# Chapter 3

# Key Concepts in Physical Science

What would you answer if someone asked you “what is everything?” In science “everything” means all the matter and energy in the universe. Matter and energy are key concepts in physical science because they make up the natural world. Einstein’s famous equation $E = mc^2$ is often used to represent science in cartoons, movies, and popular culture. The “E” in the equation stands for energy, and the “m” in the equation represents matter. Einstein used this equation to relate energy and matter.

Almost all the matter you can touch, taste, or feel is made of incredibly tiny particles called atoms. An atom is so small that if one atom were the size of a marble, you would be about the size of the entire planet Earth! In this chapter, you will learn about atoms, matter and energy – some of the most important ideas in science!

## Key Questions

1. *What is matter made of?*
2. *What is energy and where does it come from?*
3. *Are temperature and heat the same thing or are they different?*

# 3.1 Mass and the Atomic Theory of Matter

Mass describes the amount of matter in an object. A car has more mass than a bicycle because the car contains more matter (Figure 3.1). Steel, plastic, and rubber are different kinds of matter and a car has a lot more of each kind than a bicycle. Ordinary matter is made of small particles called atoms. Atoms are so small they cannot be seen even with a powerful microscope. To imagine how atoms could be real and yet unseen, look at a sugar cube. Held in your hand, a sugar cube looks like a single piece of matter. But up close, you can tell it is made up of tiny, individual crystals of sugar fused together. Matter is made up of atoms in a similar way.

## Grams and kilograms

**Kilograms** Mass is measured in kilograms (kg). Most of the world uses kilograms for daily measurement, such as buying food (the U.S. is an exception). A bunch of bananas or a 1-liter bottle of soda each have a mass of about 1 kilogram. People have a mass of around 55 kilograms. Common machines range in mass from a bicycle (about 12 kg) to a motorcycle (about 200 kg) or car (1,000 - 2,000 kg). You should try to develop an intuitive sense for how much mass there is in one kilogram since this is a basic quantity in science.


**Grams** For small amounts of mass, the kilogram is too large a unit to be convenient. One gram (g) is one-thousandth of a kilogram. One grain of rice has a mass of about a gram, so a bag of 1,000 grains of rice has a mass of approximately 1 kilogram.

### VOCABULARY

**kilogram (kg)** - the basic metric (SI) unit of mass.

**gram (g)** - a unit of mass smaller than a kilogram. One kg equals 1,000 g.


**Figure 3.1:** *A car contains more matter than a bicycle, therefore it has more mass.*

### CHALLENGE

Where did the unit of kilograms come from? Research the origin of the metric system to discover how the kilogram was first defined and what other units of mass it replaced.

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## Measuring mass in the laboratory

**Using a mass balance**

In the laboratory you will usually measure mass with a balance. The balance displays mass in grams. For example, the balance in Figure 3.2 shows the mass of six steel nuts to be 96.2 grams. A single gram is a tiny mass and balances are therefore sensitive (and quite delicate). Never drop things onto a balance! Instead, set things gently on the balance.

**Converting grams to kilograms**

For many calculations you will need to convert masses from grams to kilograms. To convert a mass in grams to kilograms, you need to divide by 1,000 since there are 1,000 grams in a kilogram (g/kg).

**Masses you will consider in science**

Ordinary objects tend to have masses between a few grams and a few hundred kilograms. You will encounter a much wider range of masses in science. A bacteria has a mass of 0.000000001 kg. That seems small — but then an atom has a mass a thousand billion times smaller. Science also concerns large masses, such as planets and stars. A star like our sun has a mass of 2 million trillion trillion kilograms.

**Converting mass units**

A laboratory balance shows the mass of a banana is 175.5 grams. How much is this in kilograms?

| | |
|---|---|
| 1. Looking for: | You are asked for the mass in kilograms. |
| 2. Given: | You are given the mass in grams. |
| 3. Relationships: | There are 1,000 grams in one kilogram. |
| 4. Solution: | 175.5 ÷ 1,000 = 0.1755 kg |

**Your turn...**

a. A sack of onions has a mass of 5 kilograms. Can this sack be measured using a balance that reads up to 500 grams? **Answer: No; 5 kg = 5,000 g**

b. Convert 1.77 kilograms to grams. **Answer:** 1,770 g

Electronic balance

**Converting from grams to kilograms**

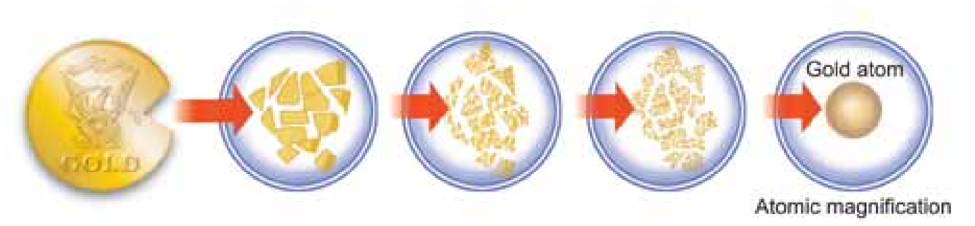
$$96.2\,\cancel{g} \times \frac{1\text{ kg}}{1{,}000\,\cancel{g}} = 0.0962\text{ kg}$$

$$96.2\text{ g} = 0.0962\text{ kg}$$

**Figure 3.2:** *A balance displays mass in grams. You may need to convert grams to kilograms when doing calculations.*

## Atoms

**The smallest piece of matter** Suppose you wanted to make the smallest possible piece of gold. You cut a pure gold coin into smaller and smaller pieces until you can't cut it any smaller. That smallest possible piece is one atom. A single **atom** is the smallest amount of gold (or any element) you can have.




**Atoms** We know ordinary matter is made up of atoms. Atoms make up everything that we see, hear, feel, smell, and touch. We cannot experience atoms directly because they are so small. Aluminum foil is thin but is still more than 200,000 atoms thick (Figure 3.3).

**Elements** An **element** is a pure substance (like gold) that cannot be broken down into other elements. All of the matter you are ever likely to experience is made from one or more of 92 naturally-occuring elements. Each of those 92 elements has a unique type of atom. All atoms of a given element are similar to each other. If you could examine a million atoms of carbon, you would find them all to be similar. But carbon atoms are different from sodium, aluminum, or oxygen atoms. The atoms of an element are similar to atoms of the same element but different from atoms of other elements.


**VOCABULARY**

**atom** - the smallest particle of matter that retains the identity of its element, such as an atom of gold.

**element** - a pure substance that cannot be broken down into other elements.

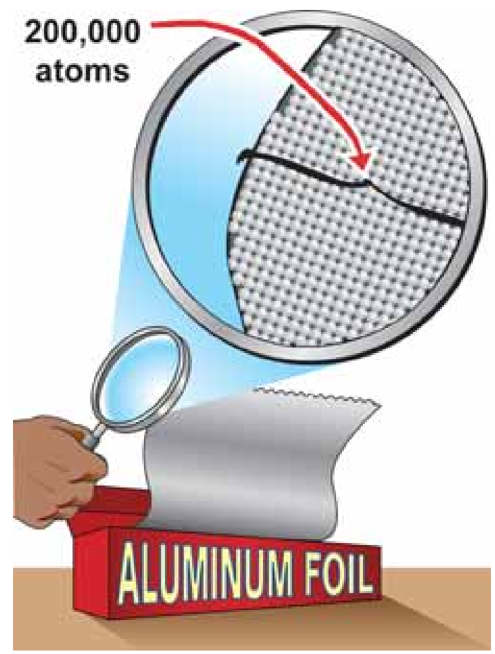



**Figure 3.3:** *Even a thin sheet of aluminum foil is 200,000 atoms thick. NOTE: In the illustration, the atoms are drawn much larger than they are in reality. You could never see an atom with a magnifying glass.*

## How atoms and elements explain chemical changes

**Compounds**

The properties of matter depend mostly on how atoms of different elements are combined in *compounds*. A compound is a substance that is made up of more than one element. Pure elements are rare. Most matter exists in the form of compounds.

**Properties depend more on compounds than on elements**

The properties of a compound are usually different from the properties of the pure elements that make up the compound. For example, salt is a compound of the elements sodium and chlorine (Figure 3.4). The properties of salt are quite different from the properties of sodium or chlorine. The pure element sodium is a soft, silvery metal. Pure chlorine is a yellow-green, toxic gas. Yet the compound of the two (salt) is a hard white crystal used to flavor food!

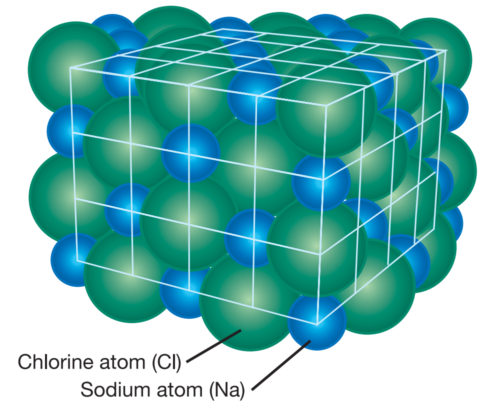
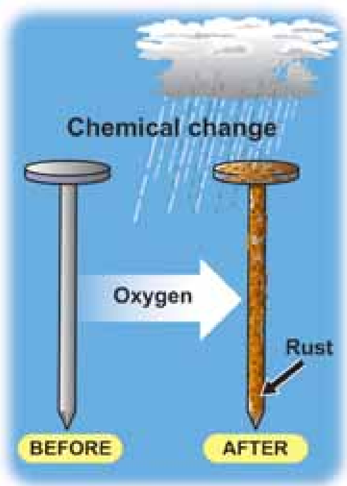




**Figure 3.4:** *Table salt is a compound made of sodium and chlorine atoms.*

**Matter can change its properties**




One kind of matter can change into another kind of matter that has different properties than the original matter. For example, if you leave an iron nail out in the rain, the silver-colored surface soon turns brown with rust. Scaly, brown rust is so different from hard, silvery steel. How does one turn into the other?

**Chemical changes can rearrange atoms**

Rust forms through a chemical change between iron in the nail and oxygen in the air. Chemical changes rearrange atoms into different molecules and compounds. Remember, the properties of matter depend on the arrangement of atoms in a compound. The iron atoms in the nail combine with oxygen atoms from the air and water to make rust. Rearranging atoms into new compounds is how one kind of matter changes into another kind with different properties.

## How atoms explain solids, liquids, and gases

**Atoms in a solid** The concept of atoms explains how the same substance can be a solid, a liquid, or even a gas. In a gold ring, every atom of gold is attached to its neighboring atoms and cannot easily move (Figure 3.5). At room temperature, gold is solid because the individual atoms are bound firmly to each other. They still wiggle around, but do not have enough energy to break away from their neighbors.

**Atoms in a liquid** A liquid holds its volume, but not its shape — it flows. Liquids flow because the atoms can move around. If you heat gold with a torch, it finally melts and becomes liquid when the temperature reaches 1,064°C (1,947°F). The atoms in a liquid have enough energy to temporarily break their attachments to their neighbors. The atoms are about as close together as they are in a solid, but they continually change neighbors, like changing partners in a fast dance.

**Atoms in a gas** A gas flows like a liquid, but can also expand or contract to fill a container. A gas can expand or contract because the atoms are completely "unbonded" from each other and are relatively far away from each other. If you kept heating the molten gold up to 2,856 °C (5,173°F), it would finally boil and turn into gold gas. Like other gases, gold gas expands to fill any container because the atoms are free to move around. Atoms in a gas are much farther apart than atoms in a liquid or solid.

**Temperature** Atoms are never still. Atoms are always moving, vibrating around like drops of water on a hot griddle. You can tell from a substance's temperature the amount of energy of motion each atom has. When the temperature is low, each atom has very little energy of motion. That is why solids form at low temperatures. When the temperature is high, each atom has a lot of energy of motion. Gases form at high temperatures because the atoms have enough energy to fly away from each other instead of sticking together.

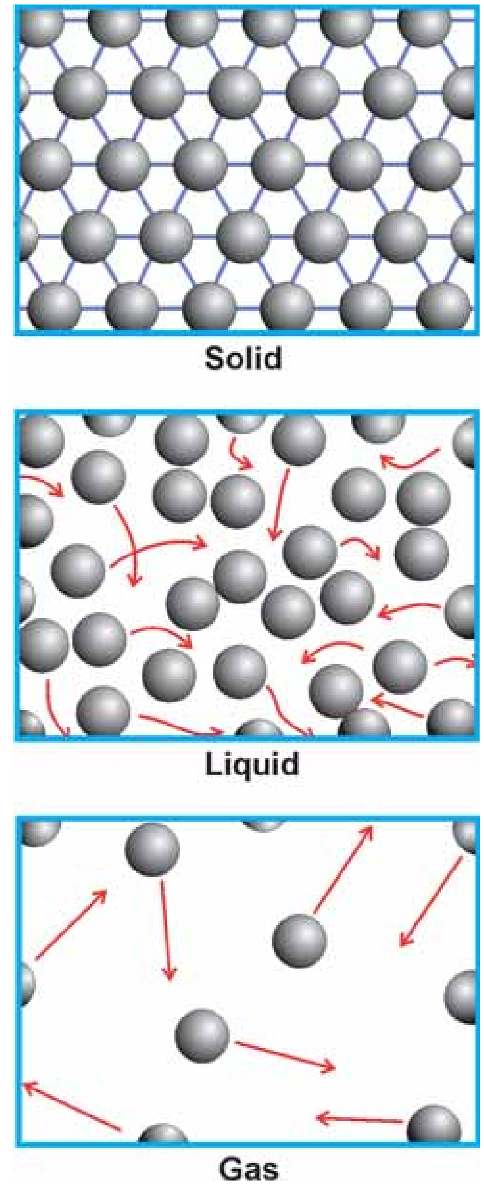



**Figure 3.5:** *Atoms in a solid, a liquid, and a gas.*

## 3.1 Section Review

1. Which of the following objects has a mass of about one kilogram?
   a. A golf ball.
   b. A one-liter bottle of soda.
   c. A medium-size dog.
   d. A motorcycle.
2. How many grams are there in 2.2 kilograms?
3. The objects on the right have the same mass. That means they:
   a. have the same size.
   b. have the same elements in them.
   c. are all the same phase of matter.
   d. contain the same amount of matter.
4. Name one substance that is solid, one substance that is liquid, and one substance that is a gas at ordinary room temperature.
5. Which of the three phases of matter (solid, liquid, gas) would be the best to use to build a bridge? Explain.
6. Is water a compound or an element? Explain.
7. Atoms of iron are much more tightly attached to each other than are atoms of lead. That means it takes more energy to separate iron atoms from one another than to separate lead atoms. Based on this information, which of the following statements is probably true?
   a. An iron bar is harder to bend than a lead bar of the same size.
   b. An iron bar is easier to bend than a lead bar of the same size.
   c. An iron bar has more mass than a lead bar of the same size.
   d. An iron bar has less mass than a lead bar of the same size.


**Figure 3.6:** *The four objects for question 3.*

### STUDY SKILLS

In the metric system, you can convert from one unit to another by shifting the decimal point.
For example:

0.056 kg = 56 grams

2.55 kg = 2,550 grams

125 grams = 0.125 kg

8 grams = 0.008 kg

Moving the decimal point to the left three digits is the same as dividing by 1,000. Moving the decimal point to the right three digits is the same as multiplying by 1,000.

# 3.2 Temperature and Energy

If you look around, you are reminded that nothing stays the same for long. Things are always changing. Motion, chemical reactions, and a cup of coffee cooling down are all examples of change. Why do these changes occur? How do the changes occur? This section is about how things change through the exchange of energy. The flow of energy connects matter, time, and space and causes things to change.

## Two important concepts: systems and energy

**What is a system?**

To learn science, we have to break up the complex universe into pieces small enough to understand. We call these pieces **systems**. In science, the word "system" means a small group of related things that work together. For example, your eye is a system that contains many parts, including a lens, pupil, and retina (Figure 3.7).

**We learn science one system at a time**

There are big, complex systems like the solar system. Gravity ties the sun and planets together so that they all interact with one another. There are also little systems within the big systems, like the weather on Earth (which is part of the solar system). Your body is a big, complex system. All the organs in your body (like your eye) are smaller systems.

**The parts of a system change by exchanging energy**

The parts of a system interact with each other by exchanging **energy**. Energy is a quantity that measures the ability to cause change. Anything with energy can change itself or cause change in other objects or systems. Energy can cause changes in temperature, speed, position, mass, or other physical variables. Energy can cause change in materials, such as burning wood changing into smoke and ashes.

- A gust of wind has energy because it can move objects in its path.
- A piece of wood in a fireplace has energy because it can change into smoke and ashes, releasing heat and light.
- You have energy because you can change the motion of your own body.

**VOCABULARY**

**system** - a small group of related things that work together.

**energy** - a quantity that measures the ability to cause change in the physical system. Energy is measured in joules.

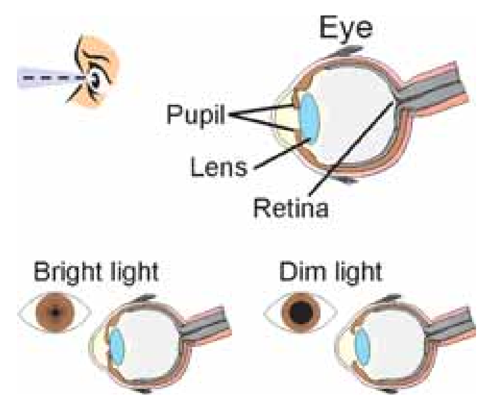



**Figure 3.7:** *Your eye is a system that includes the lens, pupil, and retina. All the parts of the system work together to create your sense of vision. The pupil opens in dim light to allow more light into the eye. The pupil closes partly in bright light.*

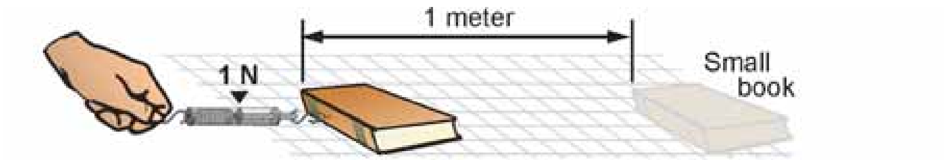
## Forces and energy

**Force is measured in newtons**

If you want to move a box, you must apply a **force** to it. Force is a fundamental quantity in physical science. In the metric system, force is measured in **newtons (N)**. A newton is a small unit of force. To lift the average person takes a force of 500 to 1,000 newtons.

**Energy is measured in joules**

The unit of energy is related to the units for force and distance. One **joule (J)** of energy is enough to push with a force of one newton for a distance of one meter. So a joule is about as much energy as it takes to pull a small book across a table. If you have more energy, you can pull with more force or for a greater distance — or both.




One joule of energy is enough to apply a force of 1 N over a distance of 1 meter

**Forces can transfer energy from one object to another**

Energy often moves through the action of forces. In fact, one important property of energy is the *stored ability to create force*. An object which has energy may exert forces to transfer its energy to another object. If an object has absolutely *zero energy,* then no forces may be produced. Another way to think about force is as an action that may transfer energy from one object to another.

**Potential energy**

Objects may have energy due to their height. For example, a book high on a shelf has more energy than a book on the floor (Figure 3.8). This kind of energy is called potential energy and comes from Earth's gravity.

**Kinetic energy**

Objects in motion have energy due to their speed. Energy of motion is called kinetic energy. The faster an object is moving, the more kinetic energy it has. If an object has kinetic energy, it may transfer that energy to other objects by applying forces. For example, if you catch a falling book, the book exerts a force against your hand. The energy of motion of the book is transferred to your hand through that force.

### VOCABULARY

**force** - a push, pull, or any action which has the ability to change motion. Force is measured in newtons.

**newton (N)** - the unit of force in the metric (SI) system.

**joule (J)** - the unit of energy in the metric (SI) system. One joule is enough energy to push with a force of one newton for a distance of one meter.

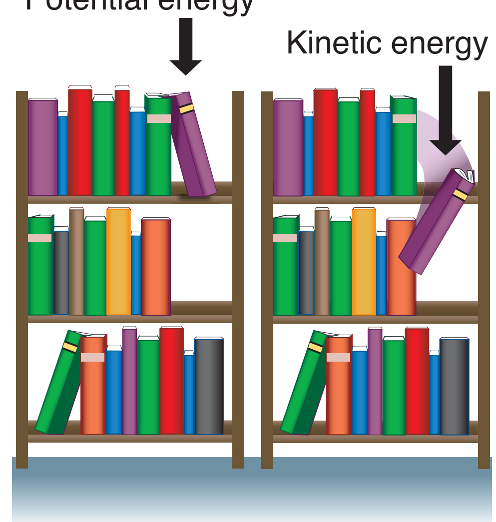
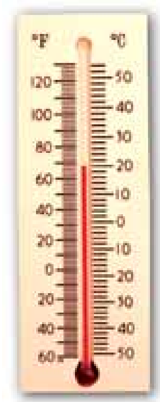



**Figure 3.8:** *Energy of motion (kinetic energy) and energy of height (potential energy).*

## Temperature

**Hot and cold** You have seen a thermometer hung outside someplace to register the **temperature**. Temperature is the measurement we use to make the sensations of hot and cold more precise. Experience has taught you to wear a coat if the weather forecast predicts a high of 40°F, and to wear shorts if a high of 95°F is predicted. But what is different about the air that makes it feel 95 degrees rather than 40?

**Thermometers** A **thermometer** is an instrument used to accurately measure temperature. The common alcohol thermometer uses the expansion of colored liquid alcohol to show temperature. As the temperature increases, the alcohol expands and rises up a long, thin tube. You read the temperature by looking at the mark the alcohol reaches.



**Fahrenheit scale** You are probably most familiar with the English system of measuring temperature, known as the **Fahrenheit scale**. It was developed in 1714 by Gabriel Fahrenheit, a German physicist who was the first person to use a mercury thermometer. He chose the lowest temperature he could create in his lab (using water, salt, and ice) to be the zero point of his scale. For the other end of the scale he used the temperature of the human body as 100 degrees. Eventually the Fahrenheit scale was standardized so that the freezing point of water is 32 degrees and the boiling point is 212 degrees.

**Celsius scale** In 1742, Anders Celsius, a Swedish astronomer, invented a temperature scale in which there were 100 degrees between freezing and boiling. He called it the centigrade scale. In 1948 this official scale of the metric system was named the **Celsius scale** in his honor. Most countries use the Celsius scale. Figure 3.9 shows how the two temperature scales compare.

### VOCABULARY

**temperature** - a measurement of hot or cold that depends on the thermal energy in a material.

**thermometer** - an instrument used to measure temperature.

**Fahrenheit scale** - temperature scale in which water freezes at 32 degrees and boils at 212 degrees.

**Celsius scale** - temperature scale in which water freezes at 0 degrees and boils at 100 degrees.

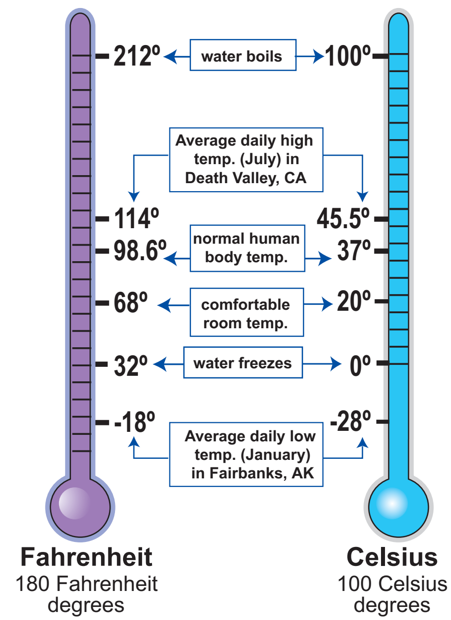



**Figure 3.9:** *The Celsius and Fahrenheit temperature scales.*

## Converting between Fahrenheit and Celsius

**Converting between the two scales**

A weather report forecasting 21°C in Barcelona, Spain, predicts a pleasant day, suitable for shorts and a T-shirt. A weather report predicting 21°F in Minneapolis, Minnesota, suggests wearing a heavy winter coat, gloves, and a hat. Because the United States is one of the few countries that still use the Fahrenheit scale, it is useful to know how to convert between the two temperature scales.

**CONVERTING BETWEEN FAHRENHEIT AND CELSIUS**

$$T_{Fahrenheit} = \frac{9}{5}T_{Celsius} + 32 \qquad T_{Celsius} = \frac{5}{9}(T_{Fahrenheit} - 32)$$

**STUDY SKILLS**

**Using the proper units**

Temperatures in Fahrenheit and Celsius are easy to confuse. Science usually works in Celsius, as do most countries. However, the United States uses Fahrenheit for everyday communication. Get in the habit of writing the units whenever you write down a number in science. For example, write 10°C instead of just 10 or 25.5 grams instead of just 25.5. This will keep you from getting confused later on.

**Converting between temperature scales**

A friend in Paris sends you a recipe for a French cake. The recipe says to bake the cake at a temperature of 200°C for 45 minutes. At what temperature should you set your oven, which uses the Fahrenheit scale?

1. Looking for: You are asked for the temperature in degrees Fahrenheit.
2. Given: You are given the temperature in degrees Celsius.
3. Relationships: Use the conversion formula: $T_F = {}^9/_5 T_C + 32$.
4. Solution: $T_F = ({}^9/_5)(200) + 32 = 392$ °F.

**Your turn...**

a. You are planning a trip to Iceland this summer. You find out that the average July temperature in Iceland is 11.2°C. What is the average July temperature in degrees Fahrenheit? **Answer:** 52.2°F

b. You are doing a science experiment with a Fahrenheit thermometer. Your data must be in degrees Celsius. If you measure a temperature of 125°F, what is this temperature in degrees Celsius? **Answer:** 51.7°C

## Temperature extremes

**Absolute zero** There is a limit to how cold matter can get. **Absolute zero** is -273°C (-459°F). You cannot have a temperature lower than absolute zero. As temperature is reduced, all atoms move more and more slowly. At -273°C atoms have the lowest energy they can have and the temperature cannot get any lower. Think of absolute zero as the temperature at which atoms are “frozen.” Technically, molecules never completely stop moving, but at absolute zero their energy is so small they might as well be stopped.

**High temperatures** Unlike with absolute zero, there is no maximum temperature for matter. As temperature increases, exotic forms of matter appear. For example, at 10,000°C atoms start to come apart and become a *plasma*. In a plasma, the atoms are broken apart into separate positive ions and negative electrons. Plasma conducts electricity and is formed in lightning and inside stars.

**Temperatures in the Solar System** When compared with temperatures in other parts of the universe, temperatures on Earth fall in a small range (Figure 3.10). In the solar system, temperatures can range from a low of approximately -270°C (-454°F) between the outer planets to a high of 15 million °C at the center of the sun.

**Temperatures on Earth** The coldest place on Earth is Antarctica. The lowest temperature ever recorded there was -89°C (-129°F) in 1983. The hottest temperature recorded on Earth was in Libya, in North Africa, in 1922 when it was 58°C (136°F). The hottest temperature recorded in California is in Death Valley where it reached 57°C (135°F). Much colder and hotter temperatures have been produced in laboratories. Scientists have experimented with temperatures as low as billionths of a degree above absolute zero and as high as 100 million million degrees Celsius.

**VOCABULARY**

**absolute zero** - the lowest temperature there can be, equal to -273.3°C or -460°F.

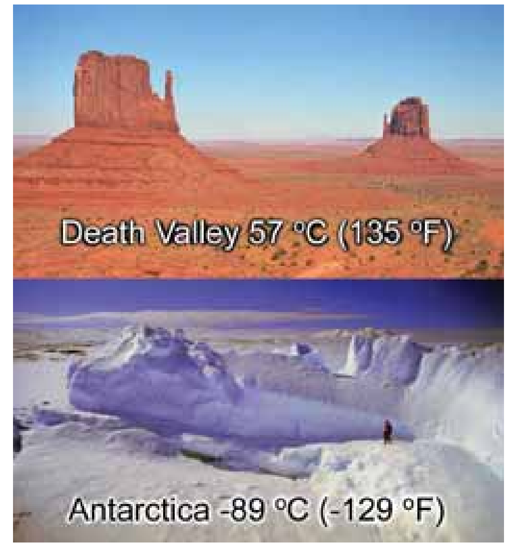



**Figure 3.10:** *Some extremes of temperature on Earth.*

**CHALLENGE**

Can you think of a reason the temperature cannot go lower than absolute zero? Hint: Think about the energy of molecules as they get colder and colder.

## Heat and thermal energy

**Temperature measures thermal energy**

Temperature measures a kind of energy called **thermal energy**. The higher the temperature, the more thermal energy is present. A hot object has more thermal energy than the same object when it is cold. On the molecular level, thermal energy comes from the motion of atoms in matter. When matter is hot, atoms are vigorously moving with lots of kinetic energy. When objects are cold, the atoms move slower and have less kinetic energy. Fundamentally, thermal energy is the total energy stored in the kinetic energy of individual atoms.

**Heat is moving thermal energy**

When you put something hot in a cold room, the temperature of the hot object decreases. The temperature of the cold air in the room increases. This is because thermal energy flows from hot to cold, or from higher temperature to lower temperature. We call thermal energy that is flowing **heat**. Heat flows from hot to cold whenever two quantities of matter at different temperatures are allowed to interact with each other (Figure 3.11).


**Calories**

Thermal energy is often measured in **calories**. One calorie is the amount of energy it takes to raise the temperature of one milliliter of water by one degree Celsius. The calorie is a slightly larger unit of energy than the joule. One calorie is 4.184 joules. There are two different units because scientists started measuring heat in calories before they knew heat was a form of energy.

**Food energy is measured in kilocalories**

Joules and calories are tiny amounts of energy compared with the energy used around you every day. Because the joule is so small, the energy in foods is measured in kilocalories, also called food calories, or just Calories with a capital "C." One Calorie (kilocalorie) is equal to 4,184 joules. The energy in a single jelly doughnut (200 Calories) is an astounding 837,000 joules.

### VOCABULARY

**thermal energy** - energy that is due to difference in temperature. Thermal energy comes from kinetic energy of individual atoms.

**heat** - thermal energy that is moving.

**calorie** - a unit of energy equal to 4.184 joules or the energy needed to heat 1 gram of water by 1°C.

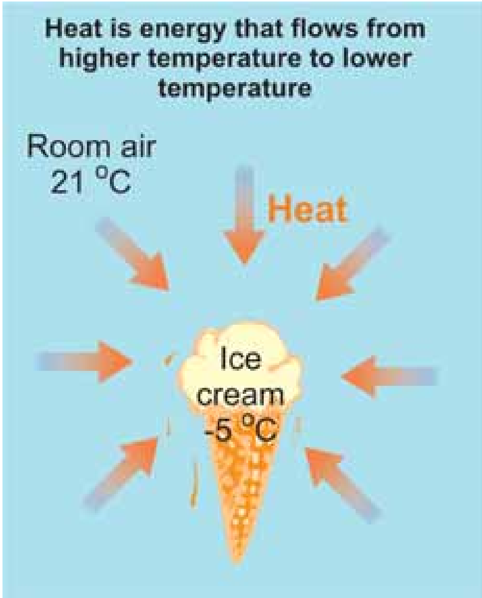



**Figure 3.11:** *Heat is the flow of thermal energy from higher temperature to lower temperature.*

## Specific heat

**Temperature and mass**

If you add heat to an object, how much will its temperature increase? It depends in part on the mass of the object. If you double the mass of the object you are going to heat, you need twice as much energy to increase the temperature.

**Temperature and type of material**

The amount of temperature increase also depends on the kind of material you are heating. It takes different amounts of energy to raise the temperature of different materials. You need to add 4,184 joules of heat to 1 kilogram of water to raise the temperature by 1°C. (Figure 3.12). You only need to add 470 joules of heat to raise the temperature of a kilogram of steel by 1°C. It takes nine times more energy to raise the temperature of water by 1 degree than it does to raise the temperature of the same mass of steel by 1 degree.

**Specific heat**

The **specific heat** is a property of a substance that tells us how much heat is needed to raise the temperature of one kilogram of a material by one degree Celsius. A large specific heat means you have to put in a lot of energy for each degree increase in temperature. Specific heat is measured in joules per kilogram per degree Celsius (joule/kg°C).

***The specific heat is the energy that will raise the temperature of one kilogram by 1°C.***

**Uses for specific heat**

Knowing the specific heat tells you how quickly the temperature of a material will change as it gains or loses energy. If the specific heat is *low* (like it is for steel), then temperature will change relatively quickly because each degree of change takes less energy. If the specific heat is *high* (like it is for water), then temperature will change relatively slowly because each degree of change takes more energy. Next time you have some for dessert, remember that your apple pie filling will stay hot for a long time because it is mostly water and water has a high specific heat.

**VOCABULARY**

**specific heat** - a material property that tells how much energy is needed to change the temperature by one degree.

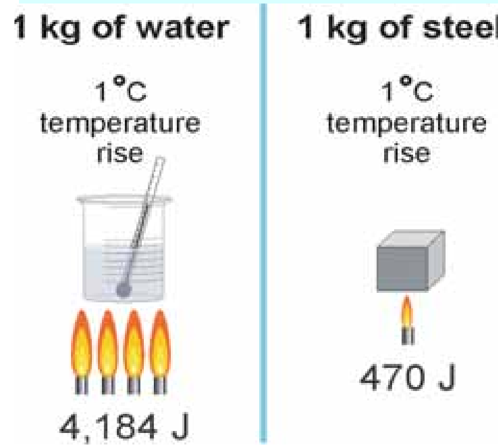



**Figure 3.12:** *It takes 4,184 joules to raise the temperature of 1 kilogram of water by 1°C but only 470 joules for a kilo of steel.*

| Material | Specific heat (J/kg°C) |
|---|---|
| water | 4,184 |
| aluminum | 900 |
| steel | 470 |
| oil | 1,900 |
| concrete | 880 |
| glass | 800 |
| wood | 2,500 |

**Figure 3.13:** *Specific heat values of some common materials.*

## Conservation of energy

**Law of conservation of energy**

One of the most important of all the natural laws concerns energy. The **law of conservation of energy** says that energy can never be created or destroyed, just converted from one form into another. The law of conservation of energy applies to all forms of energy, including potential energy, kinetic energy, and chemical energy.

***Energy can never be created or destroyed, just converted from one form into another.***

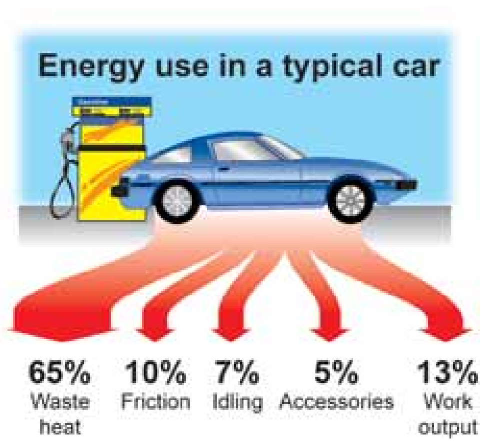
**Energy transformations**

Although it cannot be destroyed, energy can be transformed easily between its different forms. The diagram in Figure 3.14 shows the energy transformations that produce the electrical energy you use.

**Energy from water and wind**

Many parts of California get energy from water and wind. In hydroelectric power, energy is released by falling water. The potential energy of the water is converted into electrical energy. In wind power, the kinetic energy in moving air is converted into electrical energy.

**Chemical energy**




Chemical energy is energy that is stored in the bonding forces between atoms. Chemical reactions may use or release chemical energy. A car engine converts about 13 percent of the chemical energy in gasoline into kinetic energy of the moving car. Much of the remaining 87 percent of the energy in the gasoline becomes heat in the exhaust gases and radiator.

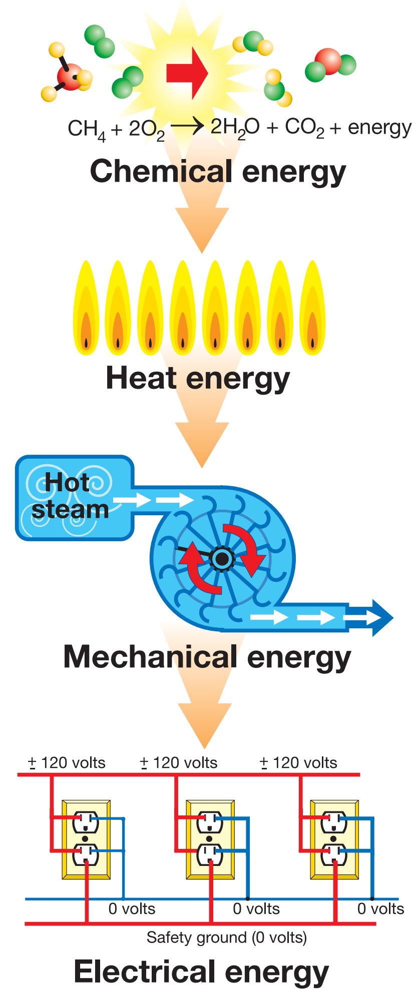



**Figure 3.14:** *.The electricity in your wall outlets at home carries energy that has been transformed several times before becoming electrical energy.*

## 'Using' and 'conserving' energy in the everyday sense

**Conserving energy**

We have all heard that it's good to "conserve energy" and not waste it. This is good advice because energy from gasoline and electricity costs money and uses resources. But what does it mean to "use energy" in the everyday sense? If energy can never be created or destroyed, how can it be "used up"? Why worry about "running out" of energy?

**Using energy**

When you "use" energy by turning on a light you are converting energy from one form (electricity) to other forms (light and heat). What gets "used up" is the amount of energy *in the form of electricity*. Electricity is a valuable form of energy because it is easy to move long distances (through wires). So the energy is not truly "used up" but is just converted into other forms. The total amount of energy stays constant.

**Power plants**

Electric power plants do not *make* electrical energy. Energy cannot be created. What power plants do is convert other forms of energy (chemical, solar, nuclear) into usable electrical energy. When someone advises you to turn out the lights to conserve energy, they are asking you to use less *electrical energy*. If people used less electrical energy, power plants would have to burn less oil, gas, or other fuels to "produce" the electrical energy.

**Running out of energy**

Many people are concerned about "running out" of energy. What they mean is running out of certain *forms* of energy that are easy to use, such as oil and gas. When you use gasoline in a car, the chemical energy in the gas mostly becomes heat energy. It is impractical to put the heat energy back into the form of gasoline, so we say the energy has been "used up" even though the energy itself is still there, only in a different form. Earth contains a limited amount of oil and gas. When what we have is gone — that is, converted from gas and oil into other forms — there will be no more. There will still be plenty of energy, just not in the form of oil or gas. Those two are valuable because much of our economy has been developed around using the energy contained in them.

### CHALLENGE

**Please turn out the lights when you leave!**

There are about 285,000,000 people living in the United States. If an average house has four light bulbs per person, it adds up to 1,140,000,000 light bulbs. The average bulb uses 100 joules of electrical energy each second. Multiplying it out gives an estimate of 114,000,000,000 joules every second — just for light bulbs.

A big electric power plant puts out 2 billion joules each second. That means 67 big power plants are burning up resources just to run your light bulbs. If everyone were to switch their incandescent bulbs to fluorescent lights, we would save 75 percent of this electricity. That means we could save 50 big power plants' worth of pollution and wasted resources.

## 3.2 Section Review

1. Write a paragraph about a system inside your home or school building. Describe what the system does as a whole. Describe at least three parts of the system. For each part, describe how it contributes to the function of the whole system.
2. Scientists would like to understand many things that are large and complex, like the ecology of Earth. Scientists divide complex things into smaller groups called systems because:
   a. It is easier to understand a small group than a large complex thing.
   b. There is not enough money to study the entire complex thing.
3. Which is the higher temperature: 30°C or 60°F?
4. A cook warms up 1 bowl of soup from 20°C to 60°C (Figure 3.15). Another cook warms up 10 identical bowls of soup from 20°C to 60°C. Which of the following statements is FALSE?
   a. Both cooks use the same amount of heat (energy) because the temperatures are the same.
   b. Both cooks use different amounts of heat (energy) even though the temperatures are the same.
5. Describe the flow of energy as a cup of hot coffee cools down as it sits on a table.
6. True or false: If the same amount of heat is applied to water, steel, and wood, the temperature of each one will rise by the same amount.
7. Imagine you are the teacher of a science class. A student brings in a newspaper article that claims the world will run out of energy by the year 2050 because all the oil will be pumped out of the planet. The student is confused because she has learned in science that energy can never be created or destroyed. How would you explain to her what "running out of energy" means in the article.

**CHALLENGE**

Research what is going on in your community around energy conservation. Write about a project that is anticipated to save energy. How much energy might be saved?

**CHALLENGE**

Every month your family pays an electric bill for energy you have used. Research the cost of electricity in your area. How much does it cost for 1 million joules? This is the amount of energy used by a single electric light bulb in three hours.

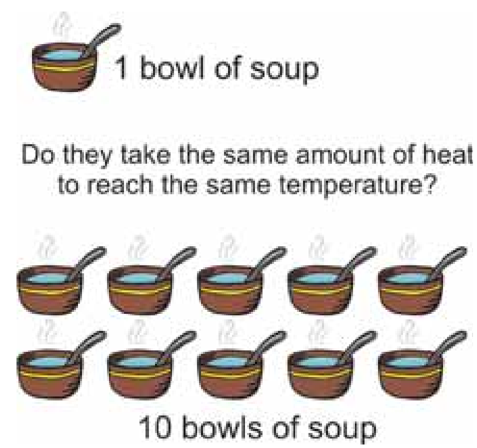



**Figure 3.15:** *Question 4*

ECOLOGY CONNECTION

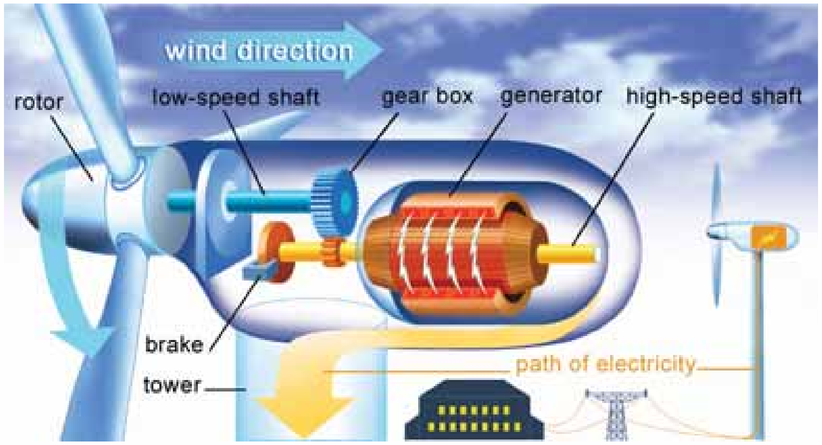
# A Mighty Energizing Wind

There is a new kind of farm that is unlike any other - it reaps the wind. These farms can help solve the energy crisis by generating electricity from the powerful forces in wind.

Not that long ago, most farms in the United States had a windmill. It was used to pump water from a well to supply the farm's needs. These days an electric motor pumps the water, and the old windmill is gone or just an antique.

New windmills, however, are going strong. Tower-mounted wind turbines that are far larger and more efficient have replaced the old models. When these big turbines are grouped, they form a wind farm. They are being built on land that is still used for farming. With support from industry and the government, wind farms are sprouting across the country. Researchers are finding ways to improve windmill efficiency and solve the issue of low wind speed.

A wind turbine is almost the opposite of a fan. A fan uses electricity to make wind; the turbine uses wind to make electricity. The operation is quite simple: Wind turns the turbine's blades, which spins a shaft that connects to a generator, which produces electricity. The old farm windmills had several blades on a small metal or even wooden tower. Today's wind turbines have two or three blades mounted on towers that may be hundreds of feet tall.




## The promise of wind's power

According to the U.S. Department of Energy, wind power costs 4 to 6 cents per kilowatt-hour. Coal-fired power costs 4.8 to 5.5 cents, and natural gas can cost as little as 4 cents, so wind power is competitive. And it has notable advantages.

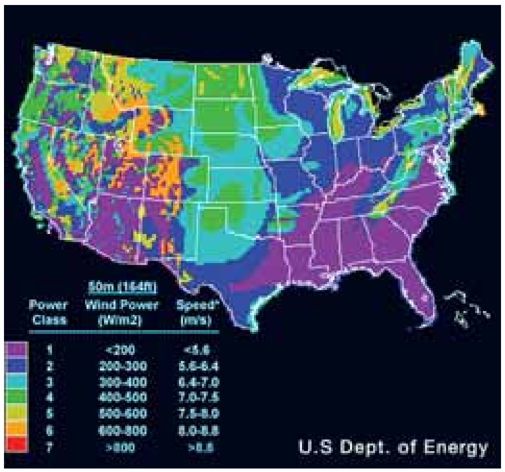
- A clean fuel source that does not pollute the air like coal- or gas-burning power plants.
- Does not need to be imported.
- Abundant resource - it will never run out.
- Requires no mining or drilling.
- One of the lowest-priced renewable energy technologies available.

Wind power can also benefit the economies of rural areas. The power companies pay rent to landowners. Since the turbines occupy only a fraction of the land on a wind farm, the landowner can farm around the towers.

## Obstacles, naturally

The biggest problem with wind power is obvious: Wind is intermittent. It cannot be counted on to blow when electricity is needed. It does not blow at a steady rate. Another problem is that electricity from wind cannot be stored, except in batteries.

Also, the best sites for wind farms are often in remote locations, in mountains or deserts, far from cities where the most electricity is needed. The map of the United States shows wind energy potential. Find your state to see how windy it is compared with other states.




According to the Department of Energy, 6 percent of the nation's land mass has wind energy resources. This area has the potential to supply more than one and half times the electricity being consumed today. Yet obstacles stand in the way of harvesting this natural resource.

- Wind farms are not always welcome in communities, for a variety of reasons.
- As the turbines spin, rotor blades produce a certain amount of noise.
- Some people dislike the industrial look of the wind-farm towers.
- Concern for the fact that some birds and bats are killed when they fly into the rotors.

## Searching for solutions

There needs to be more research and better methods of harvesting in areas with less wind speed. Wind industry scientists and engineers, in partnership with the Department of Energy, are designing, analyzing, and testing equipment and methods in order to improve performance.

Progress in research requires test after test. Before a new product such as an improved wind turbine is placed on the market, a single model is made and tested repeatedly.

Not all wind farms are on land. Offshore wind energy projects such as the Nantucket Sound wind farm are being looked at more closely. Research is underway on floating turbines to be tested in US coastal waters and the lower Great Lakes. Such sites would be one way to solve the drawback of distance from large cities that need electricity.

**Questions:**

1. How does a wind turbine operate?
2. Compare and contrast wind energy with fossil fuel.
3. What are the disadvantages to wind power?
4. Why is it important to research and study wind energy?

Chapter 3 Connection

# CHAPTER ACTIVITY Your Own Science Experiment

The scientific method sets science apart from other types of study. The method begins with observation of some phenomenon. After making observations, scientists propose a hypothesis. A hypothesis is an informed guess about the outcome of the experiment. The hypothesis is then tested to find out whether or not it is true. During this activity, you will be designing and conducting your own experiment.

## Materials:

String, assorted sizes of balls, newspaper, meter stick, stopwatch, balance, paper cups, macaroni, rubber bands, paper clips

## What you will do

1. Brainstorm with your group to decide on an experiment you could make up and carry out with the above materials. Working together, brainstorm what questions your group would like to find answers to.
2. Once you decide on an experiment you would like to design, identify the independent variable, dependent variable, and control variables. Think about how changing the different variables or keeping them constant might affect your experiment.
3. Write a procedure for your experiment. List which of the materials you are using. Think about what types of measurements and observations you need to make. Could any of the materials could be used for making measurements?
4. Make an educated guess, using your experience and knowledge, as to what you predict will happen in this experiment. Think about the relationship between the independent and dependent variables. Your educated guess is your hypothesis.
5. Carry out your experiment. Take your measurements and make your observations. Record all your data.
6. Analyze your data to determine whether your hypothesis was correct. This may involve making a graph or other type of model.
7. Write a conclusion to explain your results.

## Applying your knowledge

a. Did your results support or contradict your hypothesis? If your hypothesis turned out to be wrong, what do you think might be a correct hypothesis?

b. Did you have any problems with your experiment? Do you need to change anything in the procedure and try the experiment again?

# Chapter 3 Assessment

## Vocabulary

Select the correct term to complete the sentences.

| | | |
|---|---|---|
| kilogram | gram | atom |
| element | compound | system |
| energy | Calorie | newton |
| heat | thermometer | Fahrenheit |
| Celsius | force | conservation of energy |

***Section 3.1***

1. The basic SI unit of mass, approximately equal to 1000 grains of rice, is the ____.
2. A pure substance that cannot be broken down into other substances is known as a(n) ____.
3. A combination of elements that most often has properties different than the elements from which it is made is called a(n) ____.
4. The smallest particle of matter which retains the identity of the element it comes from is called a(n) ____.
5. An amount of mass equal to one-thousandth of a kilogram is a(n) ____.

***Section 3.2***

6. A small group of related things that work together may be called a ____.
7. A quantity that measures the ability to cause change in a physical system in units of joules is known as ____.
8. A unit of energy larger than a joule used to measure the energy available in food is the ____.
9. An SI unit used to measure force, equal to less than one-quarter of a pound, is the ____.
10. A natural law that says energy cannot be created or destroyed is the law of ____.
11. An action, measured in newtons, that has the ability to transer energy or change motion is called a(n) ____.
12. A(n) ____ is an instrument used to measure temperature.
13. The temperature scale on which the freezing point of water is 32 degrees and boiling point of water is 212 degrees is the ____ scale.
14. The temperature scale on which the freezing point of water is 0 degrees and boiling point of water is 100 degrees is the ____ scale.
15. When thermal energy flows from hot to cold it is called ____.

## Concepts

***Section 3.1***

1. Scientists find it useful to use both grams and kilograms for measuring mass. Why is it necessary to have two different SI units of mass?
2. Mass describes:
   a. an object's size.
   b. the amount of matter in an object.
   c. the type of elements in an object.
3. What laboratory instrument is most often used to measure mass?
4. Identify the following substances as an *element* or a *compound*:
   a. ____ table salt (sodium chloride)
   b. ____ oxygen gas
   c. ____ rust
   d. ____ iron

5. If a scientist were to cut a piece of the element iron into the smallest possible piece of iron, what would be the name given to that smallest piece of iron?
6. Describe the difference between the arrangement of atoms in solids, liquids, and gases.
7. Which has the lowest energy of motion?
   a. solid
   b. liquid
   c. gas
8. Which has its atoms farthest apart?
   a. solid
   b. liquid
   c. gas
9. Which of the following is a true statement?
   a. In the gas state, atoms move around freely.
   b. Liquids do not change shape easily.
   c. Gas molecules move more slowly as they are heated.

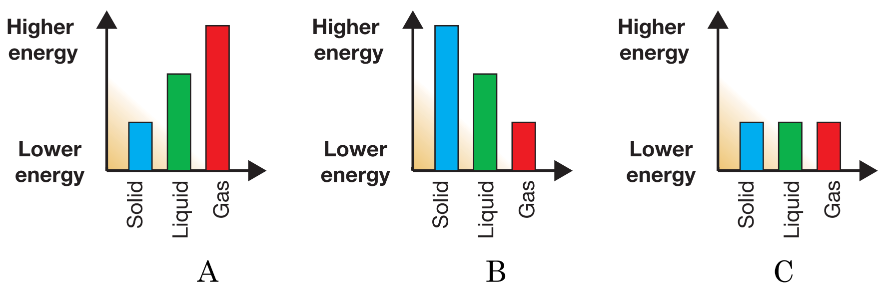
***Section 3.2***

10. Name 3 natural or man-made systems.
11. Why do scientists organize nature into systems?
12. Explain how force and energy are related.
13. Energy takes many forms. Compare potential energy to kinetic energy and give two examples of each.
14. Write the letters **KE** (kinetic energy) or **PE** (potential energy) to indicate which type of energy is illustrated by each of the following examples.
    a. ____ a car moving down the street
    b. ____ a bicycle stopped at the top of a hill
    c. ____ a box sitting on a table
    d. ____ a ball rolling across the floor
15. Which has the higher kinetic energy, ice or steam? Why?
16. Describe what happens when matter is heated to extreme temperatures greater than 10,000°C.
17. Explain the difference between thermal energy, heat, and temperature.
18. Heat always flows from ____ temperature to ____ temperature.
19. What did Gabriel Fahrenheit use to set 100°F for his Fahrenheit temperature scale?
20. What happens to atoms at absolute zero?
21. Energy is measured in:
    a. joules.
    b. newtons.
    c. kilograms.
22. People who say that "using less electrical energy will conserve energy" are not really saying (scientifically) what they mean. Explain in a scientifically accurate way what these people are trying to say.
23. What happens to the electrical energy used to turn on the lights in your home?
    a. It is used up.
    b. It is destroyed.
    c. It is converted to light and heat energy.
24. Do power plants create electrical energy from empty space?
25. When energy transformations occur in a system, the total amount of energy in the system:
    a. increases.
    b. decreases.
    c. stays the same.

## Problems

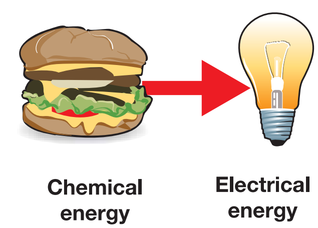
**Section 3.1**

1. Kyela has a mass of 45 kg. What is her mass in grams?
2. An average baseball has a mass of 150 grams. What is its mass in kilograms?
3. What is the mass in grams of a 0.454 kilogram soccer ball?
4. Which graph best represents the relative energy of the atoms of substances in the solid, liquid, and gas phases?




**Section 3.2**

5. For each of the following examples, which has more thermal energy?
   a. 1 kg of water at 50°C or 2 kg of water at 50°C
   b. 1 kg of ice at 0°C or 1 kg of water at 5°C
   c. 1 kg of water at 5°C or 1 kg of steam at 105°C
6. Which of the following will have the highest temperature when 1,000 joules of energy are added to it? Assume each starts at the same temperature.
   a. 1 kg of water (specific heat = 4184 J/kg°C)
   b. 1 kg of wood (specific heat = 2500 J/kg°C)
   c. 1 kg of glass (specific heat = 800 J/kg°C)
7. How much heat in joules would you need to raise the temperature of 1 kg of water by 2°C?
8. If a single light bulb uses 100 joules of energy every second, how many Calories of energy are used each second if there are 4,184 joules in one Calorie?
9. A very bright light bulb uses 150 joules of energy every second. An average fast-food burger contains 350 Calories of energy. If the energy of the burger could be converted to electricity without any energy loss, how long would the energy from the burger light the bulb?




10. One pancake contains about 80 Calories of energy. One Calorie contains 4,184 joules. What is the amount of energy in joules in one pancake?
11. A pizza restaurant advertises that their brick oven cooks their pizza at 800°F. What is this temperature in degrees Celsius?
12. Earth's core is estimated to be 7,000°C. What is this in degrees Fahrenheit?
13. Which temperature scale, Fahrenheit or Celsius, has the greatest change in temperature for one degree?
14. Describe the energy transformations or conversions for each of the diagrams below: