Fusion Energy

STARFINDER
PROGRAM 10

Instructional Objectives

After viewing the program and participating in the accompanying activities, the student will be able to:

1. describe the process by which the natural repulsion of atoms is overcome and thereby produces energy,
2. explain that stars use fusion energy, and
3. compare and contrast the current advantages and disadvantages of fusion energy as a source of energy on earth.

Synopsis

In this program, students are presented with the unlikely role of tiny atoms as the source of the incredible power of the sun. Each day these infinitesimal particles produce more energy than all the power plants on earth combined. Animation and in-studio demonstrations explain the process of atomic fusion of hydrogen atoms in solar activity. As viewers see a fusion reactor in Oakridge Tennessee, the dilemma of trying to use fusion energy on earth is introduced—currently, the heat that is needed to fuse hydrogen atoms is so high, those reactors that do not melt in the process end up using more energy than they produce.

Students will be introduced to an amateur astronomer who has been selected to carry out an observation with the Hubble Space Telescope in "The People Behind the HST."

Vocabulary

$E=mc^2$ - An equation developed by Einstein, representing the concept that matter and energy are actually different forms of the same thing. In other words, matter can be converted into energy and energy can be converted into matter. This equation allows one to determine how much energy there is in a particle of matter.

Fission - The process in which the nucleus of one atom splits to form two nuclei, releasing energy in the process.

Fusion - The nuclei of two or more atoms join together to form one new atom, releasing energy in the process. The amount of energy released by fusion is greater than that released by fission.

Helium - The second lightest element, usually made up of two protons, two neutrons, and two electrons. Helium is usually the end product of a hydrogen fusion reaction.

Hydrogen - The lightest element, usually made up of one proton, one electron and no neutrons. Hydrogen is the element most likely to undergo a fusion reaction.

Mass - A measure of the total amount of matter contained within an object.

Nucleus - The positively charged core of an atom, comprised of protons and (except for hydrogen) neutrons.

Reactor - A device used to release energy from atoms for peaceful purposes. Fission reactors split atoms to produce energy; fusion reactors attempt to join atoms to produce energy.

Speed of Light - The fastest speed that anything can move, equal to approximately 186,000 miles per second.

Previewing

Discuss the vocabulary terms.

Use a pair of magnets to remind students that like poles repel one another. Place magnets on dowels or rollers with like poles facing one another. When rolled slowly towards each other, they will repel, but if pushed rapidly towards one another, they will make contact.

Introduce the differences between fission and fusion energy.

Postviewing

Discuss the latest information received by the Hubble Space Telescope.

Discuss the roles of amateurs in astronomy or other sciences.

Provide information on astronomy clubs in your area. Help students set up an amateur astronomy club at school.

The ancient Greeks thought that atoms were unbreakable and the smallest possible particle. Even as recently as the 1800s scientists still believed atoms were tiny balls unable to be broken down. Have students research how knowledge of atoms has progressed through the ages. What do scientist now believe is the smallest component of an atom? A good source of the history of atomic research is found in *How Did We Find out about Atoms?* (Asimov, 1976).

Have students research the controversy over nuclear energy, comparing and contrasting nuclear fission and fusion. Set up an organized debate, assigning students pro or con stances on the use of nuclear power plants; whether or not government research money should go to nuclear fusion; would they want a nuclear power plant in their community.

Active Involvement

To demonstrate that atoms and molecules are in constant motion, place a few drops of food coloring into a glass of water. After 24 hours, the color will be completely dispersed through the water. This could only happen if the molecules of water are in motion.

Students can use two balloons to simulate the natural repulsion of atoms which are naturally surrounded by electrons carrying a negative charge. Tie a string to each balloon and hang them together from a stick. Make note of the fact that the balloons touch. Now, have students rub each balloon against their hair or sweater to build up a negative electrical charge. Discuss the reasons that the balloons have spread apart. Point out the fact that the negative charges now surrounding the balloons are similar to the negative charges surrounding atoms. Note: This works best on a dry day.

To provide a glimpse of the tremendous energy of the sun, students can focus some of the sun's energy. This experiment should be carried out under the supervision of an adult. Place a dry leaf or piece of paper in a metal pan under direct sunlight. Position a magnifying glass above the pan so that the light of the sun is concentrated and focused directly on the leaf or paper. Before long, the paper will begin to burn. This is similar to the way the eye focuses light on the retina, so you may wish to extend this activity to explain why no one should look directly at the sun. Make note of the fact that despite the intense energy concentrated in this small beam of light, the solar energy received on earth is only 1/two billionth of the total energy released by the sun, 93,000,000 miles away.

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See For Yourself: Experiments/Projects

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Seeing Mass Converted to Energy

A calorie is the amount of heat needed to raise the temperature of one gram of water one degree centigrade. It often refers to the energy produced by food when it is used, or "burned," by the body. This experiment demonstrates the energy produced when a walnut is burned. Try it with foods that contain more calories or fewer calories than the walnut, and compare the amount of energy produced when each is burned. Note: On earth, mass and weight are equivalent.

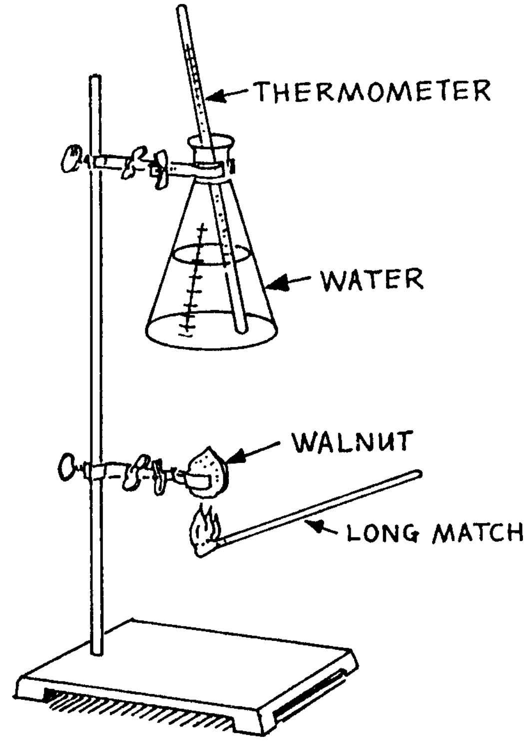
▶MATERIALS:

- graduated flask filled with 100 mL. water
- walnut (shelled)
- long match, such as one used to light a fire in a fireplace
- stand
- two clamps
- thermometer

▶DIRECTIONS:

Set up stand with flask of water directly above the walnut (see diagram).

1. Record the temperature of the water.
2. Weigh the walnut. Record the weight.
3. Using the long match, start the nut burning. Immediately after the nut has finished burning, record the temperature of the water. Record the difference in temperature from step 1 to see the increase in heat (energy).
5. Record the weight of the burned nut. How much mass (weight) was lost in the burning? To determine this, subtract weight after burning from the weight recorded in step 2.
6. In order to see the relationship between mass (weight) and energy (heat), make a bar graph of your experiment, showing the water's temperature and walnut's weight before burning, and the water's temperature and walnut's weight after burning. Does the walnut's weight increase or decrease with burning? Does the water temperature increase or decrease? Why?



7. You may want to repeat this experiment with other foods. Find some that are higher in calories and some that are lower in calories than the walnut. Compare the water temperature gains and the weight changes when different foods are burned. Add these results to your bar graph.

Make sure the burning food is always the same distance from the flask, and you always let the water return to room temperature before you start a new experiment.

Conversion of Energy to Mass

One simple way to see the conversion of energy to mass is to set up an experiment to see green leaves making food from sunlight, the energy of the sun. You may be familiar with photosynthesis, the process by which plants use carbon dioxide, water and energy (in the form of light) to produce glucose and oxygen. This process could not take place without the energy from the sun. You can test for glucose, a starch, with tincture of iodine. When applied to a starch, the iodine turns blue to blueish-black.

▶MATERIALS:

- one green plant and one coleus plant that have been in the sunlight for several hours
- green plant that has been out of the sun for several days
- 1/4 cup alcohol
- tincture of iodine
- boiling water
- double boiler, or small wide neck jar to hold over boiling water
- square of glass or tile

▶DIRECTIONS:

1. Draw a picture of the green leaf. Describe the color. Bring the uncovered jar of alcohol to a boil by heating over boiling water (never heat alcohol over an open flame). Place the leaf in the boiling alcohol to remove the chlorophyll and then transfer to a pan of hot water.
2. Place the leaf on the glass and cover with the iodine. Record the color of the leaf.
3. Repeat the procedure with leaf of a green plant that has been out of the light for several days. Record the color of this leaf and compare to the leaf in step 1.
4. Draw a picture of the coleus leaf, labeling the different colors. You may wish to use colored pencils.
5. Place the leaf in the alcohol and hot water, and then cover with the iodine. Draw and label the differences you observe in the leaf. Note: The pink and white areas of the coleus leaf do not contain chlorophyll, and so the iodine remains brownish, but the maroon areas of coleus leaf are a combination of green and pink pigments, and so have chlorophyll.

Math Fun with Energy

Einstein's equation of $E=mc^2$ shows us that a very tiny amount of mass will produce an enormous amount of energy. Mathematically, this is because the speed of light (186,000 miles per second) is so large, squaring it produces a tremendously huge number.

1. Calculate the square of the speed of light, 186,000 miles per second. Record this number. Write out the words for this number.
2. How much energy would be released if you were completely converted to energy? You can figure this out by inserting your mass (your weight) into the equation.

   $E = mc^2$
   Energy = mass X the speed of light squared
   Energy = Your weight X $186{,}000^2$ or
   Energy = Your weight X (1.86×10^{10})

Science Career Profile

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RAY STERNER

Amateur Astronomer with observing time on the HST
Education: B.S. Math/Physics
M.Sc. Radiation Health
M.S. Computer Science

Ray Sterner is a person who has seen his love of astronomy land him a place in science history. Although not employed as a scientist or astronomer, his physics, math, and computer background, along with his enthusiasm for astronomy and his sleuthing ability, have paid off. He is one of a select number of amateur astronomers who will get to use the Hubble Space Telescope. How could someone who works in the submarine department of an applied physics lab, someone who has never even taken a class in astronomy, get such a unique opportunity?

Ray grew up in the countryside of Pennsylvania, far from the glow of the city lights. On starry nights, Ray, accompanied by his Saint Bernard, would sleep outside so he could watch the stars in the sky. One of the first things he remembers seeing was a comet, which he mistakenly referred to as a "comic." The next year, he anxiously watched for a glimpse of Sputnik, the first satellite placed in orbit around the earth. While still in elementary school, Ray received a small refractor telescope, but quickly exchanged it for something better, a 6" reflector. By high school, he was able to purchase a used 12" reflector telescope. He read many astronomy books and magazines to learn and understand more.

The college that Ray attended had no astronomy courses, but his combined major of math and physics not only prepared him for his career as a mathematician at the Johns Hopkins Applied Physics Lab, it gave him a good background for understanding the structures and processes associated with astronomy.

Ray became especially interested in what happens when two galaxies collide. He wrote a program for his computer that would image these occurrences. With his program, he could see how the collision between two spiral galaxies creates two very distinct spiral arms. He then set up the program to illustrate the collision between two disk galaxies. When the collision was head on, they formed a ring galaxy, but when one galaxy was off center, the resulting pattern was that of a broken ring.

Soon after he completed the computer program, he came across an article about a "mysterious luminous arc." Astronomers had discovered an arc-like shape in the sky that they could not identify. Ray, thinking this shape looked much like the broken ring created by the colliding ring galaxies on his computer, copied the article, scaled the picture to the size of his computer program and found them to be a close match. Could he hold the answer to the astronomers' question?

The connection was not easy to make, for even though the size and shape appeared to match up, the color and brightness did not. Ray had to do a lot of reading and scientific sleuthing to find a possible answer. Finally, he came across some literature about hot blue stars that are formed when galaxies collide. This would explain the color and brightness, but Ray knew that these stars are always young—they're so hot they burn themselves out quickly. And if this arc was what he thought, it was probably too old for astronomers to still be seeing the stars formed at the time of the collision. So Ray kept reading until he found that strong stellar winds could compress nearby gasses to form new stars. X-ray images suggested that in a typical cluster of gas, there was indeed enough gas for this to have taken place. His theory now seemed a distinct possibility.

After hearing a lecture on the space telescope, Ray decided to try to get observing time with the Hubble Space Telescope. His proposal was accepted. Although he now has to wait a few more years to make his observations, Ray is still excited about the opportunity to use the first space telescope.

Ray continues to read and learn as he awaits his turn to use the telescope. He has lots of ideas on how to get more people interested in astronomy. He claims there is a wealth of "hidden information" that many would find fascinating if it were easier to find and read. For example, have you ever heard of the "great wall"—not the one in China, but a wall of galaxies that astronomers believe is 500 million light years long! Fun facts like these could get people interested in astronomy.

Right now, Ray is looking for a piece of level ground to make a new kind of map to help people visualize the immense size of our solar system. He'll need a lot of land, because if he makes the sun one foot in diameter, it will take a full mile to fit in all the planets to scale.

Ray suggests that students explore a subject that interests them instead of watching TV. Even difficult subjects will get easier and easier to understand, and increasingly more interesting as you read and learn. Don't be afraid of subjects like math—make them fun. As a kid, Ray liked to think up crazy calculations and then figure them out.

To start out, young astronomers don't need to buy an expensive telescope. With a star map and a pair of binoculars, you can locate and see the details of many objects in the sky, even asteroids. To learn more, you can read astronomy magazines and join an astronomy club. The club Ray belongs to provides support and information through speakers, monthly meetings, newsletters, star parties, and open houses. Some clubs even have special groups for kids.

Content Consultants for StarFinder - Program 10

Eric Chaisson
Space Telescope Science Institute
Operated by AURA for NASA

Eric Flescher
Shawnee Mission West High School
Shawnee Mission, Kansas

Ed Griffin
Glen Burnie High School
Glen Burnie, Maryland

Anita Stockton
Baltimore County Public Schools
Towson, Maryland

Teacher's Guide

Writers
Barbara Bourne
Patricia Murphy

Editor
Kate Harrison

Illustrator
Robert Jones

Logo Design
Dave Weaver

Graphic Designer
Bob Lindler
The Design Co-op

Typesetting
Blue Heron Typesetters