

Preface

This textbook has grown out of the first-semester honors freshman physics course that has been taught at Harvard University during recent years. The book is essentially two books in one. Roughly half of it follows the form of a normal textbook, consisting of text, along with exercises suitable for homework assignments. The other half takes the form of a problem book, with all sorts of problems (with solutions) of varying degrees of difficulty. If you've been searching for a supply of practice problems to work on, this should keep you busy for a while.

A brief outline of the book is as follows. Chapter 1 covers statics. Most of this will probably look familiar, but you'll find some fun problems. In Chapter 2, we learn about forces and how to apply $F = ma$. There's a bit of math here needed for solving some simple differential equations. Chapter 3 deals with oscillations and coupled oscillators. Again, there's a fair amount of math needed for solving linear differential equations, but there's no way to avoid it. Chapter 4 deals with conservation of energy and momentum. You've probably seen much of this before, but again, it has lots of neat problems.

In Chapter 5, we introduce the Lagrangian method, which will undoubtedly be new to you. It looks rather formidable at first, but it's really not all that rough. There are difficult concepts at the heart of the subject, but the nice thing is that the technique is easy to apply. The situation here analogous to taking a derivative in calculus; there are substantive concepts on which the theory rests, but the act of taking a derivative is fairly straightforward.

Chapter 6 deals with central forces, Kepler's Laws, and such things. Chapter 7 covers the easier type of angular momentum situations, ones where the direction of the angular momentum is fixed. Chapter 8 covers the more difficult type, ones where the direction changes. Gyroscopes, spinning tops, and other fun and perplexing objects fall into this category. Chapter 9 deals with accelerated frames of reference and fictitious forces.

Chapters 10 through 13 cover relativity. Chapter 10 deals with relativistic kinematics – abstract particles flying through space and time. Chapter 11 covers relativistic dynamics – energy, momentum, force, etc. Chapter 12 introduces the important concept of “4-vectors.” The material in this chapter could alternatively be put in the previous two, but for various reasons I thought it best to create a separate chapter for it. Chapter 13 covers a few topics from general relativity. It's not possible for one chapter to do this subject justice, of course, so we'll just look at some basic (but still very interesting) examples.

The appendices contain various useful things. Indeed, Appendices B and C, which cover dimensional analysis and limiting cases, are the first parts of this book you should read.

Throughout the book, I have included many “remarks.” These are written in a slightly smaller font than the surrounding text. They begin with a small-capital “REMARK” and end with a shamrock (♣). The purpose of these remarks is to say something that needs to be said, without disrupting the overall flow of the argument. In some sense these are “extra” thoughts, although they are invariably useful in understanding what is going on. They are usually more informal than the rest of the text, and I reserve the right to occasionally use them to babble about things I find interesting, but which you may find a bit tangential. For the most part, however, the remarks address issues and questions that arise naturally in the course of the discussion.

At the end of the solutions to many problems, the obvious thing to do is to check limiting cases.¹ I have written these in a smaller font, but I have not always bothered to start them with a “REMARK” and end them with a “♣”, because they are not “extra” thoughts. Checking limiting cases of your answer is something you should *always* do.

For your reading pleasure (I hope), I have included many limericks scattered throughout the text. I suppose that they might be viewed as educational, but they certainly don’t represent any deep insight I have on the teaching of physics. I have written them solely for the purpose of lightening things up. Some are funny. Some are stupid. But at least they’re all physically accurate (give or take).

A word on the problems. Some are easy, but many are very difficult. I think you’ll find them quite interesting, but don’t get discouraged if you have trouble solving them. Some are designed to be brooded over for hours. Or days, or weeks, or months (as I can attest to). I have chosen to write them up for two reasons: (1) Students invariably want extra practice problems, with solutions, to work on, and (2) I find them rather fun.

The problems are marked with a number of asterisks. Harder problems earn more asterisks, on a scale from zero to four. You may, of course, disagree with my judgment of difficulty, but I think that an arbitrary weighting scheme is better than none at all. As a rough idea of what I mean by the number of stars: one-star problems are solid problems that require some thought, and four-star problems are really really really difficult. Try a few and you’ll see what I mean.

Just to warn you, even if you understand the material in the text backwards and forwards, the four-star (and many of the three-star) problems will still be extremely challenging. But that’s how it should be. My goal was to create an unreachable upper bound on the number (and difficulty) of problems, because it would be an unfortunate circumstance, indeed, if you were left twiddling your thumbs, having run out of problems to solve. I hope I have succeeded.

For the problems you choose to work on, be careful not to look at the solution too soon. There is nothing wrong with putting a problem aside for a while and

¹This topic is discussed in Appendix C.

coming back to it later. Indeed, this is probably the best way to approach things. If you head to the solution at the first sign of not being able to solve a problem, then you have wasted the problem.

REMARK: This gives me an opportunity for my first remark (and first limerick, too). One thing many people don't realize is that you need to know more than the correct way(s) to do a problem; you also need to be familiar with many *incorrect* ways of doing it. Otherwise, when you come upon a new problem, there may be a number of decent-looking approaches to take, and you won't be able to immediately weed out the poor ones. Struggling a bit with a problem invariably leads you down some wrong paths, and this is an essential part of learning. To understand something, you not only have to know what's right about the right things; you also have to know what's wrong about the wrong things. Learning takes a serious amount of effort, many wrong turns, and a lot of sweat. Alas, there are no short-cuts to understanding physics.

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One last note: the problems with included solutions are called “Problems.” The problems without included solutions are called “Exercises.” There is no fundamental difference between the two, except for the existence of written-up solutions.

I hope you enjoy the book!

— David Morin