

PREFACE

Dynamics is difficult. There is no getting around that. This is particularly true for undergraduates just starting their engineering and science education, when they are beginning to wrestle with the physics and mathematics needed to gain facility with dynamics. We find that simply acknowledging this fact goes a long way toward increasing confidence. Nevertheless, the pedagogical solution is not to simplify the material to make it more manageable. Rather, we feel quite strongly that students are best served by employing careful rigor and emphasizing deep understanding of the concepts as well as by using precise mathematics. In this way, they are provided with tools and concepts that will serve them throughout their educational and professional careers. The proper response to the admitted difficulty of the subject is to slow down the presentation, perhaps stretching it over multiple quarters or semesters, and gradually building complexity rather than simplifying in a way that lacks rigor and care. To that end, we have included extensive appendices covering the mathematical skills needed to understand all material in the book.

Most students who will use this book have had an introduction to mechanics in their freshman physics courses. It is our goal to reintroduce them to the material with the added sophistication of vector calculus and differential equations. Our approach to ensuring both understanding and confidence is to emphasize careful notation and rigor. Although some students complain about the pedantry and others want to jump to the end, it is our experience that the way to ensure competence is to enforce a rigorous and careful problem-solving process. Unfortunately, too close an adherence to this principle can lead to a course—and textbook—that is dry, uninviting, and presented in a way that is inconsistent with how students learn. The challenge we undertook in writing this book was to maintain rigor (and rigorous notation) while making the material sufficiently approachable and informal that students will spend time reading it and wrestling with it.

Certainly there are many good books available that treat the subject of dynamics with complete rigor. We confess that we like a good number of them and are attracted to the top-down approach of developing the material from first principles, starting with geometry, moving on to fully three-dimensional vector kinematics, and then continuing through particle and rigid-body dynamics. In fact, we use this approach in our graduate classes, where we also include Lagrangian and Hamiltonian methods. However, we have found that undergraduates (especially sophomores and juniors) have difficulty learning the material this way. Rather, a bottom-up approach that develops skills and techniques on simpler problems—without sacrificing rigor—and gradually increases sophistication—without losing sight of the basic physics—seems to best capitalize on the way these students learn. In that sense our approach can be likened to learning to play a musical instrument. We begin with the essential fundamentals and, through repeated problem solving (practice), develop “muscle memory” as new and more difficult pieces are tackled. Yet the notations we use from the beginning—the notes, chords, and time signatures—remain the same and return again and again.

We thus take a unique approach in this book. We introduce Newton's laws and start solving important problems even before beginning a discussion of vector kinematics. We seek to maintain student interest and present key notations and skills in the context of real problems. An overemphasis on the mathematics, without maintaining a connection to the physical objectives, can cause confusion and diminish enthusiasm among students. For this reason, in some chapters we defer more detailed or complex derivations to the end of the chapter, so as not to interrupt the physical picture. Kinematics is developed slowly, always in the context of dynamics problems. Yet we insist on a very careful notation, inspired by Thomas Kane's wonderful books. We always specify reference frames and are careful to maintain the distinction between vectors, components, and scalars. The emphasis on using and understanding reference frames (and specifying the inertial frame when solving problems) is something we are particularly wedded to and find lacking in many introductory dynamics texts. *In our experience, the best thing students can do to avoid errors and enhance learning is be compulsive about notation from the start.*

We also emphasize finding equations of motion. Before computers became commonplace, dynamics education (as reflected in older textbooks) tended to emphasize finding accelerations and treating dynamics problems as slightly more complicated statics problems. Dynamics, however, is about finding equations of motion and determining trajectories. We thus introduce students early on to the idea of using ordinary differential equations to describe the motion of systems and to the use of a computer to integrate these equations. Where possible, analytical solutions to the equations of motion are presented.

We have made every effort to include examples spanning a range of difficulty and covering the most important concepts and techniques. We have tried to connect the examples to real physical systems. Certain examples regularly repeat throughout the book, so that students can see how new concepts are used on familiar problems and how new insights can be gained from increasingly sophisticated analysis.

Our approach of distinguishing examples from tutorials allows us to employ simple problems to highlight specific ideas just after they are introduced (examples) while reserving problems that synthesize many concepts for the end of the chapter (tutorials). Some tutorials can be quite difficult, and instructors may want to judiciously select among them; however, we felt presenting a wide range of difficulty and depth resulted in a text that may prove useful for years after the course is taken.

We have also chosen to adopt an informal conversational style. Although purists may be put off by this tone in a technical work, our feedback from students—after trying a number of different textbooks—is that they appreciate the approachability of conversational writing and find the material more accessible. We directly address the reader and attempt to guide him or her through the difficult task of learning dynamics.

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ENGINEERING DYNAMICS

