In the preceding chapters in this book, we have discussed the properties of matter. Observations about matter are fairly easy to make because matter in any of its forms or states has substance. All liquids, solids, and gases occupy space and can be weighed. These substances are easily handled because we can see them, touch them, or, occasionally, smell them.

In our study of chemical reactions, we learned that every chemical change is accompanied by a change in *energy*.

Energy, like matter, is an important factor in our universe. Without energy, all matter—living and nonliving—would be at a standstill. Nothing would move—nothing would live. Unlike matter, energy is somewhat mysterious because it has no weight, it does not occupy space, and it has no form or odor. However, the careful study of the motion of all types of matter has helped scientists to discover many facts about energy.

Energy is considered to be the "mover of matter." In other words, any object that moves possesses energy. When a batter hits a baseball, for example, it is easy to see that the moving baseball possesses a great deal of energy. Whatever moves—a baseball, a planet, an automobile, an animal, or a molecule—requires energy (see Fig. 14-3). Scientists define energy as the ability to do work.

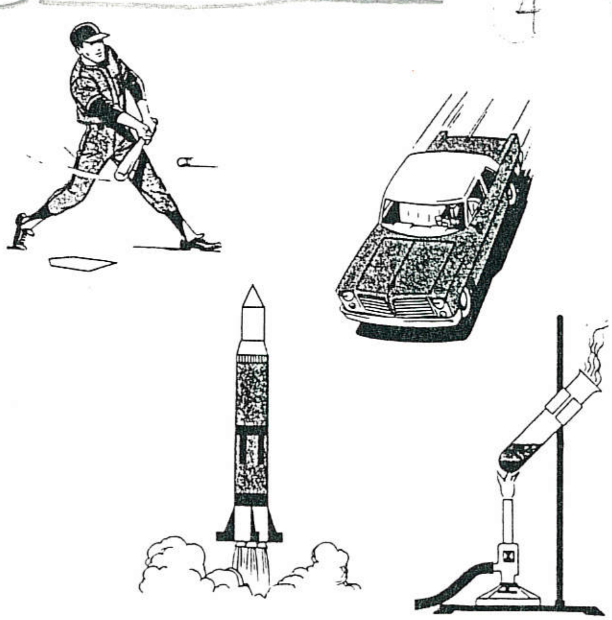


**Fig. 14-3. All of these situations require energy.**

## ENERGY AND WORK

In scientific terms, **work** is performed on a sample of matter only when the matter has been moved through a particular distance. When a student lifts his books from his desk, for example, he performs work because the books move through a specific distance (see Fig. 14-4). However, if his books are on the floor and he jumps up and down on them, he performs no work on the books because they do not move (see Fig. 14-5). In this case, the only work he does is to move his body upward each time he jumps. Any work that we perform, whether on books or on any other type of matter, is possible because our body possesses energy. That is, by exerting our muscles, we are able to move things.

**Fig. 14-4. Work is done. Fig. 14-5. Work is not done.**

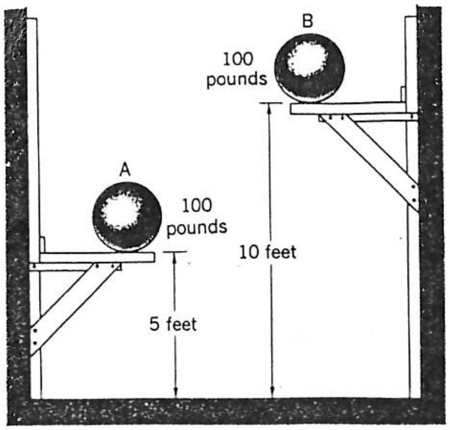
Although no one is sure of the origin of energy in the universe, we know that it exists and that it can be classified as either **potential energy** or **kinetic energy**.

## POTENTIAL ENERGY

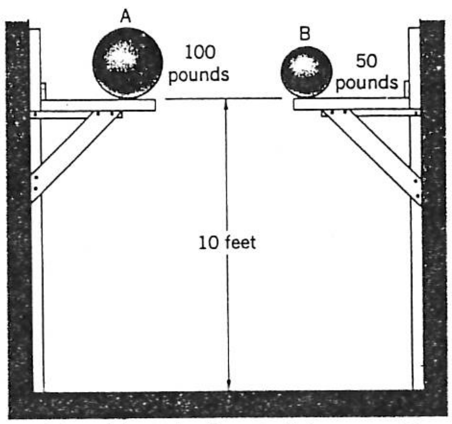
Potential energy is stored energy, such as the energy in a rock on the top of a hill.

Thus, the height to which an object is raised is one of the factors used in determining the amount of potential energy stored in the object.

A second factor used in determining potential energy is the weight of the object. When a heavier object is raised to the same height above the ground as a lighter object, the heavier object has more potential energy because the pull of gravity on the heavier object is greater.




*a.* Sphere B has twice the potential energy as A




*b.* Sphere A has twice the potential energy as B

**Fig. 14-6. Factors determining potential energy.**

Consider the situation shown in Fig. 14-6. Fig. 14-6*a* shows two steel spheres of equal weight. Sphere *A* is raised to a height of 5 feet, while sphere *B* is raised to a height of 10 feet. Sphere *B* is twice as high as *A* and therefore has twice the potential energy because the weight of the two spheres is the same. In the second case (Fig. 14-6*b*), sphere *A* weighs 100 pounds and sphere *B* weighs only 50 pounds. The two spheres are raised to the same height, 10 feet from the ground. Since the height is the same, sphere *A* has twice as much potential energy as *B* because it is twice as heavy as sphere *B*.

As the following examples show, potential energy can be released to perform useful work:

In a pile driver, a heavy weight is lifted high into the air, then dropped onto the pile or girder that is being sunk into the ground (Fig. 14-7). The higher the weight is lifted and the heavier the weight, the greater is the potential energy available for performing the work of sinking the pile.

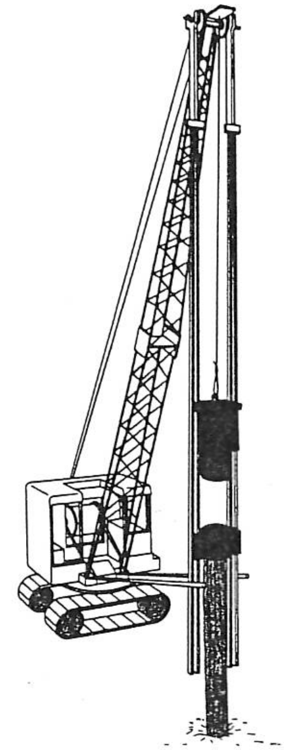


**Fig. 14-7. A pile driver.**

In most roller-coasters at amusement parks, a train of cars is raised to the very top of the roller-coaster track by a machine-driven chain mechanism. The cars are then released and "coast" down the track, through a series of turns and dips. Whenever the cars reach the bottom of a dip, there is enough energy available to carry them up the next rise. Eventually, friction slows down the cars to such an extent that the ride ends.

There are many other examples of potential energy as stored energy. For example, a model airplane may be equipped with a rubber-band motor. When the rubber band is wound by turning the propeller, the rubber band is stretched. The energy used in twisting and stretching the rubber band is now stored in the band as potential energy. When the propeller is released, the potential energy is released. As the rubber band unwinds and returns to its original size and shape, the rubber band performs work by making the propeller move through a specific distance.

Potential energy is also found stored as chemical energy. Striking examples of such stored energy are seen in explosives, such as TNT and dynamite. When these explosives are set off, a rapid release of energy—an explosion—occurs. The energy made available by these explosions can do work, such as moving rock during road building and in mining.

## KINETIC ENERGY

The energy possessed by an object in motion is called **kinetic energy** and is derived from the energy stored in stationary objects—potential energy. Under ideal conditions (that is, in the absence of friction), this transformation occurs without any loss.

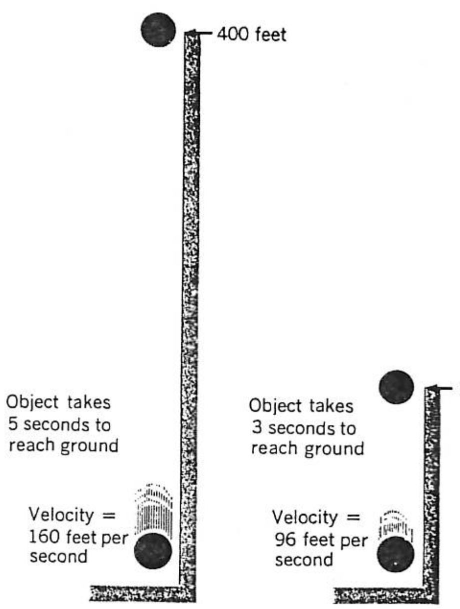



**Fig. 14-8. As a body continues to fall freely, its speed increases.**

As shown in Fig. 14-8, an object dropped from a greater height travels faster than the same object dropped from a lesser height. The sphere that was struck in our experiment also moved more rapidly as the height of the striking sphere was increased. These observations tell us that the *speed* of a body is one factor that determines how much kinetic energy a body possesses.

When a baseball is thrown gently (with little speed), a player can catch it barehanded and hardly feel it because the kinetic energy of the ball is small. On the other hand, when a pitcher throws the same baseball with great speed, the ball has much more kinetic energy and the catcher must wear a thick glove to protect his hand.

Suppose a baseball thrown with a speed of 50 miles per hour hits a wall. The ball will bounce away, doing little damage to the wall. However, should an automobile traveling at 50 miles per hour strike the wall, the wall—and the car—will probably be demolished (see Fig. 14-9). In this case, the destruction is due to the large kinetic energy resulting from the greater mass of the car. Thus, mass of an object is a second factor in determining how much kinetic energy a body possesses.

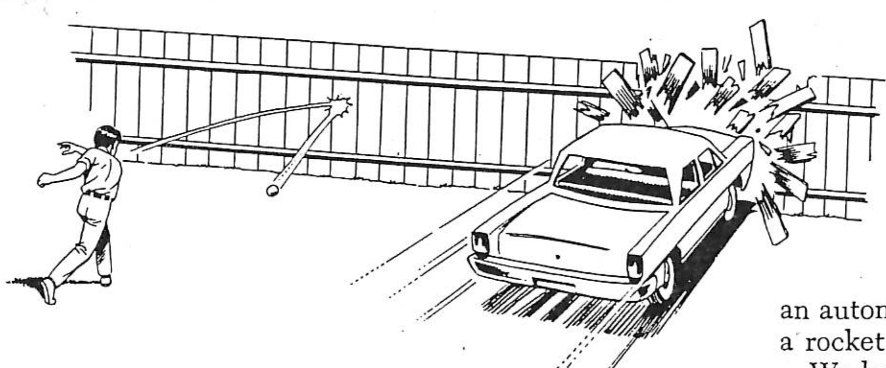


**Fig. 14-9. Mass and kinetic energy.**

Any moving object, regardless of size, possesses kinetic energy. Thus, a moving car or a rocket heading to the moon gives evidence that engines of various types produce kinetic energy and cause large objects to move. Think of the work performed by an engine in moving an automobile across the country or in moving a rocket to the moon.

We know that the molecules of matter are in constant motion and thus also possess kinetic energy. Recall that when a gas is heated, the velocity of the molecules increases and consequently the kinetic energy of the molecules also increases. This increase in kinetic energy is accompanied by a rise in temperature. Furthermore, the increased kinetic energy of the molecules of a solid weakens the attractive forces between the molecules, forming first a liquid, and finally, a gas. This is why high temperatures favor the gaseous state, whereas low temperatures favor the solid state.

# FORMS OF ENERGY

Energy may be further classified into six forms: chemical, heat, mechanical, radiant (which includes light), electrical, and nuclear.

## CHEMICAL ENERGY

Chemical energy is the potential energy stored in chemical substances. Generally, it is the energy resulting from the attractive forces that bind atoms or molecules together. When released, this type of energy can do work such as running a gasoline engine or propelling a rocket into space. When released suddenly (as in the explosion of dynamite), chemical energy can move a mountain (see Fig. 14-10). When released gradually, chemical energy is the energy that living things utilize for all of their life activities.

Living things obtain energy from the gradual oxidation of such foods as sugar. Sugar is a compound of carbon, hydrogen, and oxygen.

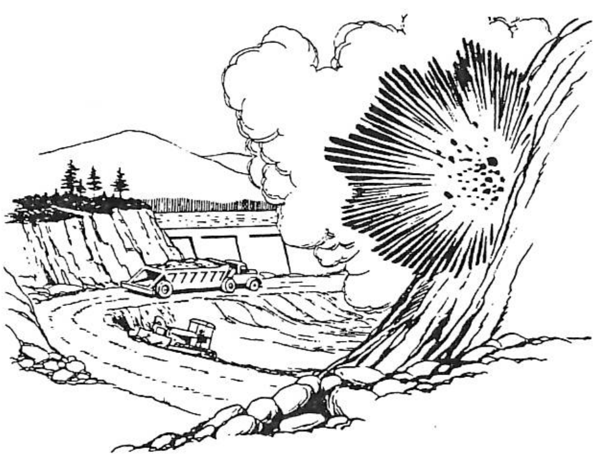


Fig. 14-10. Chemical energy can do work.

When sugar is oxidized by living things, chemical energy from the bonds (the attractive forces) holding its particles together is released. This energy can do many kinds of work. For example, it can cause muscles to contract, enabling us to move and lift objects. Chemical energy aids in the flow of nerve messages to and from the brain, and, as we have said, is involved in all life functions.

## MECHANICAL ENERGY

Mechanical energy is perhaps the form of energy most familiar to us. It includes the energy of moving objects—large and small. It is the energy with which a hammer striking a nail does the work of driving the nail into a piece of wood (Fig. 14-11). It is the energy that powers a baseball hit by a bat. It is the energy that moves a bicycle (Fig. 14-12), and powers a pile driver. From these examples, it is apparent that mechanical energy is a most useful form of energy for everyday work.

Fig. 14-11. Mechanical energy does work.

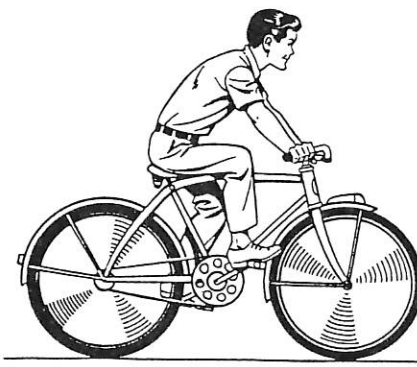


Fig. 14-12. Mechanical energy turns a wheel.

## HEAT ENERGY

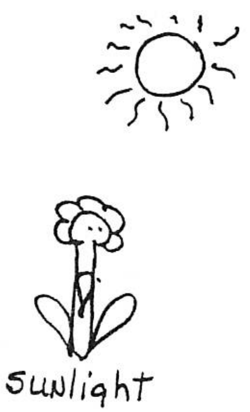
Heat energy is associated with the motion of molecules. It is a form of energy that usually results from the friction caused by substances rubbing against one another. In cold weather, we warm our hands by rubbing them together quickly. Our hands feel warmer due to the friction produced. In steam engines, heat energy changes water into steam, which in turn expands and forces pistons to move, thus driving the engine. In our homes, heat energy warms entire rooms by creating air currents near radiators, thus causing warm air molecules to move away from the radiator to other parts of the room.

## LIGHT ENERGY

Light energy, given off by all stars, floods our universe in fantastically large quantities. The light energy from the sun is the form of energy upon which all living things ultimately depend. Green plants use light energy in the manufacture of their food supplies and in giving off oxygen. Since animals depend upon plants for their food and oxygen, it is apparent that light energy makes it possible for all life to exist on earth.

Food is produced by green plants by a complex chemical process known as **photosynthesis.** In this process, which is still not completely understood, the plants combine carbon dioxide and water in the presence of sunlight and chlorophyll and convert these simple compounds to food (sugar) molecules. At the same time, the plants release oxygen. The following equation summarizes the changes that take place during photosynthesis:

$$6\ CO_2\ (g) + 6\ H_2O + \text{energy} \xrightarrow{\text{chlorophyll}} \underset{\text{sugar}}{C_6H_{12}O_6} + 6\ O_2\ (g)$$






Light energy is the most plentiful form of energy. An example of the work that light energy can do is in photography. When light strikes a surface coated with certain silver salts, these salts darken. The coated surface, when developed, becomes a negative. Light passed through the negative can produce an image (a picture) on paper also coated with these silver salts.

Light energy is also used in an electric eye. When a beam of light going to the electric eye is broken, an electric alarm or other electrical device is activated. This type of device is often used in banks as a safeguard against burglary and, at one time, was used in automatic elevators to keep the doors open for passengers.

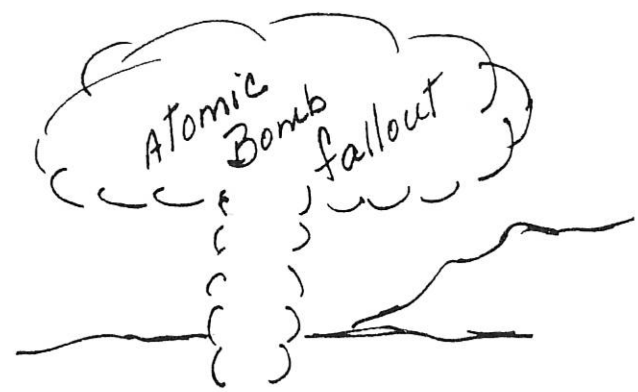
Light energy can be concentrated in special light beams called **lasers.** Laser light contains considerable energy and may be used to transmit signals over long distances. When laser light is focused by a lens, tremendous heat is developed. This energy is used to drill metals and in special kinds of eye surgery.

## ELECTRICAL ENERGY

This type of energy is associated with electric current. Electrical energy allows us to perform work with a minimum of effort and a maximum of efficiency. Such devices as electromagnets, radios, television sets, washing machines, vacuum cleaners, and many trains are operated by this form of energy.

## NUCLEAR ENERGY

Nuclear energy is the energy released by the fission (breakdown) or fusion (joining) of the nuclei of atoms. The discovery of this form of energy led to the invention of such weapons of war as the atomic bomb and the hydrogen bomb. Nuclear energy is presently being used by the electrical industry to produce heat to drive large generators that produce the great quantities of electrical energy needed by man for modern daily living.



# TRANSFORMATION OF ENERGY

Any one of the six different forms of energy can be changed or converted into another form. Such changes in the forms of energy are known as **energy transformations.** Examples of some energy transformations are:

**Mechanical Energy to Heat Energy.** This energy transformation is observed when we rub a block of wood with sandpaper. When the arm holding the sandpaper moves back and forth, mechanical energy produced in the muscles is being used. As the sandpaper rubs against the wood, friction is produced, resulting in the formation of heat energy. Consequently, both the sandpaper and the wood become hot. This transformation can similarly be observed when sawing wood, as shown in Fig. 14-13. Mechanical energy possessed by the arm causes the saw to move through the wood. After a few moments, the saw becomes warm (especially if the saw is dull) and after continued sawing, the saw becomes quite hot.

**Heat Energy to Mechanical Energy.** As we learned earlier, when heat energy is supplied to the boiler of a steam engine, the water is changed to steam under great pressure. The heat energy is thus changed to mechanical energy as the steam pressure causes the pistons and wheels of the engine to move.

**Heat Energy to Light Energy.** This energy transformation can be observed when a wire is placed in the flame of a Bunsen burner. As the wire becomes hot, it begins to glow, first with a dull red light and later with a white light. In this case, the heat energy from the flame is transformed into light energy that leaves the wire. Generally, the hotter an object is, the more light energy it produces.

**Chemical Energy to Heat Energy.** Fuels such as coal or oil, when burned, supply heat energy. In this process, the energy stored in the chemical bonds is changed to heat energy.

**Chemical Energy to Mechanical Energy.** As we have seen before, this energy transformation is vital for the survival of all living things. The chemical energy stored in foods is transformed to the mechanical energy of moving muscles, which enable us to work, breathe, play, and walk.

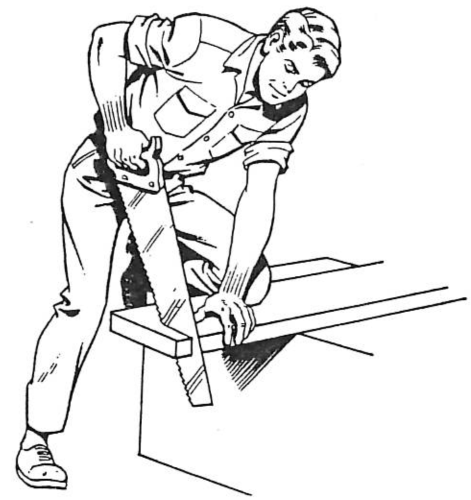


**Fig. 14-13. Converting mechanical energy into heat energy.**

**Nuclear Energy to Heat Energy.** The release of nuclear energy from the fission and fusion of atoms on the sun produces the vast amounts of heat and light energy with which we are familiar. In addition, as mentioned before, the nuclear reactors of electric companies first produce heat energy, which is then converted to electrical energy for use by the consumer.

**Mechanical Energy to Electrical Energy.** The mechanical energy of a moving stream or a waterfall can be used to operate a turbine. (Today, such moving streams are created by man-made dams.) The spinning turbine activates a generator that produces electrical energy, which is sent to factories and homes to run machinery and electrical appliances.

## REVIEW OF ENERGY TRANSFORMATIONS

In order to review a few of the energy transformations that occur, let us consider the turning of a hand generator used to light a bulb (Fig. 14-14). The *chemical energy* released in our bodies is changed to *mechanical energy* as our muscles move. This movement is used to turn the crank of the generator. The crank turns a coil of wire within the set of horseshoe

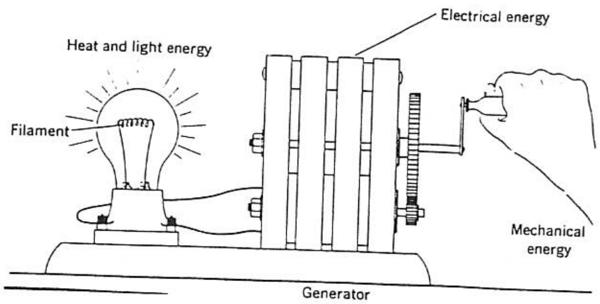



**Fig. 14-14. Energy transformations.**

magnets. This action produces *electrical energy* which flows through other wires to the bulb. In the bulb, the electrical energy causes the filament wire to become hot, thus converting electrical energy to *heat energy*. When the generator is cranked fast enough, the heated wire begins to glow, giving off *light energy*. Thus, even in this simple activity, several transformations of one form of energy to another are observed.

As we have seen, energy transformations are very common occurrences in daily life. People who do not observe carefully find it easy to believe that great amounts of energy are lost during energy transformations. However, careful measurements have shown that this is not the case. Rather, what appears to be a loss of energy is really the change of one form of energy to another, usually to heat. There is neither a loss nor a gain of energy in these transformations. This is expressed in the **law of conservation of energy**, which states that energy can neither be created nor destroyed but can be changed from one form to another.

. Accordingly, scientists now believe that our universe consists of matter and energy, which are both different forms of the same thing. Furthermore, since matter and energy may neither be created nor destroyed, the total amount of matter and energy in the universe is constant (remains the same).