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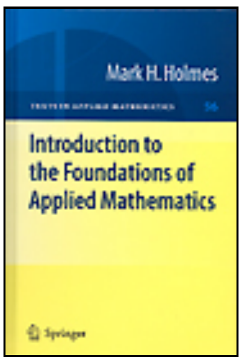
Introduction to the Foundations of Applied Mathematics

Mark H. Holmes



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[Reviewed by Joe Latulippe, on 12/28/2009]

The goal of this book is to introduce the mathematical tools needed for analyzing and deriving mathematical models. Often, books in the "Applied" sector investigate mathematical models derived from specific case studies. This way, a reader can appreciate and understand the reasons for studying such models. One drawback of this approach is that it seldom discusses general approaches or how to deal with technical difficulties that can occur when expanding or altering the model. To this end, Holmes' approach is focused on general mathematical analysis rather than that specific to any individual case study. Although the approach is general, Holmes is able to integrate the theory with application in a very nice way providing an excellent book on applied mathematics.

The book is divided into nine chapters covering topics from Dimensional Analysis to Fluid Mechanics. Included throughout these chapters are references to applications in many fields ranging from biology, chemistry, engineering, and physics, to name a few. As with any book, some topics have been left out, but the amount of material covered in the text is extensive, providing many options for using it as a classroom textbook.

The author claims that the prerequisites for the text are three semesters of Calculus (including Taylor's theorem), a lower division course in differential equations, and a matrix theory class. It seems to me, however, that a slightly higher level of mathematical sophistication is needed in order to delve into the topics found in the later part of each chapter. Thus, I would recommend this text for advanced undergraduate or graduate students. I plan to use the book for my advanced mathematical modeling class.

In the first chapter, a basic projectile problem is used to introduce and examine the ideas of dimensional analysis. Later, the theoretical formulation is discussed in greater detail and applied to a number of problems including the diffusion equation. This is followed by nondimensionalization and scaling. The exercises at the end of the chapter include many other applications, from the classical work of G. I. Taylor to atomic explosions. This leads nicely to perturbation methods, which follow in chapter two. Having also written a very good book on perturbation methods, Holmes' ability to concisely convey the finer points of the theory to his readers is showcased early in this chapter. A nice introduction to regular expansions is included at the beginning, as well as reasons why perturbation methods can be useful in analyzing problems. Although the theory becomes somewhat difficult once singular expansions and boundary layers are introduced, the section on multiple scales and two-timing offers a nice reprieve.

Before exploring models that involve partial differential equations, kinetics is discussed in chapter three. This chapter features problems involving linear and nonlinear systems of ordinary differential equations. From a modeling perspective, this section offers many different applications that can be modeled using the systems mentioned above. For example, this chapter includes predator-prey models, problems in epidemiology, the law of mass action, and enzymatic reactions. Also included in this chapter are problems that include perturbations, bringing the ideas of the previous chapters into focus. Although a background in dynamical systems is not necessary, readers with such a background will feel more comfortable with the mathematical tools than those without.

Chapters four through nine deal with partial differential equation models that can describe a variety of applications, including diffusion problems, traffic flow, continuum mechanics (in both one and three spatial dimensions), elasticity, and fluids. Traffic flow is discussed in chapter five to bring to light the ideas of modeling directed motion. The principles of characteristics, shock waves, and phantom traffic jams are introduced using the easy-to-visualize application of traffic flow. Although Holmes mentions that this can be extended to cellular automata or molecules moving through a tubule, not much attention is given to these specific applications.

Chapters six and seven deal with modeling material objects; chapter six focuses on continuum mechanics, including stress, strain, and the deformation of materials, while chapter seven investigates elastic and viscoelastic materials, including a variety of spring-mass systems. Again, the emphasis is on the mathematical formulation of constitutive laws and the mathematical tools needed to analyze the models. The text gradually becomes more advanced and culminates with a chapter on fluid flow. The topics here include steady flow, vortex motion, irrotational flow, and potential flow.

One of the best features of the book is the abundant number of exercises found at the end of each chapter. In addition to having a good selection of problem types, many of the problems investigate specific applications and include references. In addition to those previously mentioned, there are problems that explore the morphological basis for the deformation of metals and rubber, problems involving periodically forced springs including steel bars, many fluid flow problems, and a myriad of traffic flow problems. Thus, students can quickly apply the methods and tools outlined in the text to a variety of practical problems in different fields.

I think this is a great book, and I recommend it for scholarly purposes by students, teachers, and researchers.

Joe Latulippe (**jjlatulippe@csupomona.edu**) is an assistant professor of mathematics at Cal Poly Pomona. He is a Project NExT Fellow (Sun Dot '07), and is interested in mathematical biology and modeling. In his free time, Joe trains in Aikido (a non-violent Japanese martial art), and enjoys painting landscapes and drawing.

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