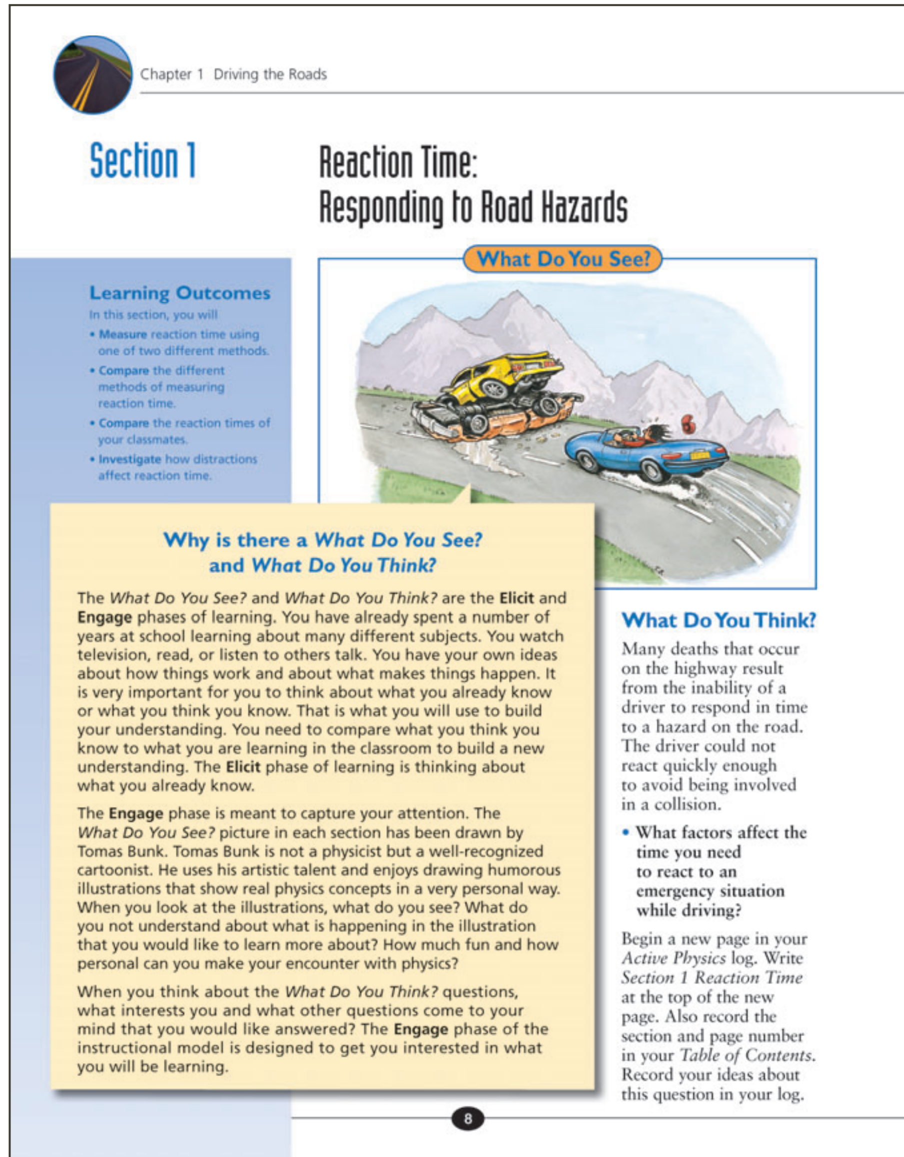
SECTION 1

Teaching Suggestions and Sample Answers

What Do You See?

Elicit responses from your students on the *What Do You See?* illustration. You might want to ask them about their initial impression of what they see in the illustration, why the artist has chosen to depict an accident, and why it is significant in the context of this section. You are likely to get many different responses. Accept all answers but try to focus on those that provide an opportunity for you to get the students engaged in the physics concepts they are about to learn.



Chapter 1 Driving the Roads

Section 1 Reaction Time: Responding to Road Hazards

What Do You See?

Learning Outcomes

In this section, you will

- **Measure** reaction time using one of two different methods.
- **Compare** the different methods of measuring reaction time.
- **Compare** the reaction times of your classmates.
- **Investigate** how distractions affect reaction time.

Why is there a *What Do You See?* and *What Do You Think?*

The *What Do You See?* and *What Do You Think?* are the **Elicit** and **Engage** phases of learning. You have already spent a number of years at school learning about many different subjects. You watch television, read, or listen to others talk. You have your own ideas about how things work and about what makes things happen. It is very important for you to think about what you already know or what you think you know. That is what you will use to build your understanding. You need to compare what you think you know to what you are learning in the classroom to build a new understanding. The **Elicit** phase of learning is thinking about what you already know.

The **Engage** phase is meant to capture your attention. The *What Do You See?* picture in each section has been drawn by Tomas Bunk. Tomas Bunk is not a physicist but a well-recognized cartoonist. He uses his artistic talent and enjoys drawing humorous illustrations that show real physics concepts in a very personal way. When you look at the illustrations, what do you see? What do you not understand about what is happening in the illustration that you would like to learn more about? How much fun and how personal can you make your encounter with physics?

When you think about the *What Do You Think?* questions, what interests you and what other questions come to your mind that you would like answered? The **Engage** phase of the instructional model is designed to get you interested in what you will be learning.

What Do You Think?

Many deaths that occur on the highway result from the inability of a driver to respond in time to a hazard on the road. The driver could not react quickly enough to avoid being involved in a collision.

- What factors affect the time you need to react to an emergency situation while driving?

Begin a new page in your *Active Physics* log. Write *Section 1 Reaction Time* at the top of the new page. Also record the section and page number in your *Table of Contents*. Record your ideas about this question in your log.

8

Students' Prior Conceptions

In this section, students will gain proficiency in applying the analytical skills needed to measure and record data precisely; to gather information necessary to describe objects and events; to characterize relationships among variables; and to argue logically. Mathematics, the precise language of science, is used to study the patterns of motion in the physical world.

1. **Measurement is only linear.** Through observations and careful data collection. students find that measurement is not only linear; this becomes more evident as students work with driving along curves, changing directions, and examine projectiles and other objects traveling through air or space. Time is a quantity that always has a positive or linear measurement. As such, it often becomes the independent variable in motion graphs and is the horizontal or *x*-axis variable.

2. **Any quantity can be measured as accurately as you want.** Students discover any quantity can be measured as accurately as the tools available and that they can only measure to the smallest unit shown on the measuring device. They discover that there is a difference between "precision" and the "accuracy" of measurement.

What Do You Think?

The *What Do You Think?* question is designed to give you a sense of how much your students know about a driver's reaction time when responding to an emergency. It is designed to elicit a discussion on the alertness of a driver while trying to avoid a hazard on the road. You might want to prompt students on the effect of listening to loud music on reaction time, as well as talking while driving, or the effect of fatigue, alcohol, or drugs.

What Do You Think?

A Physicist's Response

The identification of sensory information has the greatest impact on reaction time. The driver's experience may also play an important part in determining reaction time. Experienced drivers are more likely to recognize and prepare for potential dangers before they become emergencies. The amount of time it takes to respond to an emergency depends on the alertness of the driver. An expert driver will recognize and respond to an emergency far more quickly than an inexperienced driver.

The reaction time will also determine the distance it takes to stop an automobile. If an automobile is traveling at a high speed, the time it would take to respond to an emergency would be far more than an automobile traveling slowly because distance is directly proportional to the square of the speed. Reaction time also depends on the distractions at the time of an emergency.

3. **The only "natural" motion is for an object to be at rest.** Recognizing that Earth and all objects on Earth are in motion relative to each other, and that objects only seem at rest relative to each other due to this shared relative motion, is fundamental to students' understanding of what is considered to be a "natural motion"—an object at rest. Motion among these 'objects at rest' must be described relative to an origin or starting point described within the framework of the relative motion of Earth. This "relative motion" is what students perceive as motion. Help students recognize and apply appropriate reference frames for describing the motions observed in everyday life. Establishing origins and the motions of objects relative to these origins enables the students to delve into the physics involved in driving along the roads.
4. **Speed and velocity are the same concept.** It is important for you to lay the groundwork for student understanding of vectors as students measure motions within the "moving" framework. Moving away from the origin is assigned one direction indicated by a positive value, whereas starting away from the origin and moving toward it is assigned a different direction, as indicated by a negative sign.
5. **Objects fall at a constant speed.** Only through careful measurements, made at many different distances in the fall of an object, can students see that the speed of objects increases in a regular manner with the time of fall.
6. **The heavier the object, the faster it falls.** This prior conception persists until students drop various objects that have similar shapes and volumes but different masses from the same height and compare their speeds at the same points along the falling trajectory.

NOTES

Why is there an *Investigate*?

The *Investigate* is the **Explore** phase of the 7E instructional model. Confucius, a Chinese philosopher, said, "I hear and I forget. I see and I remember. I do and I understand." The best way to learn is by doing. In *Active Physics*, whenever possible, you will explore a concept by doing an investigation.

One purpose of the investigation is to "level the playing field" and ensure that everybody has a common experience through which to discuss physics. For example, some students have been in a motor-vehicle accident, while others have not. It would not be sensible for everybody to experience an accident. However, it is possible to provide a classroom experience that everybody can discuss and not limit the discussion to only those students who have been in an accident.

The investigation also provides you with a real dialog with nature. In *Active Physics*, you will not be limited to having to believe what somebody wrote in a book. You will have an opportunity to observe, record data, isolate variables, design and plan experiments, create graphs, interpret results, develop hypotheses, and organize your findings. Sometimes, the entire class will participate in a demonstration.

All scientists value inquiry. The **Explore** phase is part of an inquiry approach to learning. In *Active Physics*, you are not physics students, you are student physicists.

Scientists often record their results in lab books. When you see this symbol, you should record the information required for the *Investigate* in your *Active Physics* log.

Investigate

In this *Investigate*, you will measure reaction time using one of two methods. You will then compare the methods to decide which is the best method of measurement. You will also compare the reaction times of the members of your class, both with and without distractions.

1. To stop an automobile, you must first decide you want to stop. Then you must move your foot from the gas pedal to the brake pedal. The time required to decide to stop and move your foot to the brake is called your *reaction time*. Reaction time includes the time for you to react and the time for you to complete an action.

   Begin by finding how long it takes to move your right foot between imaginary gas and brake pedals.

   a) Estimate how long it takes to move your foot between the imaginary pedals. Record your estimate. (A way in which to estimate time is to count "one one-thousand, two one-thousand, three one-thousand.") Try counting like this until you reach "ten one-thousand" while your partner uses a stopwatch or clock to measure 10 s (seconds). Slow or quicken your counting pace so that it comes close to ten seconds when you finish counting "ten one-thousand." If the time to move your foot from one pedal to the other is less than one second, you can estimate how much time elapsed by how far you got in your counting of one one-thousand [for example, one (¼ s) one- (¼ s) thou- (¼ s) sand (¼ s)].

2. The first step in stopping an automobile occurs even before you move your foot to the brake pedal. It takes time to see or hear something that tells you to move your foot.

Investigate

1.a)

A reasonable estimate would be about half a second. Students usually grossly misjudge the amount of time it takes to move their foot from the gas to the brake pedal, because they are not pressing down on the gas pedal, and are not constrained by things such as the dashboard. Also, it takes approximately 0.12 s for the nerve impulse to travel from the brain to another part of the body.

CHAPTER 1

2.a)

Students typically react to the clap in about 0.25 s if they know it is going to occur, and about 0.5 s if they do not.

Method A: Starting and Stopping Stopwatches

You may choose to have all the groups do all three methods, or have each group only do one method and then repeat their results to the class. The students should then record the result of other groups in their logs.

1.a)

Reaction times will probably be between 0.5 s and 0.8 s.

1.b)

Students calculate average reaction times.

Method B: Catching a Ruler

1.a)

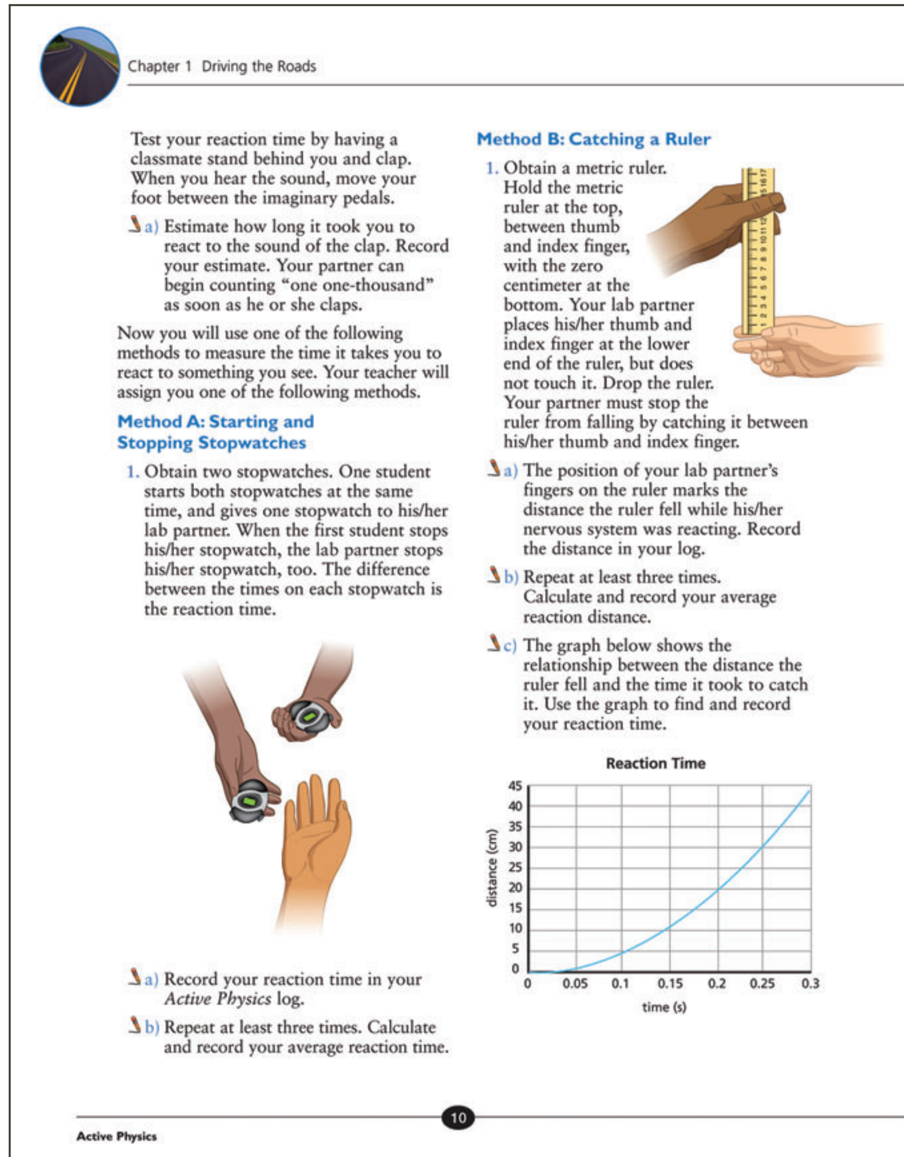
Expect the distances to vary. If students are anticipating the release by closing their fingers periodically, and their fingers are close enough together, results may be as low as 2 cm. Suggest to students that they average a number of trials to obtain a more reasonable result.

1.b)

Students calculate average reaction distances.

1.c)

The students should trace the grid in the graph where the distance intersects the time on the curved line and read down to the horizontal axis to find their reaction time.



Chapter 1 Driving the Roads

Test your reaction time by having a classmate stand behind you and clap. When you hear the sound, move your foot between the imaginary pedals.

a) Estimate how long it took you to react to the sound of the clap. Record your estimate. Your partner can begin counting "one one-thousand" as soon as he or she claps.

Now you will use one of the following methods to measure the time it takes you to react to something you see. Your teacher will assign you one of the following methods.

Method A: Starting and Stopping Stopwatches

1. Obtain two stopwatches. One student starts both stopwatches at the same time, and gives one stopwatch to his/her lab partner. When the first student stops his/her stopwatch, the lab partner stops his/her stopwatch, too. The difference between the times on each stopwatch is the reaction time.

a) Record your reaction time in your *Active Physics* log.

b) Repeat at least three times. Calculate and record your average reaction time.

Method B: Catching a Ruler

1. Obtain a metric ruler. Hold the metric ruler at the top, between thumb and index finger, with the zero centimeter at the bottom. Your lab partner places his/her thumb and index finger at the lower end of the ruler, but does not touch it. Drop the ruler. Your partner must stop the ruler from falling by catching it between his/her thumb and index finger.

a) The position of your lab partner's fingers on the ruler marks the distance the ruler fell while his/her nervous system was reacting. Record the distance in your log.

b) Repeat at least three times. Calculate and record your average reaction distance.

c) The graph below shows the relationship between the distance the ruler fell and the time it took to catch it. Use the graph to find and record your reaction time.

Active Physics 10

Teaching Tip

For *Method B* to be an accurate measure of reaction time, the student who is dropping the ruler should avoid giving visual cues. This can be accomplished by talking to another person, looking away from the student being tested, and then releasing the ruler unexpectedly. An excellent drop distance would be around 12 cm of fall.

Section 1 Reaction Time: Responding to Road Hazards

Comparing Methods of Measuring Reaction Time

1. Compare your group's average reaction-time measurements with the average reaction-time measurements of other groups using the other method.
   - a) Explain why they were not all the same.
   - b) Which method do you think most accurately measures reaction time? Explain why.
2. Compare your reaction-time measurements with those of your group and other groups that used the same method.
   - a) Record the results for the fastest, slowest, and average reaction times.
   - b) Do you think reaction times vary for people of the same age? Discuss this with your group and then record your answer.

Reaction Time with Distractions

1. Before your partner clapped or dropped the ruler, you already knew what you were supposed to do upon receiving that signal. Suppose you had to make a decision after the clap or the ruler drop. Repeat the ruler-catching experiment while being distracted by a decision you have to make.

   The student dropping the ruler now says either "red" at the moment the ruler is dropped, which means you should catch the ruler, or "green" which means you should let the ruler drop. You will have to calculate the average of five reaction times. If you catch the ruler when "green" is called, then you have to do all the trials over. (This is to ensure that you react to the color as well as the ruler dropping.)
   - a) How does your reaction time with needing to make a decision compare to your reaction time without needing to make a decision?
   - b) How could you apply the difference in reaction time when you need to make a decision to a situation while driving an automobile?

2. Suppose you are talking on a cell phone or changing a CD while driving. How do these distractions affect your reaction time? To find out, repeat the ruler drop with one hand (using the "red" and "green" cues), while at the same time you do one of the following:
   - pretend to change a CD with your other hand.
   - simulate dialing a phone number by entering the phone number on your calculator.
   - a) Compare your average reaction time with the distraction to your average reaction time without the distraction.
   - b) In your *Active Physics* log, make a list of 10 activities that could distract you from driving safely.

Comparing Methods of Measuring Reaction Time

1.a)

Reaction times that require movement of different body parts are expected to be different. Moving fingers to catch a falling ruler is much easier than moving an arm or a leg, which requires more force and more time.

1.b)

Many students will think *Method B* is more accurate.

2.a)

Students should record the fastest, slowest, and average reaction time.

2.b)

Yes, reaction times will vary for different people of the same age. Some of the reasons are genetics, health, and physical conditions.

Reaction Time with Distractions

1.a)

Expect the reaction times to be slower than previous trials. "Dropping the ruler" reaction times should vary from 0.11 s to 0.30 s for some students.

1.b)

Students should realize that because the reaction time while making a decision was greater they should follow at a distance allowing for greater reaction time.

2.a)

Students should find that simulating distractions will slow their reaction time. Point out to them that actually doing the distracting activities while driving would increase their reaction times even more.

2.b)

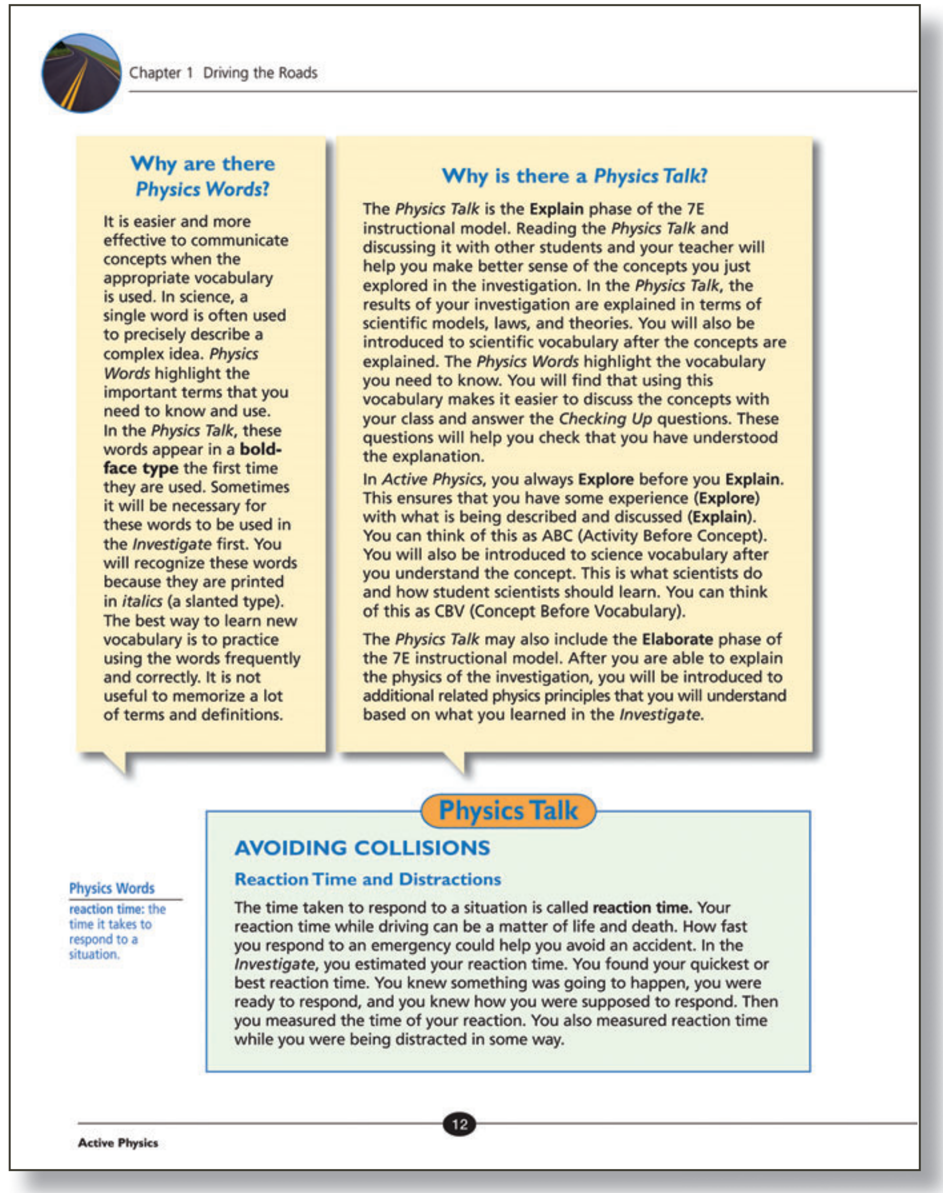
Some possible distractions while driving might include talking to friends, playing the radio, changing a tape or CD, eating or drinking in the your vehicle, using a cell phone, looking for something dropped on the floor of your vehicle, and so on.

CHAPTER 1

Physics Talk

This *Physics Talk* discusses reaction time. It explains the observations in the *Investigate* and the effect of distractions on reaction time. You might want to point out to your students why taking their eyes off the road or "driving under the influence" increases the possibility of having an accident. Ask students about various factors that affect reaction time. Making a list of responses on the board would be a good way to emphasize how these factors might prevent the driver from responding quickly at the time of an emergency.

As you discuss factors affecting reaction time, quiz students on their knowledge of driving laws in the United States. Use the opportunity to ask specific questions such as why alcohol and drugs are forbidden while driving. Discuss the dangers of using prescribed medication and the hazards of driving under the influence with subtle tact to make teenagers aware of how risky behavior on the roads is the leading cause of accidents in most countries.



Chapter 1 Driving the Roads

Why are there *Physics Words*?

It is easier and more effective to communicate concepts when the appropriate vocabulary is used. In science, a single word is often used to precisely describe a complex idea. *Physics Words* highlight the important terms that you need to know and use. In the *Physics Talk*, these words appear in a **bold-face type** the first time they are used. Sometimes it will be necessary for these words to be used in the *Investigate* first. You will recognize these words because they are printed in *italics* (a slanted type). The best way to learn new vocabulary is to practice using the words frequently and correctly. It is not useful to memorize a lot of terms and definitions.

Why is there a *Physics Talk*?

The *Physics Talk* is the **Explain** phase of the 7E instructional model. Reading the *Physics Talk* and discussing it with other students and your teacher will help you make better sense of the concepts you just explored in the investigation. In the *Physics Talk*, the results of your investigation are explained in terms of scientific models, laws, and theories. You will also be introduced to scientific vocabulary after the concepts are explained. The *Physics Words* highlight the vocabulary you need to know. You will find that using this vocabulary makes it easier to discuss the concepts with your class and answer the *Checking Up* questions. These questions will help you check that you have understood the explanation.

In *Active Physics*, you always **Explore** before you **Explain**. This ensures that you have some experience (**Explore**) with what is being described and discussed (**Explain**). You can think of this as ABC (Activity Before Concept). You will also be introduced to science vocabulary after you understand the concept. This is what scientists do and how student scientists should learn. You can think of this as CBV (Concept Before Vocabulary).

The *Physics Talk* may also include the **Elaborate** phase of the 7E instructional model. After you are able to explain the physics of the investigation, you will be introduced to additional related physics principles that you will understand based on what you learned in the *Investigate*.

Physics Talk

AVOIDING COLLISIONS

Reaction Time and Distractions

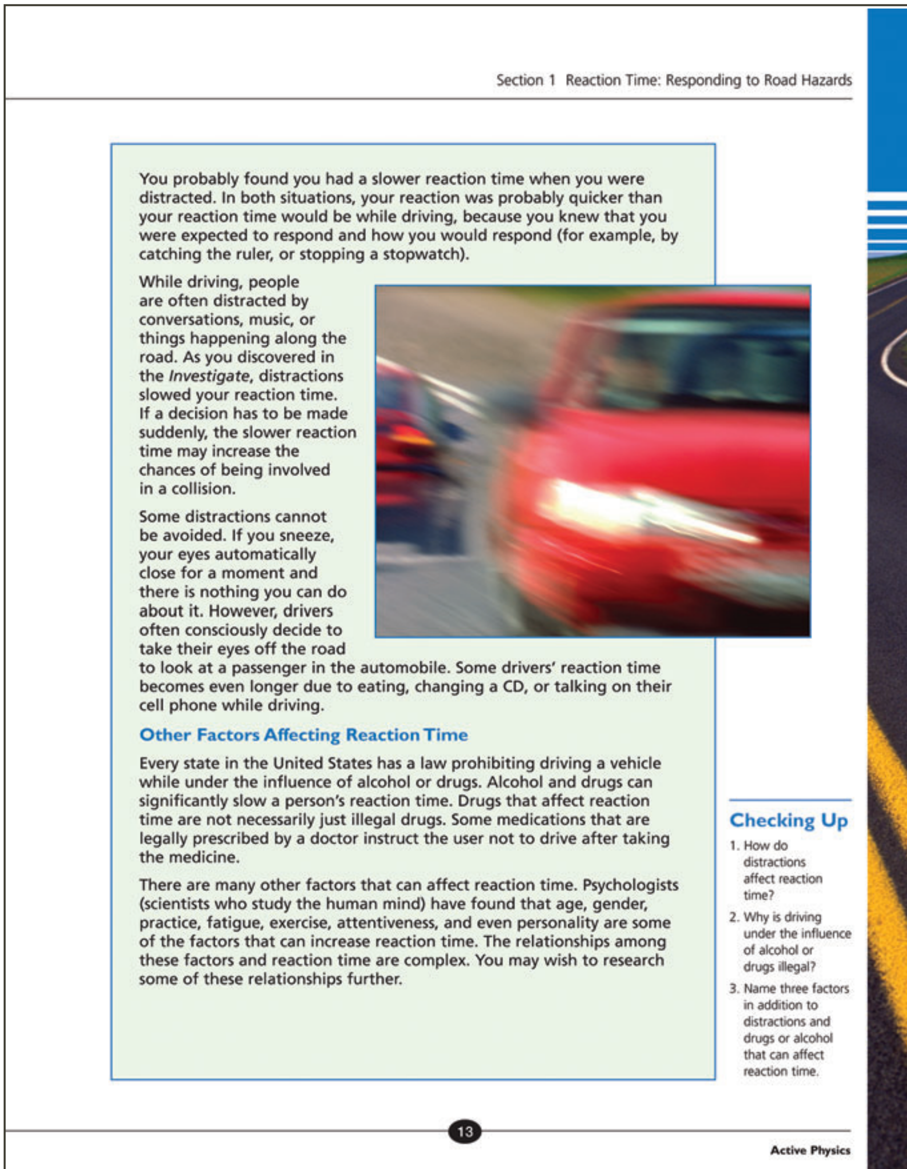
The time taken to respond to a situation is called **reaction time.** Your reaction time while driving can be a matter of life and death. How fast you respond to an emergency could help you avoid an accident. In the *Investigate*, you estimated your reaction time. You found your quickest or best reaction time. You knew something was going to happen, you were ready to respond, and you knew how you were supposed to respond. Then you measured the time of your reaction. You also measured reaction time while you were being distracted in some way.

Physics Words

reaction time: the time it takes to respond to a situation.

12

Active Physics



You probably found you had a slower reaction time when you were distracted. In both situations, your reaction was probably quicker than your reaction time would be while driving, because you knew that you were expected to respond and how you would respond (for example, by catching the ruler, or stopping a stopwatch).

While driving, people are often distracted by conversations, music, or things happening along the road. As you discovered in the *Investigate*, distractions slowed your reaction time. If a decision has to be made suddenly, the slower reaction time may increase the chances of being involved in a collision.

Some distractions cannot be avoided. If you sneeze, your eyes automatically close for a moment and there is nothing you can do about it. However, drivers often consciously decide to take their eyes off the road to look at a passenger in the automobile. Some drivers' reaction time becomes even longer due to eating, changing a CD, or talking on their cell phone while driving.

Other Factors Affecting Reaction Time

Every state in the United States has a law prohibiting driving a vehicle while under the influence of alcohol or drugs. Alcohol and drugs can significantly slow a person's reaction time. Drugs that affect reaction time are not necessarily just illegal drugs. Some medications that are legally prescribed by a doctor instruct the user not to drive after taking the medicine.

There are many other factors that can affect reaction time. Psychologists (scientists who study the human mind) have found that age, gender, practice, fatigue, exercise, attentiveness, and even personality are some of the factors that can increase reaction time. The relationships among these factors and reaction time are complex. You may wish to research some of these relationships further.

Checking Up

1. How do distractions affect reaction time?
2. Why is driving under the influence of alcohol or drugs illegal?
3. Name three factors in addition to distractions and drugs or alcohol that can affect reaction time.

Checking Up

1.

Distractions slow down reaction time, which increases the chances of being involved in a collision.

2.

Driving under the influence of alcohol or drugs is illegal because an intoxicated driver's reaction time is negatively affected, preventing him or her from being able to respond to the challenges of driving.

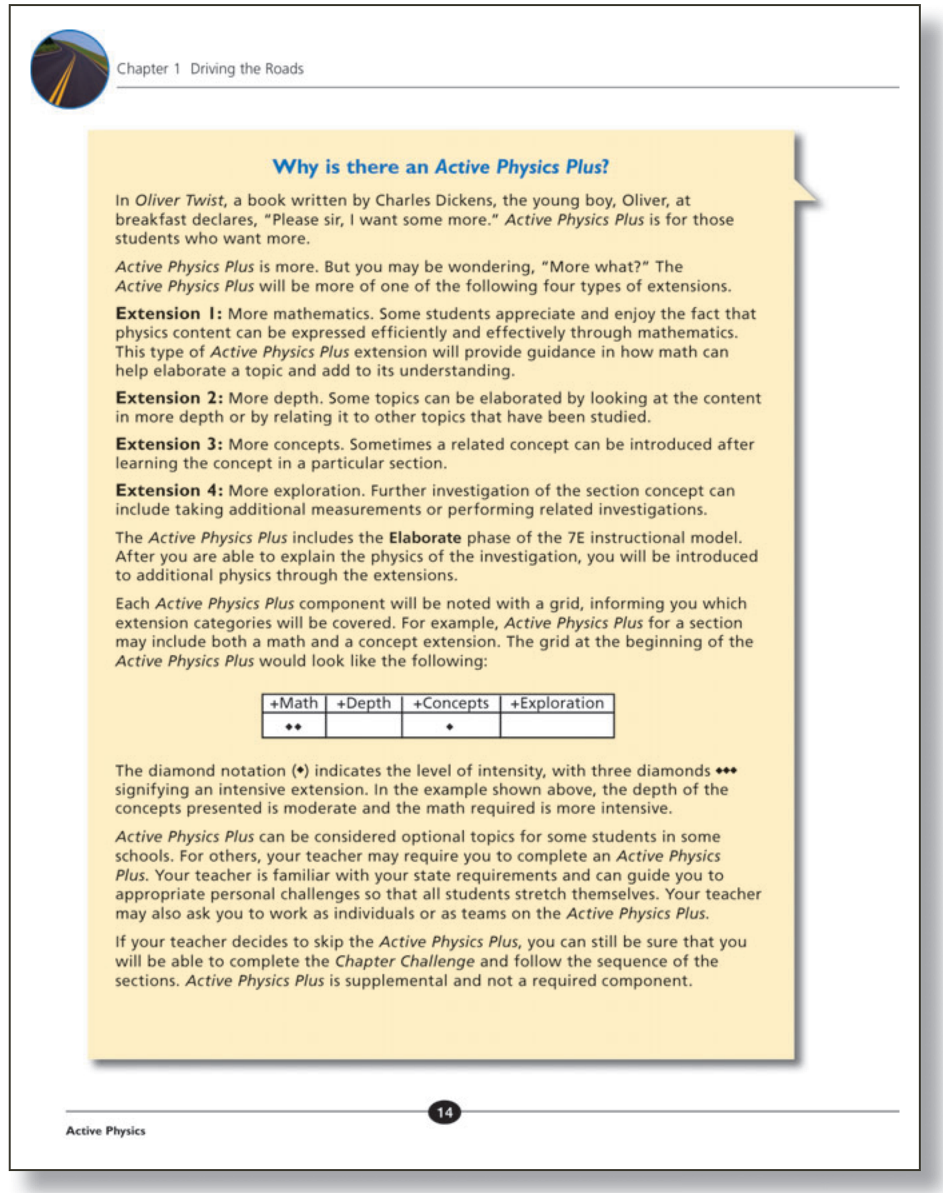
3.

Age, fatigue, and attentiveness are some of the factors that can affect reaction time.

CHAPTER 1

Active Physics Plus

Encourage students to read the *Why is there an Active Physics Plus*? Discuss how the "diamond notation" indicates the level of intensity. You could have a few student volunteers repeat their experiments to calculate the reaction time according to the equation $d = \frac{1}{2}at^2$. Writing the equation on the board will serve to emphasize its importance.



Chapter 1 Driving the Roads

Why is there an *Active Physics Plus*?

In *Oliver Twist*, a book written by Charles Dickens, the young boy, Oliver, at breakfast declares, "Please sir, I want some more." *Active Physics Plus* is for those students who want more.

Active Physics Plus is more. But you may be wondering, "More what?" The *Active Physics Plus* will be more of one of the following four types of extensions.

Extension 1: More mathematics. Some students appreciate and enjoy the fact that physics content can be expressed efficiently and effectively through mathematics. This type of *Active Physics Plus* extension will provide guidance in how math can help elaborate a topic and add to its understanding.

Extension 2: More depth. Some topics can be elaborated by looking at the content in more depth or by relating it to other topics that have been studied.

Extension 3: More concepts. Sometimes a related concept can be introduced after learning the concept in a particular section.

Extension 4: More exploration. Further investigation of the section concept can include taking additional measurements or performing related investigations.

The *Active Physics Plus* includes the **Elaborate** phase of the 7E instructional model. After you are able to explain the physics of the investigation, you will be introduced to additional physics through the extensions.

Each *Active Physics Plus* component will be noted with a grid, informing you which extension categories will be covered. For example, *Active Physics Plus* for a section may include both a math and a concept extension. The grid at the beginning of the *Active Physics Plus* would look like the following:

+Math	+Depth	+Concepts	+Exploration
♦♦		♦	

The diamond notation (♦) indicates the level of intensity, with three diamonds ♦♦♦ signifying an intensive extension. In the example shown above, the depth of the concepts presented is moderate and the math required is more intensive.

Active Physics Plus can be considered optional topics for some students in some schools. For others, your teacher may require you to complete an *Active Physics Plus*. Your teacher is familiar with your state requirements and can guide you to appropriate personal challenges so that all students stretch themselves. Your teacher may also ask you to work as individuals or as teams on the *Active Physics Plus*.

If your teacher decides to skip the *Active Physics Plus*, you can still be sure that you will be able to complete the *Chapter Challenge* and follow the sequence of the sections. *Active Physics Plus* is supplemental and not a required component.

14

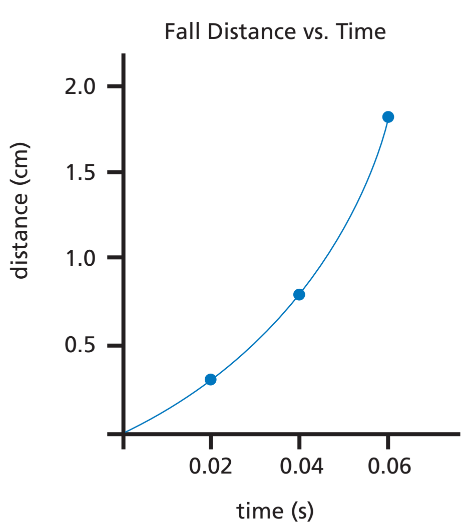
Active Physics

1.a)

Time (s)	Distance (cm)
0.00	0.00
0.01	0.05
0.02	0.20
0.03	0.44
0.04	0.78
0.05	1.23
0.06	1.76

1.b)

The graph the students generate should look like the one below. The axes should be labeled with the correct units, and the graph should have a title of fall distance vs. time.



1.c)

The shape of the graph is the same as the graph in the investigation, but this graph concentrates on the lower values of time.

2.a)

Strategy: You know the distance of fall and the acceleration of gravity, so you may use the equation directly.

For the fall distance of 6.0 cm,

$t = \sqrt{2d/a}$

$t = \sqrt{2\left(0.060\ \text{m}/9.8\ \text{m/s}^2\right)}$

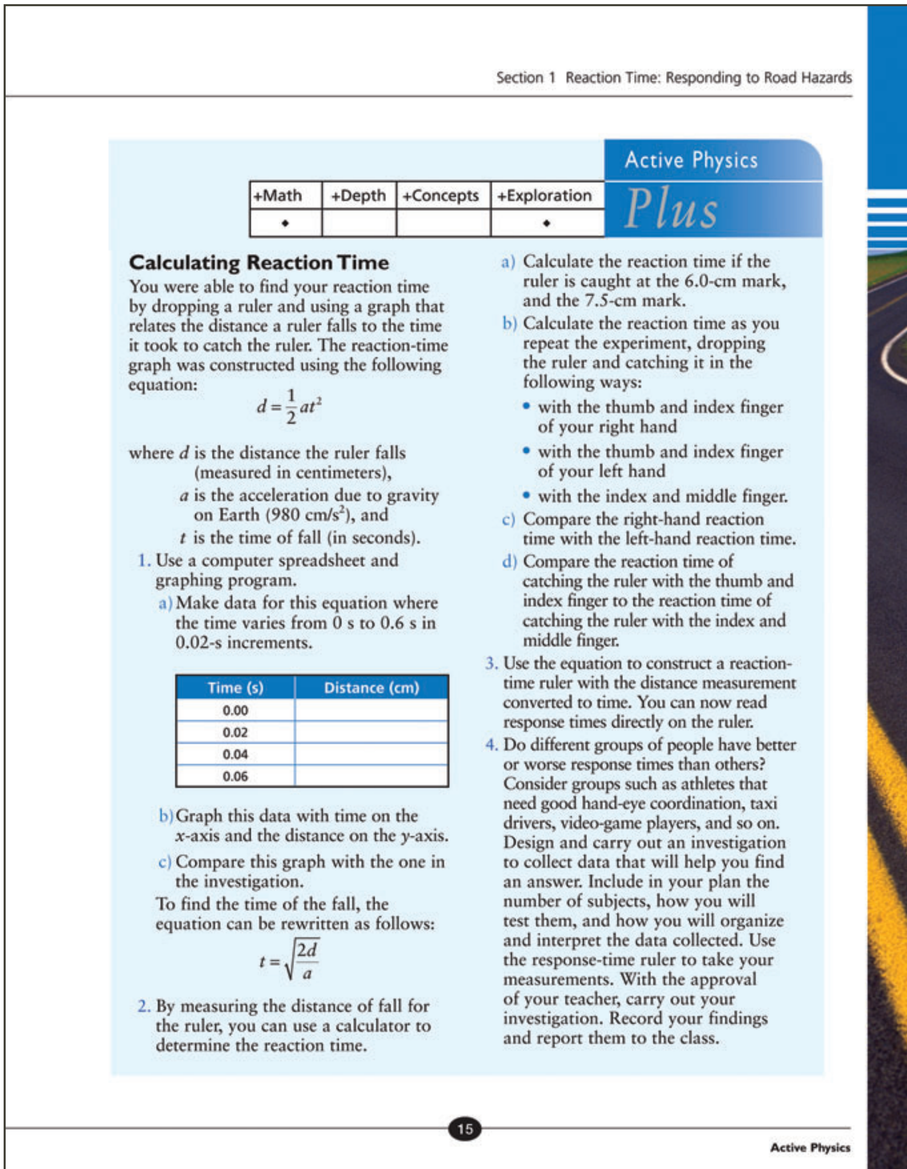
$t = 0.11\ \text{s}$

Using the same equation for the 7.5 cm fall gives

$t = \sqrt{2d/a}$

$t = \sqrt{2\left(0.075\ \text{m}/9.8\ \text{m/s}^2\right)}$

$t = 0.12\ \text{s}.$



Active Physics *Plus*

+Math	+Depth	+Concepts	+Exploration
•			•

Calculating Reaction Time

You were able to find your reaction time by dropping a ruler and using a graph that relates the distance a ruler falls to the time it took to catch the ruler. The reaction-time graph was constructed using the following equation:

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

where d is the distance the ruler falls (measured in centimeters),
a is the acceleration due to gravity on Earth (980 cm/s^2), and
t is the time of fall (in seconds).

1. Use a computer spreadsheet and graphing program.
   a) Make data for this equation where the time varies from 0 s to 0.6 s in 0.02-s increments.

Time (s)	Distance (cm)
0.00	
0.02	
0.04	
0.06	

   b) Graph this data with time on the x-axis and the distance on the y-axis.
   c) Compare this graph with the one in the investigation.

   To find the time of the fall, the equation can be rewritten as follows:

$$t = \sqrt{\frac{2d}{a}}$$

2. By measuring the distance of fall for the ruler, you can use a calculator to determine the reaction time.
   a) Calculate the reaction time if the ruler is caught at the 6.0-cm mark, and the 7.5-cm mark.
   b) Calculate the reaction time as you repeat the experiment, dropping the ruler and catching it in the following ways:
      - with the thumb and index finger of your right hand
      - with the thumb and index finger of your left hand
      - with the index and middle finger.
   c) Compare the right-hand reaction time with the left-hand reaction time.
   d) Compare the reaction time of catching the ruler with the thumb and index finger to the reaction time of catching the ruler with the index and middle finger.
3. Use the equation to construct a reaction-time ruler with the distance measurement converted to time. You can now read response times directly on the ruler.
4. Do different groups of people have better or worse response times than others? Consider groups such as athletes that need good hand-eye coordination, taxi drivers, video-game players, and so on. Design and carry out an investigation to collect data that will help you find an answer. Include in your plan the number of subjects, how you will test them, and how you will organize and interpret the data collected. Use the response-time ruler to take your measurements. With the approval of your teacher, carry out your investigation. Record your findings and report them to the class.

2.b)

The answer the student obtains for these bullets will depend upon the response distances they record on the ruler.

- The reaction time with the thumb and index finger will be significantly shorter than when the students use their middle and index finger.
- Using their non-dominant hand will slow their response time even further.
- The index finger and middle finger should prove to be the slowest time due to the musculature not being suited for a quick response in this manner.

2.c)

The answer the student obtains for these bullets will depend upon the response distances they record on the ruler. They will find that their non-dominant hand will respond more slowly.

2.d)

Students will make the comparison between the two methods of catching the ruler. The index finger and middle finger should prove to be the slower time.

3.

The students should create a ruler by placing a piece of paper over a standard 30-cm ruler to cover the markings. They should then transpose the readings from the reaction-meter graph from Part B of the *Investigate* onto the paper. At the distances that correspond to the time of fall, times of 0.05 s, 0.10 s, and 0.15 s should be laid out, along with some intermediate times. Note that the intermediate times will not be uniformly spaced between the readings of 0.05 s, 0.10 s, etc., but should be determined by the graph.

4.

This will be the result of the students' investigations with different groups and will vary depending upon which groups are chosen.

CHAPTER 1

What Do You Think Now?

Have students revisit the *What Do You See?* illustration and the *What Do You Think?* question. Encourage them to think of the effect of distractions on reaction time. Discuss how distractions could affect their reaction time at the time of an emergency. Consider sharing *A Physicist's Response* with the class to elicit their opinions. Ask them to return to their findings in the *Investigate* and explain how the alertness of their reaction determined the outcome.

This is a time to clarify previous misconceptions that students might still have. You could cite an example of a person's reaction time in response to a situation, and quiz students on whether the reaction was prompt or delayed. This will serve as a quick formative assessment to help you determine how confident students are in their understanding of reaction time.

Why is there a *What Do You Think Now?*

At the beginning of each section, you are asked to think about one or two questions. At that point, you are not expected to necessarily come up with a correct physics answer, but you are expected to think about what you know. Now that you have completed the investigation, you have learned the physics you need to know to answer the questions. Think about the questions again.

Compare your answers now to the answers you gave initially. Comparing what you think now with what you thought before is a way of "observing your thinking." Remember, research shows that stopping to think about your learning makes you a better learner.

What Do You Think Now?

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

- **What factors affect the time you need to react to an emergency situation while driving?**

How would you answer this question now? Revisit your initial ideas on reaction time, and explain why reaction time is so crucial to avoiding automobile accidents. Explain how distractions can increase the possibility of having an accident in reference to reaction time.

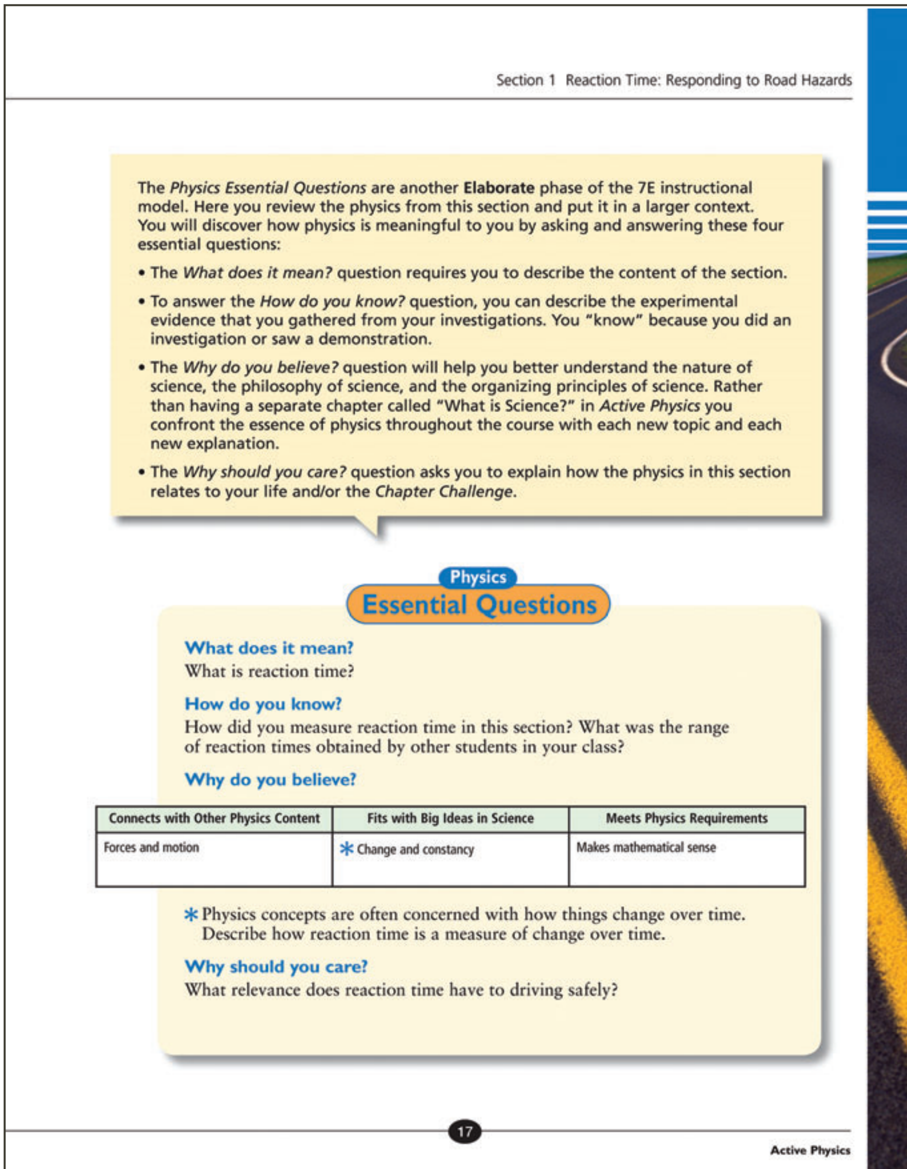
Why are there *Physics Essential Questions?*

As a student physicist, you need to focus on the *Physics Essential Questions* that unite all science endeavors.

- *What does it mean?* (What is the physics content that you are learning?)
- *How do you know?* (What evidence do you have that supports the content?)
- *Why do you believe?* (What are the organizing principles of physics? How is the physics of this section the same as the physics outside this classroom? How does the physics of this section relate to other areas of physics?)
- *Why should you care?* (How is what you learned relevant to your life and/or the *Chapter Challenge?*)

As a student physicist, you are also part of the science community that understands that what you are learning can be placed into the larger context of physics knowledge and organizing principles.

CHAPTER 1



The *Physics Essential Questions* are another **Elaborate** phase of the 7E instructional model. Here you review the physics from this section and put it in a larger context. You will discover how physics is meaningful to you by asking and answering these four essential questions:

- The *What does it mean?* question requires you to describe the content of the section.
- To answer the *How do you know?* question, you can describe the experimental evidence that you gathered from your investigations. You "know" because you did an investigation or saw a demonstration.
- The *Why do you believe?* question will help you better understand the nature of science, the philosophy of science, and the organizing principles of science. Rather than having a separate chapter called "What is Science?" in *Active Physics* you confront the essence of physics throughout the course with each new topic and each new explanation.
- The *Why should you care?* question asks you to explain how the physics in this section relates to your life and/or the *Chapter Challenge*.

Physics
Essential Questions

What does it mean?
What is reaction time?

How do you know?
How did you measure reaction time in this section? What was the range of reaction times obtained by other students in your class?

Why do you believe?

Connects with Other Physics Content	Fits with Big Ideas in Science	Meets Physics Requirements
Forces and motion	* Change and constancy	Makes mathematical sense

* Physics concepts are often concerned with how things change over time. Describe how reaction time is a measure of change over time.

Why should you care?
What relevance does reaction time have to driving safely?

Physics Essential Questions

What does it mean?

Reaction time is a measure of how long it takes to respond to a stimulus.

How do you know?

Reaction time was measured by catching a ruler and using a graph. It was also measured by stopping a stopwatch after seeing someone else stop theirs. The reaction times of students in the class probably ranged from 0.1 s to 0.2 s.

Why do you believe?

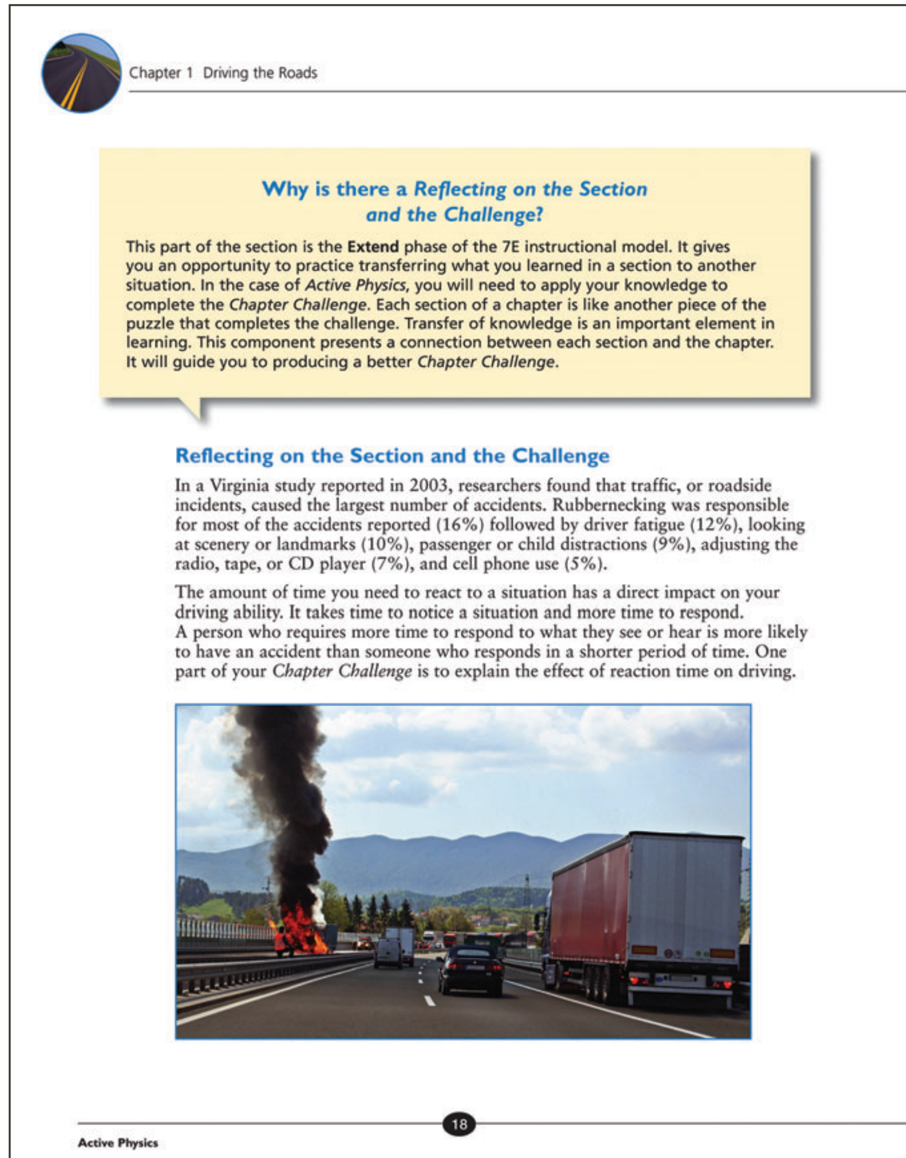
Reaction time is actually a measure of time. To record the reaction time, you must observe somebody doing something like catching a ruler or stepping on the brakes of a vehicle.

Why should you care?

The slower your reaction time, the more chance that you will not have the time to respond to an emergency and being involved in an accident.

Reflecting on the Section and the Challenge

Students can begin to reflect on how this section relates to their *Chapter Challenge*. They should be able to extend their understanding of reaction time to a situation they might want to develop that explains the significance of being alert to potential dangers. Emphasize that they also need to build their presentation with illustrations that depict the effect of driving ability on reaction time, and how being a careful driver reduces the chances of being involved in an accident.



Why is there a *Reflecting on the Section and the Challenge*?

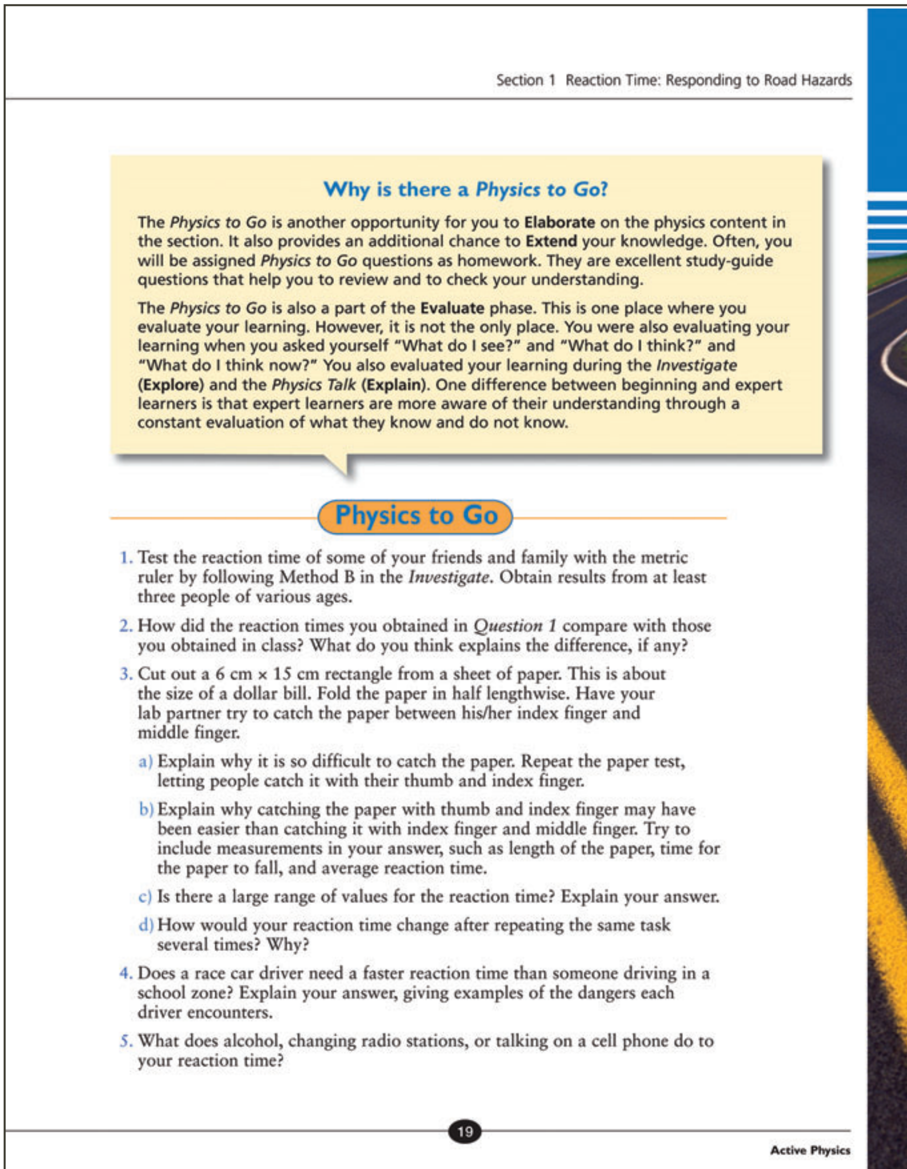
This part of the section is the **Extend** phase of the 7E instructional model. It gives you an opportunity to practice transferring what you learned in a section to another situation. In the case of *Active Physics*, you will need to apply your knowledge to complete the *Chapter Challenge*. Each section of a chapter is like another piece of the puzzle that completes the challenge. Transfer of knowledge is an important element in learning. This component presents a connection between each section and the chapter. It will guide you to producing a better *Chapter Challenge*.

Reflecting on the Section and the Challenge

In a Virginia study reported in 2003, researchers found that traffic, or roadside incidents, caused the largest number of accidents. Rubbernecking was responsible for most of the accidents reported (16%) followed by driver fatigue (12%), looking at scenery or landmarks (10%), passenger or child distractions (9%), adjusting the radio, tape, or CD player (7%), and cell phone use (5%).

The amount of time you need to react to a situation has a direct impact on your driving ability. It takes time to notice a situation and more time to respond. A person who requires more time to respond to what they see or hear is more likely to have an accident than someone who responds in a shorter period of time. One part of your *Chapter Challenge* is to explain the effect of reaction time on driving.

CHAPTER 1


Section 1 Reaction Time: Responding to Road Hazards

Why is there a *Physics to Go*?

The *Physics to Go* is another opportunity for you to **Elaborate** on the physics content in the section. It also provides an additional chance to **Extend** your knowledge. Often, you will be assigned *Physics to Go* questions as homework. They are excellent study-guide questions that help you to review and to check your understanding.

The *Physics to Go* is also a part of the **Evaluate** phase. This is one place where you evaluate your learning. However, it is not the only place. You were also evaluating your learning when you asked yourself "What do I see?" and "What do I think?" and "What do I think now?" You also evaluated your learning during the *Investigate* (**Explore**) and the *Physics Talk* (**Explain**). One difference between beginning and expert learners is that expert learners are more aware of their understanding through a constant evaluation of what they know and do not know.

Physics to Go

1. Test the reaction time of some of your friends and family with the metric ruler by following Method B in the *Investigate*. Obtain results from at least three people of various ages.
2. How did the reaction times you obtained in *Question 1* compare with those you obtained in class? What do you think explains the difference, if any?
3. Cut out a 6 cm × 15 cm rectangle from a sheet of paper. This is about the size of a dollar bill. Fold the paper in half lengthwise. Have your lab partner try to catch the paper between his/her index finger and middle finger.
   a) Explain why it is so difficult to catch the paper. Repeat the paper test, letting people catch it with their thumb and index finger.
   b) Explain why catching the paper with thumb and index finger may have been easier than catching it with index finger and middle finger. Try to include measurements in your answer, such as length of the paper, time for the paper to fall, and average reaction time.
   c) Is there a large range of values for the reaction time? Explain your answer.
   d) How would your reaction time change after repeating the same task several times? Why?
4. Does a race car driver need a faster reaction time than someone driving in a school zone? Explain your answer, giving examples of the dangers each driver encounters.
5. What does alcohol, changing radio stations, or talking on a cell phone do to your reaction time?

19

Active Physics

Physics to Go

1.

Students should test reaction times of family members and friends who are not class members.

2.

Students may find that reaction times for much older and very young family members may be slower. On the other hand, parents and siblings may be more motivated to produce excellent reaction times and therefore, may be more alert than the students tested in class.

3.a)

The length of the dollar bill is 15.7 cm. The free-fall time is under 0.2 s, which makes it nearly impossible to catch the bill unless the hand is lowered or the release is anticipated. The grasping action with the thumb and forefinger is a much more familiar one than between the forefinger and middle finger. Refer the students to the graph in the *Student Edition* following the header Method B: Catching a Ruler.

3.b)

Although the fall time for the "dollar bill" is the same in both cases, catching the paper between the forefinger and middle finger requires the movement of two fingers, while catching the paper between the thumb and middle finger moves only the index finger, hence, a quicker reaction time.

3.c)

The range of reaction times will depend upon physical limitations, age, etc. A range of reaction times that spans a factor of 2-3 would not be uncommon.

3.d)

After several trials, one might expect the reaction time to decrease as the body was trained to respond to the stimulus. Fatigue could start to set in, increasing reaction time.

4.

The speed at which the race car driver is traveling requires a very quick reaction time. Although students will investigate the relationship between distance and time in the next section, most will be able to answer this question from previous experience. Encourage students to become aware of the distractions that the average driver faces, as well as the potential dangers. Compare the focused, alert race car driver encountering oil on the track to a distracted student reacting to an obstacle in the road.

5.

Alcohol, changing radio stations, or talking on the cell phone slow down reaction time.

6.

Some of the consequences drivers face when driving with a slower reaction time include increased chance of accidents as dangerous situations arise, greater tendency toward sudden stops, delayed response to changes such as drifting off the road, possible interaction with police and the courts, including fines, etc.

7.

Auto insurance is more expensive for teenage drivers than older drivers because teenage drivers are less experienced, likely to drive fast, be distracted, and might not take the necessary precautions to avoid hazardous situations. Older drivers are more experienced and careful while driving, taking care to avoid potentially dangerous situations.

8.

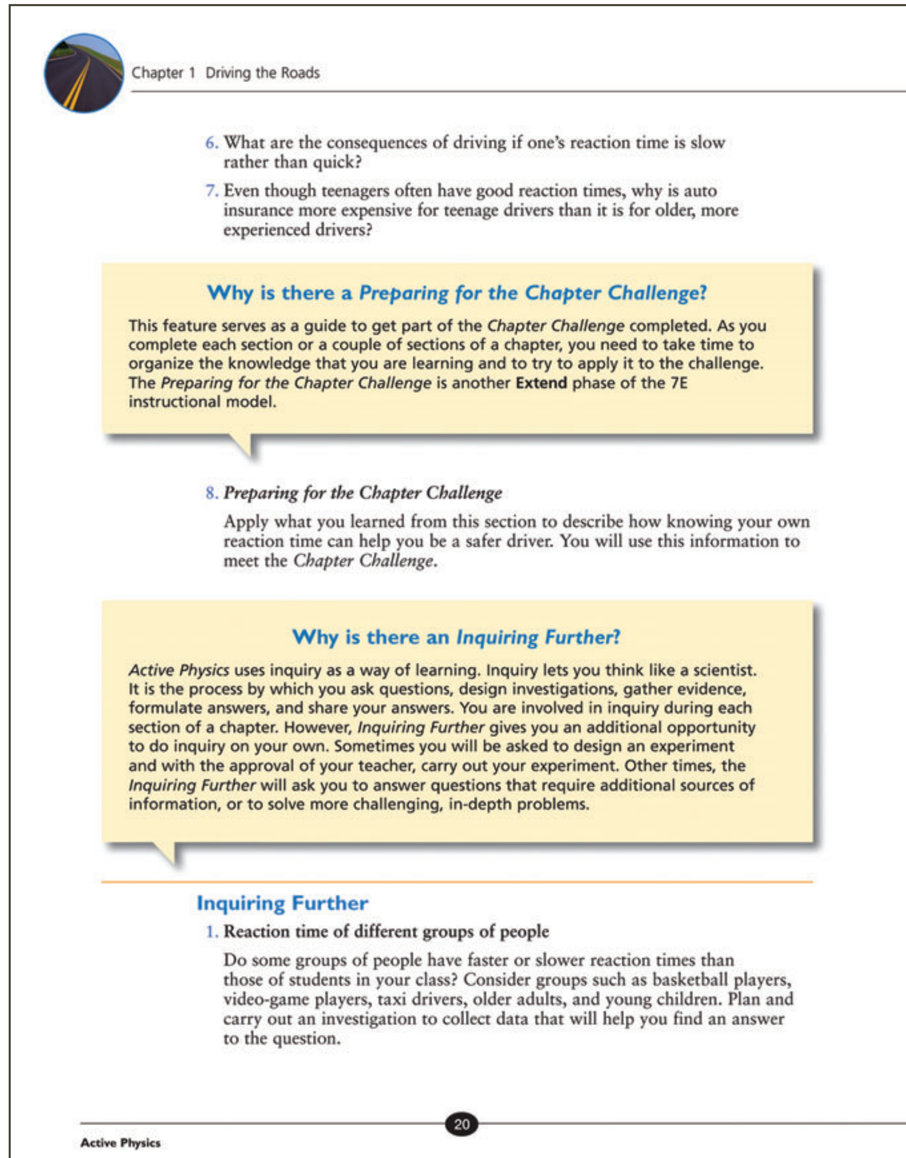
Preparing for the Chapter Challenge

Students will probably say that knowing their own reaction time would help them avoid accidents.

Inquiring Further

1. Reaction time of different groups of people

The students may choose to test the reaction times of other students on a school sports team, and possibly compare those times to the math team.



Chapter 1 Driving the Roads

6. What are the consequences of driving if one's reaction time is slow rather than quick?

7. Even though teenagers often have good reaction times, why is auto insurance more expensive for teenage drivers than it is for older, more experienced drivers?

Why is there a *Preparing for the Chapter Challenge*?

This feature serves as a guide to get part of the *Chapter Challenge* completed. As you complete each section or a couple of sections of a chapter, you need to take time to organize the knowledge that you are learning and to try to apply it to the challenge. The *Preparing for the Chapter Challenge* is another **Extend** phase of the 7E instructional model.

8. *Preparing for the Chapter Challenge*

Apply what you learned from this section to describe how knowing your own reaction time can help you be a safer driver. You will use this information to meet the *Chapter Challenge*.

Why is there an *Inquiring Further*?

Active Physics uses inquiry as a way of learning. Inquiry lets you think like a scientist. It is the process by which you ask questions, design investigations, gather evidence, formulate answers, and share your answers. You are involved in inquiry during each section of a chapter. However, *Inquiring Further* gives you an additional opportunity to do inquiry on your own. Sometimes you will be asked to design an experiment and with the approval of your teacher, carry out your experiment. Other times, the *Inquiring Further* will ask you to answer questions that require additional sources of information, or to solve more challenging, in-depth problems.

Inquiring Further

1. **Reaction time of different groups of people**

Do some groups of people have faster or slower reaction times than those of students in your class? Consider groups such as basketball players, video-game players, taxi drivers, older adults, and young children. Plan and carry out an investigation to collect data that will help you find an answer to the question.

20

Active Physics

2. Red light-green light reaction timer

This assignment may interest students who are enrolled in a technology program and be a way of getting a special reaction timer for use next year. Alternatively, digital circuits for electronic timers can either be purchased or simply constructed on a breadboard circuit. Separate red and green lights may be purchased from electronics hobby suppliers (LEDs would work) as well as the needed switches. Students with an interest in electronics should be able to construct the circuit for under $15 in parts.

1-1a **Blackline Master**

2. **Red light–green light reaction timer**

Design and build a device with a red light and a green light. If the red light turns on, you must press one button and measure the reaction time. If the green light turns on, you must press a second button and measure the reaction time. Have your teacher approve your design before proceeding. How do reaction times to this decision-making task compare with the reaction times measured earlier?

Why is there a 7E instructional model?

At the beginning of this section, you were introduced to the 7E instructional model. You were also asked to think about why you are asked to do certain things in *Active Physics*. Review the components of this section, and think about what instructional-model phase is addressed by each component.

Phases of the 7E Instructional Model	Where is it in the section?
Elicit	*What Do You See?* *What Do You Think?*
Engage	*What Do You See?* *What Do You Think?*
Explore	*Investigate*
Explain	*Physics Talk* *Physics Words*
Elaborate	*Physics Talk* *What Do You Think Now?* *Checking Up* *Physics Essential Questions* *Physics to Go*
Extend	*Reflecting on the Section and the Challenge* *Preparing for the Chapter Challenge* *Inquiring Further*
Evaluate	*Formative evaluation — You evaluate your own understanding and the teacher can evaluate your understanding during all components of the chapter. Additional evaluations may include:* Lab reports, *Checking Up*, Quizzes, *What Do You Think Now?*, *Physics Essential Questions*, *Physics to Go*.

SECTION 1 QUIZ

1-1b Blackline Master

1. A student is testing her reaction time by trying to keep a light bulb on for exactly 4 s by matching a stopwatch. When she turns the light bulb off, the stopwatch reads 4.13 s. What is her reaction time?

   a) 3.87 s
   b) 0.26 s
   c) 0.13 s
   d) 4.00 s

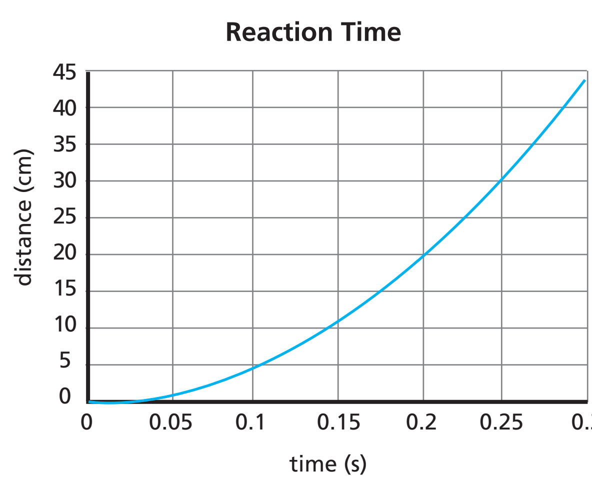
2. Which of the following will have no effect on the reaction time of a person driving an automobile?

   a) The age of the driver
   b) Distractions in the environment
   c) The speed of the automobile
   d) Talking on a cell phone while driving

3. A race car driver is being tested for reaction time. In several practice trials, the driver's reaction time was recorded as 0.18 s, 0.22 s and 0.17 s. What was the driver's average reaction time?

   a) 0.57 s
   b) 0.17 s
   c) 0.19 s
   d) 0.22 s

4. A student drops a ruler to test her reaction time, and catches it at the 19-cm mark. According to the graph below, her reaction time is closest to



   a) 0.1 s.
   b) 0.1 s.
   c) 0.2 s.
   d) 0.25 s.

5. Two students are having a contest to see who has the quickest reaction time. A third student gives them both stopwatches that were started at the same time and tells them to stop them when he says stop. The student with the quickest reaction time will have the stopwatch with the

   a) nearest time in the chart for *Question 4*.

   b) time nearest the school clock.

   c) highest time recorded.

   d) lowest time recorded.

SECTION 1 QUIZ ANSWERS

1. c) 0.13 s. The student's reaction time is the difference between when the stopwatch hits 4 s and the time it takes for her to respond by stopping the stopwatch. If she would have stopped the stopwatch in exactly 4 s, the answer would have been 1.a). The other answers are not related to the reaction time.

2. c) All the other answers are distractions, which will slow down a driver's reaction time. The automobile's speed does not affect how quickly a person can react, but will affect how far the automobile travels before the reaction starts to take effect.

3. b) The average reaction time is calculated by adding the three reaction times and then dividing by three. The highest or lowest values are reaction times for one trial only, and may be either too high or too low for various reasons.

4. c) According to the chart, the ruler will fall a distance of 19 cm in a time of almost 0.2 s. This is *not* because 0.19 is closest to 0.2!

5. d) The student who reacts in the least amount of time after the stopwatches are started has reacted the quickest.