PREFACE
to the Fifth Edition

How many times do you have to do this to get it right, Norton?
THE EDITORS ASKED, RE. THE FOURTH EDITION

I plead the fifth.
THE AUTHOR

The fifth edition is an evolutionary improvement over the fourth and earlier editions. See the updated *Preface to the First Edition* (overleaf) for more detailed information on the book's purpose and organization. The principal changes in this edition are:

- A new chapter (16) has been added on cam-driven and servo-driven linkages based on the author's recent consulting experience that indicates increased use of servomotors to drive mechanisms in machinery.

- Over 50 new problem assignments have been added. All of the problem figures are included as PDF files on the DVD so that students can easily print hard copies on which to work the solutions.

- Several of the author-written programs that come with the book have been completely rewritten to improve their interface and usability, and they are now compatible with the latest operating systems and computers. The programs FOURBAR, FIVEBAR, SIXBAR, and SLIDER have been combined in a new program called LINKAGES that does everything those programs collectively did and has some new features added. Program DYNACAM also has been completely rewritten and is much improved. Programs ENGINE and MATRIX are unchanged. These computer programs undergo frequent revision to add features and enhancements. Professors who adopt the book for a course may register to download the latest student versions of these programs from: http://www.designofmachinery.com/registered/professor.html.

- The Working Model program that was provided with earler editions was not a full-featured version of the program. It did not allow the user to save or print a model. The version of Working Model available with this text is a **fully capable version** but is provided only by means of a one-time download from a website and will run for one year from the time of installation. A password is provided with this text to enable its download.

- Many small improvements have been made to the discussion of a variety of topics in many chapters, based largely on user feedback, and all known errors have been corrected.

The extensive DVD content that was introduced in the Fourth Edition is included with the Fifth Edition as well. These include:

- The entire Hrones and Nelson Atlas of Coupler Curves and the Zhang Atlas of Geared Fivebar Coupler Curves are provided as PDFs on the DVD.

- Eighteen instructional videos that provide several lecture/demonstration tutorials on subjects such as position synthesis, coupler curves and cognates, the Grashof condition, etc. Others show real machinery that uses linkages, cams and gears for such tasks as spring manufacture, bottle printing, and pick-and-place mechanisms for automated assembly.

- Wang's Mechanism Simulation in a Multimedia Environment that contains over 100 Working Model (WM) files based on the book's figures and 19 Matlab® models for kinematic analysis and animation is included.

- Videos of two "virtual laboratories" that replicate labs created by the author at WPI are provided. These include demonstrations of the machines and spreadsheet files of the acceleration and force data taken during the experiments. The intent is to allow students at other schools to do these exercises as virtual laboratories.

Robert L. Norton
Mattapoisett, Mass.
August, 2010

If you find any errors or have comments or suggestions for improvement, please email the author at norton@wpi.edu. Errata as discovered, and other book information, will be posted on the author's web site at http://www.designofmachinery.com.

PREFACE
to the First Edition

When I hear, I forget
When I see, I remember
When I do, I understand
ANCIENT CHINESE PROVERB

This text is intended for the kinematics and dynamics of machinery topics which are often given as a single course, or two-course sequence, in the junior year of most mechanical engineering programs. The usual prerequisites are first courses in statics, dynamics, and calculus. Usually, the first semester, or portion, is devoted to kinematics and the second to dynamics of machinery. These courses are ideal vehicles for introducing the mechanical engineering student to the process of design, since mechanisms tend to be intuitive for the typical mechanical engineering student to visualize and create.

While this text attempts to be thorough and complete on the topics of analysis, it also emphasizes the synthesis and design aspects of the subject to a greater degree than most texts in print on these subjects. Also, it emphasizes the use of computer-aided engineering as an approach to the design and analysis of this class of problems by providing software that can enhance student understanding. While the mathematical level of this text is aimed at second- or third-year university students, it is presented *de novo* and should be understandable to the technical school student as well.

Part I of this text is suitable for a one-semester or one-term course in kinematics. Part II is suitable for a one-semester or one-term course in dynamics of machinery. Alternatively, both topic areas can be covered in one semester with less emphasis on some of the topics covered in the text.

The writing and style of presentation in the text are designed to be clear, informal, and easy to read. Many example problems and solution techniques are presented and spelled out in detail, both verbally and graphically. All the illustrations are done with computer-drawing or drafting programs. Some scanned photographic images are also included. The entire text, including equations and artwork, is printed directly from the author's computer disk by laser typesetting for maximum clarity and quality. Many suggested readings are provided in the bibliography. Short problems and, where appropriate, many longer, unstructured design project assignments are provided at the ends of chapters. These projects provide an opportunity for the students *to do and understand.*

The author's approach to these courses and this text is based on over 40 years' experience in mechanical engineering design, both in industry and as a consultant. He has taught these subjects since 1967, both in evening school to practicing engineers and in day school to younger students. His approach to the course has evolved a great deal in that time, from a traditional approach, emphasizing graphical analysis of many structured problems, through emphasis on algebraic methods as computers became available, through requiring students to write their own computer programs, to the current state described above.

The one constant throughout has been the attempt to convey the art of the design process to the students in order to prepare them to cope with *real* engineering problems in practice. Thus, the author has always promoted design within these courses. Only recently, however, has technology provided a means to more effectively accomplish this goal, in the form of the graphics microcomputer. This text attempts to be an improvement over those currently available by providing up-to-date methods and techniques for analysis and synthesis that take full advantage of the graphics microcomputer, and by emphasizing design as well as analysis. The text also provides a more complete, modern, and thorough treatment of cam design than any existing texts in print on the subject.

The author has written four interactive, student-friendly computer programs for the design and analysis of mechanisms and machines.[*] These programs are designed to enhance the student's understanding of the basic concepts in these courses while simultaneously allowing more comprehensive and realistic problem and project assignments to be done in the limited time available than could ever be done with manual solution techniques, whether graphical or algebraic. Unstructured, realistic design problems which have many valid solutions are assigned. Synthesis and analysis are equally emphasized. The analysis methods presented are up to date, using vector equations and matrix techniques wherever applicable. Manual graphical analysis methods are deemphasized. The graphics output from the computer programs allows the student to see the results of variation of parameters rapidly and accurately and reinforces learning.

These computer programs are distributed on DVD with this book, which also contains instructions for their use on any Windows NT/2000/XP/Vista/Windows7 capable computer. Program LINKAGES analyzes the kinematics and dynamics of fourbar, geared fivebar, sixbar, and fourbar slider linkages. It also will synthesize fourbar linkages for two and three positions. Program DYNACAM allows the design and dynamic analysis of cam-follower systems. Program ENGINE analyzes the slider-crank linkage as used in the internal combustion engine and provides a complete dynamic analysis of single- and multicylinder engine inline, V, and W configurations, allowing the mechanical dynamic design of engines to be done. Program MATRIX is a general-purpose linear equation system solver. These are student editions of professional programs that are written by the author and that he provides to companies the world over.

All these programs, except MATRIX, provide dynamic, graphical animation of the designed devices. The reader is strongly urged to make use of these programs in order to investigate the results of variation of parameters in these kinematic devices. The programs are designed to enhance and augment the text rather than be a substitute for it. The converse is also true. Many solutions to the book's examples and to the problem sets are provided on the DVD as files to be opened in these programs. Most of these solutions can be animated on the computer screen for a better demonstration of the concept than is

possible on the printed page. The instructor and students are both encouraged to take advantage of the computer programs provided. Instructions for their use are in Appendix A.

The author's intention is that synthesis topics be introduced first to allow the students to work on some simple design tasks early in the term while still mastering the analysis topics. Though this is not the "traditional" approach to the teaching of this material, the author believes that it is a superior method to that of initial concentration on detailed analysis of mechanisms for which the student has no concept of origin or purpose.

Chapters 1 and 2 are introductory. Those instructors wishing to teach analysis before synthesis can leave Chapters 3 and 5 on linkage synthesis for later consumption. Chapters 4, 6, and 7 on position, velocity, and acceleration analysis are sequential and build upon each other. In fact, some of the problem sets are common among these three chapters so that students can use their position solutions to find velocities and then later use both to find the accelerations in the same linkages. Chapter 8 on cams is more extensive and complete than that of other kinematics texts and takes a design approach. Chapter 9 on gear trains is introductory. The dynamic force treatment in Part II uses matrix methods for the solution of the system simultaneous equations. Graphical force analysis is not emphasized. Chapter 10 presents an introduction to dynamic systems modeling. Chapter 11 deals with force analysis of linkages. Balancing of rotating machinery and linkages is covered in Chapter 12. Chapters 13 and 14 use the internal combustion engine as an example to pull together many dynamic concepts in a design context. Chapter 15 presents an introduction to dynamic systems modeling and uses the cam-follower system as the example. Chapters 3, 8, 11, 13, and 14 provide open-ended project problems as well as structured problem sets. The assignment and execution of unstructured project problems can greatly enhance the student's understanding of the concepts as described by the proverb in the epigraph to this preface.