# PREFACE

Most engineering students first encounter the subject of mechanics of materials in a course covering the concepts of stress and strain and the elementary theories of axial loading, torsion, bending and shear. There is broad agreement as to the content of such courses, there are many excellent textbooks and it is easy to motivate the students by using simple examples with obvious engineering relevance.

The second course in the subject presents considerably more challenge to the instructor. There is a very wide range of possible topics and different selections will be made (for example) by civil engineers and mechanical engineers. The concepts tend to be more subtle and the examples more complex making it harder to motivate the students, to whom the subject may appear merely as an intellectual excercise. Existing second level texts are frequently pitched at too high an intellectual level for students, many of whom will still have a rather imperfect grasp of the fundamental concepts.

Most undergraduate students are looking ahead to a career in industry, where they will use the methods of mechanics of materials in design. Many will get a foretaste of this process in a capstone design project and this provides an excellent vehicle for motivating the subject. In mechanical or aerospace engineering, the second course in mechanics of materials will often be an elective, taken predominantly by students with a design concentration. It is therefore essential to place emphasis on the way the material is used in design.

Mechanical design typically involves an initial conceptual stage during which many options are considered. During this phase, quick approximate analytical methods are crucial in determining which of the initial proposals are feasible. The ideal would be to get within $\pm 30$ percent with a few lines of calculation. The designer also needs to develop experience as to the kinds of features in the geometry or the loading that are most likely to lead to critical conditions. With this in mind, I try wherever possible to give a physical and even an intuitive interpretation to the problems under investigation. For example, students are encouraged to estimate the location of flexible and stiff bending axes and the resulting neutral axis of bending by eye, and methods are discussed for getting good accuracy with a simple one degree of freedom Rayleigh-Ritz approximation. Students are also encouraged to develop a feeling for the mode of deformation of engineering components by performing simple experiments in their outside environment, for example, estimating the radius to which an initially straight bar can be bent without producing permanent deformation, or convincing themselves of the dramatic difference between torsional and bending stiffness for a thin-walled open beam section by trying to bend and then twist a structural steel beam by hand-applied loads at one end.

In choosing dimensions for mechanical components, designers will expect to be guided by criteria of minimum weight, which with elementary calculations, often lead to a thin-walled structure as the optimal solution. This demands that students be introduced to the limits imposed by elastic instability. Some emphasis is also placed on the effect of manufacturing errors on such highly designed structures—for example, the effect of load misalignment on a beam with a large ratio between principal stiffnesses and the large magnification of initial alignment or loading errors in a column below, but not too far below, the buckling load.

No modern text of mechanics of materials would be complete without a discussion of the finite element method. However, students and even some instructors are often confused as to the respective roles played by analytical and numerical methods in engineering practice. Numerical methods provide accurate solutions for complex practical problems, but the results are specific to the geometry and loading modelled and the solution involves a significant amount of programming effort. By contrast, analytical methods may be very idealized and hence approximate, but they are often quick to apply and they provide generality, permitting a whole family of designs to be compared or even optimized.

The traditional approach to mechanics is to define the basic concepts, derive a general theory and then illustrate its application in a variety of examples. As a student and later as a practicing engineer, I have never felt comfortable with this approach, because it is impossible to understand the nuances of the definitions or the general treatment until after they are seen in examples which are simple enough for the mathematics and physics to be transparent. Over the years, I have therefore developed rather untraditional ways of proving and explaining things, relying heavily on simple examples during the derivation process and using only the bare minimum of specialist terminology. I try to avoid presenting to the student anything which he or she cannot reasonably be expected to understand fully *now*.

The problems provided at the end of each chapter range from routine applications of standard methods to more challenging problems. Particularly lengthy or difficult problems are identified by an asterisk. The Solutions Manual to accompany this book is prepared to the same level of detail as the example problems in the text and in many cases introduces additional discussion. Answers to even-numbered problems are provided in Appendix D.

This book evolved out of a set of notes which I wrote for a second level course at the University of Michigan and the resulting interaction with my students and colleagues has played a crucial role in the development of my thinking about the subject. Special thanks go to Przemislaw Zagrodzki of Warsaw University of Technology and Raytech Composites Inc. for his invaluable help with the Appendix on finite element methods. I am very grateful to the staff at McGraw-Hill, whose insight into the needs of the readership have proved invaluable in suggesting changes in both style and content. I also wish to thank those reviewers who provided detailed comments on earlier versions of this manuscript, including Gordon Pennock, Purdue University; Lester Schmerr, Iowa State University; Larry Lessard, McGill University; Paul Heyliger, Colorado State University; Victor Giurgiutiu, University of South Carolina;

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