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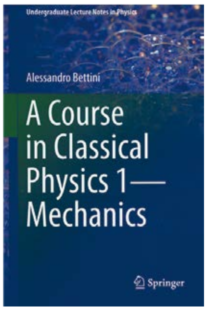

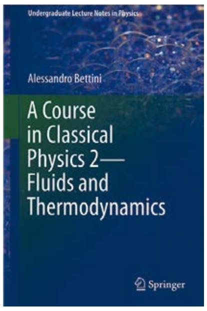

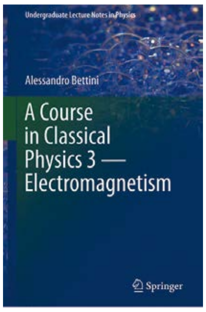

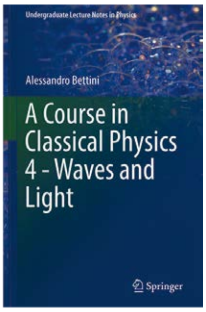

ALESSANDRO BETTINI

A COURSE IN CLASSICAL PHYSICS

Undergraduate Lecture Notes in Physics
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The monumental four-volume work by Alessandro Bettini, Professor Emeritus of the University of Padua, is one of the most extensive treatments of classical physics. The recent Springer edition of the volumes is a translation, and in-depth revision and update of the Italian version originally published by Decibel-Zanichelli. It is a systematic, comprehensive and agile treatise, fruit of the long experience gained by the author in didactic and research activities; by size, character and goals, it has no precedent in the Italian literature of classical physics.

The four volumes deal, respectively, with mechanics, fluids and thermodynamics, electromagnetism, and finally waves and light: they cover with a fresh and insightful approach everything students should learn as their basic knowledge of classical physics before embarking on modern physics. Each volume is well organized enhancing both teaching use and scientific consultation. Each chapter starts with an introduction, which presents its content, and is completed by a collection of proposed problems.

The entire project has a well-defined character, being based on methods and criteria that result in uniformity of treatment and effective synthesis, with emphasis on the experimental method. In presenting the key ideas, great attention is paid to keep the discussion clear, even when dealing with the most complex issues, without resorting to unnecessary simplifications. As a result, an important feature of the work is its completeness, providing the reader with the opportunity to acquire a comprehensive knowledge of the vast panorama of the classical physics topics, where the conceptual aspects are examined without lingering on marginal details, with comments aimed at concreteness, also enriched by references to their historical roots.

The treatise comprises a total of thirty-two chapters and almost fourteen hundred pages that expound comprehensively and authoritatively the traditional syllabus of classical physics, and more. Bettini's presentation not only covers well all the standard material, but also touches upon less common issues such as the possibility to derive the Lorentz transformations without Einstein's second postulate or to give an operational definition of the electrodynamic potentials. As such, Bettini's work represents an impressive and successful effort to provide an exemplary treatment of the subject, with mathematics brought to bear in a way that best illuminates the physics, bridging the gap between an overly descriptive approach and an advanced, formal one appropriate only for graduate students.

While these volumes are specifically designed for scientific university classes, thanks to their clarity and the well balanced progression in dealing with the difficulties of the material they should also help high school professors to refresh and deepen their training for teaching courses of physics. These textbooks should prove invaluable not only to physics majors, but also to science and engineering undergraduates seeking a sound theoretical and experimental understanding of classical physics. Most importantly, because of their broad scope and exemplary treatment, they will remain very useful to them long after taking their courses.

The **first volume** is devoted to the mechanics of point particles and rigid bodies, a concise treatment of special relativity being also provided. Chapter 1 introduces the International System measurement units, carefully describes the symmetries of space and time, presents vector algebra and kinematics. The second chapter discusses the main concepts of the dynamics of a point particle: force, the inertia law, mass, linear momentum, momentum of a force, angular momentum. It also deals with work, energy conservation and potential energy. The equivalence of inertial and gravitational mass is analyzed discussing in detail Galilei's observations on the simple pendulum. Chapter 3 is devoted to various examples of forces, including elastic forces and friction forces. The basics of mechanical oscillations are treated, while an in-depth discussion of the same is to be found in the fourth volume. Chapter 4 on gravitation is very rich and covers all the standard material on the Kepler problem, and more. A step-by-step explanation of the original Newton's determination of the $1/r^2$ law of the centripetal force acting on a planet is also provided. Chapter 5 is devoted to reference frame transformations and pseudo forces in non-inertial frames, and includes the discussion of the Eötvös experiment. Chapter 6 contains a very clear and effective presentation of special relativity, contrasting Lorentz invariance with Galilean invariance and relativistic mechanics with Newtonian mechanics. The last two chapters are devoted to the mechanics of extended systems. Chapter 7 deals with systems of particles, discussing the general conservation laws and collisions. It is also explained how Newton provided experimental evidence of the validity of the action-reaction law and the conservation of linear momentum on the basis of measurements on collisions between two pendulums. The eighth and last chapter is devoted to the dynamics of the rigid body, including gyroscopic motion.

The **second volume** treats fluids and thermodynamics. Chapter 1 is a neat presentation of the fundamentals of hydrostatics and hydrodynamics, including viscous and turbulent flows, and focuses on the physical understanding with a minimal use of mathematics. Chapter 2 introduces the basic notions of thermodynamics: equilibrium state, temperature, equation of state, thermodynamic process, work and heat, the first law of thermodynamics, the ideal gas. Chapter 3 is entirely devoted to the second law of thermodynamics: the traditional formulations of Clausius and Kelvin are clearly explained along with Carnot and Clausius theorems, leading to the concept of entropy variations. Chapter 4 contains a discussion of simple real systems and their states of aggregation: real gases and van der Waals equation, pressure-temperature phase diagram, Clapeyron equation, surface tension and capillarity of liquids. The last two chapters are a self-contained presentation of the kinetic theory of gases and transport processes, respectively. Chapter 5 explains the microscopic description of ideal gases and the Maxwell-Boltzmann distribution, and it ends with a concise, but very effective discussion of the nature of irreversibility and the Boltzmann entropy. The sixth and last chapter contains a neat and simple presentation of basic transport phenomena.

The **third volume** of the course deals with classical electromagnetic phenomena. Chapter 1 reports on electrostatics in a vacuum. The traditional concepts of electric charge and force between charges, electric fields and potentials are introduced. Noticeable are the presentation of the Millikan experiment, the discussions on charge conservation, charge quantization, charge invariance and the importance of equality of positive and negative charges. Metals and dielectrics are then considered in Chapters 2 and 4, respectively, while electrostatic energy of point and continuous charge distributions and of charges on metals are addressed in Chapter 3. Charge currents in metals and the concept of resistivity are presented in Chapter 5 where a pleasant historical interlude on the Ohm story is also reported. Time independent magnetic phenomena are presented in Chapter 6; the magnetic field and the magnetic vector potential are discussed and connected with electric currents. To be noticed is the treatment of charge distribution in current-carrying wires of different shapes, a problem often skipped by other textbooks, and the analysis of the electric and magnetic forces using special relativity. Time-dependent phenomena are studied in Chapter 7 where the electromagnetic induction is the natural link between electricity and magnetism. Alternate current circuits are also treated in this chapter, while the study of the energy in systems of steady currents is reported in Chapter 8. Diamagnetic, paramagnetic and ferromagnetic properties of matter, and the difference between the field B and the auxiliary field H are introduced in Chapter 9. Chapter 10 contains a full treatment of Maxwell equations, it is shown that they describe in a unified framework all electromagnetic phenomena and light. The electromagnetic potentials and their meaning are discussed. Eventually, it is shown that the Maxwell equations obey the relativity principle going through the Lorentz invariance of the equations for the potentials.

The **fourth volume** is dedicated to oscillatory phenomena, to waves, and in particular to light. Using the mathematical baggage already acquired in the study of mechanics and electromagnetism, in the first two chapters of the volume are studied oscillatory phenomena in systems with a single degree of freedom, then systems with two or with a large number of degrees of freedom, up to continuous systems, under different boundary conditions are considered. The one-dimensional model systems provide opportunity to elaborate the concept of dispersion relation and of resonance conditions, while for more complex systems is well introduced the concept of normal modes. The essential elements of Fourier analysis for periodic and non-periodic functions, which will be widely used in the subsequent chapters, are then addressed both in space and in time. The study of the waves is introduced in Chapter 3, starting from the analysis of their distinctive character. It is discussed how waves are generated, how they propagate, by which differential equations are described. It is worth noticing, in the comparison between sound and light, the deduction of the Doppler effect: exploiting in the proof of the effect the relativistic result that time intervals can no longer be considered invariant, as already shown in Volume 1, it is shown that the equations valid for sound are not valid for electromagnetic waves. The remaining chapters, from the fourth to eighth, are essentially devoted to the phenomena of light. At first, in Chapter 4, the concepts of phase and group velocity of a wave, and the phenomenon of dispersion are described, then reflection, refraction and dispersion of light are analysed according to the laws of geometrical optics. In Chapter 5, an in-depth analysis of interference and diffraction phenomena is presented; the concepts of point source, monochromatic source, spatial and temporal coherence, overlap of radiation from different sources are clearly discussed, and it is eventually shown how to interpret the figures generated when the radiation meets along its path the edge of an opaque object or openings in a screen. To polarization of light is dedicated Chapter 6 where it is shown that dichroism, scattering, reflection and birefringence phenomena are related to it. Mirrors, lenses, prisms, and optical images generated by them are discussed in Chapter 7. Finally in Chapter 8 the formation of images is studied, in particular when diffraction is the main phenomenon that contributes to their construction, as it happens for example in the case of holograms.

As a result of his insight and wisdom as an experienced teacher and an outstanding scientist, a distinctive feature of Bettini's presentation throughout the four volumes is not only how it uses the minimum mathematical formalism needed to understand the theory and its applications, but also how it constantly stimulates conceptual understanding by the detailed analysis of actual experiments and by the discussion of original pages written by the founding fathers of physics, Galilei and Newton above all. In line with the incipit of his treatise "Physics is an experimental science that gives a quantitative, mathematical description of natural phenomena", Bettini offers a detailed analysis of many of the experiments that have marked the development of Physics – from Galilei's incline experiment to Maxwell's determination of the velocity of light via the ratio of units experiment – and not only explains their conceptual implications, but also delves into the actual measurement instruments (such as the water chronometer) and techniques (such as the null method). In other cases, in order to present a sound experimental basis of key assertions, such as the invariance of charge, Bettini also makes reference to the modern research literature. In many instances, Bettini discusses fundamental discoveries quoting the words of giants of the like of Galilei and Newton, and never from the mere historic prospective, but rather for scientific and didactic reasons. For instance, Newton's Principia is one of the most influential books in science ever written, yet it is hardly readable even for the most dedicated student; discussing Newton's proof of the $1/r^2$ dependence of the gravitational force from the elliptical shape of the planetary orbits, Bettini takes the students by hand and shows line by line what Newton did and how he did it, illuminating the physical significance of his geometric approach, and allowing them to discover such magisterial work for themselves.

Each one of the four volumes is self-contained and suitable to be used as a textbook by itself. The notations used are always neat and effective, only in rare instances we would have preferred different ones as when an imaginary time coordinate is introduced in relativity. The typographical layout is pleasant, with many helpful figures and rare typos. Among the positive aspects that immediately capture the attention, are the orders of magnitude, the practical examples, the questions posed prompting the reader to think critically about some important concepts. The problems proposed at the end of each chapter are relatively few in number, but are well chosen to illustrate the subject matter. The answers to the problems are given only in Volumes 1 and 2, being missing in Volumes 3 and 4, while the summaries at the end of each chapter of Volumes 3 and 4, allowing to grasp at a glance the most significant concepts discussed therein, would have been appreciated also in Volumes 1 and 2, but these are minor quibbles indeed.

Phenomenological observations are always analyzed with great care and related to the fundamentals refraining from quick and muddled explanations, in this respect the in-depth discussion of the tides is exemplary. The author also takes great care to always provide precise definitions of basic concepts, for instance while discussing the symmetry properties and the lack of scale invariance of the physical laws or while contrasting quasi-static thermodinamic transformations with reversible ones. The well balanced choice of observational and theoretical arguments characteristic of Bettini's presentation is illustrated by the chapter on gravitation which, besides a clear exposition of the standard material, also includes the discussion of topics seldom treated in undergraduated textbooks such as the system of the satellites of Jupiter or the rotation curve of galaxies showing evidence for the existence of dark matter.

These textbooks stand out for the high quality of exposition, and they deserve serious consideration for any undergraduate course, even though they require a little more sophistication to be fully appreciated than do most other ones. Not only do these volumes cover all well-established topics, but they also include many not to be currently found in textbooks. Moreover, they are enriched by various gems of historical and scientific interest, taken from the works of Galilei, Newton, and other giants, which are always presented with accompanying qualitative descriptions, conceptual notions and detailed mathematical developments so that students can fully grasp their significance. Actually, using these books will be a challenging delight. All explanations are crisp and clear: they never skip the essential mathematical steps, yet always emphasize the underlying physical concepts. This is not to say that all students will find the books easy to read, but they will be much rewarded for their work with excellent physical arguments and inductive reasoning alongside rigorous proofs and realistic numerical estimates.

Alessandro Bettini has fulfilled the ambitious goal of writing a treatise that covers all of classical physics with a depth suitable for honor undergraduate courses. But, why yet another one? In the words of Richard Feynman, whose Lectures on Physics are a favorite of Bettini's, the answer is "Because there are new generations born every day. Because there are great ideas developed in the history of man, and these ideas do not last unless they are passed purposely and clearly from generation to generation". Bettini's books not only teach, but inspire, and they will appeal to students and professors alike who feel that physics is truly rich of great ideas that deserve to be studied with devotion and love.

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