

## An introduction to the theme issue

Classical mechanics is among the oldest of physics topics. Its foundations lie in mathematics and astronomy, and its theoretical and experimental aspects form much of the groundwork for how we have come to understand the physical world. Accordingly the Library of Congress classification scheme puts *analytic mechanics* in class QA (mathematics), while *descriptive and experimental mechanics* is in class QC (physics). The breadth of classical mechanics is well illustrated by the fact that *celestial mechanics* is in class QB (astronomy) and *engineering mechanics* is classified as either TA (general engineering) or TJ (mechanical engineering). *Continuum mechanics* is in both QA and TA. Clearly classical mechanics is intimately linked to mathematics, physics, astronomy, and engineering.

Although many experiments show that classical mechanics breaks down at high speeds, in strong gravitational fields, and at small distances, the theory is still remarkably useful—a fact that is well stated in the following limerick,<sup>1</sup>

*There once was a classical theory  
Of which quantum disciples were leery  
They said, "Why spend so long  
On a theory that's wrong?"  
Well, it works for your everyday query!*

The appeal of classical mechanics can be traced to its inherent mathematical beauty, its critical role in the historical development of physics, and especially in its interfaces with quantum mechanics, statistical mechanics, continuum mechanics, and thermodynamics. These characteristics make classical mechanics a fascinating topic of perennial interest. Within the domain of linear classical mechanics, physics students typically learn three common frameworks: (1) Newton's second law at the introductory level, supplemented in upper division courses by the (2) Lagrangian and (3) Hamiltonian formalisms. And although much of classical mechanics is quite old, subfields such as nonlinear systems, chaotic dynamics, and granular materials are relatively new and of current research interest.

Should these exciting new areas be included in the undergraduate physics curriculum? And if so, should the material be required or offered as an elective? Should our current courses be modified to include some of this new material? And if so, what material—if any—would we be willing to eliminate? One possibility would be to develop courses that target specific areas.<sup>2</sup> However, developing such specific courses is not always possible, particularly at smaller colleges. In addition, throughout the physics community there will undoubtedly be a wide range of opinions on just what new material should be included and what should be eliminated. Might it be time for the community at large to begin grappling with the question of whether the classical mechanics course is in need of an overhaul?

Physics education research, which began with its primary thrust in introductory mechanics, will play a pivotal role in this debate. Now extended to upper division mechanics, this subfield can guide not only curricular adaptations and modifications of standard treatments, but also inform the design of novel curricular approaches. Perhaps it is time for physics

education research to start framing the conversation of *what* physics is taught in addition to *how* physics is taught.

This special issue contains a set of carefully chosen articles that we hope will focus attention on the teaching of classical mechanics and what that might entail. Some articles contain results of research on the learning and teaching of classical mechanics at the introductory level and beyond. In recent years the Lagrangian formalism, which avoids vectors, force diagrams, and the like, has gained popularity. In this issue, the Lagrangian technique is promoted by several authors as a useful tool not only in upper division classical mechanics, but also in other physics courses. Some argue that Lagrangian mechanics, with emphasis on extremization of the classical action, might be a useful teaching tool even in introductory physics.

Classical chaos has begun working its way into the undergraduate curriculum in recent years and some relevant articles on both theory and laboratory experiments are included here. Also included are articles on relatively inexpensive modern electronic circuits that generate chaotic signals. Mathematical models that generate chaos are presented and perturbation schemes for nonlinear systems are described. Elements of history, the limits of mathematical models, and the importance of symmetries and conservation laws are also included. Some articles suggest a significant rethinking of the traditional approach to mechanics. Finally, there is a book review of an upper level classical mechanics textbook. Together with an earlier AJP review of four other classical mechanics books,<sup>3</sup> this review should assist teachers with textbook selection.

As was anticipated, many more manuscripts were submitted than could practicably be included in this theme issue, and we thank the authors of these contributions. We have made 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 classical mechanics and nonlinear dynamics. Hopefully we have succeeded. Our special thanks go to the authors of articles in this theme issue and to the many reviewers who critiqued the submitted manuscripts. We are grateful to Daniel Schroeder, the book review editor, for securing a relevant book review. We especially thank Jan Tobochnik, editor of the American Journal of Physics, Harvey Gould, the associate editor, Martin Ligare, the assistant editor, and Aimee Foster, assistant to the editor. Their efficient handling of the many submitted manuscripts and their reading of the accepted manuscripts helped produce a high quality issue consistent with AJP standards.

Finally, we call your attention to a Gordon Research Conference to be held 13–18 June 2004 at Mount Holyoke College on Physics Research and Education: Classical Mechanics and Nonlinear Dynamics. The purpose of the conference is similar to the purpose of this issue, namely, to promote innovations that improve the teaching of classical mechanics and nonlinear phenomena, in accordance with the ongoing discourse within the physics teaching community.

The conference will begin with an exciting historical overview of the development of fractals and nonlinear dynamics by people who pioneered these fields. Researchers in physics

education, classical mechanics, chaos, nonlinear dynamics and related fields, and faculty who teach classical mechanics and nonlinear dynamics will come together to discuss and share ideas. Special attention will be given to current research in classical mechanics, physics education research on how students learn classical concepts, the development of undergraduate experiments in nonlinear dynamics, how computer software can help teach classical mechanics, and related topics.

We invite interested parties to present posters at this Conference. Titles and abstracts should be sent to Kerry Browne (brownek@dickinson.edu) by 1 June 2004.

This is the third Gordon Research Conference dealing with physics research and education, the first being on thermal and statistical physics in 2000 and the second on quantum mechanics in 2002. We expect similar Gordon Research Conferences, each focusing on a specific undergraduate physics topic, to be held every two years. To learn more about the June 2004 conference, please visit (<http://www.grc.uri.edu/programs/2004/physres.htm>).

The Theme Issue Editors

Harvey S. Leff  
*California State Polytechnic University, Pomona*

David P. Jackson  
*Dickinson College*

Kerry Browne  
*Dickinson College*

Stamatis Vokos  
*Seattle Pacific University*

<sup>1</sup>David Morin, Harvard University, "There once was a classical theory: Introductory classical mechanics with problems and solutions," (<http://www.courses.fas.harvard.edu/~phys16/Textbook/>).

<sup>2</sup>See for example N. Sungar, J. P. Sharpe, M. J. Moelter, N. Fleishon, K. Morrison, J. McDill, and R. Schoonover, "A laboratory-based nonlinear dynamics course for science and engineering students," *Am. J. Phys.* **69**, 591–597 (2001).

<sup>3</sup>R. W. Robinett, "Comparative review," *Am. J. Phys.* **68**, 390–393 (2000).