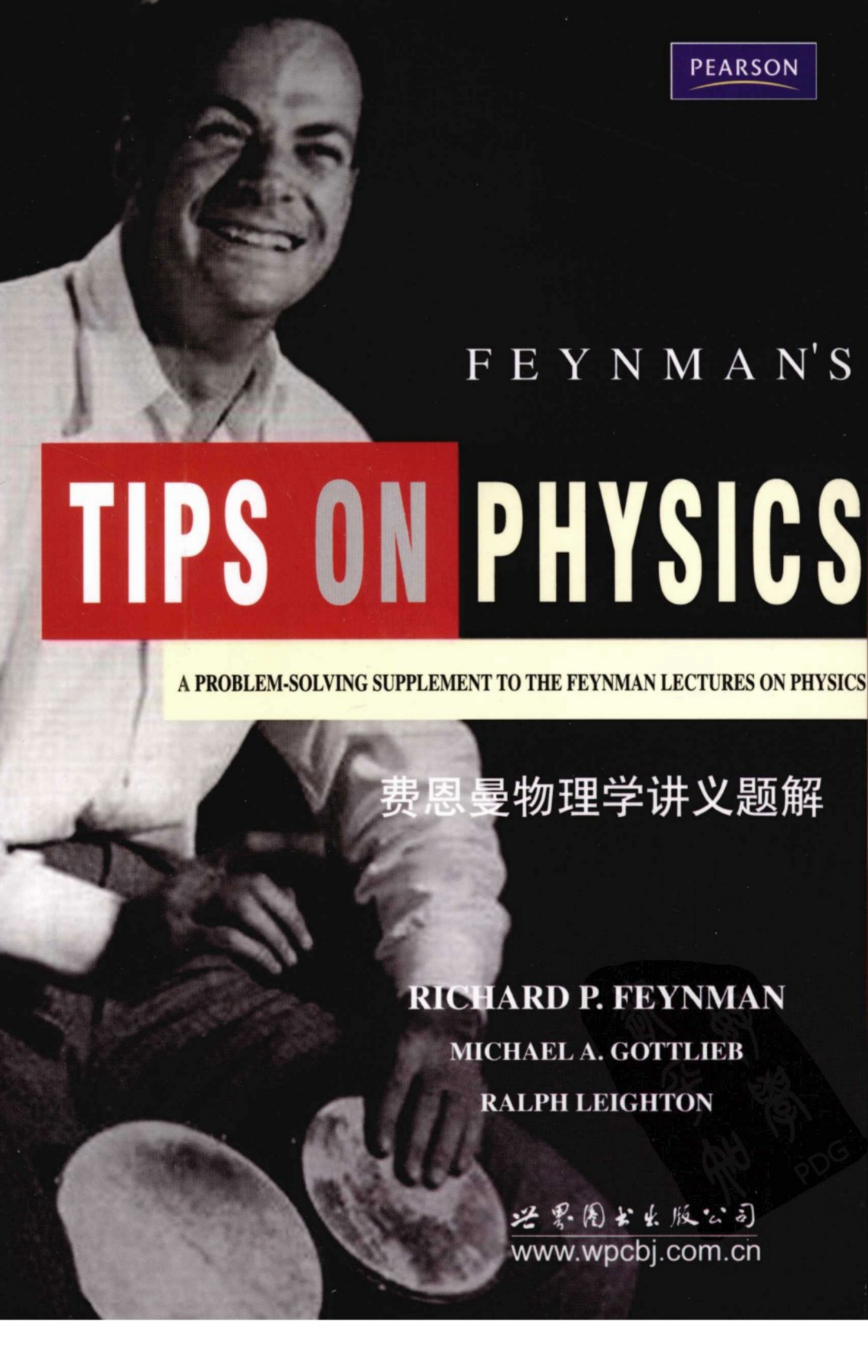

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FEYNMAN'S

TIPS ON PHYSICS

A PROBLEM-SOLVING SUPPLEMENT TO THE FEYNMAN LECTURES ON PHYSICS

费恩曼物理学讲义题解

RICHARD P. FEYNMAN
MICHAEL A. GOTTLIEB
RALPH LEIGHTON

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TIPS ON PHYSICS

A Problem-Solving Supplement to *The Feynman Lectures on Physics*

Richard P. Feynman

Michael A. Gottlieb

Ralph Leighton

With a Memoir by Matthew Sands

Exercises and Answers by
Robert B. Leighton and Rochus E. Vogt

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前言节译

……，几年前，在一次宴会上，我遇到了 Michael Gottlieb。宴会的主人在计算机屏幕上正播放着一位当红的图瓦族喉音歌手谐波泛音风格的演唱——这是使居住在旧金山附近的市民如此着迷的一件大事。Gottlieb 曾经研究过数学，对物理也很感兴趣。历此我建议他读一读《费恩曼物理学讲义》。大约一年以后，他花了他生命中的六个月时间，从头到尾专心致志地读完了这部讲义。正如 Gottlieb 在本书的引言中所述，这样做的结果最终导致了你现在读到的这本书，以及一部新的“权威版”的《费恩曼物理学讲义》。

我是这样的高兴，因为全世界对物理学感兴趣的读者现在都能研读附有这部增补材料的更正确和更完全版本的《费恩曼物理学讲义》——它将是一部在未来的几十年都会持续不断地为学生们提供丰富的知识和激发他们的灵感的不朽著作，不管他们是在曼哈顿的市中心还是在高高的喜马拉雅山上。

Ralph Leighton

2005 年 5 月 11 日

Richard Feynman, circa 1962

Introduction

I first heard of Richard Feynman and Ralph Leighton in 1986, through their entertaining book *Surely You're Joking, Mr. Feynman!* Thirteen years later I met Ralph at a party. We became friends, and over the next year we worked together on the design of a fantasy stamp honoring Feynman.[1] All the while Ralph was giving me books to read, by or about Feynman, including (since I am a computer programmer) *Feynman Lectures on Computation.*[2] The discussion of quantum mechanical computation in this fascinating book intrigued me, but without having studied quantum mechanics, I had difficulty following the arguments. Ralph recommended I read *The Feynman Lectures on Physics Volume III: Quantum Mechanics,* which I began, but Chapters 1 and 2 of *Volume III* are reproduced from Chapters 37 and 38 of *Volume I,* so I found myself backtracking through references in *Volume I* rather than progressing through *Volume III.* I therefore decided to read all *The Feynman Lectures* from beginning to end—I was determined to learn some quantum mechanics! However, that goal became secondary as time

[1]Our stamp appears in the liner notes of *Back TUVA Future,* a CD featuring the Tuvan throat-singing master *Ondar* and a cameo appearance by Richard Feynman (Warner Bros. 9 47131-2), released in 1999.

[2]*Feynman Lectures on Computation,* by Richard P. Feynman, edited by Anthony J.G. Hey and Robin W. Allen, 1996, Addison-Wesley, ISBN 0-201-48991-0.

went on and I became increasingly absorbed in Feynman's fascinating world. The joy of learning physics, simply for the pleasure of it, became my highest priority. I was hooked! About halfway through *Volume I,* I took a break from programming and spent six months in rural Costa Rica studying *The Lectures* full-time.

Every afternoon I studied a new lecture and worked on physics problems; in the mornings I reviewed and proofread yesterday's lecture. I was in e-mail contact with Ralph, and he encouraged me to keep track of errors I mentioned encountering in *Volume I.* It was not much of a burden, because there were very few errors in that volume. However, as I progressed through *Volumes II* and *III,* I was dismayed to discover increasingly more errors. In the end I had compiled a total of more than 170 errors in *The Lectures.* Ralph and I were surprised: how could so many errors have been overlooked for so long? We decided to see what could be done about getting them corrected in the next edition.

Then I noticed some intriguing sentences in Feynman's preface:

"The reason there are no lectures on how to solve problems is because there were recitation sections. Although I did put in three lectures in the first year on how to solve problems, they are not included here. Also there was a lecture on inertial guidance which certainly belongs after the lecture on rotating systems, but which was, unfortunately, omitted."

This suggested the idea of reconstructing the missing lectures and, if they proved interesting, offering them to Caltech and Addison-Wesley for inclusion in a more complete and error-corrected edition of *The Lectures.* But first I had to *find* the missing lectures, and I was still in Costa Rica! Through a bit of deductive logic and investigation, Ralph was able to locate the lecture notes, which were previously hidden away somewhere between his father's office and the Caltech Archives. Ralph also obtained tape recordings of the missing lectures, and while researching errata in the Archives after my return to California, I fortuitously discovered the blackboard photos (long believed lost) in a box of miscellaneous negatives. The Feynman heirs generously gave us permission to use these materials, and so, with some useful critiques from Matt Sands, now the only surviving member of the Feynman-Leighton-Sands trio, Ralph and I reconstructed *Review B* as a sample, and presented it with the errata for *The Lectures* to Caltech and Addison-Wesley.

Addison-Wesley received our ideas enthusiastically, but Caltech was initially skeptical. Ralph therefore appealed to Kip Thorne, the Richard Feynman Professor of Theoretical Physics at Caltech, who eventually managed to achieve a mutual understanding among all involved, and who generously volunteered his time to oversee our work. Since Caltech did not want

to amend the existing volumes of *The Lectures* for historical reasons, Ralph proposed putting the missing lectures in a separate book. That is the origin of this supplementary volume. It is being published in parallel with a new *Definitive Edition* of *The Feynman Lectures on Physics,* in which the errors I found are corrected, as are other errors found by a number of other readers.

Matt Sands' memoir

In our quest to reconstruct the four lectures, Ralph and I had many questions. We felt very fortunate to be able to get answers from Professor Matt Sands, the man whose idea it was to embark on the ambitious project that produced *The Feynman Lectures on Physics.* We were surprised that the story of their genesis was not widely known, and realizing that this project offered an opportunity to remedy that deficit, Professor Sands kindly agreed to write a memoir on the origins of *The Feynman Lectures* for inclusion in this supplement.

The four lectures

From Matt Sands we learned that in December 1961, toward the end of the first term[3] of Feynman's Caltech freshman physics course, it was decided that it would be unfair to introduce new material to the students just a few days before the final exam. So, for the week preceding the test, Feynman gave three optional review lectures, in which no new material was introduced. The review lectures were intended for students having difficulties in the class, and emphasized techniques for understanding and solving physics problems. Some of the example problems were of historical interest, including the discovery of the atomic nucleus by Rutherford, and the determination of the mass of the pi meson. With characteristic human insight, Feynman also discussed the solution to another kind of problem, equally important to at least half the students in his freshman class: the emotional problem of finding oneself below average.

The fourth lecture, *Dynamical Effects and Their Applications,* was given early in the second term of the freshman class, shortly after the students returned from winter break. Originally, it was to be *Lecture 21,* and the idea behind it was to take a rest from the difficult theoretical discussion of

[3]The academic year at Caltech is divided into three terms; the first runs from late September to early December, the second from early January to early March, and the third from late March to early June.

rotations presented in Chapters 18 through 20 and show the students some interesting applications and phenomena that arise from rotations, "just for entertainment." Most of the lecture was devoted to a discussion of technology that was relatively new in 1962: practical inertial guidance. The remainder of the lecture discussed natural phenomena that arise from rotations, and also offered a clue as to why Feynman described the omission of this lecture from *The Feynman Lectures on Physics* as "unfortunate."

After the lecture

After ending a lecture Feynman often left his microphone on. This has provided us with the unique opportunity of witnessing how Feynman interacted with his undergraduate students. The example given here, recorded after *Dynamical Effects and Their Applications,* is particularly noteworthy for its discussion of the incipient transition in real-time computing from analog to digital methods in 1962.

The exercises

In the course of this project Ralph reestablished contact with his father's good friend and colleague Rochus Vogt, who graciously gave his permission to republish exercises and solutions from *Exercises in Introductory Physics,* the collection that Robert Leighton and he had created especially for *The Lectures* back in the 1960s. Due to space limitations I chose only exercises for *Volume I,* Chapters 1 through 20 (the material covered before *Dynamical Effects and Their Applications*), preferring problems that, to quote Robert Leighton, "are numerically or analytically simple, yet incisive and illuminating in content."

Website

Readers are invited to visit www.feynmanlectures.info for more information on this volume and *The Feynman Lectures on Physics.*

Mike Gottlieb
Playa Tamarindo, Costa Rica
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We wish to express our heartfelt thanks to all who made this book possible, especially:

Thomas Tombrello, Chairman of the Physics, Mathematics, and Astronomy Division, for approving this project on behalf of Caltech, and **Carl Feynman and Michelle Feynman,** heirs to Richard Feynman, for their permission to publish their father's lectures in this book;

Matthew Sands, for his wisdom, knowledge, constructive comments, and suggestions;

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Rochus E. Vogt, for the ingenious problems and answers in *Exercises in Introductory Physics,* and for his permission to use them in this volume;

John Neer, for studiously documenting Feynman's lectures at the Hughes Aircraft Corporation, and for sharing those notes with us;

Helen Tuck, Feynman's secretary for many years, for her encouragement and support,

Adam Black, Editor-in-Chief for Physical Sciences at Addison-Wesley, for his enthusiasm and perseverance in bringing this volume to print, and

Kip Thorne, for his grace and tireless work securing the trust and support of everyone involved, and for overseeing our work.

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On the Origins of The Feynman Lectures on Physics

A MEMOIR BY MATTHEW SANDS

Education reform in the 1950s

When I first became a regular faculty member at Caltech in 1953, I was asked to teach some graduate courses. I found myself quite dismayed about the course program for the graduate students. During the first year they were given courses only in classical physics—mechanics and electricity and magnetism. (And even the E and M class covered only statics, no radiation theory at all.) I thought it was disgraceful that these hotshot students were not exposed to the ideas of modern physics (many of which had already been around for 20 to 50 or more years) until their second or third year in grad school. So I began a campaign to reform the program. I had known Richard Feynman since our days at Los Alamos, and we had both come to Caltech a few years back. I asked Feynman to join the campaign, and we outlined a new program and eventually persuaded the physics faculty to adopt it. The first year program consisted of a course in Electrodynamics and Electron Theory (taught by me), Introductory Quantum Mechanics (taught by Feynman), and, as I recall, a course in Mathematical Methods, taught by Robert Walker. I think that the new program was quite successful.

At about that time Jerrold Zacharias of MIT was stimulated by the appearance of *Sputnik* to push for a program to revitalize the teaching of high school physics in the United States. One result was the creation of the PSSC (Physical Science Study Committee) program, and the generation of many new materials and ideas, as well as some controversy.

When the PSSC program was nearing its completion, Zacharias and some colleagues (I believe among them Francis Friedman and Philip Morrison) decided that it was time to tackle also a revision of university physics. They organized a couple of large meetings of physics instructors, out of which came the formation of the Commission on College Physics, a national committee of a dozen university physics instructors, which was