Preface

Archeologists tell us that sometime around 13,000 years ago, in the then fertile valleys of the Tigris and Euphrates Rivers, several enterprising individuals began to divert water from the rivers for the purpose of growing crops. That may indeed have been the single most important step in creating our modern civilization today, and for that reason it is not uncommon to refer to those ingenious people as the first engineers on earth. Concomitantly, anthropologists tell us that it takes approximately 10,000 years for the human species to undergo any significant genetic change. Thus, we may conclude that those people were very smart, perhaps as smart as we are today, as indicated by evidence that their brains are essentially the same size as that of modern man and woman. Perhaps antithetically, the birds and the bees, the frogs and the trees, indeed virtually all other species of plants and animals on earth have undergone only modest evolution in the past 13,000 years. Yet our own species has in that (geologically) short span of time taken over this planet.

So what is going on here? Why have we humans changed so dramatically, while other species have not? The answer is of course—education. Our species is the first species, so far as we are aware, that has outrun our own evolution, and we have done so via education. Certainly Darwin's law played a great role in our quest to educate ourselves, despite the fact that it was not even espoused until the mid-nineteenth century. The fact is, our ancestors were living their lives according to Darwin's law, whether they were aware of it or not. Archeologists have determined that the invention of farming moved humans rapidly away from hunter-gatherer behaviors, and this produced a population explosion at places such as Ur in the Middle East. Apparently, within a few short centuries, cities of more than 10,000 persons had sprung up in the Mideast. The growth of these cities allowed for specialization of professions in these cities, and this led the way to the development of new technologies as more people specialized in the development of new ideas. In turn, the development of new ideas required some training, and the ability to transmit these developments through society necessitated the development of sophisticated mathematics and language. These developments led inexorably to the rise of education—a necessity for humans to survive. While the higher education complexes on our planet are essentially less than a 1,000 years old, our educational infrastructure goes back thousands of years. It may be argued that education is indeed the single most important development in the history of humankind.

I was born into the world of blackboards and chalk, slide rules, and hand-drawn graphs. Now, as I near the twilight of my career in academia, I find myself to be a euphemism for the dinosaurs of old. The way that I was taught when I was in school half a century ago is no longer germane to our society. The tools that we used are virtually all obsolete, and here is the most astonishing part—***this is the first time in recorded history that our technology has outrun our education in a single life span.*** And yet, here I sit, working at a university, attempting to educate people less than a third my age—people who grew up in a world that I did not—people who are comfortable with cell phones, ipods, ipads, 3-D television, GPS, and I could go on and on. But more importantly, people who are **NOT** comfortable with slide rules, trig tables, analytic geometry, rigorous analytic methods for solving differential equations, and hand-drawn graphs. Are these people ill-educated? Are they not prepared for college? These are questions that are beyond the scope of this textbook. But what I do know is that they are different—they are different from my generation. They think differently, and ***they learn differently.***

I have been teaching for almost 40 years. I remember when I was in college one of my professors (Dr. Thompson was his name) came to class the first day and announced, "I have been teaching 40 years. I have taught every way there is to teach, and all of them are wrong." That statement has stuck with me these past 40 years, and now I find myself on the other end of the problem. You see, I feel the same way he did. And because the evolution of technology has increased its pace, I fear that Dr. Thompson's conjecture is even more relevant today.

I have been teaching subject matter related to the subject of this textbook for my entire professional career. When I surveyed the available textbooks on this subject recently, I was surprised to find that while technology has changed, while America's youth have clearly changed, the approach taken to teaching this subject has not materially changed in the past 40 years. Actually, if one studies the mid-twentieth century texts by S.P. Timoshenko and his colleagues, it will be apparent that little has changed in significantly more than 40 years.

To my dismay, I found the following revelations within the subject matter that I reviewed: little attention to mathematical rigor, little or no attention to the pursuit of fundamental knowledge, wholesale attention to trivial details, and poor attention to ultimate outcome—***understanding of the subject***. While it is true that mechanics is a very old discipline, perhaps even the oldest of scientific disciplines, it is nonetheless clear that much has changed in the field of mechanics over the past half century. A great deal of this change has come about due to the birth and growth of the computer age. Armed with Moore's law, mechanicians have dramatically changed and improved our field of engineering and science. Especially in the field of deformable body mechanics, the inexorable spread of the finite element method over the past half century has revolutionized our ability to model deformable bodies today. And yet, we seem to have failed to alter our educational approach to the subject.

This textbook is an attempt to address this problem—to approach a first course in deformable body mechanics in such a way as to impart fundamentals to the student that will lead the student to a rigorous and logical understanding of the field as it is utilized today—in the world of high speed computing. As such, it is intended that students who master the subject matter herein will find within their grasp the ability to progress seamlessly to a second course wherein they will learn to design real world complicated and three-dimensional structural parts using already available software.

My approach herein grew out of my 40-year career in higher education, during which time I taught at four different major universities in the USA—Texas A&M University, Virginia Tech University, The University of Nebraska-Lincoln, and The University of Texas-Pan American. Over that span of time I taught courses such as statics, dynamics, mechanics of solids, advanced mechanics of solids, finite element methods, advanced structural mechanics, elasticity, plasticity, viscoelasticity, viscoplasticity, fracture mechanics, and the history of science and technology to more than 6,000 ensemble students. Perhaps serendipitously, toward the middle of my career, I taught within an experimental course sequence funded by the National Science Foundation for 13 years. This period profoundly affected my thinking on the subject.

My aim herein is to impart fundamentals with as little confusion as possible. For example, I have adopted a systematic mathematical terminology, taken at least in part from my previous textbook on the subject *Introduction to Aerospace Structural Analysis* coauthored with Walter E. Haisler. Furthermore, my intention is for the student who masters the subject matter herein to be competent to move directly to a course wherein the mechanics of deformable bodies can be modeled either two or fully three dimensionally using the finite element method. Thus, I have purposely avoided many topics that the interested reader can find in the enormous body of texts dealing with the subject of mechanics of deformable bodies.

The text opens with a short history of mechanics. This chapter is by no means exhaustive on the subject, aiming to impart the high points of historical developments that have led to our modern day understanding. The second chapter of the book deals with the underpinnings of our present day models, including fundamental universal conservation laws, definitions of the essential variables in the model, such as stress and strain, and a brief introduction to constitutive behavior of deformable bodies.

The third chapter develops the theory of uniaxial bars. Interestingly, this theory seems to have been developed after the theory of beams was developed by Leonard Euler and Daniel Bernoulli in the mid-eighteenth century, despite the fact that beams are far more physically and mathematically complicated. Perhaps it was expedience that drove Euler and Bernoulli to address the beam problem first. After all, beams were and still are our most important structural elements, whereas uniaxial bars are less prominent and perhaps more significantly, less prone to failure. Nonetheless, the chapter on uniaxial bars is of great importance for the student who is just starting out in this subject for two reasons: (1) it will pave the way toward an intimate understanding of the more complicated theories of torsion and beams and (2) the theory of uniaxial bars contains all of the essential physics of the general three-dimensional theory of elasticity employed in finite element algorithms without the encumbrance of complicated mathematics such as partial differential equations.

The fourth chapter develops the theory of torsion bars. I personally enjoy this subject because of the mathematical similarity of the torsion theory to uniaxial bar theory, despite the totally different physics involved. Such congruencies occur often in nature in widely differing fields of study, thus forming a bridge for those who are drawn to change their discipline. This chapter also forms a nice connection between the rather straightforward subject of uniaxial bars and the more challenging subject of beams.

The fifth chapter develops the theory of what I call "simple" beams. By simple I mean (1) beams that do not undergo axial extension and bending simultaneously, (2) beams whose properties vary only in their long direction, (3) beams that are initially straight, (4) beams that undergo small deformations, (5) beams that are orthotropic and linear elastic, and (6) beams that are not subjected to temperature change. As confining as these restrictions are, the theory developed in this chapter is nevertheless powerful for many practical applications. More importantly, the theory encompasses essentially all of the necessary knowledge for understanding the mechanical behavior of beams. For the reader who is interested in more advanced beams, I refer you to my previous textbook, cited above.

The sixth chapter of the book discusses the aspects of analyzing slender structural components. These include (1) the introduction of the principle of superposition and how it may be used as a practical simplifying tool, (2) the subject of stress transformations (due to coordinate rotations), and (3) how a rigorous understanding of this important but complicated subject is essential for the purpose of determining whether structural components can be expected to fail due to yielding and/or fracture.

The seventh and final chapter of the book briefly introduces the subject of structural design. While the subject of design is often quite open-ended and artistic in nature, the approach taken herein is simplistic in the sense that design is viewed as an inverse problem wherein the typical outputs that result from structural analysis of a part with a priori chosen loads, geometry, and material properties is inverted to a form in which these inputs become the outputs. A successful design will be considered to be any choice of loads, geometry, and material properties that satisfies all of the design constraints. No attempt will be made to produce an optimized design, as this constitutes an advanced subject that is beyond the scope of the present text. Rather, the goal of this closing chapter in the current text will be to explore in a straightforward manner the power of the models developed in Chaps. 1–6 of this text.

My experience is that essentially all of the material contained in this textbook can be covered in a single semester to typical university students in the USA.

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