Chapter 1

INTRODUCTION

A huge gap exists between modern science and technology and standard undergraduate physics education. Typical problems we suggest to undergraduate students in a course of physics seem to have very little in common with contemporary discoveries and advances. At the same time, probably many scientists would agree that the level of introductory undergraduate physics is high enough to estimate and sometimes even compute some important features at the very edge of modern physics.

The main idea of our book is to promote reconciliation between modern science and undergraduate physics. We believe such a reconciliation will spark interest in both physics education and the current frontiers of science. The best outcome would be if it would help students to understand and appreciate modern scientific ideas in their future education and working lives.

The book is organized as follows: In the next three chapters, we present a short popular review of selected hot topics in modern science and technology. We hope both college students and college professors will find something interesting in our review. Chapter 2 presents the current picture of the fundamental elementary particles and fundamental interactions. We briefly describe the three generations of fundamental elementary particles, the compound elementary particles, and the gauge fields. Then we describe the transformations of elementary particles and some of the powerful accelerators designed to study the interactions between the particles. Next, we consider atomic nuclei and nuclear reactions, quantum properties of an atom including such delicate questions as Schrödinger cat states. For every topic we try to give basic information about the topic as well as current information from the frontiers of contemporary research. The selected topics certainly show some bias and are not intended to

be a complete popular review. The same principle, to an even greater extent is used in the next two chapters.

In Chapter 3 we present a few applications of modern physics. We briefly describe the principles of electron spin resonance and nuclear magnetic resonance and the ideas of spin refocusing (spin echo). Then we shift to contemporary ideas of single-spin detection including magnetic resonance force microscopy and scanning tunneling microscopy. We describe nanotubes as one of the frontier directions in nanotechnology. Then we discuss superconductivity including Josephson effects and the SQUID. From these "relatively old" phenomena we shift to frontier problems: superposition states in a nanometer scale "superconducting box," the Schrödinger cat state for a superconducting current, and superconducting magnets. We also mention application of physics to fighting natural disasters. As an example, we consider tsunami and contemporary ideas of tsunami warning. Finally, we explain the intriguing contemporary ideas of quantum computation and quantum teleportation.

In Chapter 4 we consider astrophysical phenomena. We describe the fusion reactions in a normal star, like our Sun. Then we consider a normal star's evolution. We describe the origin and properties of White Dwarfs, Neutron Stars, and Black Holes. Finally, we briefly consider some of the current space flight programs, their achievements and expectations.

Chapters 5 and 6 contain short reviews of the main topics from a standard introductory undergraduate course of physics and the problems. The suggested problems are associated with frontier scientific research. Some of the problems are directly connected to the topics discussed in the previous three chapters. To solve these problems a reader does not have to go through the earlier chapters. However, if a topic connected to a problem has excited you, we encourage you to read the corresponding section.

Chapter 5 contains a short review and problems based on an introductory undergraduate, calculus-based course on mechanics including traveling and standing waves and also sound waves, which are often considered in a separate course.

Chapter 6 contains a review and problems on electricity and magnetism, including electromagnetic waves and even optical phenom-

ena, which often are also treated in a separate course on optics.

Chapter 7 contains hints to solution of the problems except for a few very simple problems.

Finally, the Appendices contain some useful data and formulas which can be used in the solution of the problems.