0.1 Preface

During the three centuries since Newton created the subject of mechanics hundreds if not thousands of authors have seen fit to produce texts and treatises. In the light of this perhaps it is not necessary to explain the production of yet another, as it has clearly become a tradition in itself. It is hoped that the present work will be helpful to both students and to those engaged by need or interest in the task of modeling the behavior of mechanical systems. Some novelty is also claimed both in content and manner of presentation. Emphasis is put on a geometrical interpretation of the algorithm developed by Kane for deriving the equations of motion. There is some limited discussion of more traditional methods, such as the Lagrange and Gibbs-Appell equations. Another novel feature of this work is the introduction of a descriptive algorithmical language, 'Sophia' for the formulation and solution of mechanics problems. Sophia is designed to provide a clear and unique encapsulation of the tasks needed to formulate and manipulate theoretical constructs so as to arrive at equations of motion. The test of this clarity of expression is to be seen in the creation of 'interpreters' which translate Sophia statements into equations of motion. Such interpreters have been constructed for two popular computer algebra systems, Maple and Mathematica. The present book uses the Maple version. It is not necessary to have Sophia in its computer embodiment to make use of this text. While it is certainly more interesting to be able to run Sophia as a computer language, the main point is that it provides a detailed prescription for the discussion of particular problems. As different methods are introduced they are 'encapsulated' into algorithms which can be invoked by Sophia statements. This is a currently popular way of looking at problems in the computer science community and it is felt it provides a rich viewpoint for the presentation, understanding of the mechanics of rigid body systems.

The realm treated by this book is sometimes called 'the mechanics of multibody systems'. Most of the literature in this subject concentrates on numerical methods and hence formulations of the subject that will be helpful in writing general purpose computer codes. For truly large systems comprising many bodies this is probably the only reasonable path. In contrast to this the present book is based on the idea that the elusive quality known as 'understanding' is best achieved by only modeling the most essential features of a problem. In fact the very problem of determining just what the essential features are is at the root of achieving understanding. While the techniques treated here may also be useful for large scale numerical modeling the main thrust is towards dealing with moderately complex systems. Here it is possible, using computer algebra, to obtain constraint free representations of the equations of motion in forms that can be readily integrated. It is known that such forms frequently lead to the most efficient numerical integration procedures, but it is also hoped that they can help the investigator achieve analytical understanding. Some discussion of this is included in the last chapter of this book, which covers methods of approximation.

Notes, on which this book is based, have been used in two advanced mechanics courses given at the Royal Institute. For the most part students have come from

the engineering physics, vehicle technology and mechanical engineering departments. The course consisted of some 60 contact hours, including a number of active computer demonstrations. The students have had good access to the Maple system and have been able to make considerable use of the Sophia programs.

Finally a word about the Sophia programs. Appendix A describes how to use the attached disks. They are also available by FTP over the internet at ftp.mech.kth.se in the directory *sophia*. Included are some tutorial files as well as a somewhat more primitive version of Sophia in Mathematica. The present main form of the programs are intended to run with MapleV release 3. There are also interface programs for placing equations derived with Sophia into Matlab format.

(Matlab, Maple and Mathematica are trade marks of their respective developers.)

I have had the great benefit of advice and encouragement from a number of my colleagues, both at the Royal Institute and other institutions. In particular I would like to thank Dr. Hanno Essén for his careful reading of the text, numerous discussions in which he set me 'on the right path' and toleration if not acceptance of some notational heresy. Dr. Arne Nordmark, a former student who in many ways has become my teacher, showed me the need to respect the difference between tangent and cotangent spaces, though the conversion was not complete. Professors Sören Andersson and Lennart Karlsson and their students helped put Sophia and the geometrical interpretation of Kane's equations into practice on 'real' problems. Professor Håkan Gustavsson, though busy with his own research programs found time to support my work through his activites with the Swedish Technical Research Council (TFR). Support has also come from the Swedish Industrial Research Council (STU) and the Volvo Research Foundation. I also am indebted to the Royal Institute of Technology, and the Mechanics department for both a wonderful research atmosphere, some of the best students in the world and a sabbatical leave which allowed me to finish the task of preparing this book. Especial thanks go to Claes Tissell and Annika Stensson for their work on applications. My own graduate student, Anders Lennartsson, has made major contributions to the utility of the Sophia programs as well as developing interface tools for moving Sophia output to Matlab and C. None of this work would have been carried out if I had not come across the works of Thomas Kane. The reading of his works has given me both new insight and interest in this classical subject and I thank him for this. Professor Leon Chua, the editor of this series, encouraged me to produce this version of the work. As editor of the Journal of Bifurcation and Chaos his belief that the community of dynamical systems researchers will obtain benefit from the ability to easily deal with complex mechanical systems has been a great encouragement to me.

The preparation of this work by one person was made possible by the modern computer tools we now are taking for granted. In particular I thank the authors of TEX and LATEX, as well as Adobe Dimension and Adobe Illustrator. The latter made it possible for a draftsman of modest talent, myself, to produce the illustrations of the present text.

Martin Lesser
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It's so simple, So very simple, That only a child can do it!
New Math, Tom Lehrer