one another and a high rate of speed. Since we cannot duplicate the high gravitational field of the sun (which causes the high density—specifically atoms being very close together), we can increase the nuclei's rate of speed by heating to more than 4 times the temperature of the sun.

The chemical formula for water is H_2O, so there are 2 hydrogen atoms in every water molecule. One out of every 6500 atoms of hydrogen in ordinary water is deuterium, giving a gallon of water the energy potential of 300 gallons of gasoline. In addition, fusion is environmentally friendly because it produces no combustion products or greenhouse gases.

While fusion is a nuclear process, the products of the fusion reaction (helium and a neutron) are not intrinsically radioactive. Short-lived radioactivity may result from interactions of the fusion products with the reactor walls, but with proper design a fusion power plant would be passively safe, and would produce no long-lived radioactive waste. Design studies show that electricity from fusion should eventually be about the same cost as present day sources.

We're getting close! While fusion sounds simple, the details are difficult and exacting. Heating, compressing and confining hydrogen plasmas at 100 million degrees is a significant challenge. A lot of science and engineering had to be learned to get fusion to where we are today.

Magnetic fusion programs expect to build their next experiments, which will produce more energy than they consume within the next 15 years. If all goes well, commercial application should be possible by the middle of the 21st century, providing humankind a safe, clean, inexhaustible energy source for the future.

Magnetic Fusion: Magnetic fields affect the flow of electricity, simply by directing how electrons move. Magnetic fusion uses magnets to fuse hydrogen particles together to form plasma. The energy released from 1 gram of fused Deuterium equals the energy from about 2400 gallons of oil. That is a LOT of clean energy to help us answer our energy challenges!

Activities:

Materials:

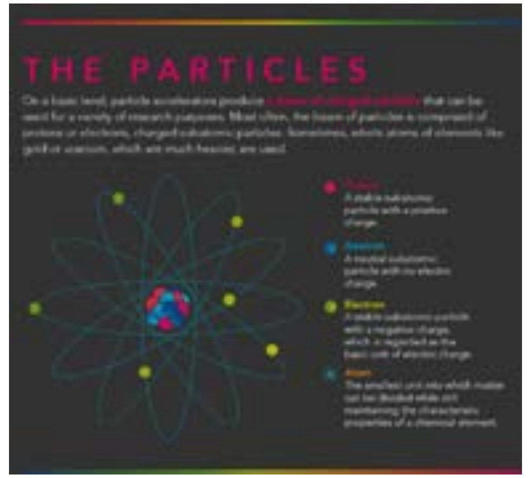
- Copies of Mini-Modeling template
- Mini-candies
- 2 long magnets and iron filings
- Copies of A STAR FOR US illustrated science booklet
- Props for multimedia presentation
- Recording device (a smartphone will suffice)

In the following activities, you will learn about the structure of sub-atomic particles, specifically the difference in the isotopes of hydrogen. You will use your knowledge of the atomic structure of hydrogen and its isotopes to design a multimedia presentation describing what happens in a fusion reaction. The Power-Up activities that support this lesson will help you understand the particles that contribute to a fusion reaction as well as having a basic understanding of the transfer of a loss in mass, to energy.

Mini-Modeling the Atom: Have you ever wondered what constitutes the atoms that make up everything we know? This activity will help you visualize these particles, where they are located in the atom, and the difference in their charges.

As we talk about sub-atomic particles, what do they look like in an atom and how are they arranged? Can you model the difference in the three isotopes of hydrogen?

You will need the attached Mini-Modeling Map and mini-candies. You can choose one color of the candy for protons, a different color for neutrons, and a third color for electrons. Can you model the three different isotopes of hydrogen on your modeling map? Can you model an atom of helium that was formed by fusion?



Infographic by Department of Energy

Examine your models and compare to the illustration. Refer to the power-up activity for a more detailed explanation for this activity.

Feel the Force: Students will use magnets and magnetic iron filings to model fusion. This will help students understand the force of a magnetic field and how that contributes to fusion reactions.

What is magnetic fusion? How does a magnetic field work to help particles come together?

Take two magnets and examine them separately. As you start to bring the magnets together, what do you observe? When two particles fuse together, they make a new substance. Using your sense of touch, what differences do you feel? Rotate the magnets and repeat observations.

Now that you have felt the force of a magnetic field, you can actually "see" that force using iron filings. Take one of your magnets and place it under a white sheet of paper. Use a small amount of iron filings and sprinkle them on top of the paper just above the magnet. What do you see?

Collect your iron filings from the paper. Now place your two magnets parallel to each other. In the same way as the first map, place your white sheet of paper over the magnets and sprinkle the iron filings on the paper. What do you observe this time? How is it different from the first map?

You might want to sketch what you see with each map or take a picture if you have a camera, that way you can compare the difference in the two pictures.

YOU be the STAR (like the Sun)! Now that you have learned about magnetic fusion and how it might help solve our future energy challenges, you will have the opportunity to shine (just like the sun!). For this activity, you will use your creativity and imagination, just like the designers of the science booklet "A Star for Us".

You will be on a team with three other students or friends and brainstorm your ideas. Your mission will be to use any media (visual, song, video, skit, etc) to help others your age understand magnetic fusion as a clean energy. You will capture your explanation in a recording no longer than 5 minutes.

Make sure you have the following: Title, Authors, Definition of Fusion and Wrap-up. Ideally, you will post to an online secure video channel. Have fun!

Next Generation Science Standards (4,5 and MS):
Students who demonstrate understanding can:

- 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
- 4-ESS3-1. Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.
- 5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen.
- 5-PS1-2. Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.
- 5-PS1-3. Make observations and measurements to identify materials based on their properties.
- MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.
- MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
- MS-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.
- MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

Science and Engineering Practices:
- Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. (4-PS3-3)
- Make observations to produce data to serve as the basis for evidence for an explanation of a
- phenomenon or test a design solution. (4-PS3-2)
- Use evidence (e.g., measurements, observations, patterns) to construct an explanation. (4-PS3-1)
- Develop a model to predict and/or describe phenomena. (MS-PS1-1),(MS-PS1-4)
- Develop a model to describe unobservable mechanisms. (MS-PS1-5)
- Analyze and interpret data to determine similarities and differences in findings. (MS-PS1-2)
- Apply scientific ideas or principles to design an object, tool, process or system. (MS-PS2-1)

Disciplinary Core Ideas:
- Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (4-PS3-2),(4-PS3-3)
- Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. (4-PS3-2),(4-PS3-4)
- Energy and fuels that humans use are derived from natural sources, and their use affects the environment in multiple ways. Some resources are renewable over time, and others are not. (4-ESS3-1)
- The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. (5-PS1-2) Measurements of a variety of properties can be used to identify materials. (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.) (5-PS1-3)
- No matter what reaction or change in properties occurs, the total weight of the substances does not change. (Boundary: Mass and weight are not distinguished at this grade level.) (5-PS1-2)
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-3)
- Some chemical reactions release energy, others store it. (MS-PS1-6)
- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3)
- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)

Crosscutting Concepts:
- Energy can be transferred in various ways and between objects. (4-PS3-1), (4-PS3-2),(4-PS3-3),(4-PS3-4)
- Over time, people's needs and wants change, as do their demands for new and improved technologies. (4-ESS3-1)
- Natural objects exist from the very small to immensely large. (5-PS1-1)
- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)
- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS1-3)
- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (MS-PS1-3)
- Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (MS-PS1-2)

Sources:

- A Star for Us: http://www.pppl.gov/sites/pppl/files/basic_pages_files/PPPL_AStarForUs_fusioncomic_download.pdf
- Next Generation Science Standards: www.nextgenscience.org

POWER SOURCES CHALLENGE

POWER UP ACTIVITIES – FUSION PHYSICS

ACTIVITY ONE:

MINI-MODELING THE ATOM

Have you ever wondered what makes up the atoms that make up everything we know? This activity will help you visualize these particles, their location in the atom, and their differences in charge.

Question:

As we learn about sub-atomic particles, what do they look like in an atom and how are they arranged? Can you model the difference in the three isotopes of hydrogen?

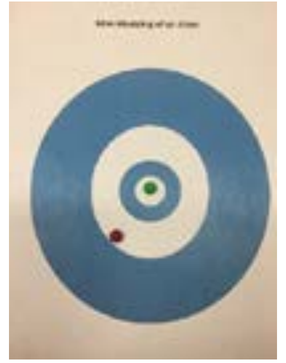
Explore:

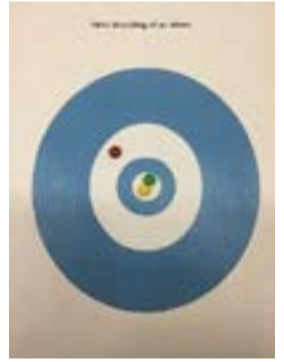
You will need the attached Mini-Modeling Map and mini-candies. You can choose one color of the candy for protons, a different color for neutrons, and a third color for electrons. Can you model the three different isotopes of hydrogen on your modeling map? Can you model an atom of helium that was formed by fusion?

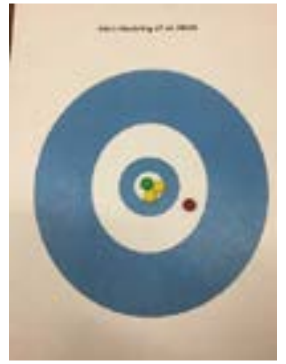
Explain:

Isotopes of an atom have the same number of protons but vary in the number of neutrons. Protons and neutrons reside in the nucleus (the center of the atom) and electrons move quickly through clouds of specific levels surrounding the nucleus. Hydrogen's most abundant isotope (99.98%) contains 1 proton, 0 neutrons and 1 electron. Deuterium (or heavy hydrogen) has 1 proton, 1 neutron and 1 electron. Tritium is present is minute amounts and has 1 proton, 2 neutrons and 1 electron. (this is already in the next column)

Check your pictures with the ones below. What color was used for proton, neutron and electron? Can you deduce which isotope is which from looking at each image?







ACTIVITY TWO:

FEEL THE FORCE

Students will demonstrate modeling fusion using magnets and magnetic iron filings to understand the force of a magnetic field and how that contributes to fusion reactions.

Question:

What is magnetic fusion? How does a magnetic field work to help particles come together?

Explore:

Take two magnets and examine them separately. As you start to bring the magnets together, what do you observe? When two particles fuse together, they make a new substance. Using your sense of touch, what differences do you feel? Rotate the magnets and repeat observations.

Now that you have felt the force of a magnetic field, you can actually see that force using iron filings. Take one of your magnets and place it under a white sheet of paper. Use a small amount of iron filings and sprinkle them on top of the paper just above the magnet. What do you see?

Collect your iron filings from the paper. Now place your two magnets parallel to each other. In the same way as the first map, place your white sheet of paper over the magnets and sprinkle the iron filings on the paper. What do you observe this time? How is it different from the first map?

You might want to sketch what you see with each map or take a picture if you have a camera, that way you can compare the difference in the two pictures.

Explain:

You have just mapped a magnetic field! You can trace the force that you felt by looking at the pattern of the iron filings. Magnetic fields affect the flow of electricity, simply by directing how electrons move. Magnetic fusion uses magnets to fuse hydrogen particles together to form plasma. These reactions produce energy. Scientists and engineers can direct the flow of charged particles by varying the number and the strength of the magnets. Compare your pictures to the one below, how are they alike or different?

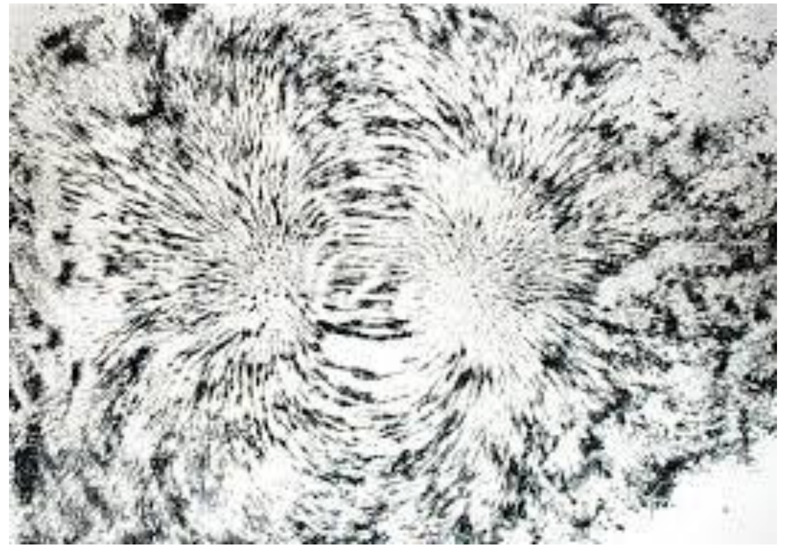


Photo from Wikimedia.org

ACTIVITY THREE:

A SWEET MODEL FOR FUSION

Students will use cookie dough to model fusion and the energy emitted through the mass deficit.

Question:

How can you model fusion and mass deficit?

Explore:

You will use two pieces of cookie dough, a balance and a microwave oven to perform this activity. You can also use an add-in such as a chocolate chip, raisin, cranberry or nut to place in the dough to represent protons and neutrons.

Take your raw dough and place the correct number of "add-ins" to represent protons and neutrons in the center. Roll into a sphere and place very close together (but not touching) on a paper plate. If you can, take the mass or weigh the dough before you cook it. Then place the dough in a microwave oven following directions on package for cook time. What happened to the two spheres? How do they look now? If you can mass or weigh the product, did you note a difference?

After making your observations and capturing "before" and "after" images, you may eat your new element!

Explain:

Fusion reactions occur when two atoms come together or fuse to form a new atom. You used two small separate pieces of dough, and after you added energy (by heating in a microwave), they became one piece. If you used add-ins to represent protons and neutrons, you made a new element because of the different amounts of protons and neutrons.

Mass deficit occurs differently in your model and in nuclear fusion reactions such as the one in the sun. If you massed your cookie dough before and after you cooked it, you should have seen a difference. Do you know why there was a difference? When baking cookies, you turn some of the water in the dough into a vapor that escapes when you open the microwave door!

But nuclear fusion is much different. The Law of Conservation of Mass states that the mass of the reactants in a chemical reaction should be equal to the mass of the products. If there is a difference, then that mass has been converted to energy according to the equation $E=mc^2$. For very small changes in mass, there is a tremendous amount of energy produced.

Photo by commons.wikimedia.org

ACTIVITY FOUR:

STEM + A (Art)=STEAM

This power-up activity introduces students to a creative and imaginative way to learn about nuclear fusion.

Question:

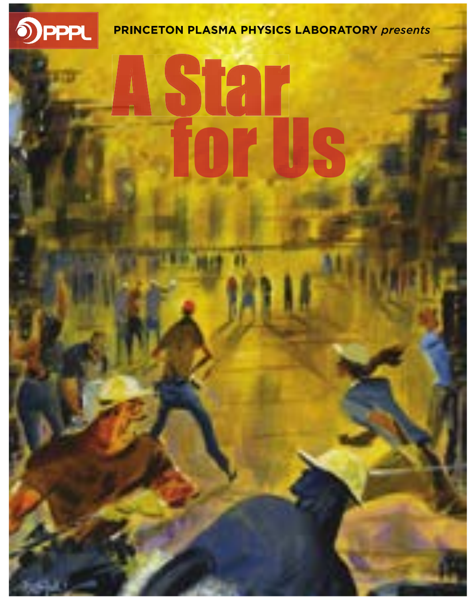
How can artists use their talents in STEM?

Explore:

Read the PPPL (Princeton Plasma Physics Laboratory) beautifully illustrated attached science booklet and think about ways to involve your unique talents to intersect with STEM disciplines.

Explain:

STEM disciplines are a wonderful place to use ALL of your talents. Science and engineering involve creative thinking to discover innovative ideas and methods. Engineering requires innovative design and original ideas to iterate and improve prototypes. This science booklet can help you think about the different ways we can think about science topics such as magnetic fusion energy and illustrate those topics for all to understand.



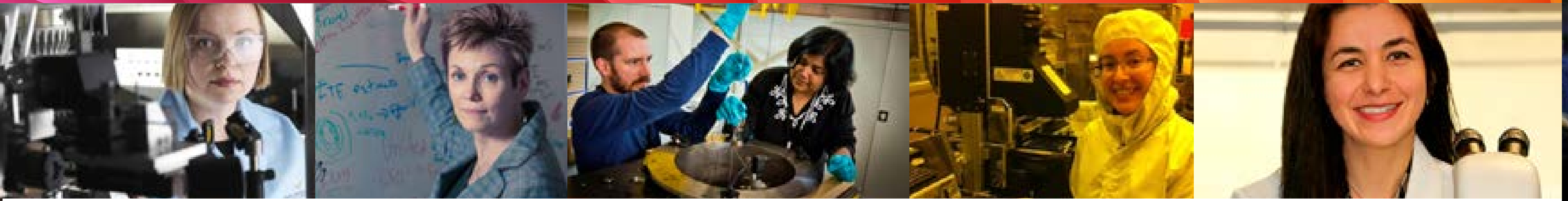
THE ENVIRONMENTALIST

Energy Efficiency

Many energy resources we use today are inefficient and sometimes harmful to our planet. However, increasing energy efficiency and reducing energy waste can make a significant difference.

The U.S. Department of Energy has teams of scientists coming up with creative solutions to help solve the challenges of tomorrow. Our National Labs work with universities and businesses to develop new energy-efficient technologies while boosting the efficiency of current technology. Our scientists care a lot about the environment, and their knowledge of science and engineering allow them to be part of the solution.

A wind turbulence model in the 3-D visualization lab, housed in the energy systems integration facility (ESIF) at National Renewable Energy Laboratory in Golden, Colorado.



"You cannot get through a single day without having an impact on the world around you. What you do makes a difference, and you have to decide what kind of difference you want to make."

Jane Goodall

Goodall's research has left an enormous impact on such fields as primatology, anthropology, and human physiology.

Images on the left/right: STEM professionals at the U.S. Department of Energy

ENERGY EFFICIENCY CHALLENGE

LEAD-FREE SOLDER - A GREEN SOLUTION FOR THE ELECTRONIC AGE

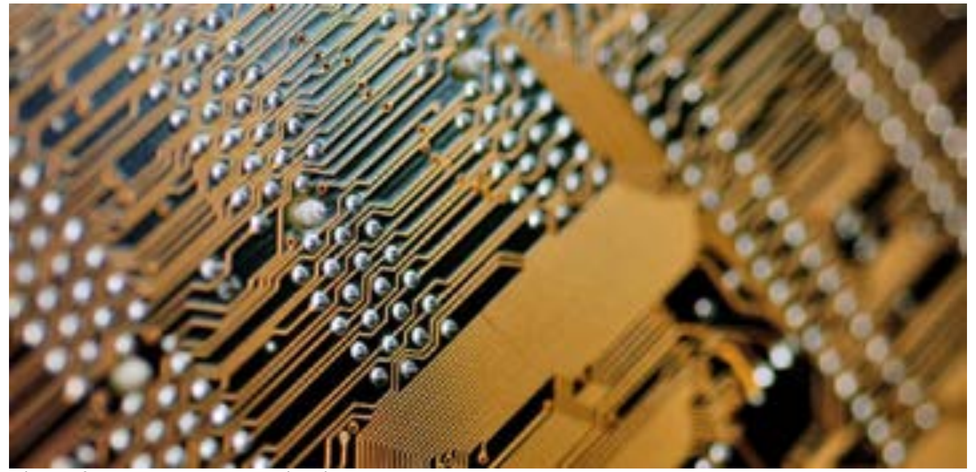


Photo from Ames National Laboratory

Summary: When you look at a circuit board like the one pictured above, what do you see? What makes the wires attach to the board and all of the electronic pieces attach to each other? This lesson will concentrate on circuits and the chemical content in solder. How is the Department of Energy leading the way for a greener future for all?

Background: Solder is a chemical mixture that binds the parts of a circuit board together. Proven to be long-lasting and sturdy, solder must meet certain criteria such as melting at a low temperature, so it does not damage delicate electronic parts. Historically, lead has been used as a solder because it was also cost-effective and met industry performance standards. Unfortunately, after using electronic devices such as electric toothbrushes or old cell phones, we throw them in the trash where they are taken to a landfill. People own more electronic devices now than ever, making the discard problem even worse. Over time, the lead can leak into the groundwater and poison the drinking water.

Do you remember when lead contaminated the Flint, Michigan drinking water in March 2016? The town's water contained too much lead, making the water unsafe to use.

Concerned about this growing problem of lead-filled discarded electronics and the risk it poses to the environment, some European countries have limited the amount of lead present in products sold there. Here at home, scientists at the U.S. Department of Energy's Ames Laboratory worked so hard to invent a lead-free solder, but it was not without its challenges. In order to encourage other vendors to use this green solder, it had to be comparable in price to its lead counterpart and retain the other properties of a good solder. After conducting many experiments, the Ames Laboratory scientists created a lead-free solder that contains not just one metal but three: tin, silver, and copper. This green substitute should help everyone in the US transition to lead-free solder and protect our environment.

Learning Objectives - After this activity, students should be able to:

- Use a periodic table to learn about the metals used in solder and the location of the heavy metals;
- Describe the difference in a homogeneous and heterogeneous mixture;
- Understand basic circuitry and what makes electrons flow;
- Disrupt a present technology and repurpose for redesign.

Introduction: We are living in the electronic age and much of our world is wired, so it makes sense that we should know how circuits are constructed. It is also interesting to think about new possibilities for electronics moving forward so the world we live in can become a greener and more energy efficient place to live.

Activities: The Power-Up activities for this lesson will help you understand circuits, parts of a circuit including solder, the chemical components involved in circuits as well as using what you learn to design a personalized motorized bot. While the explore part of the power-up activities is in the body of this lesson, the explanations are in the separate Power-up pages.

Materials: energy ball (http://www.teachersource.com/product/energy-ball/electricity-magnetism), 4 lemons, 4 pennies, 4 zinc nails, an LED, 5 alligator clip wires, two clear glasses, flashlight or laser pointer, cheap electric toothbrush, duct tape, electrical tape.

Circle of Charges: Do you conduct electricity? What is electricity? Does water conduct electricity—why or why not?

Ideally, you can stand with at least one other person, but you can also do this activity alone or in a large group (preferred). Have everyone in the group stand up and hold hands. Can you feel any electricity moving through your body? Because adult bodies are 55-60% water, do you think water conducts electricity? Why or why not?

Now that everyone is connected, one person in the group will touch one of the electrodes (metal strip) on the energy ball, while the person standing directly next to them will not touch the person, just the opposite electrode on the energy ball.

What do you see? Ask two people to release hands—what happened? Ask a different pair to release hands but lightly tap the partner's arm with a finger—what happens?

Lemon Circuits: Lemons have citric acid inside of them and weak acids are weak conductors of electricity. You can use pennies, zinc nails, alligator clips, 4 lemons and an LED to make your own circuit.

Can a few lemons be used to light up an LED (light-emitting diode)? You can use pennies, zinc nails, alligator clips, 4 lemons and an LED to make your own circuit. When you connect 4 lemons together in a series you can light an LED. Do not cut lemons but gently squeeze them so the juice will flow inside. For each lemon, you will push a penny halfway in and it will be the positive (+) side.

On the other end of the lemon, gently push a zinc nail into the center and that will be your negative (-) side. You should now have 4 lemons each with a penny and a zinc nail. Arrange your lemons in a square, aligning the copper penny on one lemon next to the zinc nail on the other lemon. Use alligator clips to connect positive (penny) to negative (zinc nail). Always connect positive to negative to allow the flow of electrons. You should have a penny not connected so use an alligator clip and connect it to the negative side of the LED (flat-side of bulb and shorter leg). Connect the zinc nail with an alligator clip to the positive side of LED (longer leg). You may have to dim the lights, but you will see your LED light up!

Where are the Metals? Now that you have learned a little more about circuits, we will learn more about solder. Solder is a combination of a mixture of metals. There are two kinds of mixtures: homogeneous mixtures and heterogeneous mixtures. Homogeneous mixtures have the components evenly distributed throughout so it appears very uniform.

What metals are involved in traditional solder? How do those metals differ from the ones in the new green solder?

Follow this link to the interactive Los Alamos National Laboratory Periodic Table (http://periodic.lanl.gov/index.shtml). We will use this periodic table to examine the metals that make up a solder mixture.

Can you locate lead on the table—it has a symbol of Pb. Lead (Pb) is a heavy metal; you can see where it is located on the periodic table. Tin (Sn), Silver (Ag) and Copper(Cu) are the metals that are used in exact amounts to make up the green solder. Can you locate them o the periodic table?

The Tyndall Effect: The Tyndall Effect is used to distinguish liquids mixtures into categories of homogeneous mixtures or heterogeneous mixtures. If a liquid mixture is homogeneous, you can shine a light through it and all of the light will exit the other side. If it is a heterogeneous mixture, the light will stay in the mixture and not exit the other side. How can you tell if a mixture is homogeneous or heterogeneous?

Explore: Take two clear glasses and pour milk in one of the glasses and apple juice in the other glass. Using a flashlight or a laser pointer, point the light from one side of the glass. Did the light come out on the other side of the glass? Why or why not?

Make your own Brush Bot: You can disrupt a present technology and repurpose for a different use! Have you ever hacked a motor in a cheap electric toothbrush and made your own moving brush bot? You can do that in this fun exercise and examine solder from inside the toothbrush.

Procedure: You must always be supervised by an adult when working with electricity and tools. Take a cheap electric toothbrush (you can get them many places for $1) and break off the handle. Unscrew the bottom and carefully remove the inner components and the motor. Keep the battery and housing to use for your Bot.

Very carefully examine the solder points (remember these may have some lead on them). How can you use the motor and the battery housing to make a brushing bot? Use your imagination and try many things until you get one that works! There is no right or wrong way to do this activity—it is up to you to use your creativity and engineering skills.

Take a picture or video of your moving Bot!

Next Generation Science Standards (NGSS, MS):

- Develop models to describe the atomic composition of simple molecules and extended structures. (MS-PS1-1)
- Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes. (MS-PS1-6)
- Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. (MS-PS2-5)

Science and Engineering Practices:

- Develop a model to predict and/or describe phenomena (MS-PS1-1) (MS-PS1-4)
- Analyze and interpret data to determine similarities and differences in findings. (MS-PS1-2)
- Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. (MS-PS3-3)

Disciplinary Core Ideas:

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of the characteristics may be incorporated into the new design. (secondary to MS-PS1-6)

- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (secondary to MS-PS1-6)

- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2)

Cross-Cutting Concepts:

- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (MS-PS1-3)
- Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). (MS-PS3- 5) The transfer of energy can be tracked as energy flows through a designed or natural system. (MSPS3-3)
- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS4-2)
- Structures can be designed to serve particular functions. (MS-PS4-3)

Sources:

1. Next Generation Science Standards www.nextgenscience.org
2. Los Alamos National Laboratory Periodic Table: http://periodic.lanl.gov/index.shtml

Girls of Energy

ENERGY EFFICIENCY CHALLENGE

POWER UP ACTIVITIES – LEAD-FREE SOLDER LESSON

ACTIVITY ONE:

CIRCLE OF CHARGES

Students will learn what it means to conduct electricity and complete a circuit.

Question:

Do you conduct electricity? What is electricity? Does water conduct electricity—why or why not?

Photo by Los Alamos National Laboratory

Explore:

Ideally, you can stand with at least one other person, but you can also do this activity alone or in a large group (preferred). Have everyone in the group stand up and hold hands.

Can you feel any electricity moving through your body? Because adult bodies are 55-60% water, do you think water conducts electricity? Why or why not?

Now that everyone is connected, one person in the group will touch one of the electrodes (metal strip) on the energy ball, while the person standing directly next to them will not touch the person, just the opposite electrode on the energy ball. What do you see? Ask two people to release hands—what happened? Rejoin hands and then ask a different pair to release hands but lightly tap the partner's arm with a finger—what happens?

Explain:

Surprisingly, people conduct electricity, which is the name given to moving electrons. When the circuit is closed and everyone is touching, the ions (charged particles) in our bodies that are dissolved in the water help us to conduct electricity. Pure water does not conduct electricity because there are no charged particles to force electrons to move. The metal strips on the energy ball are called electrodes. Their purpose is to make contact with a non-metallic part of the circuit, in this case your skin!

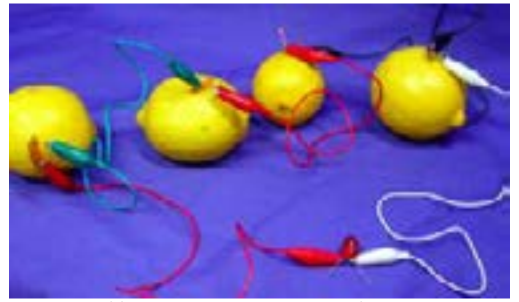
ACTIVITY TWO:

LEMON CIRCUITS

Lemons have citric acid (an example of a weak acid) inside of them and weak acids are weak conductors of electricity. You can use pennies, zinc nails, alligator clips, 4 lemons and an LED to make your own circuit.

Question:

Can a few lemons be used to light up an LED (light-emitting diode)?



http://sjesci.wikispaces.com/Electricity

Explore:

You can use pennies, zinc nails, alligator clips, 4 lemons, and an LED to make your own circuit. When you connect 4 lemons together in a series you can light an LED. Do not cut lemons but gently squeeze them so the juice will flow inside. For each lemon, you will push a penny halfway in, and it will be the positive (+) side. On the other end of the lemon, gently push a zinc nail into the center, and that will be your negative (-) side. You should now have 4 lemons each with a penny and a zinc nail. Arrange your lemons in a square, aligning the copper penny on one lemon next to the zinc nail on the other lemon.

Use alligator clips to connect positive (penny) to negative (zinc nail). Always connect positive to negative to allow the flow of electrons. You should have a penny not connected so use an alligator clip and connect it to the negative side of the LED (flat-side of bulb and shorter leg). Connect the zinc nail with an alligator clip to the positive side of LED (longer leg). You may have to dim the lights, but you will see your LED light up!

Explain:

Lemons contain an acid that helps electrons flow. When copper and zinc are together in a circuit, electrons flow from the zinc to the copper. If you have an inexpensive clock, you can try powering the clock with lemon juice also. You can also try other fruits and vegetables to see what produces enough electricity to power an LED or clock

ACTIVITY THREE:

WHERE ARE THE METALS?

Now that you have learned a little more about circuits, we will learn more about solder. Solder is a combination of a mixture of metals. There are two kinds of mixtures, homogeneous mixtures and heterogeneous mixtures. Homogeneous mixtures have the components evenly distributed throughout so it appears very uniform.

Question:

What metals are involved in traditional solder? How do those metals differ from the ones in the new green solder?

http://periodic.lanl.gov/index.shtml

Explore:

Follow the link to the interactive Los Alamos National Laboratory Periodic Table. We will use this periodic table to examine the metals that make up a solder mixture. Can you locate lead on the table with the symbol Pb?

Pb is a heavy metal; you can see where it is located on the periodic table. Tin (Sn), Silver (Ag) and Copper (Cu) are the metals that are used in exact amounts to make up the green solder. Can you locate them on the periodic table?

Use the periodic table to learn more about the specific metals mentioned above. Do you see any patterns? Could you suggest a combination of metals with similar properties that could be used as a good solder?

Explain:

After you find each of the metals in the green solder and learn more about them, you can see that they are non-toxic and much lighter metals. Scientists and engineers at DOE laboratories are working to make our world more energy efficient, greener, and safer. Over 60 companies have licensed to use this green solder, we hope many more will follow suit! Continue to research the viability of your proposed solder. Has anyone designed a solder with your particular combinations?

ACTIVITY FOUR:

THE TYNDALL EFFECT

The Tyndall Effect is used to distinguish liquids mixtures into categories of homogeneous mixtures or heterogeneous mixtures. If a liquid mixture is homogeneous, you can shine a light through it and all of the light will exit the other side. If it is a heterogeneous mixture, the light will stay in the mixture and not exit the other side.

Question:

How can you tell if a mixture is homogeneous or heterogeneous?

Explore:

Take two clear glasses and pour milk in one of the glasses and apple juice in the other glass. Using a flashlight or a laser pointer, point the light from one side of the glass. Did the light come out on the other side of the glass? Why or why not

Explain:

Homogeneous mixtures are evenly distributed and are called solutions. Because they are so well mixed, there are no particles for the light to run into or bounce off of, so the light travels straight through the liquid to the other side. Heterogeneous mixtures are not even throughout (even though it might look like they are with the naked eye!) so the light gets caught by the particles in the mixture and bounces around.

What other liquids can you test?

Homogeneous Mixtures

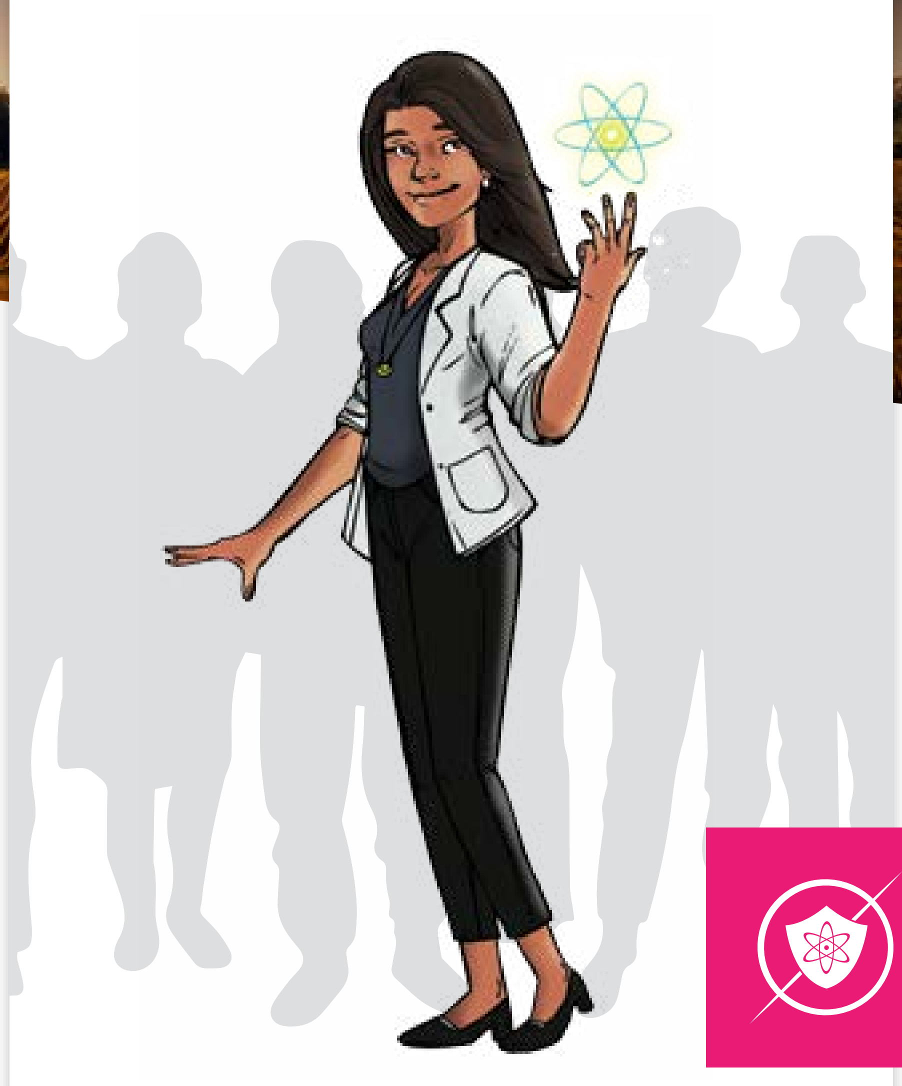
Heterogeneous Mixtures

Safety and Security

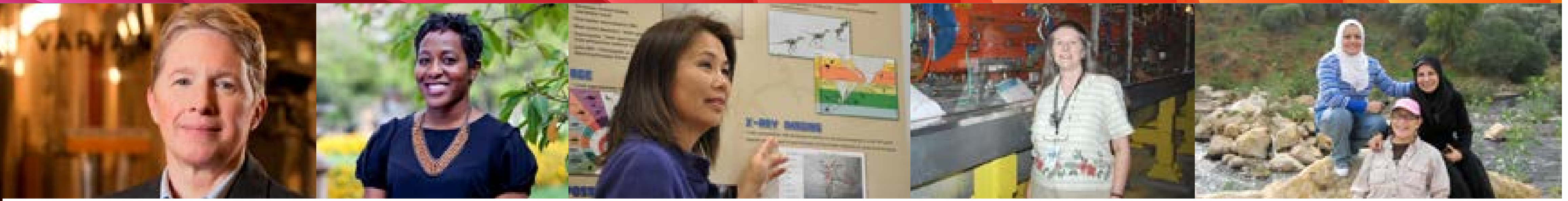
Energy is powerful; so as new sources are discovered, we must store and use it responsibly. Safety and security are always top priorities for our teams who constantly look for ways to protect us and our loved ones.

From ensuring the energy we use in our homes is safe to taking care of the biggest nuclear technologies, scientists at the U.S. Department of Energy work together to safeguard energy's tremendous power. These scientists exercise their sense of adventure and curiosity, aren't afraid to take risks, and are driven to solve even the toughest challenges in our nation and all over the world.

THE ADVENTURER



This scientist is part of a U.S. Department Of Energy team that works in the Pacific Islands collecting samples to monitor the levels of radiation in the soil, water, seafood, crops and air, ensuring radiation does not exceed acceptable levels.



"I want to make sure we use all our talent, not just 25 percent. Don't let anyone rob you of your imagination, your creativity, or your curiosity. It's your place in the world; it's your life. Go on and do all you can with it, and make it the life you want to live."

Mae Jemison

In 1992 aboard the Space Shuttle Endeavor, Mae Jemison became the first black woman to go into space. Along with being a physician, she is an accomplished actress and dancer who holds nine honorary doctorate degrees in disciplines ranging from the sciences to the humanities.

Images on the left/right: STEM professionals at the U.S. Department of Energy

Girls of Energy

SAFETY AND SECURITY CHALLENGE

TOP SUPERCOMPUTERS IN THE WORLD - FEATURING TWO of DOE'S!!

Summary: The U.S. Department of Energy (DOE) plays a very special role in keeping you safe. DOE has two supercomputers in the top ten supercomputers in the whole world. Titan is the name of the supercomputer at the Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee. Sequoia is the name of the supercomputer at Lawrence Livermore National Laboratory (LLNL) in Livermore, California. How do supercomputers keep us safe and what makes them in the Top Ten in the world?

Titan Supercomputer at Oak Ridge National Laboratory

Background: ORNL is using computing to tackle national challenges such as safe nuclear energy systems and running simulations for lower costs for vehicle engines, airplane wings and power plants. Because virtual prototypes can be tested before their physical construction, Titan runs simulations on these prototypes to lower production costs.

In fields where scientists deal with issues from disaster relief to the electric grid, simulations provide real-time situational awareness to inform decisions. DOE supercomputers have helped the Federal Bureau of Investigation find criminals, and the Department of Defense assess terrorist threats. Currently, ORNL is building a computing infrastructure to help the Centers for Medicare and Medicaid Services combat fraud. An important focus lab-wide is managing the tsunamis of data generated by supercomputers and facilities like ORNL's Spallation Neutron Source.

In terms of national security, ORNL plays an important role in national and global security due to its expertise in advanced materials, nuclear science, supercomputing and other scientific specialties. Discovery and innovation in these areas are essential for protecting US citizens and advancing national and global security priorities.

Lawrence Livermore's Sequoia ranked No. 1 on the Graph 500 list for using new techniques to solve large complex national security problems.

Sequoia and LLNL: At Lawrence Livermore National Laboratory (LLNL), Sequoia is ranked No. 1 on the Graph 500 list for using new techniques to solve large complex national security problems. The Graph500 benchmark measures how quickly a system can search through vast (petabyte and exabyte-size) data sets. This is an important indicator of a system's usefulness because computer scientists increasingly use supercomputers to analyze massive data-intensive workloads in addition to executing traditional modeling and simulation tasks. Sequoia is one of the most efficient systems in the world for processing large data sets.

Sequoia supports two missions: quantify the uncertainties in numerical simulations of nuclear weapons performance and perform the advanced weapons science calculations needed to develop the accurate physics-based models for weapon codes. Both Sequoia and Titan are primarily water-cooled and significantly more energy efficient than comparable systems, which is essential in controlling operating costs.

Learning Objectives --After this activity, students should be able to:

- Understand the orders of magnitude and prefixes used in computing
- Manipulate the binary digit system
- Be introduced to the language of computers
- Describe the different missions for security available at the National Labs.
- Connect the Women @ Energy STEM professionals with the safety and security missions at the National Labs

Introduction: Supercomputers have the ability to process massive amounts of data very quickly. In order to learn more about what they are capable of doing and how supercomputers at DOE keep us safe, we need to have a general understanding of the basics. Learning the "language" of computing is just like learning the special phrases and meanings of different disciplines. Through the activities in this lesson, you will become more familiar with how computers work and what makes a supercomputer so awesome.

Activities: The Power-Up Activities that support this lesson can be viewed in the entirety in the activity section. The Power-Ups are introduced in the lesson to enable flow for the lesson activity.

Materials:

- Stopwatch (you can use the digital timer on your phone)
- Calculator
- Access to internet
- Set of five binary cards per group for Bits and Bytes

The Big and small—Working with Orders of Magnitude: As you begin your study of computer science, there are certain words and prefixes that you will become familiar with using. In order to understand large numbers (such as the capacity for memory on a supercomputer) or small numbers (such as those needed to describe the size of an electron), we must have a basic understanding of "orders of magnitude".

An order of magnitude is based on the power of ten (10), so the difference in one order of magnitude is 10. If there is a difference in 2 orders of magnitude, then there is a difference of 10x10 or 100. And the difference in 3 orders of magnitude is 10x10x10 or 1,000.

How can we understand orders of magnitude using our heart and provide order of magnitude by just looking as a number?

Before you begin, set your timer for one minute. Then, use your fingertips of your first two fingers on your right hand to find your pulse on your left wrist. Did you find it? Count the number of pulses in just 1 minute. What was your resting heart rate? How many times would your heart beat in an hour, in a day, in a week, in a year? What would the order of magnitude be for each time period?

THE POWER OF A PREFIX! In this power-up activity, you will learn about the different prefixes and the order of magnitude related to each name. These prefixes are important to understand both ends of the spectrum, from numbers that are extremely small to numbers that are extremely large.

What role does a prefix play in words like *micro*scope, *nano*technology, *Giga*bytes and *Tera*flops?

Using the table of prefixes, record all of the ones you have encountered before and what it is used to describe. See if you can come up with a list of 15 words that use different prefixes.

The Beauty of Energy Safety and Security: The Department of Energy works 24 hours a day to keep everyone safe and secure. This activity will help you match the picture to the special program involved in our safety and security. As you match the pictures, think about all of the different careers that are associated with this energy challenge. Visit the Women @ Energy page to learn more about the many career opportunities.

What are the different areas in which the Department of Energy is working for our safety and security? Look at each of the photos in the accompanying power-up activity and try to match it to the different areas of safety and security listed here:

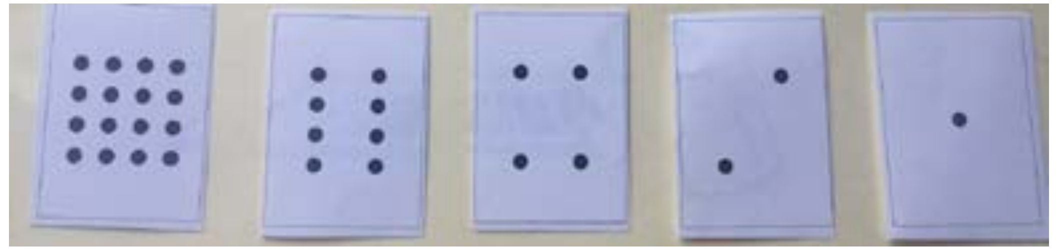
Biosecurity	Counterterrorism
Defense	Energy
Intelligence	Nonproliferation
Science	Weapons

Are there other pictures from other DOE National Labs that you can place in each special topic? Did you find STEM professionals at Women @ Energy that work in these specialty areas? What looks interesting to you?

Bits and Bytes: Learning the Basics

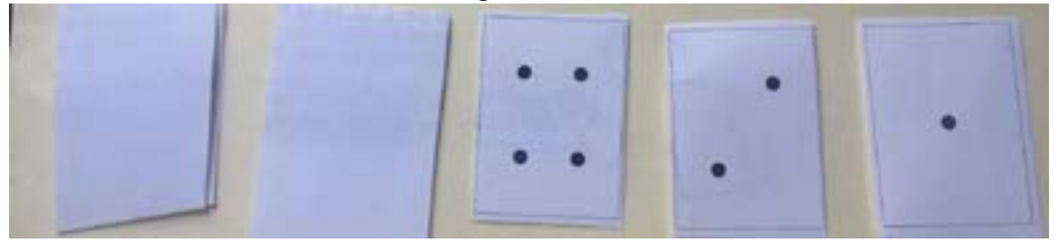
In this activity, you will be introduced to the binary digit or "bit" for short. A collection of 8 bits is called a "byte". By using this special code, a computer translates information fed into it as just zeros (0) and ones (1) to turn the information into data and back to information for the user. You will do an activity to learn about how data in computers is stored and transmitted as a series of zeros and ones.

Procedure: Each group will have 5 cards with dots on one side and nothing on the other side. The cards should be placed from left to right as follows. Do you see a pattern? How many dots would be on the next card to the left?



When a card is "dot" side up, it is a 1, if it is blank it is a 0. You then add the number of dots on the card to give the number representation of the arrangement.

What number would the next arrangement be?



0 0 1 1 1

If you deduced 7, you are correct!

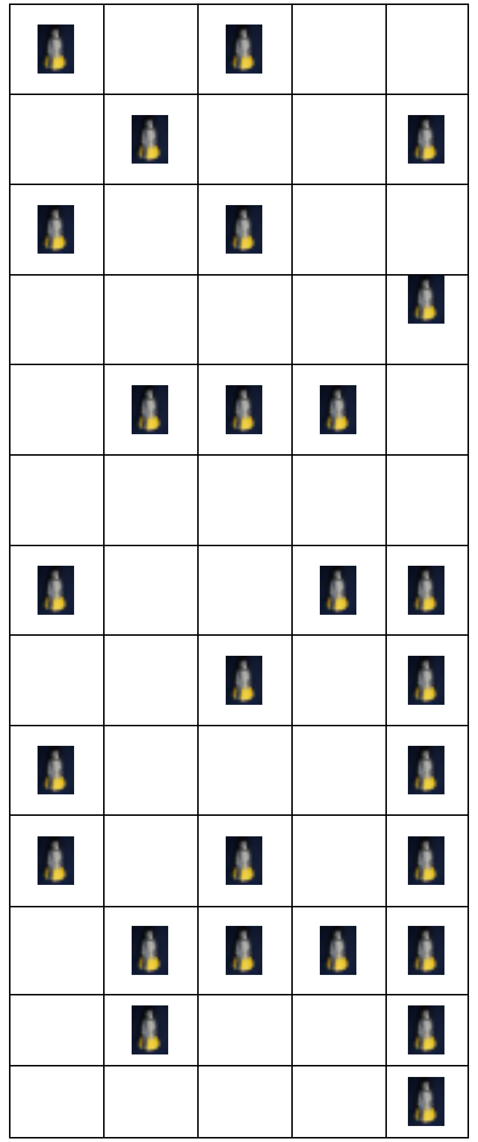
Let's try one more:

0 0 1 0 1

Did you get 5—if so, you are correct!

Computers use these series of 0's and 1's to process every bit of information that enters and everything that the user sees. Arrange your cards and write a number for 10101, 01100, and 00000. (Answers: 21, 12, 0)

Numbers can relate to the alphabet with A=1 all the way through Z=26. Write a number for each letter of the alphabet, then solve for the next message. Assume the 5 blocks represent the five cards in the specific order indicated in the first image of this activity. We will use a light bulb for 1, and the box will remain blank for 0.



What did you decode? Practice with your friends sending messages in your new secret code!

Next Generation Science Standards (NGSS 4,5, MS):
4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide.
4-PS4-3. Generate and compare multiple solutions that use patterns to transfer information.

Science and Engineering Practices: Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. (4-PS3-3)
Develop and use a model to describe phenomena. (MS-PS4-2)

Disciplinary Core Ideas: PS4.C: Information Technologies and Instrumentation Digitized information can be transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa. (4-PS4-3)
PS4.C: Information Technologies and Instrumentation Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information. (MS-PS4-3)

Cross-Cutting Concepts: Over time, people's needs and wants change, as do their demands for new and improved technologies. (4-ESS3-1)
Engineers improve existing technologies or develop new ones. (4-PS3-4)
Similarities and differences in patterns can be used to sort and classify natural phenomena. (4-PS4-1) Similarities and differences in patterns can be used to sort and classify designed products. (4- PS4-3)
A system can be described in terms of its components and their interactions. (4-LS1-1), (LS1-2)
The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-PS2-1)
Systems and System Models: Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems. (MS-PS3-2)
Advances in technology influence the progress of science and science has influenced advances in technology. (MS-PS4-3)

Scale, Proportion, and Quantity: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-ESS1-3)

Enrichment: To experience a visual, interactive orders of magnitude activity, go to: Secret Worlds: The Universe Within http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/index.html

Sources:

1. Secret Worlds: The Universe Within http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/index.html
2. Next Generation Science Standards www.nextgenscience.org

SAFETY AND SECURITY CHALLENGE

POWER UP ACTIVITIES FOR TOP SUPERCOMPUTERS LESSON

ACTIVITY ONE:

THE BIG AND SMALL — USING YOUR HEART

As you begin your study of computer science, there are certain words and prefixes that you will become familiar with using. In order to understand large numbers (such as the capacity for memory on a supercomputer) or small numbers (such as those needed to describe the size of an atom), we must have a basic understanding of orders of magnitude.

An order of magnitude is based on the power of ten (10). A difference in one order of magnitude is simply 10. If there is a difference in 2 orders of magnitude, then there is a difference of 10x10 or 100, and for 3 orders of magnitude the difference is 10x10x10 or 1,000.

Question:

How can we understand orders of magnitude using our heart and provide order of magnitude by just looking as a number?

Explore:

Using a stopwatch (you can use a digital timer on a digital device), set the timer for one minute. You can use the digital calculator later in the activity too. Before you begin, use your fingertips of your first two fingers on your right hand to find your pulse on your left wrist.

Did you find it? Count the number of pulses in just 1 minute. What was your resting heart rate? How many times would your heart beat in an hour, in a day, in a week, in a year? What would the order of magnitude be for each time period?

Explain:

Every time you feel your pulse, your heart beats. If you count 60 beats in one minute, then 60 beats x 60 minutes in an hour =3,600 beats per hour. If 60 is one order of magnitude, then 3,600 has 3 orders of magnitude. If we multiply the number of heartbeats in an hour by 24 hours in a day (3,600 x 24), we get 86,400 beats per day. That would be 4 orders of magnitude.

Do you see a pattern? Let's continue by multiplying 86, 400 beats per day by 7 days in a week (86,400 x 7) equals 604,800 which is 5 orders of magnitude. For the last calculation, figure out how many times on average your heart beat in a year. Multiply 604,800 beats per week by 52 weeks you get 31,449,600 beats per year, which equals seven orders of magnitude.

Did you find a pattern? Because our number system is based on tens, the order of magnitude is simply the number of digits in a number minus 1.

Let's double-check!

Number	Number of Digits (n)	Order of Magnitude (n-1)
60	2	1
3,600	4	3
86,400	5	4
604,800	6	5
31,449,600	8	7

We often use order of magnitude in science and engineering to help us relate to the scale of our world and estimate very small (the number of atoms within a given area) and extremely large numbers (the amount of data Titan and Sequoia can process).

For an interactive look at a specific scaling activity visit Secret Worlds: The Universe Within.

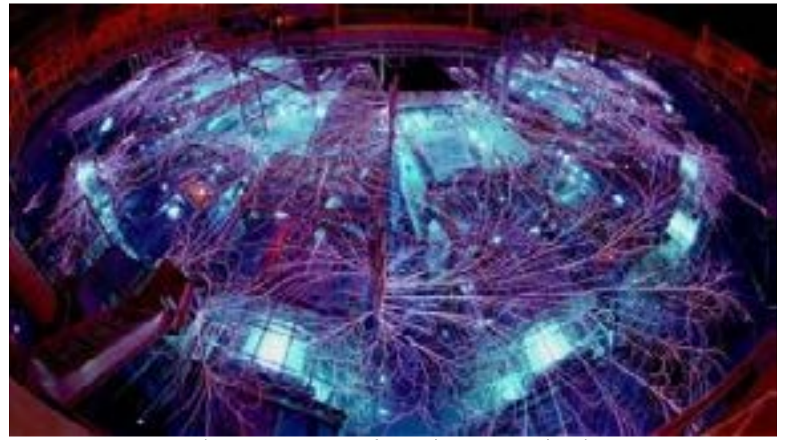


Image: Photo courtesy of Sandia National Laboratory

ACTIVITY TWO:

THE POWER OF A PREFIX

In this power-up activity, you will learn about the different prefixes and the order of magnitude that is related to each name. These prefixes are important to understand both ends of the number spectrum, from numbers that are extremely small to numbers that are extremely large.

Question:

What role does a prefix play in words like *micro*scope, *nano*technology, *Giga*bytes and *Tera*flops?

Explore:

Given the following table, record all of the prefixes you have encountered and what they describe. Can you come up with a list of 15 words that use different prefixes?

Factor	Name	Symbol	Factor	Name	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	μ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deka	da	10^{-24}	yocto	y

Image courtesy of google.com

Explain:

Examine the list of words that you collected and look at the prefixes listed above in the chart. For each of your words, does it describe something small or something large? The table above splits the prefixes into two groups, the left column uses prefixes when referring to large amounts of something and the prefixes in the right column refer to small amounts of an object. So a *micro*scope helps you to see things that are 1/1000 in size and *nano*technology uses particles that are one billionth of a meter in size. *Giga*bytes refer to one billion bytes of information, and a *Tera*flop refers to a computers speed as 1 trillion operations per second.

ACTIVITY THREE:

THE BEAUTY OF ENERGY SAFETY AND SECURITY

The Department of Energy works 24 hours a day to keep everyone safe and secure. This activity will help you match the picture to the special program involved in our safety and security. As you match the pictures, think about all of the different careers that are associated with this energy challenge. Visit the Women @ Energy page to learn more about the many career opportunities. What are the different areas in which the Department of Energy is working for our safety and security?

Explore:

Look at each of the photos and try to match it to the different areas of Safety and Security listed here.

- Biosecurity
- Defense
- Intelligence
- Science
- Counterterrorism
- Energy
- Nonproliferation
- Weapons


Image: Photo by Lawrence Livermore National Laboratory

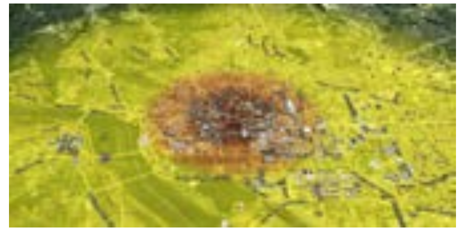


Image: Photo by Lawrence Livermore National Laboratory


13-152-65 DOE photo Lynn Freeny 12-12-2013 Oak Ridge Tennessee


Image provided by Sandia Labs


Image provided by Sandia Labs

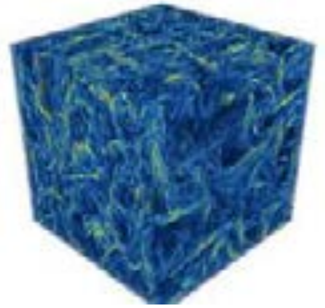


Photo by Los Alamos National Laboratory

Explain:

As you explore each of the types of safety and security provided by our National Labs, match the picture to the specific type of security it exemplifies. You can check your answers by visiting the Image Gallery at each of the labs listed to learn more about each image and how it plays into the mission of each laboratory. Make sure you check the different STEM careers through the Women @ Energy site to learn more about careers in Safety and Security.

THE
DREAMER

Innovative Technologies

Thinking creatively allows us to develop exciting products and innovative technologies that can be used to better human lives. It is incredible how many things you use every day that were created by the U.S. Department of Energy engineers. With our imagination, we push the boundaries of possibility every day to invent things that benefit people in our country, around the world, and beyond.

Scientific research at the U.S. Department of Energy has produced technologies used to build fuel efficient cars, light up our TVs, discover new forms of medicine, create new materials that make up everyday things in our living rooms, and even pave the way for space exploration. All of these things contribute to healthier and more fulfilling lives for all of us.

Researchers at the Pacific Northwest National Laboratory are developing new technologies to treat cancer directly at the tumor site, minimizing side effects caused by whole-body cancer treatments.

“Never underestimate the power of dreams and the influence of the human spirit. We are all the same in this notion: The potential for greatness lives within each of us.”

Wilma Rudolph

Overcoming polio as a child, Rudolph went on to become the first female triple Olympic gold medalist in track and field.

Images on the left/right: STEM professionals at the U.S. Department of Energy

Girls of Energy

INNOVATIVE TECHNOLOGIES CHALLENGE

HOW CAN YOU MAKE A SMARTPHONE INTO A MICROSCOPE?

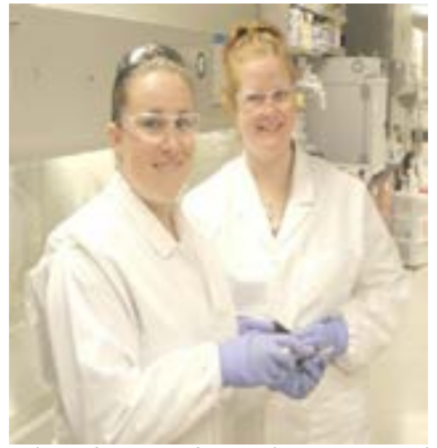


Photo from Pacific Northwest National Laboratory

Summary: This activity exposes students to a new technology called a Smartphone Microscope. Students will gain an understanding of the historical context of microscopes and their function, collect data (images) and brainstorm how this technology might be used in all STEM (science, technology, engineering and math) disciplines and careers.

Background: At the heart of innovation, creativity meets function. How did two of our engineers at the Department of Energy's Pacific Northwest National Laboratory located in Richland, Washington come up with their design for a Smartphone Microscope? Well—they were trying to solve a problem!
Rebecca Erikson and Janine Hutchison (pictured) describe in their own words how they identified a problem and created a technology to solve it: "We interviewed a lot of first responders, public health labs and civil support teams. They told us when confronted with a suspicious white powder, the first thing they do is send a sample to the lab where it is put under a microscope. An inexpensive yet powerful microscope in the field could be used to quickly determine whether the material is a threat or a hoax. Listening to their needs we were quickly reminded of a very early microscope—the Leeuwenhoek Microscope, which used a single glass sphere to provide magnification. Taking his lead, we used an inexpensive glass sphere and put it into a housing or clip that we designed and printed on a 3D Printer. Combining this microscope with the great cameras found on cell phones and tablets, we were able to create a very inexpensive microscope that has applications beyond first responders."

Learning Objectives - after this activity, students should be able to:

- Explain the historical context of the microscope and the structure of van Leeuwenhoek's instrument
- Describe how the Smartphone microscope works
- Compare and contrast the terms reflection and refraction
- Use the microscope and collect data (images), experiment with different types of specimens and analyze the different structures from patterns in the data
- Brainstorm other uses for the microscope
- Identify STEM careers that could use this microscope as a tool (Be sure to check the Women@Energy site to investigate different STEM careers at http://energy.gov/diversity/listings/women-energy)

Introduction: In the mid 1600's, van Leeuwenhoek (pictured) used his imagination and curiosity to construct a single lens microscope. Most microscopes we use now are called compound microscopes which mean they use more than one lens to magnify an image. Van Leeuwenhoek ground a bead of glass very small to be used for the lens. He was actually able to see things much clearer than scientists that used the compound microscopes at that time. When light hits an object, it can be reflected, which means the light exits the source at an angle directly back or it can be refracted which means that the light exits the substance at an angle that looks offset. Light moves differently when it passes through different substances. When light changes course, it "bends" as it moves through a glass bead and produces a point where all of the light converges. This is called the focal point and its distance from the lens is called the focal length and determines the magnification of an object. The smaller the lens, the shorter the focal length and the result is a higher magnification. The bead you will be using in your microscope magnifies 100X (100 times) and there are also beads that magnify 350X and 1000X.

*Links to open source 3D printing directions for the clips to hold these beads and a source to buy the beads are included at the end of this activity.

Activity - What is Reflection and Refraction?

Materials:

- Light source i.e., flashlight or laser pointer, or natural sunlight
- Samples to be studied
- Glass of water
- Straw
- Mirror

Procedure: In order to understand reflection, point your selected light source at a mirror. The angle of incidence (the angle at which the light hits the reflective source) is equal to the angle of reflection (the angle at which the light exits the source). For refraction, you will use a transparent glass of water and a straw. Put the straw in the water and observe. Does the straw look bent? Light moves in air at a different speed than in glass or water. Therefore, the angle of incidence is larger than the angle of refraction so the straw looks bent.

The tiny glass beads that are used in the microscope are actually put in paint that is used on roadways. Have you ever noticed that when you are driving at night that there are certain roadways which reflect the light from your headlights more intensely? That is because the roadway paint has embedded glass spheres that reflect the light from headlights at a more directed angle, back to the driver's eye. If you have access to a vial of these glass beads, shine a light on them and experience the reflective effect.

*If you want to explore further, there is a reflection animation and a virtual experiment on refraction (http://www.physicsclassroom.com/Physics-Interactives/Refraction-and-Lenses/Refraction/Refraction-Interactive)

Activity - Smartphone Microscope: What is a microscope? What does it help us do? You need to think about what you might want to look at more closely with your microscope and collect those items as samples to be studied. We have provided some suggestions for samples, but anything you can think of will be interesting. One thing to keep in mind, light needs to be able to travel through your sample to the glass bead and the lens of your camera. Also, you can use the microscope with your phone's front or rear-facing camera, but remember there is a difference in resolution between those two cameras. For example, the front camera on an IPhone6 is 1.2 Megapixels, while the rear camera is 8.0 megapixels, meaning the rear camera has a more powerful lens. If you use a camera on the back of your device, you will want to turn the flash to "ON" to illuminate your sample.

Materials

- Tablet, smartphone or digital device with a camera
- Smartphone Microscope
- Samples to examine (Suggestions)
  - Any type of leaf or grass, corn or algae
  - Flowers, butterfly wings or feathers for structural components
  - Salt, sugar, or baking soda
    - You can use a clear piece of adhesive tape to attach crystals
    - Make sure you place the crystal side of the tape directly on the microscope.
    - If you use tape, what else do you see? (You can see the adhesive that is used on tape to make things stick.)
  - Paper money
  - Strands of thread, hair, dust particles, lint
  - Different spices such as pepper, cinnamon, etc.

Procedure: Examine your microscope and clip. On the branded side of the clip you will see a glass bead. Turn on your camera App and attach the clip to your phone, tablet or digital device, placing the glass bead in line directly with the lens of your camera.

Take your sample (remember, light must be able to pass through it), and place it directly over the glass bead. Then move your sample very slowly until you think the object has the best focus. Collect your data by taking a picture of your image.

As you study your images, what patterns can you see emerging from your different samples? What would you like to look at next? What are other ways you can think about using this microscope? Which other STEM careers could use this microscope as a tool for investigation?

Enrichment: As a fun add-on to this activity, each student can send their favorite image to their educator, and the educator can share the images with the group. For each image, the group can study the image and guess the origin of the sample. Each student should present their image with the name of the sample and magnification used.

For comparative purposes, students might take a picture of their object without the magnification and then a second image using the microscope. How do these two images compare?

Putting the A in STEAM? If you would like to integrate the Arts, make a collage of all of the images taken by students and display on classroom walls or the halls of your institution.

Next Generation Science Standards (5):

4-PS3 Energy Students who demonstrate understanding can use evidence to construct an explanation relating the speed of an object to the energy of that object.

Science and Engineering Practices:

- Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. (4-PS3-3)
- Use evidence (e.g., measurements, observations, patterns) to construct an explanation. (4-PS3-1)

Disciplinary Core Ideas:

- Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (4-PS3-2), (4-PS3-3)
- Light also transfers energy from place to place. (4-PS3-2)

Cross-cutting Concepts:

- Energy can be transferred in various ways and between objects. (4-PS3-1), (4-PS3-2), (4-PS3-3), (4-PS3-4)

Science affects everyday life. (4-PS3-4)**4-PS4** Waves and Their Applications in Technologies for Information Transfer

- PS4.B: Electromagnetic Radiation

Disciplinary Core Ideas:

- An object can be seen when light reflected from its surface enters the eyes. (4-PS4-2)

Cross-cutting Concepts:

- Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena. (4-PS4-1)

MS-PS3 Energy

Cross-cutting Concepts:

- Science knowledge is based upon logical and conceptual connections between evidence and explanations (MS-PS3-4), (MS-PS3-5)

MS-PS4 Waves and their Applications in Technologies for Information Transfer

MS-PS4-2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

Science and Engineering Practices:

- Develop and use a model to describe phenomena. (MS-PS4-2)
- Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings. (MS-PS4-3)
- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS4-1)

Disciplinary Core Ideas:

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2)
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. (MS-PS4-2)

Cross-cutting Concepts:

- Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations. (MS-PS4-3)

Sources:

- Picture of van Leeuwenhoek: http://www.vanleeuwenhoek.com/images/Antonie van Leeuw Enhoek-Jan%20Verkolje-1632-1675.jpg
- Image for angle of incidence and angle of reflection (animation): http://www.physicsclassroom.com/mmedia/optics/lr.cfm
- The Refraction Interactive (with two activities and teacher notes): http://www.physicsclassroom.com/Physics-Interactives/Refraction-and-Lenses/Refraction/Refraction-Interactive
- Women at Energy site showcasing science and engineering women at the Department of Energy http://energy.gov/diversity/listings/women-energy
- Next Generation Science Standards http://www.nextgenscience.org/
- PNNL website for 3D print files for microscope clip and resource for glass beads http://availabletechnologies.pnnl.gov/technology.asp?id=393

INNOVATIVE TECHNOLOGIES CHALLENGE

POWER UP ACTIVITIES FOR SMARTPHONE MICROSCOPE LESSON

ACTIVITY ONE:

WHAT IS REFLECTION?

Students will use a laser pointer or flashlight and a mirror to study reflection and note angles of incidence and reflection

Materials

- Laser Pointer or Flashlight
- Dark Room with a mirror

Question:

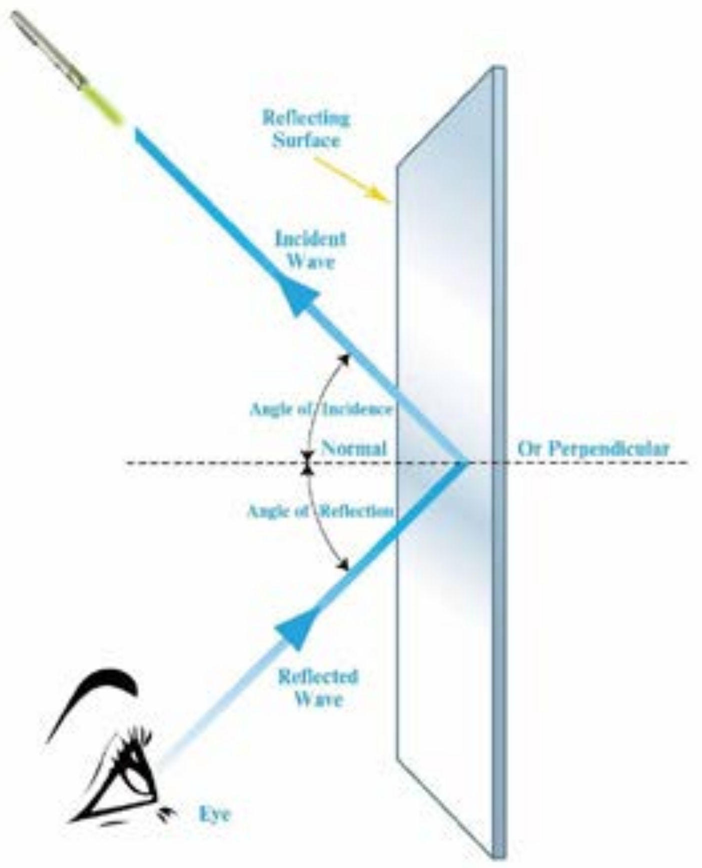
What is Reflection?

Explore:

Find a dark room that has a mirror so you can observe the light from a laser pointer (preferred) or a flashlight as it hits the mirror. Does the light bounce reflect? In which direction? How do the two angles compare? Another option would be to trace the path of the light using a white base like foam board and drawing utensil. Using a protractor, measure the angle of incidence and the angle of reflection.

Explain:

When light hits a reflective surface, it reflects at an angle equal to the incident angle. This can happen when almost all of the light is reflected, but it can also happen when only some of the light rays are reflected.



ACTIVITY TWO:

HOW IS REFRACTION DIFFERENT FROM REFLECTION?

Students will use a glass, liquids and a straw to examine how light "bends".

Materials

- Transparent Glass
- Water
- Colored Straw

Question:

How is Refraction different from Reflection?

Explore:

Take a colored straw and place it in an empty, transparent glass. Sketch how the straw appears when you observe from the side of the glass. Now, put water in the glass until it is ¾ full. Sketch what you see now when you look through the side of the glass.

What happened? How does the straw look different? Why do you think it looks different? What other liquids could you put in the glass and observe? How would these look the same—or different?

Explain:

Light energy moves through different substances with different speeds; this is called refraction. What our eye perceives comes from the refraction or bending of light due to movement through different substances. Light moves through air, water and glass at different speeds and that is why the straw appears bent. As enrichment for this activity, try this again using salt water or sugar water (with as much solid as the water can hold), syrup or oil.

Does the straw look different in each case? You can measure each angle and you can also use images of each. Explain which substance refracts more from your data and observations.

ACTIVITY THREE:

DESIGN YOUR OWN REFRACTION VIRTUAL EXPERIMENT

Students will design their own interactive refraction virtual experiment.

Question:

Can you observe how light changes speed when moving through different substances?

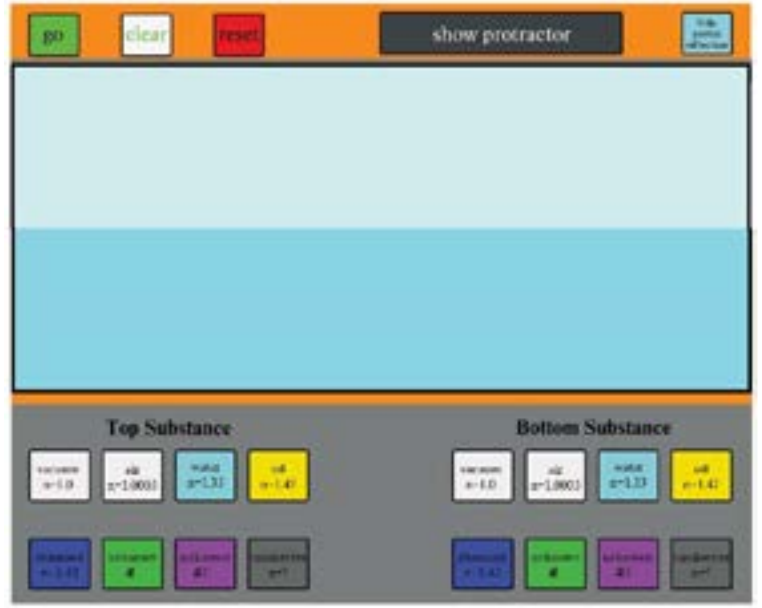
Explore:

Use this link to interactively explore how a light ray changes when passing through different substances. In order to become familiar with this interactive display, use your cursor to manipulate all of the various pieces. You can move the laser, fire the laser, use the protractor to measure angles and change the top and bottom substances to investigate varying speeds. It might work best if you select the “Hide partial reflection” button so you can see the major reflection and refraction paths of light. If you want to collect data, you can use the protractor to measure the different angles of incidence and refraction. This will help you reference how quickly light moves through different substances.

Explain:

Light moves at different speeds as it continues through different types of mediums. This interactive experiment allows students to investigate the various ways light is reflected and refracted depending on the types of materials used. This can be a simple tool to observe how light moves, but it can also be used to investigate different types of materials.

Which material bent the light at a larger angle? Which material bent the light at a smaller angle? How do those observations compare to the n value noted for each substance?



ACTIVITY FOUR:

LIGHT IS ENERGY-CAN YOU SEE THIS?

Students will use a Wint O Green Lifesaver® to examine how light is emitted when electrons are excited and return to a lower energy state.

Materials:

- Wint O Green Life Saver®
- Dark Room
- Mirror

Question:

How can you see Light Energy?

Explore:

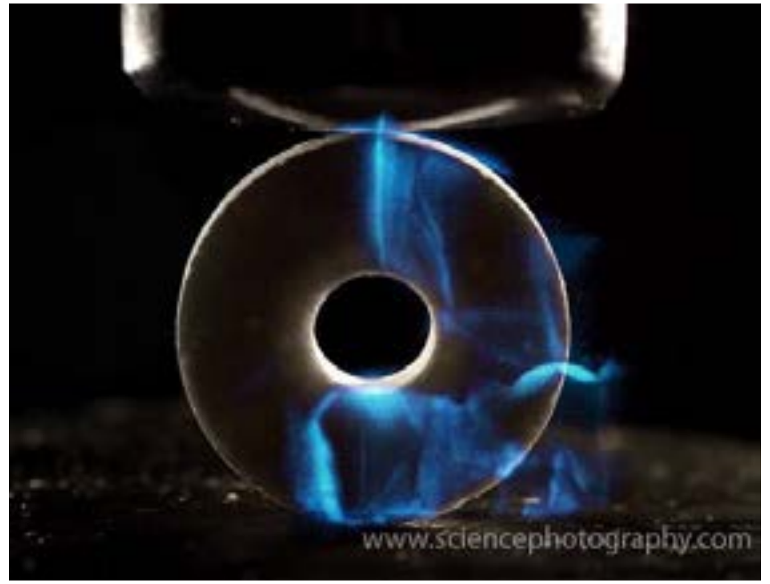
Take a Wint O Green Lifesaver® and go somewhere very dark with a mirror. Bite down on the mint and watch in the mirror to see what happens. As an alternative, you can put a few candies in a baggie and use a pair of pliers to break them.

Did you see a spark? What color was it?

Explain:

Wint O Green Lifesavers® contain a special ingredient called oil of wintergreen. This oil has a special property that absorbs energy waves we cannot see with our eyes (ultraviolet) and emits them as light that we can see. When you crunch on a candy, you disturb and excite electrons. When they lose the energy you gave them by crunching (kinetic energy), you will see that extra energy given off as blue light. Sometimes the electrons excite the nitrogen in the air as well, making the blue color more pronounced.

Light is energy and can be used in many different ways. Your Smartphone Microscope would not function without the light waves entering through the glass bead and bending to help produce an image that your eye can detect.



ACTIVITY FIVE:

REFRACTION AND CONVERGING LENSES — WHAT MAKES THE WORLD UPSIDE-DOWN?

In this activity, students will learn about converging lenses and try their hand at capturing an image that shows a converging lens.

Materials:

- Smartphone Microscope
- Digital Device with a Camera
- Transparent Glass
- Magazine or Newspaper
- Magnifying Glass
- Water
- Glass Bead

Question:

What makes the Department of Energy sign appear upside-down?

Explore:

In order to understand more about lenses and how the glass bead works as a lens in the Smartphone Microscope, we will use rounded transparent substances to demonstrate how light moves through a lens. Take a transparent glass and a magazine or newspaper and place the empty glass on top of the newspaper.

What do you see?

Now move the glass further away from the print—what happens to your image? Examine the bottom of the glass—does it appear to be the same thickness or thicker in one area?

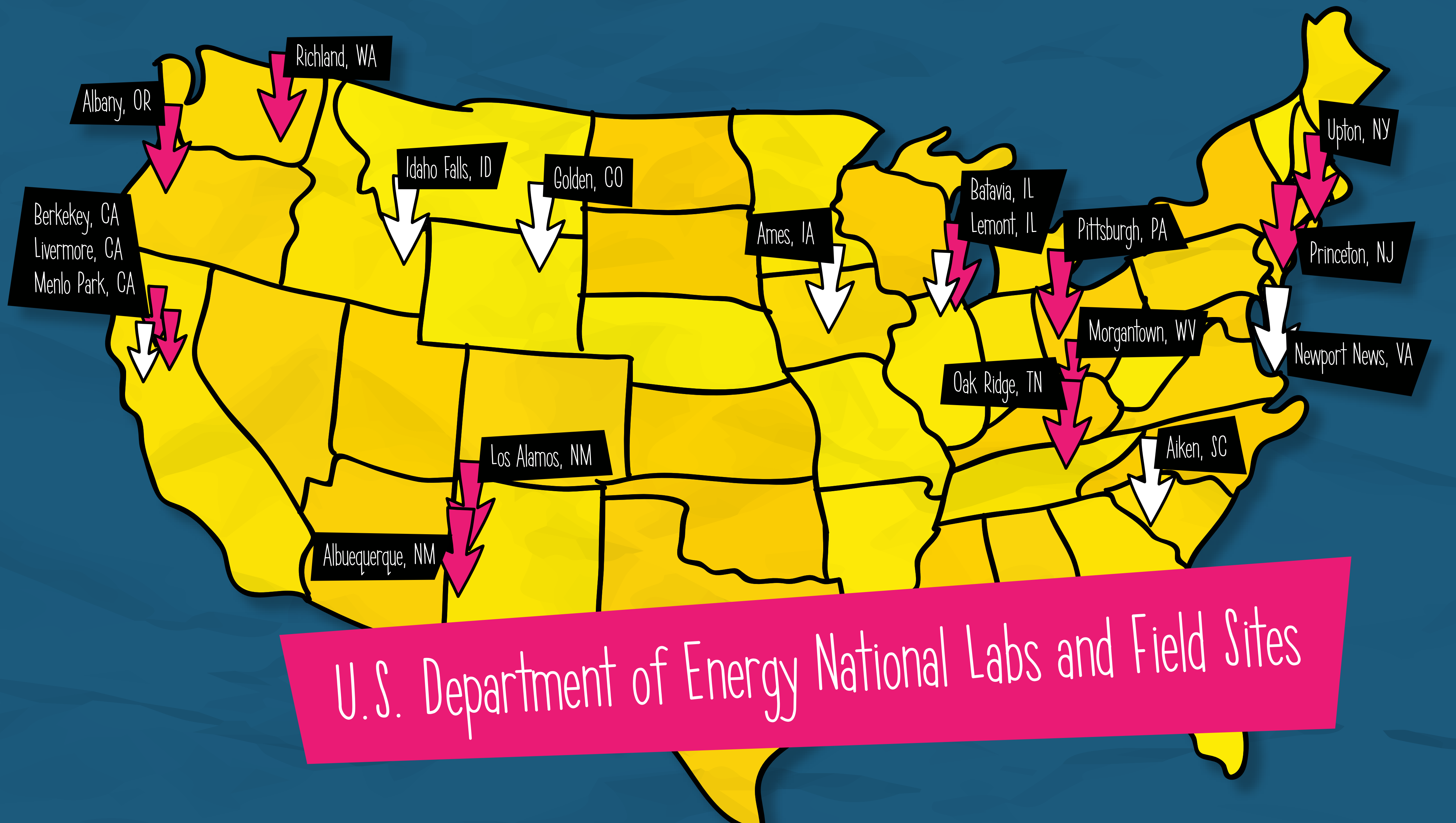
Use a magnifying glass and look at the same newsprint. What happens? Examine the magnifying glass and see if it has a uniform thickness or if it has areas that are thicker or thinner.

Using your glass bead, look at the newsprint—what do you see? Place 1 drop of water over a letter on the newsprint—what do you observe? Do things appear larger? Are they right-side up or upside-down?

Explain:

A converging lens is thicker in the middle and thinner around the edges. As light bends around the edge of the lens, it converges at the focal point. If the sample you are studying is between the focal point and the lens, the object appears right side-up and magnified. If the sample is beyond the focal point, the image appears upside-down and magnified. If you have a camera, see if you can take pictures of things that can be used as a converging lens. Water droplets hanging on a tree branch after a rainstorm work well as converging lenses! How do your collected images compare to the picture?

The amazing scientists and engineers in the U.S. Department of Energy National Labs are not much different from you, but they get to solve the most fascinating scientific challenges of our time: from combating climate change to discovering the origins of our universe.



Here are a few highlights of remarkable things that are happening in our Labs.

Argonne National Laboratory
Lemont, Il
Using (rain)cloud computing to predict climate change for the next 100 years

Brookhaven National Laboratory
Upton, NY
Using PET scans to reveal the way plants store and move energy, helping scientists engineer better crops for use in renewable biofuels

Lawrence Berkeley National Laboratory
Berkeley, CA
Working to solve one of the universe's greatest unsolved mysteries: dark matter

Lawrence Livermore National Laboratory
Livermore, CA
Exploring the use of metal 3D printing to create strong, lightweight structures for advanced laser systems—an effort that could alter the way lasers are designed in the future

Los Alamos National Laboratory
Los Alamos, NM
Demonstrating superior light-emitting properties of quantum dots that can be applied in solar energy by helping more efficiently harvest sunlight

National Energy Technology Laboratory
Albany, OR; Morgantown, WV and Pittsburgh, PA
Playing a key role in updating a 25-year-old testing standard that helps ensure quality, reduce cost, decrease waste, and support safer oil and gas operations around the world

Oak Ridge National Laboratory
Oak Ridge, TN
Providing the open scientific community access to America's fastest, most powerful supercomputers and addressing some of the biggest challenges and problems of our time

Pacific Northwest National Laboratory
Richland, WA
Developing new technologies to make even greater improvements in energy efficiency and larger reductions in energy consumption

Princeton Plasma Physics Laboratory
Princeton, NJ
Developing the scientific understanding and key innovations needed to realize fusion as an energy source for the world

Sandia National Laboratory
Albuquerque, NM and Livermore, CA
Designing gigantic blades longer than two football fields could help bring offshore 50-megawatt (MW) wind turbines to the United States and the world

Learn more about our National Laboratories at energy.gov

Take Action

Not all of us are scientists or engineers, but we can still play a role in taking care of the planet. Even the small things like conserving, recycling, observing, and getting creative can make a big difference.

CONSERVE energy by turning off things that use electricity when you don't need them. Electronics that are plugged into an outlet draw energy even if they are turned off. Plug your electronics into a power strip and you only need to flip one switch to turn them all off.

OBSERVE how many energy safety features you can find in your home. If you have a younger sibling, do you cover the outlets with plastic covers? Look at your outlets in the bathrooms or kitchen. Do you see the test and reset buttons designed to prevent electrical shock?

RECYCLE your gently used items. Most people don't consider that it takes energy to make new things. Donating things you no longer need is a great way to reduce energy use and save other people money.

OBSERVE how many solar panels you see the next time you are travelling around your neighborhood or city. Can you imagine if every house had one?

GET CREATIVE What is the best natural energy source where you live? Is it rivers or the ocean, the sun or the wind? If you could choose, what should be the future power sources for your city?

These are just a few quick examples, but there are many more things that you can do. Ask your parent, teacher, or mentor other ways that you can learn more about the science of energy and contribute to solving our energy challenges.

What will scientists work on in the future?

As the years go on, our energy challenges will get more exciting and complex. Some challenges are yet to be uncovered. If you have the passion, there are plenty of opportunities to get involved and create imaginative solutions for tomorrow.

Please go to **energy.gov/girlsofenergy** to find more activities, more scientist profiles, and the latest about our four biggest energy challenges: being smarter about power sources, increasing energy efficiency, ensuring energy safety and security, and creating new innovative technologies. Remember, be bold and embrace your interests and passions.

How do we store renewable energy effectively so we can use it later? And not just for our country, but also to share it with others in the world.

How do we build an energy system that is safe from intrusion and can withstand even the most extreme of weather conditions?

What cool materials or medicines can we invent next? How can we apply them to our everyday lives?

We have already released harmful particles into the air, and they are contributing to global warming, weather changes, and pollution. How do we limit their impact on us and future generations of people who live on our planet?

How do we engineer a more efficient energy grid, so that none of the power it produces is wasted?

Check out
energy.gov/girlsofenergy

energy.gov/girlsofenergy

STEM professionals at the U.S. Department of Energy

For more information, visit:

energy.gov/girlsofenergy

Co-produced and published by:

Vexillum Ventures

Prepared by:

MINORITIES IN ENERGY INITIATIVE

U.S. DEPARTMENT OF ENERGY

DOE/ED-0002