BOOK REVIEWS

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Comparative Review. Classical Dynamics of Particles and Systems, 4th ed. Jerry Marion and Stephen Thornton. 638 pp. Saunders College Publishing, Fort Worth, TX, 1995. Price: $111.50 ISBN 0-03-097302-3. **Classical Mechanics: A Modern Perspective, 2nd ed**. Vernon Barger and Martin Olsson. 418 pp. McGraw–Hill, New York, 1995. Price: $88.75 ISBN 0-07-003734-5. **Analytical Mechanics, 6th ed**. Grant Fowles and George Cassiday. 484 pp. Saunders College Publishing, Fort Worth, TX, 1999. Price: $107.00 ISBN 0-03-022317-2. **Introduction to Classical Mechanics, 2nd ed**. Atam Arya. 712 pp. Prentice Hall, Upper Saddle River, NJ, 1998. Price: $91.00 ISBN 0-13-505223-8. **Classical Dynamics: A Contemporary Approach**. Jorge José and Eugene Saletan. 670 pp. Cambridge U.P., New York, 1998. Price: $125.00 (cloth) ISBN 0-521-63176-9; $59.95 (paper) ISBN 0-521-63636-1. **Analytical Mechanics**. Louis Hand and Janet Finch. 592 pp. Cambridge U.P., New York, 1998. Price: $125.00 (cloth) ISBN 0-521-57327-0; $54.95 (paper) ISBN 0-521-57572-9. (R. W. Robinett, Reviewer.)

A course in classical mechanics for physics majors at the undergraduate and/or graduate levels has historically been a staple of the physics curriculum. In recent years, the usefulness of such a course has increasingly been justified (in the minds of some, at least) to the extent that it constitutes an introduction to methods in theoretical or mathematical physics or especially as a necessary background for the study of quantum mechanics. With the tremendous advances in the study of chaos and complexity in dynamical systems, the field of classical mechanics has re-emerged as an important research topic in physics, requiring a reassessment of its role in the education of a physics student. In parallel, the use of modern, multipurpose mathematical packages (such as MATHEMATICA, MAPLE, MATHCAD, etc., hereafter collectively described as M^3) has allowed not only for the more rapid analytic solution of standard problems, but for the powerful application of numerical methods to new situations, followed up with an immediate access to the visualization of the resulting solutions.

The first area represents a fundamental change in our understanding of the universe and incorporates a realization that many of the systems which have been studied so successfully for centuries are actually very special, and not at all typical of most dynamical systems. While the Clockwork Universe has not been thrown out completely, the realization by Wisdom and others that there is chaos in our solar system is a reminder, if we needed it, that complexity is the norm. The second aspect, the explosive growth in the use of sophisticated, integrated software systems (M^3) for performing a wide variety of mathematical operations, has tracked the almost exponential improvement in hardware performance. Many practicing scientists now perform most of their mathematics in this virtual world instead of on paper, with the result that knowing how to approach both standard and novel physics problems with the intent of solving them numerically instead of analytically is an important change of mindset which should be introduced into the undergraduate curriculum, in some form, however simple, as early as possible.

The first four books considered in this comparative review are revisions of previous classical mechanics textbooks at the undergraduate level which attempt, in different ways, to incorporate either qualitatively new topics such as chaos or new pedagogical approaches to more standard material using computer techniques. The last two are new texts which attempt to provide similar innovations and insights at the graduate level.

Undergraduate texts

The books by Marion and Thornton (hereafter MT) and Barger and Olsson (BO) are fairly recent (1995) new editions of existing texts, which were updated to include rather self-contained chapters on nonlinear oscillations and chaotic motion, while the books by Atam Arya (AA) and Fowles and Cassiday (FG) have focused, in very different ways, on the inclusion of problems suitable for use with standard mathematical software packages. In addition to covering standard material on Newtonian dynamics, oscillations, gravitation and other central force problems, rigid body motion, and Lagrangian techniques, the first three of these texts include enough additional chapters on various other topics (such as continuous media and waves, relativity, etc.) that they might be used for a two-semester or two-quarter course. Both MT and FG have readily available *Instructors Solutions Manuals*, which is always a plus.

At my institution, we have a one-semester course in classical mechanics, required of all physics and some astronomy majors. It is offered in both Fall and Spring semesters (with a second, optional, followup course, taught once a year) and when I have taught this course in the past I have used MT. It was my assumption that this was one of the most popular choices for such courses, and a quick survey appears to confirm this. (Using a web site which lists most American colleges and universities, I was quickly able to find 15 or more physics programs that offered undergraduate courses at this level, and found that MT was indeed the overwhelmingly popular choice.) I can understand from my own experience (and that of colleagues here) some of the reasons why this might be so. The format is well laid out, and the typography clear and modern. There are many end-of-chapter (EOC) problems of the appropriate level, and the worked-out examples are clearly identified and distinguished from the other material in the chapter. Perhaps most important, for many students, the examples are of a sufficiently ''digestible'' length and difficulty that they can be understood and built upon for use in more involved situations. The choice of a first chapter covering necessary vector calculus is appreciated by many students who, in principle, have seen the material before, but may be using it for the first time in the context of a ''serious,'' junior–senior level theory course. One of the features of MT which was very important in my choice was the fact that it had a separate chapter entitled ''Some Methods in the Calculus of Variations,'' which preceded the material on Hamilton's principle and Lagrangian techniques. This addition allows instructors to emphasize the important role played by minimum principles in physics while providing students valuable practice in the manipulation of Euler–Lagrange equations before applying them to actual problems in classical mechanical systems. The chapter on Lagrangian dynamics is, it seems to me, the longest and most comprehensive of all the choices I'm familiar with, including a larger number of worked out examples that go beyond the typical Atwood machine problems. The discussion of conservation theorems and their connections to symmetries of nature cannot, as MT themselves indicate, be overemphasized, and this text focuses on this important topic more than most, while it also includes short (but interesting) sections (and accompanying problems) on phase space ideas and Liouville's theorem, along with the Virial theorem.

Other aspects of Marion and Thornton that appeal to me include the interesting historical background (gracefully incorporated, mostly in the form of footnotes, so as not to interrupt the flow), good discussions of the more technical aspects of eigenfrequencies and eigenvectors in normal mode problems, important and interesting references to the literature in the chapter on relativity (including a discussion of the atomic clock measurements of relativistic time delays by Hafele and Keating), as well as very useful and well laid out appendices on mathematical issues, especially on solutions of ordinary differential equations. One minor quibble is the frequent lack of figure captions. While a perfectly conceived and executed figure may not need a detailed verbal explanation, it is sometimes difficult to know what is being illustrated without reading the accompanying text.

The book by Barger and Olsson is the shortest of the four we consider, but it is packed with some of the most compelling physical examples to be found in any book at this level. Worked out examples and EOC problems involving such systems as drag racers, superballs, billiards, boomerangs, tippie-tops, parabolic mirrors, the earth–moon–sun tidal system, and many others are all designed to appeal to the enthusiasm students and instructors feel alike for this subject. New sections have been added in the 2nd edition which allow its use for a two-semester course, and the section on *Newtonian Cosmology* is unique in my experience at this level, and will certainly be attractive to a number of students who have interests in this popular topic as well as providing a logical extension of more standard chapters on gravitational physics. The relativity chapter contains even more detail about the Hafele/Keating experiment (which I often use as a benchmark of just how ''modern'' a discussion of relativity tests is). The LATEX ''feel'' of the typography is not my favorite in a printed text and the worked out examples are, in some cases, less ''digestible'' to students, as they often require several different concepts to be applied at once.

In at least one semester, I have asked my students to pick a slightly more advanced topic (an interesting physical system, a more detailed numerical calculation, etc.) and write a 4–5 page ''project report'' in which they fill in the details of a calculation. These were then copied, bound, and distributed to the class at the end of the semester. I provided the students with a long list of articles appearing in AJP, as well as from several other textbooks placed on reserve, including BO. The majority of students chose to expand on the lovely worked-out examples in Barger and Olsson, and they really appreciated the book as an extra resource. I encourage anyone who's thinking of teaching an undergraduate course in mechanics to get a copy, if only for its wealth of background material and excellent problems.

These two texts also include useful discussions of chaotic dynamics, presented initially in the context of nonlinear oscillations. I think it is very important to include this aspect of classical mechanics in an undergraduate text, even if it is not covered explicitly by the instructor for whatever reason (lack of computer resources, lack of experience by the instructor, etc.) Even though there are excellent books on these topics, such as those by Moon (*Chaotic and Fractal Dynamics*) and Baker/Gollub (*Chaotic Dynamics: An Introduction*) as well as a large number of very accessible and user friendly software packages, the reality of modern textbook pricing may preclude the purchase of additional materials, so for intellectual, pedagogical, and financial reasons it is appropriate to include these topics in the primary text. The sections on chaos in MT and BO are both very good, but I mildly prefer the presentation as well as the number and difficulty level of EOC problems in MT.

The new edition of Fowles and Cassiday is a very recent (1999) release, which builds on earlier versions of the classic Fowles text. There have been a number of very positive revisions in the text and organization, including several excellent new analytic examples or EOC problems such as the rolling penny (in Sec. 9.10) and one of my favorite examples of all time: a detailed discussion of rotating coordinate systems in the context of spinning cylindrical spacecraft, à la Arthur Clarke in *Rendezvous with Rama*. There is a nice use of graphics throughout with some very compelling and helpful images (such as the visualization of the so-called ''tennis racket theorem'' in Sec. 9.5 and elsewhere). I found the variety of interesting new physical and mathematical problems a welcome addition. The most important change, however, is the incorporation of a large number of EOC *Computer Problems*, which are not directly tied to any specific software package, although the author does make occasional and appropriate use of both MATHCAD and MATHEMATICA examples in the text. I think this is a good compromise, as the worked-out analytic examples help explain the concepts and a good collection of tractable and interesting numerical problems can be attacked with almost any modern system available to and/or understood by the instructor/student. The chapter on oscillations includes a section on *The Non-linear Oscillator: Chaotic Motion* which, while not nearly as complete as the discussions of chaos in MT or BO, does provide enough background to warrant the mention of chaotic motion (or some other key word combination) in the index; the book sells itself a bit short in this regard. This edition is an excellent successor to earlier versions of the Fowles text, and a fine choice for those interested in focusing on Newtonian dynamics (especially modern numerical solutions) who do not aim to provide extensive background in Lagrangian mechanics.

The new edition of the text by Arya makes a fairly consistent choice from the very beginning of the book, namely to present most of the worked-out examples in the text in the form of MATHCAD output. Even the simplest starting example involving dimensional analysis is displayed in this manner. Leaving aside the fact that for every enthusiastic user of one of the M^3 languages there are approximately two equally happy users of the others, I fear that this approach is rather diverting and breaks up the discussion of new ideas, so that the presentation seems rather confused. The distracting dissonance between the typography of the text and the MATHCAD output does not help the flow of the book. The MATHCAD output graphs are not very professional looking (compared, for example, to some of the corresponding MATHEMATICA plots in FG) and will not help students understand the basic equations involved. In this case, I fear, one picture is not worth 10^3 words. There is also unnecessary confusion between the numbered *Figures* versus *Examples*, which is inconsistent, as well as some simple editing oversights (such as a section title on page 253, labeled ''Sec. 0.0 Section Title.'' There are some nice points such as several interesting and suggestive phase space plots, the discussion of average values of variables defined as appropriate integrals over time, and the mention of the concept of ''jerk'' [the time derivative of acceleration, $\dot{a}(t)=\dddot{x}(t)$] which is sometimes useful in an engineering context. This book does have the advantage that it is complete enough that it could be used as a stand-alone text in an undergraduate course, unlike, for example, the interesting short book on *Classical Mechanics with Maple* by R. L. Greene.

Graduate texts

The two new graduate texts considered here also attempt to update classic material with the inclusion of new physical and mathematical results. They do so in very different ways. The book by José and Saletan includes many of the most important new mathematical results in classical mechanics from the 1960s through the 1980s, often within a geometric approach (including such topics as tangent spaces, manifolds, symplectic geometry, etc.). There are interesting discussions of such topics as soliton solutions of a number of well-known equations of mathematical physics, chaotic scattering from hard disks, and a wealth of other modern, rather formal, examples from the research literature of the past three decades. I find it hard to imagine this book being used as the exclusive text in a graduate course, but it is well written, with a thorough set of references, and would serve as an excellent resource for students and faculty alike who wish to learn many of the most important aspects of the mathematical physics behind the renaissance of classical mechanics.

The text by Hand and Finch (HF) mentions its pedigree as having grown out of an advanced undergraduate course (populated, so it seems, by students from a previous honors course, many of whom had also taken AP physics courses in high school). Given the rather advanced nature of the material that follows these comments in the preface, I don't think it is truly appropriate for the vast majority of undergraduate physics majors, but it would definitely form the basis for a very interesting course at the graduate level. It covers most of the standard topics of a graduate course (at a level similar to Goldstein, for example) with a nice variety of modern material, including chaos. I very much like the elegant and expressively simple figures, and the EOC problems are suggestively and usefully titled, which is a format I appreciate. Once again there is a separate section on variational calculus, which appeals to me, as well as nice touches such as a discussion of momentum space methods (Sec. 5.7). The chapter on chaos includes just the right amount of detail, an excellent discussion of ''Chaos in the Solar System,'' and a good number of EOC project/problems. Optional, slightly more advanced topics, are included as Appendices to most chapters, which is a nice organizational device. This book is a welcome addition to the available choices for a graduate text in modern classical mechanics and I encourage instructors to consider it.

Classical versus quantum mechanics

Despite the obvious differences in the undergraduate texts considered in this review, the basic topics considered, the level of mathematical coverage, and even the order of presentation are remarkably similar from book to book. I think it can be argued that a similar convergence can be found in many E&M texts. In contrast, the manner in which the many undergraduate texts on quantum mechanics approach that important subject varies far more, ranging from very formal presentations (which may start with spin systems, Hilbert spaces, measurement theory, and the like) to ones that emphasize more physical ideas and experimental consequences. While instructors may rightly wish to emphasize the nonclassical aspects of quantum theory, it is also true that a number of students do find semi-classical connections pedagogically useful. (Understanding how the form of a quantum mechanical position-space wave function, its ''wiggliness'' and magnitude, are correlated with the classical motion of the particle is often just as helpful as knowing how to derive an analytic solution: In the case where one is checking the results of a numerical solution, such intuition may be even more important.)

While many of the most intellectually exciting promises related to quantum mechanics (such as quantum computing, cryptography, teleportation, etc.) are intrinsically related to the special ''weirdness'' inherent in wave mechanics, there have been equally interesting recent advances in semiclassical techniques. Such topics as wave packet revivals [see the recent survey by Bluhm, Kostelecký, and Porter, Am. J. Phys. **64**, 944 (1996)], periodic orbit theory, and other methods (for an excellent review see *Semiclassical Physics* by Brack and Bhaduri) have focused attention, both experimentally and theoretically, on the interface between the quantum and classical worlds. Thus one can argue that there is a place for an increased emphasis in classical mechanics texts on preparation for quantum theory, for both pedagogical and intellectual reasons.

Of the four undergraduate texts considered, only MT explicitly cites as one of its purposes to ''present a modern treatment of classical mechanical systems in such a way that the transition to the quantum theory of physics can be made with the least possible difficulty.'' Marion and Thornton do indeed provide some useful material which will likely be of help in later courses, such as detailed discussions of eigenvectors and eigenfrequencies (and matrix methods in general) in the context of coupled oscillators, and extensive discussions of wave packet solutions to wave equations (including dispersion and even the Gaussian wave packet). Mention of Poisson brackets is included in one EOC problem. Of the two graduate texts, HF mentions some of the standard Hamilton–Jacobi connections to quantum mechanics, and includes a problem involving ''deriving'' the Schrödinger equation via a variational principle, and even a sophisticated version of the infinite well problem. (Goldstein, for comparison, has by far the most references to quantum theory in his index.)

None of the books considered here, however, (or any others at this level that I have seen) makes any attempt to incorporate what I might call ''anti-correspondence principle'' examples. By this I mean simple quantum examples or problems, which could reasonably be added to classical mechanics texts, that would introduce concepts which would be of later use in quantum theory courses. Two topics come to mind as examples of the type of approach that I am encouraging.

• *Probability ideas*: If we ignore the sensitive dependence on initial conditions typical of chaotic systems, standard classical mechanics examples are archetypes of exactly predictable problems. One can, however, easily step back and ask such questions as ''What is the probability that a particle will be found in this or that region of space?'', given its classical trajectory. Classical probability distributions, $P_{\mathrm{CL}}(x)$, which can later be used to confront quantum mechanical probability densities given by $P_{\mathrm{QM}}^{(n)}(x)=|\psi_{(n)}(x)|^2$, in the large quantum number limit, can be readily obtained by asking how much time a particle spends in a region of space of size dx. Such arguments yield Wentzel–Kramers–Brillouin-like probability densities proportional to $1/v(x)$, where $v(x)$ is the classical speed. Simple exercises of this type for the ubiquitous harmonic oscillator [resulting in $P_{\mathrm{CL}}(x)=1/\pi\sqrt{A^2-x^2}$ where A is the amplitude of the classical motion] and others for even simpler systems, such as the infinite well, will be accessible to students who already know from modern physics courses that such probability ideas are important in quantum theory. One need not even supply the quantum mechanical solutions for direct comparison, as the topic is interesting in its own right (indeed, students sometimes resent such ''out of the blue'' appearances of new material). Similar ideas are sometimes illustrated at AAPT meetings in an experimental context where random measurements of particle motion, say on an air track, in a darkened room, can easily be obtained and analyzed in this manner.

Extensions to include average or expectation values of classical quantities derived from their classical trajectories would provide important practice in these skills, still in the context of classical mechanics. For example, how many students can easily calculate the average height of a ball which is dropped from a height H and bounces elastically, rebounding to its initial height? [Precisely this question was addressed in a recent article on wave packet propagation for the ''quantum bouncer,'' by Gea-Banacloche, Am. J. Phys. **67**, 776 (1999).] Studies by the Physics Education Research Group at Maryland (Redish and others) have shown that students have conceptual problems with simple probability arguments, which might be addressed sooner and with less confusion in the context of classical physics. [Discontinuous potentials also seem to be problematic for many students, and while unphysical, they are often used in the simplest quantum examples; why not introduce them in a more familiar context? For example, how many students have been asked to understand the $x(t)$ and $v(t)$ plots for a classical particle in a 1D infinite well, and to discover what information these can provide about the semi-classical limit of the corresponding stationary state solutions to the Schrödinger equation?] Discussions of probability ideas and expectation values in this context will also set the stage for later applications in courses on statistical mechanics.

• *The hydrogen atom*: All classical mechanics texts recognize the important role played by the $1/r$ potential, and they typically devote an entire chapter to gravitational physics and the structure of classical elliptical orbits. A simple extension to include a semi-classical discussion of bound-state orbits for hydrogen-like atoms in a Coulomb potential would better prepare students for future applications in atomic theory. Simple arguments, likely familiar to students from modern physics courses, about the role of quantized energies and angular momenta, can be used to help readers visualize many aspects of the semi-classical orbit structure of simple one-electron atoms. Highly excited, quasi-classical Rydberg states, which are the workhorses of atomic physics, fall into this category, and such topics as quantum defects are more easily understood with a firm classical picture of the elliptical orbit structure in mind. Sketches such as those found in older books (such as *An Introduction to Mechanics* by Kleppner and Kolenkow) of equal energy elliptical orbits for various values of the angular momentum are easily generalized to the quantum limit. Nice discussions of classical probability distributions are also possible in this system [see Rowe, Eur. J. Phys. **8**, 81 (1987), for an example]. Another important connection which can be approached from the classical side is the surprising symmetry properties of the Coulomb problem, often discussed in terms of the Lenz vector, which are responsible both for the nonprecession of closed orbits in the classical case and for the extra degeneracy of energy levels in the quantum case.

Given the fact that quantum mechanics will continue to be one of the mainstays of the undergraduate curriculum, I think that an increased emphasis along these lines, not necessarily as entire separate chapters, but simply as a few worked-out examples, or EOC problems, would help ease the transition from the familiar world of classical mechanics to the more exotic realm of the quantum.

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BOOKS RECEIVED

Astronomical Optics, 2nd ed. Daniel J. Schroeder. 478 pp. Academic, San Diego, CA, 1987, 2000. Price: $89.95 ISBN 0-12-629810-6.

Biology in Physics: Is Life Matter? Konstantin Bogdanov. 237 pp. Academic, San Diego, CA, 2000. Price not given; ISBN 0-12-109840-0.

Cavendish: The Experimental Life (revision). Christa Jungnickel and Russell McCormmach. 814 pp. Bucknell U.P., Cranbury, NJ, 1996, 1999. Price: $34.50 ISBN 0-8387-5445-7.

College Physics, 4th ed. Jerry D. Wilson and Anthony J. Buffa. 955 pp. Prentice Hall, Upper Saddle River, NJ, 1990, 2000. Price: $105.10 ISBN 0-13-084167-6.

Exploring the Art and Science of Stopping Time: The Life and Work of Harold E. Edgerton. CD-ROM. MIT, Cambridge, MA, 2000. Price: $37.95 ISBN 0-262-55031-8.

Fearful Symmetry: The Search for Beauty in Modern Physics (paperback edition). A. Zee. 356 pp. Princeton U.P., Princeton, NJ, 1986, 1999. Price: $14.95 (paper) ISBN 0-691-00946-5.

The Formation of Galactic Bulges. Edited by C. M. Carollo *et al.* 207 pp. Cambridge U.P., New York, 1999. Price: $69.95 ISBN 0-521-66334-2.

From Physics to Philosophy. Edited by Jeremy Butterfield and Constantine Pagonis. 235 pp. Cambridge U.P., New York, 1999. Price: $59.95 ISBN 0-521-66025-4.

Handbook of Nanostructured Materials and Nanotechnology; Vol. 1: Synthesis and Processing; Vol. 2: Spectroscopy and Theory; Vol. 3: Electrical Properties; Vol. 4: Optical Properties; Vol. 5: Organics, Polymers, and Biological Materials. Edited by Hari Singh Nalwa. 3583 pp. Academic, San Diego, CA, 2000. Price: $1500.00 ISBN 0-12-513760-5.

Handbook of Superconductivity. Edited by Charles P. Poole, Jr. 693 pp. Academic, San Diego, CA, 2000. Price: $120.00 ISBN 0-12-561460-8.

Hyperspherical Harmonics and Generalized Sturmians. John Avery. 196 pp. Kluwer Academic, Norwell, MA, 2000. Price: $90.00 ISBN 0-7923-6087-7.

Ion Channels and Disease. Frances M. Ashcroft. 481 pp. Academic, San Diego, CA, 2000. Price: $49.95 ISBN 0-12-065310-9.

Numerical Methods in Electromagnetism. M. V. K. Chari and S. J. Salon. 767 pp. Academic, San Diego, CA, 2000. Price not given; ISBN 0-12-615760-X.

The Philosophy of Physics. Roberto Torretti. 512 pp. Cambridge U.P., New York, 1999. Price: $64.95 (cloth) ISBN 0-521-56259-7; $23.95 (paper) ISBN 0-521-56571-5.

Physics2000. E. R. Huggins. Unpaginated. Moose Mountain Digital Press, Etna, NH, 1999. Price: $39.00 (paper); $10.00 (CD).

Solitons: Differential Equations, Symmetries, and Infinite Dimensional Algebras (translation). T. Miwa *et al.* 108 pp. Cambridge U.P., New York, 1993, 2000. Price: $39.95 ISBN 0-521-56161-2.

Spectral Asymptotics in the Semi-Classical Limit. M. Dimassi and J. Sjöstrand. 227 pp. Cambridge U.P., New York, 1999. Price: $39.95 (paper) ISBN 0-521-66544-2.

Spectral Theory and Geometry. Edited by Brian Davies and Yuri Safarov. 328 pp. Cambridge U.P., New York, 1999. Price: $44.95 (paper) ISBN 0-521-77749-6.

Thinking About Physics. Roger G. Newton. 191 pp. Princeton U.P., Princeton, NJ, 2000. Price: $24.95 ISBN 0-691-00920-1.

INDEX TO ADVERTISERS