

Lessons from Nanoscience:
A Lecture Note Series

Vol. 2

NEAR-EQUILIBRIUM TRANSPORT

Fundamentals and Applications

Mark Lundstrom
Changwook Jeong



World Scientific

Near Equilibrium Transport Fundamentals And Applications Lessons From Nanoscience A Lecture Note Volume

François Triozon, Philippe Dollfus



Near Equilibrium Transport Fundamentals And Applications Lessons From Nanoscience A Lecture Note Volume :

Near-equilibrium Transport: Fundamentals And Applications Mark S Lundstrom, Changwook Jeong, 2012-11-29

These lectures are designed to introduce students to the fundamentals of carrier transport in nano devices using a novel bottom up approach that agrees with traditional methods when devices are large but which also works for nano devices The goal is to help students learn how to think about carrier transport at the nanoscale and also how the bottom up approach provides a new perspective to traditional concepts like mobility and drift diffusion equations The lectures are designed for engineers and scientists and others who need a working knowledge of near equilibrium low field or linear transport

Applications of the theory and measurement considerations are also addressed The lectures serve as a starting point to an extensive set of instructional materials available online

Lessons From Nanoelectronics: A New Perspective On Transport (Second Edition) - Part B: Quantum Transport Supriyo Datta, 2018-03-23 Everyone is familiar with the amazing performance of a modern smartphone powered by a billion plus nanotransistors each having an active region that is barely a few hundred atoms long The same amazing technology has also led to a deeper understanding of the nature of current flow and heat dissipation on an atomic scale which is of broad relevance to the general problems of non equilibrium statistical mechanics that pervade many different fields This book is based on a set of two online courses originally offered in 2012 on nanoHUB U and more recently in 2015 on edX In preparing the second edition the author decided to split it into parts A and B titled Basic Concepts and Quantum Transport respectively along the lines of the two courses A list of available video lectures corresponding to different sections of this volume is provided upfront To make these lectures accessible to anyone in any branch of science or engineering the author assume very little background beyond linear algebra and differential equations However the author will be discussing advanced concepts that should be of interest even to specialists who are encouraged to look at his earlier books for additional technical details

Fundamentals Of Nanotransistors Mark S Lundstrom, 2017-07-11 The transistor is the key enabler of modern electronics Progress in transistor scaling has pushed channel lengths to the nanometer regime where traditional approaches to device physics are less and less suitable These lectures describe a way of understanding MOSFETs and other transistors that is much more suitable than traditional approaches when the critical dimensions are measured in nanometers It uses a novel bottom up approach that agrees with traditional methods when devices are large but that also works for nano devices Surprisingly the final result looks much like the traditional textbook transistor models but the parameters in the equations have simple clear interpretations at the nanoscale The objective is to provide readers with an understanding of the essential physics of nanoscale transistors as well as some of the practical technological considerations and fundamental limits This book is written in a way that is broadly accessible to students with only a very basic knowledge of semiconductor physics and electronic circuits

Lessons From Nanoelectronics: A New Perspective On Transport (Second Edition) - Part A: Basic Concepts Supriyo

Datta,2017-03-20 Everyone is familiar with the amazing performance of a modern smartphone powered by a billion plus nanotransistors each having an active region that is barely a few hundred atoms long The same amazing technology has also led to a deeper understanding of the nature of current flow and heat dissipation on an atomic scale which is of broad relevance to the general problems of non equilibrium statistical mechanics that pervade many different fields This book is based on a set of two online courses originally offered in 2012 on nanoHUB U and more recently in 2015 on edX In preparing the second edition the author decided to split it into parts A and B titled Basic Concepts and Quantum Transport respectively along the lines of the two courses A list of available video lectures corresponding to different sections of this volume is provided upfront To make these lectures accessible to anyone in any branch of science or engineering the author assume very little background beyond linear algebra and differential equations However the author will be discussing advanced concepts that should be of interest even to specialists who are encouraged to look at his earlier books for additional technical details

Fundamentals Of Atomic Force Microscopy - Part I: Foundations Ronald G Reifengerger,2015-09-29 The atomic force microscope AFM is a highly interdisciplinary instrument that enables measurements of samples in liquid vacuum or air with unprecedented resolution The intelligent use of this instrument requires knowledge from many distinct fields of study These lecture notes aim to provide advanced undergraduates and beginning graduates in all fields of science and engineering with the required knowledge to sensibly use an AFM Relevant background material is often reviewed in depth and summarized in a pedagogical self paced style to provide a fundamental understanding of the scientific principles underlying the use and operation of an AFM Useful as a study guide to Fundamentals of AFM an online video course available at <https://nanohub.org/courses/AFM1> Suitable for Graduate Undergraduate Independent Reading and Research Course in AFM with the combination of book and online videos

Applied Thermal Measurements At The Nanoscale: A Beginner's Guide To Electrothermal Methods Zhen Chen,Chris Dames,2018-07-13 This book aims to serve as a practical guide for novices to design and conduct measurements of thermal properties at the nanoscale using electrothermal techniques An outgrowth of the authors tutorials for new graduate students in their own labs it includes practical details on measurement design and selection sensitivity and uncertainty analysis and pitfalls and verifications The information is particularly helpful for someone setting up their own experiment for the first time The book emphasizes the integration of thermal analysis with practical experimental considerations in order to design an experiment for best sensitivity and to configure the laboratory instruments accordingly The focus is on the measurements of thermal conductivity though thermal diffusivity and thermal boundary resistance thermal contact resistance are also briefly covered and many of the principles can be generalized to other challenging thermal measurements The reader is only expected to have the basic familiarity with electrical instruments typical of a university graduate in science or engineering and an acquaintance with the elementary laws of heat transfer by conduction convection and radiation

Thermal Energy At The Nanoscale Timothy S

Fisher,2013-10-10 These lecture notes provide a detailed treatment of the thermal energy storage and transport by conduction in natural and fabricated structures Thermal energy in two carriers i e phonons and electrons are explored from first principles For solid state transport a common Landauer framework is used for heat flow Issues including the quantum of thermal conductance ballistic interface resistance and carrier scattering are elucidated Bulk material properties such as thermal and electrical conductivity are derived from particle transport theories and the effects of spatial confinement on these properties are established Lessons from Nanoelectronics Supriyo Datta,2017 Everyone is familiar with the amazing performance of a modern smartphone powered by a billion plus nanotransistors each having an active region that is barely a few hundred atoms long The same amazing technology has also led to a deeper understanding of the nature of current flow and heat dissipation on an atomic scale which is of broad relevance to the general problems of non equilibrium statistical mechanics that pervade many different fields This book is based on a set of two online courses originally offered in 2012 on nanoHUB U and more recently in 2015 on edX In preparing the second edition the author decided to split it into parts A and B titled Basic Concepts and Quantum Transport respectively along the lines of the two courses A list of available video lectures corresponding to different sections of this volume is provided upfront To make these lectures accessible to anyone in any branch of science or engineering the author assume very little background beyond linear algebra and differential equations However the author will be discussing advanced concepts that should be of interest even to specialists who are encouraged to look at his earlier books for additional technical details *Lessons from Nanoelectronics* Supriyo Datta,2017 Everyone is familiar with the amazing performance of a modern smartphone powered by a billion plus nanotransistors each having an active region that is barely a few hundred atoms long The same amazing technology has also led to a deeper understanding of the nature of current flow and heat dissipation on an atomic scale which is of broad relevance to the general problems of non equilibrium statistical mechanics that pervade many different fields This book is based on a set of two online courses originally offered in 2012 on nanoHUB U and more recently in 2015 on edX In preparing the second edition we decided to split it into parts A and B titled Basic Concepts and Quantum Transport respectively along the lines of the two courses A list of available video lectures corresponding to different sections of this volume is provided upfront To make these lectures accessible to anyone in any branch of science or engineering we assume very little background beyond linear algebra and differential equations However we will be discussing advanced concepts that should be of interest even to specialists who are encouraged to look at my earlier books for additional technical details *Lessons from Nanoelectronics: a New Perspective on Transport (Second Edition) - Part B: Quantum Transport* Supriyo Datta,2017-03-20 Everyone is familiar with the amazing performance of a modern smartphone powered by a billion plus nanotransistors each having an active region that is barely a few hundred atoms long The same amazing technology has also led to a deeper understanding of the nature of current flow and heat dissipation on an atomic scale which is of broad relevance to the general problems of non

equilibrium statistical mechanics that pervade many different fields This book is based on a set of two online courses originally offered in 2012 on nanoHUB U and more recently in 2015 on edX In preparing the second edition the author decided to split it into parts A and B titled Basic Concepts and Quantum Transport respectively along the lines of the two courses A list of available video lectures corresponding to different sections of this volume is provided upfront To make these lectures accessible to anyone in any branch of science or engineering the author assume very little background beyond linear algebra and differential equations However the author will be discussing advanced concepts that should be of interest even to specialists who are encouraged to look at his earlier books for additional technical details

Nanophysics: Coherence and Transport, 2005-08-02 The developments of nanofabrication in the past years have enabled the design of electronic systems that exhibit spectacular signatures of quantum coherence Nanofabricated quantum wires and dots containing a small number of electrons are ideal experimental playgrounds for probing electron electron interactions and their interplay with disorder Going down to even smaller scales molecules such as carbon nanotubes fullerenes or hydrogen molecules can now be inserted in nanocircuits Measurements of transport through a single chain of atoms have been performed as well Much progress has also been made in the design and fabrication of superconducting and hybrid nanostructures be they normal superconductor or ferromagnetic superconductor Quantum coherence is then no longer that of individual electronic states but rather that of a superconducting wavefunction of a macroscopic number of Cooper pairs condensed in the same quantum mechanical state Beyond the study of linear response regime the physics of non equilibrium transport including non linear transport rectification of a high frequency electric field as well as shot noise has received much attention with significant experimental and theoretical insights All these quantities exhibit very specific signatures of the quantum nature of transport which cannot be obtained from basic conductance measurements Basic concepts and analytical tools needed to understand this new physics are presented in a series of theoretical fundamental courses in parallel with more phenomenological ones where physics is discussed in a less formal way and illustrated by many experiments Electron electron interactions in one dimensional quantum transport Coulomb Blockade and Kondo physics in quantum dots Out of equilibrium noise and quantum transport Andreev reflection and subgap nonlinear transport in hybrid N S nanostructures Transport through atomic contacts Solid state Q bits Written by leading experts in the field both theorists and experimentalists

Electrical Transport in Nanoscale Systems Massimiliano Di Ventra, 2008-08-07 In recent years there has been a huge increase in the research and development of nanoscale science and technology Central to the understanding of the properties of nanoscale structures is the modeling of electronic conduction through these systems This graduate textbook provides an in depth description of the transport phenomena relevant to systems of nanoscale dimensions In this textbook the different theoretical approaches are critically discussed with emphasis on their basic assumptions and approximations The book also covers information content in the measurement of currents the role of initial conditions in establishing a steady

state and the modern use of density functional theory Topics are introduced by simple physical arguments with particular attention to the non equilibrium statistical nature of electrical conduction and followed by a detailed formal derivation This textbook is ideal for graduate students in physics chemistry and electrical engineering Nanoelectronics: A Molecular View Avik Ghosh,2016-09-29 This is one of the best available graduate level textbooks on electronic transport at the nanoscale Its unique feature is providing a thorough and completely self contained treatment of several theoretical formalisms for treating the transport problem As such the book is useful not only for the graduate students working in the field of nanoscale electrical transport but also for the researchers who wish to expand their knowledge of various fundamental issues associated with this rapidly developing field Of particular note are deep physical insights accompanying the rigorous mathematical derivations in each of the chapters as well as the clear statement of all the approximations involved in a particular theoretical formalism This winning combination makes the book very accessible to a reader with basic knowledge of quantum mechanics solid state theory and thermodynamics statistical mechanics I give this book the highest recommendation Read Full Review Serfei A EgorovUniveristy of Virginia USAThis book is aimed at senior undergraduates graduate students and researchers interested in quantitative understanding and modeling of nanomaterial and device physics With the rapid slow down of semiconductor scaling that drove information technology for decades there is a pressing need to understand and model electron flow at its fundamental molecular limits The purpose of this book is to enable such a deconstruction needed to design the next generation memory logic sensor and communication elements Through numerous case studies and topical examples relating to emerging technology this book connects top down classical device physics taught in electrical engineering classes with bottom up quantum and many body transport physics taught in physics and chemistry The book assumes no more than a nodding acquaintance with quantum mechanics in addition to knowledge of freshman level mathematics Segments of this book are useful as a textbook for a course in nano electronics

Quantum Transport Yuli V. Nazarov,Yaroslav M. Blanter,2009-05-28 Quantum transport is a diverse field sometimes combining seemingly contradicting concepts quantum and classical conduction and insulating within a single nanodevice Quantum transport is an essential and challenging part of nanoscience and understanding its concepts and methods is vital to the successful fabrication of devices at the nanoscale This textbook is a comprehensive introduction to the rapidly developing field of quantum transport The authors present the comprehensive theoretical background and explore the groundbreaking experiments that laid the foundations of the field Ideal for graduate students each section contains control questions and exercises to check readers understanding of the topics covered Its broad scope and in depth analysis of selected topics will appeal to researchers and professionals working in nanoscience *Simulation of Transport in Nanodevices* François Triozon,Philippe Dollfus,2016-11-22 Linear current voltage pattern has been and continues to be the basis for characterizing evaluating performance and designing integrated circuits but is shown not to hold its supremacy as

channel lengths are being scaled down In a nanoscale circuit with reduced dimensionality in one or more of the three Cartesian directions quantum effects transform the carrier statistics In the high electric field the collision free ballistic transport is predicted while in low electric field the transport remains predominantly scattering limited In a micro nano circuit even a low logic voltage of 1 V is above the critical voltage triggering nonohmic behavior that results in ballistic current saturation A quantum emission may lower this ballistic velocity

Instabilities and Self-organization in Materials: Fundamentals of nanoscience Nasr Mostafa Ghoniem, Daniel Walgraef, 2008 Instabilities and self organisation in materials are at the core of technological applications In nano technology manufacturing of electronic and electromagnetic devices relies on the natural tendency of materials to undergo self organisation Fundamentals are covered in volume I and applications in volume II

Adopting the Song of Phrase: An Mental Symphony within **Near Equilibrium Transport Fundamentals And Applications Lessons From Nanoscience A Lecture Note Volume**

In a global eaten by screens and the ceaseless chatter of instant connection, the melodic splendor and psychological symphony developed by the published word usually disappear in to the back ground, eclipsed by the constant noise and distractions that permeate our lives. Nevertheless, located within the pages of **Near Equilibrium Transport Fundamentals And Applications Lessons From Nanoscience A Lecture Note Volume** an enchanting fictional value full of organic thoughts, lies an immersive symphony waiting to be embraced. Crafted by an outstanding musician of language, this charming masterpiece conducts visitors on a mental trip, well unraveling the hidden melodies and profound affect resonating within each cautiously crafted phrase. Within the depths of the moving review, we will discover the book is main harmonies, analyze their enthralling publishing model, and surrender ourselves to the profound resonance that echoes in the depths of readers souls.

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