Who is this textbook for?

This school-to-work and school-to-research book helps prepare undergraduate engineers for professional careers and graduate research in forces and motion (robotics, biomechanics, vehicle dynamics, design, controls, energy, computation/simulation, graphics, and mechanical/aerospace engineering).

The textbook is easy to use and enables 2D/3D analysis of real mechanical systems. There are **340^+** guided examples/homework problems that facilitate teaching and learning.

Why is a new textbook and approach needed?

Each year, many diligent engineers graduate without the ability to methodically form free-body diagrams, calculate 3D angular velocity, wrongly think $\vec{\mathbf{T}} = I\,\vec{\boldsymbol{\alpha}}$ generally applies to rotating rigid bodies, and are unable to use kinematics or dynamics for design, control, analysis, or simulation. University instructors frequently "start all over" when teaching graduate mechanics. Moreover, industry spends large resources addressing liabilities in design, control, manufacturing, and mechanics of their 2D/3D systems.

This book's new approach is effective and easy to use. It builds on familiar operations such as vectors and free-body diagrams. Each chapter can be taught in one or two lectures and has many guided homework problems so students can master the material through practice.

Advantages of this textbook

1. **Interactive guided homework: Easier for instructors, more productive for students.**
   This textbook focuses on ***what students do***. Its most innovative feature is its **188^+** pages of guided homework where meaningful problems are synthesized in small intelligible steps. The homework has an interactive engaging style with blanks for students to complete during home study. The instructor version has completed answers (with visual cues corresponding to student blanks).

   Students are motivated to learn when they solve interesting problems that make the topic relevant. Instead of short questions with "trick" answers, the guided problems lead students **step-by-step** through a procedure so they **synthesize** the problem-solving **process**.

   Students are motivated to acquire skills relevant to the real world and their professional careers. This textbook's problems are from a wide range of engineering applications (robotics, biomechanics, mechanical, aerospace). Many of the problems can be demonstrated at home or in the classroom.

2. **School-to-work and school-to-research skills**. This textbook focuses on fundamental skills required in modern engineering, including rotation matrices, vector differentiation, angular velocity, moments/products of inertia, FBDs, and forming equations of motion.

   Optional: This book helps develop computational skills for solving time-dependent **ODEs** for dynamic systems and for solving **nonlinear algebraic equations** for geometrical and static systems. No prior knowledge of numerical methods is needed as the book shows how to use tools such as MATLAB®, **M**otion**G**enesis, ...

3. **Focused and concise**. An important criteria for any technical book is accurate, intelligible, concise information. It is unreasonable to read, digest, and prioritize 200^+ pages of special-case formulas and analyses. Instead this book focuses on foundational principles of mechanics (force, mass, and motion) in a rigorous, consistent, and methodical manner.

   This book presents essential tools in a precise, intelligible, minimal way. For example, velocity is presented with two formulas and a few pages of explanatory text. To make the concept concrete, there are several examples for each formula, each with a varying degree of conceptual difficulty. The book's appendix provides a concise **summary of equations** - with only two pages for kinematics.

4. **2D/3D**. The real world is 3D and requires 3D tools and skills. However 3D mechanics can be counter-intuitive and difficult to visualize, interpret or solve. To balance reality and understanding, the book has 3D formulas, notation, and explanations with **many** 2D example/homework problems.

Opinion: What is the point of education?

The point of education is to provide **value** to the student and to the community by providing skills, knowledge, and human contact (motivation, support, competition, feedback, etc.). These **values** include gainful employment and physical, intellectual, social, spiritual, emotional, and economic life skills. These **values** also include personal integrity and discipline that promote community integrity (honest financial and legal systems, safe structures, efficient transportation, good homes, medicine, etc.).

Opinion: What is the point of engineering education?

The point of engineering education is to provide **useful skills** and a **way of thinking** to **solve problems**. It enables students to **do** science, medicine, engineering, construction, business, etc. Engineering provides ***concepts*** (pictures, words, and ideas), ***calculations*** (mathematical operations, symbols, equations, and definitions), and ***context*** (situations and experiments in which the concepts and calculations are relevant and useful). As contrasted with theoretical mathematics or pure science, Engineering has less emphasis on proofs or ideas with little discernable value in nature or business and is more focused on **using** math and science to solve communally meaningful problems.

Teaching and learning objectives

Metrics are essential to measuring success - whether it is money in business, scores in sports, or grades in school. Vast resources are invested in education including half of states' budgets and family borrowing that takes decades to repay. Ideally, these investments (and community gratitude and respect) create incentives for teachers to devote themselves to their students via homework, labs, exams, projects, competitions, demonstrations, lecturing, and grading. Although these academic activities provide a **metric** for students, the **metric** for effective instruction begins with the question:

"What should a student be able to do at the end of instruction"[a]

[a] In the context of mechanics, our answer is "to **model** real physical systems, **form** and **solve** their governing equations, and **interpret** their results for subsequent analysis and design."

Metrics for teaching? From "The Economist", Jan 8, 2011. The math skills of Singapore's 15-year old children rated 2^{nd} in the world whereas U.S. children rated 31^{st}. 100% of Singapore instructors are from the top 30% of their academic class whereas 23% of new U.S. teachers are from the top third of college graduates. Yet, U.S. schools districts rate 99% of their educators as "satisfactory". The L.A. school district spent $3.5 million trying to fire 7 of its 33,000 teachers, and in 10 years, only fired 5 of them.