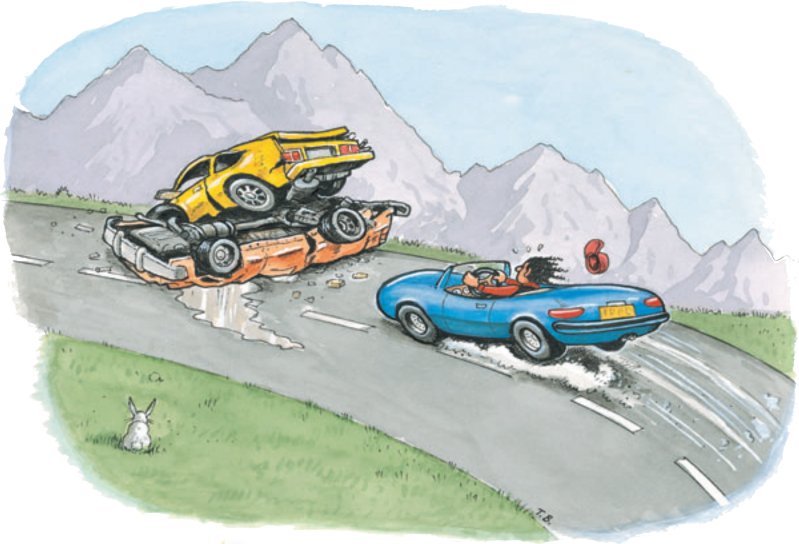
Section 1

Reaction Time: Responding to Road Hazards

What Do You See?



Florida Next Generation Sunshine State Standards:

Additional Benchmarks met in Section 1

SC.912.P.12.2 Analyze the motion of an object in terms of its position, velocity, and acceleration (with respect to a frame of reference) as functions of time.

LA.910.4.2.2 The student will record information and ideas from primary and/or secondary sources accurately and coherently, noting the validity and reliability of these sources and attributing sources of information.

MA.912.S.3.2 Collect, organize, and analyze data sets, determine the best format for the data and present visual summaries from the following: •bar graphs •line graphs •stem and leaf plots •circle graphs •histograms •box and whisker plots •scatter plots •cumulative frequency (ogive) graphs.

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 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 humor to show real physics concepts. 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?**

Record your ideas about this question in your log. Begin a new page in your *Active Physical Science* 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*.

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 Physical Science,* 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 dialogue with nature. In *Active Physical Science*, 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 Physical Science*, 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 Physical Science* 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.

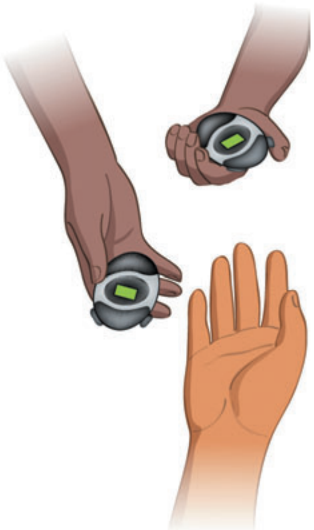
Test your reaction time by having a classmate stand behind you and clap. When you hear the sound, move your foot between the imaginary pedals.

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.

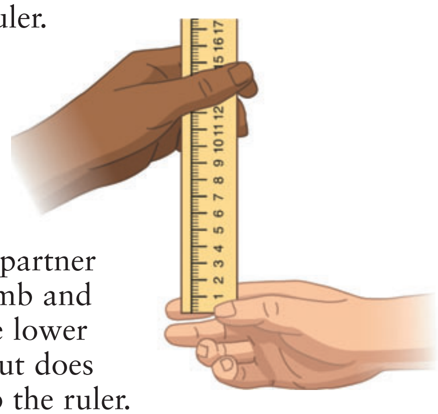


a) Record your reaction time in your *Active Physical Science* log.

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

Method B: Catching a Ruler

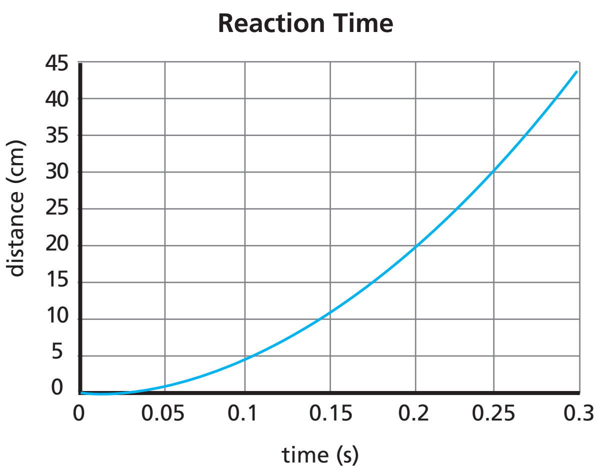
1. Obtain a metric ruler. Hold the metric ruler at the top, between thumb and index finger, with the zero centimeter at the bottom. Your lab partner places his/her thumb and index finger at the lower end of the ruler, but does not touch it. Drop the ruler. Your partner must stop the ruler from falling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



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 Physical Science* log, make a list of 10 activities that could distract you from driving safely.

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 Physical Science*, 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.

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.

Why is there a *Checking Up*?

The *Checking Up* questions help you **Evaluate** the physics principles you have learned through the *Investigate* and your understanding of the explanations in the *Physics Talk*.

The *Checking Up* questions also offer another opportunity to **Elaborate** on your understanding of the physics concepts you have learned so far.

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.

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.

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.

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.

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. In *Active Physical Science* 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?

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 Physical Science*, 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.

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?

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 Physical Science 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.

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 chapter, 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 Physical Science*. 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* *Connections to Other Sciences* *Physics at Work*
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*, *Physics Practice Test*.