Philosophy on engineering education

Intended audience

This book prepares engineers for professional careers. Engineers equipped with the skills in this book are prepared for advanced graduate research and professional work in motion and mechanics (biomechanics, automotive, energy, aerospace, machine design, robotics, computer graphics, controls, design, etc.).

Why a new textbook is needed

Each year, many diligent intelligent engineers graduate without the ability to calculate 3D angular velocity, think $\vec{\mathbf{T}} = I\,\vec{\boldsymbol{\alpha}}$ applies equally well to 2D and 3D rigid body analysis, – and are unable to use dynamics for innovative research or to design real equipment. University instructors frequently "start all over" when teaching 3D mechanics. Moreover, industry consistently spends large amounts of time and money correcting 2D designs for 3D systems. There is a problem. There is a need for a ***new approach*** to dynamics.

Although this book's new approach is effective, easy to use, and enjoyable, there is heavy reliance on familiar operations such as vector dot products and cross products. Each chapter can be taught in one or two lectures and has many homework problems so students can master the material through practice. A large number of practical homework problems have been created so that students can master the material while gaining some real engineering experience.

Advantages of this textbook's new approach

1. **Interactive guided homework: Easier for instructors, more productive for students.** This textbook focuses on ***what students do***. Its most innovative feature is its **100**$^{+}$ pages of homework where meaningful problems are synthesized in small intelligible steps. The homework has an **interactive** style with blanks for students to complete during home study (the instructor version is complete with visual cues where students have blanks).

   Students are motivated to learn when they solve interesting problems that make the topic relevant. Instead of short questions and quick "trick" answers, many problems lead students **step-by-step** through a complicated procedure so they **synthesize** the problem-solving **process** and ultimately arrive at a physically significant and satisfying result.

   Students are motivated when they acquire skills relevant to their professional lives. This textbook's problems are from a wide range of engineering applications (biomechanics, mechanical, aerospace).

2. **Three-dimensional (3D)**. Many modern engineering tools and problems are 3D and require 3D concepts and formulas. However, 3D motion can be counter-intuitive and more difficult to visualize, solve, or interpret than 2D. To strike a balance, all formulas, notations, and explanations in this textbook are fully 3D whereas many example and homework problems are 2D.

3. **Improved school-to-work skills**. This textbook teaches important work skills including rotation matrices, vector differentiation, angular velocity, inertia dyadics, and simulation.

   For example, investigations of dynamic systems can require numerical solution of time-dependent **differential equations** and static systems can require numerical solution of **nonlinear algebraic equations**. Although no prior knowledge of numerical methods is needed, the book exposes students to numerical methods through computer programs such as MATLAB® and **M**otion**G**enesis.

4. **Focused and concise**. An important criteria for any technical book is accurate, intelligible, ***concise*** information. It is unreasonable to require students to read, digest, and prioritize hundreds of pages to special-case formulas, topics, and problems. Instead this textbook focuses on foundational principles of mechanics (force, mass, and motion) in a rigorous, consistent, methodical manner.

   This book presents essential tools in a precise, intelligible, minimal way. For example, velocity is presented with four formulas and a few pages of explanatory text. To make the concept concrete, there is a variety of examples for each of 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.

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.).

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 more focus 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 sporting events, church attendance, or school grades. Vast resources are invested in education including half of states' budgets and family borrowing that takes decades to repay.[1] Ideally, these investments (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"[2]

[1] From "The Economist", January 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 top 30% of their academic class whereas only 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, succeeded in only firing 5 of them.

[2] One answer is "to **model** physical systems, **form** and **solve** their governing equations, and **interpret** their results."

