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Ashley H. Carter

热力学与统计物理简明教程

Classical and Statistical Thermodynamics

Ashley H. Carter

PEARSON Education

清华大学出版社

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Classical and Statistical Thermodynamics

影 印 版 序

热力学与统计物理学是物理学专业的一门重要专业基础理论课，是物理学专业主要骨干课程即理论物理学的四大分支之一。通过本课程的学习，使学生对热学理论的认识进一步深化。它对于物理专业的其他后续课程的学习以及从事相关科研都具有重要意义。随着量子信息、集成电路等高科技快速发展，通信、电子工程专业也需要适当地增设量子力学和热力学与统计物理等课程。

根据教育部颁发的教高[2001]4号文件《关于加强高等学校本科教学工作提高教学质量的若干意见》中的第8条关于“积极推动使用英语等外语进行教学”的意见中“暂不具备直接用外语讲授条件的学校、专业，可以对部分课程先实行外语教材、中文授课，分步到位”的建议，使用英语的原版教材有助于我国高校更新专业知识、拓宽专业视野，快速接近世界学术前沿、了解学科最新成果和进展。原版教材中所蕴涵的新的教学思想可以开阔教师的教学思路,可使教师和学生大受裨益。进入新世纪，越来越多地教育界人士认识到在本科教学中适当引进和借鉴国外名牌大学的原版教材，实行双语教学，是一条跟世界接轨的捷径，对培养人才和使我国大学教育水平跻身世界前列都有很大帮助。通过双语教学不仅可以提高学生的外语能力，而且能够使学生更好地学习专业理论知识，了解世界前沿水平的新技术、新知识，同时掌握解决实际问题的能力。

目前国内流行的教材如《热力学统计物理》（汪志诚）和《热力学与统计物理学》（马本昆、高尚惠、孙煜），其主要内容有：热力学的基本规律；均匀物质的热力学性质；单元系的相变；多元系的复相平衡和化学平衡；不可逆过程热力学简介，近独立粒子的最概然分布；玻耳兹曼统计；玻色统计和费米统计、系综理论、涨落理论、非平衡态统计理论初步。基于它们的教学内容多、理论性强的特点，较适合于理科院校物理系学生使用，讲授学时一般为72学时。由于一些工科院校计划学时大约为46学时，因此它们不太适用于目前工科院校中应用物理、电子信息类专业的教学。

美国诸伍大学（Drew University）著名教授 Ashley H.Carter 既是学者，又是教师，具有丰富的教学实践经验。他编著的教材 *Classical and Statistical Thermodynamics* 主要讲授的是平衡态热力学和统计物理。从第1章到第10章，

以热力学的四个实验定律（即热力学第零、第一、第二、第三定律）为主线讲授了平衡态热力学。在第1、2章给出了温度和平衡态等基本概念；第3、4、5章介绍了热力学第一定律及其应用；在第6、7章介绍了热力学第二定律及其应用；在第8、9、10章介绍了热力学特性函数、麦克斯韦关系式、开放系统热力学、相变、吉布斯相律及热力学第三定律。从第11章到第19章，讲授了平衡态统计物理，主要介绍了气体动理论、玻耳兹曼统计、玻色统计、费米统计、气体和固体的热容、玻色气体和费米气体的性质。在第20章介绍了信息论的基本概念及其应用。

Classical and Statistical Thermodynamics 与国内目前同类教材相比较，不涉及不可逆过程热力学、涨落理论和非平衡态统计理论。知识点比较符合我国少课时、对本课程内容要求相对较低的一些工科院校实际情况和教学大纲要求。另外，该书增加了信息论方面的教学内容。信息论的基本原理在通信理论、电子信息、计算机科学、统计学、概率论等领域都有广泛的应用。特别是对于目前学术界的热门研究课题如“量子通信”、“量子计算的理论与实验研究”、“量子信息”等，信息论都是必不可少的理论基础。

另外，本书内容全面、系统，信息量大；章节划分细致，结构清晰，层次分明；数据翔实，图表案例丰富；语言纯正、表达生动，逻辑性强；习题量大，习题大多结合实际，具有实用性，且具有一定难度，帮助学生在学习中掌握重点、理解难点，及时补充遗漏点。

吴振森

2007.10.15

Preface

This book is intended as a text for a one-semester undergraduate course in thermal physics. Its objective is to provide third- or fourth-year physics students with a solid introduction to the classical and statistical theories of thermodynamics. No preparation is assumed beyond college-level general physics and advanced calculus. An acquaintance with probability and statistics is helpful but is by no means necessary.

The current practice in many colleges is to offer a course in classical thermodynamics with little or no mention of the statistical theory—or vice versa. The argument is that it is impossible to do justice to both in a one-semester course. On the basis of my own teaching experience, I strongly disagree. The standard treatment of temperature, work, heat, entropy, etc. often seems to the student like an endless collection of partial derivatives that shed only limited light on the underlying physics and can be abbreviated. The fundamental concepts of classical thermodynamics can easily be grasped in little more than half a semester, leaving ample time to gain a reasonably thorough understanding of the statistical method.

Since statistical thermodynamics subsumes the classical results, why not structure the entire course around the statistical approach? There are good reasons not to do so. The classical theory is general, simple, and direct, providing a kind of visceral, intuitive comprehension of thermal processes. The physics student not confronted with this remarkable phenomenological conception is definitely deprived. To be sure, the inadequacies of classical thermodynamics become apparent upon close scrutiny and invite inquiry about a more fundamental description. This, of course, exactly reflects the historical development of the subject. If only the statistical picture is presented, however, it is my observation that the student fails to appreciate fully its more abstract concepts, given no exposure to the related classical ideas first. Not only do classical and statistical thermodynamics in this sense complement each other, they also beautifully illustrate the physicist's perpetual striving for descriptions of greater power, elegance, universality, and freedom from ambiguity.

Chapters 1 through 10 represent a fairly traditional introduction to the classical theory. Early on emphasis is placed on the advantages of expressing the fundamental laws in terms of state variables, quantities whose differentials are exact. Accordingly, the search for integrating factors for the differentials of work and heat is discussed. The elaboration of the first law is followed by chapters on applications and consequences. Entropy is presented both as a useful mathematical variable and as a phenomenological construct necessary to explain why there are processes permitted by the first law that do not occur in nature. Calculations are then given of the change in entropy for various reversible and irreversible processes. The thermodynamic potentials are broached via the Legendre transformation following elucidation of the rationale for having precisely four such quantities. The conditions for stable equilibrium are examined in a section that rarely appears in undergraduate texts. Modifications of fundamental relations to deal with open systems are treated in Chapter 9 and the third law is given its due in Chapter 10.

The kinetic theory of gases, treated in Chapter 11, is concerned with the molecular basis of such thermodynamic properties of gases as the temperature, pressure, and thermal energy. It represents, both logically and historically, the transition between classical thermodynamics and the statistical theory.

The underlying principles of equilibrium statistical thermodynamics are introduced in Chapter 12 through consideration of a simple coin-tossing experiment. The basic concepts are then defined. The statistical interpretation of a system containing many molecules is observed to require a knowledge of the properties of the individual molecules making up the system. This information is furnished by the quantum mechanical notions of energy levels, quantum states, and intermolecular forces. In Chapter 13, the explication of classical and quantum statistics and the derivation of the particle distribution functions is based on the method of Lagrange multipliers. A discussion of the connection between classical and statistical thermodynamics completes the development of the mathematical formulation of the statistical theory. Chapter 14 is devoted to the statistics of an ideal gas. Chapters 15 through 19 present important examples of the application of the statistical method. The last chapter introduces the student to the basic ideas of information theory and offers the intriguing thought that statistical thermodynamics is but a special case of some deeper, more far-reaching set of physical principles.

Throughout the book a serious attempt has been made to keep the level of the chapters as uniform as possible. On the other hand, the problems are intended to vary somewhat more widely in difficulty.

In preparing the text, my greatest debt is to my students, whose response has provided a practical filter for the refinement of the material presented herein.

A.H.C.
Drew University

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Without all of these people, the book would never have seen the light of day.

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