Preface

This is a series of lecture notes and problems on "Essential Graduate Physics", consisting of the following four parts:

CM: *Classical Mechanics* (for a 1-semester course),
EM: *Classical Electrodynamics* (2 semesters),
QM: *Quantum Mechanics* (2 semesters), and
SM: *Statistical Mechanics* (1 semester).

The parts share a teaching style, structure, and (with few exceptions) notation, and are interlinked by extensive cross-referencing. I believe that due to this unity, the notes may be used for teaching these courses not only in the (preferred) sequence shown above but in almost any order – or in parallel.

Each part is a two-component package consisting of:

(i) *Lecture Notes* chapter texts,[1] with a list of exercise problems at the end of each chapter, and
(ii) *Exercise and Test Problems with Model Solutions* files.

The series also includes front matter (10 pp., including this *Preface*), two brief reference appendices, *MA: Selected Mathematical Formulas* (16 pp.) and *CA: Selected Physics Constants* (2 pp), and a list of references.

The series is a by-product of the so-called *core physics* courses I taught at Stony Brook University from 1991 to 2013. Reportedly, most physics departments require their graduate students to either take a set of similar courses or pass comprehensive exams based on an approximately similar body of knowledge. This is why I hope that my notes may be useful for both instructors and students of such courses, as well as for individual learners.

The motivation for composing the lecture notes (which had to be typeset because of my horrible handwriting) for Stony Brook students was my desperation to find textbooks I could actually use for teaching. First of all, the textbooks I could find, including the most influential *Theoretical Physics* series by L. Landau and E. Lifshitz, did not match my classes, which included experiment-oriented students, some PhD candidates from other departments, US college graduates with insufficient undergraduate background, and a few advanced undergraduates. Second, for the rigid time restrictions imposed on the core physics courses, most available textbooks are way too long, and using them would mean hopping from one topic to another, picking up a chapter here and a section there, at a high risk of losing the necessary background material and logical connections between course components - and students' interest with them. On the other hand, many textbooks lack even brief discussions of several traditional and modern topics that I believe are necessary parts of *every* professional physicist's education.[2,3]

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[1] The texts are saved as separate .pdf files of each chapter, optimized for two-page viewing and double-side printing; merged files for each part and the series as a whole, convenient for search purposes, are also provided.

[2] To list just a few: statics and dynamics of elastic and fluid continua, basic notions of physical kinetics, turbulence and deterministic chaos, physics of reversible and quantum computation, energy relaxation and dephasing in open quantum systems, the van der Pol method (a.k.a. the Rotating-Wave Approximation, RWA) in classical and quantum mechanics, physics of electrons and holes in semiconductors, weak-potential and tight-binding approximations of the energy band theory, optical fiber electrodynamics, macroscopic quantum effects in

The main goal of my courses was to make students familiar with the basic notions and ideas of physics (hence the series' title), and my main effort was to organize the material in a logical sequence the students could readily follow and enjoy, at each new step understanding why exactly they need to swallow the next knowledge pill. As a backside of such a minimalistic goal, I believe that my texts may be used by advanced undergraduate physics students as well. Moreover, I hope that selected parts of the series may be useful for graduate students of other disciplines, including astronomy, chemistry, mechanical engineering, electrical, computer and electronic engineering, and material science.

At least since Confucius and Sophocles, i.e. for the last 2,500 years, teachers have known that students can master a new concept or method only if they have seen its application to at least a few particular problems. This is why in my notes, the range of theoretical physics methods is limited to the approaches that are indeed necessary for the solution of the problems I had time to discuss, and the introduction of every new technique is always accompanied by an application example or two. Additional exercise problems are listed at the end of each chapter of the lecture notes, and may be used for homework assignments. Individual readers are strongly encouraged to solve as many of these problems as possible.[4]

Detailed model solutions of the exercise problems (some with additional expansion of the lecture material), and several shorter problems suitable for tests (also with model solutions), are gathered in 6 separate files - one per semester. These files are available for both university instructors and individual readers – free of charge, but in return for a signed commitment to avoid unlimited distribution of the solutions (see the *Problem Solution Request Templates* file). For instructors, these files are available not only in the Adobe Systems' Portable Document Format (*.pdf) but also in the Microsoft Office 1997-2003 format (*.doc) free of macros, so that the problem assignments and solutions may be readily grouped, edited, etc., before their distribution to students, using either virtually any version of Microsoft Word or independent software tools - e.g., the public-domain OpenOffice.org.

I know that my texts are far from perfection. In particular, some sacrifices made at the topic selection, always very subjective, were extremely painful. (Most regretfully, I could not find time for even a brief introduction to general relativity.[5]) Moreover, it is very probable that despite all my effort and the great help from SBU students and teaching assistants, not all typos/errors have been weeded out. This is why all remarks (however candid) and suggestions by the readers would be highly appreciated; they may be sent to *klikharev@gmail.com*. All significant contributions will be gratefully acknowledged in future editions of the series.

Bose-Einstein condensates, Bloch oscillations and Landau-Zener tunneling, cavity QED, and the Density Functional Theory (DFT). All these topics are discussed, if only concisely, in these notes.

[3] Several graduate-level teaching materials are available online, including M. Fowler's *Graduate Quantum Mechanics Lectures* (http://galileo.phys.virginia.edu/classes/751.mf1i.fall02/home.html), R. Fitzpatrick's text on *Classical Electromagnetism* (farside.ph.utexas.edu/teaching/jk1/Electromagnetism.pdf), and B. Simons' lecture notes on *Advanced Quantum Mechanics* (www.tcm.phy.cam.ac.uk/~bds10/aqp.html), and D. Tong's lecture notes on several topics (www.damtp.cam.ac.uk/user/tong/teaching.html).

[4] The problems that require either more bulky calculations or more creative approaches (or both :-) are marked by stars.

[5] For an introduction to the subject, I can recommend either a review by S. Carroll, *Spacetime and Geometry*, Addison-Wesley, 2003, or a longer text by A. Zee, *Einstein Gravity in a Nutshell*, Princeton U. Press, 2013.