



The Physics ToolBox

*A Survival Guide for
Introductory Physics*

Kirsten A. Hubbard & Debora M. Katz, Ph.D.

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With a Forward by

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BROOKS/COLE

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SURVIVE YOUR INTRODUCTORY PHYSICS CLASS!



If you must take an introductory physics class, then you *need* this book. It is full of important information designed to help you:

- Ace exams
- Understand lecture
- Sharpen your math skills
- Work homework problems
- Study more efficiently
- And get help when you need it!

The Physics ToolBox is a "paperback mentor," or guide, specifically created to supplement (not replace) other materials in your introductory physics course. It provides all of the critical material needed to succeed in a typical physics class—including material overlooked elsewhere—such as:

- An introduction to the nature of physics *and* science, so that you have a better idea of *why* you need to take physics;
- A look at "what to expect" and "how to succeed" in physics classes, including a step-by-step guide to solving problems;
- A 38 page "Study Success Guide" (in the Appendix) that will help you improve your study skills, both in and out of your physics class;
- A verbal overview of all the concepts you will learn in your course, written in a way that unites ideas and draws a "big picture;"
- An *extensive* review of all of the math you will *need* (and some you won't!) to solve the many, many problems encountered in your class;
- And, much, much more!

The Physics ToolBox is written so that you can skip around the text, reading only those sections that *you* need to succeed...*when* you need them!



Sheila Tobias, a nationally-recognized researcher and author on science education issues, writes in her Forward to *The Physics ToolBox*:

"I welcome *The Physics ToolBox* [because it offers] multiple points of contact, missing links, problem-solving walk-throughs, highways and biways around and into the various topics of introductory physics."

ACKNOWLEDGMENTS

At the risk of forgetting some important people, the authors of *The Physics ToolBox* would like to thank certain individuals who have made this book possible.

First, we gratefully thank Sheila Tobias for submitting a Foreword to this book, and for her thorough and enlightening review of our manuscript. Her suggestions much improved the book.

Second, we are very thankful for the extraordinary reviews by John Jewett, which vastly enhanced the readability, accuracy, and tone of the work.

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*Science must be understood
as...a gutsy, human enterprise,
not the work of robots pro-
grammed to collect pure infor-
mation.*

STEPHEN JAY GOULD
Science Writer, 1941 -

NOTE TO THE INSTRUCTOR

Over thirty percent of all students enrolled in college-level physics courses today—some three hundred thousand students every year—will not major in physics or engineering; rather, they are taking physics classes to fulfill a non-physics major requirement.

Yet, despite the excess of supplementary materials bundled with scientific textbooks today, there are no texts, ancillary guides, or help-books targeted to the special needs of this large and unique population. We, the authors of *The Physics ToolBox*, wanted to fill this gap.

For guidance, we looked to the research of progressive physics educators* such as Sheila Tobias, a nationally-recognized science educator and author. In the books *They're Not Dumb, They're Different* and *Breaking the Science Barrier* (written with physicist Carl T. Tomizuka), Tobias and Tomizuka examine, and try to provide new approaches to, a non-major student population they call the "second tier".

Second tier students are not second rate: they are intellectually curious, just as smart as physics majors, and perform well in other subjects. More importantly, they want to succeed in their physics class. However, they are not (yet) drawn to science or, by extension, scientific pedagogy.

This puts the second tier at a disadvantage: their unfamiliarity with typical modes of science instruction challenges the study skills and personal attitudes that succeeded for them in other courses. For example, according to Tobias' experimental population, second tier students find:

Science has to be made accessible to long-distance runners—slower to start, needing more rest-and-recovery time—and not just to sprinters.

DUDLEY HERSCHBACH

Nobel Laureate in Chemistry, 1932 -

* See the bibliography for a complete list of sources.

- scientific classroom atmospheres undesirably competitive and lacking in community;
- presentation of scientific material—including lectures, reading, and exam structure—too much focused on technique, and too little focused on concepts and context; and
- that their math skills are critical to success, but not well grasped.

Rightly or wrongly, the second tier's discomfort with traditional science education makes it harder for them to succeed in college-level physics classes.

Fortunately, this situation is ameliorated when science instruction takes some of the learning needs of the second tier into account. For instance, according to Tobias, second tier students:

- are verbal, not mathematical, learners, so they need wordy, concept-driven explanations;
- need to be presented with a "big picture," otherwise, they cannot construct understanding from details; and
- need to feel welcomed in the classroom, and be able to interact with their peers, in order to succeed.

Although physics instructors cannot hope—or even wish—to meet all of the learning needs of the second tier (after all, to name one example, we cannot eliminate mathematics from physics instruction), we can offer them tools to succeed in physics via a pedagogical format that speaks to their strengths.

Here is where *The Physics ToolBox* hopes to fill a void. This book endeavors to:

- provide a more verbal and "big picture" approach to introductory physics, to supplement (*not* replace) existing readings and lecture formats;
- show students how to create a learning community to help them help themselves when they feel overwhelmed or unable to cope;
- help students identify and change their expectations about scientific learning; and
- aide students in developing an alternative scientific-mathematical mindset instead.

To meet these goals, we have divided the book into three parts:

1. A "success" section (Part I), in which potential pedagogical problems for the second tier are identified, and common sense solutions are offered (including the very important solution of self-change);
2. A physics "blueprint," or verbal overview of important introductory physics topics (Part II); and
3. A math review (Part III) meant to remediate typical second tier student's deficiencies in mathematics.

Part I is intended to be read prior to the beginning of class; Part II is designed to be read piecemeal, as each topic appears in class; and Part III is intended to be read if and when mathematical difficulties present themselves. In addition, this book includes a 38-page Appendix, offering generalized study skills for overall academic success at the college level.

It should be plain, then, that *The Physics ToolBox* is *not* (nor is it meant to be) a traditional physics text. For example, we have liberally engaged in "skipping to the punch line," deleting proofs and equations and even entire topics (most notably optics and circuit theory) in order to draw connections between important concepts. Furthermore, information that does make it into the text (especially in the "blueprint" section) is heavy on explanations and light on equations.

We have also reordered the traditional presentation of the physics canon somewhat, in the hope that students will better see a storyline there. And, perhaps most "disagreeably," we have written the entire math section as a series of tips—without context, background, or detail—so that students can quickly get the information they need to learn *physics*...without also needing to learn subtleties of math at the same time.

In short, we have omitted the kind of exposition that makes physics pleasing to professionals like you—such as reasoning from first principles, mathematical deduction, subtlety, and beauty—and replaced it with basic, "down and dirty" information that we think will help students get a good grasp of fundamental concepts. Although there are more elegant, and certainly more rigorous, ways of presenting the concepts covered in this book, we believe that certain students need to begin physics more simply.

Now, we understand—as physics instructors ourselves—that you may have deep-seated concerns about this approach. However, we would argue that some students cannot appreciate the deeper level of understanding that makes physics beautiful until they have constructed a skeletal framework of the *entire picture*. Our approach, therefore, does not completely eliminate mathematics, reasoning, or conceptual understanding—and it certainly does not replace the rigor of traditionally-taught classical physics—but it does attempt to reach the non-major student in other, less traditional ways.

In Chapter 2 we argue that a hallmark of "thinking like a physicist" is the ability to apply a limited arsenal of (appropriate) tools to a wide variety of problems. Majors students already have a well-stocked, though apprentice-level, physics toolbox containing the basic math skills, problem solving savvy, and scientific mindset needed for success in introductory college-level physics. Second tier students also have a well-stocked toolbox, but not one suitable for physics. This book strives to provide a Physics Toolbox to students that need one.

Although *The Physics ToolBox* was written with the needs of the second tier in mind, the final result, we believe, is a book that a *wide range*

To illustrate the different mindset of the second tier, consider this excerpt from Laura Fermi's memoir. Laura, the wife of Enrico, is a classic example of a second tier student. Notice her response to her husband's instruction, a classical physics (first tier) teaching style.

Enrico introduced me to the Maxwell equations. Patiently I learned the mathematical instruments needed to follow each passage...until I had digested my lesson and made it material of my own brain. Thus we arrived at the end of the long demonstration: the velocity of light and that of electromagnetic waves were expressed by the same number. "Therefore," Enrico said, "light is nothing but electromagnetic waves."

"How can you say so?"

"We have just demonstrated it."

"I don't think so. You proved only that through some mathematical abstractions you can obtain two equal numbers. But now you talk of equality of two things. You can't do that. Besides, two equal things need not be the same thing."

I would not be persuaded, and that was the end of my training in physics.

of students can enjoy and use. We have tested portions of it on all types of physics students—majors and non-majors alike—and have received very enthusiastic responses. After all, even majors need a math review now and then.

We therefore hope that you, and your students, will also find this book useful.

KIRSTEN HUBBARD
DEBORA KATZ, Ph.D.
June, 2001

FOREWORD

by SHEILA TOBIAS

When I advanced the notion of the "second tier" after engaging a small number of intellectually able but determinedly "nonscientific" learners in introductory physics and chemistry courses in the fall of 1989, I never intended the group that I had identified to be thought of as likely to respond to any one set of new or modified pedagogies or techniques.* Rather, I believed then as I do now that only *they*—and not the master teachers and textbook writers aiming to meet their needs—would be able to determine what "works" and what doesn't "work"; and that, therefore, it would be best to provide them with a *range* of materials for them to choose among.

Thus, I welcome *The Physics ToolBox*, not because it is necessarily the perfect "fit," but because, contrary to many of my reform colleagues' beliefs, there is no perfect fit. What second tier students of science need, in my experience, is redundancy, variety, alternative explanations, words and more words, diagrams, multiple approaches, and lots of back-and-fill; and *The Physics ToolBox* offers the newcomer to physics all of these and more.

Used in conjunction with a standard textbook, as an *optional addition* to lecture/labs/review sessions and even group work, this volume will provide students *who need it* with multiple points of contact, missing

* Tobias, Sheila. *They're Not Dumb, They're Different* (1990); and Sheila Tobias & Carl T. Tomizuka, *Breaking the Science Barrier* (1992).

links, problem-solving walk-throughs, highways and (as important) by-ways around and into the various topics of introductory physics.

Just as there is no "royal road" to physics—to play on a familiar anecdote told about Euclid—there may be no single pedestrian road as well. Instructors owe it to their students to let them find the footing they seek as they construct their own personal understanding of what is so "obvious" to others. Eventually, they should come to appreciate the rigor and parsimony of the classical approach. But only if they stay and succeed. And staying and succeeding is precisely what *The Physics ToolBox* hopes its student readers will be encouraged to do.

SHEILA TOBIAS
TUCSON, ARIZONA
May, 1999

NOTE TO THE STUDENT: WHY A TOOLBOX? HOW DO I USE IT?

Hello! And welcome to *The Physics ToolBox*!

This book is designed to help you *get the most* out of your introductory physics course. How so?

When you enrolled in your physics class—whether by choice or by school requirement—you broke ground on a new "physics home." Learning college-level physics is a lot like building a custom house: you start with a vision of your dream home, then you draw up a blueprint, and finally, you build it using tools and some elbow grease.

The Physics ToolBox helps you complete construction on your own "physics home." *Part I: Physics Is Fun* provides a view of the house to come; *Part II: Physics Blueprint* develops a blueprint or "big picture" overview to guide its assembly; and, *Part III: The Essential Math*, as well as the *Appendix: Studying for Success*, offers tools to help you build it.

Now, like construction in real life, building a "physics home" from scratch can be intimidating (after all, "everyone" knows that physics is "hard"). However, this book is designed to help you *get the most* out of your introductory physics course. It provides you with study skills advice, math help, tips on dealing with your instructor and your classmates, and, best of all, a fresh look at the information that makes up a typical introductory physics course—including an entire section devoted to helping



Building Your Physics House

you develop your own "big picture" understanding of the material. So, if you want to succeed in your physics class, you *need* this book.

For example, some of the great stuff in *The Physics ToolBox* includes:

- Advice on how to succeed in a typical introductory physics class (Part I), including what "physics" is and how it is taught today;
- A recasting of physics material (Part II) so that you can make connections *between* topics—connections that you might not otherwise be able to make in the barrage of details typically encountered in an introductory physics course;
- Six chapters (Part III) of critical math review and tips (*Don't worry, though! You don't have to read all of these chapters: just refer to them as math topics arise in your class.*); and
- 38 pages of study skills information that will help you improve your study habits—both in and out of your physics class.

Furthermore, *The Physics ToolBox* is written so that *the very act of reading it is practice* for your introductory physics class. For example, the chapters and sections of this book are numbered like typical physics texts; the book's tone is midway between scientific exposition and light reading (probably, right where you are); and, just like your regular physics textbook, each chapter of *The Physics ToolBox* includes many examples (further inquiries into text material), exercises (worked-out problems), and other boxes (supplemental information) that need to be dealt with *as you read along* in order to fully understand the text.

This book contains so much information, in fact, that *The Physics ToolBox* features several directional devices to help you find the material that you need, when you need it. For example, the book:

Finger Pointer! 

- has hundreds of "Finger Pointers" (such as the one in the margin to the left of this paragraph) that direct you to related or referenced material. As you read through the book, you will soon get used to looking in the margin for directions to additional information;
- includes a top-notch index to direct you to just the right page for what you need. Just like the index in your regular textbook, our index is great for "skipping around," so that you don't always have to read the book straight through.
- alerts you to advanced-level material via cross-hatching in the margin (as shown to the left). If you are not a physics major, you can usually skip this material!

Other great features of *The Physics ToolBox* include big, empty margins for you to write in (please do!), as well as a collection of inspiring, physics-related quotes from scientists and non-scientists alike.

However, remember that how much you get out of *The Physics ToolBox* completely depends upon how much effort you put in: houses are not built by toolboxes alone. *You* need to work the exercises, read the examples and other boxes, try out the study skills, meet with your in-



structor, and form a physics team (discussed in Chapter 4), in order for this book to help you.

So, as you begin your physics class, we wish you all of the best in building your physics dream home. We sincerely wish that, with the help of this *ToolBox*, you will come to love physics as much as we do. At the very least, though, we hope that you will obtain a better understanding of the beautiful physics house that already exists all around you.

And now, *The Physics ToolBox!*

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