

Preface

“Die Mechanik ist das Rückgrat der Mathematischen Physik.”

- Arnold Sommerfeld

This work is an outgrowth of lectures on mechanics given at Illinois Institute of Technology. Thorough study of classical mechanics is almost universally regarded as the mark of a strong physics education. Mechanics typically provides the first opportunity for study of dynamical systems requiring detailed analysis, rather than involving the mere application of a few basic formulas and principles to solve “standard” problems. Classical mechanics is the archetype of a physical theory – a paradigm that physicists apply when analyzing natural phenomena. Classical mechanics has stimulated dendritic development in a host of new arenas – including continuum mechanics, electromagnetism, fluids, plasma physics, the quantum theory, and statistical mechanics. Simply stated, classical mechanics reveals how physicists view the world around them.

The discipline of classical mechanics has evolved greatly over a period of nearly four centuries from the time of Kepler to the current era. A short list of some prominent figures in mechanics, along with the years of their births and deaths, is given in the Appendix at the end of the book. Classical mechanics – the oldest and most mature theory in physics – has continued to expand its horizons over the centuries.

Classical mechanics has been formulated through three distinct approaches:

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| I. | Newtonian: | infinitesimal motion from a (spacetime) point |
| II. | Least Action: | trajectory of motion between two points |
| III. | Hamilton-Jacobi: | all trajectories passing through one point |

Although the simplest problems can be solved most readily using the first or second approach, the Hamilton-Jacobi formalism permits solution of the widest variety of problems. In addition, it has paved the way for modern explorations of topics such as nonlinear dynamics, chaotic systems, strange attractors, self-organization, and “emergent” behavior.

Current investigations make use of ever more powerful computers, as well as more sophisticated and effective numerical algorithms, to analyze, present, and understand the behavior of mechanical systems.

“The purpose of computing is insight, not numbers. Machines should work. People should think.”

- Richard W. Hamming

I believe that a person learning physics, and mechanics in particular, should take full advantage of these recently developed tools. Consequently, I have introduced several “non-standard” examples and developed some new, relatively open-ended exercises, in which the “careful reader” should apply modern techniques for analysis and presentation of solutions to challenging problems. I have made extensive use of programs using the software package Mathematica, which is a trademark of Wolfram Research Inc. I have provided several programs in Mathematica for application and easy modification. Relentless examination of such exercises is the most important aspect of a study of physics.

“Physics cannot be learned just by reading and listening, but only by thinking, writing, and worrying.”

- David Atkinson

How should a course in mechanics be designed for physics students? One possibility is to develop a presentation suitable for “all” students, by providing extensive background material on mathematical topics that arise in mechanics, by reviewing traditional Newtonian mechanics, and by restricting the depth of the topics being considered. Since a number of mechanics textbooks follow this approach, I have not emphasized background material. Rather, I seek to challenge the student who will leave “no stone unturned” in pursuit of knowledge of mechanics. Classical mechanics is presented in its full scope, and the extent of the utility of its ideas is exposed through analysis of some challenging problems of the past, the present, and the future. Here are my objectives:

- To cover all of mechanics from Kepler to the twenty-first century. This book is likely to be the “last one” in a student’s formal education in mechanics, and I feel compelled to expose all the basic concepts and approaches in mechanics.
- To limit topics so that the book is appropriate for a one semester course for fourth year physics students, or those beginning graduate study. Therefore, I have left out elementary Newtonian mechanics, vector calculus, fluid mechanics, and relativity. In addition, continuum mechanics has been considered only for one dimensional systems.
- To introduce numerical analysis and visualization at an intrinsic level, rather than as an “add-on extra” to analyze problems that are readily solved by other means. Therefore, I have provided extensive numerical analyses of systems and simple Mathematica programs for further use. (These programs will run in versions 4 or later of that software package.)

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