An introduction to the theme issue

Quantum mechanics is a pivotal subject in the education of a physicist. It has a mysterious and exciting flavor because it deviates markedly from intuitive expectations and the ''normalcy'' of the classical world. Yet this strange theory is remarkably successful at describing the behavior of real physical systems. In fact, quantum phenomena dominate modern research as evidenced by recent Nobel prizes awarded for work on Bose–Einstein condensation, the quantum Hall effect, the quantum structure of electroweak interactions, and phase transitions in Helium-3.

A substantial literature on quantum mechanics already exists in the *American Journal of Physics* archives. An on-line search of AJP abstracts since 1975 using the key words ''quantum mechanics'' turned up nearly 1400 articles, notes, resource letters, and book reviews. Most of these publications are at the advanced undergraduate or graduate level, and together they represent a treasure trove to teachers and students of quantum mechanics.

Some argue that quantum mechanics should be included in introductory level courses where traditional courses have focused largely on classical physics. The many students who take only introductory physics do not obtain much exposure to quantum concepts and quantum phenomena. Their curiosity might be piqued by occasional newspaper and magazine articles on exotic quantum behavior, but their courses usually concentrate on the physics of the nineteenth century. However, an increase in time spent on quantum mechanics would come at the expense of time spent on more conventional topics, unless a totally new physics curriculum were introduced.

At both the introductory and advanced levels, there are a number of hurdles that students need to overcome to understand quantum mechanics. These include the interpretation of quantum mechanics, which is still an active area of research, and the connection between the results of abstract mathematical calculations and empirical data on real physical systems. In addition, our students' understanding of classical physics is still very tentative when they begin the study of quantum mechanics. Thus, there is a clear need for an extended, thoughtful discussion on how to handle these difficulties as well as on what elements of quantum mechanics to teach, when to teach them, how to teach them, and what we expect our students to achieve. This theme issue is a vehicle for sharing some ideas that we believe will be useful for encouraging that discussion. Hopefully, it will stimulate other new ideas and debate that will lead to further progress.

This special issue contains a set of carefully chosen articles that we believe will help people enhance their teaching of quantum mechanics, primarily at the undergraduate level. Some of the articles address the difficulties students have learning particular aspects of quantum mechanics. Others describe different interpretations, formulations, and representations in quantum mechanics. Still others discuss novel applications or some of the more subtle conceptual issues in quantum mechanics. A few of the articles address the integration of workable and affordable quantum mechanics experiments into the undergraduate curriculum, something we believe is particularly important. Although modern technology is finally bringing single photon and atom trapping experiments within grasp, it is still not common for such experiments to have found their way into undergraduate laboratory courses. We hope to see more of these kinds of articles in future issues of AJP.

A large number of manuscripts was submitted for this theme issue, and we would like to thank the authors of these contributions. Unfortunately, it was not possible to include all the submitted manuscripts in this theme issue, and we had to make some difficult choices to achieve a broad range of high-quality articles that are readable and accessible to the widest possible audience—particularly those involved in teaching undergraduate quantum mechanics. We hope we have succeeded. We would like to give special thanks to the authors of the articles in this theme issue. Some have had to rewrite portions of their manuscripts multiple times to satisfy the wishes of the reviewers and editors. We thank the many reviewers who have read and critiqued the submitted manuscripts. We are grateful to David Griffiths, the book review editor, for soliciting reviews of books on quantum mechanics, and to the writers of those reviews. We also thank Jan Tobochnik, the editor of the *American Journal of Physics*, Harvey Gould, the associate editor, and Julie Wenzel, the assistant to the editor. Their efficient handling of the many manuscripts that were submitted, and their attention to detail, made this issue not only possible, but of a quality consistent with AJP standards.

Finally, we call your attention to a Gordon Research Conference to be held June 9–14, 2002 at Mount Holyoke College in Massachusetts on Physics Research and Education: Quantum Mechanics. The purpose of this conference is similar to the purpose of this issue, namely, to promote innovations that improve the teaching of quantum mechanics, contributing to the ongoing discourse within the physics teaching community. Researchers in physics education, active researchers in quantum mechanics and related fields, and faculty who teach quantum physics and chemistry will share ideas. Special attention will be given to current research in quantum phenomena, physics education research on how students learn quantum concepts, the development of undergraduate quantum mechanics experiments, how computer software can help teach quantum mechanics, and related topics. This is the second Gordon Research Conference dealing with physics education and research, the first being on thermal and statistical physics. We expect that similar Gordon Research Conferences, each focusing on a specific undergraduate physics topic, will be held every two years. To learn more about the June 2002 conference, please visit http://www.grc.uri.edu and http://physics.dickinson.edu/GRC2.html.

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