What is Energy?

What is energy? Most of us have a feeling that we understand energy and recognize it when we see it, but coming up with a formal definition might be harder for us to do. In this section we introduce the concept of energy by having students investigate a variety of toys. They are given a list of the various categories and types of energy and are asked to form a working definition of what energy means. A series of videos and reading selections help them solidify their definition into an authoritative version.

- Lab Investigation—Exploring Energy
- Video—What is Energy?
- *ChemMatters* Reading—The Amazing Drinking Bird
- *ChemMatters* Reading—Thermometers

Exploring Energy | A Lab Investigation

Summary

Energy as a concept is both familiar and vague. Most students have a good operational definition of energy, but may not be able to verbalize a good formal definition. The purpose of this lab is to solidify student ideas of energy by providing several examples of objects whose use or operation involve energy and provide clear definitions that describe what energy is and is not.

Objective

Students will explore the definition of energy by making careful observations about simple toys that illustrate basic principles of energy.

Safety

- Goggles or safety glasses should be worn when working with any materials that can spill or splash or those that can pop or jump with any force.
- Do not cut or tear open light sticks, chemical hand warmers, or cold packs. If any materials leak from these items, clean up spills with water. Wash any chemicals from your skin with water.
- Jumping discs and poppers can react with significant force to cause injury to the face and eyes. Keep your face away from these objects.

Materials for Each Group

Here is a sample list. Collect your own devices based on what you have available and your budget. Consider asking students to bring in a household device that involves energy.

- Battery-operated flashlight
- Clock with "glow in the dark" face
- Small mechanical toy (like a wind-up car)
- Drinking bird toy
- Chemiluminescent glow or light stick
- Chemical hand-warmer
- Emergency cold packs
- Bi-metallic jumping discs
- Polymer or "poppers" toy
- A hand-wound or spring-operated music box

Time Required

One class period, approximately 45–50 minutes.

Lab Tips

A number of household objects and toys have been suggested for use in this investigation, but the final selection can be modified to whatever you have on hand. Try to choose objects that display a variety of forms of energy. Since this is a formative type of investigation, it is not critical that students are perfect in their assessments of the type of energy present or the transitions that take place. Rather, use their observations and class discussion to clarify their understanding of the concept.

Pre-Lab Discussion

This lab is basically an informal formative assessment of what students know about energy. It is a good chance to clarify student ideas about energy by identifying what is and what is not considered to be energy.

Integrating into the Curriculum

This investigation could fit into a unit on thermochemistry.

PREPARING TO INVESTIGATE

What is energy? Most of us have a feeling that we understand energy and recognize it when we see it, but coming up with a formal definition might be harder for us to do. Here are some of the basic concepts associated with a definition of energy:

- Energy is required to make things change.
- Energy is the ability to do work. The kind of work we are talking about is not like going to a job or doing chores. We are talking about work as defined in the physical sciences.
- Work is the application of a force to move an object in the direction of the force, such as when you pedal a bicycle or an electric motor lifts an elevator.
- A force is an influence that can cause an object to move or stop an object that is already moving. Think about how brakes must be applied to slow an automobile, or how you throw a ball hard to get it to go as far as possible.
- Motion is a change in distance over time.

One of the easiest ways to recognize energy is to know the various forms it can take.
All energy falls into two categories, kinetic and potential energy. Kinetic energy is the energy of motion. Think about the energy in a brick. Which has more energy, a brick lying on your foot, or a brick dropped on your foot? The dropped brick has more kinetic energy.

Energy is not an object in itself, rather, energy refers to a condition or state of an object.

The main types of kinetic energy are:

- **Electrical Energy**—The energy associated with the movement of electrons. When electrons flow through wires, we call it electricity.
- **Thermal Energy**—The energy that results from the movement of atoms and molecules and is related to their temperature. The faster the particles move, the greater the amount of energy and the higher the temperature.
- **Movement Energy**—When objects or materials flow or move from one place to another they produce energy, such as water flowing through a dam.
- **Sound Energy**—Produced by the periodic movement of matter in a medium. Sound can travel through air, solids and liquids, but not through a vacuum, because there is no matter there.
- **Radiant Energy**—A type of kinetic energy that includes light rays, X-rays, radio waves, microwaves, and any other part of the electromagnetic spectrum. Electromagnetic waves are a result of the vibration of charged particles such as electrons. Microwave ovens use radiant energy to heat food by causing the water molecules in the food to vibrate.

Potential Energy is energy that is stored. In the example above, before it fell on your foot, the raised brick had potential energy because of its position. When it fell, this energy was converted to kinetic energy of motion.

Here are the main types of potential energy:

- **Chemical Energy**—Chemical bonds hold atoms together. It takes energy to break these bonds, and energy is released when new bonds form.
- **Mechanical Energy**—Examples include a clock that is powered by a wound-up spring, or an arrow shot from a bow. With this type, energy is stored in the mechanical device by the application of a force, such as when we wind the clock or pull the bow back.
- **Nuclear Energy**—When the nucleus of an atom splits or is fused to another nucleus, energy can be released. It is the type of energy that powers our sun and is found in nuclear power plants.
- **Gravitational Energy**—This is the energy associated with an object's position in a gravitational field. A ball resting at the top of a ramp has higher potential energy than when it has rolled to the bottom. Water behind a dam has higher potential energy than when it has flowed to the river below. In each case the potential energy is due to relative position in the gravitational field.

GATHERING EVIDENCE

You will be provided with a number of toys and other common household objects. The objects can include a flashlight, a clock with a "glow in the dark" face, a small mechanical toy, a drinking bird, a light stick, a hand-warmer or emergency cold packs, poppers, or a music box, among others. Your teacher may ask you to bring in a household object that involves energy.

For each of four objects, operate the device and write a complete description about what you observe. Be sure to include details such as sounds, movements, timing, and any changes you notice. If you are unclear about how to operate any of the objects, ask your teacher to show you how. Your teacher may choose to demonstrate some of the examples for the entire class.

Name of object	Description of operation
1.	
2.	
3.	
4.	

ANALYZING EVIDENCE

To analyze what you saw for each of the objects, you need to consider what kinds of energy were involved. Using the types of energy listed in the Preparing to Investigate section on page 10, list all the kinds of energy you believe are involved in the operation of each of the objects.

Your teacher may ask you to work in small, collaborative groups to complete this section.

Name of object	Kind(s) of energy involved
1.	
2.	
3.	
4.	

INTERPRETING EVIDENCE

Although some of the toys or objects may have appeared to "run out" of energy, one of the basic rules of science is that energy cannot be created or destroyed. It only changes from one form to another. Think back to your observations and analysis of the household items and speculate about how energy changed in each of the objects. In some cases there may have been multiple transitions.

Name of object	Describe the kinds of energy transitions you observe
1.	
2.	
3.	
4.	

REFLECTING ON THE INVESTIGATION

1. How did you detect the types of energy you observed in this investigation? Which types did you feel? Which types did you hear? Which types did you see? List any other ways you detected energy.
2. One definition of energy given in this lab was "energy is the ability to do work." Considering all the objects you observed in this lab, record any examples of work that was done.
3. Given the definition of force (an influence that can cause an object to move or stop moving) identify some examples of where force was applied in this investigation.
4. Based on your experience, write a definition of energy in your own words. Also include some examples of things that are NOT energy.
5. Starting with the sun and ending with you making a piece of toast at home, write down as many types of energy and energy transitions as you can that go into your ability to have a piece of bread and toast it.
6. Often when the word "energy" is used, it refers to commercial production to help power our homes. List the major types of energy used in commercial power plants.

TEACHER'S KEY

Gathering Evidence

Only one sample is given to demonstrate typical answers. The results will vary, based on the collection of objects you provide to the class.

Name of object	Description of operation
Bi-metallic jumping disc	*The jumping disc is a shallow dome made from a special bi-metallic piece of metal, like the mechanism of many thermostats. When it is warmed to about body temperature, you can "click it" into its loaded position (dome inverted) and then carefully place it on a hard surface. When it cools down to room temperature, it suddenly snaps back into the old position, and simultaneously jumps high up in the air.*

Analyzing Evidence

Name of object	What kind(s) of energy do you observe?
Bi-metallic jumping disc	*Thermal energy is transferred to the cool disc as it is warmed by my thumb and fingers until it is warmed to about body temperature. I observed mechanical energy as I "snap" the disc into its loaded position and then carefully place it on a hard surface.* *When it cools down to room temperature, it suddenly releases its stored potential energy and snaps back into the old position, and simultaneously jumps high up in the air. It jumps several hundred times its own height, and I observed kinetic or motion energy.*

Interpreting Evidence

Name of object	Describe the kinds of energy transitions you observe
Bi-metallic jumping disc	*I observed chemical energy from my metabolism creating thermal energy, which was transferred to the disc. I used mechanical energy to click the disc into its loaded position, creating potential energy. As the disc "popped" it converted potential energy into kinetic energy as it jumped off the desk. When the disc fell back to the desk it transferred its kinetic energy into thermal energy by slightly warming up the desktop (although this is difficult to observe, I assumed it occurred).*

Reflecting on the Investigation

1. How did you detect the types of energy you observed in this investigation? Which types did you feel? Which types did you hear? Which types did you see? List any other ways you detected energy.

   Students will likely report examples of all the types of energy listed above, including nuclear energy (some glowing clock faces use tritium or promethium to create the glow).

2. One definition of energy given in this lab was "energy is the ability to do work." Considering all the objects you observed in this lab, record any examples of work that was done.

   Work is any force applied over a distance. In chemical systems it involves electrical work (moving electrons in a wire as by a battery) or work of expansion (volume expanding as a result of a chemical reaction, as when bubbles are formed in a reaction of baking soda and acid).

3. Given the definition of force (an influence that can cause an object to move or stop moving) identify some examples of where force was applied in this investigation.

   Many examples are presented, such as the spring driving the mechanical toy, using your fingers to snap the popper into its loaded position, and so on.

4. Based on your experience, write a definition of energy in your own words.

   Student answers will likely echo the definitions given in the first part of this lab. Encourage students to put the ideas in their own words.

5. Starting with the sun and ending with you making a piece of toast at home, write down as many types of energy and energy transitions as you can, that go into your ability to make toast.

   The sun provides radiant energy for wheat plants to grow, and the wheat plant stores the solar *energy in seeds via photosynthesis to create chemical potential energy. Radiant solar energy powers the water cycle, giving rivers that can turn the kinetic energy of moving water into electrical energy. Household electrical energy moves through high-resistance heating elements in the toaster and is converted into thermal energy.*

6. Often when the word "energy" is used, it refers to commercial production to help power our homes. List the major types of energy used in commercial power plants.

   The main sources of our electricity are:

   - *Coal and natural gas*
   - *Hydroelectric dams*
   - *Nuclear*
   - *Wind*
   - *Solar*

Post-Lab Discussion

Use the post-lab discussion to listen to student observations and use a group discussion to clarify any misconceptions about energy.

Additional Resources

- Thermodynamics, Real-Life Applications
  http://bit.ly/highschoolnrg1

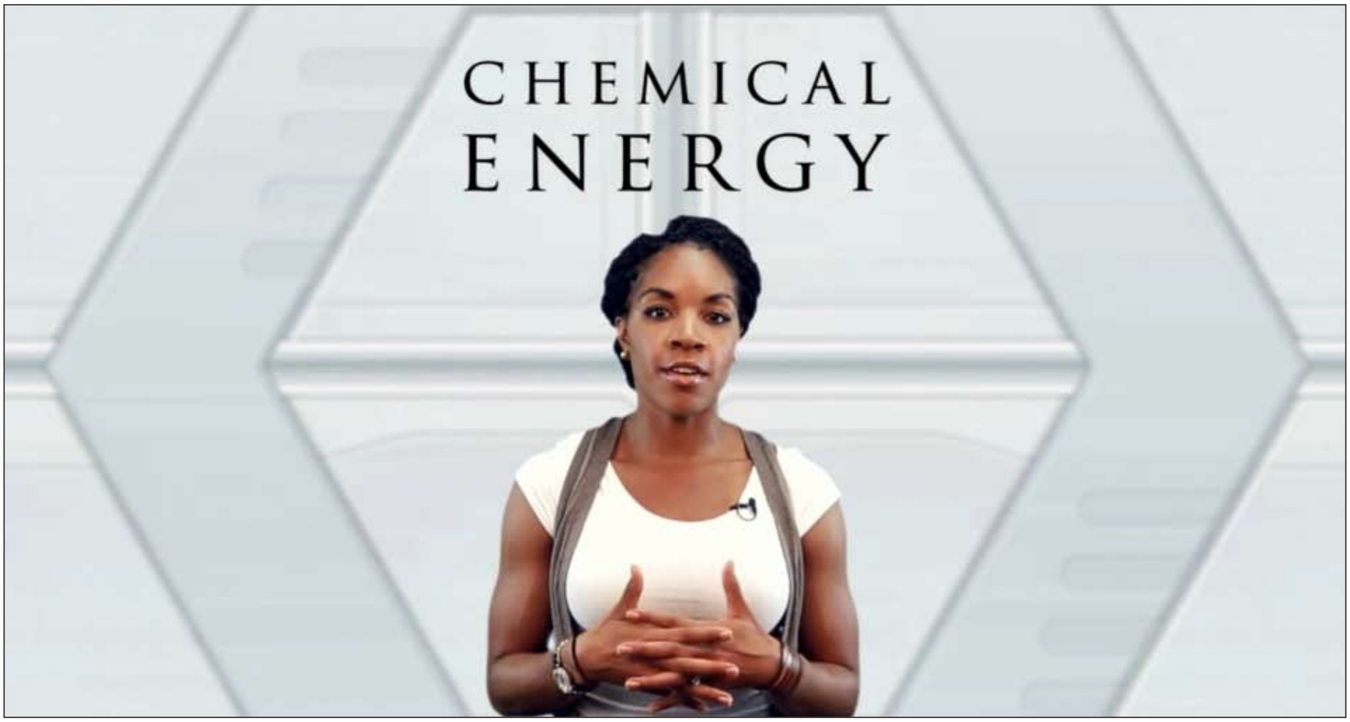
- U.S. Department of Energy, Secondary Energy Infobook, Activities and Background for High School Students
  http://bit.ly/highschoolnrg2

Note: Even in some of these official websites, there is a tendency to misrepresent heat as something that is contained by an object and flows between one object and another.

Objects/systems do not contain "heat." The motion of molecules is not heat. The term "heat content" is historic and archaic (even though it unfortunately continues in use) and comes from a time when heat was visualized as a fluid called "caloric."

As a corollary, heat does not "flow." Heat is a measure of the energy that is transferred from one object to another due to a difference in their temperatures. The energy transferred is often called "thermal energy," since it is dependent on there being a temperature difference. The form of the transfer is conduction and radiation. It's okay to call the amount of energy transferred "heat" as long as we are clear that "heat" is a number (with units) that is not found within the objects themselves, but is a measure of a process. It's best to call attention to the process by using "heat" as a verb instead of a noun, as in "When I heated the soup, it got hotter; its temperature went up."

What is Energy? | A Video



This video defines energy and explores some of its most common forms. It can be used as a supplement to an investigation, or may stand on its own to introduce a lesson or extend student learning.

highschoolenergy.acs.org/what-is-energy/what-is-energy.html

Video Transcript

Brittny
What is energy? Most of probably understand the concept of energy, or at least we can recognize it when we see it.

Chris
Here are some basic concepts that will help us define energy. First, energy is required to make things change. For example, to change this No. 2 pencil from one useful writing utensil into two less useful pieces, we need to use energy.

Brittny
Energy is the ability to do work. But we're not talking about going to work or doing your chores, we're talking about work as defined in the physical sciences. Work is the application of a force to move an object in the direction of the force. Like, when you pedal a bicycle, or when an electric

motor lifts an elevator. Energy is conserved. So, what does that mean? It means that one form of energy may be transformed into another form, but the total amount of energy remains the same. In other words, energy cannot be created, nor can it be destroyed.

Chris
One of the easiest ways to recognize energy is to know the different forms it can take. All energy falls into two categories: potential and kinetic energy. Potential energy depends on the position of an object or the arrangemet of its constituent parts. Kinetic energy is the energy of motion. Think about the energy of a brick resting on your foot compared to a brick being dropped on your foot. The moving brick has more kinetic energy, which you become painfully aware of when it transfers some of that energy onto your foot. When both bricks are resting on your foot, they have the same potential energy.

Brittny
There are four main types of potential energy. First, we have chemical energy. Chemical bonds holds atoms together. It takes energy to break these bonds and to move atoms further apart. Energy is released when new bonds form and atoms come closer together. Chemical energy is where the energy in our food comes from. Our body digests food, like this sandwich, and uses the energy to do things.

Another type of potential energy is mechanical energy. Mechanical energy is stored in a device by the application of a force, like the stored energy in a pulled bowstring. Once it is released, stored energy is converted into kinetic energy.

Two other types of potential energy include nuclear energy and gravitational energy. Gravitational energy is related to an object's position in a gravitational field. This tennis ball has a higher potential energy up here than when it falls to earth.

Chris
OK, enough about potential energy. Let's talk about kinetic energy. First of all, there's hydro or wind energy. All objects in motion have kinetic energy that can be transferred to other objects by collisions. For example, the movement of air can turn windmills to pump water or produce electricity.

Speaking of electricity, there's also electrical energy. Electrical energy is the energy associated with the movement of ions and electrons. When electrons flow through wires, we call it electricity. In addition, there's radiant energy, which comes from light waves, x-rays, and microwaves, and it's all around us.

And then, there's thermal energy. Thermal energy is the energy that results from the movement of atoms and molecules and is related to their temperature. The faster the particles move, the greater the amount of energy, and the higher the temperature.

Sound energy is produced by the periodic movement of matter in a medium. Sound can travel through gases, solids, and liquids. Pretty much any matter, but not through the vacuum of space, because there's no matter there. So you know that old sci-fi movie line about how "in space, no one can hear you scream"? Totally true. And a little terrifying.

So there you have it, the main types of potential and kinetic energy. All this talk about energy makes me want to absorb some.

Brittny
Is that my sandwich?!

Chris
Uhh ... potentially ...

The Amazing Drinking Bird!

By Brian Rohrig

The drinking bird is a mesmerizing little science toy that has fascinated young and old for more than 50 years. It is also known as the happy bird, the dippy bird, the happy dippy bird, and other variations on this same theme. It looks like a bird and will bob up and down as it appears to drink out of a glass of water. As long as it can reach the water, it will bob up and down indefinitely. The drinking bird consists of two elongated glass bulbs that are connected by a straight glass tube extending well into the interior of the bottom bulb. The only way any substance can pass between the two bulbs is through this narrow glass tube. The top bulb is covered with a porous feltlike material that also makes up the beak. On top of the head is a plastic top hat, which is only for decoration. Taped to the bottom chamber are tail feathers, which help it to maintain balance. The whole thing is suspended from plastic legs, with a horizontal piece of metal that acts as a pivot, allowing it to bob up and down.

Inside the drinking bird is a highly volatile liquid known as methylene chloride (CH_2Cl_2). Since methylene chloride is colorless, coloring must be added to enhance the visual effect. This liquid is also highly volatile, meaning it evaporates rapidly due to weak intermolecular bonds in the liquid state. Its boiling point is 39.7 °C (103.5 °F), and its vapor pressure at room temperature is 46 kilopascals (compared to only 3 kPa for water). Methylene chloride is somewhat toxic, so if a drinking bird breaks, care must be exercised in cleaning it up. Methylene chloride is commonly used as an industrial cleaner, degreaser, and paint remover.

After the methylene chloride is added by the manufacturer, most of the remaining air is then vacuumed out. Because a near vacuum now exists within the bird, the highly volatile liquid readily evaporates until the space above the liquid is saturated with vapor. At this point, a dynamic equilibrium is established within the bird between the liquid and the vapor above it. Once equilibrium is established, anytime a molecule evaporates, another molecule will condense, resulting in an overall constant amount of vapor within the bird as long as the temperature stays constant.

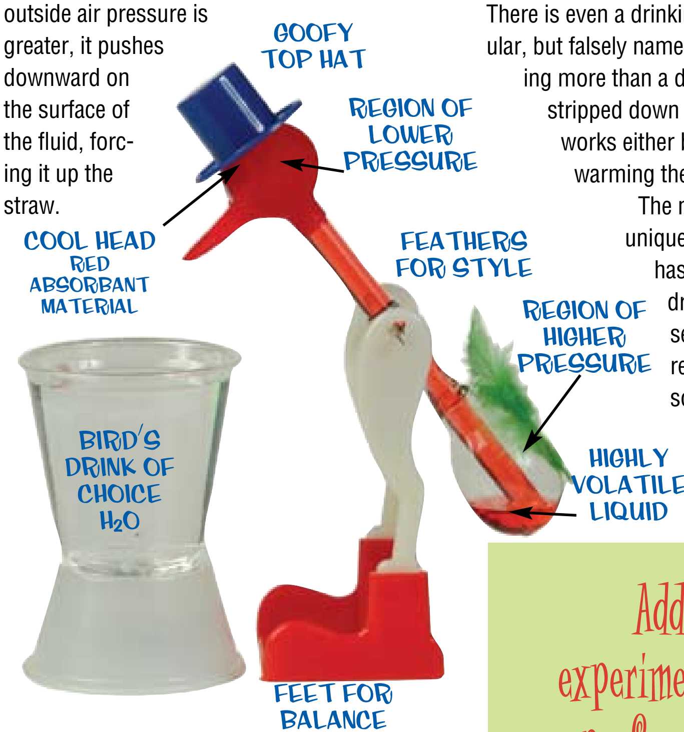
To activate the drinking bird, his head is dipped into a glass of water, and he is then set upright in such a position that when he tips his beak, he will be able to reach into the glass of

ALL PHOTOS BY MIKE CIESIELSKI; BIRDS COURTESY OF TEACHERSOURCE.COM water. Once the head is wet, a strange thing immediately begins to happen. Like magic, the fluid begins to rise upward into the head, until his head fills with liquid. The head then becomes top heavy as the center of gravity of the bird is raised. The bird then topples over, takes another drink. As the bird tips over, the liquid flows back to the bottom bulb, restoring the low center of gravity. The bird resumes its upright position, beginning the whole process all over again.

To understand what makes the fluid rise within the bird, think about what happens whenever your own head gets wet. As long as the relative humidity is not 100%, the water will immediately begin to evaporate. And evaporation always causes cooling, because it is an endothermic process. That's why you sweat when you get hot; it's not the sweating itself that cools you, but rather the evaporation of the sweat from your body. Any phase change that requires bond breaking will be endothermic, because energy is required to break bonds. This energy is drawn from the surroundings, thereby causing the temperature of the surroundings to decrease.

Because water evaporates from the head of the bird, the head immediately begins to cool. This is the most crucial point in understanding how the drinking bird works. If you could cool the head another way, the drinking bird would work just the same. When the head begins to cool, some of the vapor within the head will condense into tiny droplets of liquid. A similar process occurs at night when water vapor condenses out of the air as it cools, forming dew on the ground. Because some of the vapor condenses within the top chamber of the bird, there is now less vapor pressure in the top bulb. Less vapor means less pressure. But the vapor pressure within the bottom bulb has not changed. Because the vapor pressure in the bottom bulb is now greater than the pressure in the top bulb, the liquid is forced upward into the top chamber. (Don't say the liquid is sucked up into the top chamber—science never sucks!) Once the bird tips over, vapor from the bottom travels to the top until the pressure in both spheres equalizes and the bird begins the process all over again.

To understand how this pressure differential can cause the fluid within the bird to rise, consider what happens when you use an ordinary drinking straw. When you suck fluid up into the straw, you are creating a region of reduced pressure within the straw. Because outside air pressure is greater, it pushes downward on the surface of the fluid, forcing it up the straw.



Not only is the drinking bird educational, but it can also provide hours of entertainment. Many science museums feature displays of drinking birds. No science classroom would be complete without one. The amazing drinking bird has even appeared in a 1995 episode of *The Simpsons*, where Homer positions a drinking bird in front of his keyboard to help monitor the controls at the Springfield nuclear power plant. The artist Daniel Reynolds spent a small fortune and several years developing an art exhibit comprising a whole flock of giant 6 1/2 feet tall drinking birds, each weighing 3,000 times more than an original drinking bird. They had to be made with a special vacuum attachment in order to work properly.

There are many variations on the drinking bird. They come in a variety of styles and sizes. There is even a drinking giraffe! The very popular, but falsely named "hand-boiler" is nothing more than a drinking bird that is stripped down to the bare essentials. It works either by cooling the top or warming the bottom.

The next time you need a unique gift for the person who has everything, consider a drinking bird. A quick search on the Internet will reveal a plethora of sources. They especially make great gifts for science teachers!

Additional experiments you can perform with the drinking bird:

1. Place a gallon-size freezer bag over an operational drinking bird. He will almost immediately stop drinking. Can you explain why?
2. Have a drinking bird "drink" hot water and then ice-cold water. Which will make the bird drink faster?
3. Have the bird "drink" a liquid with a higher evaporation rate than water, such as rubbing alcohol. Does the drinking bird drink faster?
4. Instead of cooling the head, heat the body, either with your hand or a heat lamp. Does the drinking bird work?
5. If you have a spare drinking bird that you don't mind disfiguring, paint the top bulb silver and the bottom bulb black. Place in a sunny windowsill and watch it bob up and down! No water required.

Brian Rohrig is a chemistry teacher at Jonathan Alder High School in Plain City, OH. His article "There's Chemistry in Golf Balls!" also appears in this issue.

THERMOMETERS

You are feeling sick. You call the doctor and she wants to know the average kinetic energy of your body's molecules. What will you do?

By Brian Rohrig

We have all used a thermometer—to check for a fever, record data during a chemistry lab, or to help us decide how to dress before leaving for school in the morning. But have you ever thought about how a thermometer works? And when you measure temperature, just what exactly are you measuring?

The prefix thermo- refers to heat. Thermodynamics is the study of heat. A thermos either keeps heat in or out. You wear thermal underwear to prevent body heat from escaping. Despite its name, however, a thermometer does not actually record heat, but rather temperature. Temperature and heat are two radically different concepts.

Temperature is a measure of the average kinetic energy of the molecules within a substance. When you record the temperature of something, you are making a statement about how fast the molecules are moving. When you are waiting for a bus in the morning in the middle of January, instead of saying, "Boy, its cold out here this morning," it would be more accurate to say, "Boy, the molecules in the air are moving quite slow this morning!"

JUPITERIMAGES

Heat vs. temperature

Heat is a little trickier to define. Heat refers to the movement of energy from a substance of high temperature to one of low temperature. Heat always refers to energy in transit. A substance can have a high temperature, but little heat available to transfer. A drop of boiling water contains less actual heat than a bathtub full of water at a lower temperature. Temperature is a measure of only the average kinetic energy of molecules, but because heat depends on the total energy, there is not a simple, universal relation between the two.

Here's an everyday example that helps to illustrate the difference between heat and temperature. Consider ice: when you cool a drink using ice, a lot of heat flows from the drink into the ice (so the drink's temperature falls). But the temperature of the ice does not rise, it stays at 0 °C—the heat goes into breaking the interactions between water molecules to melt the ice (at 0°) to form water (still at 0°). Ice and water at 0° have the same temperature but very different amounts of heat.

Temperature scales

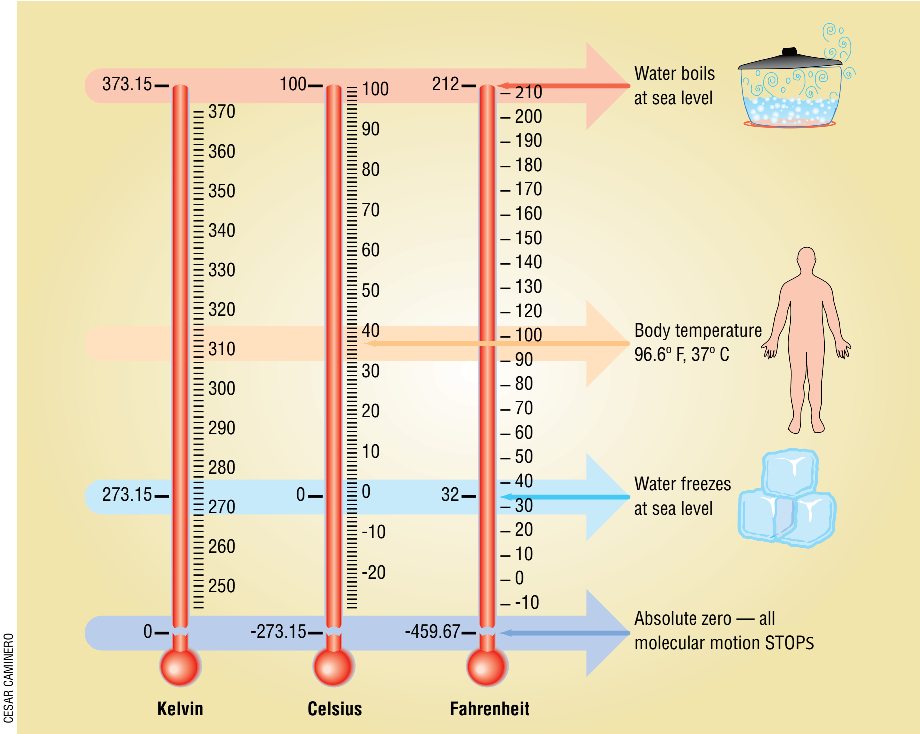
In the United States, most thermometers for everyday use are calibrated in degrees Fahrenheit. Most of the rest of the world measures temperature in degrees Celsius. At one point during the 18th century, there were nearly 35 different temperature scales in use! Many scientists felt the need to devise a uniform temperature scale that would meet widespread acceptance.

One temperature scale that met with some success was the Romer scale, which was first used in 1701. This temperature scale was invented by Ole Christensen Romer, a Danish astronomer whose biggest claim to fame was measuring the speed of light in 1676. His temperature scale set the boiling point of water at 60° and the freezing point at 7.5°. The lowest temperature you could achieve with a mixture of salt and ice was 0°. Because most people from that time period were not too concerned about the temperature of ice and salt, this scale was destined for the dustbin of history.

Daniel Gabriel Fahrenheit, a German physicist, published an alternate scale in 1724. Borrowing from the work of Romer, he set 0 °F as the lowest temperature that could be achieved with a mixture of salt, ice, and ammonium chloride. (It is unclear whether Romer also used ammonium chloride in his experiments, as many of his records were destroyed in a fire.) Fahrenheit set the freezing point of water at 32° and the body temperature of a person at 96°, which he determined by measuring the temperature under his wife's armpit. Each degree of his scale corresponded to one ten-thousandth the initial volume of mercury used in his thermometer. To this day, there is considerable controversy as to how Fahrenheit actually arrived at his temperature scale. He never did reveal exactly how he arrived at the reference points for his thermometer, as he did not want others to construct and sell the thermometers he had spent much of his life perfecting.

His scale met widespread acceptance because everyone could relate to it, since 0 °F and 100 °F were the lowest and highest temperatures typically experienced on any type of regular basis in Western Europe. If the temperature rose above 100°, you knew it was really hot. If the temperature dipped below 0°, you knew it was quite cold. Whether these points were intentionally chosen to represent these extremes or just happened to work out this way is still being debated today. The biggest problem with this scale was the freezing and boiling points of water were set at 32° and 212°, not exactly round numbers. This was an issue not so much with the general public, but rather with scientists, who tend to obsess over such things. However, others have postulated that placing 180 degrees between the freezing and boiling points of water was not arbitrary but quite rational, as this number represents the number of degrees in half a circle.

To counter this problem, Swedish astronomer Anders Celsius came up with another scale in 1742, setting the freezing and boiling points of water at 0° and 100°, with 100 divisions in between. Hence, it was termed the Centigrade scale, since the prefix centi- represents one-hundredth. Celsius had initially set the freezing point of water at 100° and the boiling point at 0°. This was later reversed after his death. Most countries that have adopted the metric system of measurement use this temperature scale, as it is conveniently broken down into units of 10. In 1948, the Centigrade scale was officially designated the Celsius scale, although some people still use the outdated term.



A comparison of three temperature scales.

Lord Kelvin

Anders Celsius

The most scientific scale in use today is the Kelvin, or absolute, temperature scale. It was devised by British scientist William Thomson (Lord Kelvin), in 1848. Because temperature is a measure of molecular motion, it only makes sense that the zero point of your scale should be the point where molecular motion stops. That is exactly what the Kelvin scale accomplishes. 0 Kelvin (K) is the point at which all molecules stop moving. 0 K is known as absolute zero, which has never actually been reached. In 2003 at MIT, scientists came very close to reaching absolute zero, obtaining a frosty temperature of 4.5×10^{-9} K.

The Kelvin scale is primarily used in science, and temperature must be expressed in Kelvin when solving many equations involving temperature, such as the gas laws. But it tends to be too cumbersome for everyday use, since the freezing point of water is 273 K and the boiling point is 373 K.

Types of thermometers

Early thermometers

The first thermometer in modern times was a crude water thermometer believed to have been invented by Galileo Galilei in 1593. In 1611, Sanctorius Sanctorius, a colleague of Galileo's, numerically calibrated the thermometer. Many of these first thermometers used wine, as its alcohol content prevented it from freezing and its red color made it easy to read. However, these first thermometers were very sensitive to air pressure, and functioned as much as a barometer as they did as a thermometer. So eventually, all thermometers were constructed of a sealed glass tube that had all the air removed. Because these vacuum tubes were shut

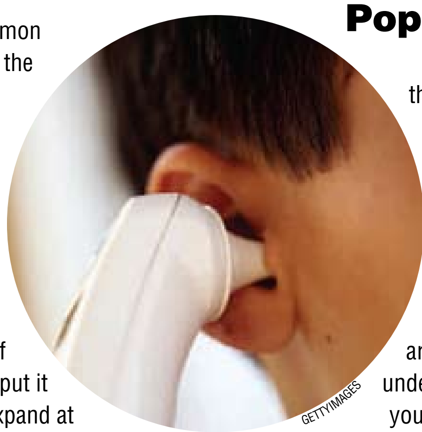
off from the outside atmosphere, changes in air pressure would not affect the temperature reading. In 1709, Fahrenheit invented the alcohol thermometer, and in 1714, he invented the first mercury thermometer. All thermometers work according to the same basic principle: objects expand when heated and contract when cooled.

Bulb thermometers

The most common thermometer is the bulb thermometer, which comprises a large bulb filled with a liquid and a narrow glass tube through which the liquid rises. All liquids expand when heated and contract when cooled (with the exception of H_2O near its freezing point; ice-cold H_2O at 0 °C contracts until 4 °C where it expands like other materials), which explains why the liquid within a thermometer rises as the temperature increases and falls when it decreases. Mercury was the liquid of choice for many years, because it expands and contracts at a very constant rate, making mercury thermometers very accurate. However, because of concerns about mercury toxicity, mercury has often been replaced with alcohol that is colored red. Mercury has a silver color. It freezes at –39 °C, so it cannot be used if temperatures get colder than this.

Bimetallic strip thermometers

Another very common type of thermometer is the bimetallic strip thermometer. This thermometer comprises two different metals, such as copper and iron, which are welded together. Each of the metals used has a different coefficient of linear expansion, or to put it simply, these metals expand at different rates. Connected to this bimetallic strip is a pointer, which points to the correct temperature on the face of the thermometer. Because these metals expand at different rates, when heated, the welded strip of metal will bend. When cooled, it will bend in the opposite direction. A variation of the bimetallic strip thermometer is the thermostat used in homes and automobile engines. These thermostats are made of a thin bimetallic strip, which is fashioned into a coil, making it more sensitive to minor temperature fluctuations.



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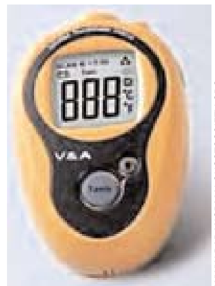
Infrared thermometer

Infrared thermometers

A fascinating thermometer is the infrared thermometer. This handheld device is used by simply pushing a button as you point it toward an object. A digital readout tells you the temperature. All objects above absolute zero are emitting infrared radiation (IR) —an invisible (to human eyes) form of electromagnetic energy. The infrared radiation we emit is commonly known as body heat. The infrared thermometer has a lens that focuses the infrared energy into a detector, which measures the IR intensity and converts that reading to temperature. Infrared thermometers have a wide variety of applications. They are used by firefighters to detect hot spots in buildings and in restaurants to ensure that served food is still warm. Infrared thermometers are also used for determining the temperature of a human body, automobile engines, swimming pools, hot tubs, or whenever a quick surface temperature is needed.



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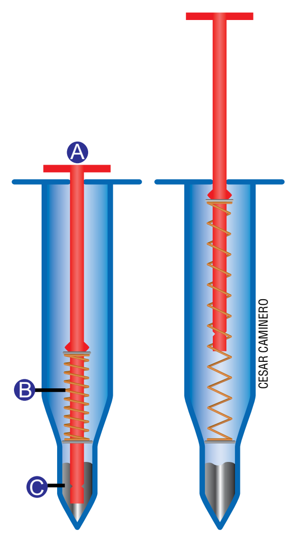
Pop ups

You are cooking that Thanksgiving turkey, and you want to make sure that the inside of the turkey is completely done. To ensure that you are not feasting on undercooked bird, you can use an ingenious device known as the pop-up turkey timer. This instrument is simply stuck into the turkey, and when the turkey is done, a red indicator pops up (A). The little red indicator is spring loaded (B) and is held in place by a blob of solid metal (C). When this metal reaches a temperature of 85 °C, which is the temperature of a fully cooked turkey, it melts, causing the red indicator to pop up.



CESAR CAMINERO

Popup turkey timer

This technology is similar to that used in sprinklers found on the ceilings of many buildings, which actually served as the inspiration for the pop-up turkey timers. When a certain temperature is reached, a metal component within these sprinklers melts, activating the sprinkler. By mixing together different metals, a particular alloy can be created with a desirable melting point. Pop-up timers can be purchased for a wide variety of different types of meat, from ham to hens. You can even buy a pop-up timer for steak, which pops up in increments indicating rare to well done.

And now for something completely different...

Perhaps the most unusual thermometer ever invented is the Galileo thermometer, based on a similar device invented by Galileo. This instrument does not look like a thermometer at all, as it is composed of several glass spheres containing different colored liquids that are suspended in a cylindrical

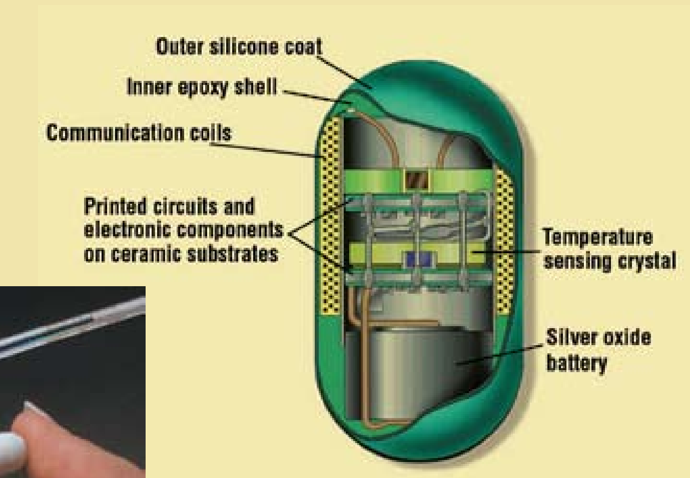
JUPITERIMAGES

Galileo thermometer

column of a clear liquid. Attached to each of the colored spheres is a little dangling metal tag with an engraved temperature. The temperature is determined by reading the tag on the lowest floating sphere. As the temperature rises, the spheres will begin to fall one by one. When the temperature falls, the spheres will then rise one by one.

The liquid within each glass sphere is composed of either colored water or alcohol. Each of the spheres is of a slightly different mass, and thus a slightly different density, since the volume of each sphere is the same. Each sphere differs in mass by about 0.006 grams. This difference is accomplished by making each tag a slightly different mass. The clear liquid surrounding the spheres is an inert hydrocarbon-based oil, similar to mineral oil. When this liquid is heated, it expands, becoming less dense. Less dense liquids exert a lesser buoyant force, so the most dense sphere will then sink. If the temperature continues to rise, the molecules of the surrounding liquid will continue to spread apart from one another, causing more spheres to fall. As the liquid cools, its molecules come closer together, exerting a greater buoyant force, causing the spheres to rise. The spheres themselves do not expand or contract nearly as much as the surrounding liquid when heated or cooled, since they are composed of glass, which hardly expands at all when heated.

Even though it looks nothing like a conventional thermometer, the Galileo thermometer still functions according to the same basic principle as most other thermometers: substances expand when heated and contract when cooled.



COURTESY OF CORTEMP

The CorTemp system can measure and record the body temperature and/or heart rate of many athletes on the field during practices or competition. Once the probe is inside the gastrointestinal tract, a crystal sensor vibrates at a frequency relative to the temperature of the body tissues surrounding it. These data are then transmitted harmlessly through the body to the monitor.

What's the future for thermometers?

Technology has come a long way since Galileo's day, but his thermometer to this day has a futuristic look to it. Another futuristic thermometer that is available today is the CorTemp thermometer. Developed by Dr. Leonard Keilson of the Applied Physics Laboratory of the Johns Hopkins University in conjunction with NASA, the CorTemp thermometer is swallowed, allowing accurate temperature readings while it travels through, or is stationed at some particular spot in the body. The probe is enclosed in a small pill that is taken internally, while the temperature readings are recorded on a device that is monitored externally.

No matter what device you use to take your temperature when you have a fever, none will make you feel better. But in this technologically advanced world today, your choice of thermometer might bring you a bit of welcomed distraction while measuring the average kinetic energy of your body's molecules.

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