FASCINATING PROBLEMS FOR YOUNG PHYSICISTS

Problem-solving is the cornerstone of all walks of scientific research. *Fascinating Problems for Young Physicists* attempts to clear the boundaries of seemingly abstract physical laws and their tangible effects through a step-by-step approach to physics in the world around us. It consists of 42 problems with detailed solutions, each describing a specific, interesting physical phenomenon. Each problem is further divided into questions designed to guide the reader through, encouraging engagement with and learning the physics behind the phenomenon. By solving the problems, the reader will be able to discover, for example, what the relation is between the mass of an animal and its expected lifetime, or what the efficiency limit is of wind turbines. Intended for first-year undergraduate students and interested high school students, this book develops inquiry-based scientific practice and enables students to acquire the necessary skills for applying the laws of physics to realistic situations.

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Discovering Everyday Physics Phenomena and Solving Them

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Preface

Solving of problems has been an indispensable part in training of generations of physicists. A student deepens the understanding of the laws of physics when challenged to apply them to specific physical systems. There is a significant number of model systems where it is relatively straightforward to apply physical laws (a point particle in the constant field, a body on an inclined plane, a body connected to a spring, simple pendulum, ideal gases, system of point charges at rest, to name a few). The problems related to these and similar systems are part of every general physics course and can be found in general physics textbooks or in separate problem books. However, these systems remain relatively abstract and students do not necessarily get a good grasp of the fact that physics describes almost all phenomena in everyday life.

The aim of our book is to bridge this gap. Namely, we have selected the problems where the knowledge of general physics can be applied to phenomena from the world around us. By solving the problems in this book, the student will be able to discover, for example, why are the world records in high jump, long jump or pole vault at the specific lengths or heights, what is the relation between the mass of the animal and its expected lifetime, what is the efficiency limit of wind turbines, how do we see, why we see nice butterfly colors, etc. The book consists of 42 problems with detailed solutions, each describing a certain interesting physical phenomenon from everyday life. Each problem is divided into several (typically 5–15) questions that guide the reader throughout the problem and help the reader to understand the physics behind the phenomenon. Most of the problems in the book were prepared by the authors, while references are given in the case of few problems that were adapted from other sources.

The inspiration for the problems came from the world around us rather than from the branches of physics. For this reason, the problems are grouped by the systems from nature that they treat. First group of problems deals with the physics of the human body. The operation of all machines that we use or see in everyday life is

based on physical laws and we address some of these machines in the next group of problems. The following group of problems addresses the physics behind various popular sport disciplines. Physical effects in the living world and in the natural phenomena such as rain, rainbow, lightning, earthquakes, and ocean waves are treated next. We then address the effects related to conversion of energy from one form to another and close the book with a group of several unrelated interesting problems.

Our intention in the problems was certainly not to give an exhaustive treatment of the phenomenon neither to exhaustively treat the phenomena from nature. The questions guide the reader to recognize and understand the basics of the main physical effects behind the phenomenon and we hope that these might stimulate the reader to investigate the phenomenon further. In this regard, the reader may find useful the Jupyter notebooks that accompany the book that contain all calculations necessary to obtain the final numerical result. The reader can use these, for example, to change the parameters of the system and see what would be the effect of these changes.

Intended audience for this book are talented high school students who are motivated to deepen their knowledge of physics and first and second year undergraduate students that take courses of general physics. The book will certainly be of use to high school teachers that work with talented students, while some easier parts of the problems can be also used as examples in regular high school classes. At the university level, the problems from the book can be used in lectures as nice examples of applications of the laws of physics in life and as homework assignments to students.

Physical laws and mathematical techniques that should be applied to solve the problems are part of high school curriculum in most countries and are in-line with the curriculum of International Physics Olympiad for high school students. The difficulty of the questions varies. Some introductory questions in the problem are easy and can be solved using direct application of formulas that describe certain physical laws, while most of the problems contain parts that are quite challenging and are of difficulty comparable to most difficult problems at International Physics Olympiad for high school students. In fact, a few of these problems were posed by authors at national physics competitions in Serbia. We would like to acknowledge our colleagues who have acted as reviewers for these problems or with whom we have discussed the problems: Veljko Janković, Dimitrije Stepanenko, Antun Balaž, Božidar Nikolić, Duško Latas, Ana Hudomal, Darko Tanasković, Dejan Đokić, Marko Opačić, Mihailo Rabasović, Aleksandar Krmpot, Nikola Jovančević, Petar Mali, Vladan Pavlović, Marko Kuzmanović, and Milan Radonjić.

Finally, we would like to give a few suggestions for students on how to use this book. The problems can be solved in any order, while the problems within a certain group were sorted from somewhat easier to more difficult. We strongly encourage

the students to make a significant effort first to solve the problem without consulting the solution. Learning in the process of trying to solve the problem is indispensable, even when the student eventually does consult the solution. When consulting the solution, we suggest to use the solution first only as a hint and go back to solve the problem using this hint.

We hope that the problems from this book will guide the students to recognize the laws of physics in the world around us, that they will deepen their knowledge of physics by solving the problems and that this book will introduce a fresh perspective to the use of problem solving in physics teaching.