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Dr. Arthur Eisenkraft has taught high school physics for over 28 years. He is currently the Distinguished Professor of Science Education at the University of Massachusetts, Boston, where he is also an Adjunct Professor of Physics and the Director of the Center of Science and Math In Context (COSMIC). Dr. Eisenkraft is the author of numerous science and educational publications and holds a patent for a Laser Vision Testing System, which tests visual acuity for spatial frequency.

Dr. Eisenkraft has been recognized with numerous awards, including: Presidential Award for Excellence in Science Teaching, 1986 from President Ronald Reagan; American Association of Physics Teachers (AAPT); Distinguished Service Citation for "excellent contributions to the teaching of physics," 1989; Science Teacher of the Year, Disney American Teacher Awards, 1991; Honorary Doctorate of Science, Rensselaer Polytechnic Institute, New York, 1993; AAPT Excellence in Pre-College Teaching Award, 1999; National Science Teachers Association (NSTA) Distinguished Service Award to Science Education, 2005 and recipient of the Robert A. Millikan Medal for "notable and creative contributions in physics education," 2009.

In 1999, Dr. Eisenkraft was elected to a three-year cycle as the President-Elect, President, and Retiring President of the NSTA, the world's largest organization of science teachers. He has served on numerous committees of the National Academy of Sciences, including the content committee that has helped author the National Science Education Standards, and in 2003 he was elected a fellow of the American Association for the Advancement of Science (AAAS). Dr. Eisenkraft has been involved with a number of projects and chaired many notable competitions, including the Toshiba/NSTA ExploraVisions Awards (1991 to present), which he co-created; the Toyota TAPESTRY Grants (1990 to 2005); and the Duracell/NSTA Scholarship Competition (1984 to 2000). In 1993, he served as Executive Director for the XXIV International Physics Olympiad after being Academic Director for the United States Team for six years.

Dr. Eisenkraft is a frequent presenter and keynote speaker at national conventions. He has published over 100 articles and presented over 200 papers and workshops. *Quantoons*, written with L. Kirkpatrick and featuring illustrations by Tomas Bunk, led to an art exhibition at the New York Hall of Science.

Dr. Eisenkraft has been featured in articles in *The New York Times*, *Education Week*, *Physics Today*, *Scientific American*, *The American Journal of Physics*, and *The Physics Teacher*. He has testified before the United States Congress, appeared on *NBC's The Today Show,* National Public Radio, and many other radio and television broadcasts, including serving as the science consultant to ESPN's *Sports Figures*.

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Welcome to Active Physics: Your Guide to Success

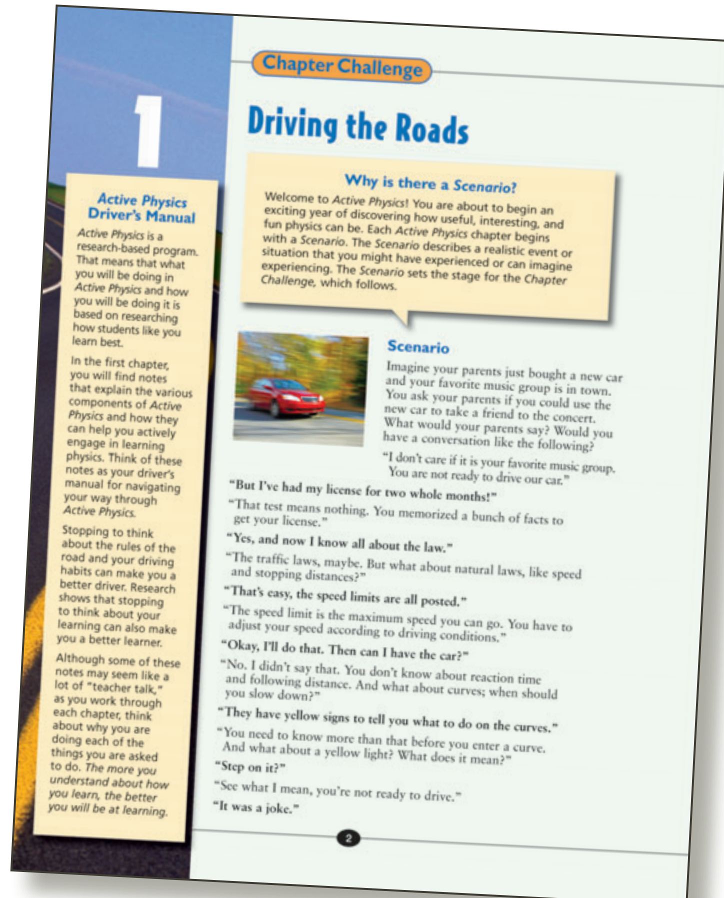
A Five-Minute Introduction

Active Physics differs from a traditional physics program, in that it contains all the physics content you need to teach, but it is presented in an excitingly innovative and meaningful way. *Active Physics* explores forces, energy, waves, electricity, and magnetism as well as optics and modern physics. The content is always placed in a larger context that emphasizes student learning through inquiry, while motivating students through a problem-based learning approach. Students learn about waves, sound, and light as part of their requirement to create a brief show that will entertain their friends (*Let Us Entertain You)*. Students apply what they have learned about Newton's laws to build an improved safety device for a car (*Physics in Action)*. Students take ownership of their understanding of atomic and nuclear physics by developing a museum exhibit on the atom and suggesting something to be sold in the museum store (*Atoms on Display*).

In this nine-chapter textbook, you will find everything you are required to teach and more. You will also find that the important concepts that your students need are covered in several chapters. This multiple exposure allows students to see the concepts in a variety of contexts and at a variety of depths. You will be able to choose which chapters meet the needs of your students and your state standards. Each section of each chapter also has an *Active Physics Plus* component that provides more mathematics, concept development, inquiry, or depth of treatment.

You may begin the year with any chapter. However, *Driving the Roads* contains the "launcher" material, which introduces the learning components to you and your students and helps provide students with a rationale for why this research-based approach to physics will help them succeed.

For the purpose of understanding the components of all chapters, the *Physics in Action* chapter will be broken down in this Five-Minute Introduction. Your students first learn about the *Chapter Challenge,* which will be the focus of their work. The challenge for this particular chapter is to create a series of voice-over narrations for sporting events. These voice-overs can



1

Chapter Challenge

Driving the Roads

Active Physics Driver's Manual

Active Physics is a research-based program. That means that what you will be doing in *Active Physics* and how you will be doing it is based on researching how students like you learn best.

In the first chapter, you will find notes that explain the various components of *Active Physics* and how they can help you actively engage in learning physics. Think of these notes as your driver's manual for navigating your way through *Active Physics*.

Stopping to think about the rules of the road and your driving habits can make you a better driver. Research shows that stopping to think about your learning can also make you a better learner.

Although some of these notes may seem like a lot of "teacher talk," as you work through each chapter, think about why you are doing each of the things you are asked to do. *The more you understand about how you learn, the better you will be at learning.*

Why is there a *Scenario*?

Welcome to *Active Physics*! You are about to begin an exciting year of discovering how useful, interesting, and fun physics can be. Each *Active Physics* chapter begins with a *Scenario*. The *Scenario* describes a realistic event or situation that you might have experienced or can imagine experiencing. The *Scenario* sets the stage for the *Chapter Challenge*, which follows.

Scenario

Imagine your parents just bought a new car and your favorite music group is in town. You ask your parents if you could use the new car to take a friend to the concert. What would your parents say? Would you have a conversation like the following?

"I don't care if it is your favorite music group. You are not ready to drive our car."

"But I've had my license for two whole months!"

"That test means nothing. You memorized a bunch of facts to get your license."

"Yes, and now I know all about the law."

"The traffic laws, maybe. But what about natural laws, like speed and stopping distances?"

"That's easy, the speed limits are all posted."

"The speed limit is the maximum speed you can go. You have to adjust your speed according to driving conditions."

"Okay, I'll do that. Then can I have the car?"

"No. I didn't say that. You don't know about reaction time and following distance. And what about curves; when should you slow down?"

"They have yellow signs to tell you what to do on the curves."

"You need to know more than that before you enter a curve. And what about a yellow light? What does it mean?"

"Step on it?"

"See what I mean, you're not ready to drive."

"It was a joke."

2

be considered tryouts for a job as the physics sports commentator. The physics sports commentator will be handed the microphone during a broadcast and will have to explain some of the sports action as examples of physics principles. To actually get this kind of job, physics content knowledge is necessary. The commentator will also have to be entertaining, articulate, and enthusiastic.

How do the students get started on the *Chapter Challenge*? How can they complete such a challenge without the necessary physics knowledge? Students are introduced to the physics they can use to complete the challenge on a need-to-know basis. This is what makes *Active Physics* unique.

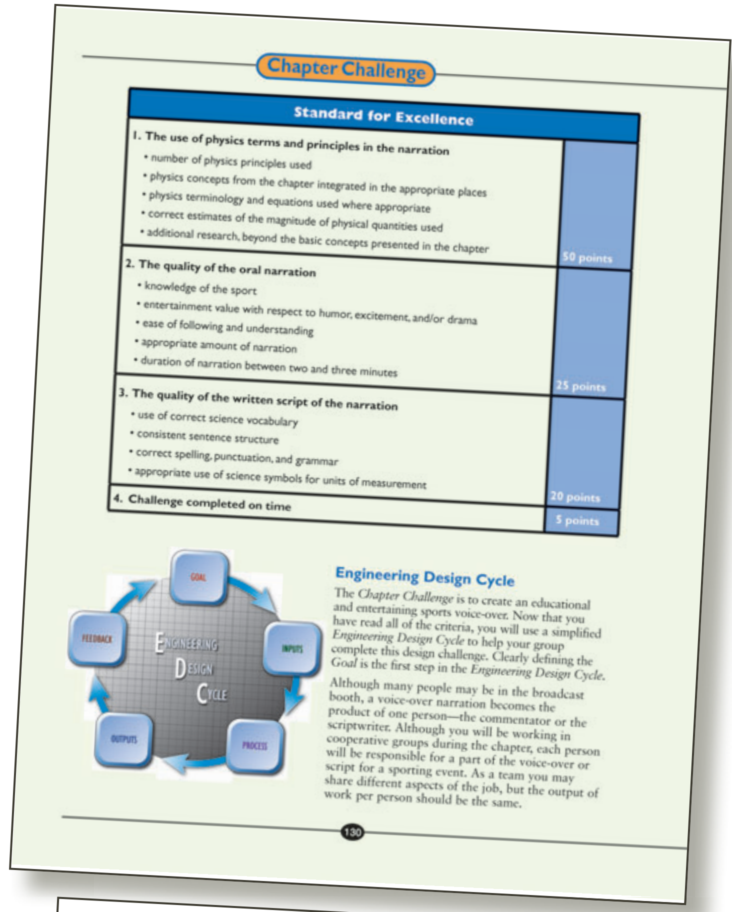
Before beginning any of the chapter, have your class discuss the *Criteria for Success*. The class decides what is expected in an excellent physics broadcast and how each of these components will be graded. For instance, they may decide that the rubric for grading will include the following factors:

- the use of physics terms and principles in the narration, including the number of physics principles and the use of equations when appropriate
- the quality of the oral narration, including the entertainment value
- the quality of the written script of the narration

Students will also need to decide whether each factor carries equal weight, or if one has a greater impact. In this way, students will have a sense of what is required for an excellent presentation before they begin, as well as a sense of ownership. Later, they will revisit the criteria before their work on the challenge is finalized. They conclude this first day by reflecting on the *Engineering Design Cycle*, a strategy by which they can get a sense of how to proceed in accomplishing this challenge.

The second day begins with the first of nine sections. As one section is completed, the next one starts. Each section includes all parts of the 7E instructional model, including an opportunity to **elicit** students' prior understanding while **engaging** them, to **explore** a physical phenomenon prior to **explaining** that concept and then **elaborating** on related physics. The students then **extend** that knowledge as they transfer their learning to the *Chapter Challenge*. You and the students will **evaluate** throughout the section. *Active Physics* is an inquiry-based curriculum— students always explore before they explain (ABC = Activity Before Concept).

For example, look at *Section 1 Newton's First Law: A Running Start*. Each section begins with a cartoon, which you can use to introduce some of the aspects that will follow in the section. More importantly, the cartoon is used to begin to engage the interests of the students with a simple *What Do You See?* question. Student answers to this question need not be correct or even relevant to physics, but it is important that they provide some response to the question. Research has found that all students, including those with special needs or English-language learners, can respond to the *What Do You See?* Students become engaged, which provides you the first opportunity to elicit their prior understanding.


Chapter Challenge

Standard for Excellence	
1. The use of physics terms and principles in the narration • number of physics principles used • physics concepts from the chapter integrated in the appropriate places • physics terminology and equations used where appropriate • correct estimates of the magnitude of physical quantities used • additional research, beyond the basic concepts presented in the chapter	50 points
2. The quality of the oral narration • knowledge of the sport • entertainment value with respect to humor, excitement, and/or drama • ease of following and understanding • appropriate amount of narration • duration of narration between two and three minutes	25 points
3. The quality of the written script of the narration • use of correct science vocabulary • consistent sentence structure • correct spelling, punctuation, and grammar • appropriate use of science symbols for units of measurement	20 points
4. Challenge completed on time	5 points

Engineering Design Cycle

The *Chapter Challenge* is to create an educational and entertaining sports voice-over. Now that you have read all of the criteria, you will use a simplified *Engineering Design Cycle* to help your group complete this design challenge. Clearly defining the *Goal* is the first step in the *Engineering Design Cycle*.

Although many people may be in the broadcast booth, a voice-over narration becomes the product of one person—the commentator or the scriptwriter. Although you will be working in cooperative groups during the chapter, each person will be responsible for a part of the voice-over or script for a sporting event. As a team you may share different aspects of the job, but the output of work per person should be the same.

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Chapter 2 Physics in Action

Section 1 Newton's First Law: A Running Start

What Do You See?

Learning Outcomes

In this section, you will
- **Describe** Galileo's law of inertia.
- **Apply** Newton's first law of motion.
- **Recognize** inertial mass as a physical property of matter.
- **Use** examples to demonstrate that speed is always relative to some other object.
- **Explain** that the speed of an object depends on the reference frame from which it is being observed.

What Do You Think?

Every sport includes moving objects or people or both. That is what makes sports entertaining.

- How do figure skaters keep moving across the ice at high speeds for long times while seeming to expend no effort?
- Why does a soccer ball continue to roll across the field after it has been kicked?

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

Investigate

In this *Investigate*, you will use a track and a ball to explore the question, "When a ball is released to roll down a track and up the opposite side of the track, how does the vertical height that the ball reaches on the opposite side of the track relate to the vertical height from which the ball is released?"

1. Make a track that has the same slope on both sides, as shown in the diagram on the next page. Your teacher will suggest how high the ends of the track sections should be.

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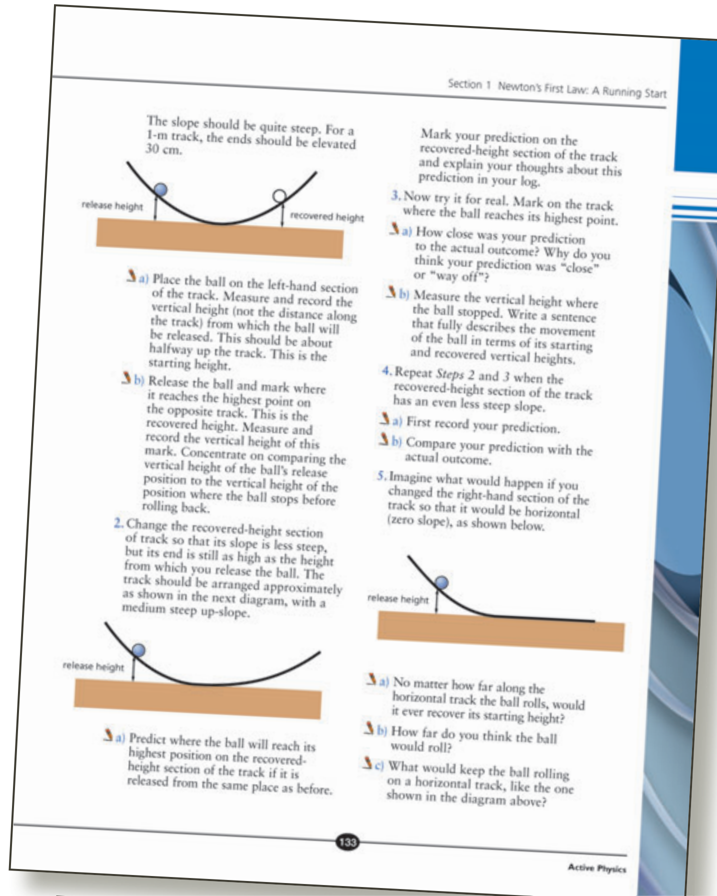
This is followed by the *What Do You Think?* question, "Why does a soccer ball continue to roll across the field after it has been kicked?" This question is intended to further elicit their prior understanding. If you listen intently and ask follow-up questions, students' prior understanding will come to the surface. This is not intended as an opportunity to correct students, but rather an opportunity to find out "what the student thinks." At the end of the section, after the students explore and gather evidence from that investigation to answer questions, you will return to this as a *What Do You Think Now?* question. That is the appropriate time to help students with confusions or inconsistencies in their responses. The *What Do You Think?* questions are directly related to the physics principles of this section – Newton's first law. Formally, you can say that these questions elicit the students' prior understanding and are part of the constructivist approach. Typically, students write a response for one minute, followed by two minutes of discussion. But you should not try to reach closure here. The questions are designed to open up the conversation.

The students then begin the *Investigate* where they will observe and measure a ball rolling along a u-shaped ramp. They will record how high the ball goes on the far side. They will use the evidence from their observations and, following reasoning similar to that of Galileo's, come to the conclusion that a ball rolling on a flat surface would continue to roll forever if friction were somehow eliminated.

Physics Talk summarizes the physics principles and provides some historical background to enhance the experience. It also presents students with text, illustrations, and photographs that provide greater insight into the physics concepts. Words that may be new or unfamiliar to students are **boldfaced**. To provide reading support, they are also defined and explained in the margin as *Physics Words*. The *Checking Up* questions at the end of the reading are designed to guide students toward the key concepts of the text. The *Physics Talk* section is most similar to the traditional textbook explanation of physics. A typical text assumes that students have observed a ball rolling across a table, while *Active Physics* ensures that all students have had a common, hands-on experience with which to build conceptual and mathematical understanding. What makes *Physics Talk* unique is that the explanations refer back to investigations and experiences that students assuredly had.


Section 1 Newton's First Law: A Running Start

The slope should be quite steep. For a 1-m track, the ends should be elevated 30 cm.

a) Place the ball on the left-hand section of the track. Measure and record the vertical height (not the distance along the track) from which the ball will be released. This should be about halfway up the track. This is the starting height.

b) Release the ball and mark where it reaches the highest point on the opposite track. This is the recovered height. Measure and record the vertical height of this mark. Concentrate on comparing the vertical height of the ball's release position to the vertical height of the position where the ball stops before rolling back.

2. Change the recovered-height section of track so that its slope is less steep, but its end is still as high as the height from which you release the ball. The track should be arranged approximately as shown in the next diagram, with a medium steep up-slope.

a) Predict where the ball will reach its highest position on the recovered-height section of the track if it is released from the same place as before. Mark your prediction on the recovered-height section of the track and explain your thoughts about this prediction in your log.

3. Now try it for real. Mark on the track where the ball reaches its highest point.

a) How close was your prediction to the actual outcome? Why do you think your prediction was "close" or "way off"?

b) Measure the vertical height where the ball stopped. Write a sentence that fully describes the movement of the ball in terms of its starting and recovered vertical heights.

4. Repeat *Steps 2* and *3* when the recovered-height section of the track has an even less steep slope.

a) First record your prediction.

b) Compare your prediction with the actual outcome.

5. Imagine what would happen if you changed the right-hand section of the track so that it would be horizontal (zero slope), as shown below.

a) No matter how far along the horizontal track the ball rolls, would it ever recover its starting height?

b) How far do you think the ball would roll?

c) What would keep the ball rolling on a horizontal track, like the one shown in the diagram above?

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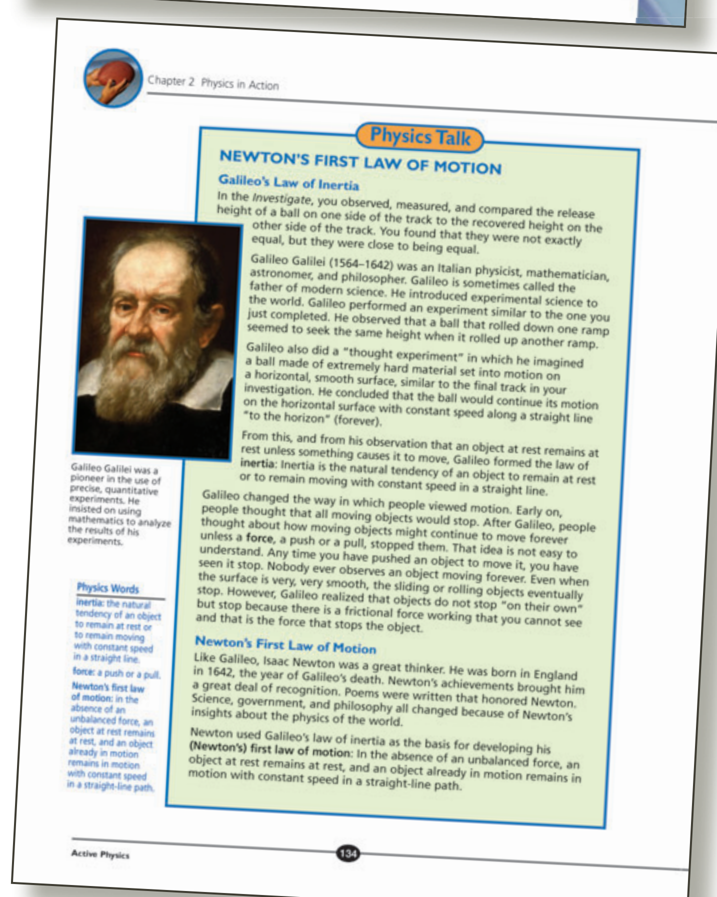
Active Physics


Chapter 2 Physics in Action

Physics Talk

NEWTON'S FIRST LAW OF MOTION

Galileo's Law of Inertia

In the *Investigate*, you observed, measured, and compared the release height of a ball on one side of the track to the recovered height on the other side of the track. You found that they were not exactly equal, but they were close to being equal.

Galileo Galilei (1564–1642) was an Italian physicist, mathematician, astronomer, and philosopher. Galileo is sometimes called the father of modern science. He introduced experimental science to the world. Galileo performed an experiment similar to the one you just completed. He observed that a ball that rolled down one ramp seemed to seek the same height when it rolled up another ramp.

Galileo also did a "thought experiment" in which he imagined a ball made of extremely hard material set into motion on a horizontal, smooth surface, similar to the final track in your investigation. He concluded that the ball would continue its motion on the horizontal surface with constant speed along a straight line "to the horizon" (forever).

From this, and from his observation that an object at rest remains at rest unless something causes it to move, Galileo formed the law of **inertia**: Inertia is the natural tendency of an object to remain at rest or to remain moving with constant speed in a straight line.

Galileo changed the way in which people viewed motion. Early on, people thought that all moving objects would stop. After Galileo, people thought about how moving objects might continue to move forever unless a **force**, a push or a pull, stopped them. That idea is not easy to understand. Any time you have pushed an object to move it, you have seen it stop. Nobody ever observes an object moving forever. Even when the surface is very, very smooth, the sliding or rolling objects eventually stop. However, Galileo realized that objects do not stop "on their own" but stop because there is a frictional force working that you cannot see and that is the force that stops the object.

Newton's First Law of Motion

Like Galileo, Isaac Newton was a great thinker. He was born in England in 1642, the year of Galileo's death. Newton's achievements brought him a great deal of recognition. Poems were written that honored Newton. Science, government, and philosophy all changed because of Newton's insights about the physics of the world.

Newton used Galileo's law of inertia as the basis for developing his **(Newton's) first law of motion**: In the absence of an unbalanced force, an object at rest remains at rest, and an object already in motion remains in motion with constant speed in a straight-line path.

Galileo Galilei was a pioneer in the use of precise, quantitative experiments. He insisted on using mathematics to analyze the results of his experiments.

Physics Words

inertia: the natural tendency of an object to remain at rest or to remain moving with constant speed in a straight line.

force: a push or a pull.

Newton's first law of motion: in the absence of an unbalanced force, an object at rest remains at rest, and an object already in motion remains in motion with constant speed in a straight-line path.

Active Physics

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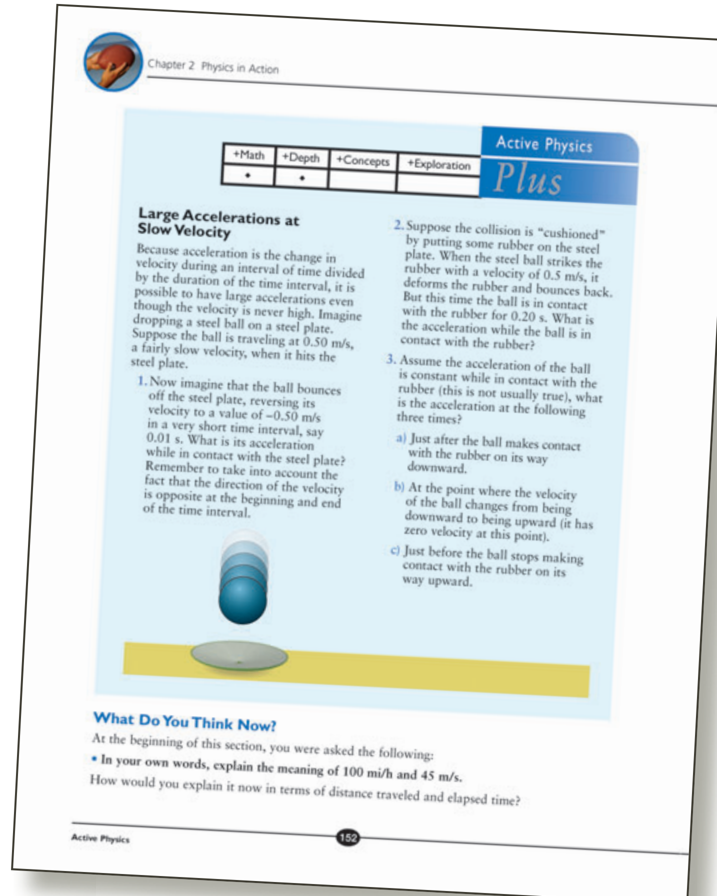
In any physics class, there will always be students with a range of interests, mathematical abilities, and motivation. In *Active Physics*, a program which provides access for all high school students, there will be an even wider range of students along these dimensions. This is why we introduce *Active Physics Plus* in each section. This section provides additional explorations, deeper analysis, more mathematics, or more content for some students. You can assign this to students who finish earlier than others, or suggest that students complete this for extra credit. It provides a way to keep all students engaged, while providing some students with more support on the concepts introduced earlier.

What Do You Think Now? revisits the original *What Do You Think?* questions and provides an opportunity for students to reflect on any changes in understanding. You can use this exercise in a similar manner with a written response in the *Active Physics* log, followed by a short classroom discussion.

One of the inherent difficulties in learning physics is connecting the new content to larger concepts that form the skeletal structure of physics, and that distinguish science from other disciplines. *Active Physics* helps students to see both the trees and the forest by focusing on the *Physics Essential Questions*. Students are asked, “What does it mean?” of one of the concepts introduced in the section. This is similar to the questions that are typically asked of students. Students are then asked to respond to “How do you know?” In response to this question, students refer back to some observational or experimental evidence that they have observed in the section. Students are then asked, “Why do we believe?” This takes one of three forms, which help students better understand how physicists view their discipline. Students are shown how the concept introduced in this section connects with other physics content, fits with the “big ideas in science,” and meets physics requirements, such as experimental evidence being consistent with models and theories. Finally, students are asked, “Why should I care?” Research has shown that student success is strongly correlated with student engagement. By asking students why they should care, they are required to connect the relevance of this section’s physics concepts to the *Chapter Challenge*.

Reflecting on the Activity and the Challenge provides a brief summary of the section and again relates the section to the larger challenge of creating a voice-over narration for a sporting event.



Chapter 2 Physics in Action

Active Physics Plus

+Math	+Depth	+Concepts	+Exploration
•	•		

Large Accelerations at Slow Velocity

Because acceleration is the change in velocity during an interval of time divided by the duration of the time interval, it is possible to have large accelerations even though the velocity is never high. Imagine dropping a steel ball on a steel plate. Suppose the ball is traveling at 0.50 m/s, a fairly slow velocity, when it hits the steel plate.

1. Now imagine that the ball bounces off the steel plate, reversing its velocity to a value of −0.50 m/s in a very short time interval, say 0.01 s. What is its acceleration while in contact with the steel plate? Remember to take into account the fact that the direction of the velocity is opposite at the beginning and end of the time interval.

2. Suppose the collision is “cushioned” by putting some rubber on the steel plate. When the steel ball strikes the rubber with a velocity of 0.5 m/s, it deforms the rubber and bounces back. But this time the ball is in contact with the rubber for 0.20 s. What is the acceleration while the ball is in contact with the rubber?

3. Assume the acceleration of the ball is constant while in contact with the rubber (this is not usually true), what is the acceleration at the following three times?

a) Just after the ball makes contact with the rubber on its way downward.

b) At the point where the velocity of the ball changes from being downward to being upward (it has zero velocity at this point).

c) Just before the ball stops making contact with the rubber on its way upward.

What Do You Think Now?

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

- **In your own words, explain the meaning of 100 mi/h and 45 m/s.**

How would you explain it now in terms of distance traveled and elapsed time?

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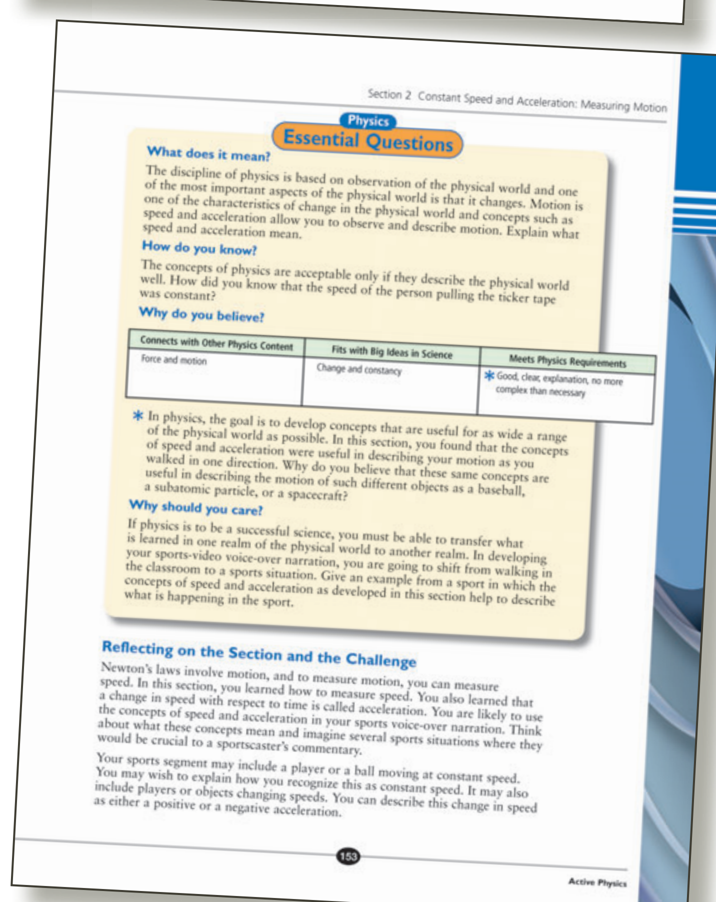

Section 2 Constant Speed and Acceleration: Measuring Motion

Physics Essential Questions

What does it mean?

The discipline of physics is based on observation of the physical world and one of the most important aspects of the physical world is that it changes. Motion is one of the characteristics of change in the physical world and concepts such as speed and acceleration allow you to observe and describe motion. Explain what speed and acceleration mean.

How do you know?

The concepts of physics are acceptable only if they describe the physical world well. How did you know that the speed of the person pulling the ticker tape was constant?

Why do you believe?

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

* In physics, the goal is to develop concepts that are useful for as wide a range of the physical world as possible. In this section, you found that the concepts of speed and acceleration were useful in describing your motion as you walked in one direction. Why do you believe that these same concepts are useful in describing the motion of such different objects as a baseball, a subatomic particle, or a spacecraft?

Why should you care?

If physics is to be a successful science, you must be able to transfer what is learned in one realm of the physical world to another realm. In developing your sports-video voice-over narration, you are going to shift from walking in the classroom to a sports situation. Give an example from a sport in which the concepts of speed and acceleration as developed in this section help to describe what is happening in the sport.

Reflecting on the Section and the Challenge

Newton’s laws involve motion, and to measure motion, you can measure speed. In this section, you learned how to measure speed. You also learned that a change in speed with respect to time is called acceleration. You are likely to use the concepts of speed and acceleration in your sports voice-over narration. Think about what these concepts mean and imagine several sports situations where they would be crucial to a sportscaster’s commentary.

Your sports segment may include a player or a ball moving at constant speed. You may wish to explain how you recognize this as constant speed. It may also include players or objects changing speeds. You can describe this change in speed as either a positive or a negative acceleration.

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The section continues with a *Physics to Go* homework assignment. Here, students are asked about the specifics of the investigation and required to apply their knowledge of physics principles to new situations. Often, the homework will include an additional investigation, *Preparing for the Chapter Challenge*, which provides students with the chance to do some background work toward their final challenge.

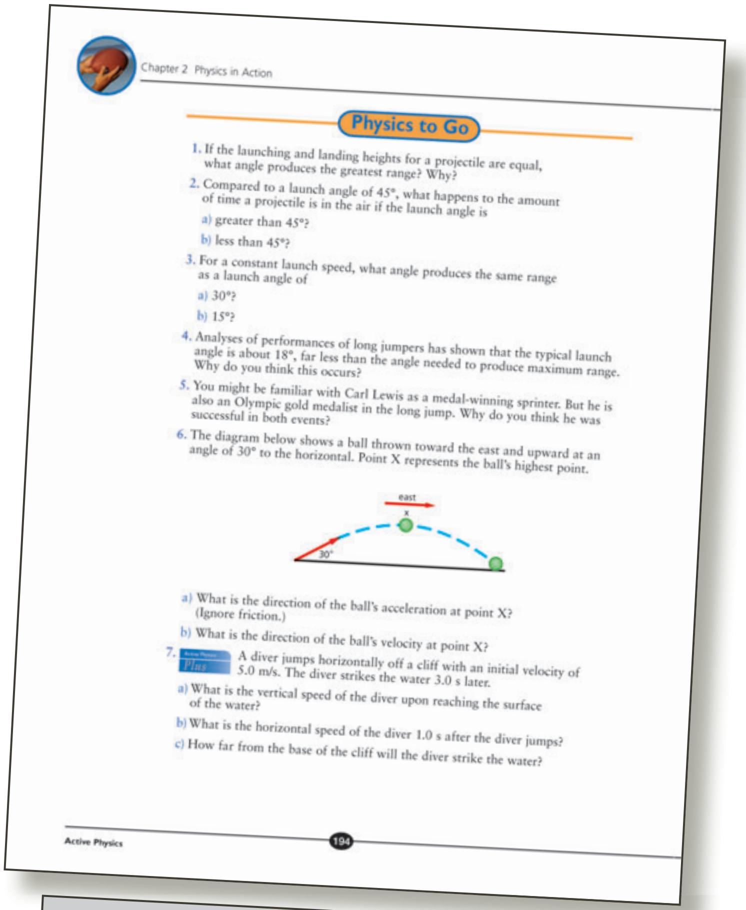
Following the *Physics to Go* homework, many sections have *Inquiring Further* exercises. These exercises often require students to design and carry out an experiment. Typically, the *Inquiring Further* option will be more challenging and can be used for extra credit.

The chapter continues through additional sections where students are introduced to other physics concepts, such as Newton's second law and projectile motion.

In the middle of each chapter, you will find a *Chapter Mini-Challenge*. This provides the students an opportunity to try out one or two of the physics principles that they are considering using for their challenge – the voice-over narration of a sporting event. Students get a first opportunity to gauge the difficulty of the challenge. They also get to see how other teams are approaching the *Chapter Challenge*. They get to receive and provide feedback on their *Mini-Challenge*. Having this chance to see what works and what doesn't work makes the final challenge that much more successful. Such feedback is important for the *Engineering Design Cycle*.

The *Chapter Challenges* that the students complete are often a part of an actual job by real people. *Physics At Work* introduces the students to these people who use the physics in the chapter as part of their careers. Reading about their lives and jobs brings another facet of the importance of physics to students and may get them thinking about their own future career. As student-scientists, they are also encouraged through the *Physics Connections to Other Sciences* to appreciate the connections among various sciences to achieve a more in-depth understanding of nature.

The *Chapter Assessment* is framed around the *Engineering Design Cycle* and begins with a review of the sections and the key concepts. Then, it outlines the steps that the students may follow in completing the challenge. The chapter concludes as the students present one of their voice-over narrations to the class. Before the students present their voice-over narrations



Chapter 2 Physics in Action

Physics to Go

1. If the launching and landing heights for a projectile are equal, what angle produces the greatest range? Why?
2. Compared to a launch angle of 45°, what happens to the amount of time a projectile is in the air if the launch angle is
   a) greater than 45°?
   b) less than 45°?
3. For a constant launch speed, what angle produces the same range as a launch angle of
   a) 30°?
   b) 15°?
4. Analyses of performances of long jumpers has shown that the typical launch angle is about 18°, far less than the angle needed to produce maximum range. Why do you think this occurs?
5. You might be familiar with Carl Lewis as a medal-winning sprinter. But he is also an Olympic gold medalist in the long jump. Why do you think he was successful in both events?
6. The diagram below shows a ball thrown toward the east and upward at an angle of 30° to the horizontal. Point X represents the ball's highest point.

   a) What is the direction of the ball's acceleration at point X? (Ignore friction.)
   b) What is the direction of the ball's velocity at point X?
7. A diver jumps horizontally off a cliff with an initial velocity of 5.0 m/s. The diver strikes the water 3.0 s later.
   a) What is the vertical speed of the diver upon reaching the surface of the water?
   b) What is the horizontal speed of the diver 1.0 s after the diver jumps?
   c) How far from the base of the cliff will the diver strike the water?

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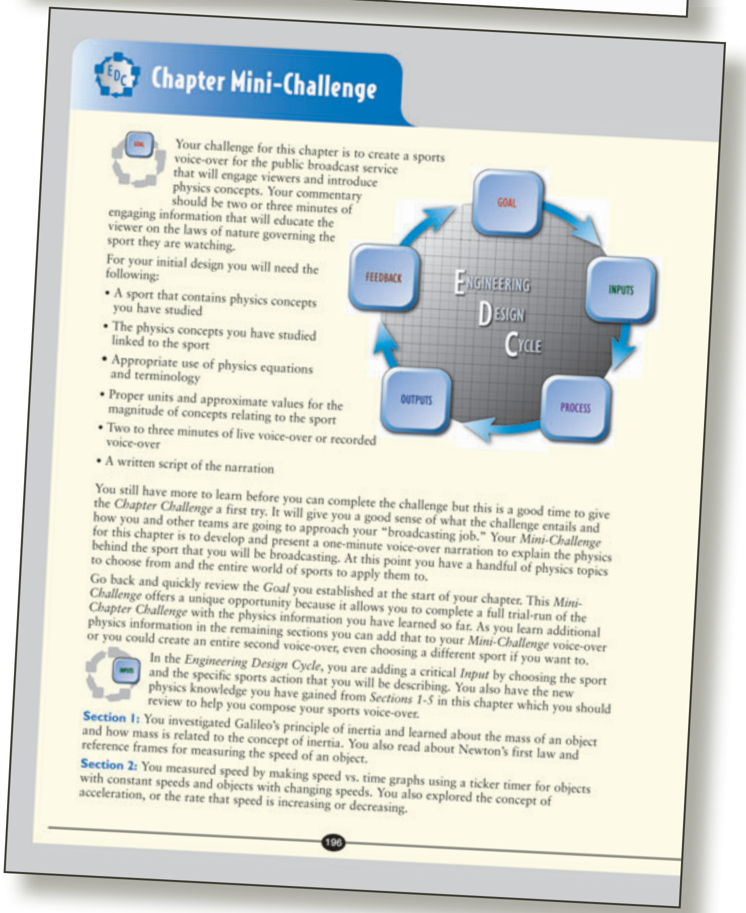

Chapter Mini-Challenge

Your challenge for this chapter is to create a sports voice-over for the public broadcast service that will engage viewers and introduce physics concepts. Your commentary should be two or three minutes of engaging information that will educate the viewer on the laws of nature governing the sport they are watching.

For your initial design you will need the following:

- A sport that contains physics concepts you have studied
- The physics concepts you have studied linked to the sport
- Appropriate use of physics equations and terminology
- Proper units and approximate values for the magnitude of concepts relating to the sport
- Two to three minutes of live voice-over or recorded voice-over
- A written script of the narration

You still have more to learn before you can complete the challenge but this is a good time to give the *Chapter Challenge* a first try. It will give you a good sense of what the challenge entails and how you and other teams are going to approach your "broadcasting job." Your *Mini-Challenge* for this chapter is to develop and present a one-minute voice-over narration to explain the physics behind the sport that you will be broadcasting. At this point you have a handful of physics topics to choose from and the entire world of sports to apply them to.

Go back and quickly review the *Goal* you established at the start of your chapter. This *Mini-Challenge* offers a unique opportunity because it allows you to complete a full trial-run of the *Chapter Challenge* with the physics information you have learned so far. As you learn additional physics information in the remaining sections you can add that to your *Mini-Challenge* voice-over or you could create an entire second voice-over, even choosing a different sport if you want to.

In the *Engineering Design Cycle*, you are adding a critical *Input* by choosing the sport and the specific sports action that you will be describing. You also have the new physics knowledge you have gained from *Sections 1-5* in this chapter which you should review to help you compose your sports voice-over.

Section 1: You investigated Galileo's principle of inertia and learned about the mass of an object and how mass is related to the concept of inertia. You also read about Newton's first law and reference frames for measuring the speed of an object.

Section 2: You measured speed by making speed vs. time graphs using a ticker timer for objects with constant speeds and objects with changing speeds. You also explored the concept of acceleration, or the rate that speed is increasing or decreasing.

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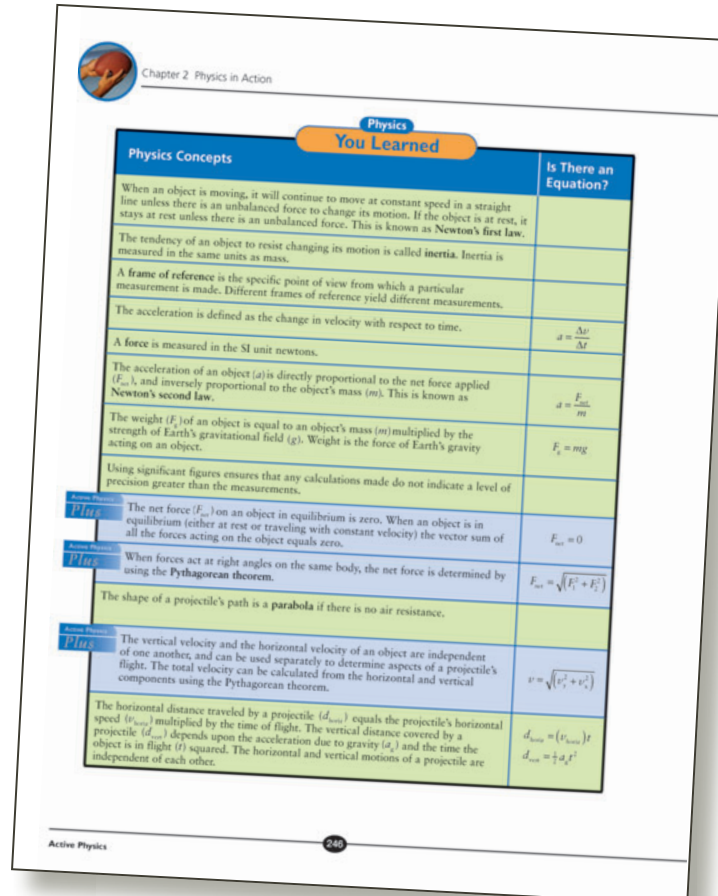
to the class for the *Chapter Challenge*, the *Criteria* should be reviewed by the class and finalized. The final summation is titled *Physics You Learned* and lists key concepts from the chapter in the meaningful context of a sentence. Presenting the *Chapter Challenge* has the following important learning outcomes:

- Students review and increase their learning of the physics concepts in preparation for completing the challenge.
- Students get to review each concept in different contexts as they observe other teams present.
- Students are motivated because they are engaged in the creative aspects of the *Chapter Challenge*.
- Students demonstrate their expertise of how they have found ways to relate physics to their personal challenge execution.
- Students can help achieve equity in that students of different backgrounds and cultures can provide insights into their backgrounds through their *Chapter Challenge*.

In addition to the *Chapter Challenge* assessment, traditional assessment questions and problems are also provided in the *Physics Practice Test*. This is in addition to the hundreds of traditional questions and problems in each section. Students are reminded of these when the *Physics Practice Test* is presented.



Chapter 2 Physics in Action

Physics You Learned

Physics Concepts	Is There an Equation?
When an object is moving, it will continue to move at constant speed in a straight line unless there is an unbalanced force to change its motion. If the object is at rest, it stays at rest unless there is an unbalanced force. This is known as **Newton's first law.**	
The tendency of an object to resist changing its motion is called **inertia.** Inertia is measured in the same units as mass.	
A **frame of reference** is the specific point of view from which a particular measurement is made. Different frames of reference yield different measurements.	
The acceleration is defined as the change in velocity with respect to time.	$a = \frac{\Delta v}{\Delta t}$
A **force** is measured in the SI unit newtons.	
The acceleration of an object (a) is directly proportional to the net force applied (F_{net}), and inversely proportional to the object's mass (m). This is known as **Newton's second law.**	$a = \frac{F_{net}}{m}$
The weight (F_g) of an object is equal to an object's mass (m) multiplied by the strength of Earth's gravitational field (g). Weight is the force of Earth's gravity acting on an object.	$F_g = mg$
Using significant figures ensures that any calculations made do not indicate a level of precision greater than the measurements.	
Active Physics Plus: The net force (F_{net}) on an object in equilibrium is zero. When an object is in equilibrium (either at rest or traveling with constant velocity) the vector sum of all the forces acting on the object equals zero.	$F_{net} = 0$
Active Physics Plus: When forces act at right angles on the same body, the net force is determined by using the **Pythagorean theorem.**	$F_{net} = \sqrt{(F_1^2 + F_2^2)}$
The shape of a projectile's path is a **parabola** if there is no air resistance.	
Active Physics Plus: The vertical velocity and the horizontal velocity of an object are independent of one another, and can be used separately to determine aspects of a projectile's flight. The total velocity can be calculated from the horizontal and vertical components using the Pythagorean theorem.	$v = \sqrt{(v_y^2 + v_x^2)}$
The horizontal distance traveled by a projectile (d_{horiz}) equals the projectile's horizontal speed (v_{horiz}) multiplied by the time of flight. The vertical distance covered by a projectile (d_{vert}) depends upon the acceleration due to gravity (a_g) and the time the object is in flight (t) squared. The horizontal and vertical motions of a projectile are independent of each other.	$d_{horiz} = (v_{horiz})t$ $d_{vert} = \frac{1}{2}a_g t^2$

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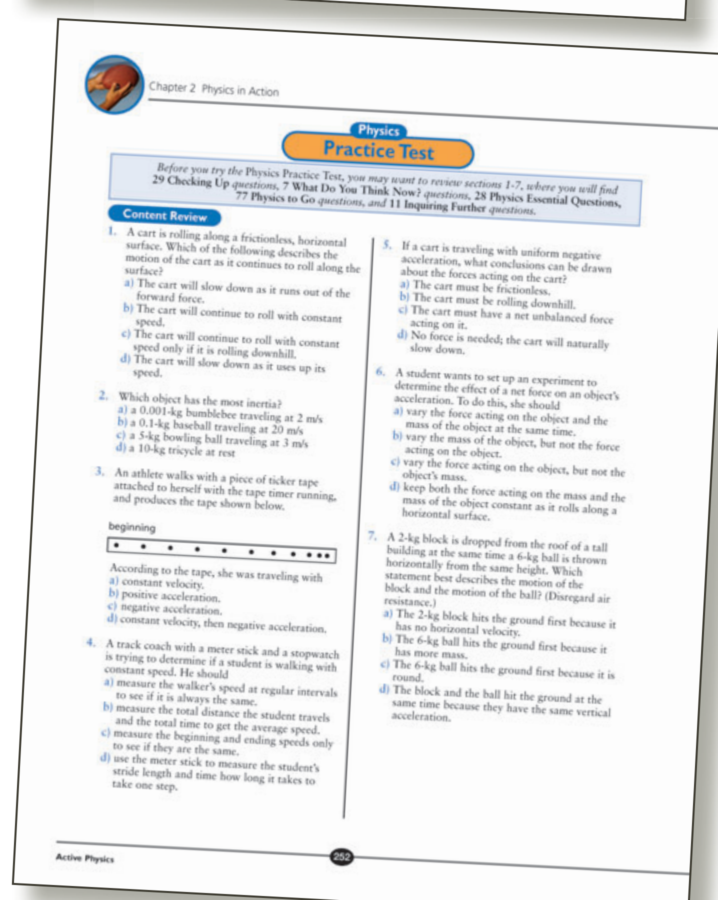

Chapter 2 Physics in Action

Physics Practice Test

Before you try the Physics Practice Test, *you may want to review sections 1-7, where you will find* **29 Checking Up** *questions,* **7 What Do You Think Now?** *questions,* **28 Physics Essential Questions, 77 Physics to Go** *questions, and* **11 Inquiring Further** *questions.*

Content Review

1. A cart is rolling along a frictionless, horizontal surface. Which of the following describes the motion of the cart as it continues to roll along the surface?
   a) The cart will slow down as it runs out of the forward force.
   b) The cart will continue to roll with constant speed.
   c) The cart will continue to roll with constant speed only if it is rolling downhill.
   d) The cart will slow down as it uses up its speed.
2. Which object has the most inertia?
   a) a 0.001-kg bumblebee traveling at 2 m/s
   b) a 0.1-kg baseball traveling at 20 m/s
   c) a 5-kg bowling ball traveling at 3 m/s
   d) a 10-kg tricycle at rest
3. An athlete walks with a piece of ticker tape attached to herself with the tape timer running, and produces the tape shown below.

   beginning

   According to the tape, she was traveling with
   a) constant velocity.
   b) positive acceleration.
   c) negative acceleration.
   d) constant velocity, then negative acceleration.
4. A track coach with a meter stick and a stopwatch is trying to determine if a student is walking with constant speed. He should
   a) measure the walker's speed at regular intervals to see if it is always the same.
   b) measure the total distance the student travels and the total time to get the average speed.
   c) measure the beginning and ending speeds only to see if they are the same.
   d) use the meter stick to measure the student's stride length and time how long it takes to take one step.
5. If a cart is traveling with uniform negative acceleration, what conclusions can be drawn about the forces acting on the cart?
   a) The cart must be frictionless.
   b) The cart must be rolling downhill.
   c) The cart must have a net unbalanced force acting on it.
   d) No force is needed; the cart will naturally slow down.
6. A student wants to set up an experiment to determine the effect of a net force on an object's acceleration. To do this, she should
   a) vary the force acting on the object and the mass of the object at the same time.
   b) vary the mass of the object, but not the force acting on the object.
   c) vary the force acting on the object, but not the object's mass.
   d) keep both the force acting on the mass and the mass of the object constant as it rolls along a horizontal surface.
7. A 2-kg block is dropped from the roof of a tall building at the same time a 6-kg ball is thrown horizontally from the same height. Which statement best describes the motion of the block and the motion of the ball? (Disregard air resistance.)
   a) The 2-kg block hits the ground first because it has no horizontal velocity.
   b) The 6-kg ball hits the ground first because it has more mass.
   c) The 6-kg ball hits the ground first because it is round.
   d) The block and the ball hit the ground at the same time because they have the same vertical acceleration.

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Features of Active Physics

1. Scenario

Each *Active Physics* chapter opens with an engaging scenario. Students from diverse backgrounds and localities have been interviewed in order to find situations that are not only realistic, but meaningful to the high school population. The scenarios set the stage for the description of the *Chapter Challenge* that immediately follows. You may choose to read the *Scenario* aloud to the class as a way of introducing the new chapter.

2. Your Challenge

The *Chapter Challenges* are the heart and soul of *Active Physics*. They provide students with a purpose for all of the work to follow and the rationale for learning. One of the most common questions that teachers hear from students is, "Why am I learning this?" In *Active Physics*, students do not raise this question. Similarly, you do not have to answer, "Because someday it will be useful to you." The question is already answered because, on day one of the chapter, students are presented with a challenge that, in essence, becomes their job for the next few weeks.

The beauty of the challenges lies in the variety of tasks and opportunities that allows students with different talents and skills to excel. Students who express themselves artistically will have an opportunity to shine in a chapter such as *Atoms on Display*. Students who enjoy sports may find *Physics in Action* a favorite. Other students who enjoy being "on-stage" may find their niche with *Let Us Entertain You*.

The challenges are not contrived situations. For example, engineers who build roller-coasters base their designs on the same physics principles students will learn in *Thrills and Chills*. Students' challenge in *Electricity for Everyone* is to address housing and electricity needs for families in different areas throughout the world. The challenge in *Sports on the Moon* requires students to create, invent, or adapt a sport that can be played on the Moon. This challenge has been successfully completed by ninth-grade high school students, twelfth-grade students, and by NASA engineers. The expectation may be different for each of these audiences, but the challenge is consistent.

3. Criteria for Success

In creating *Active Physics*, the original thought was that the generation of the challenge was enough and that all else would fall in place. Upon reflection, it was soon realized that the *Criteria for Success* must also be included. When students agree to the matrix by which their work will be measured, research has shown that the students will perform better and achieve more. It makes sense. In the simplest situation of cleaning a lab room, the teacher may simply state, "Please clean up the lab." The results are often a minimal cleanup. If the teacher begins by asking, "What does a clean lab room look like?" and students and teacher jointly list the attributes of a clean lab room (e.g., no paper on the floor, all equipment put away, all materials placed on the back of the lab tables, and all power supplies unplugged), the students respond differently and the cleanup is better. When students are asked to include physics principles in the explanation of the challenge, the students should know whether the expectation is for three physics principles or five.

The discussion of grading criteria and the creation of a grading rubric is a crucial ingredient for student success. After the introduction of the challenge, *Active Physics* requires a class discussion about the grading criteria. How much is required? What does an "A" challenge product look like? Should creativity be weighed more than delivery? The criteria will be visited again at the end of the chapter, but at this point it provides clarity to the challenge and helps establish an expectation level that the students will have set for themselves.

4. Engineering Design Cycle

Students are introduced to the *Engineering Design Cycle* to help them solve the problems necessary to successfully complete the *Chapter Challenge*. They will implement the five basic steps of the cycle (Goal, Inputs, Process, Outputs, and Feedback) throughout the chapter, culminating in the completion of the *Chapter Challenge*. Once students are presented with their challenge, they begin the first step of the cycle, which is to establish a clear Goal. Their Goal is established by defining the problem, identifying available resources, drafting potential solutions, and listing constraints and possible actions. As they experience each one of the chapter sections, they will be gaining Inputs to use in the design cycle. At the midway point of the chapter, students will get an opportunity to test their ideas and their approach to the challenge by completing the *Mini-Challenge*. Their *Mini-Challenge* will be their Output for the design cycle, and will also provide them with Feedback about which parts need to be refined. Students will repeat the *Engineering Design Cycle* during the second half of the chapter to help them prepare for the *Chapter Challenge*.

5. Physics Corner

The physics content in each chapter is summarized in a preview cartoon. The cartoon shows the students focused on the investigations and the challenge while the teacher sees the physics that the students will learn. The *Physics Corner* acts as a preview of all the physics concepts the chapter will present.

6. What Do You See?

A cartoon introduces each section and asks the question "*What Do You See?*" The students are given a humorous preview of some of the concepts and activities that the section will provide. You can use this to engage the students' attention and interest in the section. From the discussion, you can also observe what the students already know about the topics. It is not important that student responses are correct or completely relevant.

7. What Do You Think?

During the past few years, much has been written about a constructivist approach to learning. Videos of Harvard graduates, in caps and gowns, show that the students are not able to explain correctly why it is colder in the winter than it is in the summer. These students have previously answered these questions correctly in fourth grade, in middle school, and then again in high school. How else would they have gotten into Harvard? One theory for this is that they never internalized the logic and understanding of the seasons. Part of this problem is that they were never confronted by what they did believe, and were never adequately shown why they should give up that belief system. Certainly, it is worth writing down a "book's perfect answer" on a test to secure a good grade, but to actually believe requires a more thorough examination of competing explanations.

The best way to ascertain a student's prior understanding is through extensive interviewing. Much of the research literature in this area includes the results of such interviews. In a classroom, however, this one-on-one dialogue is rarely possible. The *What Do You Think?* question introduces each section in a way that elicits prior understandings. It gives students an opportunity to verbalize what they think about friction, energy, or light, before they embark on an investigation. The brief discussion of the range of answers brings the students a little closer with that part of their brains which understands friction, energy, or light. The *What Do You Think?* question is not intended to produce a correct answer or a discussion of the features of each question. It is not intended that you bring the discussion to closure. The *Investigate* that follows will provide that discussion as experimental results are analyzed. The *What Do You Think?* question should take no more than a few minutes of class time. It sets the stage for the physics investigation.

Students should be strongly encouraged to write their responses to the questions in their *Active Physics* logs to ensure that they have, in fact, addressed their prior conceptions. After students have discussed their responses in their small groups, activate a class discussion. Ask students to volunteer other students' answers that they found interesting. This may encourage students to exchange ideas without the fear of personally giving a "wrong" answer.

8. Investigate

Active Physics is a hands-on, minds-on curriculum. Students *do* physics; they do not read about doing physics. Each *Investigate* has instructions for each step of the experiment. Students are reminded that data, hypotheses, and conclusions should be recorded in their logs.

Investigates are an opportunity for students to garner the knowledge that they will need to complete the *Chapter Challenge*. Students will understand the physics principle involved because they have investigated it. In *Active Physics*, if a student is asked, "How do you know?" the response is, "Because I did an experiment!"

Recognizing that many students know how to read, but do not like reading, background information is often provided within the context of the section. Students have demonstrated that they will read when the information is required for them to continue with their exploration.

Occasionally, the *Investigate* will require the entire class to participate in a large, single demonstration simultaneously. On other occasions, you may decide that a specific *Investigate* is best done as a teacher demonstration. This would be appropriate if there is limited equipment for that one *Investigate* or the facilities are not available for every student to do the *Investigate*. Viewing demonstrations on an ongoing basis, however, is not what *Active Physics* is about.

Icons throughout the *Investigates* alert students to safety issues that should be given full attention.


Students are reminded of all safety rules throughout the program. An overview of safety rules for the physics classroom, as well as a safety contract, is available at the end of the *Teacher's Edition* front matter, and is provided as a Blackline Master in your *Teacher Resources CD*.

Most of the *Investigates* require between one and two 45-minute class periods. Considering current trends in class scheduling, there are so many time structures that it is difficult to predict how *Active Physics* will best fit your schedule. The other impact on time is the achievement and preparation level of your students. For example, in a given *Investigate*, students may be required to complete a graph of their data. This is considered one small part of the *Investigate*. If the students have never been exposed to graphing, this could require a two-period lesson to teach the basics of graphing with suitable practice in interpretation. *Active Physics* is accessible to all students. You are in the best position to make accommodations in time that reflect the needs of your students.

9. Physics Talk

Sometimes it is difficult for students to make the conceptual leap from doing an investigation to connecting the ideas into a physics principle. Indeed, if you consider the theory of multiple intelligences, some students grasp concepts more easily by reading. *Physics Talk* summarizes the physics principles and includes physics formulas and equations when appropriate. It presents students with text, illustrations, historical perspective, and photographs that provide greater insight into the physics concepts presented. If sample problems or important laws are integral to the lesson, they can be found in the *Physics Talk*.

10. Physics Words

Science has a language of its own and some concepts are more efficiently communicated when vocabulary is introduced. Certainly, in order to fully participate in science, students need to have an understanding of this language. As a part of the *Physics Talk*, the *Physics Words* highlight the important terms for students. These words are pulled outside the text area and redefined. Such support helps students understand the process of learning as they note important ideas within the text. All *Physics Words* will also be found in the *Glossary*.

11. Checking Up

Another important part of the *Physics Talk* section is the *Checking Up* questions. Each *Physics Talk* ends with several of these questions about the section in the margins outside the text. Students can use these for self-examination to make certain that they understand the most important principles. In addition, you can assign these as homework or *Active Physics* log entries for students to answer as the *Physics Talk* section is read.

12. Active Physics Plus

Active Physics Plus is an opportunity to explore physics in a variety of ways. It provides text, sample problems, and questions for students who want or need more mathematics, depth, concepts, or exploration opportunities. As a teacher, you can use the *Active Physics Plus* to accommodate your state requirements and to guide individual students' instruction to meet appropriate personal challenges so that all students extend their knowledge and skills.

13. What Do You Think Now?

This section offers the students (and you) the opportunity to return to the *What Do You Think?* questions to informally assess changes in knowledge and understanding. This reflection is beneficial to both the students and to you. If you see widespread lapses in understanding, you may spend some time helping the students to understand. Otherwise, you may want to wait for the opportunity to use the spiraling design of the curriculum to foster greater understanding.

14. Physics Essential Questions

Physics can be a difficult study for many students and one of the reasons for this is the lack of organizing principles as it is traditionally taught. For many students, physics is a vast collection of unrelated facts which one needs to memorize for the test. *Active Physics* has developed four questions that capture the organizing principles of physics for the student and make understanding more accessible.

- What does it mean?
- How do you know?
- Why do you believe?
- Why should you care?

If the students can answer these four questions (and they can), then they will likely keep their newly learned principles and concepts forever.

The first essential question, "*What does it mean?*" requires students to describe the content of the section based on what they have learned in their investigation and reading.

The second essential question that the students are asked, "*How do you know?*" is answered by a description of the experimental evidence that they discovered during the *Investigate*. Students "know" because they have done an experiment.

The third essential question, "*Why do you believe?*" emphasizes one of three ideas ("Connects with Other Physics Content," "Fits with Big Ideas in Science," or "Meets Physics Requirements") to help students understand physics as it relates to the world outside the classroom.

Finally, the last question, "*Why should you care?*" requires students to make a direct line from the section to the *Chapter Challenge*. This serves two purposes: the students have an immediate need to know this information, and also to begin planning a response to the *Chapter Challenge*.

15. Reflecting on the Activity and the Challenge

At the close of each section, students are often so involved with the completion of the single experiment that the larger context of the investigation is lost. *Reflecting on the Activity and the Challenge* is an opportunity for students to place their new insights and information into the context of the chapter and the *Chapter Challenge*. If the *Chapter Challenge* is considered a completed picture, each section is a jigsaw-puzzle piece. By completing half of the sections, the students will be able to fit puzzle pieces together and complete the *Mini-Challenge*. This *Reflecting on the Activity and the Challenge* section ensures that the students do not forget about the larger context and continue their personal momentum toward completion of the *Chapter Challenge*.

16. Physics to Go

This section provides additional questions and problems that can be completed outside of class as homework. Some of the problems are applications of the principles involved in the preceding *Investigate*. Others are replications of the work in the *Investigate*. Still others provide an opportunity to transfer the results of the investigation to the context of the *Chapter Challenge*. The *Physics to Go* questions provide a means by which students can be working on the physics principles behind the larger *Chapter Challenge*. Often, the homework will include an additional activity, *Preparing for the Chapter Challenge*, which provides students with the chance to do some background work toward their final challenge. You may wish to assign these questions to the entire class or to those students who would benefit most from the extra work.

17. Inquiring Further

Following the *Physics to Go* homework, many sections have *Inquiring Further* exercises. These exercises often require students to design and carry out an experiment. Typically, the *Inquiring Further* option will be more challenging and can be used for extra credit.

The outcome of good science instruction should be the ability of students to transfer knowledge to a different problem or task. *Inquiring Further* exercises give students the opportunity to stretch their thinking beyond the textbook and classroom setting. This can be accomplished with a provocative question or problem to solve. Students can put into practice the technique, approaches, and knowledge they have acquired by completing the section and expand upon it to gain new information. The *Inquiring Further* exercises can be assigned as independent study or as a class extension to the investigation.

18. Chapter Mini-Challenge

As a part of a focus on the *Engineering Design Cycle*, you will find a *Chapter Mini-Challenge* in the middle of each chapter. This provides the students an opportunity to set some preliminary goals for their challenge. Using the input from the first four sections of the chapter, they spend some time on the process of integrating the input and goals to design a product for testing. The *Mini-Challenge* presentation serves as the output for their plan. They will receive feedback from the experience, the other students, and you. They will use this feedback later when they refine the design of their final product in the *Chapter Challenge*.

19. Physics You Learned

This section at the end of the chapter provides a list of physics concepts that were studied in the context of the *Investigates* and the *Physics Talk*. It provides students with a sense of accomplishment and serves as a quick review of all that was learned during the preceding weeks. Students can also use this list to select those physics principles which are appropriate for their *Chapter Challenge* project. When describing any physics phenomenon, student physicists should ask themselves, "Is there an equation?" As a reminder, the *Physics You Learned* also provides a checklist of all the equations used in each chapter.

20. Physics Chapter Challenge

The *Physics Chapter Challenge* is the return to the *Your Challenge*, *Criteria for Success,* and the *Engineering Design Cycle*. The students are now ready to complete the challenge. They are able to view the challenge with a clarity that has emerged from the completion of the *Investigates* in each section and the feedback from the *Mini-Challenge*. Students are able to review the chapter as they discuss the synthesis of the information into the required context of the challenge. They should have some class time to work together to complete the challenge and to present their project. In many physics courses, all students are expected to converge on the same solution. In *Active Physics*, each group is expected to have a unique solution. All solutions must have correct physics, but there is ample room for creativity on the students' part. This is one of the features that captures the imagination of students who have often previously chosen not to enroll in physics classes.

Business leaders want to hire people who know how to work effectively in groups and how to complete projects. The *Physics Chapter Challenge* provides guidance on how to begin work on the final *Chapter Challenge* product, to set deadlines, meet all the requirements, and combine the contributions of all members of the team. This section is intended to guide, rather than direct, the student work.
You will find that the best projects will reflect the diverse interests, backgrounds, and cultures of the team members.

21. Physics Connections to Other Sciences

The *Physics Connections to Other Sciences* highlights how the fundamental ideas students learn in each chapter relate to many of the other sciences students will study. By appreciating the connections among various science disciplines, scientists develop a more in-depth understanding of nature.

22. Physics At Work

This section highlights three individuals whose work or hobby is illustrative of the physics in the *Chapter Challenge*. The *Physics At Work* speaks to the authenticity of the challenge. The profiles show how interesting and useful physics is and how important it can be in a variety of careers, and people of all walks of life.

23. Physics Practice Test

The *Physics Practice Test* provides additional assessment opportunities in the format of the traditional state assessments. Students can use the *Physics Practice Test* as a gauge to find out how well they learned the physics contained in each chapter. Before beginning the test, students should be reminded to go back to their *Active Physics* logs and homework to review the hundreds of traditional questions and problems they have answered throughout the chapter in the form of the *Physics to Go*, *Checking Up*, *What Do You Think Now?*, and *Physics Essential Questions*.

Overview of Meeting the Needs of All Students: Differentiated Instruction

Using Augmentation and Accommodations

This feature is designed for you to help struggling students. Every section has its own table with specific information that identifies learning issues in the classroom. The table also gives the location of the issue within each component of a section and recommends instructional and management strategies for helping students compensate for their difficulties. Compensation techniques have been labeled "**Accommodations,**" and the teaching of skills has been labeled "**Augmentation.**"

To understand how augmentations and accommodations can be used as tools by teachers to help struggling students with each section, take an example from *Section 3* in *Safety*. Assume some students in the class find it difficult to follow complex multi-step directions. What will these students learn about energy and work when they cannot comprehend the specific directions embedded in the *Investigate*? Their confusion impedes learning and leads to the distraction of other students. To prevent this from happening, you can either provide the students with directions they can understand (accommodation) or teach them direction-following skills (augmentations).

Augmentation of prerequisite skills involves the direct teaching of the skill. In *Section 3*, *Investigate*, *Step 6*, you might take a group of students and show them how to measure indentations in the landing material for different heights from which an egg is dropped. The advantages of augmentation are that students begin to develop the skills they need to learn independently. The disadvantage is that other students who are allowed to move through an investigation independently will finish sooner, possibly losing interest or motivation as they wait. The best plan is to differentiate the investigation at that point, providing the independent students with a related *extension* or an *anchoring task* while the other students learn to read the directions. Extensions have been provided in the lesson under the heading of *Inquiring Further*. Anchoring tasks are those that can be done independently by everyone. For example, highlighting important aspects of the *Physics Talk* by creating an outline or recording new vocabulary and researching its meaning could serve as anchoring tasks for this lesson.

Accommodations for students have the advantage of allowing them to move along with the group using a teacher-provided scaffold. If students find it difficult to follow directions, you could place students with poor reading skills with other students who are better in that area. You could provide a different set of directions in which the language is simpler, each step is labeled, and a space is provided for the tasks required. The disadvantage of doing this is that a student will most likely need this accommodation for every set of directions until the skill is learned.

Introduction to Strategies for Students with Limited English-Language Proficiency

The *Strategies for Students with Limited English-Language Proficiency* augmentations allow you to adjust your teaching strategies and differentiate them for English-language learners. Language-learning skills that actively engage students in learning new science concepts are provided for each section. These skills are called augmentations because they augment existing frameworks of teaching and learning. To develop proficiency in understanding and using new words, students are given the opportunity to explore words in context. You are provided with language-building strategies that focus on unfamiliar words and help students meet the linguistic challenges of a particular topic. Also, the use of discussion as a means of broadening oral language experiences and bridging content development adds a richer dimension of learning for students and facilitates instruction. When you plan your lessons, you can consult the augmentations to determine where it would be best to incorporate these strategies.

Students' Prior Conceptions: Overview and 7E Tools

Research in cognitive learning and how students establish foundations for understanding science have identified various categories of student conceptions that are alternative frameworks for understanding science. Definitions for these categories are cited below:

Preconceived notions—Popular conceptions rooted in everyday experiences.

Example: Many people believe that water flowing underground must flow in streams because the water they see at Earth's surface flows in streams.

Nonscientific beliefs—Include views learned by students from sources other than scientific education, such as religious or mythical teachings.

Example: Some students have learned through religious instruction about an abbreviated history of Earth and its life forms. The disparity between this widely held belief and the scientific evidence for evolution, dating back to pre-historical times, has led to considerable controversy in the teaching of science.

Conceptual misunderstandings—Arise when students are taught scientific information in a way that does not motivate them to confront paradoxes and conflicts resulting from their own preconceived notions and nonscientific beliefs.

Example: To deal with their confusion, students construct faulty models that usually are so weak that the students themselves are insecure about the concepts.

Vernacular misconceptions—Arise from the use of words that mean one thing in everyday life and another in a scientific context (e.g., "work").

Example: A geology professor noted that students have difficulty with the idea that glaciers retreat, because they picture the glacier stopping, turning around, and moving in the opposite direction. Substitution of the word "melt" for "retreat" helps reinforce the correct interpretation that the front end of the glacier simply melts faster than the ice advances.

Factual misconceptions—False conceptions often learned at an early age and retained unchallenged into adulthood.

Example: The idea that "lightning never strikes twice in the same place" is clearly nonsense, but that notion may be buried somewhere in a student's belief system.

In order for teachers to break down student prior conceptions and align their knowledge to current theory they must:

- Identify students' prior knowledge.
- Provide a forum for students to confront their misconceptions.
- Help students reconstruct and internalize their knowledge, based on scientific models.

The *What Do You Think?* and *Investigates* and sections presented in *Active Physics* are designed so that teachers are informed about basic student prior knowledge and have the tools with which to break down alternative ideas that may be strongly held by students.

Each chapter of *Active Physics* identifies lists of commonly held student preconceptions and offers opportunities for students to test their conceptual ideas. Students continually are asked to explain their reasoning, which enables you to work with students to root out prior conceptions.

Active Physics uses a 7E learning-cycle model. The steps (phases) of the 7E learning cycle are Elicit, Engage, Explore, Explain, Elaborate, Extend, and Evaluate.

The Elicit, Explain, Elaborate, and Extend phases of this learning cycle offer valuable tools for you to interview students to ascertain if prior belief systems leading to misconceptions continue to exist. You have the opportunity to encourage students to compare their preconceptions with their data analysis of the Explore stage of the learning cycle. The critical question, "*Why do you believe?*" and the Evaluate phase enable students to root out personally held misconceptions and to align new conceptual knowledge with current scientific thinking. Constant and open classroom discussions are powerful tools when wielded wisely through the listening and evaluative ear of a classroom educator. The more you understand about how students learn, the more effective you become at crafting classroom interactions to deliver the most effective learning.

Pacing Guides for Teachers

The chart on the next page is intended to show the approximate number of weeks it will take for your class to cover each *Active Physics* chapter in either the standard or accelerated mode. Your pace may be slower or faster depending on a number of variables, including the grade level of the students and your experience in using the *Active Physics* curriculum. In addition, the accelerated column is intended to provide flexibility as a reduced-equipment option, as well as a reduced-time option. Which column you choose will depend upon the time available for your students to complete the work, the academic level of the students, and the equipment available. Columns A and B contain numbers for weeks and days for each chapter in a typical classroom. In general, the average time for each chapter is five and one-half weeks.

This chart is only intended to provide an overview of the time required for the entire year. For a more detailed description of what is suggested for each chapter, see the pacing guide for that chapter. Those guides include an outline of which investigations are recommended for your students to do. It is expected that as you gain experience with the program, fewer of the investigations will be teacher-centered and your students will do more of the investigations independently. It is recommended that you consult these pacing guides prior to making your decision about which chapters to include in your program. Based on an academic year of 180 days, or 36 weeks, you can cover about seven nonaccelerated chapters in a full year. Columns C, D, and E provide three examples using seven chapters in a school year. All of these examples can be completed within a 36-week academic calendar.

To cover all of the national standards, the first eight chapters are recommended. You should make selections based upon chapter content and alignment with state standards and your school's requirements. The table also provides an accelerated schedule covering eight or more chapters in the same 36-week school year. In columns F, G, and H, three examples are shown which use eight or nine chapters. Again, these schedules fit within a school year, allowing time for school events, testing periods, and other interruptions of the schedule.

Mixing accelerated and regular chapters would be another option for a teacher who may not be able to complete the chapters in the recommended time, but still wishes to complete the first eight chapters.

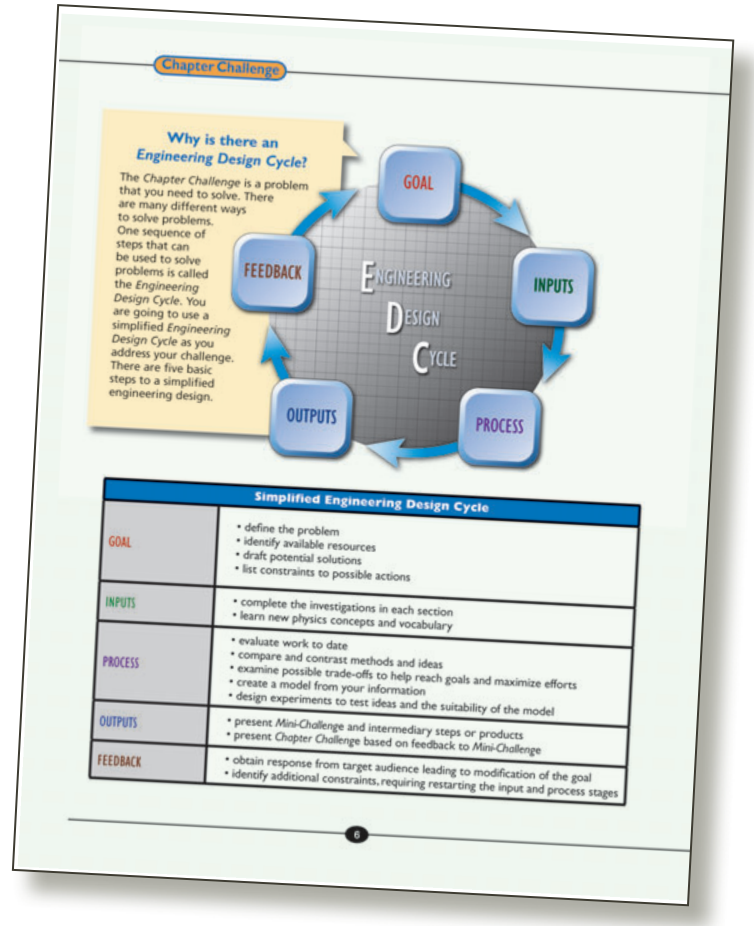
NOTES

Chapter	A Standard	B Accelerated	C Standard	D Standard	E Standard	F Accelerated	G Accelerated	H Accelerated
	# Weeks*	# Weeks*	Weeks (7 Chapters) Option 1	Weeks (7 Chapters) Option 2	Weeks (7 Chapters) Option 3	Weeks (8 Chapters) Option 1	Weeks (8 Chapters) Option 2	Weeks (9 Chapters) Option 3
1 Driving the Roads	5	4.5	5	5	5	4.5	4.5	4.0
2 Physics in Action	5.5	5	5.5	5.5		5.0		4.2
3 Safety	5	4	5		5	4.0	4.0	3.8
4 Thrills and Chills	6	5		5	5	5.0	5.0	4.2
5 Let Us Entertain You	6	5	5	5	5	5.0	5.0	4.4
6 Electricity for Everyone	5.5	4.5	5.5	5.5	5.5	4.5	4.5	4.0
7 Toys for Understanding	4	4	4			4.0	4.0	3.2
8 Atoms on Display	5	4.5	5	5	5	4.0	4.0	4.0
9 Sports on the Moon	5	4		5	5		5.0	3.6
	*Estimated number of weeks including class interruptions							
36 weeks available 180 day/school year		Total Weeks =	35	36	35.5	36	36	35.4

Engineering Design Cycle

Where can you add technology in your physics class? How can you possibly add more content to your cramped curriculum? What if you could add it in the form of a tool that helps students synthesize and present information more efficiently? The *Engineering Design Cycle* will provide a framework for completing the *Mini-Challenge* and the *Chapter Challenge*, while introducing students to the basics of engineering design. The *Engineering Design Cycle* information will show up three times during each chapter, guiding students through the problem-solving design process. The cycle will help to introduce each *Chapter Challenge*, it will be presented with each *Chapter Mini-Challenge*, and then will return to help guide students through their *Chapter Challenge* presentations to conclude each chapter. Consistent formatting for each chapter will help students acclimate quickly to the vocabulary and process of the *Engineering Design Cycle* so that it quickly becomes a tool instead of another requirement. Each iteration through the process will make students more comfortable with a structured way to solve their design challenges and increase the variety of ways they have to assemble the information they have learned.

The *Engineering Design Cycle* that is presented uses four simple steps to solve each design challenge in the *Active Physics* text. The four steps form the core of every *Engineering Design Cycle* and therefore will be familiar when students encounter it later in another setting. Each chapter will use INPUTS, PROCESS, OUTPUT, and FEEDBACK steps to help students use the information they have summarized in *What Do You Think Now?* responses and practiced in the *Physics to Go* questions during each chapter section. The steps will guide students to review and include the fundamental information from each section of the chapter. The PROCESS step will highlight a different critical thinking tool for the decision-making process to introduce students to a wide variety of tools that can be used to solve problems and arrive at conclusions. This step is the heart or engine of the *Engineering Design Cycle*. It is where most of the critical thinking must be done. There is not enough time to guide students through each and every decision-making step for each challenge, however by highlighting different tools during each one, students will have been exposed to many useful methods by the end of a typical school year.



Chapter Challenge

Why is there an Engineering Design Cycle?

The *Chapter Challenge* is a problem that you need to solve. There are many different ways to solve problems. One sequence of steps that can be used to solve problems is called the *Engineering Design Cycle*. You are going to use a simplified *Engineering Design Cycle* as you address your challenge. There are five basic steps to a simplified engineering design.

Simplified Engineering Design Cycle	
GOAL	• define the problem • identify available resources • draft potential solutions • list constraints to possible actions
INPUTS	• complete the investigations in each section • learn new physics concepts and vocabulary
PROCESS	• evaluate work to date • compare and contrast methods and ideas • examine possible trade-offs to help reach goals and maximize efforts • create a model from your information • design experiments to test ideas and the suitability of the model
OUTPUTS	• present *Mini-Challenge* and intermediary steps or products • present *Chapter Challenge* based on feedback to *Mini-Challenge*
FEEDBACK	• obtain response from target audience leading to modification of the goal • identify additional constraints, requiring restarting the input and process stages

6

Most importantly, the *Engineering Design Cycle* is presented as a lens that can be used to view the chapter challenge function within *Active Physics*. Depending on your personal interest, knowledge, and style, it will have a different function for each classroom. It will likely have a different function for each student within a classroom. For some linear thinkers, the engineering design cycle will provide a map; for more creative thinkers, it will provide an outline or maybe even a launch pad for innovative solutions to a problem. Students can only benefit from considering their design challenges through the lens of a process that is used in similar form in every engineering enterprise today. Students will learn to use a framework to compile their information and solve their chapter challenges. At the same time they will learn that there is a process for solving problems that is independent of the current problem—a process they can practice and use on every problem. Once the students are comfortable with the structure of the design cycle, they will be able to use it to guide them through each *Chapter Mini-Challenge* and final *Chapter Challenge*.

Active Physics and the National Science Education Standards

Active Physics was designed and developed to provide teachers with instructional strategies that model the following from the standards:

Guide and Facilitate Learning

- Focus and support inquiries while interacting with students.
- Orchestrate discourse among students about scientific ideas.
- Challenge students to accept and share responsibility for their own learning.
- Recognize and respond to student diversity; encourage all to participate fully in science learning.
- Encourage and model the skills of scientific inquiry as well as the curiosity, openness to new ideas and data, and skepticism that characterize science.

Engage in Ongoing Assessment of Their Teaching and Student Learning

- Use multiple methods and systematically gather data about student understanding and ability.
- Analyze assessment data to guide teaching.
- Guide students in self-assessment.
- Select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners.

Design and Manage Learning Environments that Provide Students with Time, Space, and Resources needed for Learning Science.

- Structure the time available so students are able to engage in extended investigations.
- Create a setting for student work that is flexible and supportive of science inquiry.
- Make available tools, materials, media, and technological resources accessible to students.
- Identify and use resources outside of school.
- Engage students in designing the learning environment.

Develop Communities of Science Learners that Reflect the Intellectual Rigor of Science Attitudes and Social Values Conducive to Science Learning.

- Display and demand respect for diverse ideas, skills, and experiences of students.
- Enable students to have a significant voice in decisions about content and context of work and require students to take responsibility for the learning of all members of the community.
- Nurture collaboration among students.
- Structure and facilitate ongoing formal and informal discussion based on shared understanding of rules.
- Model and emphasize the skills, attitudes, and values of scientific inquiry.

Assessment Standards

- Features claimed to be measured are actually measured.
- Students have adequate opportunity to demonstrate their achievement and understanding.
- Are deliberately designed with explicitly stated purpose.
- Assessment tasks are authentic and developmentally appropriate, set in familiar context, and are engaging to students with different interests and experiences without regard to gender, ethnicity, or race.
- Assesses student understanding as well as knowledge, the ability to reason scientifically, and communicate effectively about science.
- Improve classroom practice and plan curricula.

Active Physics and the National Science Education Standards

	Driving the Roads	Physics in Action	Safety
Physical Science			
Structure of atoms			
Structure and properties of matter		x	x
Motions and forces	x	x	x
Conservation of energy and increase in disorder		x	
Interactions of energy and matter	x	x	x
Unifying Concepts and Processes			
Systems, order, and organization			
Evidence, models, and explanations	x	x	x
Constancy, change, and measurement	x	x	x
Science as Inquiry			
Identify questions and concepts that guide scientific inquiry	x	x	x
Design and conduct scientific investigations	x	x	x
Use technology and mathematics to improve investigations	x	x	x
Formulate and revise scientific explanations and models using logic and evidence	x	x	x
Communicate and defend a scientific argument	x	x	x
Understand scientific inquiry	x	x	x
Science and Technology			
Identify a problem or a design opportunity	x	x	x
Propose designs and choose between alternate solutions		x	x
Implement a proposed solution	x	x	x
Evaluate the solutions and their consequences		x	x
Communicate the problem, process, and solution	x	x	x
Understand science and technology	x	x	x
Science in Personal and Social Perspectives			
Natural and human induced hazards	x		x
Science and technology in local, national, and global challenges	x		x
History and Nature of Science			
Science as a human endeavor	x	x	x
Nature of scientific knowledge	x	x	x
Historical perspectives		x	

Active Physics and the National Science Education Standards

Thrills and Chills	Let Us Entertain You	Electricity for Everyone	Toys for Understanding	Atoms on Display	Sports on the Moon
		x		x	
x	x	x	x	x	
x		x	x	x	x
x		x	x	x	x
x	x	x	x	x	x
x		x	x	x	
x	x	x	x	x	x
x	x	x	x	x	x
x	x	x	x	x	x
x	x	x	x	x	x
x	x	x	x	x	x
x	x	x	x	x	x
x	x	x	x	x	x
x	x	x	x	x	x
x	x	x	x	x	x
x	x	x	x	x	x
x	x	x	x	x	x
x		x	x	x	x
x	x	x	x	x	x
x	x	x	x	x	x
x		x		x	
		x	x	x	
x	x	x	x	x	x
x	x	x	x	x	x
x		x	x	x	x

Active Physics: Bridging Research and Practice

Over the past 20 years, advances in cognitive science and learning have steered educators to teaching practices that can support more effective learning. No longer must teachers base their practice on instinct and what appears to work. The common wisdom of practice can now be integrated with research results to provide better curriculum.

Active Physics bridges the research with high-quality physics instruction, moving the research results from the cognitive laboratory to the classroom. Below is a brief summary of some approaches in *Active Physics* and the rationale for their use.

The publication by the National Research Council of the National Academy of Sciences entitled *How People Learn* is a must-read for all teachers. It helps provide research and examples in a conversational tone. The three findings emphasized in the book are worthwhile ways to begin explaining how *Active Physics* bridges these findings and classroom instruction.

Key Finding 1: Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp new concepts and information, or they may learn them for purposes of a test, but revert to their preconceptions outside the classroom.

All *Active Physics* sections begin by eliciting students' prior understanding. This is first done with a student response to the *What Do You See?* cartoon and is immediately followed by a written *What Do You Think?* prompt. Both set the stage for the content of each section. Each section ends by having students return to confront their initial understandings and the evidence they have generated during the investigation. *What Do You Think Now?* allows students to use evidence to support their arguments and help recognize what they have learned.

Key Finding 2: To develop competence in an area of inquiry, students must: (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application.

Active Physics students learn all the required content and factual knowledge in the context of investigations, evidence, and reflection on that evidence. They do not learn the facts in isolation, but as part of the knowledge and information required to complete a *Chapter Challenge*. Through the *Physics Essential Questions* feature, students must also explain:

- What does it mean?
- How do you know?
- Why do you believe?
- Why should you care?

The *Why do you believe?* question requires students to understand the content of each section with respect to (a) connections with other physics content, (b) how it fits with the "big ideas of science," and (c) how it meets physics requirements such as experimental evidence being consistent with models and theories. When students are required to retrieve and apply their content knowledge, they are able to refer to the challenge. For example, when introduced to a new concept, students can ask themselves, "Did I first encounter this concept when I was trying to complete a challenge having to do with sports or a challenge having to do with electrical appliances or a challenge having to do with light and sound?" The next step is for the student to remember which investigation may have had to do with this new topic. Finally, students can retrieve the content that emerged from their investigation. This is in sharp contrast to having a student try to remember a concept because it was in Chapter 1 or Chapter 9.

Key Finding 3: A "metacognitive" approach to instruction can help students learn to take control of their learning by defining learning goals and monitoring their progress in achieving them.

The *What Do You Think Now?* question is one way in which students must reflect on their learning, and come to the understanding that what they knew a few days ago may have to be modified as a result of the evidence from their investigation, analysis, and class discussion. *Active Physics* also requires students to transfer the knowledge from each section to their required execution of the ***Chapter Challenge***. This is not simply recall, but a creative extension of their knowledge. In planning to complete the ***Chapter Challenge***, students must organize their knowledge as well as manage these projects. Both tasks require students to be aware of their own learning processes. From the opening of the chapter, where students are introduced to the ***Chapter Challenge***, they are required to create a set of criteria by which their future project will be evaluated. They also must decide the weighting of each element. This helps students define their learning goals. As they move through the chapter, they monitor their progress in achieving these goals. Additional aspects of *Active Physics* also strengthen the bridge between research and practice.

Problem-based Learning Model

Each chapter begins with an engaging scenario that challenges students and sets the stage for the learning investigations and chapter assessments to follow. Chapter content and *Investigates* are selectively aimed at providing students with the knowledge and skills needed to respond effectively to the challenge. This scenario-challenge framework provides students with a new focus and topic in successive chapters, and covers a wide variety of student interests.

7E Instructional Model

The 7E instructional model used at the section and chapter levels (and described in more detail in this *Teacher's Edition*) ensures that research about learning encourages teaching that supports learning. A table (from the *Student Edition*) listing each component of a section and what phase of the 7E instructional model it addresses, is provided at the bottom of this page.

- **Elicit:** *What Do You See?* and *What Do You Think?* seek to ensure that students' prior knowledge is addressed.
- **Engage:** Students learn when they are motivated.
- **Explore:** Students investigate and have experience with the concept prior to being told, in the abstract, about how things are or how they should be explained.
- **Explain:** The explanation of a concept follows the students' introduction to the phenomenon.
- **Elaborate:** Students can investigate the implications of the new concept and see how it pertains to other situations.
- **Extend:** Students transfer and apply their knowledge from what they have learned to the larger chapter challenge.
- **Evaluate:** There are opportunities for students to evaluate their own learning as well as for teachers to evaluate their learning in all parts of the instructional model and at the end using traditional homework problems.

INTRODUCTION

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.*

Multiple Exposure Curriculum

The thematic nature of the course requires students to continually revisit fundamental physics principles throughout the semester, extending and deepening their understanding of these principles as they apply them in fresh contexts and new *Chapter Challenges*. This repeated exposure fosters the retention of content and process, and the transferability of learning. The development of critical-thinking skills also is promoted by multiple exposure and application.

Inquiry-based Learning

All of the six to ten sections per chapter routinely involve inquiry at some level. In some sections, students must design an experiment to explore a concept. At other times, they will collect and interpret data to formulate a new concept. Students are regularly asked to answer questions about what they think and what they do, as well as to support their statements with concrete data. "Activity Before Concept" (ABC) provides a strong base for inquiry-based learning as the students always have a common lab experience upon which to understand the concept. For the same reason, it is important to show the students a concept before exposing them to the vocabulary associated with the concept, "Concept Before Vocabulary" (CBV).

Constructivist Approach

Students are continually asked to explore how they think about certain situations. As they investigate each new situation, they are challenged to either explain observed phenomena using an existing paradigm or develop a more consistent one. This approach can be used to help students recognize previous notions and abandon these in favor of a more powerful idea offered by scientists.

Authentic Assessment

As the culmination of each chapter, students are required to demonstrate their ability to use their newly acquired knowledge by adequately meeting the challenge posed in the chapter introduction. Students are then evaluated on the degree to which they accomplish this performance task using a rubric based on their own input. The curriculum also includes other methods and instruments for authentic assessments as well as nontraditional procedures for evaluating and rewarding desirable achievements.

Cooperative Grouping Assignments

Use of cooperative groups is integral to the curriculum as students work together in small groups to acquire the knowledge and information needed to address the series of challenges presented through the chapter scenarios. Today's business model requires employees to work cooperatively in small groups to accomplish business goals. Students learn to value the abilities and contributions of others while maintaining a focus on the group goal of providing a meaningful response to the *Chapter Challenge*.

Problem Solving

For the curriculum to be meaningful and relevant to students, problem solving related to technological applications is an essential component of the course. Problem solving ranges from simple numerical calculations, to more involved decision-making situations where multiple alternatives must be compared. In some investigations, students are asked to compare class data, determine which data is useful and valid, and suggest reasons for other data falling short of this goal. Seen in its entirety, each chapter is a large problem to be solved, with multiple correct solutions and opportunities for design change before completion.

Challenging Learning Extensions

In every section, an *Active Physics Plus* is provided to encourage further learning through increased mathematical analysis, depth of treatment of the content and concepts, or an additional laboratory exploration. Throughout the text, a variety of *Inquiring Further* and *Preparing for the Chapter Challenge* exercises are provided for more motivated students. These extensions range from more challenging design tasks, to enrichment readings, to intriguing and unusual problems. Many of the extensions provide additional opportunities for the oral and written expression of student ideas.

Research-based Model

Active Physics relies upon the proven NSF developmental process as well as the most up-to-date research in pedagogy and learning theory. The research-based NSF process, with its strict criteria and standard, usually takes three to four years to complete. The curriculum is written and first tested in the classroom in the Pilot Test. Following data collection and evaluation, the curriculum is rewritten and retested in the Field Test classrooms. Following a second evaluation by a nationally recognized independent evaluation team, the curriculum is rewritten again. Expert review panels also guide the process at each stage.

Responds to Equity Concerns

A diverse classroom is a wonderful place for exposure to the various cultures of students and their experiences. However, in most cases, it is impossible for the teacher to become an "expert" in each culture represented by the students and to bring that into the classroom. *Active Physics* honors the diversity of students by allowing them to creatively bring their culture into the classroom in the format of the *Chapter Challenge*, for example, through sports, entertainment, or habitats.

Misconceptions

Students arrive in class knowing a great deal about the world. Researchers in cognitive science have identified various categories of student "alternative" understandings of the world. Each chapter of *Active Physics* identifies lists of commonly held student preconceptions and offers activities for students to test their conceptual ideas about understanding each learning goal. Students continually are asked to explain their reasoning. This process enables the teacher to interview and work with students to root out prior conceptions and establish scientific foundations of understanding of the principles involved.

Understanding by Design

Wiggins and McTighe have introduced the notion that in preparing instruction, teachers should first decide on the enduring understandings and concepts they expect their students to learn. Teachers should then decide what evidence they will accept to show that their students understand these enduring understandings and concepts. Finally, teachers should develop curriculum to ensure that students will be able to present that evidence of learning. In *Active Physics,* the students begin each chapter by identifying and developing a challenge. Next, they develop criteria for excellence for completing this challenge. They then go about learning the concepts in each section while adding their evidence of understanding and creativity to their *Chapter Challenge*.

Student Motivation

- When students are motivated, they learn and remember more. *Active Physics* engages students intellectually by:
- Presenting interesting and meaningful challenges.
- Allowing student creativity in the execution of the challenges.
- Allowing each student group to demonstrate expertise in the physics content and the presentation of their knowledge.
- Providing students with choices about how they will demonstrate their physics knowledge in creative ways.
- Teachers permitting—even encouraging—different forms of expression and respecting student views.
- Students creating original and public products.
- Students sensing that the results of their work were not predetermined or fully predictable.

Integrated Instructional Units

Rather than introducing lab experiments haphazardly, *Active Physics* always incorporates lab investigations into the larger instructional unit to provide the most benefit to the student. As noted in the National Research Council study, *America's Lab Report,* the use of integrated instructional units has been shown to support more learning than do traditional lab approaches.

Cooperative Learning

Benefits of Cooperative Learning

Cooperative learning requires you to organize and structure a lesson so that students work with other students to jointly accomplish a task. Group learning is an essential part of balanced methodology. It should be blended with whole-class instruction and individual study to meet a variety of learning styles and expectations as well as maintain a high level of student involvement.

Cooperative learning has been thoroughly researched and agreement has been reached on a number of results. Cooperative learning:

- promotes trust and risk-taking
- elevates self-esteem
- encourages acceptance of individual differences
- develops social skills
- permits a combination of a wide range of backgrounds and abilities
- provides an inviting atmosphere
- promotes a sense of community
- develops group and individual responsibility
- reduces the time on a task
- results in better attendance
- produces a positive effect on student achievement
- develops key employability skills

As with any learning approach, some students will benefit more than others from cooperative learning. Therefore, you may question as to what extent you should use cooperative learning strategies. It is important to involve the student in helping decide which type of learning approaches they prefer, and to what extent each is used in the classroom. When students have a say in their learning, they will accept to a greater extent any method which you choose to use.

Phases of Cooperative Learning Lessons

Organizational Pre-lesson Decisions

What academic and social objectives will be emphasized? In other words, what content and skills are to be learned and what interaction skills are to be encouraged or practiced?

What will be the group size? Or, what is the most appropriate group size to facilitate the achievement of the academic and social objectives? This will depend on the amount of individual involvement expected (small groups promote more individual involvement), the task (diverse thinking is promoted by larger groups), nature of the task or materials available and the time available (shorter time demands smaller groupings to promote involvement).

Who will make up the different groups? Teacher-selected groups usually have the best mix, but this can only happen after the you get to know your students well enough to know who works well together. Heterogeneous groupings are most successful in that all can learn through active participation. The duration of the groups' existence may have some bearing on deciding the membership of groups.

How should the room be arranged? Practicing routines where students move into their groups quickly and quietly is an important aspect. Having students face-to-face is important. You should still be able to move freely among the groups.

What Materials and/or Rewards Might be Prepared in Advance?

Setting the Lesson

Structure for Positive Interdependence: When students feel they need one another, they are more likely to work together—goal interdependence becomes important. Class interdependence can be promoted by setting class goals which all teams must achieve in order for class success.

Explanation of the Academic Task: Clear explanations and sometimes the use of models can help the students. An explanation of the relevance of the activity is importance. Checks for clear understanding can be done either before the groups form or after, but they are necessary for delimiting frustrations.

Explanation of Criteria for Success: Groups should know how their level of success will be determined. Structure for Individual Accountability: The use of individual follow-up activities for tasks or social skills will provide for individual accountability.

Structure for Individual Accountability: The use of individual follow-up activities for tasks or social skills will provide for individual accountability.

Specification of Desired Social Behaviors: Definition and explanations of the importance of values of social skills will promote student practice and achievement of the different skills.

Monitoring/Intervening During Group Work

Through monitoring students' behaviors, intervention can be used more appropriately. Students can be involved in the monitoring by being "a team observer," but only when the students have a very clear understanding of the behavior being monitored.

Interventions to increase chances for success in completing the task or investigation and for the teaching of collaborative skills should be used as necessary—they should not be interruptions. This means that as the facilitating teacher, you should be moving among the groups as much as possible. During interventions, the problem should be turned back to the students as often as possible, taking care not to frustrate them.

Evaluating the Content and Process of Cooperative Group Work

Assessment of the achievement of content objectives should be completed by both you and the students. Students can go back to their groups after an assignment to review the aspects in which they experienced difficulties.

When assessing the accomplishment of social objectives, two aspects are important: how well things proceeded and where/how improvements might be attempted. Student involvement in this evaluation is a very basic aspect of successful cooperative learning programs.

Organizing and Monitoring Groups

An optimum size of group for most investigations appears to be four; however, for some tasks, two may be more efficient. Heterogeneous groups organized by the teacher are usually the most successful. You will need to decide what factors should be considered in forming the heterogeneous groups. Factors which can be considered are: academic achievement, cultural background, language proficiency, sex, age, learning style, and even personality type.

Level of academic achievement is probably the simplest and initially the best way to form groups. Sort the students on the basis of marks on a particular task or on previous year's achievement. Then choose a student from each quartile to form a group. Once formed, groups should be flexible. Continually monitor groups for compatibility and make adjustments as required.

Students should develop an appreciation that it is a privilege to belong to a group. Remove from group work any student who is a poor participant or one who is repeatedly absent. These individuals can then be assigned the same tasks to be completed in the same timeline as a group. You may also wish to place a ten percent reduction on all group work that is completed individually.

The chart at the end of this Cooperative Learning section presents some possible group structures and their functions.

What Does Cooperative Learning Look Like?

During a cooperative learning situation, students should be assigned a variety of roles related to the particular task at hand. A list of possible roles that students may be given is provided below. It is important that students are given the opportunity of assuming a number of different roles over the course of a semester.

Leader:
Assigns roles for the group. Gets the group started and keeps the group on task.

Organizer:
Helps focus discussion and ensures that all members of the group contribute to the discussion. The organizer ensures that all of the equipment has been gathered and that the group completes all parts of the investigation.

Recorder:
Provides written procedures when required, diagrams where appropriate and records data. The recorder must work closely with the organizer to ensure that all group members contribute.

Researcher:
Seeks written and electronic information to support the findings of the group. In addition, where appropriate, the researcher will develop and test prototypes. The researcher will also exchange information gathered among different groups.

Encourager:
Encourages all group members to participate. Values contributions and supports involvement.

Checker:
Checks that the group has answered all the questions and the group members agree upon and understand the answers.

Diverger:
Seeks alternative explanations and approaches. The task of the diverger is to keep the discussion open. "Are other explanations possible?"

Active Listener:
Repeats or paraphrases what has been said by the different members of the group.

Idea Giver:
Contributes ideas, information, and opinions.

Materials Manager:
Collects and distributes all necessary material for the group.

Observer:
Completes checklists for the group.

Questioner:
Seeks information, opinions, explanations, and justifications from other members of the group.

Reader:
Reads any textual material to the group.

Reporter:
Prepares and/or makes a report on behalf of the group.

Summarizer:
Summarizes the work, conclusions, or results of the group so that they can be presented coherently.

Timekeeper:
Keeps the group members focused on the task and keeps time.

Safety Manager:
Responsible for ensuring that safety measures are being followed, and the equipment is clean prior to and at the end of the investigation.

Group Assessment

Assessment should not end with a group mark. Students and their parents have a right to expect marks to reflect the students' individual contributions to the task. It is impossible for you as the instructor to continuously monitor and record the contribution of each individual student. Therefore, you will need to rely on the students in the group to assign individual marks as merited. There are a number of ways that this can be accomplished. The group mark can be multiplied by the number of students in the group, and then the total mark can be divided among the students.

Some Possible Group Structures and Their Functions*

Structure		Brief Description	Academic and Social Functions
Team Building	Roundrobin	Each student in turn shares something with his/her teammates.	Expressing ideas and opinions, creating stories. Equal participation, getting acquainted with each other.
Class Building	Corners	Each student moves to a group in a corner or location as determined by the teacher through specified alternatives. Students discuss within groups, then listen to and paraphrase ideas from other groups.	Seeing alternative hypotheses, values, and problem solving approaches. Knowing and respecting differing points of view.
Mastery	Numbered heads together	The teacher asks a question, students consult within their groups to make sure that each member knows the answer. Then one student answers for the group in response to the number called out by the teacher.	Review, checking for knowledge comprehension, analysis, and divergent thinking. Tutoring.
Mastery	Color coded co-op cards	Students memorize facts using a flash card game or an adaption. The game is structured so that there is a maximum probability for success at each step, moving from short to long-term memory. Scoring is based on improvement.	Memorizing facts. Helping, praising.
Mastery	Pairs check	Students work in pairs within groups of four. Within pairs students alternate — one solves a problem while the other coaches. After every problem or so, the pair checks to see if they have the same answer as the other pair.	Practicing skills. Helping, praising.
Concept Development	Three-step interview	Students interview each other in pairs, first one way, then the other. Each student shares information learned during interviews with the group.	Sharing personal information such as hypotheses, views on an issue, or conclusions from a unit. Participation, involvement.
Concept Development	Thinkpair-share	Students think to themselves on a topic provided by the teacher; they pair up with another student to discuss it; and then share their thoughts with the class.	Generating and revising hypotheses, inductive and deductive reasoning, and application. Participation and involvement.
Concept Development	Team wordwebbing	Students write simultaneously on a piece of paper, drawing main concepts, supporting elements, and bridges representing the relation of concepts/ideas.	Analysis of concept into components, understanding multiple relations among ideas, and differentiating concepts. Role-taking.
Multifunctional	Roundtable	Each student in turn writes one answer as a paper and a pencil are passed around the group. With simultaneous roundtables, more than one pencil and paper are used.	Assessing print knowledge, practicing skills, recalling information, and creating designs. Team building, participation of all.
Multifunctional	Partners	Students work in pairs to create or master content. They consult with partners from other teams. Then they share their products or understandings with the other partner pair in their team.	Mastery and presentation of new material, concept development. Presentation and communication skills.
Multifunctional	Jigsaw	Each student from each team becomes an "expert" on one topic area by working with members from other teams assigned to the same topic area. On returning to their own teams, each one teaches the other members of the group and students are assessed on all aspects of the topic.	Acquisition and presentation of new material review and informed debate. Independence, status equalization.

*Adapted from Spencer Kagan (1990), "*The Structural Approach to Cooperative Learning*," Educational Leadership, December 1989/January 1990.

Active Physics—A Research-Based Curriculum

Active Physics has been funded by the National Science Foundation (NSF) and exemplifies the NSF's goals and objectives to improve science, mathematics, and technology education for all students. *Active Physics* is aligned with the National Science Education Standards (NSES) and follows the guidelines of the NSES to improve science-content knowledge, thinking skills, and problem-solving abilities for all students, regardless of background or ability. The NSES were guided by certain principles:

- Science is for all students.
- Learning science is an active process.
- School science reflects the intellectual and cultural traditions that characterize the practice of contemporary science.
- Improving science education is part of systemic education reform.

Adhering to these principles, *Active Physics* relies on the rigorous research of the NSF development process as well as incorporating into its instructional model the most up-to-date research on pedagogy and learning theory. The *Active Physics* curriculum consequently promotes positive student attitudes toward science and positive perceptions of the student as learner. It engages students through its use of real-world contexts and provides a deeper understanding of the role of science and technology in the workplace.

The NSF Research-Based Curriculum Development Process

The NSF Instructional Materials Development Program ensures that each of the curriculum development programs it has funded follows strict *research-based* criteria throughout the development process. The project grants are extremely competitive and only awarded to development teams that have established themselves to be distinguished leaders in science education. The initial development grant for *Active Physics* was awarded to the American Association of Physics Teachers and the American Institute of Physics. The embedded research-based development process with the strict criteria and standards for all NSF-funded programs, usually takes at least three to four years to complete.

Project Evaluation and Research Design

A crucial component to all NSF development projects is the ongoing research and evaluation of the development process and materials by a nationally recognized independent evaluation team. The research and evaluation of these projects is comprehensive and provides both formative and summative information to the development teams as well as to the NSF for review. The formative feedback and information is used to optimize the curricular revision process, and the summative evaluation examines the effectiveness of the curricular materials on teachers and students throughout the three-year process. *Active Physics* initially went through a four-year curriculum development process. An abbreviated description of that process included:

First Year of the Curriculum Development Process—Content Specialists, Master Teachers

- Under the direction of a distinguished, active, and dynamic Advisory Board, the program's Principal Investigators select physicists, physics educators, and high school physics teachers to collaborate on the development of the first draft of the curriculum materials. These teams also serve as part of the Review

Committee to assess each other's works for pedagogical strategies and content accuracy. The curriculum is then reviewed and evaluated by other leading educational specialists for pedagogy, content, safety, equity, readability, cognitive effectiveness, and efficacy, and then the curriculum is revised again based on those results.

- All new materials proceed through the following system for development and revision:
  - Approved by Content Review Committee comprised of leading content experts
  - Approved by the following consultants: science educators, master teachers, and cognitive scientists
  - Micro-tested by the development group (A micro-test is a series of tests of a few students with careful observation and follow-up interviews by the developers.)

Second Year of the Curriculum Development Process—Content Specialists Pilot to Ensure Curriculum Is Correct and Rigorous

- The curriculum is then ready to be pilot tested by a select group of high school teachers from across the country. After an extensive summer training course, these teachers spend the next year piloting the program in their classrooms.
- Pilot-tested by master teachers in their classrooms
- Pilot materials, classes, teachers, and students are studied and evaluated based on an established evaluation and research design model
- Materials are then revised based on the pilot feedback, experts' reviews and evaluation and research reports.

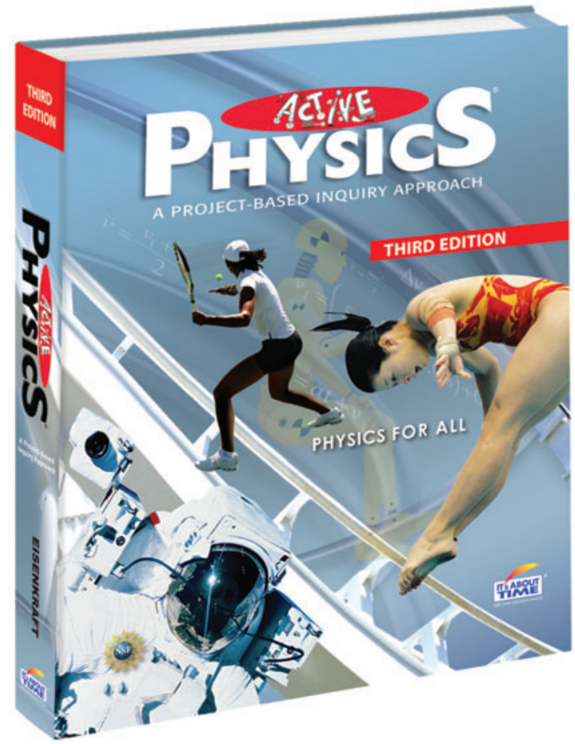
Third Year of the Curriculum Development Process—Diverse Classrooms to Ensure Approach is Appropriate for All Students

- The curriculum is now ready to be field-tested by a broad range of high school teachers from across the country. After an extensive summer training course, these teachers spend the next year field-testing the materials in their classrooms.
- Like the pilot test, the research/evaluation component of the revision process is designed to inform the next iteration and revision of the materials.
- Field-testing of the materials conducted in a wide range of classrooms by teachers with a wide range of experience and expertise
- Field-test materials, classes, teachers, and students are studied and evaluated based on the evaluation and research design model
- Materials are then revised again based on the field-test feedback, experts' reviews and evaluation and research reports.

Fourth Year of the Development Process

- Additional consultant specialists in cognitive psychology, assessment, technology, science education, and equity continue to be brought into the project to review the materials and secure its pedagogical approach and content basis. Finally, the product is turned over to the commercial publisher to mold into a commercial product. Publishing decisions cannot take precedence over content requirements or instructional strategies.

Active Physics Third Edition



The *Active Physics Third Edition* was also funded by NSF. Revision goals were to revise the original *Active Physics* materials to reflect the feedback, experiences, and research accumulated after several years of implementation in school districts throughout the United States. The original curriculum was designed as six thematic, modular components. Each module contained three independent chapters, thus allowing for the adjustable sequencing of modules and chapters as determined by each school or district. The objectives followed and established by the original *Active Physics* curriculum were to

- Dramatically increase physics enrollment throughout the country
- Significantly decrease the achievement gap in physics
- Allow both male and female students from all ethnic backgrounds to enjoy physics and to succeed in physics
- Allow students to better understand physics-related issues and technologies, and to be able to identify and evaluate personal and societal impacts
- Develop in students an appreciation and understanding of science as a process, develop the skills and attitudes of a scientist, and develop an ability to apply these in realistic and relevant problem-solving and decision-making activities.

Active Physics successfully grew its market share during the eight years it was released, however, there were important lessons learned from the districts implementing the program, and it became clear that a restructuring of the content and format of the materials into a single text book, as well as developing additional content to meet state standards was necessary. To this end, the revision goals and objectives were to

- Restructure and insert additional content appropriate for a "Physics for All" as well as a "Physics First" sequencing
- Provide a stronger emphasis on the organizing principles of physics
- Integrate higher-level mathematics skills into the physics of the curriculum as a separate component to reflect the needs of advanced students, thus creating additional flexibility in the program for use by low- or high-level achieving students.

Active Physics Third Edition also went through a national field test where teachers used the revised materials and reported back to the development group strengths and weaknesses and ways in which the materials could be modified for more effectiveness. Simultaneously, a research study was taking place that compared the physics achievement and attitudes of the more than 3000 students involved in the field test with students taught the prior year by the same teacher using a different curriculum. Some highlights of this research report follow on the next page.

Highlights of the Active Physics Third Edition Research Report

This report compares the outcomes of teachers and students using *Active Physics* Revision to teachers and students using traditional physics curricula. These comparisons were based on a variety of data including several different types of student tests, student surveys, and teacher surveys.

Methodology

Data were collected from both treatment (teachers using *Active Physics* Revision) and comparison (teachers not using *Active Physics* Revision) teachers and their students over the two-year period of this evaluation. The comparison teachers used their "normal" curriculum, while the treatment teachers used the *Active Physics* Revision curriculum. The main comparison used a time-lag design where the outcomes for students in the first year (comparison students) were contrasted to the outcomes for students in the second year (treatment students). This means that the students are not the same in the two years; they are different cohorts, but they are from the same schools and being taught by the same teachers. Therefore, they can be considered a matched comparison group.

Instruments

Several different instruments were used to collect data. Teachers and students completed post-surveys (end of the school year) and students completed one of three physics achievement tests. The teacher survey asked about individual and school characteristics as well as teachers' perceptions of the curriculum they were using that year. The teacher survey also provided information on chapter usage, use of *Chapter Challenges*, and time spent on a given chapter. The student survey asked about individual characteristics, attitudes about science and physics, parental education and involvement in school, and perceptions about the classroom environment. During the field test-year (2005-2006), students and teachers also completed pre-surveys (start of the school year), and students completed pre-tests. These pre-surveys and tests were a subset of items from the post-instruments. The student pre-survey did not ask students about parental involvement or their perceptions of the classroom environment. The teacher pre-survey asked about attitudes toward teaching.

Sample

There were 3657 students overall, with 538 in the comparison group and 3119 in the treatment (*Active Physics* Revision) group. The groups were well matched.

Results

The analyses were designed to determine if any differences existed between *Active Physics* Revision and comparison students and if there were any changes pre-to-post in the teachers and students who used *Active Physics* Revision.

Conclusions

The straightforward, single-variable data analyses show positive results for students studying the *Active Physics* Revision curriculum during the field-test year in comparison to results for students during the comparison year. Although the most conservative analysis did not show any effects for content achievement, less conservative analysis did show that students who participated in *Active*

Physics Revision during the field-test year outperformed students who had studied physics during the comparison year. This was true even though the comparison group students reported higher levels of parental involvement than the *Active Physics* Revision students. Additionally the *Active Physics* Revision students reported being more involved in their physics classes than comparison students.

Pre-to-post comparisons show that the *Active Physics* Revision students gained significantly in content knowledge over the course of the year. Higher post-test scores were also directly related to the amount of time their teachers spent using *Active Physics* Revision.

Three student attitude items show pre-to-post improvement in attitude: *I want to take more science classes; I think about the physics I experience in everyday life* and *to understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed*. These ideas appear to be directly related to the type of experience provided by *Active Physics* Revision and are good indicators of the positive effect of the *Active Physics* Revision curriculum.

Teacher survey data also show favorable comparative results for *Active Physics* Revision in the field-test year. The teachers in the field-test year reported more favorable attitudes toward the *Active Physics* Revision curriculum than the teachers in the comparison year, although none of the differences were significant. This suggests that the teachers viewed the *Active Physics* Revision curriculum more favorably than the curriculum used during the comparison year. *Active Physics* Revision teachers also reported using three National Standards-based teaching techniques more than the comparison teachers. The *Active Physics* Revision teachers reported that their students spent more time making presentations, completing projects, and writing reflections than the comparison teachers.

In summary, the data indicate that, in general, the students in the field-test year performed as well or better than the students in the comparison year. This suggests that the *Active Physics* Revision curriculum may be superior to the curricula used during the comparison year in some ways and at least comparable in the others investigated.

New Components and Features of Active Physics Third Edition

Active Physics continues to be responsive to the most current research on learning and continues to follow its established and proven successful 7E instructional model that includes the following:

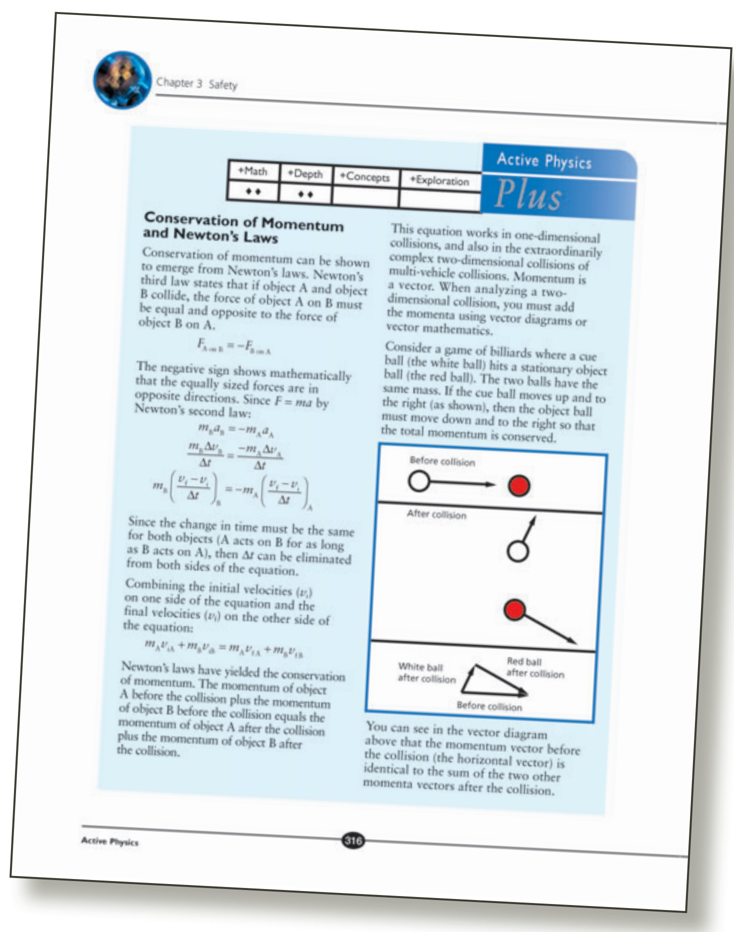
- Eliciting prior understanding through the *What Do You See?* illustrations and the *What Do You Think?* questions.
- Focusing the learning around a *Chapter Challenge* that drives content, motivates students, and builds context.
- Placing investigations before concept introductions and readings.
- Exploring through hands-on inquiry.
- Transferring the learning of content from the investigations and readings to the *Chapter Challenge*.

There are several new components and features in the revised materials. For example, a Launcher Chapter has been created as the first chapter in *Active Physics Third Edition*. In this first chapter, students are introduced to the many features of the program. What is unique about this introduction is that it also explains to the students why each feature is included and how it will help them learn physics. Prefaced by the statement, "The more you understand about how you learn, the better you will be at learning," it encourages students to expand their metacognitive awareness. This unique metacognitive feature will greatly enhance student learning, as research has shown that students learn better when they know how they learn. The first time an *Active Physics* feature is presented, it has a commentary explaining its purpose and begins with 'Why is there a….?' For example, the 7E Instructional Model is fully explained and then referred to later in the textbook.

The knowledge and organizing principles that unite all areas of physics and all science endeavors are overtly emphasized. At the end of each section, students are asked to answer four *Physics Essential Questions* that relate the content in the section the students just completed to the body of science as a whole. *What does it mean?*, *How do you know?*, *Why do you believe?*, and *Why should you care?* are questions that strengthen the scientific inquiry in which students are engaged. The questions assist students in learning to think like a scientist in the classroom, as well as promote their future involvement as responsible citizens in society.

The *Physics Talk* feature has been expanded considerably in *Active Physics Third Edition*. While the *Physics Talk* still uses the students' common experiences during the *Investigate* as the starting point and focusing event for each reading, the new *Physics Talk* readings provide better, more thorough, and more in-depth explanations of the concepts explored in the investigation. The results of the students' investigations are carefully explained in terms of scientific models, laws, and theories. The vocabulary the students need to discuss and explain the physics concepts is boldfaced in the text and also provided in the margin as *Physics Words*.

Active Physics Third Edition takes physics for all a step further than previous editions. An *Active Physics Plus* feature provides text, sample problems, and questions for students who want or need more mathematics, depth, concepts, or exploration. Previous editions were focused on providing sound physics to students who might have ordinarily not considered taking a physics course. The excitement generated in *Active Physics* students through the approach of learning physics concepts as a hands-on, inquiry experience is well documented. Unfortunately, there was a perception that this approach would exclude students that would ordinarily take a physics course. By providing an *Active Physics Plus* feature, *Active Physics Third Edition* is all-inclusive.



Chapter 3 Safety

Active Physics Plus

+Math	+Depth	+Concepts	+Exploration
♦♦	♦♦		

Conservation of Momentum and Newton's Laws

Conservation of momentum can be shown to emerge from Newton's laws. Newton's third law states that if object A and object B collide, the force of object A on B must be equal and opposite to the force of object B on A.

$$F_{A\ on\ B} = -F_{B\ on\ A}$$

The negative sign shows mathematically that the equally sized forces are in opposite directions. Since $F = ma$ by Newton's second law:

$$m_B a_B = -m_A a_A$$

$$\frac{m_B \Delta v_B}{\Delta t} = \frac{-m_A \Delta v_A}{\Delta t}$$

$$m_B\left(\frac{v_f - v_i}{\Delta t}\right)_B = -m_A\left(\frac{v_f - v_i}{\Delta t}\right)_A$$

Since the change in time must be the same for both objects (A acts on B for as long as B acts on A), then Δt can be eliminated from both sides of the equation.

Combining the initial velocities (v_i) on one side of the equation and the final velocities (v_f) on the other side of the equation:

$$m_A v_{iA} + m_B v_{iB} = m_A v_{fA} + m_B v_{fB}$$

Newton's laws have yielded the conservation of momentum. The momentum of object A before the collision plus the momentum of object B before the collision equals the momentum of object A after the collision plus the momentum of object B after the collision.

This equation works in one-dimensional collisions, and also in the extraordinarily complex two-dimensional collisions of multi-vehicle collisions. Momentum is a vector. When analyzing a two-dimensional collision, you must add the momenta using vector diagrams or vector mathematics.

Consider a game of billiards where a cue ball (the white ball) hits a stationary object ball (the red ball). The two balls have the same mass. If the cue ball moves up and to the right (as shown), then the object ball must move down and to the right so that the total momentum is conserved.

You can see in the vector diagram above that the momentum vector before the collision (the horizontal vector) is identical to the sum of the two other momenta vectors after the collision.

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Expanding the 5E Model

A proposed 7E model emphasizes "transfer of learning" and the importance of eliciting prior understanding

Arthur Eisenkraft

Sometimes a current model must be amended to maintain its value after new information, insights, and knowledge have been gathered. Such is now the case with the highly successful 5E learning cycle and instructional model (Bybee 1997). Research on how people learn and the incorporation of that research into lesson plans and curriculum development demands that the 5E model be expanded to a 7E model.

MIKE OLLIVER

The 5E learning cycle model requires instruction to include the following discrete elements: *engage*, *explore*, *explain*, *elaborate*, and *evaluate*. The proposed 7E model expands the *engage* element into two components—*elicit* and *engage*. Similarly, the 7E model expands the two stages of *elaborate* and *evaluate* into three components— *elaborate*, *evaluate*, and *extend*. The transition from the 5E model to the 7E model is illustrated in Figure 1.

These changes are not suggested to add complexity, but rather to ensure instructors do not omit crucial elements for learning from their lessons while under the incorrect assumption they are meeting the requirements of the learning cycle.

Eliciting prior understandings

Current research in cognitive science has shown that eliciting prior understandings is a necessary component of the learning process. Research also has shown that expert learners are much more adept at the transfer of learning than novices and that practice in the transfer of learning is required in good instruction (Bransford, Brown, and Cocking 2000).

The *engage* component in the 5E model is intended to capture students' attention, get students thinking about the subject matter, raise questions in students' minds, stimulate thinking, and access prior knowledge. For example, teachers may engage students by creating surprise or doubt through a demonstration that shows a piece of steel sinking and a steel toy boat floating. Similarly, a teacher may place an ice cube into a glass of water and have the class observe it float while the same ice cube placed in a second glass of liquid sinks. The corresponding conversation with the students may access their prior learning. The students should have the opportunity to ask and attempt to answer, "Why is it that the toy boat does not sink?"

The engage component includes both accessing prior knowledge and generating enthusiasm for the subject matter. Teachers may excite students, get them interested and ready to learn, and believe they are fulfilling the engage phase of the learning cycle, while ignoring the need to find out what prior knowledge students bring to the topic. The importance of *eliciting* prior understandings in ascertaining what students know prior to a lesson is imperative. Recognizing that students construct knowledge from existing knowledge, teachers need to find out what existing knowledge their students possess. Failure to do so may result in students developing concepts very different from the ones the teacher intends (Bransford, Brown, and Cocking 2000).

A straightforward means by which teachers may elicit prior understandings is by framing a "what do you think" question at the outset of the lesson as is done consistently in some current curricula. For example, a common physics lesson on seat belts might begin with a question about designing seat belts for a racecar traveling at a high rate of speed (Figure 2, p. 58). "How would they be different from ones available on passenger cars?" Students responding to this question communicate what they know about seat belts and inform themselves, their classmates, and the teacher about their prior conceptions and understandings. There is no need to arrive at consensus or closure at this point. Students do not assume the teacher will tell them the "right" answer. The "what do you think" question is intended to begin the conversation.

The proposed expansion of the 5E model does not exchange the *engage* component for the *elicit* component; the engage component is still a necessary element in good instruction. The goal is to continue to excite and interest students in whatever ways possible and to identify prior conceptions. Therefore the elicit component should stand alone as a reminder of its importance in learning and constructing meaning.

Explore and explain

The *explore* phase of the learning cycle provides an opportunity for students to observe, record data, isolate variables, design and plan experiments, create graphs, interpret results, develop hypotheses, and organize their findings. Teachers may frame questions, suggest approaches, provide feedback, and assess understandings. An excellent example of teaching a lesson on the metabolic rate of water fleas (Lawson 2001) illustrates the effectiveness of the learning cycle with varying amounts of teacher and learner ownership and control (Gil 2002).

Students are introduced to models, laws, and theories during the *explain* phase of the learning cycle. Students

FIGURE 1

The proposed 7E learning cycle and instructional model.

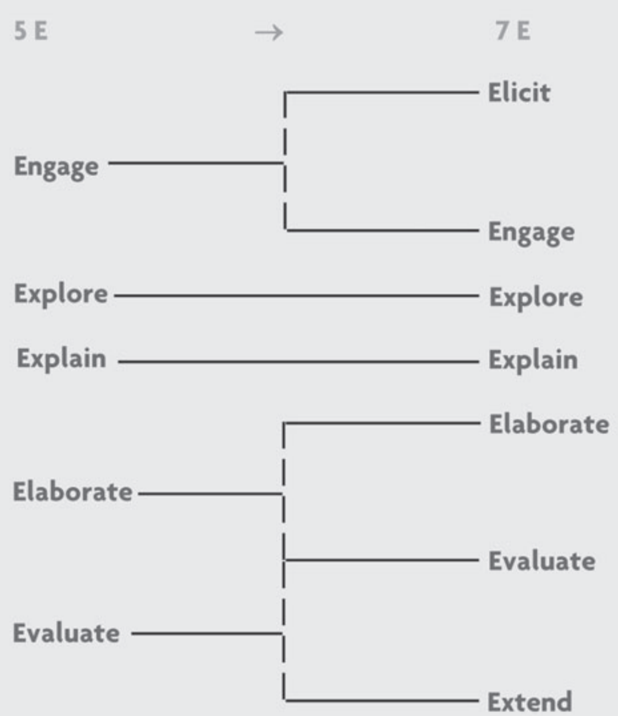

FIGURE 2

Seatbelt lesson using the 7E model.

Elicit prior understandings

- Students are asked, "Suppose you had to design seat belts for a racecar traveling at high speeds. How would they be different from ones available on passenger cars?" The students are required to write a brief response to this "What do you think?" question in their logs and then share with the person sitting next to them. The class then listens to some of the responses. This requires a few minutes of class time.

Engage

- Students relate car accidents they have witnessed in movies or in real life.

Explore

- The first part of the exploration requires students to construct a clay figure they can sit on a cart. The cart is then crashed into a wall. The clay figure hits the wall.

Explain

- Students are given a name for their observations. Newton's first law states, "Objects at rest stay at rest; objects in motion stay in motion unless acted upon by a force."

Engage

- Students view videos of crash test dummies during automobile crashes.

Explore

- Students are asked how they could save the clay figure from injury during the crash into the wall. The suggestion that the clay figure will require a seat belt leads to another experiment. A thin wire is used as a seat belt. The students construct a seat belt from the wire and ram the cart and figure into the wall again. The wire seat belt keeps the clay figure from hitting the wall, but the wire slices halfway through the midsection.

Explain

- Students recognize that a wider seatbelt is needed. The relationship of pressure, force, and area is introduced.

Elaborate

- Students then construct better seat belts and explain their value in terms of Newton's first law and forces.

Evaluate

- Students are asked to design a seat belt for a racing car that travels at 250 km/h. They compare their designs with actual safety belts used by NASCAR.

Extend

- Students are challenged to explore how airbags work and to compare and contrast airbags with seat belts. One of the questions explored is, "How does the airbag get triggered? Why does the airbag not inflate during a small fender-bender but does inflate when the car hits a tree?"

summarize results in terms of these new theories and models. The teacher guides students toward coherent and consistent generalizations, helps students with distinct scientific vocabulary, and provides questions that help students use this vocabulary to explain the results of their explorations. The distinction between the explore and explain components ensures that concepts precede terminology.

Applying knowledge

The *elaborate* phase of the learning cycle provides an opportunity for students to apply their knowledge to new domains, which may include raising new questions and hypotheses to explore. This phase may also include related numerical problems for students to solve. When students explore the heating curve of water and the related heats of fusion and vaporization, they can then perform a similar experiment with another liquid or, using data from a reference table, compare and contrast materials with respect to freezing and boiling points. A further elaboration may ask students to consider the specific heats of metals in comparison to water and to explain why pizza from the oven remains hot but aluminum foil beneath the pizza cools so rapidly.

The elaboration phase ties directly to the psychological construct called "transfer of learning" (Thorndike 1923). Schools are created and supported with the expectation that more general uses of knowledge will be found outside of school and beyond the school years (Hilgard and Bower 1975). Transfer of learning can range from transfer of one concept to another (e.g., Newton's law of gravitation and Coulomb's law of electrostatics); one school subject to another (e.g., math skills, applied scientific investigations); one year to another (e.g., significant figures, graphing, chemistry concepts in physics); and school to nonschool activities (e.g., using a graph to calculate whether it is cost effective to join a video club or pay a higher rate on rentals) (Bransford, Brown, and Cocking 2000).

Too often, the elaboration phase has come to mean an elaboration of the specific concepts. Teachers may provide the specific heat of a second substance and have students perform identical calculations. This practice in transfer of learning seems limited to near transfer as opposed to far or distant transfer (Mayer 1979). Even though teachers expect wonderful results when they limit themselves to near transfer with large similarities between the original task and the transfer task, they know students often find

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elaborations difficult. And as difficult as near transfer is for students, the distant transfer is usually a much harder road to traverse. Students who are quite able to discuss phase changes of substances and their related freezing points, melting points, and heats of fusion and vaporization may find it exceedingly difficult to transfer the concept of phase change as a means of explaining traffic congestion.

Practicing the transfer of learning

The addition of the *extend* phase to the *elaborate* phase is intended to explicitly remind teachers of the importance for students to practice the transfer of learning. Teachers need to make sure that knowledge is applied in a new context and is not limited to simple elaboration. For instance, in another common activity students may be required to invent a sport that can be played on the moon. An activity on friction informs students that friction increases with weight. Because objects weigh less on the moon, frictional forces are expected to be less on the moon. That elaboration is useful. Students must go one step further and extend this friction concept to the unique sports and corresponding play they are developing for the moon environment.

The *evaluate* phase of the learning cycle continues to include both formative and summative evaluations of student learning. If teachers truly value the learning cycle and experiments that students conduct in the classroom, then teachers should be sure to include aspects of these investigations on tests. Tests should include questions from the lab and should ask students questions about the laboratory activities. Students should be asked to interpret data from a lab similar to the one they completed. Students should also be asked to design experiments as part of their assessment (Colburn and Clough 1997).

Formative evaluation should not be limited to a particular phase of the cycle. The cycle should not be linear. Formative evaluation must take place during all interactions with students. The *elicit* phase is a formative evaluation. The *explore* phase and *explain* phase must always be accompanied by techniques whereby the teacher checks for student understanding.

Replacing *elaborate* and *evaluate* with *elaborate*, *extend*, and *evaluate* as shown in Figure 1, p. 57, is a way to emphasize that the transfer of learning, as required in the extended phase, may also be used as part of the evaluation phase in the learning cycle.

Enhancing the instructional model

Adopting a 7E model ensures that eliciting prior understandings and opportunities for transfer of learning are not omitted. With a 7E model, teachers will *engage* and *elicit* and students will *elaborate* and *extend*. This is not the first enhancement of instructional models, nor will it be the last. Readers should not reject the enhancement because they are used to the traditional 5E model, or worse yet, because they hold the 5E model sacred. The 5E model is itself an enhancement of the three-phrase learning cycle that included exploration, invention, and discovery (Karplus and Thier 1967.) In the 5E model, these phases were initially referred to as explore, explain, and expand. In another learning cycle, they are referred to as exploration, term introduction, and concept application (Lawson 1995).

The 5E learning cycle has been shown to be an extremely effective approach to learning (Lawson 1995; Guzzetti et al. 1993). The goal of the 7E learning model is to emphasize the increasing importance of eliciting prior understandings and the extending, or transfer, of concepts. With this new model, teachers should no longer overlook these essential requirements for student learning. ■

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Safety Contract: Safety in the Physics Classroom

Physics is a laboratory science. During this course you will be doing many investigations in which safety is a factor. To ensure the safety of all students, the following safety rules will be followed. You will be responsible for abiding by these rules at all times. After reading the rules, you and a parent or guardian must sign a safety contract acknowledging that you have read and understood the rules and will follow them at all times. The safety contract is also provided as a *Blackline Master* in your *Teacher Resources CD*.

General Rules

1. Never work in the lab unless your teacher or an approved substitute is present.
2. You must follow all directions carefully and use only materials and equipment provided by your teacher. Only experiments approved by your teacher may be carried out in the physics classroom.
3. Do not start work on a lab experiment until told to do so by your teacher.
4. Identify and know the location of a fire extinguisher, fire blanket, emergency shower, eyewash, water shut-offs, and telephone.
5. Eating, drinking, chewing gum, or applying cosmetics is strictly prohibited.
6. All spills and accidents must be reported to your teacher immediately.
7. Be aware of what other groups are doing when you move about in the lab area. Some lab experiments will overlap lab stations at times.
8. If using any kind of flame, use extreme caution. Keep your hands, hair, and clothing away from flames.
9. Long hair must be tied back at all times. No loose clothing/sandals are allowed in the laboratory; long sleeves must be rolled up; bulky jackets, as well as jewelry, must be removed.
10. If any equipment appears defective or breaks while in the lab, report it to your teacher immediately.
11. There will be no running, jumping, pushing, or other behavior considered inappropriate in the science laboratory. You must behave in an orderly and responsible way at all times.

Equipment Rules

1. All equipment must be checked out and returned properly.
2. Do not touch any equipment until you are instructed to do so.
3. When working with electric circuits of any kind, do not plug in or energize the apparatus until the instructor has inspected your circuit and approved the connections and safety considerations.
4. Whenever changing electric connections, always unplug or de-energize the circuit before hand.
5. Assume all electric circuits are dangerous.
6. If any piece of equipment falls on the floor, immediately pick it up and secure it to the table. If working with apparatus that is to be used on the floor, make certain that no other students will walk in that area.
7. Notify your teacher immediately if you observe any unsafe condition.
8. Never stand where a body part is directly below a suspended mass of any kind, or any position where a mass might fall.
9. Some material may become very hot during use. Be aware of these objects and safeguard them so that they can not be touched inadvertently.
10. Safety goggles should be worn in all lab situations unless specifically exempted by your teacher.
11. All equipment is to be used for its intended purpose in the lab only.
12. When doing computer-assisted labs, make no changes to the computer programs without the specific permission of your teacher.
13. Do not start any part of the lab exercise until all members of your group are ready.
14. Never shine a laser in such a manner that the beam or its reflection might strike a person in the eye. Avoid looking at the direct reflection of a laser beam from any shiny surface.
15. If a thermometer or any other glassware breaks, immediately report the breakage to your teacher.
16. Do not handle any radioactive material.
17. No cell phones or other personal electrical devices are to be used in the laboratory space.

Work Area

1. When working in the laboratory, all materials should be removed from the workstation except for instructions, log books, and data tables. Materials should not be placed on the floor, as this is a hazard for someone walking with glassware or equipment.
2. The work area should be kept clean at all times. After completing an experiment, wipe down the area.

Safety Contract

The following contract may be reproduced and must be signed by each student and a parent or guardian before participating in laboratory experiments.

I have read **Safety in the Physics Classroom** and understand the requirements fully. I recognize that there are risks associated with any physics experiment and acknowledge my responsibility in minimizing these risks by abiding by the safety rules at all times.

Please list any known medical conditions or allergies:

____

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____

I do / do not wear contact lenses. (Circle one)

Emergency phone contact ____

Student signature ______________________________ Date ______________

Parent or guardian signature ______________________ Date ______________

Teacher signature ______________________________ Date ______________

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