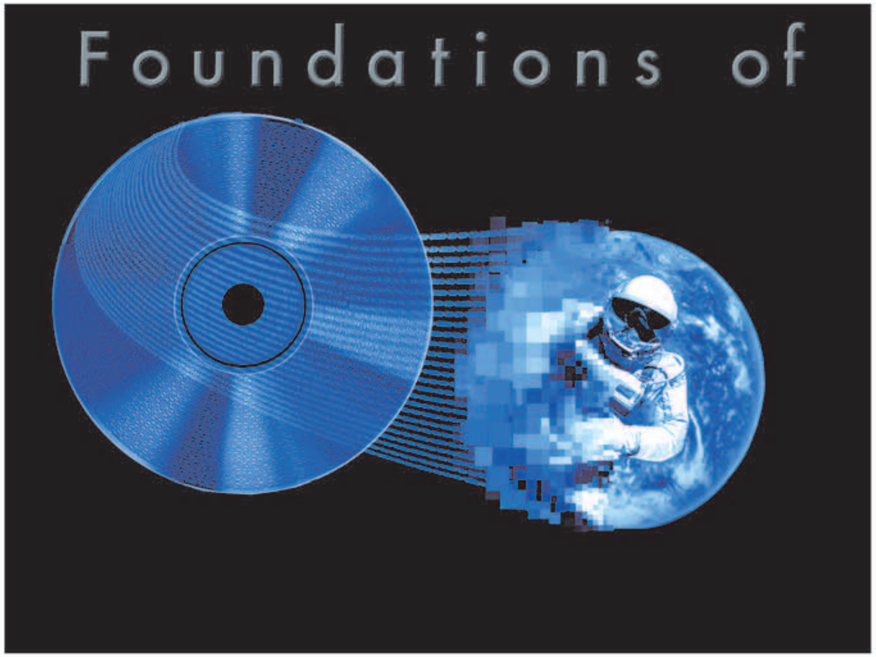

Physics

Tom Hsu, Ph.D.

Teacher's Guide

First Edition
CPO Science
Peabody, Massachusetts 01960

cpo science

About the Author

Dr. Thomas C. Hsu is a nationally recognized innovator in science and math education and the founder of CPO Science (formerly Cambridge Physics Outlet). He holds a Ph.D. in Applied Plasma Physics from the Massachusetts Institute of Technology (MIT), and has taught students from elementary, secondary and college levels across the nation. He was nominated for MIT's Goodwin medal for excellence in teaching and has received numerous awards from various state agencies for his work to improve science education. Tom has personally worked with more than 12,000 K-12 teachers and administrators and is well known as a consultant, workshop leader and developer of curriculum and equipment for inquiry-based learning in science and math. With CPO Science, Tom has published textbooks in physical science, integrated science, Earth and space science, and also written fifteen curriculum Investigation guides that accompany CPO Science equipment. Along with the CPO Science team, Tom is always active, developing innovative new tools for teaching and learning science, including an inquiry-based chemistry text.

Foundations of Physics Teacher's Guide

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The CPO Science Program

> *"The whole of science is nothing more than a refinement of everyday thinking."*
>
> *Albert Einstein*

It was Albert Einstein who said, "*It is nothing short of a miracle that the modern methods of instruction have not yet entirely strangled the holy curiosity of inquiry.*" The great 20th-century scientist, thinker and theorist was a strong believer in learning by discovery and exploration. The method of learning by memorization of complex facts or rote learning Einstein considered "a very grave mistake to think that the enjoyment of seeing and searching can be promoted by means of coercion and a sense of duty."

The CPO Foundations of Physics Program is created around the premise that science is a process of exploration and discovery of ideas and that this new knowledge connects and enhances our lives. The program is presented and sequenced in a way that moves the student through an inquiry-based learning approach. For example, each Investigation begins with a key question that forms the foundation for the learning in the Investigation. In many sections, students complete experiments and hands-on activities before reading and conceptualizing ideas in the student text. Throughout all the instruction, probing questions stimulate exploration, discovery, the quest for data to prove theories, and the need to communicate findings to others.

Scope and sequence

Unlike other textbooks that match content to National Science Education Standards, the CPO Science Program was written directly to state standards. The standards form the benchmark criteria from which each science topic, specific content requirement, and science process was developed. The program provides numerous opportunities for students, teachers, and schools to meet the standards and the state testing requirements. Matching the standards to CPO Unit topics ensures that students will receive the highest quality science instruction to the depth and breadth necessary to meet teaching needs.

On request, CPO Science staff will provide you with your state correlation; many correlations also can be found on the CPO Science website. The correlation document demonstrates the alignment between your standards and the Foundations of Physics Program. The index lists page numbers from the CPO Student Edition and Investigation Lab Manual where examples of specific correlations are found. The Physics Scope and Sequence chart found on the following pages demonstrates the careful consideration and detailed content match between the Student Edition and its accompanying Investigations. These charts can be reviewed as a quick reference to the teaching and learning objectives covered in this program.

Meeting all students' needs

Learning science through investigation is an active process allowing students to gain abstract conceptual knowledge. Most students learn best when reading is enhanced by doing. The CPO Physics Program combines strong, in-depth coverage of physics content with abundant hands-on learning activities in order to meet the variety of learning styles. Real-world examples and application sections provide students the authenticity that validates their connection to the science content. Teaching tips are found in the teacher's guide for providing further information, skill development, and practice problems.

The Multilevel Classroom of Today

The Foundations of Physics Program has been designed to meet the challenge of bringing in-depth, accurate science to all students. To teach in-depth science concepts and skills, the design of the Student Edition reflects the use of instructional aids and strategies to meet that diversity of student need. Careful consideration has been taken to include reading, mathematics, and learning techniques that help all students grasp science concepts and skills.

Reading and concept-learning strategies

Main idea indicators — Main idea indicators appear in the left margin of each paragraph in the Student Edition to help students find information and understand the main concepts in the instruction. Students can use the indicators in the following ways:

- Read all the main idea indicators before reading the section text as a whole.
- List the important points of the section.
- Create outlines and concept maps.
- Find answers to questions by skimming and scanning the indicators for a quick review.

Highlighted vocabulary — As in any discipline or occupation, people must understand the subject's terminology and know how to use it correctly. Terms, units of measurement, and concepts are highlighted in blue so that students may easily identify key words that are important to learn in understanding physics content.

Bold highlighted points — Important scientific concepts, formulas, and laws appear in larger, bold print. Blue type is used to label the variables and further explain the concepts. These statements identify the most important learning points and what to review when studying.

Math and formula identification — Math is integrated throughout the text, with many example problems and a sequence of steps outlining how to solve the problems. Formulas are clearly marked, with each variable clearly labeled.

Building problem-solving skills by using key questions

Asking questions before starting an activity focuses students on what they will learn during the experiment or reading. Each Investigation begins with a key question that students need to answer. Students build problem-solving and critical thinking skills as they tackle each Investigation question. The following is a suggested sequence to use for deciphering questions:

- Have the student reread the question.
- Underline the action words and explain what is being asked.
- Identify the important words (usually vocabulary words).
- Have the students rewrite the question in their own words.
- Help students decide what they will need to know in order to answer the question.

Reading illustrations and graphics for science concepts

Some students learn best through visual clues and illustrations. Others need the dual support of text and visual clues in order to comprehend science concepts and theories. Our student text and Investigations manual have numerous content-rich illustrations, charts, tables, and graphics. Suggestions for using the visual clues include:

- Give students enough time to analyze the graphics and illustrations. Decoding the meaning of a visual is like reading text.
- Ask the students to explain verbally what they see in the graphic and what is being demonstrated.
- Teach students to read data tables and graphs so that they understand how to organize and represent data. Numerous examples and questions requiring completion of tables are presented with explanations.
- Have students organize into teams, then illustrate a concept or create graphics for the section. Other team members decide which concept or section is to be illustrated.

Reading, understanding, and using math formulas

Formulas help students describe relationships between quantities. After students understand the basis for formulas and how they represent relationships, they can use them as tools for solving problems or predicting outcomes. We emphasize understanding relationships rather than simply memorizing formulas. All formulas are in bold type and the variables are clearly labeled.

- Math formulas are connected to the data-collection process during hands-on activities. The formulas are all in the context of the Investigation; as a result, students apply math formulas to actual science experiences.
- Important math formulas are highlighted, written in large print, and also explained in the text.
- Example problems illustrate how to use the formula and how it can be applied to other situations. Students' learning of the formulas is reinforced throughout the Student Edition and in the assessment sections.
- Only the most relevant math formulas are presented in the text and explained in depth.
- A reference section in the Investigation manual contains an easy-to-read table of all the formulas in the program.

Expressing learning in a variety of ways

Students learn differently and use various avenues for expressing their knowledge. In the review questions at the end of each chapter in the Student Edition, students are asked to answer questions. These questions are presented in different difficulty levels. They allow students to express their knowledge and demonstrate their learning in several modalities. Question formats include matching vocabulary and definitions, designing an experiment, researching information, giving other examples, writing short answers, drawing diagrams, using a diagram to answer a question, comparing and contrasting, true and false, and finding information through the Internet.

Evaluation and Assessment

"It is not the answer that enlightens but the question."

Eugene Ionesco

The CPO Science Program is committed to presenting material in a variety of ways to meet the diversity of student learning styles. Students learn in a combination of modalities and demonstrate understanding through a variety of modes. A combination of evaluation methods is available to ensure multilevel and diverse opportunities. A variety of methods is necessary in order for students to demonstrate science content knowledge, application skills, performance abilities, and scientific process and problem-solving skills to the best of their ability. Below are descriptions of the different evaluations.

Review and practice — formative assessment

Review questions, found at the end of each chapter, evaluate student progress on key chapter objectives. These questions provide students with opportunities to practice vocabulary, apply concept knowledge, use computational ability, and solve problems. Review questions also provide students practice in using formulas and math. Skill and Practice Worksheets, provided for additional practice in problem solving and applying conceptual knowledge, are ideal for use as homework assignments. These worksheets are provided for every chapter in the text and are found on the Teacher Support CD.

Assessing broader knowledge with assessment questions — summative assessment

The assessment questions have been carefully designed to test all the important topics covered in a unit. Included in the questions are examples of graphs, charts, and computational information needed to answer questions and demonstrate application skills. The assessment questions are on the ExamView® CD and consist of multiple-choice and multiformat questions that can be used to build your own exams and questions designed to meet the unit content. These questions are designed to reflect typical standardized test questions. Exposure and practice in answering multiple-choice-type and short-answer questions has proved helpful to students in formal standardized testing situations. There are over 1,200 questions on the ExamView® CD. The Examview® booklet includes the questions along with their level of difficulty and the answer.

Learning and applying skills — performance assessment

Being able to justify conclusions based on active experimentation and data collection is a powerful skill in today's technological world. Performance assessment measures how well a student can solve problems and demonstrate understanding through application. The Foundations of Physics Program builds the self-confidence students need in order to tackle problems through the use of investigation.

Each Investigation begins with a key question that students answer at the end of the hands-on activity. These activities allow the teacher to observe students' ability to think and work through a lab process. Investigations rely on team participation to solve the key questions and problems. Students are continuously exposed to a systematic problem-solving method that encourages observation, collection of data, and justification of findings.

Safety

Safety is highlighted throughout the CPO Science Program by the use of safety icons and safety tips in the Investigations. The Investigations activities and experiments have been written to reduce safety concerns in the laboratory. The equipment required for the Investigations is very stable and easy to use and manage. All the chemistry-related Investigations use supplies and chemicals that can be purchased readily in a grocery or hardware store. Although this does not mean that these supplies are nontoxic, you will be able to dispose easily of most of these chemicals. In cases where you are concerned about safety and proper use or disposal, we strongly recommend that you obtain the Materials Safety Data Sheets (MSDS) for the chemicals. These are easily obtained by calling the manufacturer of the product.

The CPO Science Program introduces students to basic safety using a Safety Skill Builder worksheet (see the Skill and Practice Worksheets that come with the Ancillaries). This skill builder includes basic safety information, a quiz that can be administered to the students after you have covered safety in the laboratory, and a student safety contract. Use the skill builder as a guide for your lesson and fill in any information and guidelines that are particular to your classroom and school. Safety is such a crucial concern when working in a laboratory environment that having students sign a contract may emphasize that safety in the science lab is everyone's responsibility. We recommend devoting an entire lesson to safety in the classroom and laboratory.

Units and Measurement

The CPO Science Program was designed to prepare students to be successful in any career, not just academia. Students need to be fluent with scientific skills in any system of units prevalent in the workplace. Virtually all engineering and industrial careers require proficiency in both English and metric units. Even metric measures are not standardized. Research scientists use two varieties of metric: meter-kilogram-second (MKS) for physics and centimeter-gram-second (CGS) for chemistry. Ocean and air transportation industries use nautical miles. Medicine uses both Fahrenheit and Celsius temperature scales. Astronomers use light-years. The message to take from this diversity is that students need to learn and practice science in several systems of units because they will encounter different systems outside the classroom.

Because of their extensive practical use, English units are presented in the Student Edition and Investigations, however metric units are emphasized throughout the text. The use of English units was done to connect the student's common experience and also to provide a bridge between the systems. Almost all concepts are presented in metric units, with an occasional reference to other systems when appropriate. All of the assessments use only metric units, which is common practice for standardized tests. It is our opinion that a basic high school science education should be focused on developing practical quantitative reasoning, problem solving, and observational skills. By presenting a mixture of units as they occur in the real world, we help prepare students for success in any endeavor that requires scientific thinking, such as business, industry, or education, as well as for further study in science.

Organization of the Program

"Hear and you forget; see and you remember; do and you understand."
Confucius

The CPO Science Program has four components: Student Edition, Investigations, Teacher's Guide, and Equipment. These components interweave and reinforce inquiry-based learning, hands-on discovery, and grasping science concepts through reading. Abstract concepts and skill development opportunities are presented in a variety of ways to address many and diverse learning styles. Enhancing the readings are clear, accurate illustrations that reinforce the learning of abstract concepts. By the end of each section, students have completed a hands-on experiment, answered essential questions, completed a reading to master the science content, and also have read an application of how the science is used in the real world.

The one-volume Teacher's Guide provides information, answers, and teaching tips. Ancillary teaching tools also include three CD-ROMs containing student answer sheets for the Investigations, color teaching tools, the entire student text on an electronic book file, and the ExamView® question builder.

Student Text

The basic organizational structure of the student text is the unit. There are nine units, each one broken into topic chapters containing three content-specific sections. The unit themes covered in the Foundations of Physics Program were chosen for their relevance to CPO's commitment to provide in-depth coverage of science concepts. The glossary and index have been designed so students can quickly skim for page numbers and definitions. Each student chapter contains pertinent content and skill-development reading with numerous illustrations for reading support. Each chapter contains an extensive review question section that evaluates the student's progress in areas such as vocabulary development, concept understanding, computation skills, and problems. Special features of the Student Edition:

- **Chapter page:** This introductory page presents the important objectives of the student reading, including pertinent vocabulary.
- **Side heading outlines:** Developing literacy skills in math and reading is stressed throughout the instruction. Left-margin side headings highlight the main ideas in the text and help the student grasp reading concepts through skimming, scanning, and key-word identification.
- **Highlighted vocabulary:** Science vocabulary mastery is paramount for science concept understanding. Science vocabulary can be highly technical and abundant. Vocabulary words are highlighted for easy identification and defined in a variety of ways.
- **Numerous visual teaching tools:** The Student Edition contains graphics, charts, illustrations, and data tables supporting abstract conceptual learning. These teaching tools reinforce instruction and aid in visual representation of material necessary for addressing the broad range of learning styles. The visuals are precise in content and presentation and reflect CPO's commitment to accuracy, science content excellence, and inquiry-based instruction.
- **Formulas:** The most important formulas and laws are highlighted and in bold type, with each variable labeled.
- **Math:** The use of math is integrated in the physics instruction. Numerous problems are presented for student practice, each containing the steps for solving the problems.

Investigations

> *"The greatest tragedy of Science: the slaying of a beautiful hypothesis by an ugly fact."*
>
> *Thomas Huxley*

The Investigations are the heart of the CPO Science Program. We believe that most students learn best and are motivated to learn through direct experience and exploration activities. Key questions focus the student on the main points of the concept to be learned and what they should be able to answer after the experiment. There is one Investigation for each student reading section. The student reading and Investigation closely compliment the science instruction and reinforce the same principles.

Each Investigation is introduced with a key question that the students will be able to answer after completing the hands-on activity. Students are also given learning goals for each Investigation and a short informational piece to get them thinking about the content of the Investigation. Student answer sheets are found on the Teaching Tools CD-ROM. The answer sheets contain more space for writing and larger tables and graphs. The teacher can print and duplicate the sheets for students' use.

Investigations are usually completed before the accompanying student reading chapter. The CPO philosophy is based on the premise that through discovery, the students will begin to understand science concepts and build on them with new skill development. The student readings strengthen the students' knowledge of theory and aid their understanding. For certain Investigations, the student reading must be done first so that students have the basic knowledge necessary to complete the Investigation. Whether a chapter should be read before or after an Investigation is explained under the reading synopsis heading in the teacher's guide pages for each section.

Special features

- **Data collection, graphing, and the scientific process:** These skills are emphasized and reinforced throughout the program and students are frequently encouraged to practice these skills as self-learners.
- **Lesson planning page:** The information you need to know to teach and conduct the Investigation is available in the teacher's guide section pages. The learning goals and questions, equipment setup, consumable materials list, teaching sequence, and a synopsis of the student reading are all found on the lesson introduction pages.
- **Icons:** Throughout the Investigations, icons are used to point out safety requirements and to reference the unit that is being presented. The unit icons are the same as for the accompanying material.
- **Explanation:** Further content information and explanation is sometimes given to the student in the Investigation to assist in its completion and to present background skill knowledge.
- **Equipment:** Specialized equipment has been designed to accompany the teaching of the Investigations. The equipment is durable and provides consistent and accurate results. The equipment pictured in the Investigation is the same as the equipment the student is using to complete the hands-on activity. Student text illustrations also show the same equipment used for experimentation.

Teacher's guides

"The most important thing in science is not so much to obtain new facts as to discover new ways to think about them."

William Bragg

The teacher's guides are constructed around the same premise as the student instructional materials: inquiry-based learning. The guides include a sample demonstration lesson for each Investigation, written as a dialogue between the teacher and the class. These samples demonstrate how to teach the Investigation using inquiry-based teaching and student group discovery. The sample demonstration is only one example of teaching the Investigation with possible student responses. Teaching tips, the accompanying student section synopsis, and teaching strategies are also included.

The first two pages of each teacher's guide section contain a clear, concise overview of the Investigation. It is our belief that a quick guide is useful in outlining the learning objectives, setting up the Investigation, and mapping the sequence of the Investigation procedures. These pages contain a brief synopsis of the student reading, a review of the leading question, the learning objectives, and a clear equipment and consumable materials list. Detailed equipment setup instructions are included in an Equipment Setup Booklet that comes with each physics equipment kit.

The Investigation lesson pages present a sample teaching scenario written as a dialog between the teacher and class. The dialogs present actual lessons taught from the teacher's point of view, as well as possible student responses. The dialogs provide excellent support for teachers who are new to the subject area, as they identify possible student misconceptions and highlight important learning content. The dialogs provide teaching tips such as:

- What to put on the chalkboard.
- How to teach by questioning.
- What reactions the students may have and how to respond.
- Interesting stories to make connections between key concepts and everyday life.
- Computational information and more problems.

On the facing page of the dialog is a miniature Investigation page and the answers for the Investigation. The dialog and Investigation page have corresponding reference numbers to aid in matching the dialog to the Investigation.

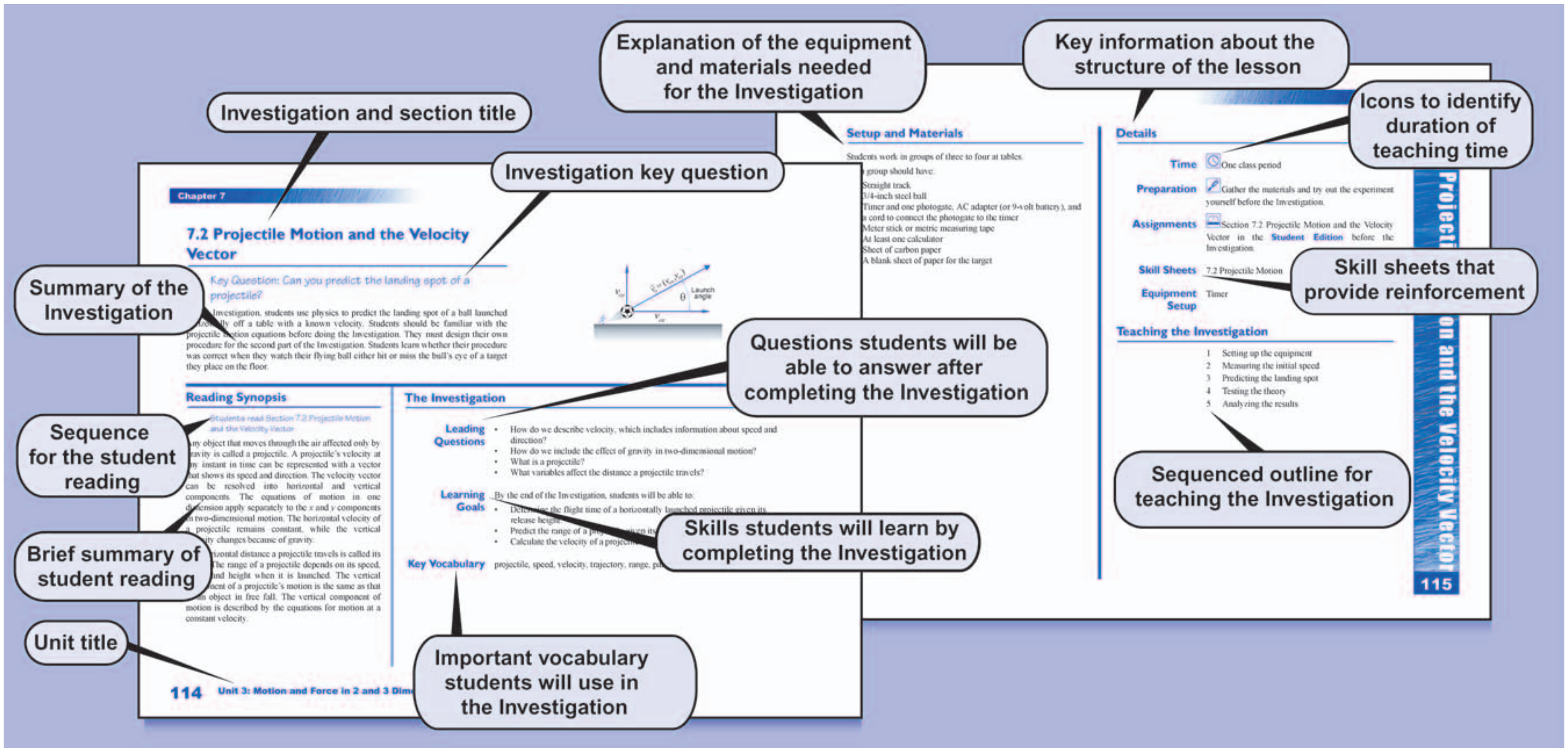
Teacher's guides contents

The teacher's guide contains an explanation of the program, scope and sequence charts, the summaries and dialogs for each chapter, a miniature Investigation page and accompanying answers, and a list of consumable materials. Answers for the review questions in the student text are also included.

The Teacher's Guide Investigation Overview Pages

The teacher's guide for each Investigation begins with the overview pages. The overview pages correspond to each section of the Student Edition and each Investigation in the CPO Science Program. These pages review the instructional components, beginning with a summary of what the students will learn in the Investigation. Included are a synopsis of the reading, pertinent vocabulary from the Investigation, learning goals, and the key and leading questions that students will be able to answer after completing the Investigation. It is important to note that below the heading for the reading synopsis, there is a suggested sequence for teaching the student section and the Investigation. The student reading section frequently follows completion of the hands-on Investigation. In some sections, the student reading must be completed first in order for students to assimilate the skills and concepts required to complete the Investigations.

The second page outlines the equipment and material needed, preparation considerations, skill sheets, and the sequence of teaching steps.



Teacher's Guide Demonstration Lessons

Each teacher's guide demonstration lesson contains an outline of the lesson, a "sample dialog," and teaching strategies and tips. These pages also include the Investigation and sample answers to the activity. In the facing-page format, you can review the sample dialog between the teacher and students, the Investigation page, and sample data and answers. All the information you will need to teach the Investigation is easily skimmed in this format.

Below are features of the dialog, Investigation answer page, and sidebar teacher notes.

Outline: This section contains an at-a-glance sequence of steps that a teacher can skim. It is a quick guide to what is taught in the Investigation and notes on the Investigation.

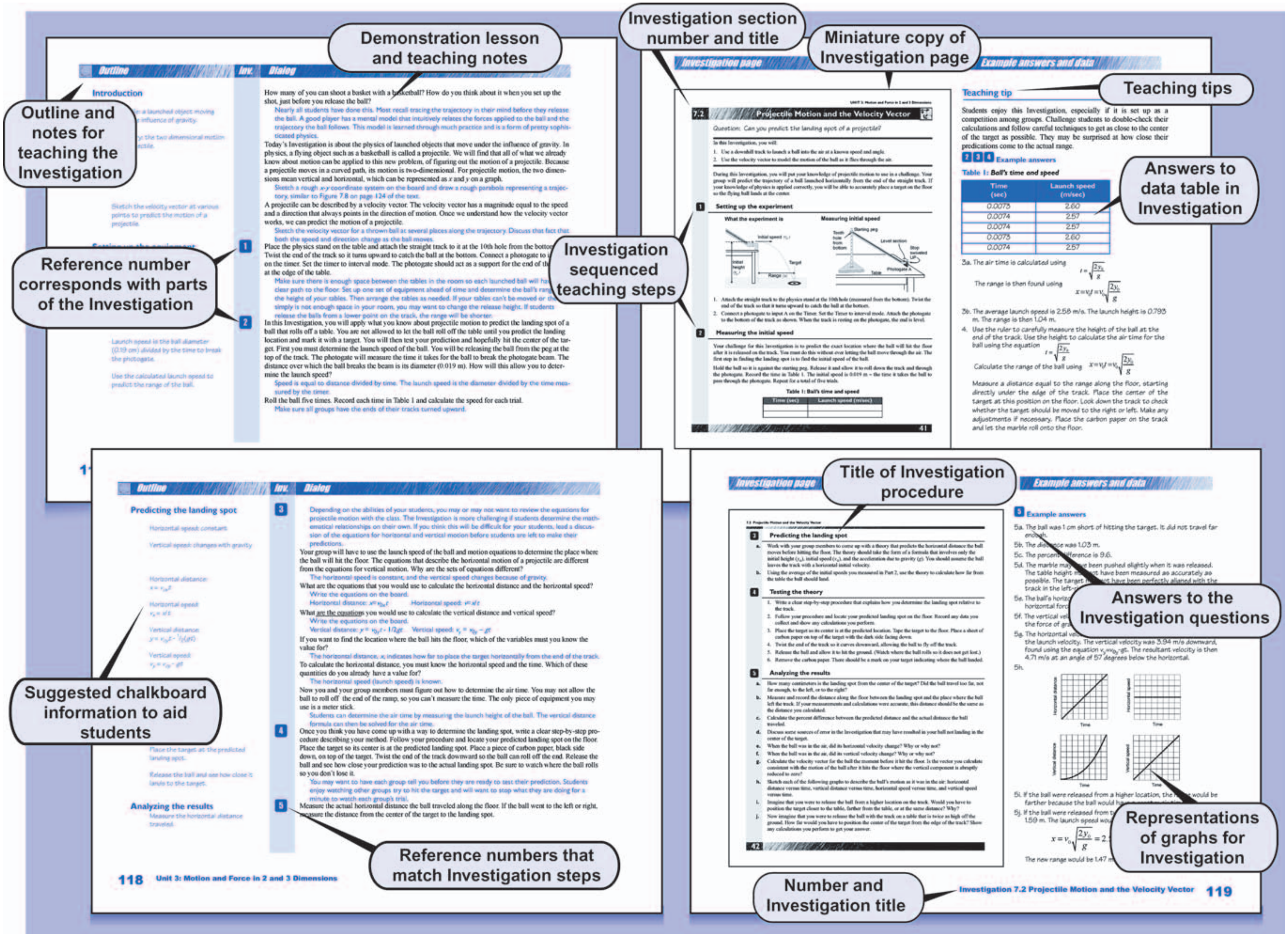
Inv.: In this column the teacher will find a reference number that matches the parts of the Investigation page. These corresponding numbers guide you to the part discussed in the dialog.

Dialog: This section is presented as an exchange between the teacher and the class. This sample lesson outlines what the teacher would actually say to the class and typical responses from the students. Helpful teaching ideas and tips such as: "Students will need access to water," "Group supervision is important at this point" are included. The teacher's directions and comments to the students are printed in black, and responses and directions are in blue text. It is our hope that teachers will review the dialog before presenting the Investigations to the class, both as a supportive tool and to help clarify the goals and important points of each Investigation.

Investigation: This is a miniaturized Investigation page that is referenced in the dialog. The teacher can refer to the numbers at the left of the Investigation page and match them to the opposite page as numbers under the "Inv" column. These numbers indicate what part of the Investigation the dialog is referring to.

Example answers and data: Sample student data, answers to Investigation questions, and graphs are found in the right-hand sidebar area. The data and some of the reflective answers are only examples of data and responses that could be given by the students.

Sidebar notes: Teaching tips, information, and more reinforcement ideas for students are also found in the right-hand sidebar area.


Demonstration lesson and teaching notes
Investigation section number and title
Miniature copy of Investigation page
Teaching tips
Outline and notes for teaching the Investigation
Answers to data table in Investigation
Reference number corresponds with parts of the Investigation
Investigation sequenced teaching steps
Title of Investigation procedure
Answers to the Investigation questions
Suggested chalkboard information to aid students
Representations of graphs for Investigation
Reference numbers that match Investigation steps
Number and Investigation title