

Solutions to the problems in Chapter 6 and 7

6.3 Pressure of a Fermi gas at zero temperature

The number of electrons N and the internal energy U , in the volume V , are

$$N = V \int_0^\infty D(\varepsilon) f(\varepsilon) d\varepsilon, \quad U = V \int_0^\infty \varepsilon D(\varepsilon) f(\varepsilon) d\varepsilon. \quad (1)$$

The Fermi distribution function $f(\varepsilon)$ and the density of states (per unit volume) $D(\varepsilon)$ are

$$f(\varepsilon) = \frac{1}{e^{\beta(\varepsilon - \mu)} + 1}, \quad D(\varepsilon) = A\sqrt{\varepsilon}, \quad A = \frac{\sqrt{2m^3}}{\pi^2 \hbar^3}. \quad (2)$$

At zero temperature

$$f(\varepsilon) = \theta(\varepsilon_F - \varepsilon), \quad \varepsilon_F = \frac{\hbar^2 k_F^2}{2m}, \quad k_F = (3\pi^2 n)^{1/3} \quad (3)$$

Introducing the step function and $D(\varepsilon) = A\sqrt{\varepsilon}$ in (1), we may determine $U(0)$ and an alternative expression for A :

$$N = V \int_0^{\varepsilon_F} A\sqrt{\varepsilon} d\varepsilon = \frac{2}{3} V A \varepsilon_F^{3/2} \Rightarrow A = \frac{3n}{2\varepsilon_F^{3/2}}, \quad U(0) = V \frac{2}{5} A \varepsilon_F^{5/2} = \frac{2}{5} N \varepsilon_F \quad (4)$$

i.e. $U \propto \varepsilon_F \propto k_F^2 \propto V^{-2/3}$ and the pressure at zero temperature is

$$P = -\frac{\partial U(0)}{\partial V} = \frac{2}{3} \frac{U}{V} = \frac{2}{5} n \varepsilon_F = \frac{(3\pi^2)^{2/3} \hbar^2 n^{5/3}}{5m} \quad (5)$$

in sharp contrast to a classical gas, where the zero-temperature pressure is zero.

6.4 Density of states in low dimensions

The density of states in $\vec{k}$ -space is $D_{\vec{k}} = 2/(2\pi)^d$ in d dimensions (6.34)

$$D(\varepsilon) = \int |d\vec{k}| \delta(\varepsilon - \varepsilon_{\vec{k}}) \equiv \int D_{\vec{k}} \delta(\varepsilon - \varepsilon_{\vec{k}}) d\vec{k} = \frac{2}{(2\pi)^d} \int \delta(\varepsilon - \varepsilon_{\vec{k}}) d\vec{k} \quad (1)$$

Introducing “spherical coordinates” in d dimensions and $k = |\vec{k}|$, then

$$d\vec{k} = \begin{cases} 2 dk & , \quad d = 1 \\ 2\pi k dk & , \quad d = 2 \\ 4\pi k^2 dk & , \quad d = 3 \end{cases} \quad (2)$$

The factor 2 in the one-dimensional case appears because the one-dimensional wave vector may assume both positive and negative values, whereas $k \geq 0$ per definition.

$$\varepsilon_{\vec{k}} = \varepsilon_k = \frac{\hbar^2 k^2}{2m} \quad \Rightarrow \quad k = \frac{\sqrt{2m\varepsilon_k}}{\hbar}, \quad dk = \left(\frac{m}{2\hbar^2 \varepsilon_k} \right)^{1/2} d\varepsilon_k \quad \Rightarrow \quad (3)$$

$$D(\varepsilon) = \begin{cases} \frac{2}{2\pi} \int_0^\infty 2 \delta(\varepsilon - \varepsilon_k) \left(\frac{m}{2\hbar^2 \varepsilon_k} \right)^{1/2} d\varepsilon_k = & \frac{\sqrt{2m}}{\pi \hbar} \varepsilon^{-1/2}, \quad d = 1 \\ \frac{2}{(2\pi)^2} \int_0^\infty 2\pi \frac{\sqrt{2m\varepsilon_k}}{\hbar} \delta(\varepsilon - \varepsilon_k) \left(\frac{m}{2\hbar^2 \varepsilon_k} \right)^{1/2} d\varepsilon_k = & \frac{m}{\pi \hbar^2}, \quad d = 2 \\ \frac{2}{(2\pi)^3} \int_0^\infty 4\pi \frac{2m\varepsilon_k}{\hbar^2} \delta(\varepsilon - \varepsilon_k) \left(\frac{m}{2\hbar^2 \varepsilon_k} \right)^{1/2} d\varepsilon_k = & \frac{\sqrt{2m^3}}{\pi^2 \hbar^3} \varepsilon^{1/2}, \quad d = 3 \end{cases}$$

Ashcroft And Mermin Chapter 1 Solutions

Claude Leroy, Pier-Giorgio Rancoita



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Princeton Problems in Physics with Solutions Nathan Newbury, Mark Newman, 2015-03-25 Aimed at helping the physics student to develop a solid grasp of basic graduate level material this book presents worked solutions to a wide range of informative problems These problems have been culled from the preliminary and general examinations created by the physics department at Princeton University for its graduate program The authors all students who have successfully completed the examinations selected these problems on the basis of usefulness interest and originality and have provided highly detailed solutions to each one Their book will be a valuable resource not only to other students but to college physics teachers as well The first four chapters pose problems in the areas of mechanics electricity and magnetism quantum mechanics and thermodynamics and statistical mechanics thereby serving as a review of material typically covered in undergraduate courses Later chapters deal with material new to most first year graduate students challenging them on such topics as condensed matter relativity and astrophysics nuclear physics elementary particles and atomic and general physics

Foundations of Nanomechanics Andrew N. Cleland, 2013-03-09 Why write another book on mechanics There are after all a number of excellent texts that describe in great detail the way classical solids behave when acted upon by static and time varying forces many of these are cited in this monograph These texts treat solids as continuous objects and quantum mechanics does not enter the discussion Furthermore the atomic nature of the solid is implicit but does not enter in a central role At the other end of the spectrum texts on condensed matter physics focus on the quantum mechanical nature of the solid these contain quite clear descriptions of acoustic waves in solids describing their dynamic and thermal properties and how they interact with electrons in the solid but contain little information regarding bulk deformations This text focussing on the mechanics of very small objects attempts to provide a link between these two approaches in addition to describing the theories of both the classical and the quantum mechanical solid I attempt to outline where the classical description breaks down and quantum mechanics must be applied to understand the behavior of a nanoscale object I have tried to merge the continuum description of the solid with the atomic one and to show how and where quantum mechanics plays a role especially as the size scale of the system is reduced making the quantized energy scale larger and the role of thermal vibrations more important

Solved Problems in Classical Electromagnetism J. Pierrus, 2018-08-02 Classical electromagnetism one of the fundamental pillars of physics is an important topic for all types of physicists from the theoretical to the applied The subject is widely recognized to be one of the most challenging areas of the physics curriculum both for students to learn and for lecturers to teach Although textbooks on electromagnetism are plentiful hardly any are written in the question and answer style format adopted in this book It contains nearly 300 worked questions and solutions in classical electromagnetism and is based on material usually encountered during the course of a standard university physics degree Topics covered include some of the background mathematical techniques electrostatics magnetostatics elementary

circuit theory electrodynamics electromagnetic waves and electromagnetic radiation For the most part the book deals with the microscopic theory although we also introduce the important subject of macroscopic electromagnetism as well Nearly all questions end with a series of comments whose purpose is to stimulate inductive reasoning and reach various important conclusions arising from the problem Occasionally points of historical interest are also mentioned Both analytical and numerical techniques are used in obtaining and analyzing solutions All computer calculations are performed with Mathematica^{CO} and the relevant code is provided in a notebook either in the solution or the comments

Fundamentals of Solid-state Electronics Chih-Tang Sah, 1991 This is perhaps the most comprehensive undergraduate textbook on the fundamental aspects of solid state electronics It presents basic and state of the art topics on materials physics device physics and basic circuit building blocks not covered by existing textbooks on the subject Each topic is introduced with a historical background and motivations of device invention and circuit evolution Fundamental physics is rigorously discussed with minimum need of tedious algebra and advanced mathematics Another special feature is a systematic classification of fundamental mechanisms not found even in advanced texts It bridges the gap between solid state device physics covered here with what students have learnt in their first two years of study Used very successfully in a one semester introductory core course for electrical and other engineering materials science and physics junior students the second part of each chapter is also used in an advanced undergraduate course on solid state devices The inclusion of previously unavailable analyses of the basic transistor digital circuit building blocks and cells makes this an excellent reference for engineers to look up fundamental concepts and data design formulae and latest devices such as the GeSi heterostructure bipolar transistors

Electromagnetic Waves Carlo G. Someda, 2017-12-19 Adapted from a successful and thoroughly field tested Italian text the first edition of *Electromagnetic Waves* was very well received Its broad integrated coverage of electromagnetic waves and their applications forms the cornerstone on which the author based this second edition Working from Maxwell's equations to applications in optical communications and photonics *Electromagnetic Waves Second Edition* forges a link between basic physics and real life problems in wave propagation and radiation Accomplished researcher and educator Carlo G Someda uses a modern approach to the subject Unlike other books in the field it surveys all major areas of electromagnetic waves in a single treatment The book begins with a detailed treatment of the mathematics of Maxwell's equations It follows with a discussion of polarization delves into propagation in various media devotes four chapters to guided propagation links the concepts to practical applications and concludes with radiation diffraction coherence and radiation statistics This edition features many new and reworked problems updated references and suggestions for further reading a completely revised appendix on Bessel functions and new definitions such as antenna effective height Illustrating the concepts with examples in every chapter *Electromagnetic Waves Second Edition* is an ideal introduction for those new to the field as well as a convenient reference for seasoned professionals

The Potential Distribution Theorem and Models of Molecular

Solutions Tom L. Beck, Michael E. Paulaitis, Lawrence R. Pratt, 2006-08-31 An understanding of statistical thermodynamic molecular theory is fundamental to the appreciation of molecular solutions This complex subject has been simplified by the authors with down to earth presentations of molecular theory Using the potential distribution theorem PDT as the basis the text provides a discussion of practical theories in conjunction with simulation results The authors discuss the field in a concise and simple manner illustrating the text with useful models of solution thermodynamics and numerous exercises Modern quasi chemical theories that permit statistical thermodynamic properties to be studied on the basis of electronic structure calculations are given extended development as is the testing of those theoretical results with ab initio molecular dynamics simulations The book is intended for students taking up research problems of molecular science in chemistry chemical engineering biochemistry pharmaceutical chemistry nanotechnology and biotechnology

Quantum Theory

Charis Anastopoulos, 2023-08-31 The ideal text for a two semester graduate course on quantum mechanics Fresh comprehensive and clear it strikes the optimal balance between covering traditional material and exploring contemporary topics Focusing on the probabilistic structure of quantum mechanics and the central role of symmetries to unify principles this textbook guides readers through the logical development of the theory Students will also learn about the more exciting and controversial aspects of quantum theory with discussions on past interpretations and the current debates on cutting edge concepts such as quantum information and entanglement open quantum systems and quantum measurement theory The book has two types of content Type A material is more elementary and is fully self contained functioning like a separate book within the book while Type B content is at the level of a graduate course Requiring minimal physics background this textbook is appropriate for mathematics and engineering students in addition to physicists Introducing cutting edge topics in the field the book features about 150 concept checking questions 300 homework problems and a solutions manual

Photonic

Probes of Surfaces P. Halevi, 2012-12-02 This volume is devoted principally to optical spectroscopies of material surfaces and also encompasses scattering techniques and theoretical response analysis as well as spectroscopies In addition to solid surfaces some attention is also devoted to interfaces between two solids between a solid and a liquid and to a liquid vapor interface These surfaces may be clean and perfect in which case the purpose of the spectroscopical method at hand is to determine the deviation of the atomic structure in the surface region from that in the bulk namely the surface reconstruction Otherwise the surface may be imperfect due to roughness strain or overlayers in which case the spectroscopy can yield information on the nature of such imperfections including the monitoring of growth processes One of the foremost purposes of surface spectroscopies is to extract information on atomic and molecular adsorbates on solid surfaces Most of the 10 chapters are concerned with photonic sources of excitation the respective spectral regions ranging from the far infrared to X rays In conclusion this book provides a state of the art review of all major types of photonic probes of surfaces and interfaces and deals with both applications and experiment and theory

Molecular Dynamics Simulation Studies of Liquid

Water and Aqueous Ionic Solutions James Edward Roberts,1995 *Semiconductor Wafer Bonding : Science, Technology, and Applications V* Charles E. Hunt,2001 **Spectroscopic Methods in Mineralogy and Geology** Frank C. Hawthorne,2018-12-17 Volume 18 of Reviews in Mineralogy provides a general introduction to the use of spectroscopic techniques in Earth Sciences It gives an Introduction To Spectroscopic Methods and covers Symmetry Group Theory And Quantum Mechanics Spectrum Fitting Methods Infrared And Raman Spectroscopy Inelastic Neutron Scattering Vibrational Spectroscopy Of Hydrous Components Optical Spectroscopy Mossbauer Spectroscopy MAS NMR Spectroscopy Of Minerals And Glasses NMR Spectroscopy And Dynamic Processes In Mineralogy And Geochemistry X Ray Absorption Spectroscopy Applications In Mineralogy and Geochemistry Electron Paramagnetic Resonance Auger Electron And X Ray Photoelectron Spectroscopies and Luminescence X Ray Emission and New Spectroscopies The authors of this volume presented a short course entitled Spectroscopic Methods in Mineralogy and Geology May 13 15 1988 in Hunt Valley Maryland *Electronic Structure* Richard M. Martin,2020-08-27 An authoritative text in condensed matter physics unifying theory and methods to present electronic structure to students and researchers **Thermal Physics** Robert Floyd Sekerka,2015-08-19 In Thermal Physics Thermodynamics and Statistical Mechanics for Scientists and Engineers the fundamental laws of thermodynamics are stated precisely as postulates and subsequently connected to historical context and developed mathematically These laws are applied systematically to topics such as phase equilibria chemical reactions external forces fluid fluid surfaces and interfaces and anisotropic crystal fluid interfaces Statistical mechanics is presented in the context of information theory to quantify entropy followed by development of the most important ensembles microcanonical canonical and grand canonical A unified treatment of ideal classical Fermi and Bose gases is presented including Bose condensation degenerate Fermi gases and classical gases with internal structure Additional topics include paramagnetism adsorption on dilute sites point defects in crystals thermal aspects of intrinsic and extrinsic semiconductors density matrix formalism the Ising model and an introduction to Monte Carlo simulation Throughout the book problems are posed and solved to illustrate specific results and problem solving techniques Includes applications of interest to physicists physical chemists and materials scientists as well as materials chemical and mechanical engineers Suitable as a textbook for advanced undergraduates graduate students and practicing researchers Develops content systematically with increasing order of complexity Self contained including nine appendices to handle necessary background and technical details [Proceedings of the First Donegani Scientific Workshop on Strategies for Computer Chemistry](#) Camillo Tosi,2012-12-06 **Ferroelectricity in Doped Hafnium Oxide** Uwe Schroeder,Cheol Seong Hwang,Hiroshi Funakubo,2019-03-27 Ferroelectricity in Doped Hafnium Oxide Materials Properties and Devices covers all aspects relating to the structural and electrical properties of HfO₂ and its implementation into semiconductor devices including a comparison to standard ferroelectric materials The ferroelectric and field induced ferroelectric properties of HfO₂ based films are considered promising for various applications including non volatile

memories negative capacitance field effect transistors energy storage harvesting and solid state cooling Fundamentals of ferroelectric and piezoelectric properties HfO₂ processes and the impact of dopants on ferroelectric properties are also extensively discussed in the book along with phase transition switching kinetics epitaxial growth thickness scaling and more Additional chapters consider the modeling of ferroelectric phase transformation structural characterization and the differences and similarities between HfO₂ and standard ferroelectric materials Finally HfO₂ based devices are summarized Explores all aspects of the structural and electrical properties of HfO₂ including processes modelling and implementation into semiconductor devices Considers potential applications including FeCaps FeFETs NCFETs FTJs and more Provides comparison of an emerging ferroelectric material to conventional ferroelectric materials with insights to the problems of downscaling that conventional ferroelectrics face

Silicon Solid State Devices and Radiation Detection Claude Leroy, Pier-Giorgio Rancoita, 2012 This book addresses the fundamental principles of interaction between radiation and matter the principles of working and the operation of particle detectors based on silicon solid state devices It covers a broad scope with respect to the fields of application of radiation detectors based on silicon solid state devices from low to high energy physics experiments including in outer space and in the medical environment This book covers state of the art detection techniques in the use of radiation detectors based on silicon solid state devices and their readout electronics including the latest developments on pixelated silicon radiation detector and their application The content and coverage of the book benefit from the extensive experience of the two authors who have made significant contributions as researchers as well as in teaching physics students in various universities

Solid State Physics John J. Quinn, Kyung-Soo Yi, 2018-02-23 This book provides the basis for a two semester graduate course on solid state physics The first half presents all the knowledge necessary for a one semester survey of solid state physics but in greater depth than most introductory solid state physics courses The second half includes most of the important research over the past half century covering both the fundamental principles and most recent advances This new edition includes the latest developments in the treatment of strongly interacting two dimensional electrons and discusses the generalization from small to larger systems The book provides explanations in a class tested tutorial style and each chapter includes problems reviewing key concepts and calculations The updated exercises and solutions enable students to become familiar with contemporary research activities such as the electronic properties of massless fermions in graphene and topological insulators

Guided Wave Optics and Photonic Devices Shyamal Bhadra, Ajoy Ghatak, 2017-12-19 Guided Wave Optics and Photonic Devices introduces readers to a broad cross section of topics in this area from the basics of guided wave optics and nonlinear optics to biophotonics The book is inspired by and expands on lectures delivered by distinguished speakers at a three week school on guided wave optics and devices organized at the CSIR Central Glass and Ceramic Research Institute in Kolkata in 2011 An Introduction to Guided Wave Optics and Photonic Devices Principles Applications and Future Directions The book discusses the concept of modes in

a guided medium from first principles emphasizing the importance of dispersion properties in optical fibers It describes fabrication and characterization techniques of rare earth doped optical fibers for amplifiers and lasers with an eye to future applications Avoiding complex mathematical formalism it also presents the basic theory and operational principles of fiber amplifiers and lasers The book examines techniques for writing fiber Bragg gratings which are of particular interest for smart sensing applications A chapter focuses on the fundamental principles of Fourier optics and its implementation in guided wave optics In addition the book explains the critical phenomena of soliton dynamics and supercontinuum generation in photonic crystal fiber including its fabrication process and characteristics It also looks at plasmonics in guided media and nonlinearity in stratified media both key areas for future research The last chapter explores the importance of lasers in biophotonic applications Written by experts engaged in teaching research and development in optics and photonics this reference brings together fundamentals and recent advances in one volume It offers a valuable overview of the field for students and researchers alike and identifies directions for future research in guided wave and photonic device technology

The Specific Heat Of Matter At Low Temperatures Ahmet Tari,2003-08-12 Recent discoveries of new materials and improvements in calorimetric techniques have given new impetus to the subject of specific heat Nevertheless there is a serious lack of literature on the subject This invaluable book which goes some way towards remedying that is concerned mainly with the specific heat of matter at ordinary temperatures It discusses the principles that underlie the theory of specific heat and considers a number of theoretical models in some detail The subject matter ranges from traditional materials to those recently discovered heavy fermion compounds high temperature superconductors spin glasses and so on and includes a large number of figures tables and references The book will be particularly useful for advanced undergraduate and postgraduate students as well as academics and researchers a **Conquering the Physics GRE** Yoni Kahn,Adam Anderson,2018-03 A self contained guide to the Physics GRE reviewing all of the topics covered alongside three practice exams with fully worked solutions

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