Fundamentals of

PHYSICS

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Preface

During the past few years, we have observed gradual but steady changes in the character of the calculus-based introductory physics course. In a large number of schools, less time is available than was previously the case. In others, it appears that not so much attention may be given to a careful and detailed explanation of the subject matter. Also, changes in course requirements at the upper levels of science and engineering curricula have indicated the need for a shorter book than *Physics.**

For these reasons and others, we have been persuaded to prepare an alternate version of the earlier book. The modifications have taken several forms. One has been to remove a large amount of the supplementary material and some of the appendix material that appear in *Physics.* Another has been to condense several chapters and to combine some of them. This necessarily led to careful rewriting and we took advantage of this opportunity to revise some of the material of Part II as well. Other alterations were made in the questions and problems. Many new problems have been added and some, such as those applying to deleted material, have been removed. A number of the new problems fall into what we describe as a "confidence-building" category.

The effect of this surgery has been to decrease appreciably the size of the book and to reduce somewhat its level of sophistication without sacrificing a broad coverage of the fundamentals. *Fundamentals of Physics* emerges then as both a shorter and an easier alternative to *Physics.* This book consequently will be relevant to those courses in which time and prior preparation of the student do not permit the use of the more thorough treatment and somewhat more rigorous pace set by *Physics.*

Authors are perhaps the least qualified persons to engage in an abridgment of their works. We were very fortunate to have had the active assistance of Farrell Edwards and John Merrill, both of Utah State University, in this task. Professors Edwards and Merrill have taught a one-year physics course at their school for some time and are experienced in ways to achieve the objectives we sought. They discussed with us in detail where material ought to be removed or condensed. They joined us in doing much of the required rewriting and contributed a number of new problems. And, equally important, they did much of the work involved in seeing the book safely through production. To them go our heartfelt thanks. Completing this book in a reasonable length of time would not have been possible without their contributions.

We are grateful to Wiley for its outstanding cooperation and especially to Donald

* David Halliday and Robert Resnick, *Physics*, Wiley, New York, 1966.

Deneck, Physics Editor, whose management of this task was superb. Richard Martin, of Alfred University, was also helpful in providing additional material for the problem sets of most of the chapters.

We believe that *Fundamentals of Physics* is relevant and appropriate to a new spectrum of students and courses, and hope it will contribute to the improvement of physics education.

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CHAPTER 1

Measurement

1–1 Physical Quantities, Standards, and Units

The building blocks of physics are the physical quantities in terms of which the laws of physics are expressed. Among these are force, time, velocity, density, temperature, charge, magnetic susceptibility, and numerous others. Many of these terms, such as force and temperature, are part of our everyday vocabulary. When these terms are so used, their meanings may be vague or may differ from their scientific meanings.

For the purposes of physics the basic quantities must be defined clearly and precisely. One view is that the definition of a physical quantity has been given when the procedures for measuring that quantity are specified. This is called the *operational* point of view because the definition is, at root, a set of laboratory operations leading to a number with a unit. The operations may include mathematical calculations.

Physical quantities are often divided into *fundamental quantities* and *derived quantities*. Such a division is arbitrary in that a given quantity can be regarded as fundamental in one set of operations and as derived in another. Derived quantities are those whose defining operations are based on measurements of other physical quantities. Examples of quantities usually viewed as derived are velocity, acceleration, and volume. Fundamental quantities are not defined in terms of other physical quantities. The number of quantities regarded as fundamental is the minimum number needed to give a consistent and unambiguous description of all the quantities of physics. Examples of quantities usually viewed as fundamental are length and time. Their operational definitions involve two steps: first, the choice of a *standard*, and second, the establishment of procedures for comparing the standard in such a way that a number and a unit are determined as the measure of that quantity.