SECTION 9

Conservation of Energy: Defy Gravity

Section Overview

By calculating an athlete's time in air, called "hang time," students find out if the skater or basketball player at any point is able to counter the effect of gravity by hanging in the air. They watch a video of the skater doing a triple-axle jump, both in slow motion and at normal speed, and multiply the number of frames (pictures completed every 1/30 s) by the time the skater remains in air. Students then locate their center of mass to make a better estimate of how high they are able to jump. They jump as high as they can to calculate and record the vertical height through which their center of mass shifts during the jump. They use the concepts of work, spring potential energy (*SPE*), gravitational potential energy (*GPE*), and kinetic energy (*KE*) to help them analyze the energy transformations that take place during the jump. The students measure the position of their center of mass at the ready, launch, and peak positions and use these values along with their mass and the acceleration of gravity to calculate the energy forms at the various positions. Using the principle of conservation of energy, the students create a chart to compares value of the energies at the three different positions, as well as the sum of the *GPE*, *SPE*, and *KE* at these positions.

Background Information

Read the *Physics Talk* in the student text for this section before proceeding. Energy is simply stored work, and work is transformed into kinetic energy and gravitational potential energy in a vertical jump. Research has shown that the location of the center of mass within the jumper's body varies only slightly for the body positions assumed during the process of the vertical jump. The force that lifts and accelerates the body's center of mass during a vertical jump is provided by muscles of the leg, ankles, and feet. The method of analysis used for this activity assumes that the muscular force is constant as the body rises from "ready" to "launch" positions. This is not entirely accurate—in a real jump, the force varies—but is a reasonable approximation of reality.

The center of mass of an object is the only idea introduced in this section. The center of mass is the point at which the entire mass of an object may be thought of as being concentrated for purposes of analyzing the translational (along a path) or rotational (spinning) motion of the object. For practical purposes, the location of the center of mass of an object having only one significant dimension—such as a straight stick, loaded teeter-totter, twirler's baton, screwdriver, or wrench—corresponds to the object's balance point. For a two-dimensional object—such as a sheet of plywood cut into any shape—the location of the center of mass corresponds to the balance point located on either of the two large, flat surfaces of the object. To the extent that a two-dimensional object—such as a triangle cut from a sheet of plywood—may have significant thickness and, therefore, actually be three-dimensional, the center of mass would be located within the object, "in line" with the balance point, at the center of the thick dimension. For objects with simple three-dimensional shapes—such as homogeneous or symmetrically layered spheres such as bowling balls, basketballs, cubes, rectangular solids and cylinders—the center of mass is located within the center. An alternative to balancing an object to locate the center of mass is to suspend the object from any point that is not the center of mass. When suspended, gravity serves to orient the object so that its center of mass is located directly below the point of suspension. Earth "views" an object near it as a "point mass" (located at the object's center of mass) and pulls the point mass as close to Earth as possible. A line extended straight downward from the point of suspension passes through the object's center of mass. The intersection of two such lines, corresponding to two points of suspension, locates the object's center of mass.

Crucial Physics

- The center of mass of an object is the point that moves due to forces on the object as if all the mass of the object were located at that point.
- Energy is "stored work" and energy comes in different forms.
- Energy is conserved when there are no outside forces acting on the objects under consideration.

Learning Outcomes	Location in the Section	Evidence of Understanding
Measure changes in height of the body's center of mass during a vertical jump.	***Investigate*** Steps 4-6	Students record the height in meters of their body's distance from its center of mass to the floor at three different positions of their vertical jump.
Calculate changes in the gravitational potential energy of the body's center of mass during a vertical jump.	***Investigate*** Step 6	Students record the distance from the floor to their center of mass at the "peak position." Then they subtract the height at the peak of the jump height from the launch height.
Apply the definition of work.	***Investigate*** Steps 3 and 5 ***Physics Talk***	Students' work, which is required to lift themselves from the ready to the launch position, is their weight times the change in height.
Recognize how work is related to energy.	***Investigate*** Steps 5 and 6 ***Physics Talk***	Students do work with their leg muscles to provide the energy of the jump that is converted into kinetic energy.
Apply the joule as a unit of work and conservation of energy to the analysis of a vertical jump, including weight, force, height, and time of flight.	***Investigate*** Step 7 ***Physics Talk***	Students use the same units for all measures of energy and work in their calculations of the energy transformations between work, *SPE*, *GPE*, and *KE* during the jump.
Describe the concepts of work and conservation of energy to the analysis of a vertical jump, including weight, force, height, and time of flight	***Physics Talk***	Students read the *Physics Talk* and learn about conservation of energy based on tables providing a breakdown of total energy.

Section 9 Materials, Preparation, and Safety

Materials and Equipment

PLAN A		
Materials and Equipment	**Group (4 students)**	**Class**
Meter stick, wood	2 per group	
Calculator, basic	1 per group	
Tape, masking, 3/4 in. x 60 yds		6 per class
MBL or CBL Technology (to record probeware activity*		1 per class
Probeware, motion detector*		1 per class
Scale, bathroom*		1 per class
TV with VCR*		1 per class

*Additional items needed not supplied

PLAN B		
Materials and Equipment	**Group (4 students)**	**Class**
Meter stick, wood		2 per class
Calculator, basic	1 per group	
Tape, masking, 3/4 in. x 60 yds		6 per class
MBL or CBL Technology (to record probeware activity*		1 per class
Probeware, motion detector*		1 per class
Scale, bathroom*		1 per class
TV with VCR*		1 per class

*Additional items needed not supplied

Note: Time, Preparation, and Safety requirements are based on Plan A, if using Plan B, please adjust accordingly.

Time Requirement

This *Investigate* should take at least one class period or 40 minutes.

Teacher Preparation

- Obtain a TV and VCR (or DVD player) that has single-frame advance capability to show the students stop-frame video of an athlete jumping. Have a common bathroom scale available for students to determine their mass, but place it in a location in the classroom where students can obtain their mass privately.
- Set up a motion detector, computer, and interface if available. Attach the motion detector to the classroom ceiling so the students can jump underneath it to measure their jump height.

Safety Requirements

Students who do not wish to jump should not be forced to do so. Check with the school nurse to see if any students might have physical limitations that would preclude their jumping in class.

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Meeting the Needs of All Students

Differentiated Instruction: Augmentation and Accommodations

Learning Issue	Reference	Augmentation and Accommodations
Understanding vocabulary	***What Do You Think?*** ***Investigate*** Steps 1.c) and 2 ***Physics to Go*** Step 2	**Augmentation** • Explain the meaning of "defy" and provide examples. **Accommodation** • Show a video clip of a bobsled team in action before students are asked to answer this question because they may have no idea what bobsledding means.
Visual perception and attention	***Investigate*** Steps 1.a) and 2.a)	**Augmentation** • Ask students to count the individual frames in the video for the figure skater and basketball player. • Students with vision issues could be assigned to record the class data on the board and help do the hang time calculations.
Scientific measurement	***Investigate*** Step 4	**Augmentation** • Students struggle with metric conversions. Tell them to find the vertical distance in centimeters. Then show them how to do the conversion. • Students often leave out decimal points and do not understand the importance of decimals in determining the value of numbers. Teach this concept in the context of money ($0.50 versus $50.00).
Measuring "peak position"	***Investigate*** Step 6	**Augmentation** • Teach strategies for marking "peak position" and then measuring it. For example, make one group member responsible for being the height-marker of the "peak position." Then have a pair of students measure the distance from the floor to the peak position. • Students could also jump near the blackboard and mark the peak position with chalk before measuring.
Recording data for calculations	***Investigate*** Steps 3-8	**Augmentation** • To help students record data accurately, model how to set up a table or record sheet before beginning the *Investigate*. **Accommodation** • Provide a blank copy of a data table for students to tape into their logs.
Creating a chart to understand an essential concept	***Investigate*** Step 7.d)	**Augmentation** • Model and ask students to turn their paper to landscape format to create any tables/charts that are larger than four columns. This will accommodate students with large handwriting and fine-motor issues. • Ask students to first draw the template of a table based on the teacher's sample. The table should fill most of the page. • If students are using lined paper, they can use the vertical lines on the paper to space out their columns (about five lines per column). Encourage them to quickly draw the appropriate number of rows. • Make sure students include a column for total energy. **Accommodation** • Provide a blank chart for students to tape into their logs and record the values.

Learning Issue	Reference	Augmentation and Accommodations
Understanding the conservation of energy principle	***Physics Talk***	**Augmentation** • Students struggle to conceptualize energy transfer and conservation because they cannot see the energy changing from one form to another. Also, the most common way for students to understand this principle is to compare the total energy of a system before and after the transfer of energy. Show students that the total energy of a system is always conserved. • Ask pairs of students to make drawings to represent the energy transfers involved when a person jumps. Students could use the values presented in the tables in this section to mathematically support their sketches. **Accommodation** • Provide a teacher-made worksheet or sketch of a person jumping on which students can add "types of energy" labels or "number of joules" labels.
Solving multi-step problems and using more than one formula in an assignment	***Physics Talk*** ***Physics to Go***	**Accommodation** • Provide opportunities to practice individual formulas for mastery before combining concepts into one multi-step problem that requires the use of a few different formulas and concepts.
Solving for velocity using the *KE* formula	***Physics Talk*** Sample Problem d)	**Augmentation** • Students struggle to understand the concept of square root and square root functions. Provide direct instruction in how to solve for velocity using the *KE* formula. Make sure that students understand that v^2 means v multiplied by v. **Accommodation** • Some students may not be developmentally or academically prepared at this time to solve for velocity using the *KE* formula.

Strategies for Students with Limited English-Language Proficiency

Learning Issue	Reference	Augmentation
Vocabulary comprehension	***What Do You Think?***	Given the "Defy Gravity" focus of this section, it is essential that all students understand the concept of hang time. Hang time is how long an athlete stays in the air after jumping. Some athletes stay in the air so long they appear to defy, or overcome, gravity.
Understanding scientific concepts	***Physics Essential Questions***	Students likely think of a theory as a guess or an assumption based on little understanding or information. But the word "theory" has a different meaning in science. A theory, in science, is an organized body of knowledge known to accurately predict and explain a specific set of phenomena in the natural world. The law of conservation of energy is a scientific theory that has stood the test of time. Remind students of the definition of "model" from *Section 5:* A model is anything that accurately represents what we know about how the natural world behaves. A theory is just as much a model as a mathematical model or a physical model.

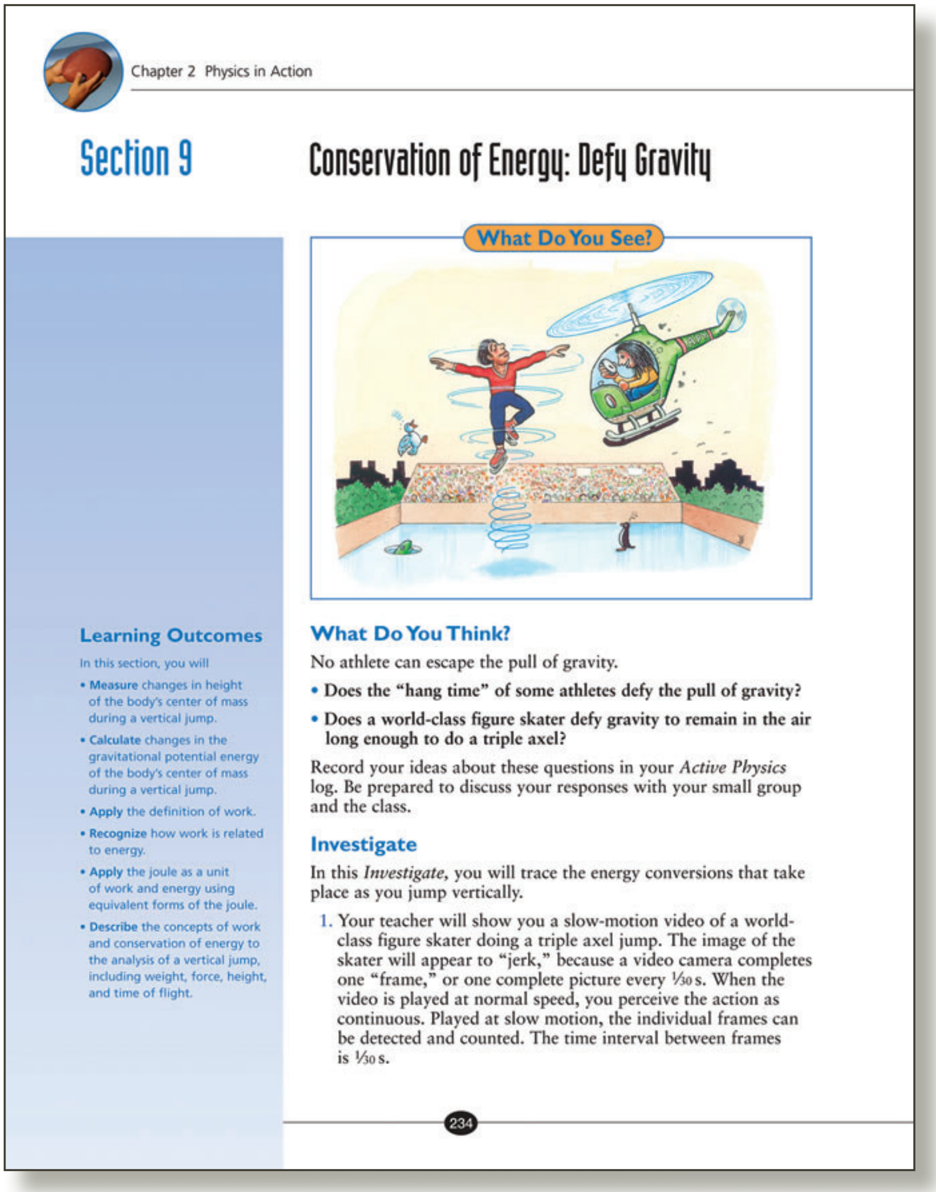
Two important aspects of learning a new language are speaking and writing in that language. Some ELL students will be self-conscious and shy about speaking in front of their peers, while others will be less reluctant to try. Be sure to encourage all ELL students to speak in class, and give them opportunities to write on the board from time to time. Experience will broaden their comfort level. Over time, the shy students will get increasingly less self-conscious about speaking in front of their classmates.

SECTION 9

Teaching Suggestions and Sample Answers

What Do You See?

There are many points of interest that your students are most likely to bring up when they are asked to discuss the illustration. Each image provides a focus that relates to the main topic. Consider various aspects of students' responses and encourage them to articulate their thoughts without hesitation. The *What Do You See?* stage provides the centerpiece on which you can build the rest of your students' understanding.



Chapter 2 Physics in Action

Section 9 Conservation of Energy: Defy Gravity

What Do You See?

Learning Outcomes

In this section, you will

- **Measure** changes in height of the body's center of mass during a vertical jump.
- **Calculate** changes in the gravitational potential energy of the body's center of mass during a vertical jump.
- **Apply** the definition of work.
- **Recognize** how work is related to energy.
- **Apply** the joule as a unit of work and energy using equivalent forms of the joule.
- **Describe** the concepts of work and conservation of energy to the analysis of a vertical jump, including weight, force, height, and time of flight.

What Do You Think?

No athlete can escape the pull of gravity.

- **Does the "hang time" of some athletes defy the pull of gravity?**
- **Does a world-class figure skater defy gravity to remain in the air long enough to do a triple axel?**

Record your ideas about these questions in your *Active Physics* log. Be prepared to discuss your responses with your small group and the class.

Investigate

In this *Investigate*, you will trace the energy conversions that take place as you jump vertically.

1. Your teacher will show you a slow-motion video of a world-class figure skater doing a triple axel jump. The image of the skater will appear to "jerk," because a video camera completes one "frame," or one complete picture every $\frac{1}{30}$ s. When the video is played at normal speed, you perceive the action as continuous. Played at slow motion, the individual frames can be detected and counted. The time interval between frames is $\frac{1}{30}$ s.

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Students' Prior Conceptions

The concepts of force, motion of the center of mass of an object, free fall, weight, work, energy, and conservation of energy culminate to perplex students as they master the concepts building throughout the activities in this chapter. It is essential for students to explain the concepts in their own words and for teachers to listen to and probe student understanding so that the preconceptions listed in *Sections 1-8* are not overlooked. Explaining work, identifying the forces involved, examining weight and the center of mass, and considering the height of the vertical jump along with the time of the flight all act to perplex students in their analysis of the conservation of energy during a vertical jump. It is vital for the teacher to recognize students' preconceptions that continue to hinder understanding in order to help compare prior conceptions with observable behavior in order to prevent many misconceptions.

What Do You Think?

While recording their ideas, some students might ask you what hang time means. Instead of being locked down in a question and answer session, gently remind them that their task for the *What Do You Think?* questions is to record their answers in their *Active Physics* logs. Ask them to ponder what they already know and how they can respond to these questions. You might want to emphasize that the main purpose of this task is to stimulate their scientific thinking to prepare them for the inquiry-driven approach followed in *Active Physics*.

What Do You Think?

A Physicist's Response

No, the hang time does not defy the pull of gravity. Hang time is mere illusion. The pull of gravity continues to act, but this cannot be detected because the people's eyes cannot detect the rapid movement that happens in the flash of a second.

The world-class figure skater cannot defy gravity long enough to do a triple-axle. Each turn brings him very slightly toward the ground.

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Investigate

1.a)

The skater is in the air for 15 frames.

1.b)

Time in air (s) = Number of Frames

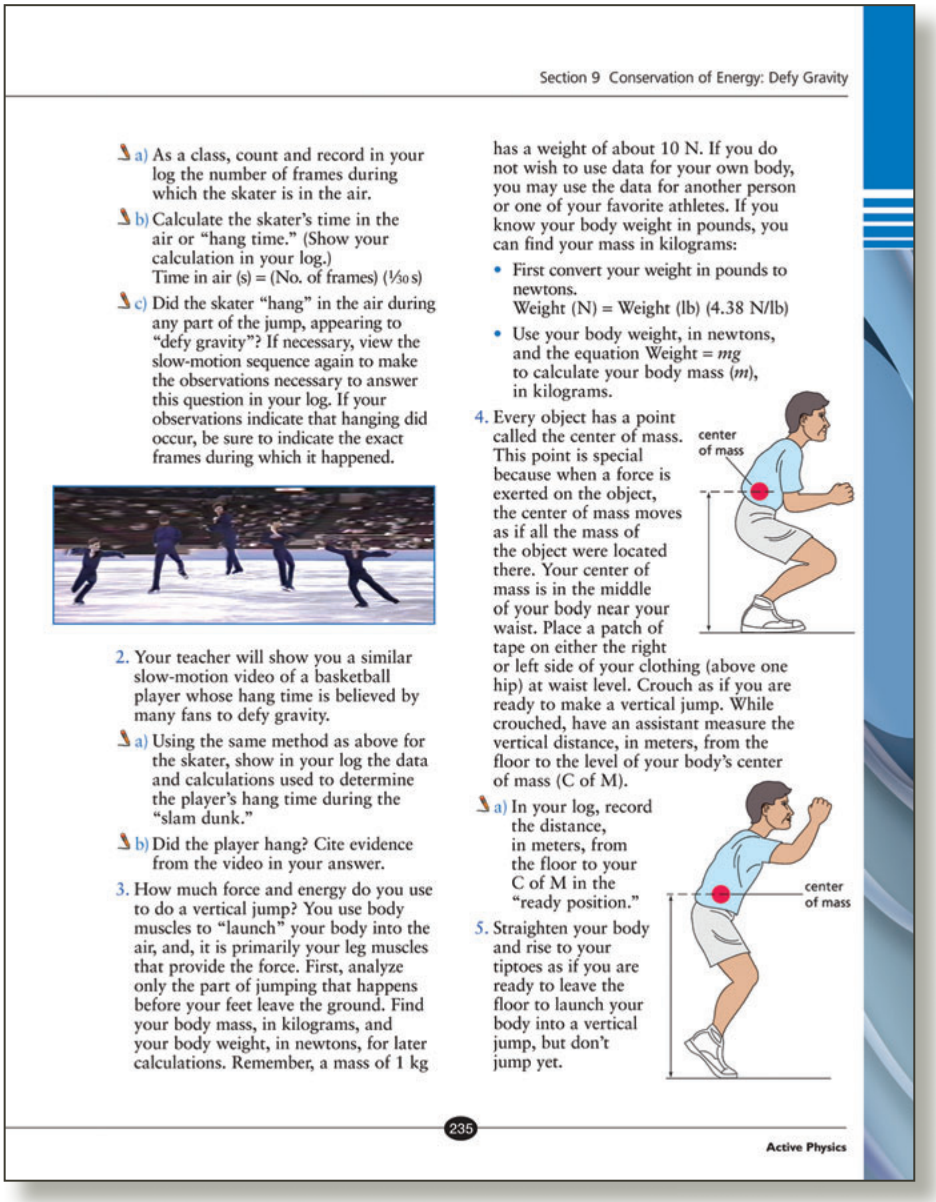
$(15)(1/30\text{ s}) = \frac{1}{2}\text{ s}$

1.c)

During the time frame viewed on the video, the skater's position is constantly changing. Although there is no hang time, the vertical change in position at the peak is at its slowest, giving the impression of a hang time. If students continue to say they observe hang time, ask them for a suitable definition of hang time. If they come up with a useable definition, they should not be able to observe it in the video.

2.a)

The basketball player is in the air for 31 frames.



Section 9 Conservation of Energy: Defy Gravity

a) As a class, count and record in your log the number of frames during which the skater is in the air.

b) Calculate the skater's time in the air or "hang time." (Show your calculation in your log.)
Time in air (s) = (No. of frames) ($\frac{1}{30}$ s)

c) Did the skater "hang" in the air during any part of the jump, appearing to "defy gravity"? If necessary, view the slow-motion sequence again to make the observations necessary to answer this question in your log. If your observations indicate that hanging did occur, be sure to indicate the exact frames during which it happened.

2. Your teacher will show you a similar slow-motion video of a basketball player whose hang time is believed by many fans to defy gravity.

a) Using the same method as above for the skater, show in your log the data and calculations used to determine the player's hang time during the "slam dunk."

b) Did the player hang? Cite evidence from the video in your answer.

3. How much force and energy do you use to do a vertical jump? You use body muscles to "launch" your body into the air, and, it is primarily your leg muscles that provide the force. First, analyze only the part of jumping that happens before your feet leave the ground. Find your body mass, in kilograms, and your body weight, in newtons, for later calculations. Remember, a mass of 1 kg has a weight of about 10 N. If you do not wish to use data for your own body, you may use the data for another person or one of your favorite athletes. If you know your body weight in pounds, you can find your mass in kilograms:

- First convert your weight in pounds to newtons.
  Weight (N) = Weight (lb) (4.38 N/lb)
- Use your body weight, in newtons, and the equation Weight = mg to calculate your body mass (m), in kilograms.

4. Every object has a point called the center of mass. This point is special because when a force is exerted on the object, the center of mass moves as if all the mass of the object were located there. Your center of mass is in the middle of your body near your waist. Place a patch of tape on either the right or left side of your clothing (above one hip) at waist level. Crouch as if you are ready to make a vertical jump. While crouched, have an assistant measure the vertical distance, in meters, from the floor to the level of your body's center of mass (C of M).

a) In your log, record the distance, in meters, from the floor to your C of M in the "ready position."

5. Straighten your body and rise to your tiptoes as if you are ready to leave the floor to launch your body into a vertical jump, but don't jump yet.

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Active Physics

Time in air (s) = Number of Frames (31)(1/30 s) = 31/30 s = $1\frac{1}{30}$ s = 1.03 s

2.b)

During the time frame viewed on the video, the basketball player's position is constantly changing. There is no hang time but due to the slow vertical change of position it may appear that way. (As the ball is moving upward before the player leaves the ground, on the way down his arms are extended and lift the ball into the net, giving the illusion of hanging in the air.)

3.a)

Students' answers will vary according to their weight in pounds. Be aware that some students may be sensitive about their weight and be reluctant to write it down. To avoid this problem, you may choose to only have one student in the group, or class, do the jumping and everyone in the class use this weight and height in their calculations. Expect to help students when applying their own data to replicate the calculations presented as an example in *Physics Talk*. Ask the students about the forces acting on them between the "ready" and "launch" positions and between the "launch" and "peak" positions.

4.a)

Students record the distance from the floor to their center of mass in the crouched or "ready" position.

Teaching Tip

If the student is going to jump near the wall, the group can just place pieces of masking tape on the wall to correspond to the "ready" and "launch" positions, and then measure the distance between them.

5.a)

Students record the distance from the floor to their center of mass in the launch position.

5.b)

The students calculate the difference between the ready and launch heights.

6.a)

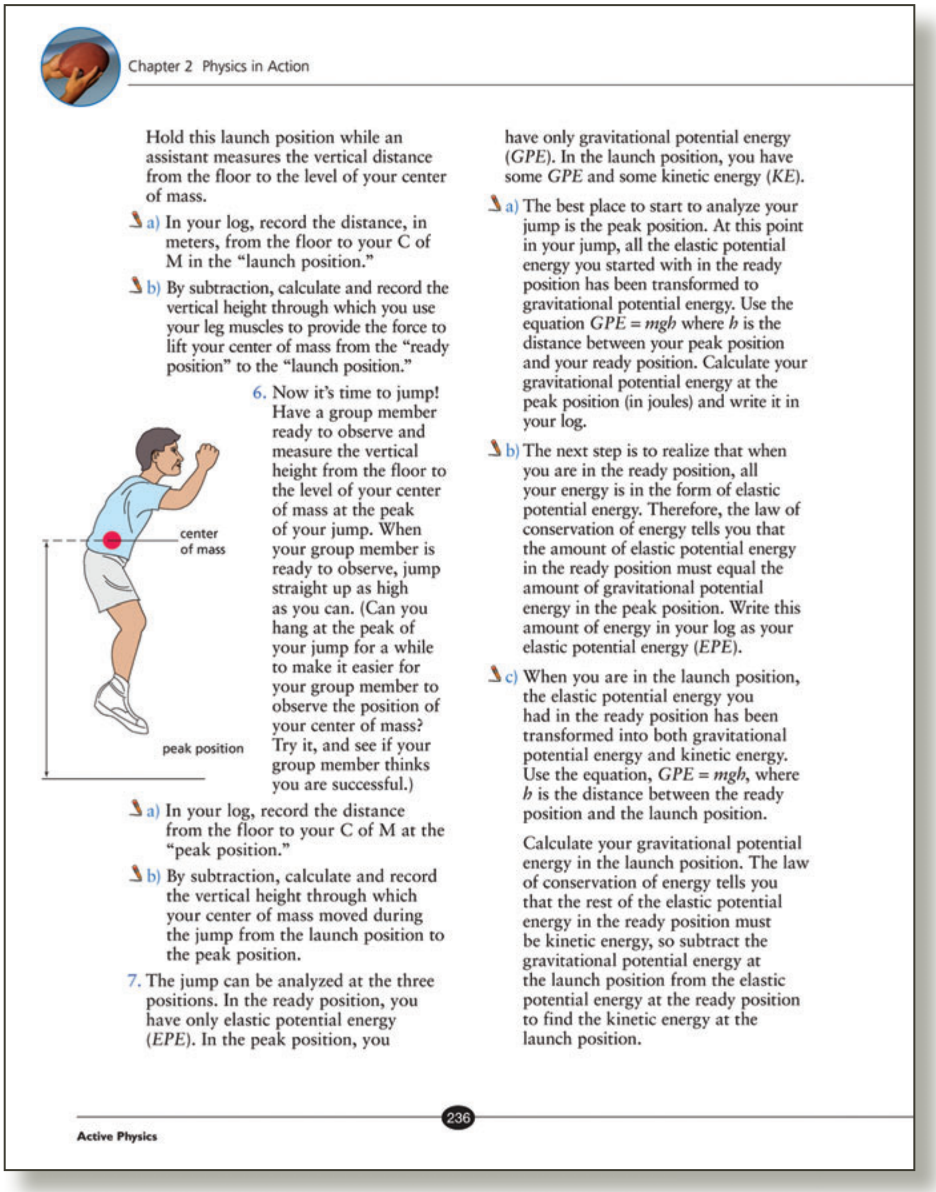
Students measure the height of the center of mass from the floor at the peak of the jump. One student should indicate the position with their finger, and hold that position while another measures the height after the student has landed.

6.b)

The students calculate vertical jump height by subtracting the height at the peak of the jump height from the launch height.

Teaching Tip

A motion detector can easily be attached to the ceiling of the classroom for the students to check the height of their jump. This quickly becomes a competitive exercise for many students, so you may want to limit its use to only serve as an additional check on the height reached by the jumpers in each group. To determine the height of the jump, have the students stand underneath the motion detector. Start the detector, and then have the students crouch down and jump directly upward toward the detector. The height of their jump is the difference between their distance from the detector when standing, and the minimum distance from the detector reached while jumping.



Chapter 2 Physics in Action

Hold this launch position while an assistant measures the vertical distance from the floor to the level of your center of mass.

a) In your log, record the distance, in meters, from the floor to your C of M in the "launch position."

b) By subtraction, calculate and record the vertical height through which you use your leg muscles to provide the force to lift your center of mass from the "ready position" to the "launch position."

6. Now it's time to jump! Have a group member ready to observe and measure the vertical height from the floor to the level of your center of mass at the peak of your jump. When your group member is ready to observe, jump straight up as high as you can. (Can you hang at the peak of your jump for a while to make it easier for your group member to observe the position of your center of mass? Try it, and see if your group member thinks you are successful.)

a) In your log, record the distance from the floor to your C of M at the "peak position."

b) By subtraction, calculate and record the vertical height through which your center of mass moved during the jump from the launch position to the peak position.

7. The jump can be analyzed at the three positions. In the ready position, you have only elastic potential energy (*EPE*). In the peak position, you have only gravitational potential energy (*GPE*). In the launch position, you have some *GPE* and some kinetic energy (*KE*).

a) The best place to start to analyze your jump is the peak position. At this point in your jump, all the elastic potential energy you started with in the ready position has been transformed to gravitational potential energy. Use the equation $GPE = mgh$ where h is the distance between your peak position and your ready position. Calculate your gravitational potential energy at the peak position (in joules) and write it in your log.

b) The next step is to realize that when you are in the ready position, all your energy is in the form of elastic potential energy. Therefore, the law of conservation of energy tells you that the amount of elastic potential energy in the ready position must equal the amount of gravitational potential energy in the peak position. Write this amount of energy in your log as your elastic potential energy (*EPE*).

c) When you are in the launch position, the elastic potential energy you had in the ready position has been transformed into both gravitational potential energy and kinetic energy. Use the equation, $GPE = mgh$, where h is the distance between the ready position and the launch position.

Calculate your gravitational potential energy in the launch position. The law of conservation of energy tells you that the rest of the elastic potential energy in the ready position must be kinetic energy, so subtract the gravitational potential energy at the launch position from the elastic potential energy at the ready position to find the kinetic energy at the launch position.

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Active Physics

7.a)

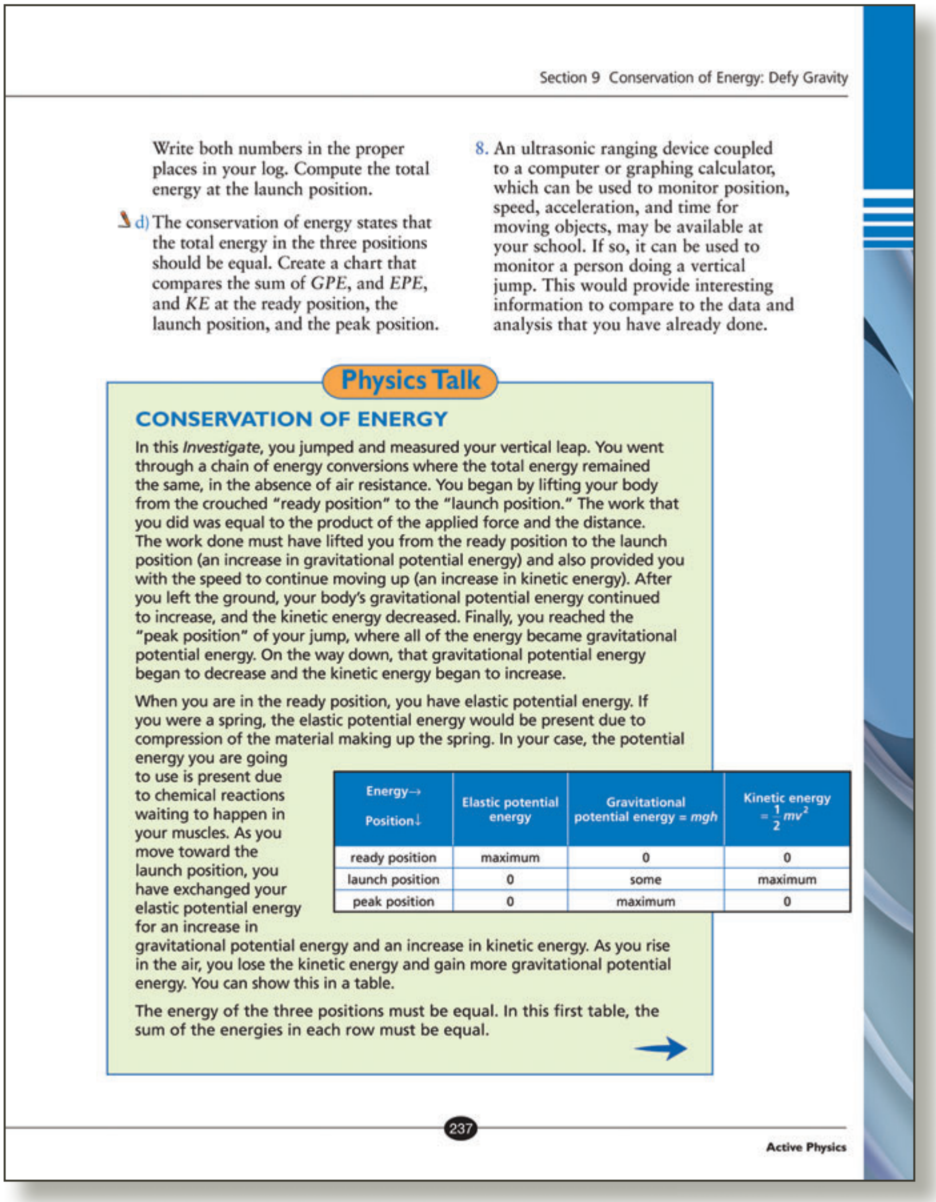
Answers will vary. The *GPE* will equal *mgh* where *h* is the difference in height measure in *Step 6.b)*.

7.b)

The students copy their answer from *Step 7.a)* here.

7.c)

The students calculate their potential energy in the launch position by *mgh* where *h* is the height measure in *Step 5.b)*. The *KE* at the launch is then the difference between the values of *Step 7.a)* and the energy they measured in the first part of this step.



Section 9 Conservation of Energy: Defy Gravity

Write both numbers in the proper places in your log. Compute the total energy at the launch position.

d) The conservation of energy states that the total energy in the three positions should be equal. Create a chart that compares the sum of *GPE*, and *EPE*, and *KE* at the ready position, the launch position, and the peak position.

8. An ultrasonic ranging device coupled to a computer or graphing calculator, which can be used to monitor position, speed, acceleration, and time for moving objects, may be available at your school. If so, it can be used to monitor a person doing a vertical jump. This would provide interesting information to compare to the data and analysis that you have already done.

Physics Talk

CONSERVATION OF ENERGY

In this *Investigate*, you jumped and measured your vertical leap. You went through a chain of energy conversions where the total energy remained the same, in the absence of air resistance. You began by lifting your body from the crouched "ready position" to the "launch position." The work that you did was equal to the product of the applied force and the distance. The work done must have lifted you from the ready position to the launch position (an increase in gravitational potential energy) and also provided you with the speed to continue moving up (an increase in kinetic energy). After you left the ground, your body's gravitational potential energy continued to increase, and the kinetic energy decreased. Finally, you reached the "peak position" of your jump, where all of the energy became gravitational potential energy. On the way down, that gravitational potential energy began to decrease and the kinetic energy began to increase.

When you are in the ready position, you have elastic potential energy. If you were a spring, the elastic potential energy would be present due to compression of the material making up the spring. In your case, the potential energy you are going to use is present due to chemical reactions waiting to happen in your muscles. As you move toward the launch position, you have exchanged your elastic potential energy for an increase in gravitational potential energy and an increase in kinetic energy. As you rise in the air, you lose the kinetic energy and gain more gravitational potential energy. You can show this in a table.

Energy→ Position↓	Elastic potential energy	Gravitational potential energy = *mgh*	Kinetic energy $= \frac{1}{2}mv^2$
ready position	maximum	0	0
launch position	0	some	maximum
peak position	0	maximum	0

The energy of the three positions must be equal. In this first table, the sum of the energies in each row must be equal.

→

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Active Physics

7.d)

The students create a chart that shows the $SPE = KE + GPE$ for the top of the jump.

8.

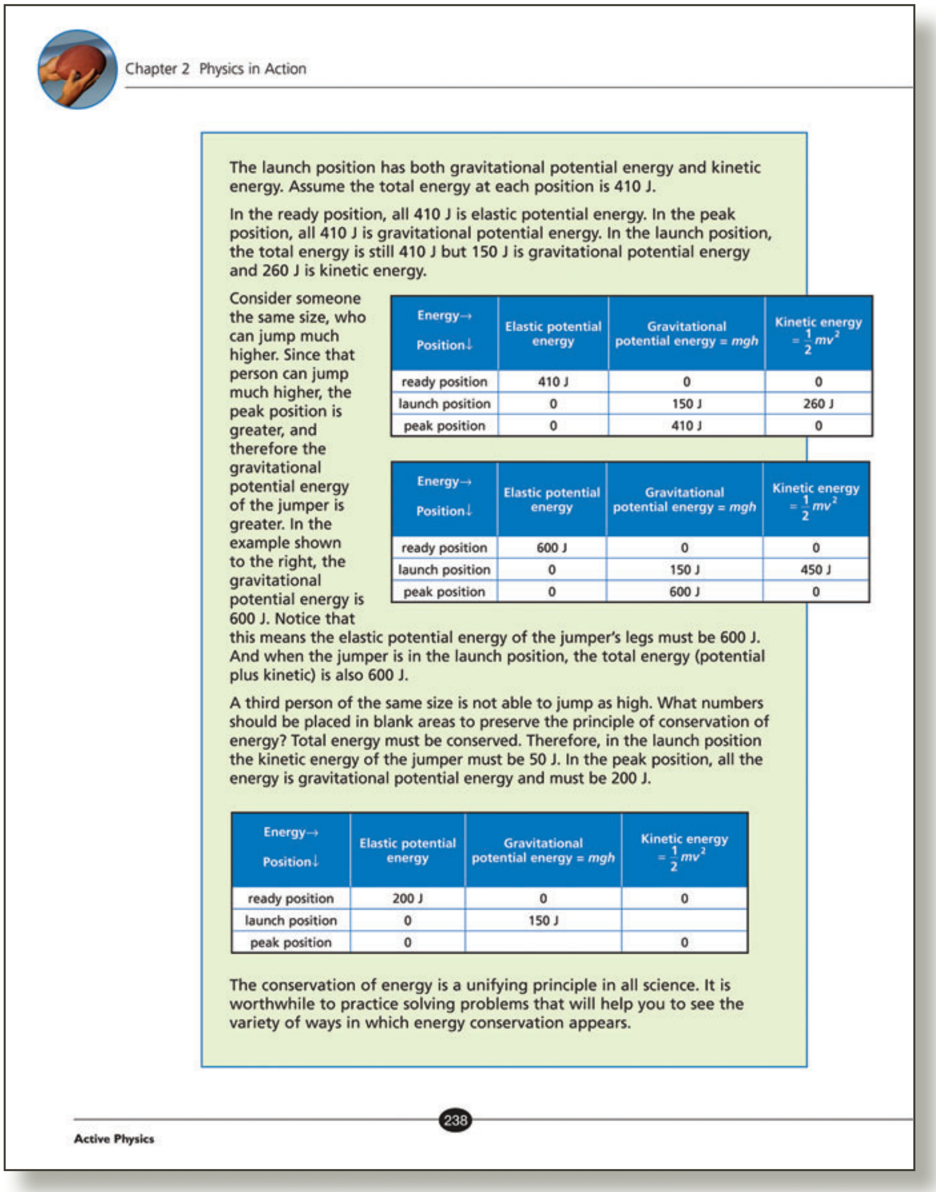
The students may try to jump under a motion detector. The height of the jump and the height during the ready position may be easily measured with this device.

2-9a **Blackline Master**

Physics Talk

As students read the *Physics Talk*, have them revise their definitions of gravitational potential energy, spring potential energy, and kinetic energy. Ask them to write a brief explanation of how energy conversions took place during the *Investigate*, how work done brought about a change in energy, and what happened to the total energy of a system. Once students have written their explanation, divide them into groups and have them share their responses, then invite them to discuss their responses with the whole class. Suggest to students that they can illustrate their explanation with diagrams showing an athlete in different positions. Have them label each diagram. A useful visual would be the use of bar graphs to indicate the amount of energy in the form of *GPE*, *SPE*, and *KE* in the various positions, as well as the total energy of the system. The students should realize that the total energy remains constant for the system, and should have a total energy graph that indicates this in all positions.

Choose the results of one member of the class (or yourself if you did the jump) as an example of how to calculate the energy in the various positions, as it is shown in the *Physics Talk*. Have them work out the values of gravitational potential energy and kinetic energy at their launch position. The height of jump of a second class member may be chosen, or perhaps that of an Olympic athlete as a comparison for additional practice. A person jumping on a trampoline provides another opportunity for students to examine energy conversion. A discussion of why jumping on a trampoline yields ever-increasing heights (up to a point), while successive jumps on a hard floor do not, should convince the students that the *SPE* stored in the deformed trampoline is restored to the jumper, while the hard floor does not respond in a similar manner. They should know how jumping from a hard surface produces a difference in the kinetic energy of rebound as compared to jumping from a soft surface like a trampoline.



Chapter 2 Physics in Action

The launch position has both gravitational potential energy and kinetic energy. Assume the total energy at each position is 410 J.

In the ready position, all 410 J is elastic potential energy. In the peak position, all 410 J is gravitational potential energy. In the launch position, the total energy is still 410 J but 150 J is gravitational potential energy and 260 J is kinetic energy.

Energy→ Position↓	Elastic potential energy	Gravitational potential energy = mgh	Kinetic energy $= \frac{1}{2}mv^2$
ready position	410 J	0	0
launch position	0	150 J	260 J
peak position	0	410 J	0

Energy→ Position↓	Elastic potential energy	Gravitational potential energy = mgh	Kinetic energy $= \frac{1}{2}mv^2$
ready position	600 J	0	0
launch position	0	150 J	450 J
peak position	0	600 J	0

Consider someone the same size, who can jump much higher. Since that person can jump much higher, the peak position is greater, and therefore the gravitational potential energy of the jumper is greater. In the example shown to the right, the gravitational potential energy is 600 J. Notice that this means the elastic potential energy of the jumper's legs must be 600 J. And when the jumper is in the launch position, the total energy (potential plus kinetic) is also 600 J.

A third person of the same size is not able to jump as high. What numbers should be placed in blank areas to preserve the principle of conservation of energy? Total energy must be conserved. Therefore, in the launch position the kinetic energy of the jumper must be 50 J. In the peak position, all the energy is gravitational potential energy and must be 200 J.

Energy→ Position↓	Elastic potential energy	Gravitational potential energy = mgh	Kinetic energy $= \frac{1}{2}mv^2$
ready position	200 J	0	0
launch position	0	150 J	
peak position	0		0

The conservation of energy is a unifying principle in all science. It is worthwhile to practice solving problems that will help you to see the variety of ways in which energy conservation appears.

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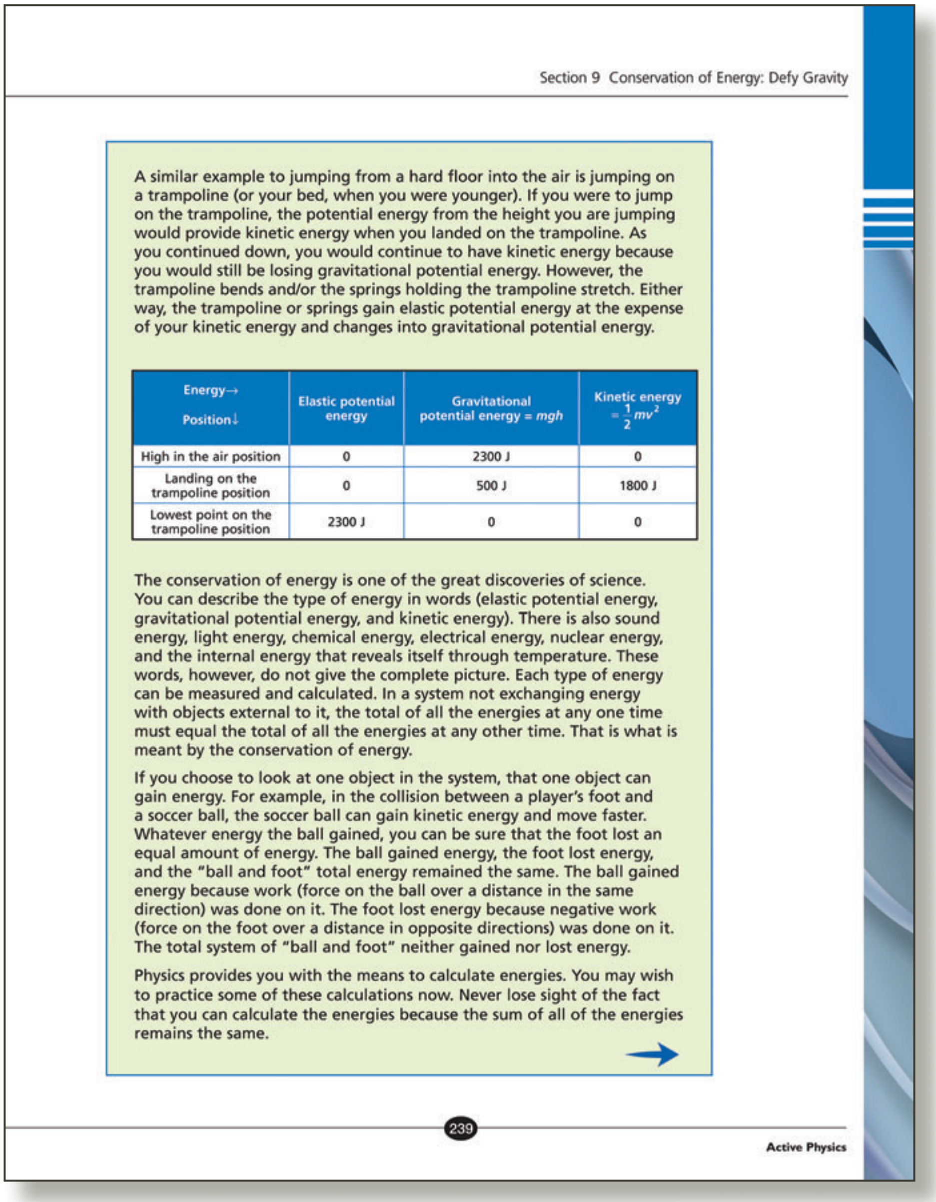
Active Physics

When students are introduced to other forms of energy like light energy, chemical energy, heat energy, and sound energy, reemphasize that each type of energy can be measured and the total energy of a closed system is always conserved when this energy is transformed from one form into another. Write one of the sample problems in the *Physics Talk* on the board and discuss each step of the strategy. Be sure to emphasize the connection between work and energy, and how doing work on a system will change the system's total energy, while energy transformations within the system do not.



Section 9 Conservation of Energy: Defy Gravity

A similar example to jumping from a hard floor into the air is jumping on a trampoline (or your bed, when you were younger). If you were to jump on the trampoline, the potential energy from the height you are jumping would provide kinetic energy when you landed on the trampoline. As you continued down, you would continue to have kinetic energy because you would still be losing gravitational potential energy. However, the trampoline bends and/or the springs holding the trampoline stretch. Either way, the trampoline or springs gain elastic potential energy at the expense of your kinetic energy and changes into gravitational potential energy.

Energy→ Position↓	Elastic potential energy	Gravitational potential energy = *mgh*	Kinetic energy $= \frac{1}{2}mv^2$
High in the air position	0	2300 J	0
Landing on the trampoline position	0	500 J	1800 J
Lowest point on the trampoline position	2300 J	0	0

The conservation of energy is one of the great discoveries of science. You can describe the type of energy in words (elastic potential energy, gravitational potential energy, and kinetic energy). There is also sound energy, light energy, chemical energy, electrical energy, nuclear energy, and the internal energy that reveals itself through temperature. These words, however, do not give the complete picture. Each type of energy can be measured and calculated. In a system not exchanging energy with objects external to it, the total of all the energies at any one time must equal the total of all the energies at any other time. That is what is meant by the conservation of energy.

If you choose to look at one object in the system, that one object can gain energy. For example, in the collision between a player's foot and a soccer ball, the soccer ball can gain kinetic energy and move faster. Whatever energy the ball gained, you can be sure that the foot lost an equal amount of energy. The ball gained energy, the foot lost energy, and the "ball and foot" total energy remained the same. The ball gained energy because work (force on the ball over a distance in the same direction) was done on it. The foot lost energy because negative work (force on the foot over a distance in opposite directions) was done on it. The total system of "ball and foot" neither gained nor lost energy.

Physics provides you with the means to calculate energies. You may wish to practice some of these calculations now. Never lose sight of the fact that you can calculate the energies because the sum of all of the energies remains the same.

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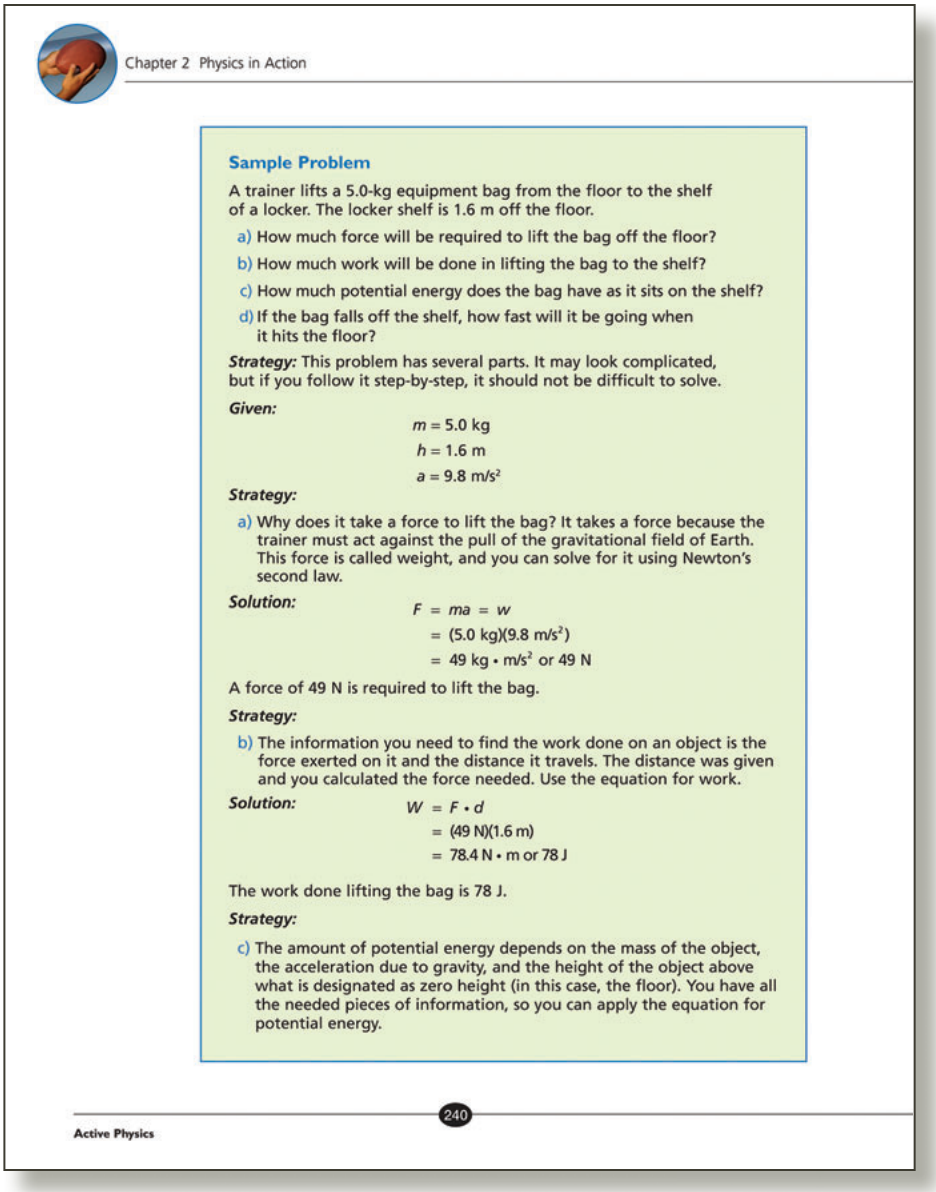
Active Physics



Sample Problem

A trainer lifts a 5.0-kg equipment bag from the floor to the shelf of a locker. The locker shelf is 1.6 m off the floor.

a) How much force will be required to lift the bag off the floor?

b) How much work will be done in lifting the bag to the shelf?

c) How much potential energy does the bag have as it sits on the shelf?

d) If the bag falls off the shelf, how fast will it be going when it hits the floor?

Strategy: This problem has several parts. It may look complicated, but if you follow it step-by-step, it should not be difficult to solve.

Given:

$m = 5.0\text{ kg}$

$h = 1.6\text{ m}$

$a = 9.8\text{ m/s}^2$

Strategy:

a) Why does it take a force to lift the bag? It takes a force because the trainer must act against the pull of the gravitational field of Earth. This force is called weight, and you can solve for it using Newton's second law.

Solution:

$$\begin{aligned} F &= ma = w \\ &= (5.0\text{ kg})(9.8\text{ m/s}^2) \\ &= 49\text{ kg}\cdot\text{m/s}^2 \text{ or } 49\text{ N} \end{aligned}$$

A force of 49 N is required to lift the bag.

Strategy:

b) The information you need to find the work done on an object is the force exerted on it and the distance it travels. The distance was given and you calculated the force needed. Use the equation for work.

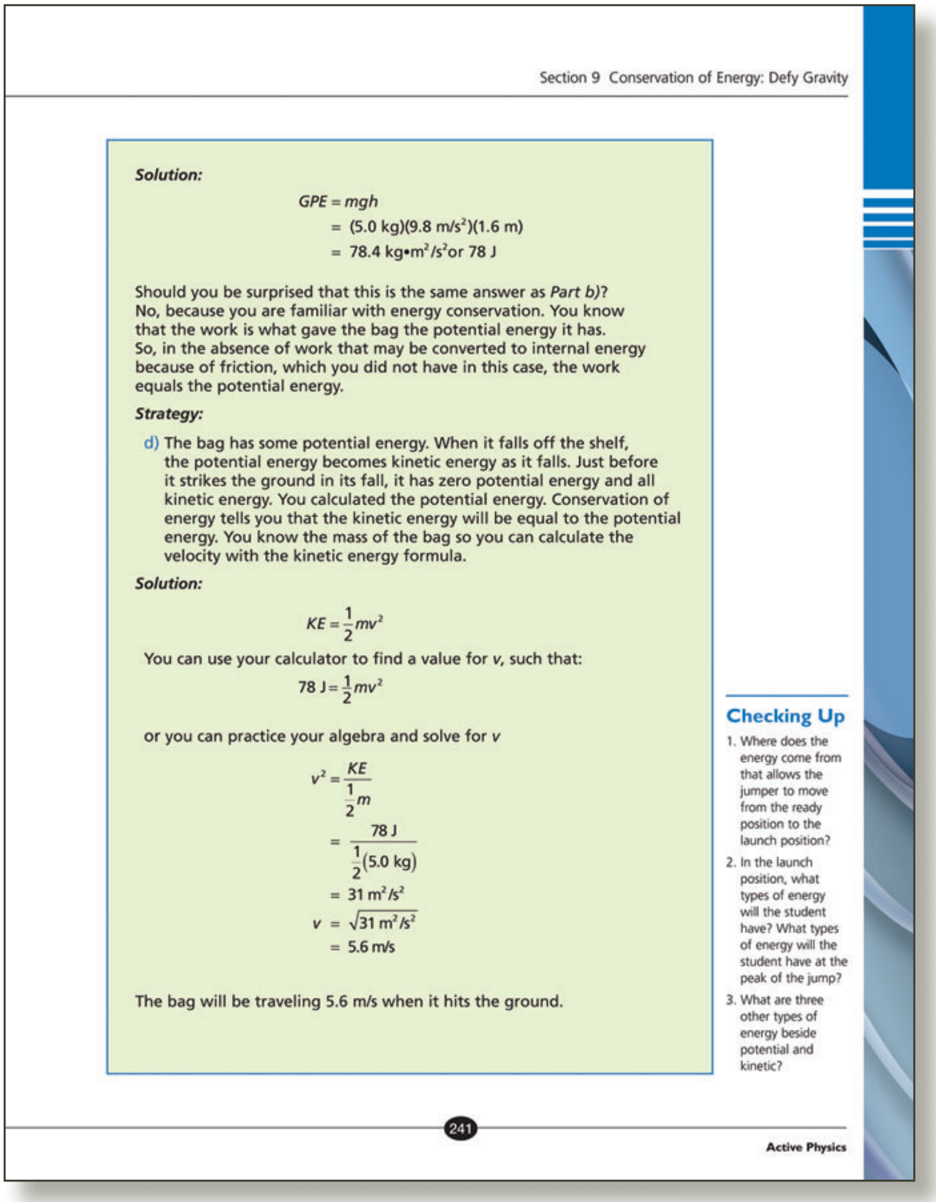
Solution:

$$\begin{aligned} W &= F \cdot d \\ &= (49\text{ N})(1.6\text{ m}) \\ &= 78.4\text{ N}\cdot\text{m or } 78\text{ J} \end{aligned}$$

The work done lifting the bag is 78 J.

Strategy:

c) The amount of potential energy depends on the mass of the object, the acceleration due to gravity, and the height of the object above what is designated as zero height (in this case, the floor). You have all the needed pieces of information, so you can apply the equation for potential energy.



Section 9 Conservation of Energy: Defy Gravity

Solution:

$$\begin{aligned} GPE &= mgh \\ &= (5.0\ \text{kg})(9.8\ \text{m/s}^2)(1.6\ \text{m}) \\ &= 78.4\ \text{kg}\bullet\text{m}^2/\text{s}^2 \text{or } 78\ \text{J} \end{aligned}$$

Should you be surprised that this is the same answer as *Part b)*? No, because you are familiar with energy conservation. You know that the work is what gave the bag the potential energy it has. So, in the absence of work that may be converted to internal energy because of friction, which you did not have in this case, the work equals the potential energy.

Strategy:

d) The bag has some potential energy. When it falls off the shelf, the potential energy becomes kinetic energy as it falls. Just before it strikes the ground in its fall, it has zero potential energy and all kinetic energy. You calculated the potential energy. Conservation of energy tells you that the kinetic energy will be equal to the potential energy. You know the mass of the bag so you can calculate the velocity with the kinetic energy formula.

Solution:

$$KE = \frac{1}{2}mv^2$$

You can use your calculator to find a value for v, such that:

$$78\ \text{J} = \frac{1}{2}mv^2$$

or you can practice your algebra and solve for v

$$\begin{aligned} v^2 &= \frac{KE}{\frac{1}{2}m} \\ &= \frac{78\ \text{J}}{\frac{1}{2}(5.0\ \text{kg})} \\ &= 31\ \text{m}^2/\text{s}^2 \\ v &= \sqrt{31\ \text{m}^2/\text{s}^2} \\ &= 5.6\ \text{m/s} \end{aligned}$$

The bag will be traveling 5.6 m/s when it hits the ground.

Checking Up

1. Where does the energy come from that allows the jumper to move from the ready position to the launch position?
2. In the launch position, what types of energy will the student have? What types of energy will the student have at the peak of the jump?
3. What are three other types of energy beside potential and kinetic?

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Active Physics

Checking Up

1.

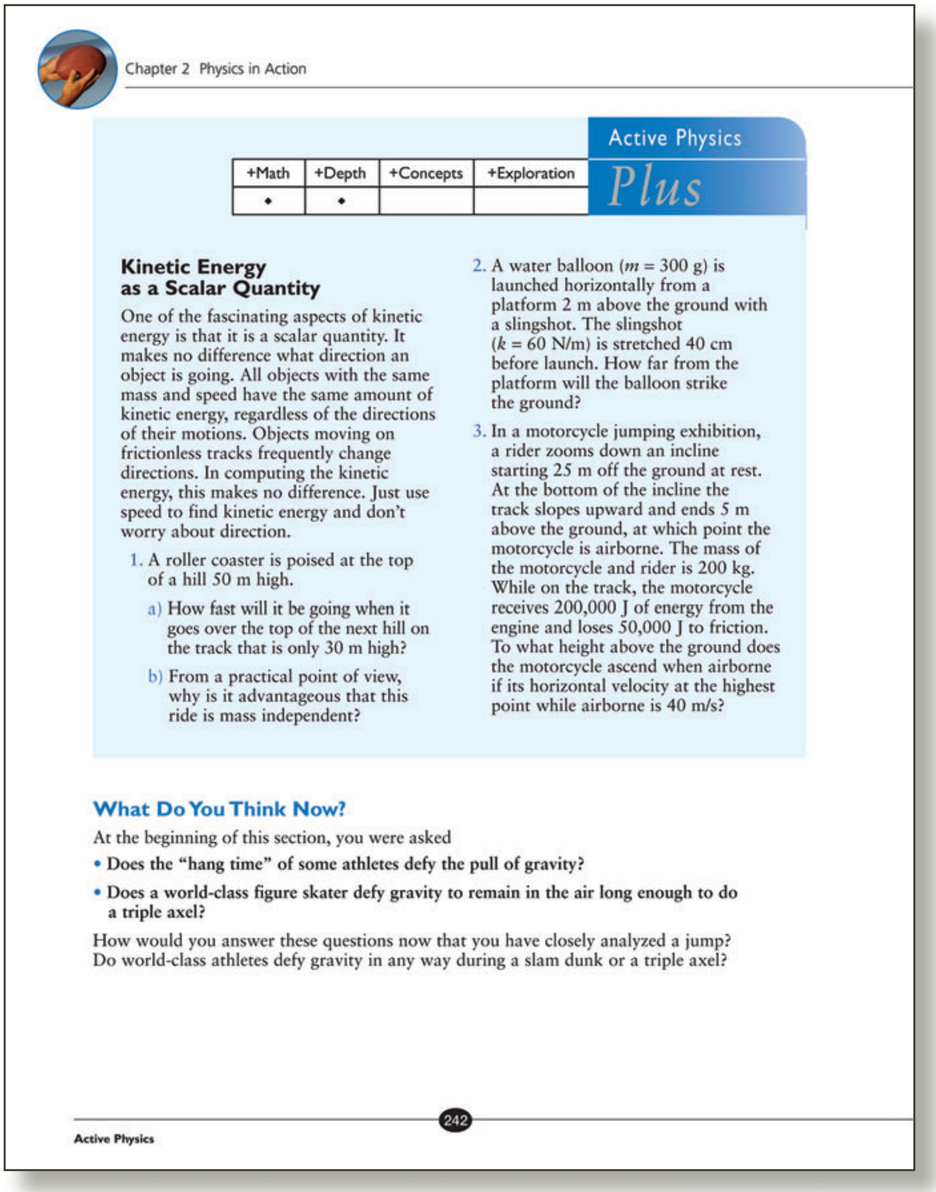
The energy is provided by the student’s muscles.

2.

In the launch position, the students will have gravitational potential energy and kinetic energy. At the peak of the jump, the students will have gravitational potential energy.

3.

Other forms of energy include sound, electrical, chemical, nuclear, and internal energy or heat. However, all these energies may be classified as either kinetic or potential when observed on an atomic level.



Active Physics **Plus**

+Math	+Depth	+Concepts	+Exploration
•	•		

Kinetic Energy as a Scalar Quantity

One of the fascinating aspects of kinetic energy is that it is a scalar quantity. It makes no difference what direction an object is going. All objects with the same mass and speed have the same amount of kinetic energy, regardless of the directions of their motions. Objects moving on frictionless tracks frequently change directions. In computing the kinetic energy, this makes no difference. Just use speed to find kinetic energy and don't worry about direction.

1. A roller coaster is poised at the top of a hill 50 m high.
    a) How fast will it be going when it goes over the top of the next hill on the track that is only 30 m high?
    b) From a practical point of view, why is it advantageous that this ride is mass independent?
2. A water balloon ($m = 300$ g) is launched horizontally from a platform 2 m above the ground with a slingshot. The slingshot ($k = 60$ N/m) is stretched 40 cm before launch. How far from the platform will the balloon strike the ground?
3. In a motorcycle jumping exhibition, a rider zooms down an incline starting 25 m off the ground at rest. At the bottom of the incline the track slopes upward and ends 5 m above the ground, at which point the motorcycle is airborne. The mass of the motorcycle and rider is 200 kg. While on the track, the motorcycle receives 200,000 J of energy from the engine and loses 50,000 J to friction. To what height above the ground does the motorcycle ascend when airborne if its horizontal velocity at the highest point while airborne is 40 m/s?

What Do You Think Now?

At the beginning of this section, you were asked

- **Does the "hang time" of some athletes defy the pull of gravity?**
- **Does a world-class figure skater defy gravity to remain in the air long enough to do a triple axel?**

How would you answer these questions now that you have closely analyzed a jump? Do world-class athletes defy gravity in any way during a slam dunk or a triple axel?

Active Physics Plus

While students are solving problems, ask them how they could explain that kinetic energy is a scalar quantity. One justification for kinetic energy being a scalar can be seen from the formula

$$KE = \tfrac{1}{2}mv^2$$

Because the energy is proportional to velocity squared, it would make no difference if the velocity were in the positive or negative direction. The square of either would be positive and the previous direction would be lost. On a simpler level, there simply is no direction associated with kinetic energy because the work necessary to cancel the energy would be independent of the direction in which the object moves.

Point out that each answer should highlight the transformation of energy and how the law of conservation of energy is helpful in finding the value of a quantity. Ask students to share their answers with their classmates, then have a whole-class discussion on each problem.

1.a)

$\tfrac{1}{2}mv^2 = mg\Delta h$. Solving for v we have $v = \sqrt{2g\Delta h} = 20$ m/s.

1.b)

Velocity is the same regardless of the number of people in the roller coaster. If the ride were people dependent, numerous problems might arise. If the cart went faster with more people, increasing the number of people would increase the chances of a collision between carts. Also, the "thrill" of the ride would depend upon how many people were in the car. Finally, the stresses created on the roller-coaster structure would depend upon the cart's speed, which would vary greatly if the speed was mass dependent.

2.

The spring potential energy is

$$\tfrac{1}{2}kx^2 = \tfrac{1}{2}(60\text{ N/m})(0.4\text{ m})^2 = 4.8\text{ J}$$

The kinetic energy of the launched balloon equals the spring potential energy. Setting these two equal and solving for v we have

$$\tfrac{1}{2}mv^2 = 4.8\text{ J}$$

$$v = \sqrt{\frac{2(4.8\text{ J})}{m}} = 5.7\text{ m/s}$$

The vertical fall distance determines the time in the air for an object launched horizontally or

$$d = \tfrac{1}{2}at^2$$

$$t = \sqrt{\frac{2d}{a}} = \sqrt{\frac{2(2\ \text{m})}{(10\ \text{m/s}^2)}} = 0.63\ \text{s}$$

The horizontal distance traveled is the horizontal speed multiplied by the time in the air or

$d = vt$, which gives $d =$

$(5.7\ \text{m/s})(0.63\ \text{s}) = 3.6\ \text{m}$

3.

At the start, the energy of the motorcycle is all gravitational potential energy:

$PE = mgh =$

$(200\ \text{kg})(9.8\ \text{m/s}^2)(20\ \text{m}) =$

$39{,}000\ \text{J}$.

The motorcycle gains 200,000 J of energy and loses 50,000 J of energy while on the ramp, so its total energy when airborne equals the net energy gained, which is

$200{,}000\ \text{J}\ (\text{from the motor}) +$

$39{,}000\ \text{J}(\text{from } PE) -$

$50{,}000\ \text{J}(\text{due to friction}) =$

$189{,}000\ \text{J}$.

At the highest point while airborne, the motorcycle has a kinetic energy of $KE = \frac{1}{2}mv^2 =$

$\frac{1}{2}(200\ \text{kg})(40\ \text{m/s})^2 = 160{,}000\ \text{J}$.

Therefore, the rest of the energy, $189{,}000\ \text{J} - 160{,}000\ \text{J} = 29{,}000\ \text{J}$ must be gravitational potential energy. So, the height can be found using

$$PE = mgh \text{ or } h = \frac{PE}{mg} =$$

$$\frac{29{,}000\ \text{J}}{(200\ \text{kg})(9.8\ \text{m/s}^2)} = 15\ \text{m}.$$

What Do You Think Now?

The *What Do You Think Now?* questions give students the opportunity to bring up any questions that they might have, revisit their responses, and modify them where necessary. You might want to return to the *What Do You See?* illustration and ask students if they now understand which concept the artist was trying to capture. Encourage them to discuss their ideas. Consider sharing *A Physicist's Response* with them. At this stage, students should show confidence in their answers.

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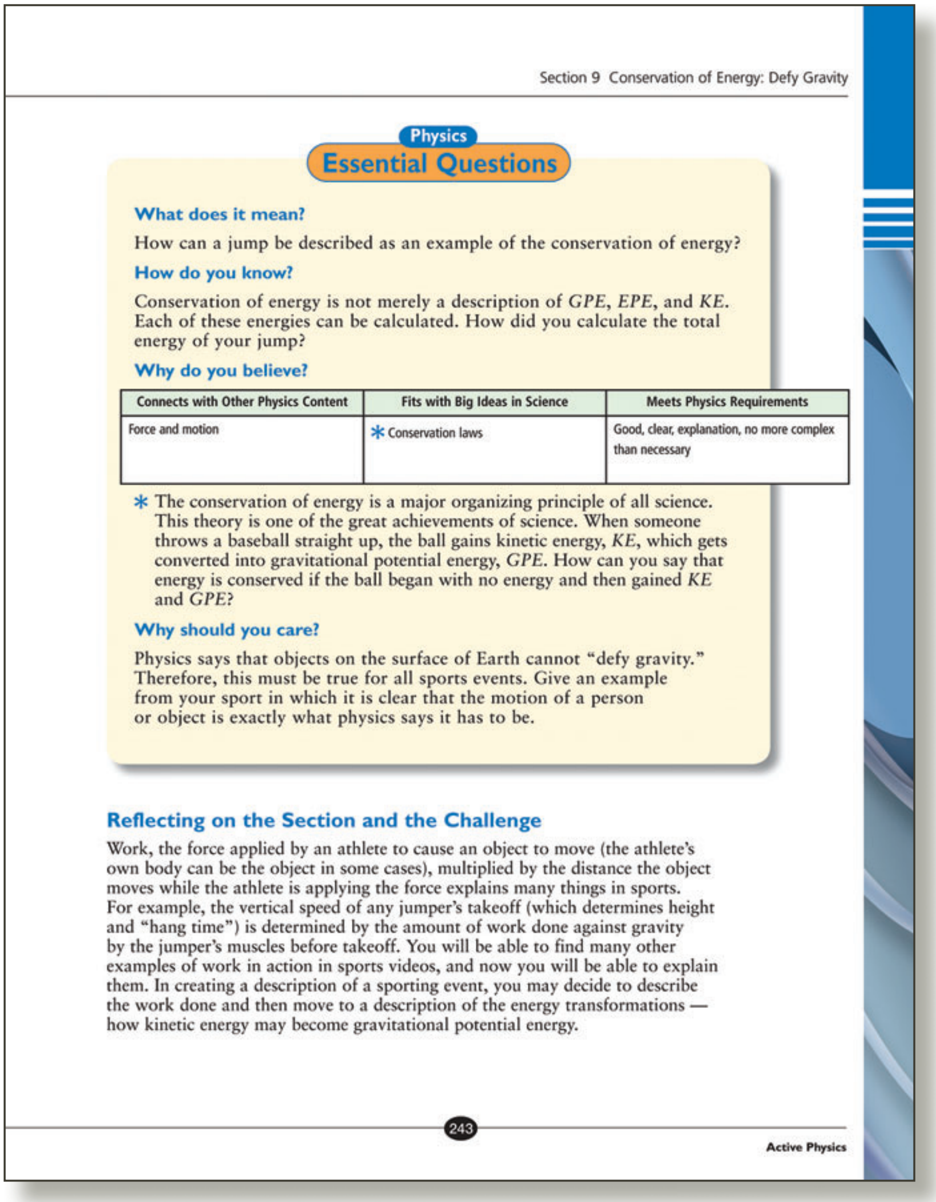


Physics

Essential Questions

What does it mean?

How can a jump be described as an example of the conservation of energy?

How do you know?

Conservation of energy is not merely a description of *GPE*, *EPE*, and *KE*. Each of these energies can be calculated. How did you calculate the total energy of your jump?

Why do you believe?

Connects with Other Physics Content	Fits with Big Ideas in Science	Meets Physics Requirements
Force and motion	* Conservation laws	Good, clear, explanation, no more complex than necessary

* The conservation of energy is a major organizing principle of all science. This theory is one of the great achievements of science. When someone throws a baseball straight up, the ball gains kinetic energy, *KE*, which gets converted into gravitational potential energy, *GPE*. How can you say that energy is conserved if the ball began with no energy and then gained *KE* and *GPE*?

Why should you care?

Physics says that objects on the surface of Earth cannot "defy gravity." Therefore, this must be true for all sports events. Give an example from your sport in which it is clear that the motion of a person or object is exactly what physics says it has to be.

Reflecting on the Section and the Challenge

Work, the force applied by an athlete to cause an object to move (the athlete's own body can be the object in some cases), multiplied by the distance the object moves while the athlete is applying the force explains many things in sports. For example, the vertical speed of any jumper's takeoff (which determines height and "hang time") is determined by the amount of work done against gravity by the jumper's muscles before takeoff. You will be able to find many other examples of work in action in sports videos, and now you will be able to explain them. In creating a description of a sporting event, you may decide to describe the work done and then move to a description of the energy transformations — how kinetic energy may become gravitational potential energy.

Reflecting on the Section and the Challenge

After students have read *Reflecting on the Section and the Challenge* in their *Active Physics* textbooks, focus attention on the important aspects of this section by highlighting key physics concepts. Discuss how work is related to energy transformations. Ask students to reflect on a specific event in a sports video that illustrates the work done by an athlete, as well as the energy transformations that took place during the sporting event. Emphasize that concepts learned in this section could be applied to their *Chapter Challenge*.

Physics Essential Questions

What does it mean?

The energy of the muscles provides the body with kinetic energy which propels the body in the air where it gains gravitational potential energy. The sum of *EPE*, *KE*, and *GPE* is constant for any point in the jump.

How do you know?

$KE = \frac{1}{2}mv^2$

$GPE = mgh$

$EPE = \frac{1}{2}kx^2$

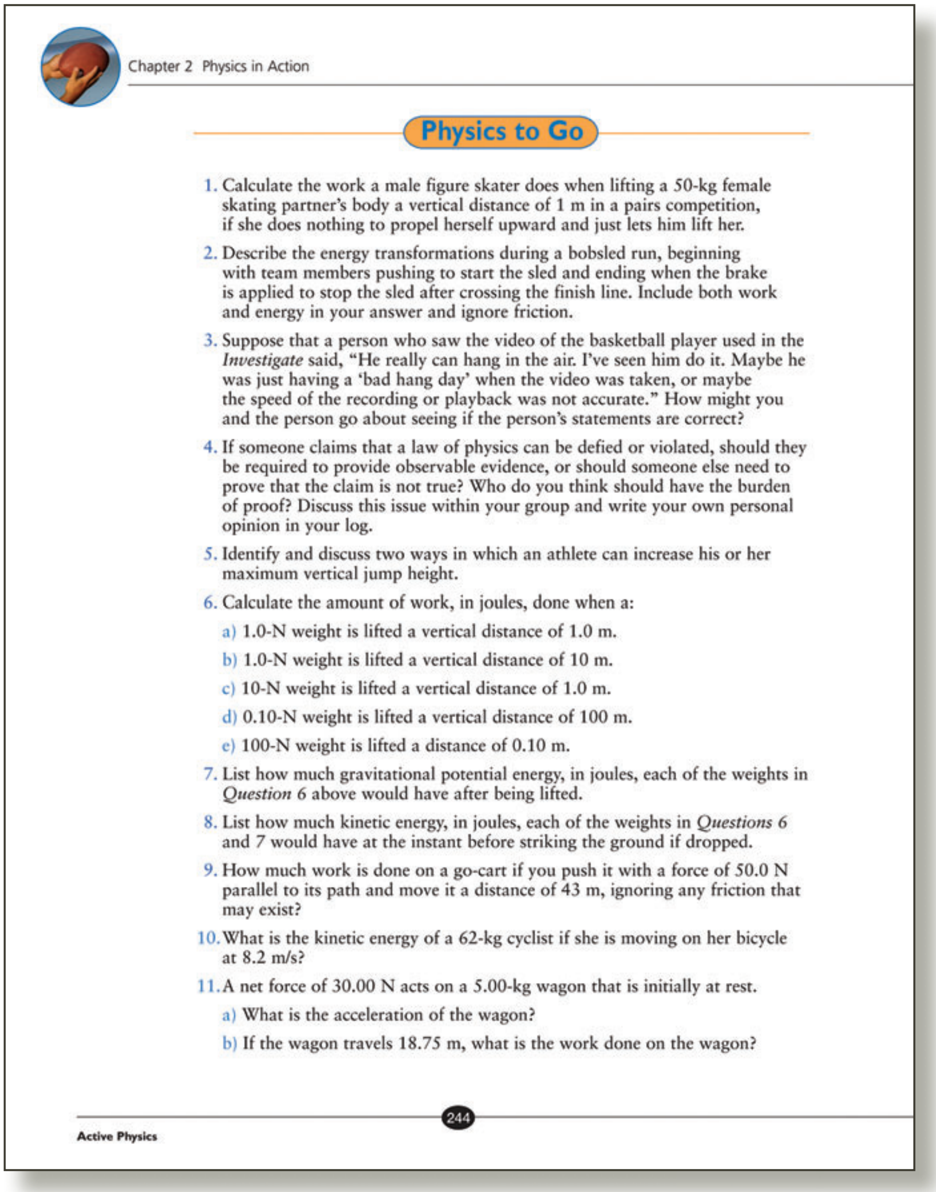
Why do you believe?

The energy came from the work done by your arm. Chemical energy in your muscles provided the kinetic energy of the ball.

Why should you care?

The conservation of energy can explain how a high jumper uses the muscles in her legs to give her body kinetic energy. This kinetic energy and more chemical energy from the legs propels her into the air, where she gains gravitational potential energy and clears the bar.

Physics to Go



Chapter 2 Physics in Action

Physics to Go

1. Calculate the work a male figure skater does when lifting a 50-kg female skating partner's body a vertical distance of 1 m in a pairs competition, if she does nothing to propel herself upward and just lets him lift her.
2. Describe the energy transformations during a bobsled run, beginning with team members pushing to start the sled and ending when the brake is applied to stop the sled after crossing the finish line. Include both work and energy in your answer and ignore friction.
3. Suppose that a person who saw the video of the basketball player used in the *Investigate* said, "He really can hang in the air. I've seen him do it. Maybe he was just having a 'bad hang day' when the video was taken, or maybe the speed of the recording or playback was not accurate." How might you and the person go about seeing if the person's statements are correct?
4. If someone claims that a law of physics can be defied or violated, should they be required to provide observable evidence, or should someone else need to prove that the claim is not true? Who do you think should have the burden of proof? Discuss this issue within your group and write your own personal opinion in your log.
5. Identify and discuss two ways in which an athlete can increase his or her maximum vertical jump height.
6. Calculate the amount of work, in joules, done when a:
   a) 1.0-N weight is lifted a vertical distance of 1.0 m.
   b) 1.0-N weight is lifted a vertical distance of 10 m.
   c) 10-N weight is lifted a vertical distance of 1.0 m.
   d) 0.10-N weight is lifted a vertical distance of 100 m.
   e) 100-N weight is lifted a distance of 0.10 m.
7. List how much gravitational potential energy, in joules, each of the weights in *Question* 6 above would have after being lifted.
8. List how much kinetic energy, in joules, each of the weights in *Questions* 6 and 7 would have at the instant before striking the ground if dropped.
9. How much work is done on a go-cart if you push it with a force of 50.0 N parallel to its path and move it a distance of 43 m, ignoring any friction that may exist?
10. What is the kinetic energy of a 62-kg cyclist if she is moving on her bicycle at 8.2 m/s?
11. A net force of 30.00 N acts on a 5.00-kg wagon that is initially at rest.
   a) What is the acceleration of the wagon?
   b) If the wagon travels 18.75 m, what is the work done on the wagon?

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Active Physics

1.

$$\text{Work} = Fd = (mg)d =$$

$$(50\text{ kg})(10\text{ m/s}^2)(1\text{ m}) = 500\text{ J}.$$

2.

Before jumping on the sled, team members do work while running and pushing the sled to give the sled and their bodies kinetic energy; therefore, $Fd = \frac{1}{2}mv^2$. After the team has jumped on the sled, the total energy of the team and sled is equal to the kinetic energy gained during the pushing phase plus the gravitational potential energy = mgh, where h is the vertical distance from the top to the bottom of the hill. At the bottom of the hill, the kinetic energy of the sled should be equal to the kinetic energy gained during the pushing phase plus the loss in potential energy due to coming down the hill, $\frac{1}{2}mv^2 + mgh$. The brake must do enough work to cause the sled to lose all of its kinetic energy by exerting a force in the direction opposite the sled's motion.

3.

It is apparent that the person wants to believe that the player can defy gravity and is attempting to justify that belief by rejecting scientific evidence. It could be said that the person is not reflecting open-mindedness, a desirable attribute in scientific pursuits. To address the situation, you may offer to video tape in slow motion the player, as many times as necessary, to ascertain if in any of the cases the player is able to "hang." After several attempts, even this person may agree he was mistaken.

4.

The burden of proof rests with the person making the claim.

5.

One way is to increase the force the athlete is able to exert using muscles, and the other way is to lose weight without decreasing muscular force.

6.a)

$$1.0\text{ N} \times 1.0\text{ m} = 1\text{ J}$$

6.b)

$$1.0\text{ N} \times 10\text{ m} = 10\text{ J}$$

6.c)

$$10\text{ N} \times 1.0\text{ m} = 10\text{ J}$$

6.d)

$$0.10\text{ N} \times 100\text{ m} = 10\text{ J}$$

6.e)

$$100\text{ N} \times 0.10\text{ m} = 10\text{ J}$$

7.

All answers are the same as for *Question* 6 on the previous page.

8.

All answers are the same as for *Question* 6 on the previous page.

9.

$W = Fd = (50.0\text{ N})(43\text{ m}) =$

$2150\text{ J }(2200\text{ J})$

10.

$KE = \frac{1}{2}mv^2 = \frac{1}{2}(62\text{ kg})(8.2\text{ m/s})^2$

$= 2084\text{ J }(2100\text{ J})$

11.a)

$F = ma \quad a = F/m =$

$30.0\text{ N}/5.0\text{ kg} = 6\text{ m/s}^2$

11.b)

$W = Fd = (30.0\text{ N})(18.75\text{ m}) =$

563 J

NOTES

NOTES

12.a)

$W = Fd \quad d = W/F =$

$(40{,}000 \text{ J})/(3200 \text{ N}) =$

12.5 m (12 m)

12.b)

$F = ma \quad a = F/m =$

$(3200 \text{ N})/(1200 \text{ kg}) = 2.7 \text{ m/s}^2$

13.

The work done is equal to the change in *KE*. The final *KE* is 0.

The initial *KE* can be found.

$KE = \frac{1}{2}mv^2 =$

$\frac{1}{2}(0.150 \text{ kg})(40 \text{ m/s})^2 = 120 \text{ J}$

14.

The change in *KE* is equal to the work done. Calculate the change in *KE* and then calculate the distance.

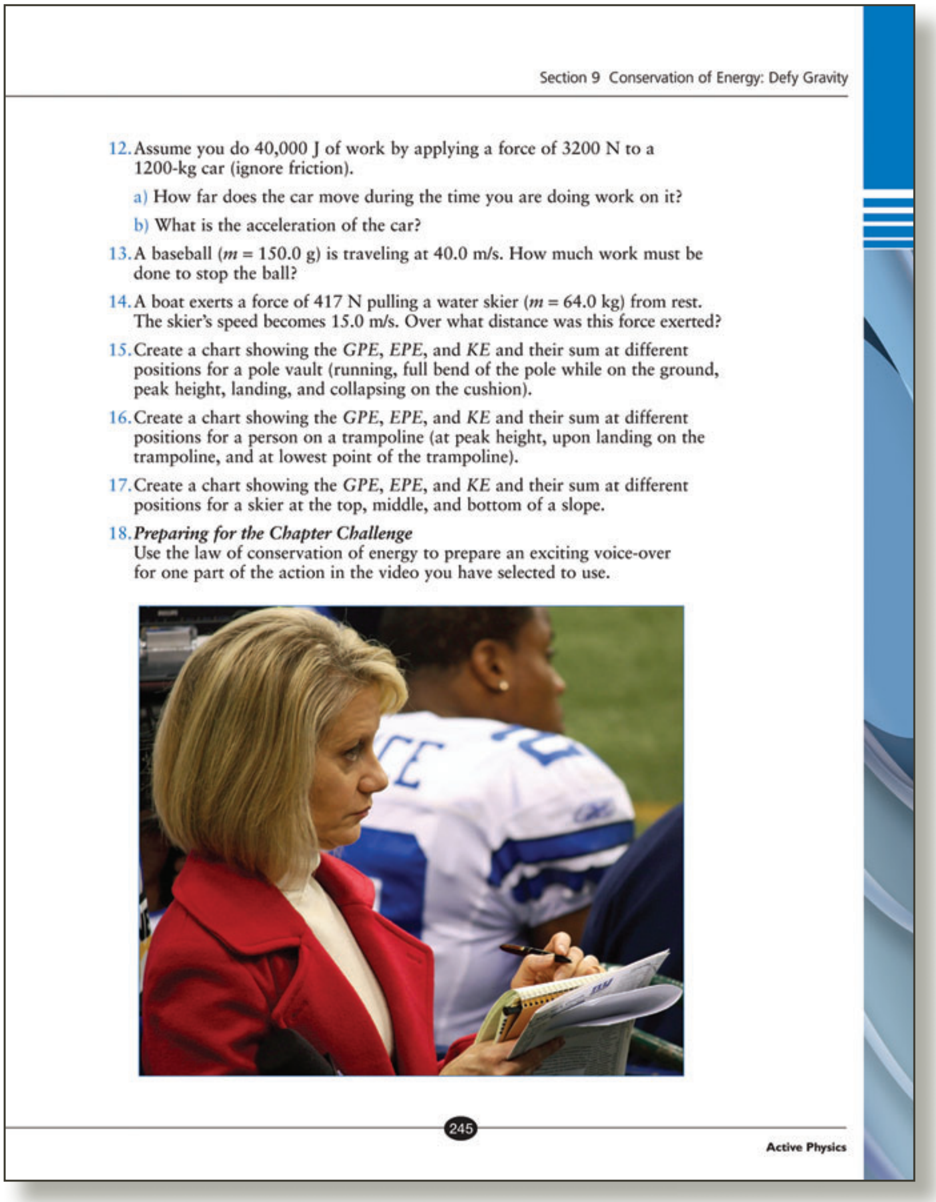
$KE = \frac{1}{2}mv^2 =$

$\frac{1}{2}(64.0 \text{ kg})(15.0 \text{ m/s})^2 = 7200 \text{ J}$

$W = Fd$

$d = W/F =$

$(7200 \text{ J})/(417 \text{ N}) = 17 \text{ m}$



Section 9 Conservation of Energy: Defy Gravity

12. Assume you do 40,000 J of work by applying a force of 3200 N to a 1200-kg car (ignore friction).
    a) How far does the car move during the time you are doing work on it?
    b) What is the acceleration of the car?
13. A baseball ($m = 150.0$ g) is traveling at 40.0 m/s. How much work must be done to stop the ball?
14. A boat exerts a force of 417 N pulling a water skier ($m = 64.0$ kg) from rest. The skier's speed becomes 15.0 m/s. Over what distance was this force exerted?
15. Create a chart showing the *GPE*, *EPE*, and *KE* and their sum at different positions for a pole vault (running, full bend of the pole while on the ground, peak height, landing, and collapsing on the cushion).
16. Create a chart showing the *GPE*, *EPE*, and *KE* and their sum at different positions for a person on a trampoline (at peak height, upon landing on the trampoline, and at lowest point of the trampoline).
17. Create a chart showing the *GPE*, *EPE*, and *KE* and their sum at different positions for a skier at the top, middle, and bottom of a slope.
18. ***Preparing for the Chapter Challenge***
    Use the law of conservation of energy to prepare an exciting voice-over for one part of the action in the video you have selected to use.

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Active Physics

15.

A sample table might look like the one below.

	KE	*GPE*	*EPE*	Sum of energies
Running	1000	0	0	1000
Pole bent	100	0	900	1000
At peak	150	850	0	1000
Landing	1000	0	0	1000
On cushion	0	0	0	0

16.

	KE	*GPE*	*EPE*	Sum of energies
Peak height	0	1000	0	1000
Landing	900	100	0	1000
Lowest point	0	0	1000	1000

17.

	KE	*GPE*	*SPE*	Sum of energies
Top of Mt	0	1000	0	1000
Middle	500	500	0	1000
Bottom	1000	0	0	1000

18.

Preparing for the Chapter Challenge

The students should choose a sports event that includes elastic potential energy and a thorough description of what is happening during the energy transformations. Many sports that include rackets, bats, or other objects striking a ball, puck, etc., will have stored energy. A baseball transition might go as follows: work is done by the pitcher to give the ball *KE*, the loss of *KE* into spring *PE* when the ball strikes the bat, the change from elastic *PE* to *KE* as the ball leaves the bat, the transformation of some of the *KE* to Gravitational *PE* as the ball rises, then returning to *KE* as the ball falls, and finally the work done by the fielder who catches and stops the ball. Additional discussion might include the energy lost to heat in the bat, and the air due to frictional forces.

SECTION 9 QUIZ

2-9b **Blackline Master**

1. A baseball bat strikes a baseball of mass that is at rest, and as a result the baseball flies away from the bat. The kinetic energy gained by the baseball as it leaves the bat is due to the

   a) loss of potential energy of the ball as it falls back to the ground.

   b) work done by the bat on the ball.

   c) gain in potential energy as the ball rises to the peak of its trajectory.

   d) loss of mass after the ball is hit.

2. A catapult with a spring constant of 10,000 N/m is used to launch a target from the deck of a ship. The spring is compressed a distance of 0.5 m before the 1.56-kg target launched. What is the target's velocity as it leaves the spring?

   a) 10 m/s
   b) 20 m/s
   c) 30 m/s
   d) 40 m/s

3. A ball is thrown vertically upward. As the ball rises, the ball's total energy

   a) decreases.

   b) increases.

   c) remains the same.

4. A 10-kg mass at rest on a horizontal frictionless table is accelerated by a force of 20 N. How much work is needed to accelerate the ball to a velocity of 10 m/s?

   a) 5 J
   b) 200 J
   c) 500 J
   d) 2000 J

5. An object is lifted upward at a constant speed. The gain in potential energy of the object is due to the

   a) work done on the object.

   b) total force applied to the object.

   c) change in kinetic energy of the object.

   d) weight of the object.

SECTION 9 QUIZ ANSWERS

1. b) work done by the bat on the ball. This work will not be equal to the loss of *GPE* when the ball falls down, since it will still be moving forward when it lands, and will maintain some *KE*.

2. d) $SPE = KE$ or $\frac{1}{2}kx^2 = \frac{1}{2}mv^2$. Canceling the $\frac{1}{2}$'s on each side gives $(10{,}000\ \text{N/m})(0.5\ \text{m})^2 = (1.56\ \text{kg})v^2$, and $v = 40\ \text{m/s}$.

3. c) by conservation of energy

4. c) The work needed is equal to the increase in $KE = \frac{1}{2}mv^2 = 500\ \text{J}$.

5. a) Because the object is lifted with constant speed, there is no change in *KE*, so all the work goes into increasing *GPE*.

NOTES