2

USING THE TEXT

2.1 INTRODUCTION

The importance of active learning

In any introductory physics course, time is short. This means that it is important to use each class session to the fullest. Research into physic education has consistently underlined the idea that physics students *must* become personally and actively involved in the learning process if they are going to make their physics knowledge functional. But when are you going to find the time to get students actively involved with the material?

Research has also indicated that traditional lectures, no matter how beautifully constructed and compellingly delivered, are generally ineffective at transferring functional knowledge about physics at least to most students (except for a few that learn best aurally). Moreover, the attention span of a typical college student is now roughly 15 minutes and decreasing. This suggests that delivering even a wonderful 50-minute lecture to a huge class of passive students is *not* going to be the most effective way to spend precious class time.

Moreover, giving a brilliant lecture may actually be counterproductive, in that many students come into a physics class ready to believe that physics is for geniuses and they personally are unable to think like a physicist. A great lecture, while it might be pleasurable for both you and the students, does them no service if it reinforces their passivity and belief that only others can do physics.

This text is designed to support active learning

Taken together, these things suggest that if you want your students' knowledge of physics to be more functional than superficial, it is important to spend more class time doing active-learning exercises and less time lecturing. This in turn means that the *text* must serve as the primary channel for getting ideas to the students initially: class time should be spent mostly in active exercises that help students make these ideas their own.

This is fine to *say*, but most textbooks simply are not suited for this role: they are generally too terse, superficial and/or noisy to serve as the primary conduit for new information. This means that students *need* lectures to make sense of the reading, and yet cannot effectively absorb what they get in lecture. This is one of the ways that the traditional course sets too many students up for failure.

Overview of the sections in this chapter

The *Six Ideas* textbooks have a number of pedagogical features that are briefly described in the preface to each unit text. The purpose of this chapter is to describe these features and their pedagogical purpose in more detail. There are features that that are intended to make it easier to read (see **section 2.2**), encourage them to read actively (see **section 2.3**), and support active learning in the classroom and collaborative work during recitation sections (see **section 2.4**). **Section 2.5** offers ideas about how to get students actually to read the text before coming to class. **Section 2.6** muses about the upside and downside to having examples in the text, and **section 2.7** discusses some of the unusual notation conventions in the book. **Section 2.8** describes some possibilities for cutting or rearranging material to create an appropriately paced syllabus.

2.2 TEXT FEATURES FOR EASIER READING

I have intentionally designed the *Six Ideas* text to serve as the primary way that students get new information, so that *you* can spend class time doing examples and demonstrations, active-learning exercises, answering questions, and other things that can only be done in class. The text has many features that I hope will make it easier to use for this purpose than a traditional textbook.

Text features that make it easier for students to read and understand it

1. The writing style is expansive and conversational. I have tried to present arguments, derivations, and discussions more completely and clearly than in typical texts. While this makes the text less compact, it also makes it less mysterious and more satisfying. I have also tried to make the writing personal and vivid, so that it is more engaging and easier to read.

2. Each chapter corresponds to one class session. This gives the reading assignment for each class day a sense of direction and cadence that helps students group ideas in logical sets rather than in disconnected strings. (This also makes it easier for you to establish an appropriate pace for the course.)

3. Each chapter begins with a map and overview. The map uses a computer menu metaphor to show the student at a glance how the chapter fits into the general flow of the unit. The two-page overview provides students with a preview of the argument in the chapter, which helps give them a sense of direction as they read. The overview also provides a concise review of the chapter for later study, so that students do not have to wade back into the expansive text to refresh their memories.

4. Sidebar comments help students locate ideas and keep the big-picture issues in focus.

5. Each unit has a glossary. A poor understanding of technical terms is one of the leading causes of student confusion. Technical terms are stated in boldface the first time that they are used in the text and defined very carefully in the body of the chapter (and usually in the overview as well) and then are defined *again* in the glossary. Having the glossary helps students review these words without having to wade again into the text. The definitions in the glossary are often stated using slightly different words than the definitions in the body of the text: if one definition confuses, the other may enlighten. Glossary entries are keyed to the section in which the word appears.

6. The text uses "user-friendly" notation and terminology. Misleading connotations of technical terms and ambiguous symbols are another leading source of student confusion. For example, many traditional texts use v in one context as a symbol for speed (which, being a magnitude of a vector, is always positive) and in another context as a velocity component in one-dimensional motion (which can be positive or negative). The *Six Ideas* texts are careful to make a notational distinction in such cases. We also found in early trials that part of the reason that students fail to make the distinction between vectors and scalars is that they actually do not *see* the boldface notation used in traditional texts and/or register it as being meaningful: therefore I use "arrow-over" notation for vectors consistently in the *Six Ideas* texts (which has the advantage that students can easily reproduce it by hand). Terms like "centripetal force" and "work" also have misleading connotations that are avoided with alternative terminology.

Comments about the two-page chapter overview

The two-page overview (which is new in the second edition) has already been a source of some controversy among early readers of the manuscript. Some have criticized the overview because it uses terms and concepts that a student will not understand before reading the chapter. Others have worried that students will read only the overview and skip the chapter. Let me make it very clear that in spite of its placement, my *primary* goal for this "overview" is to provide a useful summary for students *after* they have read the chapter. I would hope that students might *also* find the overview a useful thing to scan before they read the chapter, so that they can orient themselves, but I neither expect or intend that students understand the overview completely before reading the chapter.

During the 2001-2002 academic year, students at Pomona were exposed to both the new 2-page overview and the format used in the first edition, which consisted of initial overview plus briefer final summary, and were asked to compare the two on an anonymous questionnaire. Though agreement was not universal, the majority of students found the new format more helpful, and *very* few reported ever reading the overview instead of the chapter. When asked to comment, a number of students specifically stated that reading the overview did *not* provide a realistic alternative to reading the chapter.

2.3 TEXT FEATURES FOR ACTIVE READING

However, even reading a text is typically a passive activity: information goes in one eye and out the other (as the cliché almost goes). But reading a text need not be passive. An *active* reader writes comments and questions in the margin, works through missing steps in the algebra, and underlines crucial ideas. These activities help the reader fully engage and "own" the material.

How an active reader reads a textbook

The problem is that few students have developed or even been exposed to active reading skills. The *Six Ideas* text provides explicit instruction in active reading and specific features that help students become active readers.

7. Wide outside margins provide space for questions, comments, missing algebra and the like. (Note the wide margins in this document!) While these margins also contain some figures and sidebar comments, I have made a real effort in typesetting the text to avoid cluttering up the margin too much. This should enable students (with your encouragement!) to use margins effectively.

8. Exercises embedded in the text prompt students to reflect on what they have read, fill in missing algebra, and so on. Answers (sometimes even fairly complete solutions) to these exercises appear at the end of each chapter to give students instant feedback on how they are doing. In addition to many other things, I have used exercises to engage and guide students in working through derivations (which otherwise are generally ignored). Besides engaging the mind, doing exercises will probably raise good questions that can be discussed in class.

I am still trying to figure out the best ways to encourage students to use these tools. When I help students individually in my office, I look for and encourage them to use the margins, and often suggest (if their questions are vague) that they read the chapter again and write some questions in the margin that we can talk about next time. But I have not yet hit upon a way to do this more generally. Ideas, anyone?

Ideas for encouraging students to use these features

2.4 TEXT FEATURES FOR DEVELOPING SKILLS

There are a variety of thinking and mathematical skills that students need to develop to be successful in an introductory physics course, but most texts seem to assume that students have either learned these skills in a previous course or are able to pick them up by osmosis. Early trials of *Six Ideas* showed us that many students needed *explicit* instruction in problem-solving and model-building skills. Moreover, many students seemed to need at least a review (if not outright instruction) regarding the mathematical tools that physicists use.

The *Six Ideas* text includes two important features that address these needs.

9. *Physics Skills* sections in certain chapters provide explicit instruction in or reviews of issues such as problem-solving techniques, model building, making approximations and estimates, significant figures, and so on. These sections set the discussion of these issues off from the body of the text so that students realize that these tools and techniques are generally applicable.

The text explicitly discusses problem-solving skills

10. Problem-solving frameworks are used throughout the course (but especially emphasized in the first two units) to help teach students expert-like approaches to solving physics problems. These frameworks, which were inspired by Alan Van Heuvelen's *Overview Case-Study Physics*, guide students through the process of drawing appropriate diagrams, defining symbols, thinking through the relevant physics concepts before beginning the math, and then checking their work. “Interaction diagrams” and “model diagrams” also help students visualize the physical problem and guide them toward successful solutions.

Students need help appreciating the worksheets

Students need to be convinced that using the framework format is worthwhile: following the framework seems to many students to be extra work at first. It helps if you discuss the purpose of each section of the framework verbally (even though it is discussed in the text) and remind them occasionally that the the frameworks are consciously designed to model the approaches that expert problem-solvers have learned are *effective* for dealing with difficult problems. It is also useful to insist that students follow the framework explicitly for at least some of the homework problems that they turn in.

It also helps if you discipline yourself to use the framework when working examples in class. (Before long in my classes, my slavish following of the framework becomes a shared joke: “Now, what do we do first?” I say in exaggerated tones, and the class responds in unison, “Draw a picture!”).

2.5 HOW TO ENCOURAGE STUDENTS TO READ

Why students resist reading

The purpose of the text features discussed in the previous section is to make it easier for students to read and really understand the text, making lengthy expository lectures unnecessary. The problem is that few students have any experience with using a text to replace lectures. They will have been trained by previous experiences to come to class, listen to the lecture, and then *maybe* read the text just before a test or if they have trouble with the homework. They will assume that this text is like all the science texts that they have encountered previously and will treat it accordingly. They will generally consider it a great waste of time to read the text carefully, write comments, do exercises and so on. They will try to blackmail you into giving lectures by being obviously unprepared.

When we first recognized this problem in early trials, I tried a variety of techniques to either *force* students to read the text before class or *reward* them for doing so. In the process, I learned quite a bit about what doesn’t work. Ultimately I came to understand (after many experiments) that students need to *choose* of their own free will to read the text before class, not because of punishments or rewards that they will receive, but because they believe that it is valuable to do so. (In retrospect, I am ashamed that I had to *experiment* to find out that it was most effective to treat students like free and intelligent adults.)

Three ways to encourage students to read the text

At Pomona in recent years, we have used a combination of three techniques to *encourage* (but not force) students to make the right choice about reading before class: (1) We clearly **describe** the benefits of active reading, and make it clear that this text is *different* from most science texts, that class sessions will be designed to benefit those who have prepared, and exactly why this the best way to proceed, (2) we **follow through** with our promise to orient class sessions toward those who have come to class prepared to learn, and (3) we **assign daily homework** to those students who choose the appropriate evaluation contract: this acts effectively as a goad and an excuse to prepare for class.

Because of various difficulties with the daily homework, in 1998-1999 we will replace daily homework with a short “reading quiz” that can only be completed successfully if students have done the reading (taking a cue from Eric Mazur’s book *Peer Instruction: A Users Manual*). Another whole approach entirely to ask students to hand in questions that they have about the reading. In all cases, one must consider *very* carefully how students will be evaluated. The possibilities will be considered more fully in chapters 4 and 6 of this manual.

It is helpful to remind students occasionally of the benefits of being active readers, and reinforce students for scribbling in their books and asking thoughtful questions. If you observe any correlation between active reading and good test scores, make sure that the students know about it!

2.6 ABOUT EXAMPLES

This text has fewer worked examples than many texts

Students really like a text with lots of worked examples, and this is a big selling point for many texts. But this book deliberately has fewer examples than many such books. Why?

Students need to be weaned from too much reliance on examples

Students in traditional introductory courses quickly learn that one of the most effective ways to solve a homework problem is to find an example that is just like the problem and essentially copy it without much understanding. Students really like examples partly because really *thinking* about a problem is hard and time-consuming. But I want students to learn how to apply their physics knowledge to realistic situations. Realistic situations are by their very nature complex and idiosyncratic, and therefore resist being neatly fit into patterns that a student can emulate mindlessly. Therefore, students who develop a learning style that depends too heavily on examples will be ill-equipped to apply whatever physics knowledge they have to realistic situations.

Even so, there is a place for *some* examples. Appropriately chosen examples can illustrate a new way of thinking or a very general pattern that can really help set a student free to learn. In *Six Ideas*, therefore, I have tried to provide students with a few appropriately chosen examples.

Other aids for students

However, I have also provided them with a number of *other* ways to practice and develop their skills without falling into mindless patterns of problem-solving. First and foremost, the ***exercises*** are intended to do much of what examples do in an ordinary text, while at the same time encouraging students to wrestle for themselves with the problem first. In some cases where an example might be found in a traditional text, I have often tried to provide an exercise instead. In most cases, I provide a fairly complete solution to the exercise at the end of the chapter. Secondly, the ***problem-solving-frameworks*** provide *general* patterns for solving problems of various types. Explicit instruction in the general pattern for a given type of problem should make it easier for students to get started and also help focus their attention on the physical principles. I also think that doing some specific ***examples in class*** can actually be more helpful than text examples, particularly if you can actively involve students in the process of selecting the example, working out the solution, and explicitly considerating the *process* used to solve the problem.

These things provide the same basic help that textbook examples provide without encouraging mindless behavior. (Your students may need to be convinced of the benefits of this approach, though!)

2.7 NOTATION, UNITS, AND SIGNIFICANT FIGURES

Some examples of unconventional notation in the texts

This textbook uses some unusual notation and terminology conventions, every one of which has been adopted after considerable thought and classroom testing (early trials of this text were even more radical about this than the present edition). Good notation, consistently used, is one of the text's main weapons against student confusion and fuzzy thinking.

I have already described my care in making the distinction between vector magnitudes (which are always positive) and vector components (which may be positive or negative) even in the case of one-dimensional motion, and how I use the arrow-over (instead of bold face) notation for vectors. I have also been very deliberate about always using $\vec{F}_N$, $\vec{F}_T$, $\vec{F}_{SF}$, (or whatever subscript is appropriate) for various kinds of forces, rather than using **N**, **T**, **f**, and so on. I think that using a single notational pattern for *all* forces helps students understand the difficult concept of force. I have also been very careful to label forces according to the type of interaction involved, rather than the direction of the force (hence, I never use "centripetal," and only use "normal" after some explanation). I have been deliberate about avoiding the term *work* for the mechanical quantity usually given that name [please see A. J. Mallinckrodt and H. S. Leff, "All about work," *Am. J. Phys.* **60**(4), 356-365 (1992) before judging that I am crazy], and have been careful to distinguish between $[d\vec{p}]$ and $d\vec{p}$, and between $[dK]$ and dK (to keep clear the difference between an interaction's contribution to an object's momentum or kinetic energy and the actual change in that object's momentum or kinetic energy). I use the thermodynamic convention that $dW = -PdV$ instead of $dW = +PdV$ to clarify the similarity and distinction between heat and work and to make the first law of thermodynamics clearer and easier to remember. In unit *E*, I use *V* for potential difference only after a careful explanation of the possible pitfalls, I use the Coulomb constant *k* and k/c^2 instead of ε_0 and μ_0 to emphasize connections with gravity (as well as other reasons) and I use $\vec{\mathbb{B}} \equiv c\vec{B}$ as a handy way of expressing the magnetic field in the same units as the electric field. These are just some examples of the notation choices I have made.

Please help these notations achieve their aims!

The point is that every time I go against the prevailing notation conventions in introductory texts, I have done so for a particular pedagogical reason that I have found strongly compelling. Obviously, my efforts in this regard will come to naught (and students may end up being even more confused) if you do not support these conventions as you teach. I am therefore begging you to help the process by sticking with the notation. I realize that this is difficult (every now and then, even I slip back into habitual modes of expression in class), but I really think that you will find that careful and *consistent* use of the notation in the text can really help increase student understanding.

The same kind of thing applies to the way I treat units and significant digits

The same general comments apply to units and significant figures. In spite of my years of teaching experience, I am perpetually amazed that students fail to appreciate how keeping track of units can help them reason clearly and keep from making simple errors. I have therefore been very deliberate about *always* attaching units to quantities that need units. I have also tried to discourage students from plugging in numbers too early in a problem (partly because students doing this tend to drop the units when doing so). While I have been less emphatic than some about the importance of having exactly the right number of significant figures (partly because I recognize that counting significant figures is just a quick and dirty approximation to a real uncertainty analysis), I think that it is important that students be discouraged from just writing down whatever number of digits appear on their calculator without thinking about what they are doing. Please help support the text by insisting that the students adhere to these standards.

"Do not do *algebra* with numbers"

By the way, I am not *completely* rigid about insisting that students avoid *all* calculations until the exact end of a problem. Calculating intermediate results can be *very* helpful, and gives students a sense of security. The mantra here should really be *do not do <u>algebra</u> with numbers*, particularly numbers with attached units.

2.8 CREATING YOUR SYLLABUS

The standard syllabus

As discussed in the first chapter of this manual, each chapter of this text is designed to correspond to one standard 50-minute class session. Units *C*, *N*, and *R* can be completely covered in a semester having at least 39 class sessions (this includes two class sessions for midterm exams), and Units *E*, *Q*, and *T* can be covered in a semester having a total of 42 class sessions (again including two sessions for midterm exams). Sample syllabi for this "standard" approach appear in chapter 6 of this manual.

An adaptation to the quarter system

A straightforward adaptation of the text to three quarters would be to teach units *C* and *N* in the first quarter (28 class sessions, including one midterm), units *R* and *E* in the second quarter (27 class sessions, including a midterm), and units *Q* and *T* in the final quarter (25 class sessions, including a midterm). One of the reasons for the suggested ordering of the units is that they fit nicely into quarters this way.

This course less elegantly fits situations where the class is offered in two 70 or 75-minute sessions per week. Here one would simply have to assign about a chapter and a half per class session.

The general approach to reducing the course's pace

Doing one chapter per 50-minute class session is really the *maximum* pace possible, and is challenging for students even at selective colleges and universities. The abilities and/or preparation of the students at your institution may require you to go through the units at a more gentle pace. The best way to do this, I think, is to (1) cut material from the course and then (2) add class sessions every so often that are devoted to consolidation, review, and/or additional discussion of concepts and examples (while still following a regimen of one chapter per session for the remaining class sessions).

Four ideas That Shaped Physics?

What can be cut? The most drastic approach is to cut whole units. Units *C*, *N*, *R*, and *E* pretty much represent the irreducible core of the course: these units depend in intricate ways on each other and should be offered in essentially this order. A much gentler two-semester course would involve covering just these four units: *C* and *N* in the first semester (27 class sessions plus review and exam days) and *R* and *E* in the second semester (26 class sessions plus review and exam days). This would allow for a review day roughly every two chapters; a typical week might consist of two chapter-oriented class sessions plus a review day. This should, I think, provide ample time for students at the vast majority of colleges and universities to get through the material. (Covering these four units in two 70-minute class sessions per week at the rate of one chapter per class session also yields a similarly gently-paced approach to the course.)

Five Ideas That Shaped Physics?

Another straightforward possibility (particularly if your second semester is short) is to omit *either* unit *Q* or unit *T*. It is true that units *E* and *Q* are unquestionably the hardest in the course, so it may be more important to reduce the pace during these units than it would be during the first semester. Indeed, several of the institutions that adopted *Six Ideas* earlier omitted unit *T*. If you would like to cover some of both of units *Q* and *T*, one can cut major portions of unit *Q* without loss of continuity (see the discussion below).

How to make cuts at the chapter level

It is also possible to make cuts at the chapter level of many of the units. The information that follows brings together (for your convenience) the information about cutting chapters that appears in the preface to each unit text. Please refer to the unit-specific information in that preface for more information about the content of that unit and how various units are related.

Possible cuts in Unit *C*

Almost every chapter in unit *C* is essential preparation or background for other parts of the course (indeed, most chapters have been deliberately pared down so that only what is essential remains). If one is desperate for something to cut, one might omit chapter C12 (which looks at some interesting and contemporary applications of conservation of energy as well as studying elastic and inelastic collisions). The rest of the unit is pretty much an indivisible whole.

Possible cuts in Unit *N*

Unit *N*, like unit *C*, is a mostly indivisible whole. Chapter N5 (which looks statics problems) could probably be omitted if cuts are absolutely necessary: it is needed elsewhere in the course. Chapters N13 and N7 also cover material that not needed in the rest of the course, but chapter N7 is very important for developing students' understanding of Newton's third law and how linked objects interact, and dropping chapter N13 would mean that students would not see the fulfillment of the unit's "great idea."

Possible cuts in Unit *R*

The shortest possible treatment of relativity using unit *R* would be to omit chapters R5 and R8 through R10. This would yield a six-session introduction to basic relativistic kinematics (with no dynamics or $E = mc^2$). Adding chapter R5 and/or R8 would provide a richer introduction to pure kinematics. Note that R8 is useful for underlining the reasons that the speed of light represents a cosmic speed limit, an idea that lays groundwork for chapter E10 in unit *E*.

The shortest introduction that includes dynamics would be to omit chapters R5, R7, and R8, and add a single class session devoted to sections R5.2 through R5.5 and sections R8.2 and R8.5. This would fit everything that is really useful for units *E* and *Q* within eight class sessions.

However, students find the material in chapters R5 and R7 some of the most interesting in the book, and R7 is also the chapter where they really test their understanding of relativistic kinematics in the context of tough paradoxes. Therefore, I really recommend doing the whole unit if you have time.

The appendix on the Doppler shift can be covered (if desired) any time after section R5.3, and can either displace some of the latter sections of chapter R5, some of the middle sections of chapter R8, or be added to chapter R7 (which, though challenging, involves fewer new ideas than the other chapters).

Possible cuts in Unit *E*

Because the time-constraints on unit *E* were so severe, I have already cut from this unit virtually everything that is not essential to the eventual goal of understanding electromagnetic waves as a solution to Maxwell's equations. Only the last chapter (chapter E16) is optional, though it is highly recommended if students are to appreciate the meaning of the electromagnetic wave solution.

If more material simply *must* be cut, one can also omit chapter E14 on induction (which is only really *needed* for chapter E16). The only next step would be to omit the section on Maxwell's equations entirely (chapters E12 through E16). While none of this material (except for chapter E15) is really necessary for any other unit, omitting these chapters will never give students a chance to see what the unit's "great idea" is about.

Unit *E* assumes that students are fairly familiar with basic differential and integral calculus, and also that they have the kind of firm grounding in newtonian mechanics that units *C* and *N* provide. Unit *R* is also useful as background for this unit; if it is necessary to discuss this unit before unit *R*, then some class time should be budgeted to talk about the principle of relativity and the cosmic speed limit. Chapter E15 in particular is important preparation for chapter Q1, so if this chapter is omitted (or unit *Q* is discussed before unit *E*), some time must be budgeted to discuss the material in this chapter before unit *Q* begins.

Possible cuts in Unit *Q*

Chapters Q1 through Q8 are the irreducible core of unit *Q*. This part of the unit depends on previous units as follows: in addition to basic mechanics, students need to know a few things about waves (discussed near the end of unit *E*), a bit about how electric fields are related to potential differences, and Coulomb's law. There is a part of chapter Q4 that refers to relativistic energy, but one can skip over this if necessary. Chapter Q9 (a superficial overview of atomic physics), chapters Q10-Q11 (concerning the Schrödinger equation), and chapters Q12-Q15 (an examination of nuclear physics) represent packets of material that are essentially independent of each other, and thus can be kept or ejected as necessary. The following table summarizes possibilities for shortening unit *Q*:

Class days	Chapters	Comments
8	Q1-Q8	just the basics
9	Q1-Q9	the basics + atomic physics
10	Q1-Q9, Q10-Q11	the basics + the Schrödinger equation
11	Q1-Q11	the above + atomic physics
12	Q1-Q8, Q12-Q15	the basics + nuclear physics
13	Q1-Q9, Q12-Q15	the basics + atomic and nuclear physics
14	Q1-Q9, Q10-Q15	everything but atomic physics
14	Q1-Q14	everything but nuclear technology

I personally often use the last plan.

Be sure to budget a day to talk about waves if unit *E* does not precede this unit. Note also that chapters Q11-Q14 use the relativistic relationship between energy and mass, so chapter R9 (or a class day talking about this issue) is a necessary prerequisite if these chapters are included.

Possible cuts in Unit *T*

Chapters T1 through T6 form the irreducible core of unit *T*. If you have to cut chapters, drop chapter T7 first. Section T7.2 also draws on the "particle-in-a-box" model presented in unit *Q*, so if this unit precedes *Q* in your syllabus, you will either have to drop the section, drop the chapter, or spend some time discussing this model. Chapters T8 and T9 could be omitted as well, though I consider these chapters to be part of the goal of the unit.