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大学电子信息科学与技术英汉实验丛书

大学物理实验

吴宗森 王均义 于广亮 编著



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University Physics Experiment

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大学电子信息科学与技术英汉实验丛书

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序

为了培养高质量的人才,在高等学校的教学计划中,应该充分重视实验课的设置,并把课程的各个环节抓紧、抓好。尤其在本科生阶段,更要让学生接受全面的训练,从常见仪器的使用、基本量的测量,到按照一定的要求搭建系统以满足特定的性能指标,到有意地探寻和隔离非主要因素、探寻和突出主要因素,并观察其对于最终结果的影响。这样,由易而难、由简单而复杂,环环相扣、步步升高,教学工作才能扎实有效。

南京大学电子科学与工程学院李元教授长期从事电子技术教学工作,对于实验教学一向十分重视。他转往南京大学金陵学院后,一度执掌全院教务处和信息科学与工程学院的领导岗位。在他的带领下,陈孝桢教授、吴宗森教授、王均义教授、沈一骑高工、何菁博士等一批在大学电子信息科学与技术领域内有重要影响的专家学者齐心协力,先后开设了模拟电路实验、数字电路实验、电工学综合实验、通信原理实验、嵌入式系统实验、大学物理实验等课程,并编写了相应的教材,集结为丛书。经过多年的使用和实践,证明这些课程和教材在基础的层面上恰如其分地反映了学科发展的趋势,符合当前学生的实际,对于培养学生的独立工作能力发挥了很好的作用,也得到了国内同行的高度认同。

这些课程和教材也吸引了国外同行的注意,有英国 ESSEX 大学、法国勒芒大学、加拿大罗里尔大学、日本北海道情报大学等学校主动要求交流。可惜,由于教材原来都用中文写成,语言的障碍使有关部门无法把这些教材送往国外,或者送出后没有起到其应有的作用。与此同时,随着学校国际化程度的日益提高,在学生这一层面上的涉外活动也不断增多,要求学校在关心学生能否通过四级或六级英语考试的同时,注意加强对他们专业英语能力的培养。

这样,李元等教授就萌发了一个想法,将原有的实验教材进行重新整理、出新,并进行初译,然后交由吴宗森教授、加拿大罗里尔大学 Sturtevant 教授进行英语文字上的加工与译审,使之成为英汉实验丛书,正式出版以飨国内外广大读者。

我很高兴地得知,经过有关教授一年多的努力,这套英汉实验丛书即将完成,并陆续付印。希望这套丛书的出版,对于培养我国电子信息科学与技术领域的专门人才、对于促进国际交流都能有所裨益。

吴培亨

南京大学教授
中国科学院院士

2013. 12

Preface

Welcome to "University Physics Labs". The information age is upon us, but physics is still and will remain to be the foundation and the core of natural science. It follows that physics holds its place as one of the basic and compulsory courses for students majoring in Information Science and Engineering. And the developments and discoveries in modern sciences and technology are invariably bonded with physics. Years ago an international poll was held to nominate ten scientists worldwide in terms of their contributions to sciences and their influences on sciences as well as on mankind. Over half of the scientists selected turned out to be physicists. This clearly shows how closely related is human activities to physics. And physics experiment is an integral part of physics. It can safely be said that a physics theory is vulnerable without the verification of its physics experiment. In the history of the past century no Nobel Prize for Physics has been reportedly awarded to any physicists without the proof of scientific experiments. This indicates what important roles physics experiments play in scientific research.

Before getting involved into any specific experiments, a basic and preparatory knowledge concerning many frequently occurring experiment errors is provided in the first chapter of this book. Many issues related to analyses of experimental uncertainties, including the sources the uncertainties come from, the quantitative calculations and analyses of the errors. Also the data processing and graphing are discussed in introductory study.

Our physics labs include three parts: the mechanics and vibrations, electricity and optics as well. The first part involves with kinematics, dynamics, mechanics of materials and vibrations including several classic experiments. The second part includes the electrical experiments, which are related to DC bridge, Hall effect, Lissajous Pattern, and DC circuit analysis using Excel. Finally, the optical experiments consist of the following experiments: reflection and refraction of light, optical spectrometer, Newton's ring, Photoelectric effect and basic characteristics related to lasers.

The book is written in English, but to make it easier for some Chinese students, we have attached “Brief Introduction of the Lab”, “Scientific Vocabularies” and “Notes” in Chinese. The writers of this book began to use this book from Sept. 2013, with bilingual lecturing and instructing. The course was well received by students who not only listened with concentration in class but also enjoyed the challenge of writing their lab reports in English. Through our personal experience we are deeply aware of the toughness of teaching natural sciences in native and world languages interchangeably. But while we feel our attempt of bilingual teaching in universities well worthwhile and rewarding, we found a nationwide difficulty in this practice owing to a lack of qualified teachers and availability of lab textbooks. This book is attempted to fill in, at least in a limited way, the gap. We believe strongly most of our students in colleges or universities are ready to take bilingual science courses.

The three writers of this book are all graduates from Nanjing University but in different years and through different experiences. The book not only features the traditional rigorous training style of physics experiment of Nanjing University but also is a reflection of our teaching careers both in China and in other parts of the world. We take this opportunity to express our heartfelt gratitude to our predecessors. We owed our thanks to Terry Sturtevant for his contribution for the original works in the labs. In the course of writing and editing the book Zhang Jianrong gave us a great support. Jin Lingchen and Yu Hai sent us unselfishly dedicated efforts to assist us with drawing and illustrations, shooting photos and preparing laboratory equipment before and during the labs. We would like to express our sincere thanks to them. Without their help this book is impossible to come out.

Wu Zongsen, Wang Junyi and Yu Guangliang

前言

欢迎来到“大学物理实验”。尽管信息时代已经到来,但是,物理学仍然是,将来也必然是一切自然科学的基础和核心。理所当然,物理学也是大学信息科学和工程专业的必修基础课程。近现代科学和技术的发展无一例外地与物理学息息相关。国内外前些年就近代史上对科学本身的贡献和对人类的影响力投票选择十大科学家,结果揭晓这十大科学家中一半以上是物理学家。由此可见,物理学和人类活动有着多么密切的联系。物理实验又是物理学不可分割的左膀右臂。倘若一个物理理论得不到物理实验的验证,其生命力必定是脆弱的。百年历史上,尚无诺贝尔物理学奖颁给得不到物理实验证实的物理学家的纪录,这表明了物理学实验有多么重要。

进入物理实验之前,本书的物理实验之基本知识讨论了有关实验误差的许多问题,包括实验不确定性的来源,误差的定量计算和分析,以及数据作图和曲线拟合的有关问题。

本书的物理实验包括了物理学的三大部分:力学和振动、电学、光学。第一部分的力学和振动的实验囊括了运动学、动力学、材料力学及振动的几个经典实验。它们分别是:球体和圆柱体的下落和滚动,单摆和物理摆,杨氏模量,弦上的行波和驻波。第二部分是电学实验,它们分别是:利用直流电桥测量电解质的电导率,霍尔效应,用示波器上李萨如图形测量空气中的声速,利用发光二极管测定普朗克常数,以及使用电子制表软件分析DC电路。第三部分是光学实验,它们分别是:平行光束在球形界面上的反射和折射,用分光计测定三棱镜的折射率,光的干涉,光电效应,和激光束的基本特性。

本书一共有十四个实验,每个实验都由目的(Purpose)、理论(Theory)、实验设备(Apparatus)、实验步骤(Procedure)和计算(Calculation)组成。我们格外重视训练学生的分析能力,特别是分析物理测量中不确定性(Uncertainty)的来源和误差的定量计算。全书以英语为主,但是照顾到不同层次学生的实际需要,在全英语叙述实验之后,我们还用中文的“实验简介”、“科技词汇”和“注释”对实验做了详细介绍,也对实验中的疑难生词和句子加以解释。

我们自2013年开始用双语教学法在部分学生中试用本教材。令人欣慰的是大部分学生都欢迎和接受我们的教材和双语教学法。学生们不仅兴趣盎然地听老师的英语(或双语)授课,而且,他们也认真地用英语书写物理实验报告。我们从实践中深切地体会到,我国双语(即英语和汉语)教学在自然科学领域虽然看上去相当沉寂,但是前途其实相当

光明。目前高校双语教学的困难来源于缺乏训练有素的双语教师和可供使用的双语教材,而这本教材正好可以弥补这一现状。我们的试验有力地证明了,只要教师合格,教材可取,学生不是问题。目前绝大多数大学学生经过小学和中学十多年的英语学习,已经具备了接受自然科学双语教学的良好基础。

我们三人都毕业于南京大学物理系,虽然经历了不同的年代和岁月。我们编写的这本教材既保留了南京大学物理实验教学一贯的严谨作风,又渗透了我们在国内外物理教学的经历中留驻的痕迹。借此机会,我们向南京大学物理系的前辈们表示由衷的感谢。Terry Sturtevant 在加拿大 WLU 的前期工作对这本书的编写无疑十分重要,我们向他表示敬意。在编著本书的过程中,章建荣给予了我们大力的支持,金凌晨和俞海在本书中的插图绘制、照片拍摄和实验室器材准备方面给予了我们全力的协助和支援,在此谨向他们表示衷心的感谢。

吴宗森 王均义 于广亮

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Lesson 1-1 Forwards about Labs

第1课 实验前言

It's not that I'm so smart, it's just that I stay with problems longer.

—Albert Einstein

Objectives about labs

Chapter 1 Fundamentals of Physics Labs

through space and time, along with related concepts such as energy and force. More broadly, it is the **fundamental analysis of nature to understand how the universe behaves.**

第1章 物理实验之基本知识

Learning physics is not only about understanding the theory, but also about doing physics experiments. The importance of physics experiments is not only in understanding, verifying and finding the laws of physics through the labs, but also any remarkable breakthrough in physics always is related strongly to physics experiments.

With the rapid developments of physics in the recent decades, the relationship of physics with physics labs is closer than ever. Consequently, students are in need to be familiar with the basic labs like mechanics, waves, photonics, electricity, heat, magnets and semiconductors. Also, cultivating and training interdisciplinary intellectuals have become a urgent task for our universities. Especially, our students are required to know modern optics, optical fiber communication technologies, sensor technologies, modern biology, modern material science, and so on. The students are required not only to understand and follow all experimental steps, but also discover the basic physics laws behind the data they obtained from the labs.

The goal of physics labs is as follows:

- ① Establishing and extending the basic skill for physics experiments;
- ② Verifying the existed physics laws and theories;
- ③ Studying how to implement, operate and eventually design experiments to explore new phenomena and laws in physics.

Physics experiment requirements

1. Pre-Lab Prepare Request

Before stepping in the physics laboratories, students are required to understand

Lesson 1-1 Forwards about Labs

第 1 课 实验前言

It's not that I'm so smart, it's just that I stay with problems longer.

—Albert Einstein

Objectives about labs

Physics is the natural science that involves the study of matter and its motion through space and time, along with related concepts such as energy and force. More broadly, it is the general analysis of nature to understand how the universe behaves.

Learning physics can not take place completely and successfully without doing physics experiments. The importance of physics experiments is not only in understanding, verifying and finding the laws of physics through the labs, but also any remarkable breakthrough in physics always is related strongly to physics experiments.

With the rapid developments of physics in the recent decades, the relationship of physics with physics labs is closer than ever. Consequently, students are in need to be familiar with the basic labs like mechanics, waves, photonics, electricity, heat, magnets and semiconductors. Also, cultivating and training interdisciplinary intellectuals have become a urgent task for our universities. Especially, our students are required to know modern optics, optical fiber communication technologies, sensor technologies, modern biology, modern material science, and so on. The students are required not only to understand and follow all experimental steps, but also discover the basic physics laws behind the data they obtained from the labs.

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Physics experiment requirements

1. Pre-Lab Prepare Request

Before stepping in the physics laboratories, students are required to understand:

① What are the main purposes of the lab?

② What is the related background?

③ How is the experiment going on?

④ What are the experimental procedures?

If available please browse the internet for the query or investigation on the corresponding experiments and relevant keywords for both Chinese or English. Try to understand what the content you should do in this lab and sum up the experiment in your own words. If any doubt occurs, you do your own thought first and later ask the lab instructors if necessary. These steps are critical for leading to a success of your experiment.

2. The experimental class requirements

During the period of experiments, you focus on the labs with a constant care and alertness, compare the part of theory with the experiment data, seize the key points, study the physics principle and understand the essence behind the phenomenon you observe.

Most fresh students do not know how to use the instrument properly in the lab, however, it is a big help to read the manuals carefully before starting your experiment. It certainly helps you to reduce or avoid the unnecessary mistakes and overcome obstacles for operating your instruments. Please be familiar with the frequently employed instruments or devices, such as multimeters, oscilloscopes, and function generators for instruments, verniers and calipers for devices.

If the equipment is more complex, you must read the operation manual, or check the manual on line. Never rely solely on the teacher. If you assume that you can count on the teacher, that is definitely wrong! While exploring the complex instruments, the simple way to regard it as a black box approach, to understand the relationship between input and output parameter, minimize all influence of instrument itself, so you can do labs with your heart, not distracted by complex instruments operation.

3. The data recording and processing of the experiment

The most precious things are the experimental raw data and various outputs of intermediate results, such as output waveforms, the output images. Some raw data can be stored directly in the equipments used, like digital oscilloscopes. If you have flash disk in hand, just copy it and use it later when you deal with the experimental data for your calculation and analysis.

Your data of measurements should accompany with the measurement uncertainties, recording precision, and system zero error, etc. Always keep them together in your mind.

It is extremely important that you have a right and obligation to record and copy the original data from your measurements, however, you prohibit to create or change your

data which is the crime of falsification of data. Never think about it and never touch it!

4. The lab report

The Lab report is a comprehensive summary of the experimental data after the experiment, a complete report should include the following contents:

- ① The lab title, lab room number, lab tutor and date;
- ② The purpose of the experiment;
- ③ The lab background and physics principle;
- ④ A list of lab apparatus used;
- ⑤ Experimental procedures;
- ⑥ Recorded experimental data;
- ⑦ Calculations and uncertainties analysis and discussion;
- ⑧ A summary and conclusion with your own words or the problem you solved.

Students are encouraged to write down their personalized summaries and conclusions, also the calculation and uncertainty analysis are very important to reflect how well the students are involved with the labs during and after the labs.

本课简介

本课介绍物理实验的重要性和基本要求。

在第一段物理实验的目的中讲到,学习物理实验的目的有三点:①建立和增强基本的实验技能;②验证现有的物理定律和理论;③学会如何安装、操作及最终设计探索物理新现象的实验。

在第二段的实验要求中,首先提出实验预习时,要求知道:①实验的目的是什么;②实验是如何进行的;③相关的背景是什么;④实验的步骤是哪些。其次,在实验课进行时,要不断查阅所使用仪器设备的说明书,不要仅仅依赖于老师的回答。记录和处理数据时,要忠实于原始数据,切忌伪造数据,那可是一种犯罪。

最后一段,讲叙如何书写实验报告。它通常由八个方面组成:①实验名称、实验室房间号、实验教师和时间;②实验目的;③实验背景和物理原理;④实验仪器清单;⑤实验步骤;⑥记录的实验数据;⑦计算和误差分析及讨论;⑧总结和结论。

科技词汇

multimeter

oscilloscope

function generator

vernier

caliper

falsification of data

万用电表

示波器

函数信号发生器

测径仪

游标尺

伪造数据

uncertainty analysis

system zero error

lab title

with your own words

personalized summary

不确定性分析

系统零点误差

实验题目

用自己的语言

个性化的小结

注 释

1. It's not that I'm so smart, it's just that I stay with problems longer.

—Albert Einstein

并非我聪明,而是我在坚持。

——爱因斯坦

2. Learning physics can not take place completely and successfully without doing physical experiments. The importance of physical experiments is not only in understanding, verifying and finding the laws of physics through the labs, but also any remarkable breakthrough in physics always is related strongly to physics experiments.

不做物理实验是无法全面和出色地完成物理学习的。物理实验的重要性不仅在于通过实验去理解、证实和发现物理规律,而且,任何物理学中重大的突破总是和物理实验密不可分。

3. Most fresh students do not know how to use the instrument properly in the lab, however, it is a big help to read the manuals carefully before starting your experiment. It certainly helps you to reduce or avoid the unnecessary mistakes and overcome obstacles for operating your instruments. Please be familiar with the frequently employed instruments or devices, such as multimeters, oscilloscopes, and function generators for instruments, verniers and calipers for devices.

由于大多数入学的新生不知道如何正确地使用实验室里的仪器,因此,在动手操作之前仔细阅读实验手册会给你很大帮助。它会让你降低或避免许多不必要的错误,克服操作上的障碍。务必熟悉常用的仪器和器件,如万用电表、示波器、函数信号发生器等仪器,测径仪及游标尺等器具。

4. Your data of measurements should accompany with the measurement uncertainties, recording precision, and system zero error, etc. Always keep them together in your mind.

你的测量数据必须附上测量不确定性,记录精度,以及系统的零点误差。时刻记住把它们记录在一起,缺一不可。

5. It is extremely important that you have a right and obligation to record and copy the original data from your measurements, however, you are prohibited to create or change your data which is the crime of falsification of data. Never think about it and never touch it!

特别重要的是,你有权利和义务记录和誊写你的原始数据,但是绝不可制造或篡改数