

5.3 Potential Energy



Figure 5.17 What do a lump of coal, a snow-covered mountain, and a lump of uranium ore have in common? How are these objects related to energy?

The photographs in Figure 5.17 — coal, snow, and uranium ore — show the three major sources of energy used to produce electrical energy in Canada. The photographs do not show energy being transformed or any work being done. Nevertheless, energy is stored in each of these substances. This stored energy can be transformed into forms of energy that can do work. Physicists refer to stored energy as **potential energy**. In this section, you will look at several forms of potential energy, including those shown in Figure 5.17. Then you will focus on one specific form of stored energy — gravitational potential energy.

Forms of Potential Energy

Elastic Potential Energy

Elastic potential energy is the easiest form of potential energy to visualize. An object is **elastic** if it always returns to its original form after its shape has been distorted. Work must be done on the object to distort an elastic object. That work gives the object **elastic potential energy** because the object tends to return to its original shape when it is released. For example, energy is stored in stretched or compressed springs, stretched elastic bands, bent diving boards, or stretched trampolines. You might have seen or tried out an amusement park slingshot ride similar to the one shown in Figure 5.18. The motor does work to stretch the bungee cords that hold the frame containing the seat. When the frame is released, the elastic potential energy stored in the stretched bungee cords is rapidly converted into kinetic energy. The riders shoot straight up into the air.



Figure 5.18 A very large amount of energy is stored in the stretched bungee cords in this slingshot ride. As the seat and passengers shoot up into the air, they have lots of kinetic energy. As the seat and passengers slow down and come to a stop at the highest point, what happens to their kinetic energy?

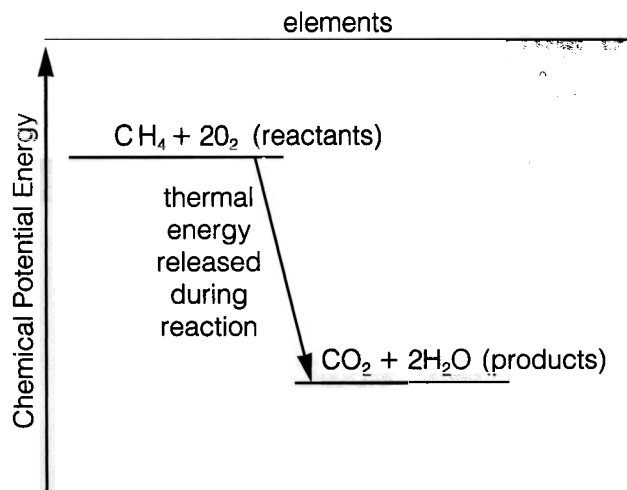
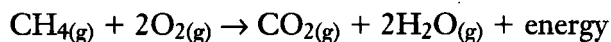


Figure 5.19 Chemicals that are high on the potential energy scale can react to form compounds lower on the scale and release thermal energy.

Chemical Potential Energy

If you have already studied Unit 1, you know that energy is released when bonds are formed between atoms to make molecules. The amount of energy released is much smaller for some compounds than for other compounds. Compounds that lose very little energy when the bonds are formed have the potential of releasing even more energy by undergoing chemical reactions and forming different compounds. The burning of methane in oxygen is an example of such a reaction.



Compounds such as methane are said to have large amounts of **chemical potential energy**. You can visualize the relationships among the reactants, products, and chemical potential energy in diagrams such as Figure 5.19.

Suppose two compounds are low on the chemical potential energy scale and you want them to react and produce compounds that are higher on the scale. You must add energy to the system to make the reaction go forward. In nature, this energy comes from the Sun. Plants capture solar energy and use it to synthesize glucose and other compounds from carbon dioxide and water. The process, as you probably know, is called photosynthesis. The plants themselves and the animals that eat the plants can use the glucose for energy for life processes. The chemical reactions that provide energy for cells are called cellular respiration. The summary reactions are shown below.



These reactions are portrayed on a chemical potential energy scale in Figure 5.20. When plants and animals die, their tissues still contain glucose and related compounds. These plant and animal remains are eventually buried deep underground. Over millions of years, bacterial action, as well as heat and pressure, convert plant material into coal, and animal material into oil and natural gas. These are the fossil fuels that store chemical potential energy. Humans then burn the fossil fuels for transportation and for electrical energy generation. The formation of fossil fuels is included in the energy diagram in Figure 5.20.

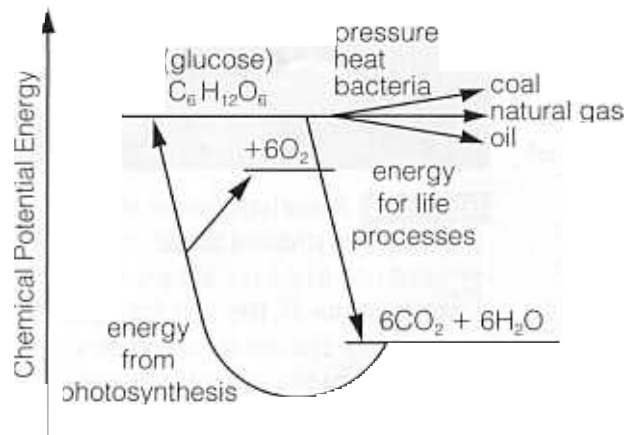


Figure 5.20 Glucose is the principal form of chemical potential energy for plants and animals. Solar energy drives photosynthesis and enables plants to convert carbon dioxide and water back into glucose. The tissues of dead plants and animals are transformed into fossil fuels over millions of years.

DidYouKnow?

The chemical equations for the combustion reactions of methane and glucose are very similar. In both cases, the compounds — methane and glucose — react with oxygen and produce carbon dioxide and water. The combustion of methane produces intense heat and flames. When glucose reacts with oxygen, there are no flames or intense heat. Are the reactions fundamentally the same?

The answer is yes. However, in living systems, glucose does not react directly with oxygen and release all of the energy in one step. Glucose is broken down into carbon dioxide and water in many small steps. A little heat is released in each step. Much of the energy is used to make other compounds that are high on the chemical potential energy scale. The energy in these compounds is used directly for such processes as muscle contraction, nerve conduction, synthesis of bio-molecules, and all processes needed for life.

Nuclear Potential Energy

Very large nuclei — mainly uranium and plutonium — have the potential to split into two smaller nuclei with the release of large amounts of energy. These large nuclei store **nuclear potential energy**. The nuclear reactions that release the stored energy are illustrated in Figure 5.21. When a free neutron collides with a uranium nucleus, the nucleus absorbs the neutron. As a result, the uranium nucleus becomes unstable and splits — or fissions — into two smaller nuclei. Two or three free neutrons are also expelled from the original uranium nucleus. The total mass of the products — the two smaller nuclei and the neutrons — is smaller than the total mass of the original uranium nucleus and the neutron it absorbed. This extra mass has been converted into energy in the form of kinetic energy of the fission products and the neutrons. The process continues because at least one of the free neutrons (expelled when the original uranium atom split) is absorbed by another uranium nucleus. This process is called a *chain reaction*. In Chapter 4, you learned that the kinetic energy of atoms and molecules is thermal energy. Therefore, the nuclear potential energy that was released when the large nuclei fissioned has been transformed into thermal energy. This thermal energy in nuclear reactors converts water into the steam that drives an electric generator.

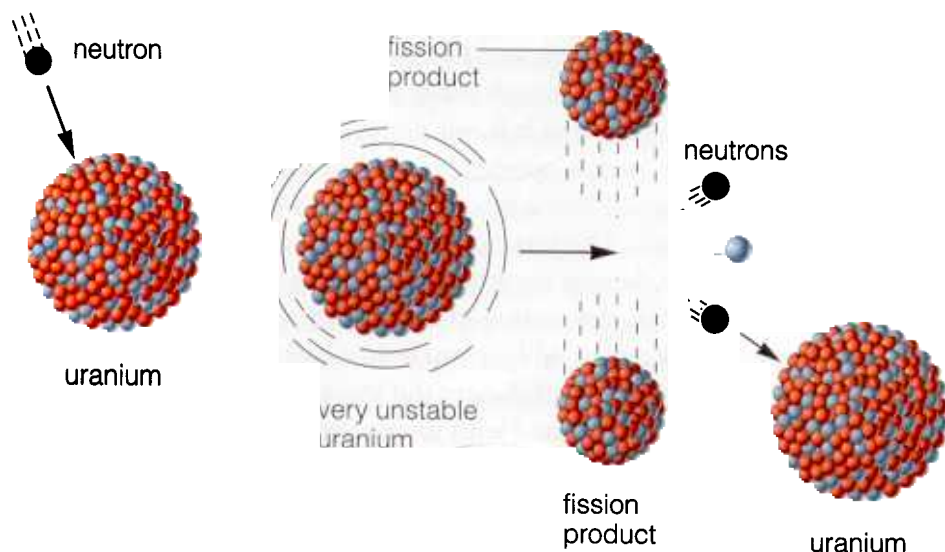


Figure 5.21 This diagram illustrates nuclear fission, the splitting of a very large nucleus.

Gravitational Potential Energy

What do snow-capped mountains in the photograph at the beginning of this section have to do with potential energy? Examine Figure 5.22 to find the answer. The figure shows how solar energy causes water to evaporate into water vapour. Moving air masses carry the water vapour over mountains. The water condenses, forming clouds, and then it snows. The snow melts and runs into streams and rivers. Eventually, the water might run into a reservoir. While held behind the dam, the water in the reservoir has the potential of turning a turbine and generating electrical energy. Since gravity is the force that pulls the water down, the water is said to have **gravitational potential energy**. In the remainder of this chapter, you will learn how to calculate gravitational potential energy and predict the motion of objects under the force of gravity.

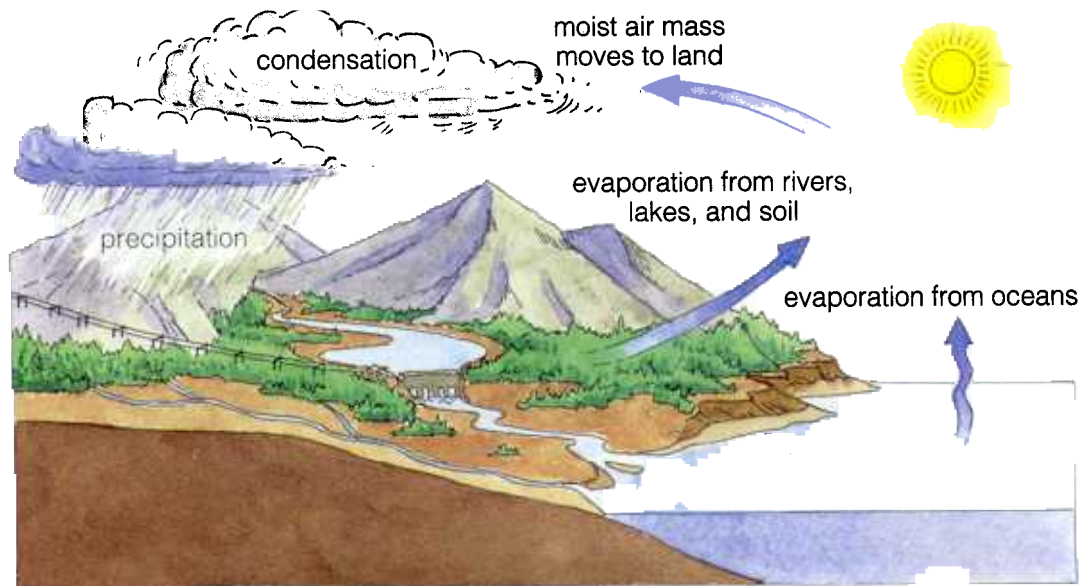


Figure 5.22 You might have seen diagrams similar to this one under the title “The Water Cycle.” Humans have learned how to use the water cycle to provide useful energy.

Explaining Gravity

To discuss gravitational potential energy in detail, you need to learn some basic concepts about the force of gravity. **Gravity** is a property of all objects with mass. Any two masses attract each other with a gravitational force. However, the force is so small that it is not noticeable unless one of the masses is extremely large, such as a moon, planet, or star.

In Section 5.1, you learned that a force acting on an object causes a change in the motion of the object. The force of gravity is always acting on objects near Earth. Therefore, if there is no other force acting on an object to balance the force of gravity, the motion of that object will change. The object will accelerate downward. When you hold a ball or any other object, you are exerting a force on it that balances the force of gravity. When you release the ball, it falls to the ground with increasing speed because it is accelerating downward. Normally, when you drop an object, air friction exerts an upward force that affects the acceleration of the object. If there were no air friction, all objects near Earth’s surface would fall with the same acceleration, called the **acceleration due to gravity**. The acceleration due

to gravity has its own symbol, g , and has an approximate value of 9.81 m/s^2 . This value means that the speed of a falling object increases by 9.81 m/s every second. The acceleration due to gravity is not exactly the same at all points on Earth because Earth is not a perfect, uniform sphere.

Calculating Gravitational Potential Energy

If you were to lift a book above your desk and then drop it, the book would accelerate downward with the acceleration due to gravity. After you lifted the book, it had the potential of falling and thus gaining kinetic energy. Therefore, the book had stored energy while you were holding it. The potential energy that an object has before it is dropped is called **gravitational potential energy**. The amount of gravitational potential energy that the book had is equal to the amount of work that you did in lifting it. To determine how much work that is, you need to know how far you lifted the book and what force you exerted on it. You can choose or measure the distance that you raised the book. How do you determine the force that you exerted on it? Your muscles will tell you that the weight of the book affects the amount of force that you must exert on the book. What is weight?

Mass and weight are *not* the same. Mass affects the weight, but it is not weight. If you took that book to the Moon, it would not feel nearly as heavy as it feels on Earth. However, it would still have the same mass. Weight is the force of gravity acting on a mass. You can calculate the weight of an object by multiplying its mass times the acceleration due to gravity.

Weight

$$F_g = mg$$

where F_g is used to represent weight and the units are newtons (N)

m is the mass in kilograms (kg)

g is the acceleration due to gravity in metres per second squared (m/s^2)

Note: A newton (N) is equivalent to a kilogram metre per second squared ($\text{kg}\cdot\text{m/s}^2$).

When you lift an object with uniform motion, you must exert a force on it equal to its weight. With this information, you can now determine the amount of work that you must do to lift an object from one point to another. In Chapter 4, you learned that work equals force times distance. When the work is done against gravity, the force is the weight of the object or the force of gravity acting on it. The direction of the motion must be parallel to the direction of the force. That is, the distance over which work is done against gravity must be the height that you lift the object. If you move the object horizontally while lifting it, the horizontal motion does not contribute to the work done against gravity. Therefore, you do not include horizontal distance in your calculation. For clarification, study Figure 5.23.

When all of the work done on an object gives the object gravitational potential energy, the amount of work done is equal to the amount of gravitational potential energy gained by the object, or $W = \Delta E_g$. You can use this information to develop a formula for gravitational potential energy as shown on the next page.

DidYouKnow?

Gravity on the Sun, Moon, and other planets is quite different. The size and mass of the planet determines the strength of the gravitational force. If you can jump 1 m (100 cm) on Earth, that same effort would produce the following:

- 3.3 cm on the Sun
- 34.5 cm on Jupiter
- 67.7 cm on Neptune
- 80.3 cm on Saturn
- 85.5 cm on Uranus
- 101 cm on Venus
- 240 cm on Mars
- 250 cm on Mercury
- 406 cm on Pluto
- 554 cm on Earth's Moon

DidYouKnow?

In 1971, the *Apollo 15* crew landed on the Moon in their lunar landing module named “Falcon.” Astronaut Dave Scott took a falcon feather and a hammer on one of his Moon walks. He dropped the hammer and the falcon feather simultaneously. They hit the Moon’s surface at exactly the same time. This demonstration showed that all objects fall with the same acceleration when there is no air friction.

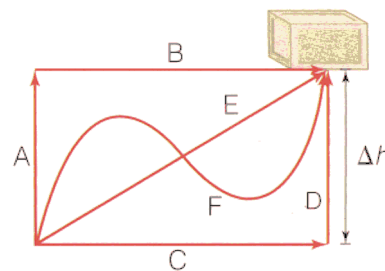
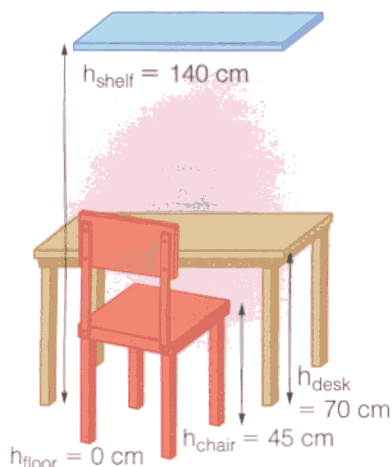


Figure 5.23 Regardless of the path through which you move an object, the vertical distance, Δh , is the distance over which you do work against gravity.



- Write the formula for work.

$$W = F\Delta d$$

- The force that you must exert to do work against gravity is the weight of the object. Substitute F_g for force. The distance over which you do work against gravity is the vertical height. Substitute Δb for Δd .

$$W = F_g\Delta b$$

- The force due to gravity is the mass times the acceleration due to gravity, mg . Substitute mg for F_g .

$$W = mg\Delta b$$

- The gravitational potential energy that an object has is equal to the work done on it against gravity. Use the symbol, E_g , to represent gravitational potential energy.

$$E_g = mg\Delta b$$

Remember that distance and therefore height always refers to a difference between two specific points. Therefore, gravitational potential energy always refers to those two points. The lower point is often called the reference point. You always specify your reference point by reporting the gravitational potential energy *relative to* a certain position. Recall the example of lifting the book from the desk and then dropping it. In this instance, you would describe the gravitational potential energy of the book relative to the desktop. You are free to choose any reference position that you wish as long as you clearly specify that position.

You will gain a better understanding of gravitational potential energy after you study the Model Problems, complete the Practice Problems, and carry out the investigations that follow.

Gravitational Potential Energy

$$E_g = mg\Delta b$$

where E_g is the gravitational potential energy in joules (J)

m is mass in kilograms (kg)

g is the acceleration due to gravity in metres per second squared (m/s^2)

Δb is the height in metres (m)

Model Problem 5

Part A

The shelf in your school locker is 1.8 m above the floor. If your science book has a mass of 1.2 kg, what is its gravitational potential energy relative to the floor if it is sitting on the shelf?

Given

height of the book, $\Delta b = 1.8 \text{ m}$

mass of the book, $m = 1.2 \text{ kg}$

acceleration due to gravity, $g = 9.81 \text{ m/s}^2$

Required

gravitational potential energy of the book relative to the floor, E_g

Analysis

All of the needed values are given so you can use the formula $E_g = mg\Delta b$.

Solution

$$E_g = mg\Delta h$$

$$E_g = (1.2 \text{ kg})\left(9.81 \frac{\text{m}}{\text{s}^2}\right)(1.8 \text{ m})$$

$$E_g = 21.1876 \frac{\text{kg}\cdot\text{m}^2}{\text{s}^2}$$

$$E_g \approx 21 \text{ J}$$

Paraphrase

The book has 21 J of gravitational potential energy relative to the floor.

Part B

If you did 565 J of work on a 12 kg box by carrying it up a flight of stairs, how high is the flight of stairs?

Given

work done on the box, $W = 565 \text{ J}$

mass of the box, $m = 12 \text{ kg}$

acceleration due to gravity, $g = 9.81 \text{ m/s}^2$

Required

height of the flight of stairs, Δh

Analysis

The work done on the box is equal to the gravitational potential energy of the box relative to the bottom of the stairs. You can use the formula for gravitational potential energy, but you must solve for height. You can approach this problem in two different ways. You could rearrange the formula by using the rules of algebra to solve for height. You could also substitute the numerical values into the equation and then solve for the height. Both methods are shown below.

Solution

Solve for height in formula, then substitute numerical values.

$$E_g = mg\Delta h$$

$$\frac{E_g}{mg} = \frac{mg\Delta h}{mg}$$

$$\Delta h = \frac{E_g}{mg}$$

$$\Delta h = \frac{565 \frac{\text{kg}\cdot\text{m}^2}{\text{s}^2}}{(12 \text{ kg})\left(9.81 \frac{\text{m}}{\text{s}^2}\right)}$$

$$\Delta h = 4.7995 \text{ m}$$

$$\Delta h \approx 4.8 \text{ m}$$

Substitute numerical values and then solve for height.

$$E_g = mg\Delta h$$

$$565 \text{ J} = (12 \text{ kg})\left(9.81 \frac{\text{m}}{\text{s}^2}\right)(\Delta h)$$

$$\frac{565 \frac{\text{kg}\cdot\text{m}^2}{\text{s}^2}}{117.72 \frac{\text{kg}\cdot\text{m}}{\text{s}^2}} = \frac{(117.72 \frac{\text{kg}\cdot\text{m}}{\text{s}^2})(\Delta h)}{117.72 \frac{\text{kg}\cdot\text{m}}{\text{s}^2}}$$

$$4.7995 \text{ m} = \Delta h$$

$$\Delta h \approx 4.8 \text{ m}$$

Paraphrase

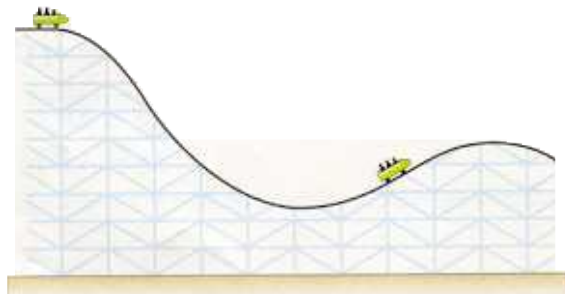
The height of the stairs was 4.8 m.



Practice Problems

Use the information about work and gravitational potential energy discussed on the previous pages to complete the following problems.

41. A picture with a mass of 3.8 kg hangs on a wall 2.1 m above the floor. What is the gravitational potential energy of the picture relative to the floor?
42. A 27 kg child sits at the top of a playground slide that is 2.8 m above the ground. What is the child's gravitational potential energy relative to the ground?
43. A roller coaster raises its passengers a vertical distance of 42.1 m above the ground. If the total mass of the roller coaster and passengers is 5.27×10^3 kg, what is the gravitational potential energy of the roller coaster and passengers relative to the ground? How much work did the engine do on the roller coaster and passengers in carrying them to the top?
44. How far would you have to lift a 1.2 kg book to give it 40.0 J of gravitational potential energy?
45. A chair lift did 5.60×10^5 J of work on a 64 kg skier to carry the skier to the top of the mountain. How high is the top of the mountain relative to the base of the lift?
46. How high would you have to throw a 0.300 kg baseball so that it would have 120.0 J of gravitational potential energy at its highest point relative to the ground?
47. You did 583 J of work on a box of books while carrying it a vertical distance of 3.3 m up a flight of stairs. What was the mass of the box of books?
48. While a child is swinging on a playground swing, she reaches a height of 2.8 m above the ground. If she had 604 J of gravitational potential energy relative to the ground at the highest point, what is her mass?
49. A boulder rests on a ledge 36 m above a lake. If it has 2.8×10^5 J of gravitational potential energy relative to the lake surface, what is the mass of the boulder?



Gravitational Potential Energy and Work

If you roll a rock off a high cliff, you become aware of the gravitational potential energy it had while sitting on the cliff. This is evident in the kinetic energy it has as it rolls down. However, you may not be aware of the work done to get the rock to the top of the cliff unless you carried it there yourself. **Note:** You will be working with both mass and weight. Recall that the weight of an object is a force equivalent to the object's mass times the acceleration due to gravity (mg).

Question

Is the work done to raise an object to a height more than, less than, or the same as the gravitational potential energy of the object?

Safety Precautions



- Use caution when handling weights.

Apparatus

3 different objects with known masses between 1–2 kg
force scale measuring up to 2000 N
metre stick or measuring tape
calculator
lab table
pen

Materials

paper
graph paper

Procedure

- 1 Read through the procedure and make a data/analysis table, such as the one shown below.
- 2 Using the force scale, hold each object just above the lab table. **Record** their weights.
- 3 **Measure** the height of the lab table above the floor and **record** it in your data/analysis table.



DATA (observations)			ANALYSIS (using data)		
Mass (kg)	Force or Weight (N)	Height or Distance (m)	Work Done ($W = F\Delta d$)	Potential Energy ($E_p = mg\Delta h$)	Area in Graph ($A = Iw$)

CONTINUED ►

- 4 Lift each object from the floor to the lab table slowly and steadily. Try to keep the force reading on the scale constant. **Calculate** the work you did on each object and **record** in the data/analysis table.



- 5 **Calculate** the gravitational potential energy for each object and **record** each value.
- 6 On your graph paper, label the vertical axis “force” and the horizontal axis “distance.” Be sure the scale on each axis is appropriate for the values of force (weight) and distance (height) in your data/analysis table.

- 7 Draw three lines horizontally across the graph, one for the force exerted on each object (its weight). Draw one vertical line at the point representing the distance all three objects were lifted.
- 8 **Calculate** the area of each rectangle formed on the graph and **record** in the table.

Analyze

1. How is the force needed to lift each object related to its weight?
2. What is the relationship between the work needed to lift each object and the gravitational potential energy of the object relative to the floor?
3. How is the area of each rectangle on the graph related to the work done to lift the object onto the table?

Extend Your Skills

Describe an experiment you could do to test the calculated gravitational potential energy of each object on the table.

Pause & Reflect

Here is an opportunity to review your understanding of the relationship between mass and weight. In this investigation, you used the formula $W = F\Delta d$ to calculate the work done to lift an object with a weight of F_g . To calculate gravitational potential energy, you used $E_p = mg\Delta h$. Notice that Δd in the one formula has the same value as Δh in the other formula, and notice that $W = E_p$. Explain in your note book that, according to this reasoning, $F_g = mg$.

Free Fall

Think About It

A common energy-conversion process used in Canada converts gravitational potential energy of water into electrical energy. As you saw in Chapter 4, the falling water from a dam strikes the vanes of a turbine, causing it to spin. The vanes are mounted on a shaft that is connected to a generator. As the coils of the generator spin in a magnetic field, electric current is produced. The gravitational potential energy of the water has now become electrical energy.

In this investigation, you will use measurements, calculations, and graphs to analyze a free-falling object. For our purposes, a steel ball (mass = 400 g) has been used to represent a mass of water. The ball is dropped from a height of 2 m. Its position and speed are measured every tenth of a second.

What to Do

- 1 Copy the table below in your notebook. Complete it by calculating the gravitational potential energy, the kinetic energy, and the total energy of the ball at each position.

Time (s)	Height (m)	Speed (m/s)	Gravitational Potential Energy (J)	Kinetic Energy (J)	Total Energy (J)
0	2.00	0			
0.10	1.95	1.1			
0.20	1.81	1.9			
0.30	1.55	3.0			
0.40	1.22	3.9			
0.50	0.73	5.1			
0.60	0.20	6.0			

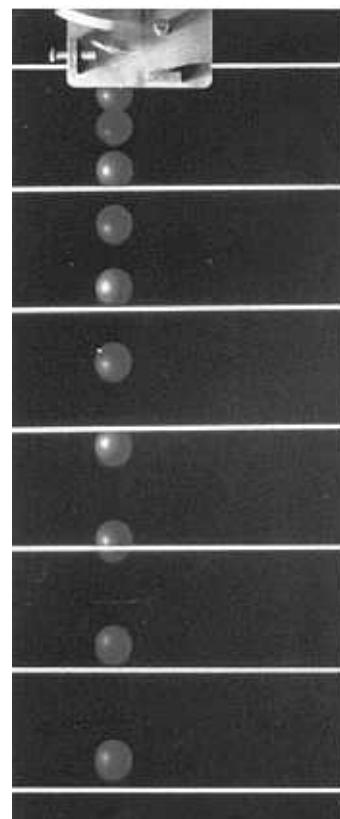
- 2 Plot a graph of the speed of the ball versus the time.
- 3 Plot graphs of gravitational potential energy versus time, kinetic energy versus time, and total energy versus time. Plot these all on the same set of axes.

Analyze

- 1 Use the speed versus time graph to describe the motion of the ball.
- 2 Use the energy graph from Step 3 to describe:
 - (a) how the potential energy changes as the ball falls
 - (b) how the kinetic energy changes as the ball falls
 - (c) how the total energy of the ball changes as it falls

Extend Your Knowledge

Use your completed table from step 1 to calculate the change in gravitational potential energy during each successive tenth of a second. Do the same for kinetic energy. Record your results in an appropriate table. What can you conclude about these changes in potential and kinetic energy?



Section 5.3 Summary

In this section, you learned the meaning of potential energy. You then learned about four different kinds of potential energy: elastic potential energy, chemical potential energy, nuclear potential energy, and gravitational potential energy. You studied gravitational potential energy in more detail. You learned that mass and weight are not the same but they are both related to gravitational potential energy. You solved problems and carried out investigations about gravitational potential energy. Finally, you studied the relationship between work and gravitational potential energy.

Check Your Understanding

1. Define potential energy.
2. Briefly describe how energy can be stored in
 - (a) elastic materials
 - (b) chemical compounds
 - (c) large nuclei
 - (d) objects under the influence of gravity
3. Under what conditions would the value of g , the acceleration due to gravity, be the acceleration of an object?
4. Explain the difference between mass and weight.
5. An airliner with a mass of 1.50×10^5 kg flies at an altitude of 9750 m. What is the airliner's gravitational potential energy relative to sea level?
6. A chandelier with a mass of 27 kg hangs above the centre of a banquet hall. If the chandelier has 4000.0 J of gravitational potential energy relative to the floor, how high is it hanging above the floor?
7. **Apply** When astronauts went to the Moon, they were able to jump higher than they could on Earth, even while wearing heavy spacesuits. Use what you have learned about gravity and gravitational potential energy to explain why the astronauts could jump so high on the Moon.
8. **Apply** Have you ever lifted a box that you thought was full but was actually empty? If so, you probably lifted it much faster and higher than you meant to lift it. From what you know about gravity and doing work against gravity, try to explain why this happens.
9. **Critical Thinking** Cables that lift elevators usually go over a pulley and are attached to some very heavy weights called counterbalances. Explain how these counterbalances reduce the amount of work that a motor must do to lift an elevator.

CHAPTER at a glance

Now that you have completed this chapter, try to do the following. If you cannot, go back to the sections indicated in parentheses after each part.

- (a) Distinguish between displacement and distance. (5.1)
- (b) Explain the meaning of the term “uniform motion.” (5.1)
- (c) Describe the characteristics of a position versus time graph for (a) uniform motion and (b) accelerated motion. (5.1)
- (d) How can you determine the speed of an object from a “line of best fit” on a position versus time graph? (5.1)
- (e) How does accelerated motion differ from uniform motion? (5.1)
- (f) Describe some evidence that indicates that mass and speed affect the kinetic energy of an object. (5.2)
- (g) What are the basic SI units that are equivalent to the joule? (5.2)
- (h) Discuss and give examples of positive and negative work. (5.2)
- (i) Describe an example of a direct relationship between work and kinetic energy. (5.2)
- (j) How could you know, by looking at an object, that it has elastic potential energy? (5.3)
- (k) How is it possible to make chemical compounds from reactants that have a lower chemical potential energy than the products? (5.3)
- (l) What form of energy is transformed into kinetic energy when a nucleus splits or fissions? (5.3)
- (m) Why do you weigh less on the Moon than on Earth? (5.3)
- (n) What properties of an object determine its gravitational potential energy? (5.3)
- (o) How is work related to gravitational potential energy? (5.3)

Prepare Your Own Summary

Summarize the chapter by doing one of the following. Use a graphic organizer (such as a concept map), produce a poster, or write the summary to include key chapter concepts. Here are a few ideas to use as a guide.

- Write a clear definition of work and show how it is related to motion, kinetic energy, and the four forms of potential energy discussed in this chapter.
- Choose an object such as a car, an airplane, a hydro-electric plant, or any other complex machine of your choice. Show how all of the major concepts in the chapter apply to your object.

- Choose a sport and show how an understanding of the concepts in this chapter affect how the sport is played.
- Write a science fiction story that contradicts the concepts in this chapter. Ask a classmate to do the same. See if you can find the contradictions in your classmate’s story and if your classmate can find the contradictions in your story.



5 Review

Key Terms

scalar

vector

distance

displacement

position

time

time interval

speed

velocity

uniform motion

line of best fit

acceleration

potential energy

elastic

elastic potential energy

chemical potential energy

nuclear potential energy

gravity

acceleration due to gravity

gravitational
potential energy

Understanding Key Concepts

Section numbers are provided in parentheses if you need to review.

- Describe in words and in a mathematical formula the relationship between position and displacement. (5.1)
- Why is it necessary to define the concept of a time interval instead of just using the term “time”? (5.1)
- You learned two different formulas for velocity, $\bar{v} = \frac{\Delta \vec{d}}{\Delta t}$ and $\bar{v} = \frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1}$. Explain the difference between the formulas. How would you decide which one to use? (5.1)
- Sketch position versus time graphs that illustrate the following situations.
 - zero velocity
 - uniform motion
 - increasing velocity
- Describe the process for finding the velocity of an object from a position versus time graph of its motion. (5.1)
- Sketch a velocity versus time graph that illustrates a positive acceleration. (5.1)
- If you double the speed of an object, by what factor will its kinetic energy increase? (5.2)
- Two objects, A and B, have the same speed but the mass of A is double that of B. What is the kinetic energy of A relative to that of B? (5.2)
- When an object slows down, into what form of energy is kinetic energy most likely to be transformed? (5.2)
- A friend tells you that, when driving a car, you should always leave a distance equal to four car lengths between your car and the one ahead of you. Explain why this is not necessarily a good rule to follow. (5.2)
- Potential energy is sometimes described as energy that results from the position or condition of an object. Give an example of one case in which potential energy is a result of the position of an object. Give another example of a case in which the potential energy is a result of the condition of an object. (5.3)
- Sketch a chemical potential energy scale and put two horizontal lines on it. On the upper line, write “products” and on the lower line, write “reactants.” If this reaction was expressed as the equation below, on which side would you write “energy”? (5.3)

$$\text{reactants} \rightarrow \text{products}$$
- You could say that fossil fuels and hydro-electric energy are both forms of solar energy. Explain why this statement is true. (5.3)
- Briefly describe the process of nuclear fission that is used by nuclear reactors to produce electrical energy. (5.3)
- A label on a bag of potatoes in the grocery store says that the potatoes “weigh 5 kg.” Explain what is wrong with that statement. What should the label say? (5.3)
- One student says that the gravitational potential energy of a book is 12 J. Another student says that the gravitational potential energy of the same book is 19 J. Explain the conditions under which both students might be correct. (5.3)

Developing Skills

17. Design and, if possible, carry out an experiment that shows how air friction affects the motion of falling objects. Have your design approved by your teacher before performing any experiment.
18. Find out how scientists study free fall by using long vertical tubes from which all air is removed by a pump. Do research with print resources or on the Internet.
19. Collect data on the motion of an object such as a laboratory cart or a jogger. Use the data to make position versus time and velocity versus time graphs. Study the graphs and describe the motion.
20. Do research with print resources or on the Internet to learn about the theories of Aristotle and Galileo regarding the motion of falling objects.

Problem Solving/Applying

21. A racehorse ran a 1.8 km race in exactly 2 min and 18 s. What was the horse's average speed?
22. A driver is on a highway that has provided an odometer test zone in which signs mark every kilometre for 25 km. He checks his watch and sees that it is 1:16 p.m. when he passes the 5.0 km marker. When he passes the 25 km marker, his watch reads 1:31 p.m. What was his average speed for that section of the test zone?
23. A 0.046 kg golf ball is travelling with a speed of 5.1 m/s. What is the kinetic energy of the golf ball?
24. A Ping-Pong™ ball with a mass of 2.0 g is travelling at 3.8 m/s. What is the kinetic energy of the Ping-Pong™ ball?
25. The kinetic energy of a long freight train is 4.8×10^8 J when it is moving at a speed of 40.0 m/s. What is the mass of the train?
26. A 55 kg pronghorn antelope has 25 000 J of kinetic energy. How fast is the antelope running?
27. A rock climber climbed 25 m directly up a cliff. If the mass of the climber and her gear was 75 kg, what was the climber's gravitational potential energy relative to the base of the cliff?
28. A crane lifts a 550 kg container to a height of 24 m above the deck of a ship. What is the gravitational potential energy of the container relative to the deck of the ship?
29. Piano movers used 4000.0 J of energy to lift a 314 kg grand piano onto a moving van. How high did they lift the piano?
30. A hydraulic lift raised a car up 0.22 m. If the car had 3800 J of gravitational potential energy relative to its original position, what was the mass of the car?

Critical Thinking

31. You learned that, in nuclear fission, some of the mass of the original nucleus is converted into the kinetic energy of the product nuclei. Kinetic energy of atoms and molecules is thermal energy. What do you think is the source of the thermal energy in chemical reactions that produce thermal energy? Do research with print resources or on the Internet to check your prediction.
32. In a group, brainstorm examples of how the following professions might require a working knowledge of kinetic and potential energy.
 - a set designer in a theatre
 - a director or stunt person filming an action movie
 - a modern-dance choreographer
 - a swimming coachBe as specific as possible in your answers.

Pause & Reflect

Go back to the answers you wrote for the Focussing Questions. How would you change your answers now that you have finished this chapter?