A Student's Guide to the Schrödinger Equation

Quantum mechanics is a hugely important topic in science and engineering, but many students struggle to understand the abstract mathematical techniques used to solve the Schrödinger equation and to analyze the resulting wave functions. Retaining the popular approach used in Fleisch's other Student's Guides, this friendly resource uses plain language to provide detailed explanations of the fundamental concepts and mathematical techniques underlying the Schrödinger equation in quantum mechanics. It addresses in a clear and intuitive way the problems students find most troublesome. Each chapter includes several homework problems with fully worked solutions. A companion website hosts additional resources, including a helpful glossary, Matlab code for creating key simulations, revision quizzes and a series of videos in which the author explains the most important concepts from each section of the book.

DANIEL A. FLEISCH is Emeritus Professor of Physics at Wittenberg University, where he specializes in electromagnetics and space physics. He is the author of four other books published by Cambridge University Press: *A Student's Guide to Maxwell's Equations* (2008); *A Student's Guide to Vectors and Tensors* (2011); *A Student's Guide to the Mathematics of Astronomy* (2013); and *A Student's Guide to Waves* (2015).

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About this book

This edition of *A Student's Guide to the Schrödinger Equation* is supported by an extensive range of interactive digital resources, available via a companion website. These resources have been designed to support your learning and bring the textbook to life, supporting active learning and providing you with feedback.

Please visit **www.cambridge.org/fleisch-SGSE** to access this extra content.

The following icons appear throughout the book in the bottom margin and indicate where resources for that page are available on the website.

Interactive Simulation

Learning Objective

Video

Worked Problem

Quiz

Glossary - Glossary items are highlighted bold in the text and full explanations of the term can be found on the website

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Preface

This book has one purpose: to help you understand the Schrödinger equation and its solutions. Like my other *Student's Guides*, this book contains explanations written in plain language and supported by a variety of freely available online materials. Those materials include complete solutions to every problem in the text, in-depth discussions of supplemental topics, and a series of video podcasts in which I explain the most important concepts, equations, graphs, and mathematical techniques of every chapter.

This *Student's Guide* is intended to serve as a supplement to the many comprehensive texts dealing with the Schrödinger equation and quantum mechanics. That means that it's designed to provide the conceptual and mathematical foundation on which your understanding of quantum mechanics will be built. So if you're enrolled in a course in quantum mechanics, or you're studying modern physics on your own, and you're not clear on the relationship between wave functions and vectors, or you want to know the physical meaning of the inner product, or you're wondering exactly what eigenfunctions are and why they're so important, then this may be the book for you.

I've made this book as modular as possible to allow you to get right to the material in which you're interested. Chapters 1 and 2 provide an overview of the mathematical foundation on which the Schrödinger equation and the science of quantum mechanics is built. That includes generalized vector spaces, orthogonal functions, operators, eigenfunctions, and the Dirac notation of bras, kets, and inner products. That's quite a load of mathematics to work through, so in each section of those two chapters you'll find a "Main Ideas" statement that concisely summarizes the most important concepts and techniques of that section, as well as a "Relevance to Quantum Mechanics" paragraph that explains how that bit of mathematics relates to the physics of quantum mechanics.

So I recommend that you take a look at the “Main Ideas” statements in each section of Chapters 1 and 2, and if your understanding of those topics is solid, you can skip past that material and move right into a term-by-term dissection of the Schrödinger equation in both time-dependent and time-independent form in Chapter 3. And if you’re confident in your understanding of the meaning of the Schrödinger equation, you can dive into Chapter 4, in which you’ll find a discussion of the quantum wavefunctions that are solutions to that equation. Finally, in Chapter 5, you can see how these principals and mathematical techniques are applied to three situations with specific potentials: the infinite rectangular potential well, the finite rectangular potential well, and the quantum harmonic oscillator.

As I hope you can tell, I spend a lot of time thinking about the best way to explain challenging concepts that my students find troubling. My *Student’s Guides* are the result of that thinking, and my goal in writing them is elegantly expressed by A. W. Sparrow in his wonderful little book *Basic Wireless*: “This booklet makes no pretence of superseding the numerous textbooks already published. It hopes to prove a convenient stepping-stone towards them by concise presentation of foundation knowledge.” If my efforts are half as successful as those of Sparrow, you should find this book helpful.

Acknowledgments

If you find the explanations in this *Student's Guide* helpful, it's because of the insightful questions and helpful feedback I've received from the students in my Physics 411 (Quantum Mechanics) course at Wittenberg University. Their willingness to take on the formidable challenge of understanding abstract vector spaces, eigenvalue equations, and quantum operators has provided the inspiration to keep me going when the going got, let's say, "uncertain." I owe them a lot.

Thanks is also due to Dr. Nick Gibbons, Dr. Simon Capelin, and the production team at Cambridge University Press for their professionalism and steady support during the planning, writing, and production of this book.

Most curiously, after five *Student's Guides*, twenty years of teaching, and an increasing fraction of our house taken over by physics books, astronomical instrumentation, and draft manuscripts, Jill Gianola continues to encourage my efforts. For that, I have no explanation.

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