SECTION 5

Hooke's Law: Finding Your "At Rest" Weight

Section Overview

Students investigate the difference between mass and weight and how springs are used to determine an object's weight using Hooke's law. They begin by calculating and comparing the weights of different objects and learn that in the metric system the mass of an object is measured in kilograms and weight in newtons. They find what the weight in newtons is of a bowling ball weighing 11-lb and a 1/4-lb burger. Students then find the metric equivalent weight of a roller-coaster car that weighs 1500 lbs.

To investigate how a spring is used to measure the weight of an object, students record the changing stretch of a spring by hanging different masses from a spring that is attached to a ring stand. They plot a graph of the stretch of the spring on the x-axis versus the weight hung on the spring on the y-axis, and determine the slope of the line and the spring's "spring constant."

Students repeat their investigations for a second spring that looks different, make a prediction about the stretch of the spring, and then test the accuracy of their prediction. They compare the slope of the line obtained from this graph to the slope from the previous graph. They also plot a graph for an "invented" third spring and write the description of the spring that would have that data. Finally, using the spring constant for each spring the students create a scale to measure the weight of different masses, three known and two whose weight is unknown.

Background Information

Students often have a great deal of difficulty in distinguishing mass and weight. That is probably because in everyday experience a type of conversion between mass and weight has been created. When you want to know how far you can throw something, you first lift it up and down to determine its weight. Knowing the weight, you can deduce its corresponding mass and know how hard it will be to push or throw. You also tend to confuse mass and weight because in common English usage, you use the same terms like ounces or pounds for both mass and weight. In countries that use the SI system, groceries such as meat or fruits, are sold by the kg, but the "mass" is determined by weighing them on a spring scale.

In physics, the distinction between mass and weight is crucial to our understanding. Mass is inertia—a resistance to motion. It is also the amount of matter. Weight is a force. Our weight on Earth is the force that Earth exerts on us. The unit for mass is the kilogram. The unit for weight is the newton. From Newton's second law, you can see that $1\ \text{N} = 1\ \text{kg} \cdot \text{m/s}^2$. It is sometimes useful to use alternate units for g of N/kg. Since an object resting on the table has mass and weight, it might clear up some misunderstandings if students are calculating the weight by multiplying the mass by g in units of N/kg, rather than the equivalent m/s^2. In symbols, you write $F_w = mg$. F_w is the weight (or weight force).

If gravity is the only force acting on an object, then Newton's second law tells you that $F_w = ma = mg$. Then the object's acceleration equals g, (9.8 m/s^2 near the surface of Earth). In that case, the object is said to be in "free-fall." Hooke's law states the relationship between the force that a spring can exert on an object and the stretch of the spring needed to exert that much force. The larger the stretch (or compression) of the spring, the larger the exerted force. This is written mathematically as $F = -kx$. The negative sign indicates that when you stretch a spring to the right, the restoring force from the spring is to the left. The force exerted by the spring and the displacement (stretch) are in opposite directions.

Hooke's law is sufficiently accurate for measuring weights of food, gold, and many other materials throughout the ages. You either hang objects from the scale and stretch the spring or place objects on the scale and compress the spring. Hooke's law is also used as a first approximation when other materials are stretched or compressed. If a piece of rubber was to be stretched, the first guess for the force would be Hooke's law—the force is directly proportional to the stretch. Springs can stretch beyond their ability to restore themselves to their original shape. As they stretch to this point, they no longer follow Hooke's law. Graphing the data, one would notice that the graph of force versus displacement (stretch) would begin to diverge from the straight line of the earlier data.

Crucial Physics

- Weight is the force of gravity acting on an object. If the object is on or near Earth's surface then the strength of the gravitational field is nearly constant and is given by 9.8 N/kg. This is also called the acceleration due to gravity. The object's weight is then given by $F_w = mg$. Weight, like all forces is a vector and acts toward Earth's center. The units for force are newtons.
- The force exerted on an object by a spring is a restoring force that is directly proportional to the distance the spring is stretched or compressed from its natural length. The spring force is described by Hooke's law: $F_s = -kx$, where F_s is the force exerted by the spring on an object, x is the distance the spring is stretched or compressed from its natural length, and k is the spring constant. The spring constant of a spring describes how easy or difficult it is to stretch or compress a spring and is measured in newtons per meter.

Learning Outcomes	Location in the Section	Evidence of Understanding
Distinguish between mass and weight.	***Investigate*** Part A, Step 1	Students learn the definition of weight in physics and find that the metric unit of mass is kilograms and weight is newtons.
Calculate weight in newtons for a given mass.	***Investigate*** Part A, Step 2 ***Physics Talk***	Students calculate and compare the weights of a gymnast and football player with different masses.
Measure the effect of weight on the vertical stretch of a spring.	***Investigate*** Part B, Step 7.a) ***Physics Talk***	Students record measurements of the stretch of a spring from it zero position length using weights of different masses.
Illustrate the relationship between weight and stretch of a spring in a graph.	***Investigate*** Part B, Steps 7-11 ***Physics Talk***	Students plot a graph with the stretch of the spring on x-axis and weight on y-axis. Students learn that slope of the graph is a straight line. Students draw graphs for different springs.
Use a spring to create a scale and explain how Newton's second law is used in the creation of the scale.	***Investigate*** Part C, Steps 1-3 ***Physics Talk***	Students create a scale and choose five objects, three of known masses and two of unknown masses and explain how Newton's second law is used to determine the weight on an object.
Calculate spring forces using Hooke's law.	***Physics to Go*** Questions 3, 4, 6, and 7	Students solve problems to calculate the spring constant of a spring.

Section 5 Materials, Preparation, and Safety

Materials and Equipment

PLAN A		
Materials and Equipment	**Group (4 students)**	**Class**
Holder, right-angle, cast iron	1 per group	
Rod, aluminum, 3/8 in. x 12 in. (to act as crossarm)	1 per group	
Ring stand, large	1 per group	
Meter stick	1 per group	
Ruler, metric, in./cm	1 per group	
Springs, set, Hooke's law	1 per group	
Hanger, mass	1 per group	
Weight, slotted, 12-piece set, 1 g–500 g	1 per group	
Scale, electronic, 0.1-g readability, 0–1500 g		1 per class
Paper, graph, pkg. of 50		1 per class
Tape, masking		6 per class
Card, index, unlined, 3 in. x 3 in.		1 per class
Paper, sheet*	1 per group	
Pad, easel**		1 per class
Markers**		6 per class

*Additional items needed not supplied
**Item used in *Mini-Challenge.*

Time Requirement

Allow one class period or 45 minutes for the *Investigate* of this section.

Teacher Preparation

- Cut 8½ by 11 sheets of paper into three strips to allow each student to make a paper spring.
- Determine how the students will attach pointers to the masses suspended from the springs to take their readings.
- If there are an insufficient number of springs for each group to have a set, the students may swap springs to get a different one.
- Determine good examples of "unknown" masses that the students can weigh. The mass of these samples should be in the weight range measured by the students.
- Ensure that the given weights are able to stretch the spring, but not beyond its point of elasticity. You may want to consider how the students can mount the ruler so that it does not shift as they add weights to the spring.

Safety

- Students should be aware that masses might fall off the spring or mass hanger. Make certain that no feet are located below the spring where the masses may fall. Placing a soft surface underneath the area where the masses might fall will also protect the floor.
- When the masses are removed from the springs quickly while in the stretched position, the springs might be launched off their holders. Eye protection is again absolutely necessary.

Materials and Equipment

PLAN B		
Materials and Equipment	**Group (4 students)**	**Class**
Holder, right angle, cast iron		1 per class
Rod, aluminum, 3/8 in. x 12 in. (to act as crossarm)		1 per class
Ring stand, large		1 per class
Meter stick		1 per class
Ruler, metric, in./cm		1 per class
Springs, set, Hooke's law		1 per class
Hanger, mass		1 per class
Weight, slotted, 12-piece set, 1 g–500 g		1 per class
Scale, electronic, 0.1-g readability, 0–1500 g		1 per class
Paper, graph, pkg. of 50		1 per class
Tape, masking		6 per class
Card, index, unlined, 3 in. x 3 in.		1 per class
Paper, sheet*		1 per class
Pad, easel**		1 per class
Markers**		6 per class

*Additional items needed not supplied
**Item used in *Mini-Challenge.*

Time Requirements

- Allow one class period or 45 minutes for the *Investigate* (all parts), the *Physics Talk*, as well as other parts of the section from the Pacing Guide.

Teacher Preparation

- Note the preparations for Plan A as well as these below.
- Several students should be recruited to assist you in taking the measurements and recording them on the board for the rest of the class to record in their journals. If a camera and projection system are available they should be used so the students can see more clearly what is occurring.
- Have a ring stand with a horizontal bar attached set up in the front of the classroom. Have different springs, a mass hanger, and a series of slotted masses available at the front of the room, along with a meter stick.
- Test the various springs that will be used prior to class to ensure they provide repeatable results when the masses are hung from them.
- Cut 8½ by 11 sheets of paper into three strips, enough for one per group plus one for you to allow the students to make paper springs. Have students follow your example as the paper springs are tested.
- Have several "unknown masses" available to hang on the springs and have the students determine the mass from the recorded stretch.
- Summarize the *Investigate* to familiarize the students with what they will be observing.

Safety

- When the masses are removed from the springs quickly while in the stretched position the springs might be launched off their holders. Eye protection is again absolutely necessary.

Meeting the Needs of All Students

Differentiated Instruction: Augmentation and Accommodations

Learning Issue	Reference	Augmentation and Accommodations
Doing multi-step unit conversions	***Investigate*** Part A, Step 4	**Augmentation** • Learning how to complete unit conversions is an important skill in science classes. Using direct instruction, teach students a strategy for unit conversions that can be applied to all unit conversions. $\frac{11\ \cancel{lb}}{1} \times \frac{1\ \cancel{kg}}{2.2\ \cancel{lb}} \times \frac{9.8\ N}{1\ \cancel{kg}} = 49\ N$ • Learning a problem-solving process takes repetition and practice, but once the process is mastered, most students with learning disabilities have a lot of success applying procedures.
Making graphs	***Investigate*** Part B, Steps 7 and 9 ***Physics to Go*** Question 3	**Augmentation** • Students have created a graph in the three sections preceding this one and have probably done so with some support. At this point, students should be gaining some independence with graphing, however, sometimes students do not generalize skills to new situations. Explicitly show students how graphing the stretch of the spring vs. weight and then interpolating data is the same set of skills they practiced in *Section 4*. Then ask students to work in pairs to create the graph and make predictions.
Applying new concepts	***Investigate*** Part B, 10.a) ***Physics to Go*** Question 3	**Augmentation** • The two previous graphs in this *Investigate* were comparing amount of stretch vs. weight and now students are being asked to graph spring force vs. amount of stretch. While these concepts are related, students may have a difficult time applying what they have learned to create a graph for an "invented" spring that does not have any known data points. • One way to differentiate this activity would be to allow students to draw a graph for the "invented" spring and then write a statement to defend their graphs. Other students could choose between two graphs that have been created by someone else, and write a statement to defend that choice. **Accommodation** • Make sure students can view all three of their graphs side-by-side at one time. This will make comparisons and differences much more obvious. Many students do not notice similarities and differences unless they are right in front of them.
Calculating slope	***Investigate*** Part B, Step 9.c) ***Physics Talk*** Sample Problem 2 ***Active Physics Plus*** ***Physics to Go*** Questions 3.c) and 7	**Augmentation** • Most students can define slope as rise over run. When asked to apply this definition to find the slope of a graph, students often have difficulty determining the values for rise and run. Using the formula $\text{slope} = \Delta y / \Delta x$ may help students. If they are able to identify how much the y-values changed and how much the x-values changed using the line on the graph, they can divide to find the slope. • Provide direct instruction to review the method for calculating slope from a graph or a chart. **Accommodation** • Highlight the y-axis with one color and the x-axis with another color. Then use the corresponding colors to highlight rise and run in the slope formula. This is a visual cue to remind students which scale they should be using to determine values for rise and run.

CHAPTER 4

Strategies for Students with Limited English-Language Proficiency

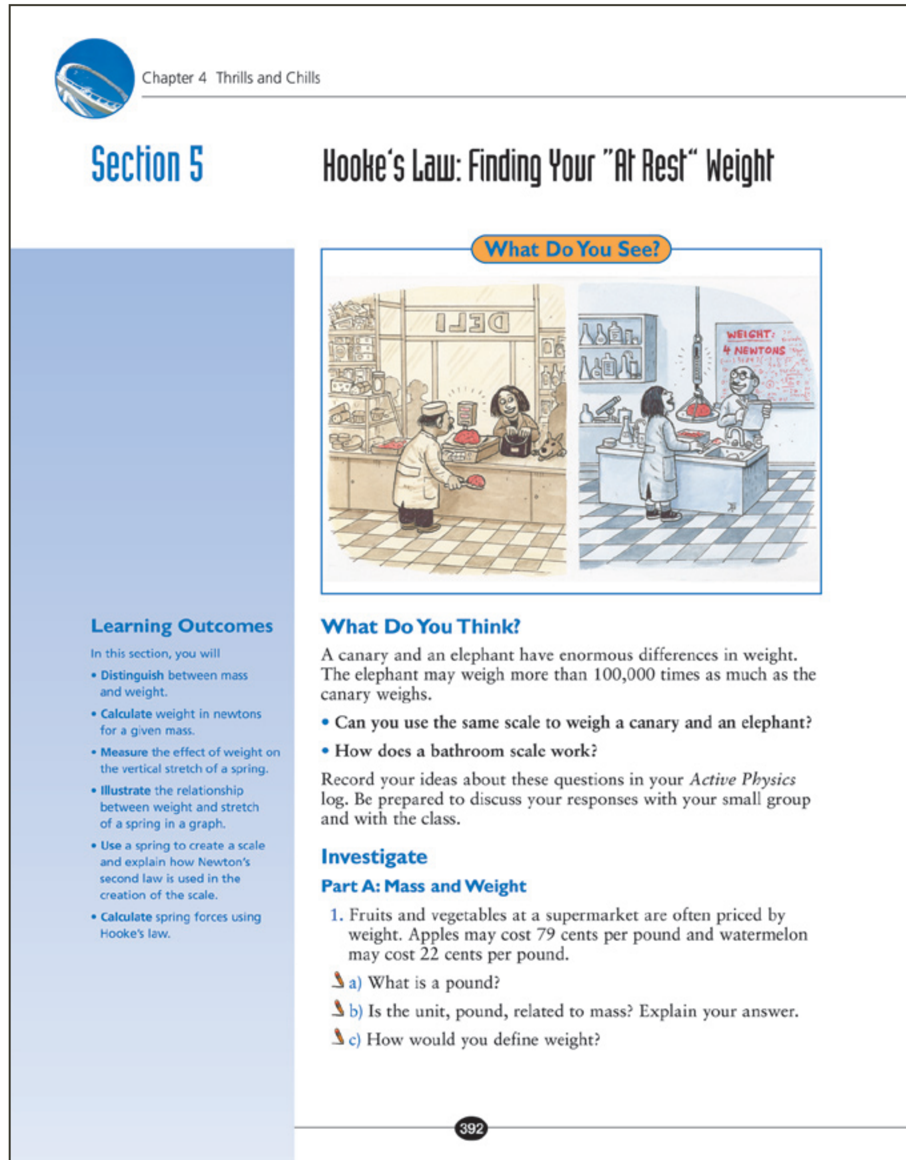
Learning Issue	Reference	Augmentation
Understanding concepts	***Investigate*** Part A, Step 3.a)	After students have answered the question, check their understanding of the difference between weight and mass by asking: What would be the mass of the gymnast and the football player on the Moon?
Research skills	***Investigate*** Part A, Step 4	If time and curiosity allow, have students see whether they can find out why we use pounds instead of newtons as the nonscientific unit of weight. Students may find it interesting that the abbreviation "lb" comes from the Latin *libra*, which means scales or balance.
Vocabulary comprehension Higher-order thinking	***Investigate*** Part B, Step 7.b)	• Help students use context clues to infer the meaning of the term "unconventional," if necessary. It may help to ask what *convention* they *usually* use in graphing. • Before students draw their graphs, hold a class discussion to get students' opinions on why the independent variable (the weight) is graphed on the y-axis instead of on the x-axis. Have the same discussion after they have drawn their graphs, to see whether their thinking has changed.
Vocabulary comprehension	***Investigate*** Part B, Step 7.c)	"Interpolation" is an important term, and an important skill, in science. To make sure students have a solid grasp of what it means, it may help to discuss how interpolation differs from extrapolation. Discuss why an interpolation might be more reliable than an extrapolation.
Comprehension	***Investigate*** Part B, Step 9.c)	Check to make sure that students understand "best-fit line." When drawing this line, they should *not* connect the data points.
Understanding concepts Vocabulary comprehension	***Physics Words***	Encourage students to write a summary of Hooke's law in their own words, which will allow you to check their understanding. ELL students may need assistance to properly comprehend "restoring force."
Understanding concepts	***Physics Talk*** Hooke's Law Describes the Restoring Force a Spring Exerts	To make sure students understand the meaning of the negative sign in the equation for Hooke's law, have them explain it in their own words.
Comprehension	***Physics Talk*** Sample Problem 1	Make sure students understand what omitting the negative sign from their calculations really means. The negative sign is not necessary in any mention of the magnitude of the force. It is important only when indicating the direction of the force.
Vocabulary comprehension	***Physics Talk*** Sample Problem 2	ELL students may need help interpreting "rise over run" as a definition of slope. One way to help students visualize the relationship is to use the example of a set of stairs. The solid vertical piece of wood in each step is called a riser, so it represents the rise. The depth of each step is the run.
Vocabulary comprehension	***Active Physics Plus***	Check students' interpretations of the word "reciprocal," and correct if necessary.
Understanding concepts	***Physics Essential Questions*** What does it mean?	To fully grasp the content of this section, students need to be clear on the differences in meaning of "spring force," "spring stretch," and "spring constant." Point out that the term "spring" can be a noun or a verb, but in these three terms it is an adjective.

SECTION 5

Teaching Suggestions and Sample Answers

What Do You See?

This is an illustration that communicates its message through images that clearly indicate that a woman buying something to eat at a deli is having her purchase weighed again on a different scale. Project the illustration on a transparency using an overhead projector. Consider asking students why the weight is written in newtons and not in kilograms and why the woman is using a second scale to measure the weight. In a discussion prompt students to observe the setting of the two visuals in the *What Do You See?* section. Remind students that their answers are all valuable at this point because they will be shaping up their original


Chapter 4 Thrills and Chills

Section 5 Hooke's Law: Finding Your "At Rest" Weight

What Do You See?

Learning Outcomes

In this section, you will

- **Distinguish** between mass and weight.
- **Calculate** weight in newtons for a given mass.
- **Measure** the effect of weight on the vertical stretch of a spring.
- **Illustrate** the relationship between weight and stretch of a spring in a graph.
- **Use** a spring to create a scale and explain how Newton's second law is used in the creation of the scale.
- **Calculate** spring forces using Hooke's law.

What Do You Think?

A canary and an elephant have enormous differences in weight. The elephant may weigh more than 100,000 times as much as the canary weighs.

- **Can you use the same scale to weigh a canary and an elephant?**
- **How does a bathroom scale work?**

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

Investigate

Part A: Mass and Weight

1. Fruits and vegetables at a supermarket are often priced by weight. Apples may cost 79 cents per pound and watermelon may cost 22 cents per pound.
   a) What is a pound?
   b) Is the unit, pound, related to mass? Explain your answer.
   c) How would you define weight?

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Students' Prior Conceptions

Student understanding of the previous sections ladders their comprehension of the differences between mass and weight. This section enables students to discover what they believe and to compare it with what they actually know through direct experimentation. This section also furthers cognitive development of more than one type of potential energy.

1. **Students confuse the ideas of mass and weight.** The teachers' attention is directed to the extensive discussion of prior conceptions associated with mass and weight in *Physics in Action*. The opportunity to assess the coherence of student thinking on "at rest" weight as measured with the spring scale provides measured data around which mass can be discerned from weight.

2. **Everyday language leads students to think that mass is something you get by weighing an object.** Using the spring scale to measure the weight of various known masses will help students to build templates for correlating mass and weight. Calculation of the restoring force of the spring or the "spring force" and relating force to acceleration will also establish another connection between weight and apparent weight. Additionally, the opening exists for the teacher to emphasize differences between weight and apparent weight. The acceleration component of the net force or the change in the acceleration due to certain types of motion indicate why students may "feel" weightless at certain points on roller-coaster rides or when riding in an elevator. Mass remains constant, weight may change.

responses as they progress further in the section. Your main emphasis should be in engaging students' curiosity and getting them involved in thinking about the topic they will be investigating.

What Do You Think?

The *What Do You Think?* questions encourage students to think about weight. The enormous differences in the weight of a canary and elephant will prompt student to the think of the scale used for measurement. Ask students to record their answers in their *Active Physics* logs, and assure them at the same time that you are not evaluating their answers at this point. Students should feel confident in discussing their ideas. You might want to ask students to record the questions that come up in their minds after they have written down their responses to the *What Do You Think*? section. Note the misconceptions that students might have and post them on a wall in your classroom so that you can address them at a later stage when students have carried out their experiments in the *Investigate*. There is no reason to expect that the students would know how a bathroom scale works, particularly if the scale they have at home is electronic.

Investigate

Part A: Mass and Weight

1.a)

A pound is a unit of weight, the force that Earth exerts on an object.

1.b)

The pound is related to the mass of an object. The greater the mass, the greater the weight. A pound is approximately 0.45 kg.

1.c)

Strictly speaking, weight is the force that Earth's gravity exerts on an object. If you are on the Moon, it is the force that the Moon's gravity exerts on you.

What Do You Think?

A Physicist's Response

The same scale could not be used for an elephant and a canary. The canary scale must be able to differentiate between grams, while the elephant scale needs to be accurate only to the nearest kilogram. Although you could build an elephant scale to the precision needed for a canary scale, it would be prohibitively expensive and serve no obvious purpose. The bathroom scale is similar to the spring that the students used in the pop-up toy. The greater the force applied, the more the spring is compressed. If a pointer is attached to the spring, and a properly calibrated scale is near the pointer, the spring can be used for determining the force of the weight for a given stretch of the spring.

NOTES

NOTES

2. In physics, weight is defined as the force of gravity on an object. The weight (force) is the mass of an object multiplied by the strength of the gravitational field at the location of the object. Large masses are heavy (have large weights) and small masses are light. In the metric system, the mass of an object is measured in kilograms. The strength of the gravitational field near the surface of Earth is 9.8 N/kg (newtons per kilogram). The unit newton per kilogram is equivalent to meters per second every second. Using this information, you can calculate a student's weight (force). The student has a mass of 50 kg.

weight (force) = mass × strength of gravitational field

$$F_w = mg$$
$$= (50\text{ kg})(9.8\text{ N/kg})$$
$$= 490\text{ N (newtons)}$$

The unit for weight is the newton (N). *Weight* is a force and has the same units as any other force.

a) Calculate and compare the weights of a gymnast with a mass of 40 kg and a football player with a mass of 110 kg.

3. On the surface of the Moon, the strength of the gravitational field is only about 1.6 N/kg.

a) What would be the weights of the gymnast and the football player in *Step 2.a)* if they were on the Moon?

4. The newton is the metric unit for weight. However, you may wish to compare this to a pound, with which you are more familiar. Each kilogram (mass) has a weight of 2.2 lb on Earth. A 220-lb football player has a mass of 100 kg. The weight (force) exerted on 100 kg, according to the equation $F_w = mg$, is 980 N.

a) Find the weight in newtons of a bowling ball that weighs 11 lb.

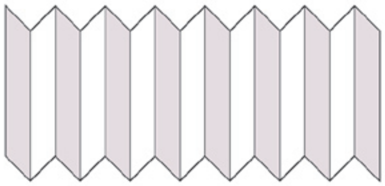
b) Find the weight in newtons of a ¼-lb burger (a patty that has a weight of ¼-lb).

5. The weight of a ¼-lb burger is close to 1 N. In a country that uses metric measurements, a restaurant could call their ¼-lb burger a "Newton Burger." You can use this as an approximate way to determine how much something weighs in newtons if you know the weight in pounds. A 50-lb person has the equivalent weight of 200 quarter-pound burgers (200 × ¼-lb). Therefore, the 50-lb person has an approximate weight of 200 N.

a) Using this technique, find the approximate weight in newtons of a roller-coaster car that weighs 1500 lb.

Part B: The Properties of Springs

1. Make a spring from a piece of paper. Take a piece of 8½ × 11 paper. Fold it like an accordion.



2. With a small force, stretch the paper spring slightly.

a) Record what happens when you release the paper.

3. With a small force, compress the paper spring slightly.

a) Record what happens when you release the paper.

2.a)

For the gymnast,
$F_w = mg = (40\text{ kg})(9.8\text{ N/kg}) =$ 392 N (or about 400 N).

For the football player,
$F_w = mg = (110\text{ kg})(9.8\text{ N/kg}) =$ 1078 N (or about 1100 N).

3.a)

For the gymnast

$F_w = mg_{moon} =$
$40\text{ kg} \times 1.6\text{ N/kg} = 64\text{ N}.$

For the football player

$F_w = mg_{moon} =$
$110\text{ kg} \times 1.6\text{ N/kg} = 176\text{ N}.$

The weights are considerably smaller on the Moon, but of course the masses are the same.

4.a)

$(11\text{ lb}) \times (1\text{ kg}/2.2\text{ lb}) \times (9.8\text{ N/kg}) = 49\text{ N}$

4.b)

$(0.25\text{ lb}) \times (1\text{ kg}/2.2\text{ lb}) \times (9.8\text{ N/kg}) = 1.1\text{ N}$

5.a)

1500 pounds is approximately 6000 1/4-lb burgers.
1500 lb = 6000 N

Part B: The Properties of Springs

1.

Students fold an 8 ½ x 11 piece of paper in the shape of an accordion. The creases in the paper will let the piece of paper act like a spring.

2.a)

When you release the paper, it springs back to its original shape.

3.a)

When you release the paper, it springs back to its original shape.

CHAPTER 4

4.a)

If you stretch it too far, it won't return to its shape.

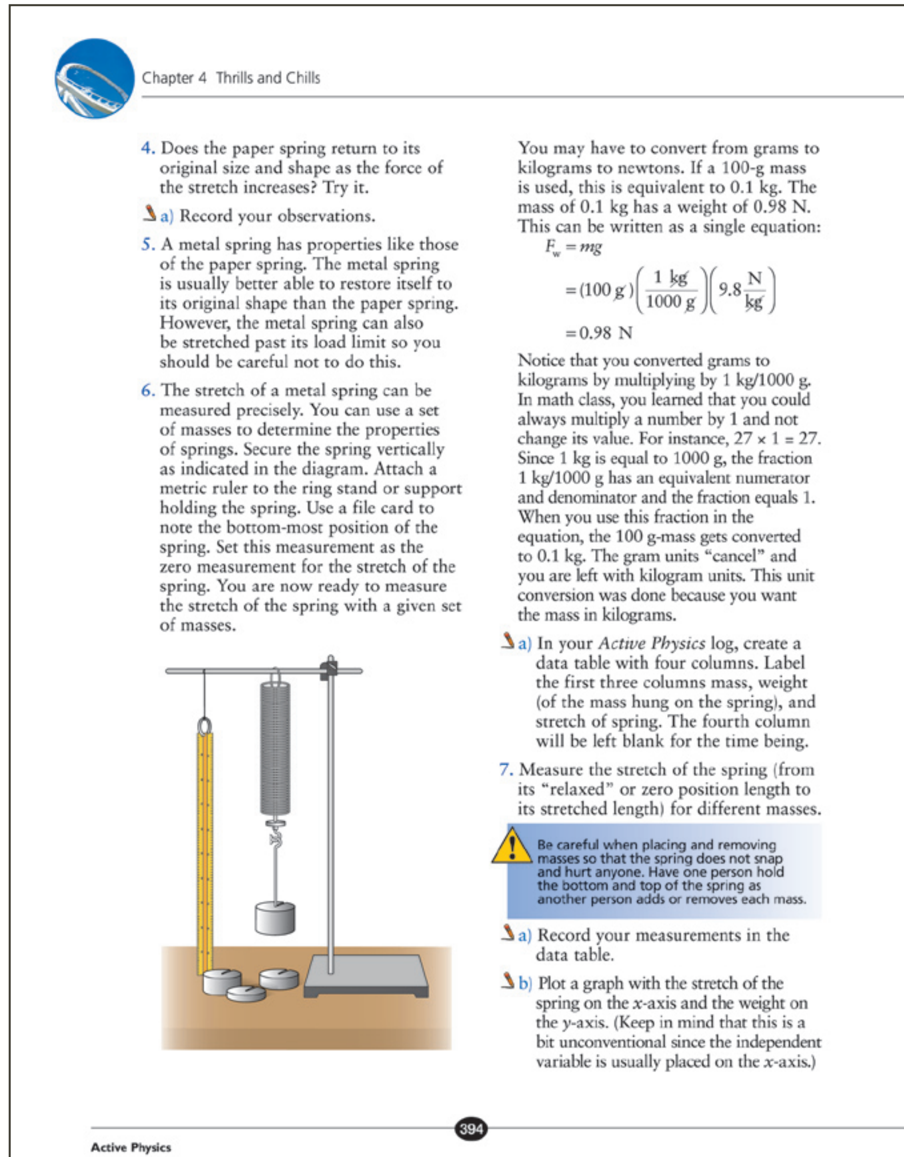
5.

You could use a metal paper clip as a spring for heavier weights than the paper. But if you stretch the paper clip too far, like the paper its shape is distorted and it does not return to its original shape.

6.a)

Students create a data table in their log. See table below:

Mass	Weight	Stretch	



4. Does the paper spring return to its original size and shape as the force of the stretch increases? Try it.

a) Record your observations.

5. A metal spring has properties like those of the paper spring. The metal spring is usually better able to restore itself to its original shape than the paper spring. However, the metal spring can also be stretched past its load limit so you should be careful not to do this.

6. The stretch of a metal spring can be measured precisely. You can use a set of masses to determine the properties of springs. Secure the spring vertically as indicated in the diagram. Attach a metric ruler to the ring stand or support holding the spring. Use a file card to note the bottom-most position of the spring. Set this measurement as the zero measurement for the stretch of the spring. You are now ready to measure the stretch of the spring with a given set of masses.

You may have to convert from grams to kilograms to newtons. If a 100-g mass is used, this is equivalent to 0.1 kg. The mass of 0.1 kg has a weight of 0.98 N. This can be written as a single equation:

$$F_w = mg$$

$$= (100 \text{ g})\left(\frac{1 \text{ kg}}{1000 \text{ g}}\right)\left(9.8 \frac{\text{N}}{\text{kg}}\right)$$

$$= 0.98 \text{ N}$$

Notice that you converted grams to kilograms by multiplying by 1 kg/1000 g. In math class, you learned that you could always multiply a number by 1 and not change its value. For instance, 27 × 1 = 27. Since 1 kg is equal to 1000 g, the fraction 1 kg/1000 g has an equivalent numerator and denominator and the fraction equals 1. When you use this fraction in the equation, the 100 g-mass gets converted to 0.1 kg. The gram units "cancel" and you are left with kilogram units. This unit conversion was done because you want the mass in kilograms.

a) In your *Active Physics* log, create a data table with four columns. Label the first three columns mass, weight (of the mass hung on the spring), and stretch of spring. The fourth column will be left blank for the time being.

7. Measure the stretch of the spring (from its "relaxed" or zero position length to its stretched length) for different masses.

Be careful when placing and removing masses so that the spring does not snap and hurt anyone. Have one person hold the bottom and top of the spring as another person adds or removes each mass.

a) Record your measurements in the data table.

b) Plot a graph with the stretch of the spring on the *x*-axis and the weight on the *y*-axis. (Keep in mind that this is a bit unconventional since the independent variable is usually placed on the *x*-axis.)

7.a)

Data will vary depending upon the springs used. Note that it is important that the amount of stretch be measured from the relaxed position of the spring.

7.b)

The graph should be a straight line.

7.c)

Students predict the stretch for a given weight. They should predict the stretch for a weight that they can test in the following step.

8.a)

Students should have been able to predict the stretch with considerable accuracy.

9.a)

Students describe the difference in the springs. If you are using different springs for different groups, each group of students can exchange the springs.

9.b)

Students' graphs should differ in the stretch values recorded. The students will probably use the same value for the weights attached to the springs. The result of graphing force versus distance will again be a straight line. The slope of the line will be different from the previous graph.

9.c)

The slope of the line is a measure of the difficulty in stretching the spring. The greater the slope, the "stiffer" the spring, and the less it will stretch for a given force.

c) From your graph, predict what the stretch would be for a weight that you have not tried, but between the weights that you have measured. This type of prediction from a graph is called *interpolation.*

8. Test your prediction by measuring the stretch of the spring for that weight.

a) How accurate was your prediction?

9. Repeat the investigation for a second spring that looks different from the first. The spring may have larger or smaller coils, or the coils may be closer together or further apart. You should have a new data table, a new graph, and a new interpolation.

a) Describe how the springs differ in physical appearance.

b) Describe how the springs differ in terms of the data tables and corresponding graphs.

c) Draw the best-fit line for your two graphs. How is the slope of the line related to the force necessary to stretch the spring?

10. Suppose you have another spring whose spring constant is different from the two springs you investigated.

a) Draw a graph for this "invented" third spring. Plot spring force versus amount of stretch on your graph.

b) Write a description of a spring that would have such data. The description should include the ease or difficulty of stretching the spring.

11. Return to the first data table you made in *Step 6.a*). Divide the weight of the mass hung on the spring by the stretched distance for each measurement.

a) Record the values in the fourth column.

b) What do you notice about these calculated values?

c) Repeat the calculations for the second data table.

d) What value might your invented spring have for this column?

e) How do the values in the fourth column relate to the slope of the graph?

f) The slopes of these graphs are the spring constant (*k*) for each spring. Explain why it is called a spring constant.

Part C: The Spring as a Weighing Machine

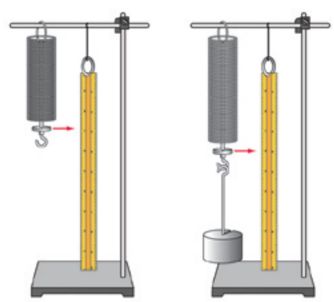
1. The spring stretches a different amount for each hanging mass or weight. Create a scale for weighing objects using one of the two springs that you have previously used. A scale has a spring and an arrow (a pointer) that points to the number representing the weight of the hanging object.

2. Choose three known masses.

a) Measure their weight on your scale. Record your values.

3. Choose two objects of unknown weight.

a) Measure their weight on your scale. Describe each object and record its weight.



10.a)

The graph should be a straight line with a third slope.

10.b)

Students' description should include whether the spring was harder to stretch than the previous springs, based on the slope of the graph they have drawn.

11.a)

Students complete the fourth column in their data table.

11.b)

The weight of the suspended object divided by the stretch distance should give the same value for each pair of data points for the spring.

11.c)

The weight of the suspended object divided by the stretch distance should give the same value for each pair of data points for the spring, but this value will be different than that of the previous spring.

11.d)

The value for the "invented spring" will depend upon the slope of the line drawn for the spring. If the slope is greater than the previous springs the value should be higher, and vice versa.

11.e)

The values in the fourth column are essentially the same as the slope of the graph if the spring has not reached its elastic limit.

11.f)

The spring constant is called this because it is a constant that relates the stretch of the spring to the weight added.

Part C: The Spring as a Weighing Machine

1.

Students should attach a pointer to the spring. If a meter stick setup is used similar to the one shown in *Step 3*, the meter stick should be covered with a piece of paper with values of weights rather than distances. The values of weights should correspond to the values for that stretch of the spring.

2.a)

Students' values will vary, depending on the known masses chosen.

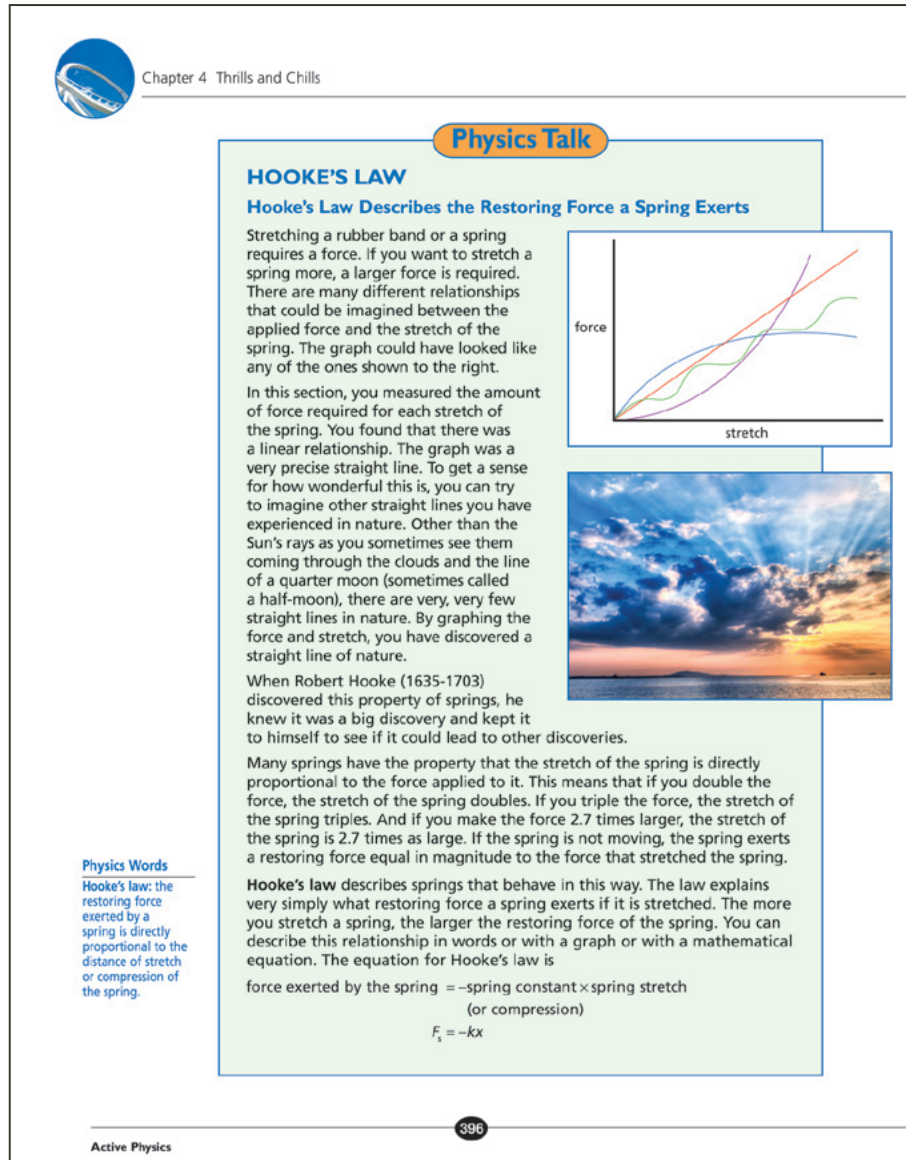
3.a)

Answers will vary. Encourage students to estimate the weight before taking their measurements.

Physics Talk

The *Physics Talk* describes the experiments done in the *Investigate* to discover the property of springs. Students are introduced to Hooke's law that is expressed both in words and as a mathematical equation. The sample problems show how the spring constant is calculated from the Hooke's law equation and also from a graph of force versus stretch of the spring. Students read about the difference between mass and weight and how bathroom scales measure weight. They are shown how the force exerted by the spring in a bathroom scale is equal to the force of gravity that acts downward on a person who steps on the scale.

While discussing the linear relationship between the force applied and the stretch of a spring, ask them to explain Hooke's law. Determine if students understand how a restoring force of a spring is related to the applied force. Point out that the spring constant for different springs is different and determines the stiffness of a spring. Discuss the equation of Hooke's law and ask students about the absolute value of the force exerted by a spring, and why there is a negative sign in the equation. Consider writing the sample problems on the board to detail the strategy used to solve each problem. Discuss how the spring constant can be calculated from a graph of force versus stretch of a spring.


Chapter 4 Thrills and Chills

Physics Talk

HOOKE'S LAW

Hooke's Law Describes the Restoring Force a Spring Exerts

Stretching a rubber band or a spring requires a force. If you want to stretch a spring more, a larger force is required. There are many different relationships that could be imagined between the applied force and the stretch of the spring. The graph could have looked like any of the ones shown to the right.

In this section, you measured the amount of force required for each stretch of the spring. You found that there was a linear relationship. The graph was a very precise straight line. To get a sense for how wonderful this is, you can try to imagine other straight lines you have experienced in nature. Other than the Sun's rays as you sometimes see them coming through the clouds and the line of a quarter moon (sometimes called a half-moon), there are very, very few straight lines in nature. By graphing the force and stretch, you have discovered a straight line of nature.

When Robert Hooke (1635-1703) discovered this property of springs, he knew it was a big discovery and kept it to himself to see if it could lead to other discoveries.

Many springs have the property that the stretch of the spring is directly proportional to the force applied to it. This means that if you double the force, the stretch of the spring doubles. If you triple the force, the stretch of the spring triples. And if you make the force 2.7 times larger, the stretch of the spring is 2.7 times as large. If the spring is not moving, the spring exerts a restoring force equal in magnitude to the force that stretched the spring.

Hooke's law describes springs that behave in this way. The law explains very simply what restoring force a spring exerts if it is stretched. The more you stretch a spring, the larger the restoring force of the spring. You can describe this relationship in words or with a graph or with a mathematical equation. The equation for Hooke's law is

force exerted by the spring = −spring constant × spring stretch (or compression)

$$F_s = -kx$$

Physics Words
Hooke's law: the restoring force exerted by a spring is directly proportional to the distance of stretch or compression of the spring.

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Active Physics

To understand how bathroom scales read weight, the difference between mass and weight should be emphasized during a discussion of this *Physics Talk*. Ask students to write the definitions of mass and weight in their *Active Physics* logs. Students should be able to connect Newton's second law to the net force and know that this force is zero when the spring in the scale stops moving.

Section 5 Hooke's Law: Finding Your "At Rest" Weight

where F_s is the force exerted by the spring,
x is the stretch (or compression) of the spring, and
k is the spring constant.

The negative sign in the equation indicates that the pull by the spring is opposite to the direction it is stretched or compressed. Stretch a spring down and it pulls up. Stretch a spring to the right and it pulls to the left. Compress a spring to the left and it pushes to the right.

The spring constant (k) is an indication of how easy or difficult it is to stretch or compress a spring. You can determine the value of the spring constant (k) by measuring the force exerted by the spring and the stretch of the spring. This is what you did in the *Investigate*. You varied the force by using different weights and measured the stretch. The measure of the stiffness of the spring is represented by k. A stiff spring will have a large value for k; a "soft" spring will have a small value for k. The spring constant, k, depends on the material from which the spring is made and the shape and size of the coils.

Sample Problem I

A 3.0-N weight is suspended from a spring. The spring stretches 2.0 cm (0.020 m). Calculate the spring constant.

Strategy: If a 3.0-N weight is suspended at rest from the spring, the spring must be applying a force of 3.0 N. If the spring were applying a force of less than 3.0 N, the weight would accelerate down. If the spring were applying a force of more than 3.0 N, the weight would accelerate up. When the force of gravity on the mass is 3.0 N down and the spring exerts a force of 3.0 N up, then the mass has no net force on it and it remains at rest once the friction brings it to rest. In the *Investigate*, you always took your measurements when the mass had stopped moving.

Given:

$F = 3.0$ N

$x = 0.020$ m

Solution:

The magnitude of the force is

$$F_s = kx$$

Solving for k

$$k = \frac{F_s}{x} = \frac{3.0\text{ N}}{0.02\text{ m}} = 150\text{ N/m}$$

Note that the stretch of the spring, x, was converted from centimeters to meters. The result tells you that it would take a force of 150 N to stretch the spring 1 m. You also ignored the negative sign in calculating the magnitude (size) of the force. From here on, the negative sign in the equation will be omitted. In mathematics, you would say that you are calculating the absolute value of F using the absolute value of the stretch, x. You must always keep in mind that the direction of the force is opposite to the direction of the stretch.

4-5a Blackline Master

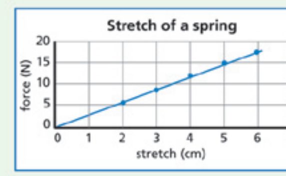
With a set of data points for the weight and the stretch, you would find that all values of k are the same or constant (at least approximately) for a given spring. The spring constant is k. As you determined in the *Investigate*, you can also record the data on a graph. The graph can also be used to determine the spring constant (k).

$F_s = kx$
$y = \text{slope} \times x$

If the data are graphed so that the force is on the y-axis and the stretch is on the x-axis, then the spring constant will be the slope of the graph. You can see this if you compare the equations for Hooke's law and the equation for a straight line (when the y-intercept is zero).

Sample Problem 2

Weights are hung from a spring and the stretch is measured. The data collected is shown in the graph to the right. Calculate the spring constant from the graph.

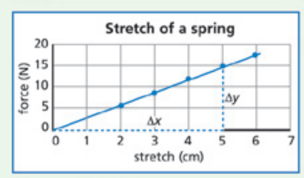


Strategy: Since the force is on the y-axis and the stretch is on the x-axis, you can compare the equations for a straight line and Hooke's law.

Hooke's law: $F_s = kx$ Straight line: $y = \text{slope} \times x$

The slope of the graph will be equal to the spring constant, k.

Given:



Solution:

$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{\Delta y}{\Delta x}$

$= \frac{15 \text{ N}}{5.0 \text{ cm}}$

$= 3 \text{ N/cm}$

Mass and Weight

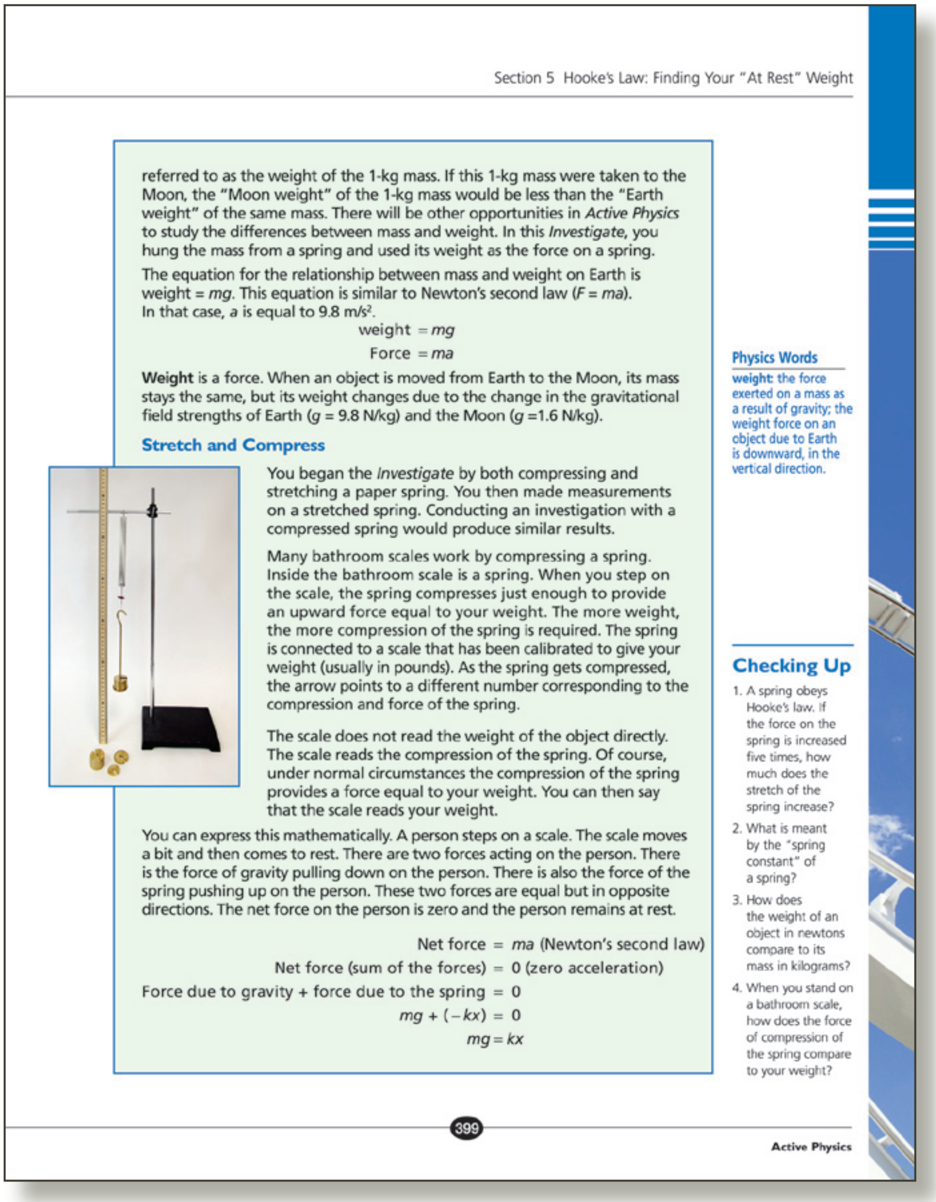
In this section, you used specific masses as weights. A 1-kg mass on Earth has a weight of 9.8 N.

$$\text{weight} = mg$$

where m is mass in kilograms and
g is the gravitational field strength of the Earth (9.8 N/kg = 9.8 m/s²).

$$\text{weight} = (1 \text{ kg})(9.8 \text{ N/kg})$$
$$= 9.8 \text{ N}$$

A 1-kg mass has a specific amount of matter and a specific volume. Of these three properties, only the mass is related to the weight. When the 1-kg mass is on Earth, there is a force attracting the 1-kg mass to Earth. This force is also



referred to as the weight of the 1-kg mass. If this 1-kg mass were taken to the Moon, the "Moon weight" of the 1-kg mass would be less than the "Earth weight" of the same mass. There will be other opportunities in *Active Physics* to study the differences between mass and weight. In this *Investigate*, you hung the mass from a spring and used its weight as the force on a spring.

The equation for the relationship between mass and weight on Earth is weight = mg. This equation is similar to Newton's second law ($F = ma$). In that case, a is equal to 9.8 m/s².

$$\text{weight} = mg$$
$$\text{Force} = ma$$

Weight is a force. When an object is moved from Earth to the Moon, its mass stays the same, but its weight changes due to the change in the gravitational field strengths of Earth (g = 9.8 N/kg) and the Moon (g = 1.6 N/kg).

Physics Words

weight: the force exerted on a mass as a result of gravity; the weight force on an object due to Earth is downward, in the vertical direction.

Stretch and Compress

You began the *Investigate* by both compressing and stretching a paper spring. You then made measurements on a stretched spring. Conducting an investigation with a compressed spring would produce similar results.

Many bathroom scales work by compressing a spring. Inside the bathroom scale is a spring. When you step on the scale, the spring compresses just enough to provide an upward force equal to your weight. The more weight, the more compression of the spring is required. The spring is connected to a scale that has been calibrated to give your weight (usually in pounds). As the spring gets compressed, the arrow points to a different number corresponding to the compression and force of the spring.

The scale does not read the weight of the object directly. The scale reads the compression of the spring. Of course, under normal circumstances the compression of the spring provides a force equal to your weight. You can then say that the scale reads your weight.

You can express this mathematically. A person steps on a scale. The scale moves a bit and then comes to rest. There are two forces acting on the person. There is the force of gravity pulling down on the person. There is also the force of the spring pushing up on the person. These two forces are equal but in opposite directions. The net force on the person is zero and the person remains at rest.

$$\text{Net force} = ma \text{ (Newton's second law)}$$
$$\text{Net force (sum of the forces)} = 0 \text{ (zero acceleration)}$$
$$\text{Force due to gravity + force due to the spring} = 0$$
$$mg + (-kx) = 0$$
$$mg = kx$$

Checking Up

1. A spring obeys Hooke's law. If the force on the spring is increased five times, how much does the stretch of the spring increase?
2. What is meant by the "spring constant" of a spring?
3. How does the weight of an object in newtons compare to its mass in kilograms?
4. When you stand on a bathroom scale, how does the force of compression of the spring compare to your weight?

Checking Up

1.

The stretch of the spring increases by five times when the force on the spring is increased five times, so long as the elastic limit of the spring is not exceeded.

2.

The spring constant indicates how easy or difficult it is to stretch or compress a spring. The value of the spring constant is determined by measuring the force exerted by the spring and the stretch of the spring.

3.

The weight of a 1-kg mass in kilograms is 9.8 N on Earth. The weight of a 1-kg mass is equal to the mass multiplied by the acceleration of gravity at that location.

4.

The force of compression of the spring on a bathroom scale is equal to the weight of a person standing on the scale.

Active Physics Plus

Students plot the stretch of the spring on the vertical axis and the weight of the suspended object on the horizontal axis of a graph. Some people prefer to plot the data this way because they view the weight of the suspended object as the independent variable (the "cause") and like to put independent variables on the x (horizontal) axis. In this case, the slope of the straight line is equal to $1/k$, the reciprocal of the spring constant. A stiffer spring will be represented by a line with a smaller slope.

The experimental design for testing a rubber band will be the same as for determining Hooke's law for a spring. Generally, a rubber band is not as linear as a spring, but the stretch does increase with the force.

What Do You Think Now?

The *What Do You Think Now?* section focus students' attention on what they have learned so far in the section. Encourage them to apply what they have learned to review and update their answers. Have them return to the *What Do You See?* section and discuss how their original impressions of the illustration may have been altered. Students should reassess their understanding of physics concepts and share their answers with their classmates in small groups. Sharing *A Physicist's Response* with students will provide students with a comprehensive answer to the *What Do You Think?* questions. Point out that their revision should incorporate the key information they now have on bathroom scales.

Active Physics Plus

+Math	+Depth	+Concepts	+Exploration
••	•	•	••

Graphing Force on the X-axis

If a graph for a stretched spring is constructed so that the force is on the x-axis and the stretch is on the y-axis, then the slope will be the reciprocal of the spring constant or $1/k$. You can see this by comparing the equations for Hooke's law and for a straight line.

In the following equation, capital X and Y are used to label the axes to avoid confusion with x, for stretch. The equation for a straight line passing through the origin is

$$Y = \text{slope} \times X$$

Hooke's law for the magnitude of the force (omit the minus sign) is

$$F_s = kx$$

$$x = \left(\frac{1}{k}\right)F_s$$

Since the force is on the X-axis and the stretch x is on the Y-axis, the slope of the straight-line graph is $1/k$.

$$x = \frac{1}{k}F_s$$

$$Y = \text{slope} \times X$$

Graph the data in *Physics to Go, Question 7* by putting the amount of stretch (x) on the y-axis and the force on the x-axis. From the slope of the graph, find the spring constant, k.

Hooke's Law and the Stretch of a Rubber Band

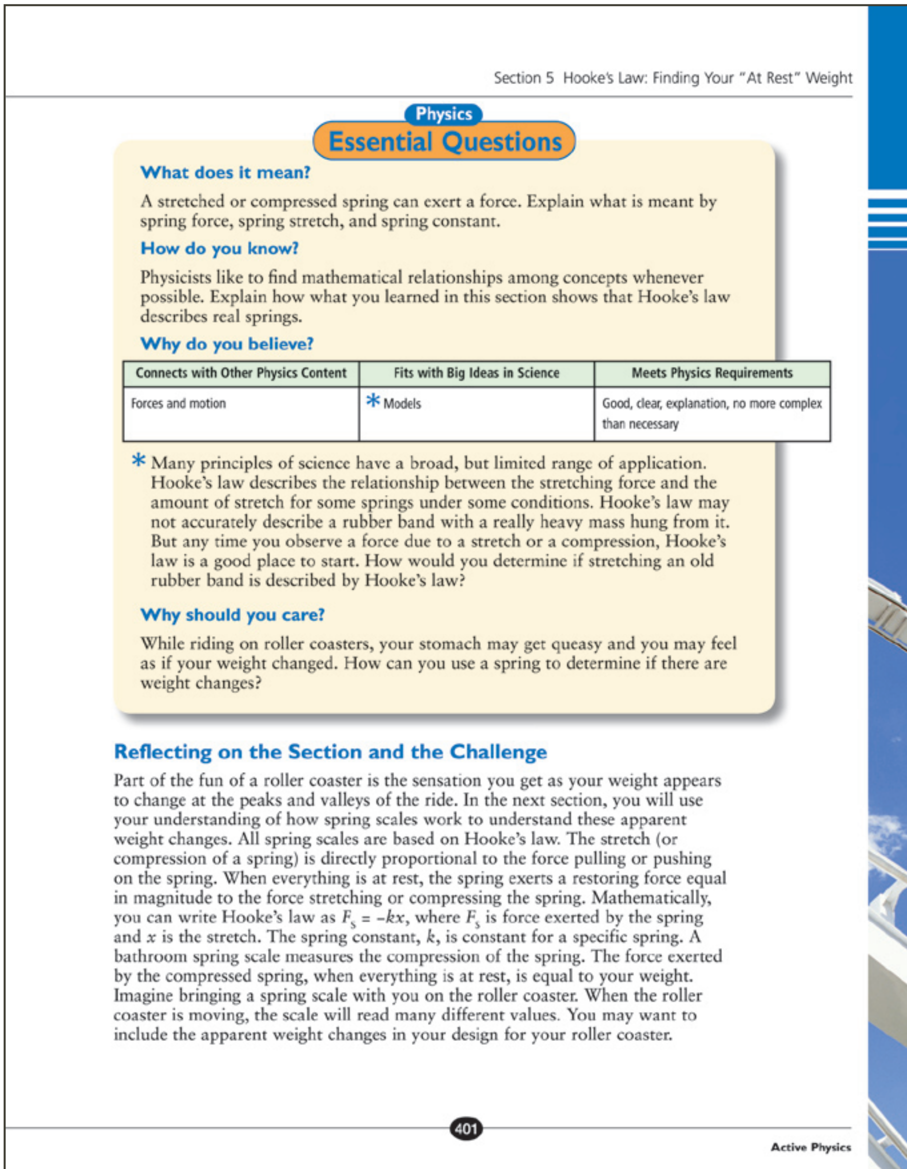
Design an experiment to see if the amount of stretch of a rubber band is described by Hooke's law. With your teacher's permission, carry out the experiment.

What Do You Think Now?

At the beginning of this section, you were asked the following:

- **Can you use the same scale to weigh a canary and an elephant?**
- **How does a bathroom scale work?**

Now that you have completed this section, how would you answer these questions? Include the concepts of weight and Hooke's law and springs in your answer.


Section 5 Hooke's Law: Finding Your "At Rest" Weight

Physics **Essential Questions**

What does it mean?

A stretched or compressed spring can exert a force. Explain what is meant by spring force, spring stretch, and spring constant.

How do you know?

Physicists like to find mathematical relationships among concepts whenever possible. Explain how what you learned in this section shows that Hooke's law describes real springs.

Why do you believe?

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

* Many principles of science have a broad, but limited range of application. Hooke's law describes the relationship between the stretching force and the amount of stretch for some springs under some conditions. Hooke's law may not accurately describe a rubber band with a really heavy mass hung from it. But any time you observe a force due to a stretch or a compression, Hooke's law is a good place to start. How would you determine if stretching an old rubber band is described by Hooke's law?

Why should you care?

While riding on roller coasters, your stomach may get queasy and you may feel as if your weight changed. How can you use a spring to determine if there are weight changes?

Reflecting on the Section and the Challenge

Part of the fun of a roller coaster is the sensation you get as your weight appears to change at the peaks and valleys of the ride. In the next section, you will use your understanding of how spring scales work to understand these apparent weight changes. All spring scales are based on Hooke's law. The stretch (or compression of a spring) is directly proportional to the force pulling or pushing on the spring. When everything is at rest, the spring exerts a restoring force equal in magnitude to the force stretching or compressing the spring. Mathematically, you can write Hooke's law as $F_s = -kx$, where F_s is force exerted by the spring and x is the stretch. The spring constant, k, is constant for a specific spring. A bathroom spring scale measures the compression of the spring. The force exerted by the compressed spring, when everything is at rest, is equal to your weight. Imagine bringing a spring scale with you on the roller coaster. When the roller coaster is moving, the scale will read many different values. You may want to include the apparent weight changes in your design for your roller coaster.

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Reflecting on the Section and the Challenge

Students now get a chance to reflect on what they have learned in this section and ponder how their knowledge can be applied to the *Chapter Challenge*. Consider asking students why they experience different sensations on a roller-coaster ride, how does the weight change during the ride, and how is Newton's second law related to Hooke's law. You might want to have a student read this section aloud so that you can highlight important aspects of this section and its broader relation to the *Goal* for this chapter. Encourage them to record their reflections in their *Active Physics* logs.

Physics Essential Questions

What does it mean?

As you pull on a spring, the spring pulls back. When you compress a spring, the spring pushes back. The force of the spring varies as the stretch (or compression). The spring constant tells you how difficult it is to stretch a spring and the spring's force for a given stretch.

How do you know?

Hooke's law states that $F = -kx$. When the force of the spring was measured for each stretch, it was found that the ratio of the force to the stretch was a constant for a given spring.

Why do you believe?

You can design an experiment that measures the force of the rubber band and its stretch. If the plot of your data of force versus distance is a straight line, you know that the rubber band is obeying Hooke's law.

Why should you care?

If you carry a spring scale on the roller coaster, you will be able to observe changes in the scale reading during these motions.

Physics to Go

1.a)

Given:
$m = 100$ kg

$F_w = mg = (100\ \text{kg})(9.8\ \text{N/kg}) = 980\ \text{N} \approx 1000\ \text{N}$

1.b)

Given:
$m = 10$ kg

$F_w = mg = (10\ \text{kg})(9.8\ \text{N/kg}) = 980\ \text{N} \approx 100\ \text{N}$

1.c)

Given:
$m = 60$ kg

$F_w = mg = (60\ \text{kg})(9.8\ \text{N/kg}) = 590\ \text{N} \approx 600\ \text{N}$

2.a)

Given:
$\frac{1}{4}$ lb = 1 N

130 lb = 520 quarter-pounds = 520 N

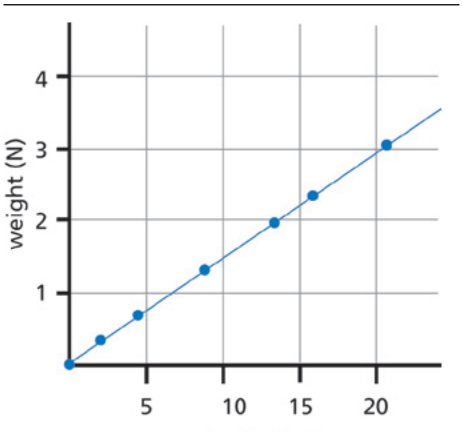
2.b)

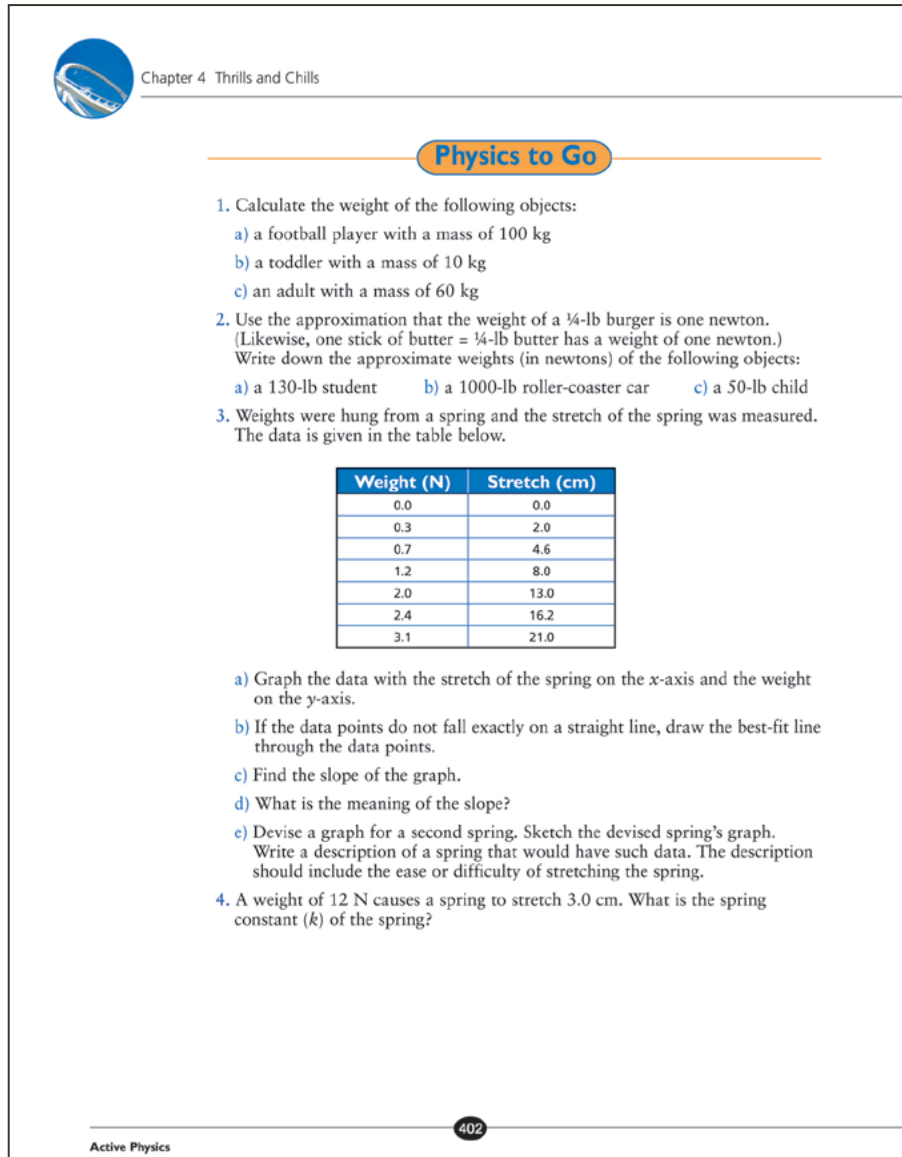
1000 lb = 4000 N

2.c)

50 lb = 200 N

3.





Chapter 4 Thrills and Chills

Physics to Go

1. Calculate the weight of the following objects:
   a) a football player with a mass of 100 kg
   b) a toddler with a mass of 10 kg
   c) an adult with a mass of 60 kg
2. Use the approximation that the weight of a ¼-lb burger is one newton. (Likewise, one stick of butter = ¼-lb butter has a weight of one newton.) Write down the approximate weights (in newtons) of the following objects:
   a) a 130-lb student b) a 1000-lb roller-coaster car c) a 50-lb child
3. Weights were hung from a spring and the stretch of the spring was measured. The data is given in the table below.

Weight (N)	Stretch (cm)
0.0	0.0
0.3	2.0
0.7	4.6
1.2	8.0
2.0	13.0
2.4	16.2
3.1	21.0

   a) Graph the data with the stretch of the spring on the *x*-axis and the weight on the *y*-axis.
   b) If the data points do not fall exactly on a straight line, draw the best-fit line through the data points.
   c) Find the slope of the graph.
   d) What is the meaning of the slope?
   e) Devise a graph for a second spring. Sketch the devised spring's graph. Write a description of a spring that would have such data. The description should include the ease or difficulty of stretching the spring.
4. A weight of 12 N causes a spring to stretch 3.0 cm. What is the spring constant (k) of the spring?

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Active Physics

3.a)

Students' graph should have the weight on the vertical axis and the stretch on the horizontal axis. The points should be graphed and should fall on a straight line rising to the right.

3.b)

The students should draw a "best fit" line that is close to as many points as possible.

3.c)

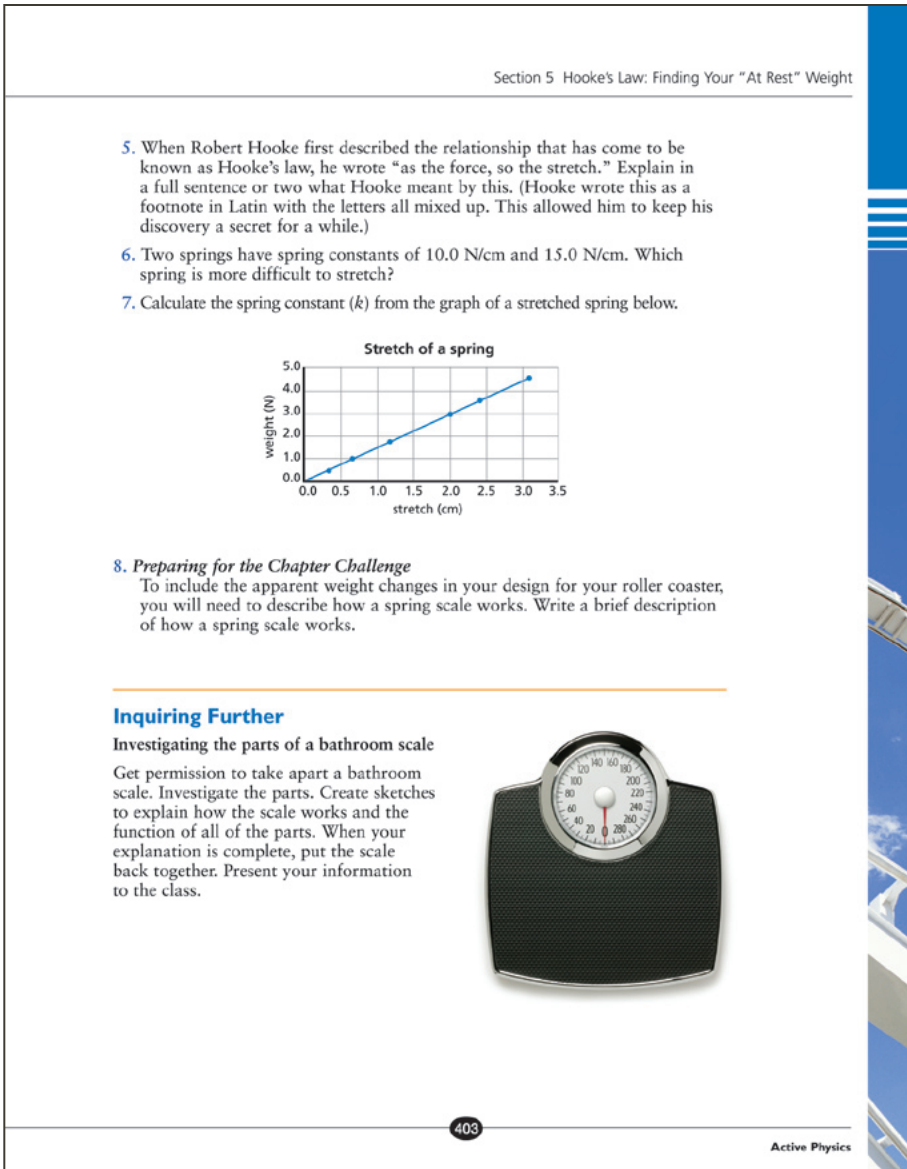
slope = rise/run = 3.1 N/21.0 cm = 3.1 N/0.210 m = 1.47 N/m

3.d)

The slope gives us the spring constant, a measure of the stiffness of the spring.

3.e)

Students' answers will vary. Graphs that double or triple the values in the data table would be


Section 5 Hooke's Law: Finding Your "At Rest" Weight

5. When Robert Hooke first described the relationship that has come to be known as Hooke's law, he wrote "as the force, so the stretch." Explain in a full sentence or two what Hooke meant by this. (Hooke wrote this as a footnote in Latin with the letters all mixed up. This allowed him to keep his discovery a secret for a while.)

6. Two springs have spring constants of 10.0 N/cm and 15.0 N/cm. Which spring is more difficult to stretch?

7. Calculate the spring constant (k) from the graph of a stretched spring below.

8. *Preparing for the Chapter Challenge*
To include the apparent weight changes in your design for your roller coaster, you will need to describe how a spring scale works. Write a brief description of how a spring scale works.

Inquiring Further

Investigating the parts of a bathroom scale

Get permission to take apart a bathroom scale. Investigate the parts. Create sketches to explain how the scale works and the function of all of the parts. When your explanation is complete, put the scale back together. Present your information to the class.

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acceptable. If the spring drawn has a steeper slope, it will be harder to stretch.

4.

Given:
$F = 12$ N; $x = 3$ cm

$F = kx$
$k = F/x = 12$ N$/3.0$ cm $=$ 4.0 N/cm $= 400$ N/m

5.

As the weight pulling on the spring increases, the stretch of the spring increases in proportion. (Double the weight, you double the stretch.)

6.

The 15.0-N/cm spring requires 15 N to stretch it one centimeter, while the 10.0 N/cm requires only 10 N to stretch it one centimeter.

7.

The spring constant will be the change in F (rise) divided by the change in stretch (run).

$k = F/x = 3.0$ N$/2.0$ cm $=$ 1.5 N/cm $= 150$ N/m

8.

Preparing for the Chapter Challenge

A bathroom scale has a spring attached to the top and bottom. When you stand on the scale, the spring is compressed. The compression is proportional to your weight. The weight corresponding to the compression is displayed as the number on the scale.

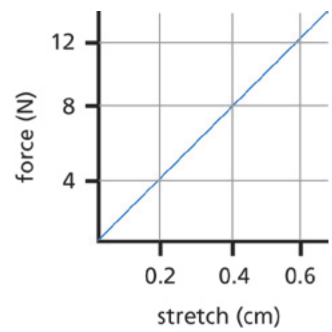
Inquiring Further

For this *Inquiring Further*, it is assumed that the students will be disassembling a spring-based bathroom scale rather than a digital scale. The spring-based scale relies upon a spring that undergoes compression with a pointer attached to the spring. The scale will often have a calibration dial that allows the user to set the zero mark when there is no weight on the platform. The digital scale relies upon a strain gauge, where the electrical resistance of the sensitive element varies with the applied force. This value is then converted to a reading on the display. For the spring-based scale, the students will list parts such as the case, the spring, the dial, the mounting mechanism, etc.

SECTION 5 QUIZ

4-5b **Blackline Master**

1. The graph below shows the relationship between the force applied to a spring and the spring's stretch. What is the spring constant of the spring?



a) 20 N/m
b) 9.8 N/m
c) 0.60 N/m
d) 0.50 N/m

2. An unstretched spring with a spring constant of 100 N/m stretches a distance of 0.40 m when a mass is attached to the spring. The size of the mass must be of

a) 9.8 kg.
b) 0.004 kg.
c) 25 kg.
d) 4.0 kg.

3. A 5.0-kg stone is dropped from a bridge 40-m high. What is the weight of the stone?

a) 8 N
b) 50 N
c) 200 N
d) 0.20 N

4. The ratio of an object's weight to its mass is equal to the

a) object's inertia.
b) acceleration due to gravity.
c) object's kinetic energy.
d) object's gravitational potential energy.

5. A 2.0-kg mass attached to a spring scale is being lifted upward with constant velocity. The reading on the spring scale must be

a) equal to 20 N.
b) greater than 20 N.
c) equal to 2.0 N.
d) greater than 2.0 N.

SECTION 5 QUIZ ANSWERS

1. a) The spring constant may either be found from the slope of the graph, or by using the equation $F_s = kx$. Choosing values from the graph of $F_s = 12$ N and a stretch of 0.60 m and solving for k gives $k = F_s/x = 12\ \text{N}/0.60\ \text{m} = 20\ \text{N/m}$.

2. d) Using the equation $F_s = kx$, and solving for the force gives $F_s = (100\ \text{N/m})(0.40\ \text{m}) = 40\ \text{N}$ for the force. This force is the weight of the mass. To find the mass use the equation $F_w = mg$. Solving the equation for the mass gives $m = F_w/g$ or $m = (40\ \text{N})/(10\ \text{m/s}^2) = 4.0\ \text{kg}$.

3. b) The weight can be found from the mass using the equation $F_w = mg$. Solving for $F_w = (5\ \text{kg})(10\ \text{m/s}^2) = 50\ \text{N}$.

4. b) The ratio of an objects weight (mg) divided by its inertia (measured in terms of mass, m) yields $mg/m = g$, the acceleration due to gravity.

5. a) When an object is traveling with constant velocity, the net force on the object must be zero. The upward force supplied by the spring scale must exactly balance the downward force provided by the weight of the mass. To find the weight of the mass, use the equation $F_w = mg$. $F_w = 2.0\ \text{kg}(10\ \text{m/s}^2) = 20\ \text{N}$, so the spring scale must read 20 N. Students may think it has to read more than 20 N to keep moving upward, but once the object is traveling with constant upward speed only 20 N is needed to maintain the motion.