

Preface

The variational approach is probably the most powerful technique and unifying concept of theoretical physics, but in the same way it is not common to explain it to its full extent to undergraduate students, which later results in a splitting between the method and the languages of theorists and those of “the rest of the world,” at least for what concerns physicists. I think it is important to try to fill in this gap by introducing them as early as possible, thus keeping a common understanding in this discipline.

With the notable exception of Lagrangian and Hamiltonian mechanics, there is a consolidated teaching tradition in undergraduate physics courses in which there is little room for a complete exposition of variational techniques. This is indeed for good reason. Classical physics can be explicated in an extremely efficient way without resorting to these relatively advanced methods, which on the contrary can appear too abstract in such an elementary context.

However, there is a price to pay with this approach. At some point the student comes to more advanced subjects such as quantum or relativistic physics, where such techniques are extremely useful, if not necessary. The risk, then, is that these are perceived as completely detached from the familiar background, and accepted without a real understanding. In this way the nontheoretical physicist will quickly forget this “anomalous event.” This problem might be avoided if, after the regular exposition of classical physics, the same concepts were revised from the point of view of the variational approach.

This book undertakes the problem from the point of view of the gravity field theories, trying to introduce the variational approach by stressing its continuity from the classical to the relativistic realm. Such a job can be accomplished only by treating in parallel the evolution of the dynamics along the same theoretical path.

Despite its great power, however, the variational approach is ultimately a technique, whereas the essential physical meaning of theories lies on their fundamental principles. It is for this reason that the exposition tries to highlight as clearly as possible the connection between theories and principles at the very basic mathematical level.

The book is organized in four parts, which follow the basic ideas underlined above.

The first one tries to give a gentle introduction to variational principles using Newtonian dynamics and gravity as a case study. In the next chapters, the link between classical physics and Euclidean geometry is analyzed from the point of view of the founding principles. This part concludes with the discovery of the internal inconsistency between electrodynamics and these principles in their classical formulation.

The second part starts from the failure of classical physics with respect to the principle of relativity to arrive at an alternative formulation of such a principle. Building upon it to get to special relativity in its Minkowskian formulation, this part ends by observing the infeasibility of a special relativistic theory of gravitation.

By analyzing this problem in more detail, the third part deals with general relativity, some of its applications, and how and why this theory could be extended or modified.

In this book, I tried to gauge the exposition with a particular emphasis on the physical concepts, which sometimes required momentarily delaying some mathematical details. For this reason the appendices contained in the fourth part are not to be considered just as supplementary material. Rather, they carry essential information needed for the complete understanding of the text, and should be tackled in parallel to the respective chapters, where appropriate references can be found.

Finally, this book contains 42 exercises. It is important to solve all of them entirely, because in some cases they include other mathematical details referred to in the main text. Furthermore, this number might not be a mere coincidence, if it has to be the “Answer to the Ultimate Question of Life, the Universe, and Everything,” as somebody argued.

I wish to thank my family for their support during the writing of this book, and I am deeply grateful to my wife. Without her continuous encouragement, steady support, and unshakeable patience this book would have never been completed.

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Alberto Vecchiato

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From Newton to Einstein and Beyond

Vecchiato, A.

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