Review of 'Classical Mechanics: From Particles to Continua and Regularity to Chaos'*

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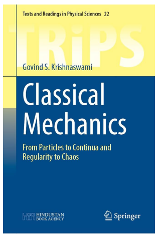

Classical Mechanics: From Particles to Continua and Regularity to Chaos
Govind S. Krishnaswami
Published by Springer Nature
Pages: 792

In the preface to their book, *Classical Dynamics, a Modern Perspective*, E C G Sudarshan and N Mukunda had written, "We see classical dynamics not as a *part of* physics, but as physics itself" (my emphasis). While this was indeed true for the two centuries between Newton and Maxwell, the late nineteenth and twentieth centuries brought in a lot of novelty through theories of electromagnetism, quantum mechanics, and quantum field theory. Both in the formal and practical domains, these newer areas tended to dominate. Classical mechanics did not look anymore like "all of physics" and got relegated to an essential but unexciting place in the physics curriculum. Young students would want to get past it quickly to where the "action" was—quantum mechanics and its various offshoots. Today, textbooks on quantum mechanics proliferate, while it is rare to see a major new text on classical mechanics.

It is a joy, therefore, to read the new book by Govind S. Krishnaswami, *Classical Mechanics: From Particles to Continua and Regularity to Chaos* published as part of the TRIPS series by Hindustan Book Agency. The book is a labor of love. It runs to an intimidating seven hundred and thirty pages and is not meant to be carried around casually. In an era where books travel easier across borders, typically have cheap Asian editions, and often have (not very legal) online availability, one may wonder about the need for another mechanics textbook. A quick walk through the main texts that have trained generations of physicists may help put Krishnaswami's book in context.

Classical mechanics texts, from the undergraduate level to that of research monographs, usually consider a combination of the following (i) the core-transition from Newtonian to Lagrangian and Hamiltonian mechanics and development of the subject in the latter language, (ii) some treatment of continuous media, e.g., wave propagation, elasticity, fluid mechanics, etc, (iii) a treatment of the special theory of relativity (which has an uncomfortable position in classical mechanics), (iv) discussion of nonlinear dynamics, integrability and chaos, and (v) the presentation of advanced mathematical tools for example from geometry, group theory, and topology,

*Vol.30, No.6,
DOI: https://doi.org/10.1007/s12045-025-1820-3

that provide a formal setting for discussion of topics in (iv).

The first major textbook in English on classical mechanics was probably E B Whittaker's *A Treatise on the Analytical Dynamics of Particles and Rigid Bodies* in 1904. Whittaker focused on Lagrangian particle mechanics. No continua, relativity had not yet appeared, and neither had "chaos". The treatment was based on analysis, on which Whittaker was a master. The next major book would be H Goldstein's *Classical Mechanics*' (1950)—probably still the most widely used graduate textbook—now in its third edition. Early Goldstein included the core topics of continuum physics and special relativity but did not go into nonlinear systems or modern mathematical tools. Nonlinear physics would make an appearance only in the third edition (2002), but without getting into advanced mathematics.

Landau and Lifshitz wrote a slim volume on mechanics, as Volume 1 of their *Course on Theoretical Physics*. The book is a masterpiece of conciseness and discusses only the core of classical mechanics. Landau–Lifshitz, of course, had other volumes to take up relativity, continuous media, etc. In the 1970s appeared the undergraduate text by D Kleppner and R Kolenkow, *An Introduction to Mechanics*, which just treated the core topics and special relativity. At the introductory level, it remains one of the best offerings. There were major texts in the 1960s–70s, for example, Abraham and Marsden's *Foundations of Mechanics* (1967), and V. I Arnold's *Mathematical Methods of Classical Mechanics* (1978), which brought focus to the geometrical methods in mechanics. The last significant text I can think of is by Jose and Saletan, *Classical Dynamics, a Contemporary Approach* (1998), which does not treat relativity and avoids advanced mathematics, but provides coverage of traditional mechanics, continua, and nonlinear systems.

Krishnaswami's book, in terms of its coverage, is similar to Jose–Saletan, except, at several places, the mathematical treatment is much more demanding. The breadth is remarkable; it covers all of (i)–(v), though not at a uniform depth. That also makes the book harder to pin down to a particular level of pedagogy. We come to this later after a look at the contents.

Chapters 1 and 2 look, respectively, at one-dimensional problems and the Kepler problem. These chapters are the most elementary and accessible, but they afford surprises. For example, the determination of a potential from the time period of motion (known as a function of energy) is not seen in most texts. It gets a clear discussion and highlights the limitations of the 'inverse' approach. Problem 2 in Chapter 1 puts up what it calls the 'Taylor–Sedov–von Neumann blast wave problem' and asks for a dimensional estimate of the blast wave radius of an explosion as a function of time. G I Taylor apparently just used time-stamped photographs of the blast wave to estimate the yield of the Trinity nuclear test. This is not routine one-dimensional classical mechanics, and it can get the students excited. Chapter 2 covers the traditional material quickly and moves to a discussion of Rutherford scattering. There is a small section on the three-body problem. Several of the problems involve celestial mechanics or space manoeuvres.

Chapter 3 is the heart of the book and discusses the transition from Newtonian to Lagrangian and Hamiltonian mechanics. It is 80 pages long and quite demanding. There are notions like differential forms and symplectic leaves, which would be unfamiliar to most Masters level physics students. There are sixty problems at the end of the chapter.

The next two chapters are self-contained discussions of special relativity and the phase space, respectively. Chapters 6 and 7 take up small oscillations and then nonlinear oscillators, including a presentation of the Lindstedt–Poincaré perturbation theory. This is followed by chapters on rigid body dynamics and non-inertial frames.

Next, in Chapters 10–12, come discussions on canonical transformations, action-angle variables and Hamilton–Jacobi theory. Within them, they touch upon the notion of Kolmogorov–Arnold–Moser (KAM) tori, Lax pairs, and the Henon–Heiles and Toda systems. Fermi–Pasta–Ulam does not seem to make an appearance, but what is present is enough to make interested students follow up on more detailed dynamical systems texts. Chapters 13–15 follow up with linear stability analysis, bifurcations, and the transition to chaos. Between them they have a rich collection of problems and symbolic and numerical computations are suggested as part of the exercises. On the whole, Chapters 11–15 comprise a 150-page segment focusing on dynamical systems and is almost a book within a book. There are, of course, complete books on the topic, a classic being *Chaos and Integrability in Nonlinear Dynamics* by Michael Tabor (1988), but within a broad classical mechanics framework, I have not seen the kind of detail that Krishnaswami presents.

Chapter 16 in my print version is a bit of an oddity. It is on deformable media, but is only one and a half pages long! Maybe this is an introduction to the next three chapters on the wave equation, the heat equation (and its connection to Brownian motion), and fluid mechanics? Even if it is, calling this a ‘chapter’ seems odd since other themes in the book were not grouped in this manner. This, however, is a very minor issue.

Finally, for those daunted by some of the mathematics in the book, there is a hundred-page-long segment at the end that touches on ‘mathematical and kinematical background’ and ‘manifolds, tensors, and groups’.

As would be obvious from the long description above, the book indeed fulfills its promise of ‘particles to continua’ and ‘regularity to chaos’ and includes mathematical preliminaries where needed. While some books come close in coverage, none quite have this breadth. But would that be inducement enough for a reader? And who, potentially, would use this text?

Physics is a truly international enterprise, and students tend to use the 'best' available text in the language they know, English, let us say. That is why Goldstein dominated classical mechanics and Jackson dominated electrodynamics. However, new texts bring a new pedagogical experience to life. A physicist who has done research on mechanics and attempts to teach the subject has new insights to offer or a new set of problems that illuminate a particular concept. It is in this sense that Krishnaswami's book is of value. It brings together one person's perspective on a broad swathe of classical physics that he has researched on and taught for a long time. The choice of problems, in particular, attests to this. While the book is too long and varied for a single classical mechanics course, an active researcher, or graduate student, or inspired undergraduate could dip into it to clarify a concept or locate interesting problems.

There is also some pleasure in seeing a significant text emerge from India. In classical mechanics, this is a rarity. My reading could be selective, but I can only think of Sudarshan and Mukunda, A K Raychaudhuri's set of lectures called *Classical Mechanics* (1983) and the book by N C Rana and P S Joag—*Classical Mechanics* (1991). The last two emerged from or were related to, lectures given, respectively, at Presidency College, Calcutta, and in the TIFR–University of Pune system. The present one, similarly, emerged from lectures at the Chennai Mathematical Institute. Apart from its pedagogical value, the text will also inform aspiring PhD students that there is lively research activity in classical mechanics, at least in some places in India.

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