ELEMENTARY TEXTBOOK ON PHYSICS

ELEMENTARY TEXTBOOK ON PHYSICS

Edited by G. S. Landsberg

In three volumes

Volume 1

MECHANICS
HEAT
MOLECULAR PHYSICS

ИЗДАТЕЛЬСТВО МИР

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ELEMENTARY TEXTBOOK ON PHYSICS

Volume 1

ЭЛЕМЕНТАРНЫЙ УЧЕБНИК ФИЗИКИ

Под редакцией академика

Г. С. ЛАНДСБЕРГА

В 3-х томах

ТОМ 1

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From the Preface to the First Russian Edition

The title *Elementary Textbook on Physics* for this book reflects our endeavour to write a book that will acquaint the reader with fundamentals of physics as a science. This should be the goal when teaching physics at high schools, technical schools, or vocational training schools. We hope that this book can be used as the main physics textbook in all such schools since the underlying principles have universal application.

These principles impart certain features to the book which distinguish it from existing high-school textbooks. The features require some explanation, which should mainly be the task of the teachers. Hence we address this preface to those who teach physics.

Lecturers at universities and engineering colleges have a sad impression that the students who have finished high school possess a poor grasp of physics. What is most striking is not their lack of information or theoretical concepts but rather the absence of clear and correct ideas about the relations between these concepts. Students often cannot say what forms the basis of a definition, what is the result of an experiment, and what should be treated as a theoretical generalisation of experimental knowledge. New facts are often taken as self-evident corollaries, and for this reason the importance of the facts remains unrecognised. Sometimes, different formulations of the same statements are mistaken as different laws.

Naturally, the teaching of physics at universities differs considerably from teaching at high schools in the volume of material, depth of presentation, and in the systematic use of mathematical tools. However, at an early stage, physics (or an introduction to it) should be taught as a *science* and not as an aggregate of individual facts. In other words, the facts should be used as a basis for creating in the minds of students a clear idea about the scientific approach typical of physics. It goes without saying that this approach is experimental.

Nobody would venture to deny that physics is an experimental science or that its laws are established with the help of experiments. In some textbooks, however, these statements are presented as declarations to which the first pages are devoted. Subsequently, the experiments are mainly used as illustrations, and the fact that physical concepts are inseparable from experiments slips away from the students. It is necessary, however, to persuade students that logically formulated definitions become meaningful only after having been verified experimentally, i.e. as a *result of measurements*. Every concept introduced in physics acquires a concrete meaning only if a certain method of observation and measurement is associated with it. Without this, a concept cannot find any application in the investigation of actual physical phenomena.

Let us consider, for example, the simple concept of uniform motion. Whether a given motion is uniform depends on the method of observation. The motion of a train, for example, can be rightfully treated as uniform if we use rough methods for measuring each segment of the path and the time intervals. If we use more accurate methods, however, the motion may turn out to be nonuniform. If a motion satisfies the established definition of uniformity for a method of observation, all laws of uniform motion are applicable to it, and all conclusions and calculations are valid for it with an accuracy which is characteristic for the method of measurement.

A clear idea about the *experimental* nature of physical laws is of utmost importance: it makes physics a *natural science* rather than a system of speculative constructions. On the other hand, it sets the limits of applicability of physical laws and theories based on them and shows how science can be developed.

At the first stage of teaching physics, a correct *idealisation* of phenomena and the significance of this idealisation are equally important. Naturally, every teacher or textbook writer appreciates the necessity of idealisation and uses it wherever required. However, the idealisation is sometimes unjustified.

Idealising a phenomenon is to neglect those features which are insignificant for a problem and to retain the required properties. In this respect, the same phenomenon can be idealised to different extents depending on the problem. Moreover, using a correct idealisation, we can sometimes omit certain features of a phenomenon and retain other features that would appear to be inseparable from those we neglected. For example, one of the most widespread and useful idealisations in mechanics is the concept of a perfectly rigid body or incompressible liquid. These idealisations are required for a wide variety of mechanical problems in which deformations do not play a significant role and where the change in the size and shape of a body can be ignored. However, stresses caused by strains in a deformed body are significant in the dynamics of phenomena. For this reason, the idealised concept of a perfectly rigid body as a body *without* deformations makes the simplest problems in mechanics meaningless unless certain reservations are made. It is necessary to establish from the outset that we ignore deformations in a solid or liquid but take into account the stresses which are caused in the idealised body by deformations and which explain all the phenomena under consideration. Without a clear idea about this, it is impossible to understand even the simplest phenomenon and, for example, to say why a load rests on a table in spite of the fact that the force of gravity acts on it, since we cannot see the other force, viz. the elastic tensile force exerted by the table and balancing the force of gravity.

An introduction to the physics as a science and the explanation of such idealised concepts should be made with great care. When used correctly, these concepts can be very helpful and considerably simplify the formulation of laws and calculations. But reticence or an incorrect application of the concepts may lead to the risk inherent in teaching, viz. the formation of erroneous notions which will later handicap further and deeper understanding. By way of example, we can mention the concepts of a magnetic pole or a geometric ray. There is no doubt that these concepts have value, and it would be irrational to do without them. However, the utmost care and explanation are essential to avoid any confusion that the introduction of these concepts might create. Many of us who evaluate inventions or theoretical work are aware, for example, that confidence in the infallibility of geometrical optics based on an erroneous interpretation of the useful concept of geometric ray can lead to serious confusions.

* * *

Like every other form of education, teaching at high school can never be exhaustive. However, it must be planned in such a way that the student could and would *increase his knowledge* but should by no means repeat the *whole thing*. This should be the ultimate aim of everyone venturing to write a textbook. It is imperative that methodological and methodical imperfections like the ones mentioned above be meticulously avoided.

The group of physicists who took upon themselves the task of compiling this *Elementary Textbook on Physics* were guided by these principles. Their decision to do so was not motivated by a desire to alter the conventional contents but by the considerations listed above. For this reason, "simple" questions, which are normally discussed in a few lines, are given extensive coverage in this book. It is because of this approach, and by no means due to an increase in the number of topics, that the volume of this book exceeds that of conventional textbooks.

Moscow, June 1948 *G. Landsberg*

From the Publishers of the Tenth Russian Edition

Elementary Textbook on Physics first appeared in 1948-52 under the editorship of Academician G.S. Landsberg (1890-1957) and immediately became popular with students preparing for entrance examinations in physics. The success of the book was due very much to the fact that each section was written by a specialist. Contributors to the book included the scientists S.E. Khaikin, M.A. Isakovich, M.A. Leontovich, D.I. Sakharov (Vol. 1), S.G. Kalashnikov (Vol. 2), S.M. Rytov, M.M. Sushchinskii (with the participation of I.A. Yakovlev), F.S. Landsberg-Baryshanskaya, and F.L. Shapiro (Vol. 3).

The distinguishing feature of this course is that it contains a comparatively small number of formulas and mathematical calculations. The main attention in this textbook is devoted to the explanation of the essence of physical phenomena. The material is presented on a high scientific level and at the same time in a form comprehensible to school students. Another feature of the book is that it describes a large number of technical applications of physical laws. In this respect, the book has no analogue among textbooks on physics written on this level in the world.

During a quarter of a century, *Elementary Textbook on Physics* has seen nine editions. The previous ninth edition was issued in 1975. Although separate sections of the book have been updated during the preparation of earlier editions, the present (tenth) edition is the result of a considerable revision to incorporate SI units as well as new terminology.

The chapters of Volume 2 on magnetic phenomena have been heavily revised. In the previous editions, these phenomena were presented on the basis of Coulomb's law for magnetic charges. While preparing the manuscript for the tenth edition, these chapters were rewritten on the basis of the concept of the magnetic field of moving charges and currents. To meet the requirements of the SI system of units, the formulas on electromagnetism are presented in a rationalised form. Magnetic induction **B** is used as the main force characteristic of the magnetic field rather than the magnetic field strength **H**, as it was done in the previous editions.

The text has been partially renewed and supplemented by I.Ya. Barit, L.G. Landsberg, F.S. Landsberg-Baryshanskaya, V.I. Lushchikov, S.M. Rytov, I.V. Savel'ev, M.M. Sushchinskii, M.S. Khaikin, S.M. Shapiro, O.A. Shustin, and I.A. Yakovlev. The first two volumes were edited by I.V. Savel'ev and the third volume by the persons mentioned above.

Introduction

The knowledge acquired by a student at high school and the observation of the surroundings (among other things, the information concerning the unimaginable potentialities of the modern technology) inevitably lead to the question: how could man, with his low physical ability and imperfect organs of senses which allow him a very limited scope to directly observe the physical phenomena, create modern technology with its huge possibilities which extend far beyond the fictions by J. Verne? Almost everybody would answer this question without thinking: *this miracle was brought about by the science of nature*. The physical science plays a particularly important role in this triumph of man.

What are the tools at the disposal of the physical science that allow it to reign the world?

First of all, physics clearly deals with phenomena in real world, and hence the first step in gaining knowledge about these phenomena involves *observations*.

However, scientific observation is not a simple problem. Let us watch, for example, falling bodies. It can be easily seen that a body dropped from a small height strikes the ground with a small force, while the impact as a result of a fall from a large height can be much stronger and may even destroy the falling body. The observation of rain drops does not reveal, however, any difference in the impacts of the drops from low and high clouds. Everybody knows that a pilot who falls from an aeroplane is smashed to death, while a pilot who jumps with a parachute even from a larger height lands smoothly. Aircraft bombs, especially heavy ones, hit with a tremendous force that enables them to pierce multistorey buildings. Thus, a comparatively simple phenomenon of falling may proceed in different ways. If we want to control this phenomenon, we must find the relationship between its different aspects, viz. establish how certain characteristics of the motion of a body are influenced by the shape and mass of the body, the height from which it falls, etc. and (this is most important) draw *general conclusions* from these facts, which explain why the body falls in this way and not in another way.

The same problems emerge in studying any other phenomenon. We must establish what affects a phenomenon and learn how to suppress or enhance its individual aspects. For this purpose, we must be able to analyse