Feynman's Preface

These are the lectures in physics that I gave last year and the year before to the freshman and sophomore classes at Caltech. The lectures are, of course, not verbatim—they have been edited, sometimes extensively and sometimes less so. The lectures form only part of the complete course. The whole group of 180 students gathered in a big lecture room twice a week to hear these lectures and then they broke up into small groups of 15 to 20 students in recitation sections under the guidance of a teaching assistant. In addition, there was a laboratory session once a week.

The special problem we tried to get at with these lectures was to maintain the interest of the very enthusiastic and rather smart students coming out of the high schools and into Caltech. They have heard a lot about how interesting and exciting physics is—the theory of relativity, quantum mechanics, and other modern ideas. By the end of two years of our previous course, many would be very discouraged because there were really very few grand, new, modern ideas presented to them. They were made to study inclined planes, electrostatics, and so forth, and after two years it was quite stultifying. The problem was whether or not we could make a course which would save the more advanced and excited student by maintaining his enthusiasm.

The lectures here are not in any way meant to be a survey course, but are very serious. I thought to address them to the most intelligent in the class and to make sure, if possible, that even the most intelligent student was unable to completely encompass everything that was in the lectures—by putting in suggestions of applications of the ideas and concepts in various directions outside the main line of attack. For this reason, though, I tried very hard to make all the statements as accurate as possible, to point out in every case where the equations and ideas fitted into the body of physics, and how—when they learned more—things would be modified. I also felt that for such students it is important to indicate what it is that they should—if they are sufficiently clever—be able to understand by deduction from what has been said before, and what is being put in as something new. When new ideas came in, I would try either to deduce them if they were deducible, or to explain that it *was* a new idea which hadn't any basis in terms of things they had already learned and which was not supposed to be provable—but was just added in.

At the start of these lectures, I assumed that the students knew something when they came out of high school—such things as geometrical optics, simple chemistry ideas, and so on. I also didn't see that there was any reason to make the lectures

Foreword

A great triumph of twentieth-century physics, the theory of quantum mechanics, is now nearly 40 years old, yet we have generally been giving our students their introductory course in physics (for many students, their last) with hardly more than a casual allusion to this central part of our knowledge of the physical world. We should do better by them. These lectures are an attempt to present them with the basic and essential ideas of the quantum mechanics in a way that would, hopefully, be comprehensible. The approach you will find here is novel, particularly at the level of a sophomore course, and was considered very much an experiment. After seeing how easily some of the students take to it, however, I believe that the experiment was a success. There is, of course, room for improvement, and it will come with more experience in the classroom. What you will find here is a record of that first experiment.

In the two-year sequence of the Feynman Lectures on Physics which were given from September 1961 through May 1963 for the introductory physics course at Caltech, the concepts of quantum physics were brought in whenever they were necessary for an understanding of the phenomena being described. In addition, the last twelve lectures of the second year were given over to a more coherent introduction to some of the concepts of quantum mechanics. It became clear as the lectures drew to a close, however, that not enough time had been left for the quantum mechanics. As the material was prepared, it was continually discovered that other important and interesting topics could be treated with the elementary tools that had been developed. There was also a fear that the too brief treatment of the Schrödinger wave function which had been included in the twelfth lecture would not provide a sufficient bridge to the more conventional treatments of many books the students might hope to read. It was therefore decided to extend the series with seven additional lectures; they were given to the sophomore class in May of 1964. These lectures rounded out and extended somewhat the material developed in the earlier lectures.

In this volume we have put together the lectures from both years with some adjustment of the sequence. In addition, two lectures originally given to the freshman class as an introduction to quantum physics have been lifted bodily from Volume I (where they were Chapters 37 and 38) and placed as the first two chapters here—to make this volume a self-contained unit, relatively independent of the first two. A few ideas about the quantization of angular momentum (including a discussion of the Stern-Gerlach experiment) had been introduced in Chapters 34 and 35 of Volume II, and familiarity with them is assumed; for the convenience of those who will not have that volume at hand, those two chapters are reproduced here as an Appendix.

This set of lectures tries to elucidate from the beginning those features of the quantum mechanics which are most basic and most general. The first lectures tackle head on the ideas of a probability amplitude, the interference of amplitudes, the abstract notion of a state, and the superposition and resolution of states—and the Dirac notation is used from the start. In each instance the ideas are introduced together with a detailed discussion of some specific examples—to try to make the physical ideas as real as possible. The time dependence of states including states of definite energy comes next, and the ideas are applied at once to the study of two-state systems. A detailed discussion of the ammonia maser provides the framework for the introduction to radiation absorption and induced transitions. The lectures then go on to consider more complex systems, leading to a discussion of the propagation of electrons in a crystal, and to a rather complete treatment of the quantum mechanics of angular momentum. Our introduction to quantum mechanics ends in Chapter 20 with a discussion of the Schrödinger wave function, its differential equation, and the solution for the hydrogen atom.

The last chapter of this volume is not intended to be a part of the "course. It is a "seminar" on superconductivity and was given in the spirit of some of the entertainment lectures of the first two volumes, with the intent of opening to the students a broader view of the relation of what they were learning to the general culture of physics. Feynman's "epilogue" serves as the period to the three-volume series.

As explained in the Foreword to Volume I, these lectures were but one aspect of a program for the development of a new introductory course carried out at the California Institute of Technology under the supervision of the Physics Course Revision Committee (Robert Leighton, Victor Neher, and Matthew Sands). The program was made possible by a grant from the Ford Foundation. Many people helped with the technical details of the preparation of this volume: Marylou Clayton, Julie Curcio, James Hartle, Tom Harvey, Martin Israel, Patricia Preuss, Fanny Warren, and Barbara Zimmerman. Professors Gerry Neugebauer and Charles Wilts contributed greatly to the accuracy and clarity of the material by reviewing carefully much of the manuscript.

But the story of quantum mechanics you will find here is Richard Feynman's. Our labors will have been well spent if we have been able to bring to others even some of the intellectual excitement we experienced as we saw the ideas unfold in his real-life Lectures on Physics.

December, 1964 MATTHEW SANDS

Contents