Survey of High-School Physics Texts

Conceptual Physics

Conceptual Physics

Author: Paul Hewitt

Publisher: Addison-Wesley, 2725 Sand Hill Road, Menlo Park, CA 94025; third edition, 1999

Cost: $52

Physical Characteristics: 1 volume, 40 chapters, 690 pages, 1.5 kg, full color

Peripherals Available: These are excellent. Teacher's edition includes demonstrations, teaching suggestions, and answers to text problems; lab manual includes some labs for Apple computers; teaching guide; concept-development practice book with worksheets for concepts; problem-solving exercises in physics—math-related problem solving exercises that may be used to supplement text; package of 100 overhead color transparencies; next-time questions—challenging questions that may be used to open or conclude a class; Testworks CD-ROM; Active Physics CD-ROM; CP Surf Internet site—puzzles, demonstrations, games; interactive physics simulations software; video disks; video tapes.

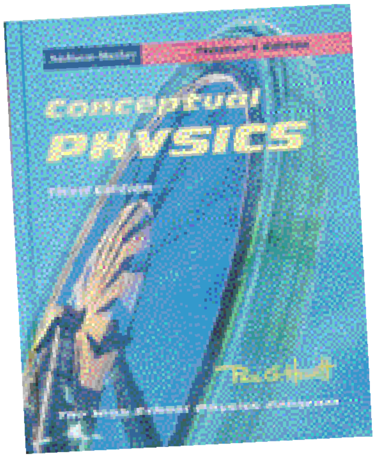
Content Distribution: Introductory and math review, 3%; kinematics and motion in a plane, 5%; forces and vectors, 20%; work and energy, 3%; heat and states of matter (including fluids), 19%; waves, 5%; light and optics, 14%; electricity and magnetism, 14%; modern and nuclear physics, 12%

Intended Audience: Designed to appeal to a broad range of 9th through 12th grade students

Reading Level: 9th through 12th grade. There was some disagreement among the reviewers on this point.

Math Level: Very, very basic. As the title indicates, this text is primarily conceptual rather than quantitative.

Special Features: Glossary, index, radioactive decay; some brief activities; appendix includes sections on working with units in physics, on graphing, on qualitative vector applications, and one on exponential growth and decay. There is a great Internet site associated with this text.



General Comments

The credo of *Conceptual Physics* is concepts before calculations. The material is quite different from mainstream physics texts in that there is very little reliance on equations, although the third high-school edition has more equations and problem solving than previous editions. The book's theme is that an understanding of physics is a vital part of understanding the world around us, and that all students will be able to attain that understanding.

The ideas of physics are applied to everyday concepts. For example, on page 68, air resistance and terminal velocity are discussed. In addition to the classic "feathers versus coins" example, heavy skydivers versus light ones are presented. The text asks if the force of air resistance is the same for a falling baseball and a falling tennis ball and which will have the greater acceleration. The text discusses issues that are of high interest to students.

The text is generally clear and concepts are related and flow logically from one chapter to the next. The text is supported by relevant color photographs, author illustrations, cartoons, and comic strips that are humorous and to the point. Students like them. There are inserts such as "Physics of Sports" and "Doing Physics" activities, as well as "Links to Biology" and "Careers in Physics" items. Support materials that accompany the text are terrific.

The teacher's guide is an invaluable resource that complements the text. The transparency package humorously illustrates major physics concepts, and a book called *Next Time* asks provocative questions. All peripherals are useful.

The book contains a variety of types of questions. Mid-chapter questions, highlighted in yellow, are largely conceptual, generously scattered throughout the text, and answered in footnotes at the bottom of the page. There is one sample problem for $F=ma$ (p. 62), one for momentum conservation, one for torque, and a couple of others. There are many fewer than in a typical text. The end of each chapter includes:

1. Review questions (usually a short conceptual question designed to recall key ideas)
2. Activities that can be done with little or no equipment
3. "Plug and chug" questions that offer one-step problem solving
4. Think and explain questions that require a little critical thinking
5. Think and solve problems that reinforce math concepts and might involve more variables. Answers to these problems are available only in the teacher's edition.

The formal level of mathematics would be accessible to virtually any student in high school. Very few traditional equations are used. Projectile motion is presented without any quantitative calculations at all.

Our reviewers found a few physics mistakes in the text and quite a number of "fuzzy" explanations. However, in terms of accuracy *Conceptual Physics* rated above average for the texts in this survey.

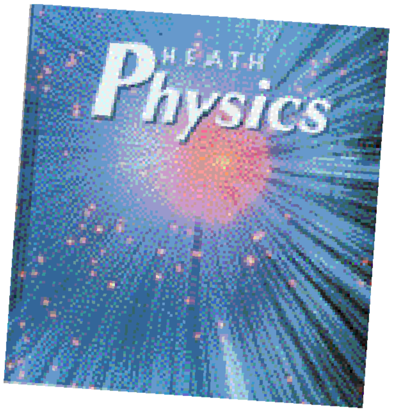
The text does present "real" physics and generally does an excellent job explaining concepts. Many, if not most, traditional physics curricula and tests require more equations than are present in this text, but high-school teachers who reviewed the text did not feel that this was a major obstacle. The Supplemental Problem-Solving Exercise Book and Concept Development Practice Book provide more exposure to traditional equations. There are not many graph questions, even in the supplement. Most reviewers stated a need to supplement the text with problem sets from other sources, but they did not feel this would be very difficult. The lack of mathematics and equations might make this a difficult textbook for a beginning teacher to use. Among high-school texts, *Conceptual Physics* is different enough from other texts to place it in a class by itself.

The Textbooks Surveyed

- ***Active Physics***, Arthur Eisenkraft; **Publisher:** It's About Time, 84 Business Park Drive, Armonk, NY 10504; copyright 1998; **Cost:** Each module: $14.95 softcover; $18.95 hardcover; plus videos and software.
- ***Conceptual Physics***, Paul Hewitt; **Publisher:** Addison-Wesley, 2725 Sand Hill Road, Menlo Park, CA 94025; third edition, 1999; **Cost:** $52.
- ***Heath Physics,*** David G. Martindale, Robert W. Heath, William W. Konrad, Robert R. Macnaughton, and Mark A. Carle; **Publisher:** D.C. Heath and Co., Lexington, MA; copyright 1992; **Cost:** $53.
- ***Holt Physics,*** Raymond A. Serway and Jerry S. Faughn; **Publisher:** Holt, Rinehart and Winston, Harcourt Brace & Company, Dallas, TX 78746-6487; copyright 1999; **Cost:** $49.80.
- ***Physic-AL,*** Brian Martin and Cornelis Spronk; **Publisher:** J. M. LeBel Enterprises, 1815 Monetary Lane, Dallas, TX 75006; second edition, 1994; **Cost:** $44.95.
- ***Physics: Principles and Problems,*** Paul W. Zitzewitz, **Publisher:** Glencoe/McGraw-Hill, 936 Eastwind Drive, Westerville, OH 43801; copyright 1999; **Cost:** $47, plus peripherals.
- ***PSSC (Physical Science Study Committee) Physics,*** Uri Haber-Shaim, John H. Dodge, Robert Gardner, and Edward A. Shore; **Publisher:** Kendall/Hunt Publishing, 2460 Kerper Blvd., P.O. Box 539, Dubuque, IA 52004-0539; seventh edition, 1991; **Cost**: $49.99.

Survey of High-School Physics Texts

Heath Physics



Authors: David G. Martindale, Robert W. Heath, William W. Konrad, Robert R. Macnaughton, and Mark A. Carle

Publisher: D.C. Heath and Co., Lexington, MA; copyright 1992

Cost: $53

Physical Characteristics: 1 volume, hardcover, 840 pages, 1.7 kg, full color

Peripherals: Teacher's guide, lab manual (student and teacher editions), computer test bank (with teacher's guide)

Intended Audience: 11th or 12th grade academic students, probably not honors level

Reading Level: 11th or 12th grade

Math level: High-school algebra, geometry, and some trigonometry

Content Distribution: Kinematics, 8%; force and vectors, 14%; work, energy, power, 6%; heat and thermodynamics, 5%; fluids, 5%; waves, 5%; sound, 8%; light and optics, 15%; electricity and magnetism, 21%; modern physics, 13%

Special Features: Appendices covering metric units, physical constants, trigonometric tables, scientific notation, the periodic table, isotopes, orders of magnitude, error estimation, graphing, and answers to problems. Articles relating physics to other fields ("Physics Connects..."), how certain devices work ("Technology") and interview essays on careers. Laboratory exercises ("Investigations") included in the text

General Comments

Each chapter of *Heath Physics* follows a logical and set format. First there is a clear list of one-sentence statements of the chapter objectives, usually followed by a brief (two to three paragraphs) qualitative introduction, giving a basic motivation for the chapter. Then the subject matter of the chapter is developed in a generally clear and logical way, typically with one concept or subtopic per chapter section. Mathematics and illustrative examples are introduced as needed. Continuity from one section to the next is good.

Many worked-out sample problems and easy (one-step) exercises (called "practice") are interspersed throughout the text as topics are introduced. Good use is made of diagrams, figures, and photographs (averaging two or three per page). At the end of each chapter, there are "Investigations," which are instructions for informal experiments for students to do, usually with simple equipment. Also at the end of every chapter is a "Chapter Summary," which reviews in a list of 10 to 20 brief statements the important facts covered in the chapter. The "Summary" is followed by a "Chapter Review," which contains essay questions and numerical problems of varying difficulty.

The text is well organized and aimed at students in the 11th or 12th grade who have a reasonable grasp of algebra, geometry, and elementary trigonometry. Pre-calculus would be helpful but not absolutely necessary. Both the reading level and mathematical-skill level required make this book suitable for a "standard" physics course. Honors-level students would not be challenged by this text, unless supplementary materials (particularly problems) were added. Topics are developed in a traditional manner and derivations of equations are handled well.

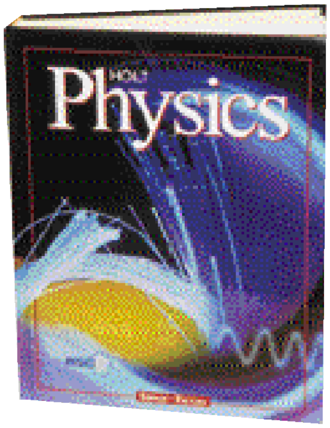
There are some notable omissions of certain standard topics, however. For example, projectile motion is barely mentioned and not developed as a topic. The same is true of Coulomb's Law, which is only mentioned in the caption for a picture of Coulomb. In the thermodynamics chapter, probably the weakest in the book, the First Law is presented only in a very restricted form (as it applies to cyclical heat engines) and its connection to internal energy is not explicitly stated. Despite these and other lesser omissions, inaccuracies, and lapses of continuity, the text's exposition is basically sound, more so than many other texts.

The text has a number of features that are designed to engage student interest. Good use is made of photographs and real-life examples. Also included in many chapters are short (one-page) essays on careers in fields that are more or less related to physics, featuring interviews with people who actually work in those fields. An effort is made to depict women and people from minority groups in career roles in physics and related fields. The historical development of major ideas in physics is well handled and integrated into the text narrative.

Overall, *Heath Physics* is a solid and traditional text, containing a well-balanced mix of concepts, mathematical development, applications, and history. It would be suitable for a standard high-school physics course in the junior or senior year.

Survey of High-School Physics Texts

Holt Physics



Authors: Raymond A. Serway and Jerry S. Faughn

Publisher: Holt, Rinehart and Winston, Harcourt Brace & Company, Dallas, TX 78746-6487; copyright 1999

Cost: $49.80

Physical Characteristics: one volume, 1002 pages, 2.2 kg, full color throughout

Peripherals Available: Teacher's solutions manual; problem workbook; lab book; review worksheets; test generator computer bank with lab analysis tools; teaching transparencies; Interactive Tudor software

Content Distribution: Introduction, 3%; kinematics, 8%; forces, 3.4%; work and energy, 3.2%; momentum and collisions, 3%; rotational motion and gravity, 3%; rotational equilibrium, 3.5%; fluids, 3.2%; heat and thermodynamics, 7.3%; vibrations and waves, 3.6%; sound, 3.2%; light reflection and refraction, 6.7%; light interference, 2.6%; electric current and circuits, 5.6%; magnetism, 2%; induction and alternating current, 3.2%; atomic, 3%; modern electronics, 2.3%; subatomic, 3.6%

Intended Audience: Traditional high-school physics class

Reading Level: 11th and 12th grades

Math Level: basic algebra, simple trigonometry

Special Features: Appendices: math review, symbols, SI units, table of constants; periodic table, isotopes, answers to selected problems, glossary; 10 pages of consumer information; 11 pages of "tomorrow's technology"; 18 pages of "Physics on the Edge"; 10 pages of "Science, Technology, and Society"; 5 Timelines; 25 lab experiment directions; 20 "Quick Labs"; chapter summaries; sample problems worked out on every topic; chapter-end problems: single-concept, multiple-concept review; occasional directions for solving problems with graphing calculator

General Comments

This book is visually attractive, with many color pictures and diagrams. To some extent, the color-coded special features make the pages appear "busy." Students will have to learn to use the text, rather than just read it.

Topics are presented in the standard sequence and with the standard explanations. There is no attempt to devise novel approaches or to make less more. On the contrary, the coverage is encyclopedic. Part of the page count is explained by the large number of lab experiments that are built into the text, both mini-labs and formal labs.

Although the text appears to be at a high level for math treatment, very little math is needed besides simple algebra and trigonometry. Actually, the book is surprisingly nonquantitative. That is to say, problems are solved to three significant figures (always), but no attention is then paid to the significance of the number obtained. This is also true of the main part of the text; the relative size of things is not discussed.

The text is filled with the standard formulas of introductory physics, but practically none of them are derived. They are asserted without any attempt to justify the details or to examine the functional dependencies.

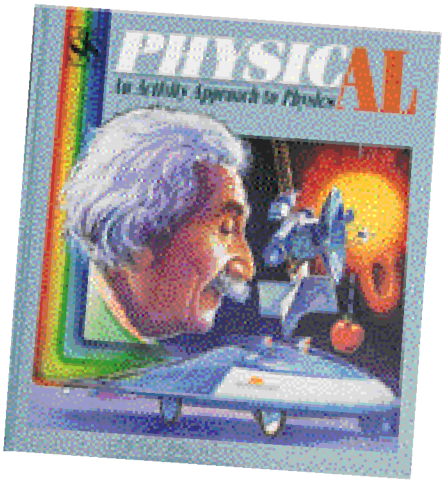
Like most physics texts and most physics courses, this text is not built around a theme. There is no apparent continuity from one topic to the next. Newton's laws are presented, but seldom used again.

There is no emphasis on gender or race inclusion, nor is there any emphasis on the historical development of physics, except for the timelines, which are not fed into the main subject. In the teacher's edition, there is reference at the beginning of each chapter to statements from the National Science Education Standards. There appears to be no attempt to make the text match the Standards.

There is a good selection of problems requiring single- and multiple-concept calculations, and also questions involving conceptual understanding. As in the text itself, the relative size and significance of numerical answers is not emphasized.

This text is a first edition, but reviewers were still surprised at the large number of physics mistakes.

Physic–AL



Authors: Brian Martin and Cornelis Spronk

Publisher: J. M. LeBel Enterprises, 1815 Monetary Lane, Dallas, TX 75006; second edition, 1994

Cost: $44.95

Physical Characteristics: one volume, 587 pages including appendices and index, 1.3 kg, colors include black, white, sepia, and gray

Peripherals: Teacher's reference manual, solution manual, student exercise book, unit tests, *Physic–AL* computer disk, computer test/homework program (18 disks and mid-term and final exams), computer test bank (ASCII format)

Intended Audience: 11th and 12th grades

Reading Level: 11th and 12th grades

Math Level: Students would need a strong background in algebra, as well as some trigonometry and geometry.

Content Distribution: Kinematics and motion in a plane, 12%; vectors and forces, 16%; work and energy, 15% (that includes 38 pages on heat and 24 pages on home energy conservation); waves, 6%; light and optics, 12%; electricity and magnetism, 21%; modern and nuclear, 12%

Special Features: This book contains numerous labs and activities. There is a glossary, index, many worked-out sample problems, and appendices (on uncertainties measurement, algebraic relationships, SI Units, useful constants). Reference is made to computer programs that could be used for some labs and certain topics.

General Comments

The subtitle of this text is "An Activity Approach to Physics," and so its special features center on activities and labs. Most reviewers felt that these are good to have, but that their predominance gives something of a choppy feel to the material. The labs vary in difficulty; some students might find them difficult. Many major concepts are left for the student to discover, but these are not always talked about afterwards. This makes it the responsibility of the teacher to make sure the students come to the correct conclusions after each lab. The book does a very good job of presenting the history of many of the topics discussed. Most of the reviewers felt this was one of the strongest positive features about the book.

This text includes many derivations that are not always covered in high-school texts (for example, the derivation of the radius of a hydrogen atom in terms of fundamental constants). Some derivations are easy to follow; others would be a little difficult for the average student. The book encourages students to use dimensional analysis and some estimations (for example, using the acceleration due to gravity as 10 m/s^2) when solving problems. Some reviewers felt that reliance on dimensional analysis is useful, but not as effective as careful substitution into equations. Real-world numbers are found primarily in the problems and not in the reading material.

Certain topics seem to need more color. This second edition still presents some out-of-date material (for example, the discussion of the Superconducting Super Collider on page 397). Photographs are found primarily on the first page of each chapter, with a very few scattered throughout the material. Diagrams or sketches illustrate the chapters. The book includes information in the margins about science and technology, which reviewers found interesting. We believe these were put there as student motivators, but in some cases they have nothing to do with the material being presented in the chapter.

The approach to covering the physics is traditional in some respects and nontraditional in others. Several reviewers found this book a difficult one to understand, due in part to the unusual way some material is presented. Vectors are presented in rectangular and polar coordinates, and a lot of time is spent converting between the two. Because of this presentation, topics such as projectile motion (which relies heavily on vectors) are presented in very nonstandard ways. The section on optics does not cover ray tracing or the thin-lens equations. Instead the book relies solely on the power equation (in diopters) to find images. The section on electricity uses both resistance and conductance to cover the material. The section on collisions and momentum uses computer diagrams to plot time versus position to represent the collisions. Reviewers did not feel that these treatments would help the students understand the material better, and may be confusing. Reviewers noted that important topics such as solid state, nuclear reactions, laws of thermodynamics, and phase diagrams are given limited coverage or omitted.

The book contains many problems for students to try, and many sample problems are worked out. These are primarily one-step or two-step problems. Some sections are more difficult than others. Many problems require students to do unit changes and other preliminary calculations before actually practicing the new formulas being introduced. Conceptual problems are presented. Also, many problems and questions are presented as part of lab activities.

Presentation of everyday applications is done better in some units than others. The text does address some environmental issues. It does not do a very good job of presenting women or minorities. There are historical biographies throughout the book. With very few exceptions, all of these scientists are white males. The book does not show women or minorities working with science. The book was written before the National Standards became widespread.

Due to the unique presentation of certain topics, teachers in states that have statewide exams many find this text more difficult to use than books that cover the material in a more standard manner. The reviewers found no major physics mistakes in the second edition, but there are certain content areas that are not well covered or not covered at all; teachers will have to fill in the missing information. The extensive number of labs and the interesting historical coverage make this a good reference book.

Dan Cohen, Rob Parker, back, Christina Geraci, center, and Joanne Wang, front

Heather Feinstein, back, and Emily Maglio

Survey of High-School Physics Texts

Physics: Principles and Problems

Author: Paul W. Zitzewitz

Publisher: Glencoe/McGraw-Hill, 936 Eastwind Drive, Westerville, OH 43801; copyright 1999

Cost: $47, plus peripherals

Physical Characteristics: one volume, 800 pages, 31 chapters, 1.6 kg, full color

Peripherals: Study guide, lab manual, videodisc, Mindjogger Videoquiz, computer test bank, transparencies, problem solution manual, CD-ROM for teacher resource package, Mechanical Universe videos, Physics for the Information Age interactive CD-ROM for students; about 15 other booklets with worksheets, enrichment exercises, alternative assessments, reteaching, use of graphing calculators, etc.

Content Distribution: Introduction/math review, 6%; kinematics and motion in a plane, 11%; forces and vectors, 10%; work, energy, and momentum, 11%; heat and states of matter, 7%; waves, 6%; light and optics, 12%; electricity and magnetism, 19%; modern physics and solid state, 18%.

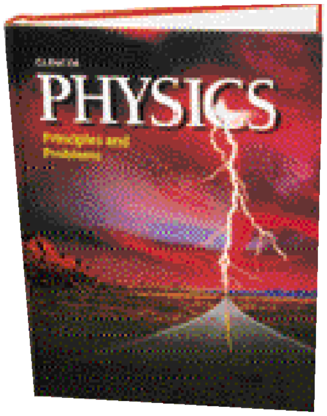
Intended Audience: 11th and 12th grade academic students, possible honors use

Reading Level: 11th and 12th grade

Math Level: Students should have completed high-school algebra, geometry, and trigonometry

Special Features: Index; glossary; appendix with extensive math review (referenced throughout text); appendix with completely written solutions to practice problems in text; short "pocket" labs; in-text labs; Help-Wanted sections addressing career concerns; physics and technology/physics and society sections; How It Works sections; graphing calculator activities; website at www.glencoe.com/sec/science for students to access additional problems and physics news; extensive learning styles perspective

Alternative Assessment: Recommendations for portfolio/journal activities in teacher's wraparound edition; booklet offered



General Comments

The accuracy and presentation for this textbook were well regarded by most reviewers. While there are editing problems leading to errors in diagrams and solutions to problems, the rate does not seem high for a first edition. There are some notable mistakes. The use of average acceleration is unusual and seems to be a stand-in term for constant acceleration. Average acceleration is defined as $(v_1–v_0)/(t_1–t_0)$, which is true for acceleration in a straight line, but the book addresses more complicated situations as well. At another point, the equation is given as $(\bar{v}_1–\bar{v}_0)/(t_1–t_0)$, a meaningless expression. When discussing kinematics, the concept of an instant of time is stated to be when $t=0$, which is both incorrect and confusing for students. Many conceptual errors appear in solutions in the teacher's edition.

The consensus of the reviewers is that this book demonstrates an encyclopedic coverage of the subject matter covered in a typical high-school class, with some enrichment (e.g., changing acceleration, capacitors, illumination, extensive modern physics section, and many thought-provoking questions and problems). Some traditional topics not specifically covered are density, Hooke's Law, the Doppler-effect equation, the gas laws, real mechanical advantage, vector parallelograms (concurrent vectors), stringed instruments, use of decibel, and wave phase.

Development and presentation are carried out in a typical way, but with some unusual approaches. For example, the component method is used for vector analysis; the simpler parallelogram method is more common on the high-school level. The system of vector diagrams used in kinematics is somewhat confusing, but may be worth the trouble in helping students understand this difficult topic. The subject matter is usually well developed, with every chapter introduced by a problem or question that will be answered later. Some questions are interesting and will draw the student in; others seem inappropriate. Overall appeal varies from section to section. Every chapter has an open-ended lab, where students must plan their course of action, as well as "pocket" labs.

The graphics in this text generated great enthusiasm among reviewers, with almost every page displaying diagrams, photographs, or graphs with lots of color. Additional sections try to catch the student's interest in career opportunities, societal issues, and modern technology. The presence of these features may be overwhelming for the student interested only in reading about a particular concept.

The text makes an obvious attempt to meet the education standards being issued by various agencies. Compliance with the National Science Education Standards is addressed specifically in the teacher's edition. Learning-style activities are also suggested throughout the teacher's edition. These often seem gratuitous, not well thought out, nor particularly designed for the style. This is especially true for the learning-disabled student. Mastery learning is invoked. Alternative assessments are suggested in the form of a physics journal, but the activities don't have much continuity to demonstrate a student's overall competence.

This text tries to give a balanced ethnic representation, with students of all races appearing in photographs throughout the book. Problems include names that reflect this diversity. Young women engaged in physics activities are present in photographs.

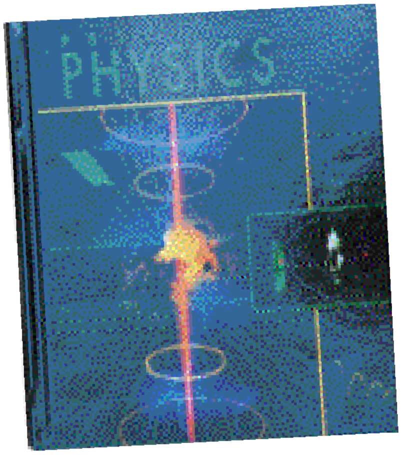
The book has an extensive number of problems and questions. Concrete practice problems follow each topic, with solutions completely written out in an appendix. Section review questions often contain conceptual questions. At the end of a chapter there are more conceptual questions organized by section, Level 1 and Level 2 problems. Some graphing-calculator and "critical thinking" challenge problems are also offered. These are not solved in the student's edition.

The only serious deficiency in this book is a lack of historical perspective. Some "connection" sections are developed in the teacher's edition, and a few vignettes appear about scientists such as Snell and Newton, but these are few and far between.

Overall, this is a very complete textbook system with a large amount of peripheral support material. It strives to make use of the latest educational trends, while essentially preserving the traditional high-school physics curriculum.

Kip Praissman, Jenna Steinhauer, and Ramneek Rana demonstrate a level-headed approach to the use of physics texts.

PSSC (Physical Science Study Committee) Physics



Authors: Uri Haber-Shaim, John H. Dodge, Robert Gardner, and Edward A. Shore

Publisher: Kendall/Hunt Publishing, 2460 Kerper Blvd., P.O. Box 539, Dubuque, IA 52004-0539; seventh edition, 1991

Cost: $49.99

Physical Characteristics: One volume, hardcover, 621 pages, 1.6 kg; introductory chapter photos are in color, other photos and illustrations are monochrome or two-color (brown and black); blend of old and new photos and illustrations

Peripherals Available: Teacher's guide and resource, lab manual, test item manual

Content Distribution: Due to the unusual (albeit coherent and logical) approach of thematic development, it is very difficult to quantify the number of pages apportioned to each topic. A rough approximation by percentage of coverage is as follows: Kinematics and motion, 13%; vectors and force, 9%; work and energy, 11%; electricity and magnetism, 18%; light and optics, 7%; modern and nuclear, 15%; heat and thermodynamics, 4%; waves, 10%; other (telescopy, stars and our solar system, binary number theory, logic gates, relativistic dynamics, frames of reference, and windmills), 13%

Intended Audience: Upper-level physics students, well grounded in arithmetic operations (algebra, trigonometry, possibly pre-calculus) and mathematical logic (if/then statements).

Reading Level: 11th and 12th grades

Math Level: 11th and 12th grades

Special Features: This book is arranged thematically, not topically. Therefore, pieces of what would be considered traditional topics (e.g., waves, electricity) are woven throughout the text and used as the authors see fit to develop the larger concept. There are 20 "core" chapters and 8 optional chapters. Each chapter begins with a qualitative statement about a particular concept. Natural phenomena involving that concept are introduced, and mathematical explanations and interpolations are applied as the concept is explored. In addition to an index, there are several appendices (history of development of the text, data on the solar system, physical constants, and conversion factors).

The text does an admirable job of explaining some novel topics such as stellar distances, luminosity, windmills, and turbines, and even analyzes entropy changes in various cycles of a steam engine. There is an interesting comparison of Coulomb's Law and Newton's Law of Gravitation.

Each chapter contains several problems calling for both qualitative and quantitative responses. Most problems are multiple-step and call for high-order thinking skills. No answers are given in the text. The teacher's edition provides solutions to such problems.

General Comments

The content is presented from a very logical and mathematically accurate manner. The text begins with very basic assumptions and mathematically expands them into larger concepts and topics. The material treatment is different from the mainstream high-school physics texts in that it relies heavily on mathematics and logic to develop its points. Mainstream texts tend to develop their topics more qualitatively and then move on to quantitative analysis.

The text is very well organized in its topical development. It is clearly intended for the student who has a firm grasp of algebra and is comfortable with mathematical explanations. A student who is weak in algebra would tend to get lost in the formulas and might miss the physical concepts. Generally speaking, the *level* of arithmetic is appropriate, but the sheer *volume* of mathematics and mathematical reasoning would be overwhelming for all but the upper-level students.

The reading level is definitely geared to the older or more gifted young student. Occasionally some of the sentences tend to be somewhat long and convoluted. Sometimes they contain several cogent facts that would be better delineated as separate sentences. For example, this sentence (p. 244) describes the function of a television or radar display: "The pictures they paint are produced by deflecting the electron beam so that it traces a path over the whole face of the tube while the strength of the beam is varied to make each little region of the screen glow bright or stay dark in response to signals from a TV camera or radar antenna." Students will simply not take the time and effort to analyze and interpret such complex sentences.

Some topics are not covered: mechanical power; lasers/holography; fusion; polarization of waves; diverging lenses; fiber optics; band theory (solid state); ac motors; Joule heating (mechanical equivalent of heat); vector equilibrants; latent heats/phase changes; capacitance.

Although the text does not highlight historical development per se, it does a good job at mentioning it throughout the chapters. A historical perspective of the comparison of gravitational and electric forces is presented with reference to Kepler, Newton, Cavendish, and Coulomb; the discovery of magnetic effects is traced from the Greeks, ancient Chinese to modern times.

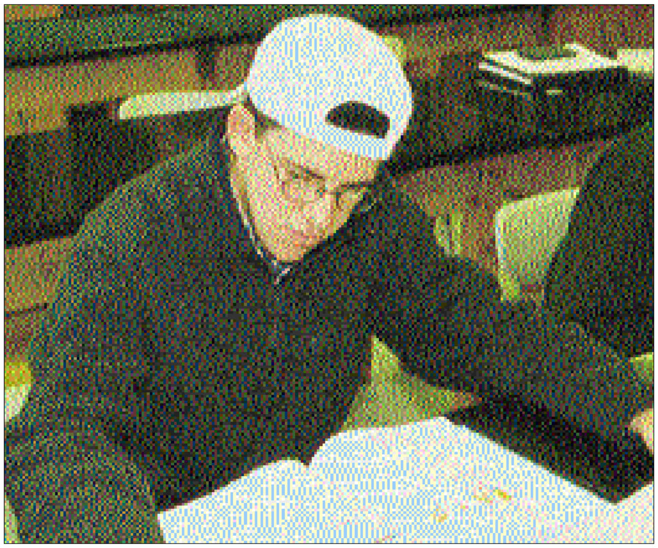
There is no discernable attempt to address sociological issues, nor obvious attempt to identify or meet the National Standards. However, much of the text would be found appropriate to address them.

There are a very few editing errors in the text such as a mislabeled or unlabeled feature in a diagram. This probably owes to the fact that the original edition was developed more than 40 years ago and has been updated periodically up to this seventh edition. The physics is sound and the only error (if it could be called that), is when the text refers to Coulomb's Law (page 124) and states that... "the force is inversely proportional to the square of the separation r between the two charges." The text does not point out that "r" actually refers to the separation between the centers of the charges or the separation between "point charges." The same omission is true for Newton's Law of Universal Gravitation. This is certainly not a catastrophic omission and the problems presented in the text are appropriate for this level of definition.

Summary

This text is solidly grounded in physics and is a must for every high-school teacher's reference shelf. It is always useful to have a ready reference for the derivation of formulas and development of concepts from conceptual ideas to concrete formulations. Upper-level physics classes could find this invaluable as a primary text. However, mainstream physics classes may find this text wanting for more everyday examples, plain language explanations, and sample problems with answers. It is not the type of text a teacher would find useful for out-of-class reading assignments for most students because the level of reading and mathematics is quite rigorous.

Ramneek Rana



Aaron Gorin

Survey of High-School Physics Texts

Physics Textbook Review Committee

Tania Entwistle (Ward Melville High School, Setauket, NY)

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Quibbles, Misunderstandings, and Egregious Mistakes

One of the assignments of the review committee was to note physics mistakes in the seven high-school texts selected. Many of the mistakes we found are matters of interpretation or emphasis. Not everyone in our 14-member committee spotted the same mistakes, or agreed about the seriousness of any particular item. What follows is meant to be tutorial. The items that we discuss are common to many of the texts, though not all. Indeed, in two of the textbooks we found very few substantial mistakes. We won't identify the source of any item, but will take the occasion to comment about why we think each one is wrong, or at least unfortunate.

The problems we raise are meant for teachers, not high-school students. In many cases our caveats would be too arcane for beginning students. However, teachers should be aware of some of the booby traps of simple explanations. Mark Zemansky, that great teacher of thermodynamics, put it nicely in the September 1970 issue of *The Physics Teacher,* page 295:

Teaching thermal physics
Is as easy as a song.
You think you make it simpler
When you make it slightly wrong.

A word before we begin. It's impossible to write a text, particularly a first edition, without including mistakes. Most of us have critically examined only a fraction of the things we teach. We tend to teach as we were taught, and when we write texts we repeat arguments that we heard at our mother's knee. It is said that Persian rug weavers would always leave at least one knot untied, so that the gods would not be jealous. In that spirit, the authors of our texts need fear no divine retribution.

There is another reason to go about our task with a light heart. There is a saving grace to our educational system, and that is the fact that students retain only a very small fraction of what they are taught. If 10% of a text is wrong, and students some years later remember only 10% (and even if both estimates are high), then a 1% remnant misunderstanding is surely down in the noise. Of course, it might be argued that the retention rate for error is greater than for truth.

Introductory Material

1. In the introductory material, which few students will ever read, there is usually a tendency to exaggerate the importance of the subject. "Everything around you can be described and understood using the tools of physics." "The same physics principles that are used to predict the interactions between two planets can also be used to predict the paths of two colliding galaxies...." Both of these claims are patently not true.

2. Many texts teach the "scientific method" illustrated step-by-step. The idea that there is such a method, or that memorizing the steps can be helpful, is anathema to practicing physicists.

3. Claims that the simple models of physics can be used to explain complex phenomena are often false. The physics teacher's "fly ball" is not the baseball player's fly ball. A sailboat cannot be usefully modeled as a point object, and water does not usually behave as if it were smooth flowing, with no internal friction. Using simple models to understand phenomena is valid only if the model is a good first approximation.

4. Most texts still instruct students to calculate error by subtracting the "accepted" value from their experimental value. This, of course, is about as unscientific as one can get. The technical meaning of error is *uncertainty,* not discrepancy. An uncertainty in measurement may arise from the precision limitations of the measuring instrument, from the nature of the object being measured, or from the skill and needs of the measurer. The value of the ± error should be reflected in the number of significant figures cited. In many of the texts, the number of digits given is not significant or is unrealistic.

Kinematics

1. The difficulty in reducing the error in measuring short time intervals with human-actuated devices is seldom stressed, and the consequences are rarely taken into account. Under most circumstances, human reaction time is longer than $1/5$ s.

2. The values obtained in calculations for velocity and acceleration are seldom compared with familiar quantities from everyday life. Often the resulting values are unrealistic. Accelerations can be compared with g. Speeds in m/s can be converted to mi/hr by multiplying by 2.2.

3. The effect of air resistance on the motion of objects is seldom mentioned, even qualitatively. A qualitative description along with a short table of terminal velocities would be understandable at any level.

4. Some texts have special sections offering a brief glimpse of advanced topics. For instance, in kinematics there may be a discussion of some of the formulas of the special theory of relativity. While there need be no derivation of these formulas, there should at least be some quantitative examples of the consequences.

Circular Motion

1. The topic of gravitation is frequently mixed with rotational motion or with Newton's laws of dynamics. Students end up thinking that the gravitational force is necessarily a centripetal force, or that it concerns a fourth law of motion.

2. Circular motion, with all its special relationships and names (ω, α, I, τ), should not be introduced *unless it is needed for other topics.*

3. The universal gravitational constant, G, should not be presented without any indication of how it could be measured, or without discussion of its importance or value.

4. If tides are discussed, there should be a reference to the water bulges on opposite sides of Earth, and an explanation given for that.

Vectors and Forces

1. The most common deficiency in this area is the poor or absent treatment of vector components, and the subsequent confusion about signs and mathematical expression that arise from this deficiency. Many books fail to distinguish between a component equation and a vector equation, and often mix the two. For instance, in one book the vector momentum, $\boldsymbol{P}$, of a body is given by the equation: $\boldsymbol{P} = -9.0 \times 10^3$ kg•m/s. This equation is invalid, since the quantity on the left is a vector, while that on the right is not. A correct expression might read $P_x = -9.0 \times 10^3$ kg•m/s, where P_x is the x-component of momentum.

2. Apparently it has become popular to define and differentiate contact forces and field forces. This is a meaningless distinction, something like differentiating between chemical and physical interactions.

3. Only one of the texts presents Newton's First Law as a statement about reference frames. Instead, a typical statement is, "It is an object's nature to maintain its state of motion." This sounds Aristotelian. What if the motion were one of acceleration? Only one text presents Newton's Second Law in a philosophically acceptable way. See *Phys. Teach.* **36**, 391 (Oct. 1998). The others bypass the problem or use circular reasoning. For instance, "Therefore, mass, which is a measure of the amount of matter in an object, is also a measure of the inertia of an object." That statement is, of course, meaningless.

4. There is a general misunderstanding as to whether Newton's Second Law is a definition or result of experiments. For instance, one text says, "This happens because the acceleration of an object is directly proportional to the net external force acting on it." By fiat! There is no appeal to experiment or any wonder why this is so. For a lengthy explanation, see *Phys. Teach.* **36,** 456 (Nov. 1998).

5. The common interpretation of Newton's Third Law is not so much a mistake as it is a misinterpretation. We find statements such as, "Forces always exist in pairs" and "One force is referred to as the *action* and the other force is called the *reaction*." The interaction between two objects is not composed of two separate parts. To use the words action and reaction implies that there is some sequence to the phenomenon. See *Phys. Teach.* **36**, 544 (Dec. 1998).

6. In most texts, the subject of friction is presented as a sideline to the use of Newton's Second Law. When the subject is expanded, most of the comments are wrong. For instance, "While the object is in motion, these small welds cannot form, and the frictional force decreases." That's not why there is a difference between static and kinetic friction. Static friction is usually caused by the congealing of dirt on surfaces in contact. The standard friction formula presented, $F_{\text{friction}} \propto F_{\text{N}}$ is valid only for dry sliding friction. Most of the texts, however, apply it to other situations where it does not apply, such as the friction of sleds or wheels with rubber tires. In general, rolling friction is not treated at all, which is just as well, because the subject is complicated.

7. The texts differentiate between mass and weight in various chapters. All of them refer to g as the "acceleration due to gravity." This is surely confusing, if not misleading, to students who wonder why acceleration should have anything to do with the weight of an object sitting still on a pan balance. A more useful definition of g is that it is the gravitational field strength. The analogy with the electric field strength can be made early as well as late. Thus $F_{\mathrm{grav}} = mg$ is analogous to $F_{\mathrm{electric}} = qE$. To two significant figures, g = 9.8 N/kg; thus the weight of 1.0 kg is 9.8 N. Otherwise the weight of 1.0 kg is 9.8 kg m/s^2, which of course is valid, but confusing for a student.

8. The vector nature of forces and acceleration is ignored or treated very casually in most of the books, leading to questionable and confusing discussions and applications of Newton's laws. Even in one-dimensional motion the failure to treat kinematical and dynamical quantities as vectors leads to confusion about signs.

9. Much of the discussion of the laws of motion uses the terminology of "balanced" and "unbalanced" forces, rather than emphasizing that the Second Law relates to the total or net force acting on a particular mass. This probably is a consequence of the failure to carefully develop the concept of vector addition.

10. A more general flaw is the way that physics is presented as a series of disconnected laws and rules. The books dutifully present Newton's three laws, then proceed to ignore them in developing new concepts. For example, few of the books effectively relate conservation of momentum to the Third Law. Some of them derive centripetal acceleration but fail to connect it to satellite motion with the Second Law.

11. Most of the books try to apply physics to "real-world" situations, but they offer little guidance in the development of simplified models. Good physics (and good science in general) consists in abstracting from a complex, real-world situation a simple model that can be related to fundamental laws. There is no discussion of how one goes about this.

12. Several of the books also confuse metaphysics with physics. They make statements such as "Physicists still don't know what forces really are" or "Even Newton couldn't explain what gravity really is." The fundamental laws of classical mechanics and electromagnetism have been well understood since the nineteenth century. The goal of the physicist is to develop theoretical models that accurately and concisely describe all of the observed phenomena in the universe.

13. A very disturbing property of the teacher's edition versions available for some of the books is the presence of very bad errors in the comments directed to the teacher. Obviously the editors paid much less attention to the development of this material.

Waves and Fluids

1. Some texts avoid derivations and simply assert formulas. If a formula is presented, however, it should be analyzed and shown to be plausible. What are the consequences of its functional relations? What are some sample values when it is applied to familiar situations? For instance, if pressure in a fluid is derived or asserted to be $P = P_{\mathrm{atm}} + \rho gh$, then at what depth of water is the pressure equal to $2P_{\mathrm{atm}}$?

2. Hooke's Law is usually presented as if it were a law for all springs. It is not, however; witness the behavior of the spring in a car seatbelt. If seatbelt springs obeyed Hooke's Law, we would all be strangled.

3. The period of a pendulum depends on the amplitude of the arc. Without going to the mathematical explanation, a text can explain why simple harmonic motion is only a first approximation for pendulum motion. This is a good occasion to point out the value and limitation of models.

4. The use of ripple tanks to demonstrate wave behavior has almost completely phased out of school laboratories in the United States. That's too bad, because with knowledgeable skill, the ripple tanks can be made to illustrate many aspects of wave motion. If they were used, we would not find statements such as this one taken from one of the texts: "Ripple waves are formed by the vibrations of molecules."

5. It's hard to wipe out the old-physicists' tale about sound not being able to travel in a partial vacuum. The experiment with the ringing alarm clock in a bell jar being evacuated seems so convincing. However, it isn't a matter of sound not traveling in a low-pressure region. The effect is due to poor impedance match between the bell and low-density air, and between the air and the jar.

6. There's a lot of confusion about what happens in the superposition of two waves. For instance, in one text we find, "Electromagnetic radiation...can also occupy the same space at the same time through superposition." That's a tautology, not an explanation! In a prologue to that same chapter, there is a statement that "Two different material objects can never occupy the same space at the same time." That would seem to rule

out electron pairs in the same energy level. It would even seem to rule out mixing a pint of alcohol with a pint of water. (You get less than a quart.)

The superposition principle is misstated in some texts. They say that the amplitudes (*A*) of the individual waves should be added together, rather than the displacements associated with each (mechanical) wave at the point of interest.

7. Many authors think that the electron size given by the de Broglie formula determines the resolution of electron microscopes. Not so, by a factor of 100! The resolution is limited by practical realities of the focusing electrodes.

8. One of the favorite illustrations in the texts for the applications of sound waves is the picture of a fetus. No text, however, puts in numbers and presents information about the frequency of wavelength used, or the reasons for using such frequencies. Because the resolution is about equal to the wavelength, it would be desirable to have wavelengths as small as possible. A frequency of 1 MHz would produce a wavelength of 1.5 mm in water where the speed of sound is 1500 m/s. In this frequency range, the penetration depth in flesh is about 200 wavelengths. For diagnostic purposes, a compromise must be struck between penetration depth and resolution. Medical ultrasound devices usually operate between 1 and 5 MHz.

9. The explanations of musical instruments usually involve diagrams of standing waves on strings or in pipes. That's a very poor model for what really happens with musical instruments. With strings, right after being bowed or plucked or struck, the string does not have the shape of a sinusoid, but rather appears as two straight lines, anchored at the ends and meeting at the displaced point. This kink then travels back and forth, the period of the oscillation depending on the length of the string and the travel time for a round trip. Of course, the triangular shape of the string can be mathematically analyzed as a Fourier sum of sinusoidal overtones. Also, the higher frequencies radiate best, leaving the string finally as the fundamental half wavelength pictured in the texts [See R. Johns, "Musical String Vibrations," *Phys. Teach.* **15**, 145 (March 1977)].

10. A number of authors present problems where it is assumed that sound spreads in all directions from a point source. For instance, to get the author's answer to one problem you must assume that the sound from a dolphin spreads out in three dimensions. Not so, particularly when the wrong answer is 20 km. Under most circumstances, sound waves are bouncing and reflecting off walls or are propagating in a narrow sheath because of atmospheric or liquid density or temperature layers.

11. Most texts assert that "Frequency determines pitch." This is not necessarily true. It is more accurate to say something like: The pitch our brain associates with a sound is determined primarily by the frequency of the sound, although there are sounds that can "trick" our brains, much like optical illusions sometimes can trick our brains. An example of such an "acoustical illusion" is a complex sound that contains the overtones of a fundamental frequency, but not the fundamental frequency itself; the listener in this case "hears" the pitch associated with the fundamental, even though it is not present!

12. Considerable space is devoted to diagrams and rules for the reflection of pulses on a rope. However, there is no apparent application for this arcane knowledge. Although it makes a good analogy to reflections of electromagnetic waves and to sound, there is no proof given for the validity of the analogy, and, indeed, the applications are not dealt with anyway.

13. In several texts, blood pressure is described in qualitative terms, but no numbers are given to link it to atmospheric pressure, or to the numbers that are obtained in the doctor's office. For instance, a reading of "150" might be compared with atmospheric pressure of 760 mm of mercury.

14. Several texts repeat the canard about the range of liquid jets coming from three holes in a can. The claim is that the water coming from the lowest hole where the pressure is greatest, will have the longest range. That's not generally true. This phenomenon was correctly described by Lester Paldy in the September 1963 issue of *The Physics Teacher*, page 126.

15. Most of the texts present the Bernoulli formula without derivation, but also with very little explanation. When applied to the lift of an airfoil, the explanation and diagrams are almost always wrong. At least for an introductory course, lift on an airfoil should be explained simply in terms of Newton's Third Law, with the thrust up being equal to the time rate of change of momentum of the air downwards. See C. Waltham, "Flight without Bernoulli," *Phys. Teach.* **36**, 457 (Nov. 1998).

16. The behavior of molecules in a liquid is more like that of molecules in a solid than that of molecular particles in a gas. In a liquid the molecules vibrate in their tem-

porary locations and meander very slowly from one such nest to another. They do not dash about and hit the walls, as illustrated in some of the texts.

17. The notion of coherence is incorrectly described in several texts, typically with numerous errors. Coherence is related to the phase difference (say between two waves at a point) being constant, whatever its value. Not being in phase, and not being coherent, are distinct concepts. Two waves can be coherent and not be in phase. And two vibrations can be in phase momentarily, yet not be coherent.

18. In defining pressure, a number of texts omit any reference to the fact that the resulting force on a surface is normal to the surface area.

19. Several books, in discussing the total force exerted on a body by the pressure of the atmosphere, add the forces on each surface, as if force were a scalar, rather than a vector. Quoting from one book, "This pressure is called atmospheric pressure; the force it exerts on our bodies (assuming a body area of 2 m^2) is extremely large...." Actually, of course, the total force is approximately zero.

Work, Energy, and Heat

1. Most of the texts claim that if you hold a chair up in the air or walk across the room with it, you are doing no work. That contradicts common sense, since doing these things would strain your muscles and tire you out. You would claim you were doing work and would want to be paid, either in money or food. Of course energy is expended and work is done in holding a chair motionless. That's because the human muscles flex back and forth while holding the chair, doing lots of work. You can show students how to avoid this work by leaving the chair on a table, or by pushing it across the room on rollers.

2. In some texts, energy formulas are given without derivation, or without any explanation of the functional dependence. Why, for instance, does kinetic energy depend on v^2? And where did that 1/2 come from?

3. Homework and sample problems frequently generate answers that are unrealistic. Texts seldom comment on the plausibility of the functional dependence of the formulas or the qualitative validity of the answers. One book has a Ping-Pong ball traveling at 160 m/s. That's about 350 mph!

4. Most of the texts name and make a fuss about the work–kinetic energy theorem. This theorem, which relates work done on an object to the change of kinetic energy of the object, is intrinsically useless. Shortly after proposing the theorem, the text will show how the work may also be turned into potential energy or lost in a form of heat.

5. Most of the texts follow the lead of university texts and introduce the subject of negative work. Introductory students always find this confusing. There is never any need to talk about negative work *in introductory physics*. Work is a special kind of transfer of energy from one object to another. You can keep track of the source of the work and thus the algebraic sign by requiring that the system doing the work must get energy from some other source such as food or fuel. This way of looking at things eliminates the silly assignment of negative work being done by friction. Friction can't do work.

6. In most texts there remains a problem about the relationship between mass and energy. Mass cannot be turned into energy. It *is* energy. The mass of the electron, for instance, can be given as 9.1×10^{-31} kg or 0.51 MeV. The mass-energy relationship is simply one of units. Of course mass, like other forms of energy, can be transformed into yet other forms of energy.

7. Simple machines are rarely treated well in high-school texts. Ideal simple machines are examples of the conservation of energy. Real simple machines lose energy due to friction. There are interesting laboratory exercises to measure the efficiencies of real machines. It is not generally appreciated that many simple machines that we use in everyday life, such as screwdrivers and can openers, are basically impedance transformers between our soft hands and hard metal. In these cases, the variables of concern are not so much input force and output distance as input pressure and areas of application.

   The classification of levers into three kinds is a particularly useless and silly scheme. The only possible use of the system is to serve as an easily graded quiz question in elementary school.

8. Most of the texts equate temperature to the average kinetic energy of particles in a substance. This relationship is valid for ideal gases, but is not true for solids or liquids. Quantum effects can lock out certain energy levels, thus prohibiting energy exchanges between particles. For instance, at room temperature,

the average kinetic energy of the electrons in a metal is of the order of several eV or tens of thousands K.

9. Diagrams of particle motion usually show little circles bouncing freely to model molecules in a gas, and little circles shoulder-to-shoulder to model molecules or atoms in a solid. The model for liquids is usually somewhere in between, with considerable spaces between the little circles. This obviously cannot be the case, since the density of a liquid and its solid is about the same. In the liquid, the little circles should be shown shoulder-to-shoulder also, although not in a regular crystalline array.

10. Free-body collisions are often modeled in terms of the collision of billiard balls or of a golf club and a golf ball. These, however, are not at all free-body collisions. The billiard balls roll, and when they collide they skid for a while on the felt before taking off in a new direction. Neither momentum nor energy is conserved. See N. Derby and R. Fuller, "Reality and Theory in a Collision" *Phys. Teach.* **37,** 24 (Jan. 1999). With the club hitting the golf ball, the club and arms form a complicated system.

11. Many of the texts avoid or give incorrect explanations about the expansion of solids and liquids when they are heated. Materials expand because of the asymmetry of the potential wells in which the atoms exist. As the amplitude of oscillation of the atoms increases, the average displacement increases, and because of the asymmetry of the potential well, the solid expands.

12. None of the texts explain the interesting operation of ordinary thermometers as change-of-volume amplifiers, or raise the question of linearity of temperature scales.

13. In one text, specific heat capacity is incorrectly explained by the argument that in sunshine the temperature of the air is less than that of a pool of water. A prime factor of the temperature of a pool of water is evaporation. Sunlight warms air primarily through the air's contact with the ground.

14. In general the texts fail to emphasize the importance of the subject of heat capacity. The thermometer and the measurement of heat capacities are major sources of our knowledge of the microstructure of matter.

15. All of the texts have a diagram of the temperature of water as heat is fed into a sample, starting out with ice. The graph shows abrupt changes in the slopes as the ice melts or as the water starts to boil. The actual experiment is difficult to do, and casual experiments would not yield the graphs shown. For instance, if you simply put an ice cube in a glass of water, the temperature in the middle of the ice cube may be –5 °C, the temperature at the surface 0 °C, and the temperature a few millimeters away +5 °C. To get an experimental curve close to the one shown in the text would require starting out with ice mush and constant stirring.

16. Many of the texts claim that the internal energy of a substance is proportional to its temperature. This is not true. There are many ways that internal energy can be locked into a substance without affecting the temperature. Consider, for example, that change of phase from ice to water takes place at constant temperature.

17. One of the texts describes an isothermal process in terms of slowly heating a balloon that expands. Left out, however, is the work necessary to stretch the rubber balloon.

18. Thermodynamics has many concepts that are hard to understand. What is the student to think, however, of the following explanation from one of the texts? "Instead of using the difference in potential energy to do work, heat engines do work by making use of a difference in the energy transferred by heat between the two substances at different temperatures."

19. When high-school texts attempt to explain thermodynamics, they almost always offer information that is too little and too confusing. For instance, one text devotes only two sentences to the reason why heat engines must feed heat to a sink at lower temperatures. In that same text, the ideal gas law is given less than two pages, and the second law of thermodynamics is mentioned on only one page, and in a very unsatisfactory way.

Optics

1. Chapters on light usually start out with an assertion that light can be treated as electromagnetic waves with oscillating electric and magnetic fields. Usually, however, the topic of light precedes that of electricity and magnetism. Fields have not been introduced or discussed.

2. It is common to be told that "light always travels in a straight line." When we look at a distant object, the light that arrives at our eyes typically has traveled in a straight line, or nearly so. But light does not always travel in a straight line. When light crosses a boundary between two materials, such as between air and water, or air and glass, the light can change direction; this process is called refraction. And when light passes through an opening, or even simply passes by an edge, it will be dispersed, or "diffracted," from its original

direction. Sometimes this effect is noticeable, and sometimes not, but it always occurs. Both of these processes, that of refraction and diffraction, depend on the wave properties of light.

3. It is claimed that "...microwave radiation causes water molecules to rotate and the food temperature to increase." That's not the way microwave cooking works. The water molecules can't rotate because they're all locked together in clusters. There is no particular resonance in water at the standard microwave frequency. The heating is caused by the forced oscillation of charges in the material, which does not have to be water. Butter, for instance, will melt rapidly in a microwave oven.

4. Most of the texts show only principal rays in the ray diagrams for lenses and mirrors. There should be some explanation or diagrams showing that rays are going off from the source in all directions, and that we deal with principal rays only for convenience.

5. A common mistake in describing farsightedness is to claim that "the image is formed behind the retina." The miswording is often accompanied by a ray diagram confirming the idea. This statement may lead students to believe that the retina is transparent.

6. The diagrams and explanation of the rainbow are usually wrong or incomplete. It is crucial to the explanation of the rainbow to analyze the angle of minimum deviation. Otherwise, there would be no explanation of why rays entering the drop at different heights leave the drop with a slight concentration at the observed angle.

7. Most texts have an exaggerated view of the temporal coherence of laser beams. The ordinary school He-Ne lasers stay coherent for only a few nanoseconds.

Electromagnetism

1. Attempts to be quantitative about the effects of electromagnetism or about the atomic particles are apt to be misleading. One text claims that "1.0 C is a substantial amount of charge." It is indeed, but the text offers no justification for such a claim. The same text asks, "If a glass rod is rubbed with silk, and the glass becomes positive and the silk becomes negative, how does this affect the mass of the glass rod?" The answer is that the mass of the glass rod is *slightly* less because electrons have been removed from it. However, this decrease is too small to be directly measurable with any known technique.

2. When dealing with electrons or other subatomic particles, the values for force and energy in terms of SI units make the results meaningless to students without further explanation. For instance, in one text, the students are asked to calculate the potential energy of two electrons that are "touching." An electron radius from a "classical model" is given. The answer is 4×10^{-14} J, which is left without further comment. The formula for the electric potential energy between a pair of charges is given without derivation, or without plausibility examples.

3. The electron volt is usually introduced as a unit of energy, and its numerical relationship to the joule is given. None of the texts, however, point out the utility of such a definition, or the many types of interactions on the atomic scale that take place with an exchange of a few electron volts.

4. In the study of waves, a superposition principle is declared. Another (and very different) superposition principle is asserted for electric fields and electric potentials. In most of the texts there is no attempt to justify the principle or to give some simple examples.

5. There is general confusion about what makes charges move. One text says "A potential difference within a battery causes charges to move." The cause and the result are backwards. It is the movement of charges within the battery that gives rise to the potential difference between its terminals. And it is the electric field associated with this potential difference that causes charges to move in a wire connected between the terminals of the battery. A potential difference is the work done per charge. The customary language reinforces the fallacy that potential difference is analogous to pressure, and that resistance is some sort of obstacle course. Consider, for example, two resistors in parallel, made of the same material, but one twice as long as the other. The longer one presents twice as many "obstacles," but the work done per charge is the same for both. (The electric field in the long resistor is half that in the short one.)

6. With most texts, electrical capacitance is defined and formulas are given without any examples of what capacitors look like or of typical values of capacitance. There is a notion that molecules of dielectrics will rotate when they are in an electric field, thus explaining the dielectric constant of materials between capacitor plates. For solid dielectrics, there is distortion, not rotation, of the molecules.

7. Some books explain why work is required to store charges in a capacitor, but no mention is made of repulsion or moving charges against an electric field, and magically a factor of one-half occurs in the formula without any explanation.

8. Explanations of lightning often appeal to analogies with small-scale sparks, or with electrical breakdowns in plastic. These are poor analogies for the very complex mechanism of lightning in the air.

9. In explaining drift velocity of electrons in a wire, one text says, "The energy gained by the electrons as they are accelerated by the electric field is greater than the average loss in energy due to the collisions." If that were the case, then the electrons of course would accelerate, not drift at constant velocity.

10. Introductory texts face a dilemma when dealing with everyday electricity. Except for flashlights, most of the electricity used in every day life is in the form of alternating current, and is at lethal voltages. A typical example of the authors' problem is the following statement taken from one of the texts. "When you plug an appliance into an outlet, a potential difference of approximately 120 V is applied to the device, thereby generating a current." Of course, the potential difference varies sinusoidally between plus and minus 170 volts.

11. With circuitry problems, it is particularly important to consider the significance of the values obtained. In one sample problem, for instance, the resistance of a space heater is calculated to be 4 ohms. The resulting current would trip the circuit in most homes.

12. In explaining electron tunneling, one text shows a well that apparently is in an infinite plane. The second graph shows a probability distribution for an electron in that well, with some small probability of being outside the well boundaries. But as long as the well is in an infinite plane, that electron can't tunnel anywhere. The final location of the electron must be in a region in which the electron has a non-negative kinetic energy!

13. Unfortunately, texts can no longer use the old standby of Christmas-tree light strings as an example of a series circuit. In the old days with those lights, if one bulb went out, the whole circuit went out. These days, without using parallel wires, there is a much more clever system buried within each bulb so that if one bulb goes dead the rest of the lights stay on.

14. It's hard for authors to keep current about technological developments, or to get hard numbers out of technical industries. One text calls for the electrical distribution system in neighborhoods to be at 20,000 volts instead of the more customary 2,000 volts. In another place, it is claimed that "safe potential differences can only be provided by dc generators if a power station is close to where the electricity will be used." There is a competitive technology much used in Europe for sending dc over long distances and stepping down the voltages as required.

15. One text repeats a common misunderstanding that "field lines are drawn to show the path taken by this small positive test charge when allowed to move freely under the influence of the electric force." As long as the charge starts from rest, its path to begin with will have the direction of the field at that point. But the inertia of the test charge will prevent it from following the field lines through space. A fly ball, for instance, does not follow the gravitational field lines.

Modern Physics

1. Blackbody radiation is mentioned by several of the texts, and there are even descriptions of how to produce an approximation to such radiation. However, there is no indication of why this phenomenon should have been of any interest to physicists in the nineteenth century. Yet the problem was crucial to the development of quantum mechanics. All black bodies, made of any material, yielded the same energy spectrum as a function of temperature. Classical electromagnetism predicted that the spectra should be radically different, increasing in intensity at short wavelengths. The quantum revolution started with Planck's proposal that the radiators in the blackbody have discrete energy levels. For radiation of short wavelength, the frequency would be high. A transition would require an energy jump of $h\nu$. Such a large jump in energy would be rare, and so the energy spectrum would go to zero at short wavelengths.

2. Several texts show graphs of the intensity of radiation as a function of wavelength. Crucially, however, the y-axis should be in terms of intensity *per wavelength interval.*

3. In a sample problem the student is asked how much energy is carried away from a vibrating grandfather clock during one quantum change. The formulas give a number of joules, which is surely meaningless, and there is no indication about how this energy is to be carried away from the vibration.

4. It's hard to get science history straight. In one text we are told that "Hertz happened to notice that when light strikes certain metallic surfaces electrons are emitted from the surface...this effect is called the photoelectric effect." Hertz certainly didn't discover the photoelectric effect, and he hardly described what he did observe as electrons being emitted. He did, however, find that his detector gaps sparked more easily (and thus were more sensitive) if the gaps were in the line of sight of the transmitting antenna spark. This spark was giving off ultraviolet light, which we now know produced photoelectrons from the receiver gap electrodes, thus initiating the spark.

5. Another example of poor history is the assertion that in the days of Newton there were models of the atom in terms of tiny hard indestructible spheres, and "this model was a good basis for the kinetic theory of gases." This couldn't have been a very good basis because it took 200 years from the time of Newton to the creation of the kinetic theory of gases.

6. Analogies to explain the behavior of subatomic particles are apt to be cute, and mostly wrong. It's hard to model the size scales involved. A proposed demonstration in one of the texts involves having students throw beans through the spokes of a rotating wheel. The spokes are supposed to be analogous to the electrons in an atom. The moral is that some beans can get through without being scattered. Most students will remember the beans and forget the analogy.

7. In descriptions of emissions spectra, there is seldom any discussion of the role of the slit in the source, or why a line spectrum is produced instead of one with concentric circles. The "lines" in a line spectrum are the focused images of the slit that passes the light through the grating or prism.

8. In many of the texts, there is confusion both in diagrams and in written material about the nature of particles. The particles don't travel in waves, nor is there a mystery as to whether they are particles or waves. The waves characterize probability functions that give the probability of certain events with the particles taking place.

9. Many of the texts try to cram all of atomic and molecular and nuclear physics into one final chapter. When profound topics are described in a paragraph, the explanation is frequently unintelligible and not quite true. For instance, in one text the explanation of the uncertainty principle contrasts classical mechanics with quantum mechanics. "In classical mechanics there is no limitation to the accuracy of our measurement and experiments." "This unlimited precision does not hold true in quantum mechanics." That's not strictly true. It's a question of measuring certain variables simultaneously that causes the problem. The product of the uncertainty of our knowledge of position, x, and the uncertainty of our knowledge of the x-*component* of momentum of an object must be equal to or greater than Planck's constant.

10. Several of the books neglect the neutrino in their description of beta decay. Such a particle was first proposed in connection with beta decay in order to account for energy and spin conservation.

11. The challenging concept that the probability of finding an electron at a certain location in an atom may be represented graphically by an electron cloud diagram is presented in several of the texts. The explanations are vague, and perhaps confusing. One text says that the quantum mechanical model of the atom is "a more complex model in which the electrons are represented by clouds spreading over the interior of the atom." This gives the impression that the electron itself is a cloud rather than the probability of it being found at a certain location is represented by the cloud.

12. One book states that "there is strong evidence which suggests that individual electrons are themselves spinning." While it is true that electrons have an intrinsic property that we label as "spin," and which indeed acts like angular momentum, the evidence does not suggest that they are actually spinning entities. Models of the electron cannot properly connect their "spin" magnetic moments with a reasonable classical rotating charge distribution. Indeed, to high precision, the electron appears to be a point particle.

What's the Use of High-School Physics Texts?

Ecclesiastes 12:12 – And further, by these, my son, be admonished :
of making many books there is no end; and much study is a weariness of the flesh.

Do Students Read Physics Texts?

Of the making of many books, there is certainly no end, but do high-school physics texts cause much weariness of student flesh? Certainly, if the students carry them back and forth to school, the Preacher had it right. The lightest of the books we surveyed had a mass of 0.44 kg, but that was only one of the six volumes comprising the whole text. The heaviest physics book weighed 21 N, and contained 1,002 pages. The teacher's edition was even heavier, requiring teachers with strong backs.

However, there is apparently no need to worry about our students' health or posture. Anecdotal information indicates that most students don't read their physics texts anyway. At best, the text serves as a reference for formulas and facts needed for the solution of homework problems. The student reads the problem, looks at the symbols required, thumbs through that section of the chapter to find a similar problem or formula, and plugs in the numbers. Good students don't have to read the whole chapter in order to solve the homework problems. Poor students don't read much anyway. Almost no one, of course, reads the author's carefully written foreword to the student.

There are happy exceptions to these pessimistic generalizations. If the text includes lab or activity directions, the students will read in order to perform the exercise. That appears to be the case with the *Active Physics* texts. If the writing is skillfully friendly, with occasional touches of humor, then the students will read if no painful study is required. Students and teachers report that this is true of *Conceptual Physics.*

There was an astonishing incident in the early days of *PSSC Physics* concerning students and the first hardbound edition of the new PSSC text. It was in Huntington, New York. Several students asked their teacher, Wilt Baty, if they could buy their books at the end of the year. The administration could find no mechanism for such an unexpected request, but warned the students that if they lost their texts, they would have to pay for them. On the last day of school the whole class lined up at the office, clutching their books which they reported lost, and paid their bills.

How Do Teachers Use Physics Texts?

Most high-school physics teachers use the textbook only as a source of homework problems (though we will see some exceptions later). For the teacher's own use, the text can serve as a floor of expectations and as a guide to the scheduling of topics throughout the year. The class text, or others in the teacher's possession, also provides resource or review material for lectures. New teachers particularly need the guidance of a text, both for pacing the course and for background information. Many experienced teachers pride themselves on not needing a text, either for themselves or their students. In this case, students depend on the teacher's lectures to demonstrate methods of problem solving, which requires the students to take good notes—and a nearly infallible teacher.

How Can Students Be Persuaded to Read the Text?

Some teachers use reading quizzes. A few teachers who give regular reading assignments administer such quizzes without warning. Others occasionally choose some particular section of the text and warn the students that they will face a test on the subject the next day.

A few teachers allow students to use "cheat sheets" when taking tests. Students are encouraged to take notes while reading the text and then transfer them to their crib sheets. These teachers assure their students that material taken directly from the text, not necessarily dealt with in class, will be on the test.

Some teachers use "reading summaries." Students are asked to summarize each section of the reading assignment in one or two sentences. Slower students are given more structure; they are asked to respond to specific questions on the reading.

Before starting to use the text, some teachers spend time introducing it to their students. Who are the authors and where do they teach? What do they claim in the foreword? Does the book have useful appendices? Glossary? Answers to problems? Sample problems worked out? Teachers choose a few of the pictures for discussion, including the cover photo. Why did the author choose them? For entertainment? Is there a physics point?

Should Physics Teachers Encourage the Reading of Texts?

One of the purposes of taking a science course is to learn certain skills. The mechanical skills of pouring without spilling and measuring without parallax may be useful in future science courses. In describing the virtues of a physics course, however, we emphasize the more abstract skills of logical thinking and using analogies. Surely one of these skills is reading. The reading required for technical purposes is different in many ways from the reading of a novel or even a history book. With a physics text, the reader must be in constant dialogue with the author. This may require taking notes (better than highlighting), and repeating derivations and sample problems on a separate sheet of paper. The reading, and the writing that goes with it, will certainly take much more time per page than reading a novel.

Students will not develop skill in reading the physics text if they are not instructed. Perhaps early in the semester, and occasionally throughout the year, there should be class lessons in reading the text. Everyone should have the text in front of them, and one student should read a few sentences out loud. Stop! How can the author say that? What about the previous rule? Does the new one agree? Now a few more sentences leading to a definition, perhaps the definition of work. Stop! Does that make sense? Do you agree with the author? Will you hold this chair at arm's length, without doing work and therefore without being paid? What's the resolution of the apparent paradox? And so forth.

Ask students to compare the text's development of a tricky topic with the approach used in class. Point out a particularly successful figure or ask a question about it. Require each student to find an example in everyday life of some topic in the book. (Think of all the examples of reflection and refraction.) Consider asking each student to write an original test item on a topic in the text; the best one will be incorporated in the next test.

Why bother? An experienced teacher doesn't need a text. The students can learn everything they need to know from the class lectures. But wait until next year when some of these students will be taking a university physics course. On the left-hand side of the lecture blackboard there will be the week's problem and reading assignment: Chapter 5, pages 102–127. What the professor means by that is: "Read Chapter 5." And read it as one must read a technical book, by arguing with the author all the way. If 18-year-olds come to college not knowing how to read a textbook, nobody is going to teach them,

Even if the teacher is experienced and confident, the student should have access to other sources with other viewpoints. As the review committee discovered in this project, many high-school physics texts are carefully written and edited. The explanations, worked over as they have been to put them into writing, are often better than a teacher can come up with in front of a class, and the figures are easier to understand than those that most teachers can draw on the chalkboard. The texts have been reviewed and critiqued by referees. Students using a text are learning from a superior tutor. Of course, note that the committee did find physics mistakes in most of the texts we reviewed in this project. In most cases there were few enough so as to be manageable in the classroom by an informed teacher. If the teacher disagrees with the text, it can be a particularly valuable lesson for the student to learn that there can be differences of interpretation or opinion between experts.

Choosing a Text

Sometimes teachers have no choice in the text for their students. Perhaps the texts were chosen some years ago and the books have not completely fallen apart (certainly not from usage!). In many states there are statewide adoptions, with the choices made by committee, sometimes under political pressures.

If you have a choice, here are some items that were proposed by Tom Miner, a very experienced and wise physics teacher:

1. Subject content

a) Does the book deal with the subject matter you plan to teach?
b) Is the material presented at the right level?
c) Are the basic concepts of physics illustrated by practical examples without being smothered by such applications?
d) Is the subject matter correct?
e) Is the development of content based on student experiences, either from everyday life or from laboratory experiences?

2. Style

a) Is the book readable by the type of student you will be teaching?
b) Do you think it will appeal to student interest?
c) Does the author's style invite thought rather than memorization?
d) Are topics described and explained clearly? (Note the use of topic sequences, freedom from run-on sentences, continuity of thought, summarizing sentences, and an appropriate vocabulary.)
e) Are words defined and explained at the point where they are first used?

3. Organization

a) Is there an attempt to show relationships between parts of the course, or is the subject matter compartmentalized and fragmented?
b) Are basic matters introduced before the more complex relationships depending on them are considered?

4. Illustrative materials

a) Are photographs chosen to enlighten and to engage the student's interest rather than merely to decorate the text?

b) Has color been used effectively?
c) Do illustrations appear on the same page as the text to which they refer?
d) Are captions complete and helpful?
e) Are drawings clear, uncluttered, accurate and well-labeled? Are the drawings artistically acceptable?
f) Does the formatting, with pictures, diagrams, extra features, and special typography, give such a busy impression on the page that the text gets lost?

5. Teaching aids

a) If you want chapter-end reviews, does the book have them, and are they informative summaries, not mere lists of definitions and formulas?
b) Do you want a glossary, and if so, does the glossary in this book define technical terms understandably and correctly?
c) Are chapter-end exercises useful, graded in difficulty, and numerous enough to give the teacher a good selection? Are there some questions requiring recall only, and others calling for thought, imagination, and ability to synthesize? Do the problems encourage comprehension, with only a few of the plug-in type? Are answers supplied for some of the problems? (Not all teachers consider this desirable.) Do some of the questions require project work, with a few of the tasks challenging enough to intrigue a superior student?
d) Is the index adequate? Try a few words. (This is not a trivial point.)
e) What ancillary materials are available? Overhead transparencies? Teacher's guide? Computer disks? WWW home page? Lab book?

6. Checkpoints

As a final test, study the presentation of a few difficult topics. Here are some suggestions of topics that many authors find troublesome to write about clearly and correctly. With these, particularly, you and the author may have different viewpoints.

a) Distinction between weight and mass
b) Centripetal and centrifugal forces
c) Diffraction
d) Electric potential
e) Induced electromotive force (emf) and Lenz's law
f) Binding energy and nuclear mass
g) Friction and its causes
h) Laws of thermodynamics

7. Post-Use Review

One of the most useful ways to evaluate a text is to ask an opinion from those who have used it. A "post-use" review provides insight that simply is not available otherwise. In particular, it provides information about how students view the book.

The Ideal Text

Your ideal text would probably not be the committee's ideal text, and vice versa. Actually, committee members probably couldn't agree either. However, here are a few points to consider.

1) Some say that a good text should have a theme and continuity. Each topic should be introduced not only for its own sake but for its continued usefulness throughout the course. The theme might be the conservation principles, or modern (20th century!) physics, or the history of physical science development, or how things work. Others say that there are practical reasons for producing a text that spreads a smorgasbord of topics from which the teacher can pick and choose. Furthermore, such an encyclopedic approach allows the school to match state requirements (such as the New York State Regents exams.) Yet a third school of thought says that it wouldn't make any difference whether the text had a theme, because students live from test to test and have more important things to worry about than logical development of a course, which is of interest only to teachers.

2) Although the committee gave passing grades to most of the texts for accuracy in physics, the accuracy is noticeably lower than in the most widely used college texts. We strongly urge publishers to get experienced and well-known reviewers for both texts and teachers' guides. Allow the reviewers to critique early and final versions in detail, including figures and captions.

3) An ideal text (and course) for a student going on to college to study some technological subject would not be an ideal text for a high-school student wanting only a liberal arts view of the universe. Both kinds of students should end up with a liberating view, but only the future scientist should have to take a course that is, in effect, a prologue to advanced physics. If learning to use vectors gets in the way of having a quantitative understanding of the scale of the universe, then let the vectors go. Or let them wait until next year. Of course, the reading and math level of the book must be tuned to the grade level for which it is intended.

4) Shorten the book. Five hundred pages is enough. Lighten the book. Five newtons is enough. If it is light enough, the kid may take it home. If it is short enough, the kid may read it. If someone writes a really good short book, following the standard syllabus, it might dominate the market.

A System to Change Both Mass and Applied Force

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In a high-school physics course, situations involving a system with a changing mass are commonly dealt with in the context of momentum, if at all. In an effort to have my students deal with the dynamics and kinematics of nonlinear acceleration systems, I proposed a system in which the applied force and system mass change. Traditional labs in mechanics investigate systems in which the applied force and system mass (and therefore acceleration) are constant. Introducing systems that do not undergo constant acceleration gives students the opportunity to draw heavily on the physics, experimental design, and analysis they have learned. With the advent of computer measuring devices such as ultrasonic motion detectors, the motion of more complicated systems can be studied.

The system described here is such a situation. It consists of a cart full of sand that loses mass as it travels. This mass loss causes a corresponding decrease in the frictional force exerted on the cart. Therefore this system is characterized by a changing mass and changing net external force. We describe here the equipment, the data, and a derivation of a mathematical model of velocity in terms of time for the system.

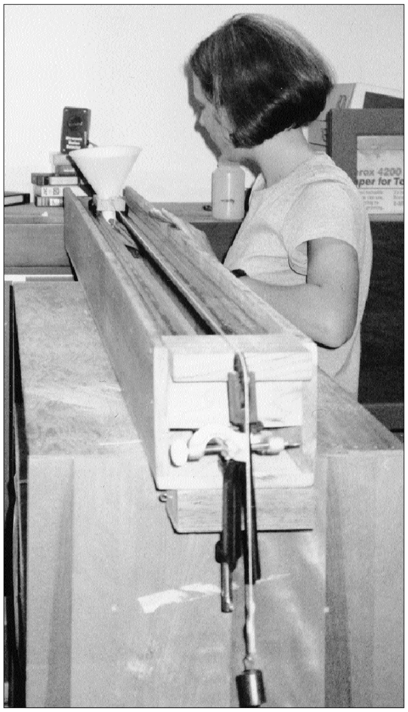

Fig. 1. Co-author Chaplin using the custom-built track and cart system.

F	net force on the cart
m_c	initial mass of the cart and sand
m_p	mass hanging on the pulley
W	force applied to the cart by the hanging mass
f	frictional force on the system
μ	effective coefficient of friction
R	rate of sand mass lost from the funnel
g	9.8 m/s^2

Fig. 2. Nonstandard variables used in derivation of mathematical model.

The System

The specially designed and built system (see Fig. 1) includes a low-mass wooden cart with a hole in the top into which is inserted a funnel. The wooden base of the cart rolls on wheels borrowed from PASCO dynamics carts and, as in many Newton's second-law experiments, the cart is pulled along the track by a mass hanging from the end of a pulley. The track, however, is unique in that it is elevated over a trough and has a slit along its middle. The funnel that will hold the sand projects through this slit and below the track to the trough. There the sand is collected and contained. To facilitate keeping the sand in the funnel until starting time, we cut an opening in the side of the trough at the release point; the experimenter places a hand through this opening and holds a fabric cover in place over the funnel's spout. We use an ultrasonic motion detector to collect velocity time data of the accelerating cart, but a Smart Pulley would work equally well.

Mathematical Model of System

The system can be mathematically modeled by applying Newton's second law and then integrating to find the velocity as a function of time. The variables used in this derivation are defined in Fig. 2.

Applying Newton's second law to the system gives the equation

$$F = W - f \qquad (1)$$

Inserting specific variables into (1) and bringing the net force on the cart to the right side yields

$$a(m_c - Rt) = m_p\,(g - a) - \mu(m_c - Rt)$$

Using the time derivative of velocity for acceleration yields

$$\begin{aligned}&\frac{dv}{dt}(m_c - Rt)\\ &\quad = m_p\left(g - \frac{dv}{dt}\right) - \mu(m_c - Rt) \qquad (2)\end{aligned}$$

Rearranging to isolate $\frac{dv}{dt}$ gives