Quantum Machines Measurement Control Of Engineered Quantum Systems Lecture Notes Of The Les Houches Summer School Volume 96 July 2011

As a continuation of classical condensed matter physics texts, this graduate textbook introduces advanced topics of correlated electron systems, mesoscopic transport,quantum computing, optical excitations and topological insulators. The book is focusing on an intuitive understanding of the basic concepts of these rather complex subjects.

Quantum mechanics, the subfield of physics that describes the behavior of very small (quantum) particles, provides the basis for a new paradigm of computing. First proposed in the 1980s as a way to improve computational modeling of quantum systems, the field of quantum computing has recently garnered significant attention due to progress in building small-scale devices. However, significant technical advances will be required before a large-scale, practical quantum computer can be achieved. Quantum Computing: Progress and Prospects provides an introduction to the field, including the unique characteristics and constraints of the technology, and assesses the feasibility and implications of creating a functional quantum computer capable of addressing real-world problems. This report considers hardware and software requirements, quantum algorithms, drivers of advances in quantum computing and quantum devices, benchmarks associated with relevant use cases, the time and resources required, and how to assess the probability of success.

A quantum computer is a computer based on a computational model which uses quantum mechanics, which is a subfield of physics to study phenomena at the micro level. There has been a growing interest on quantum computing in the 1990's and some quantum computers at the experimental level were recently implemented. Quantum computers enable super-speed computation and can solve some important problems whose solutions were regarded impossible or intractable with traditional computers. This book provides a quick introduction to quantum computing for readers who have no backgrounds of both theory of computation and quantum mechanics. “Elements of Quantum Computing” presents the history, theories and engineering applications of quantum computing. The book is suitable to computer scientists, physicists and software engineers.

During the last ten years Quantum Information Processing and Communication (QIPC) has established itself as one of the new hot topic fields in physics, with the potential to revolutionize many areas of science and technology. QIPC replaces the laws of classical physics applied to computation and communication with the more fundamental laws of quantum mechanics. This becomes increasingly important due to technological progress going down to smaller and smaller scales where quantum effects start to be dominant. In addition to its fundamental nature, QIPC promises to advance computing power beyond the capabilities of any classical computer, to guarantee secure communication and establish direct links to emerging quantum technologies, such as, for example, quantum based sensors and clocks. One of the outstanding feature of QIPC is its interdisciplinary character: it brings together researchers from physics, mathematics and computer science. In particular, within physics we have seen the emergence of a new QIPC community, which ranges from theoretical to experimental physics, and crosses boundaries of traditionally separated disciplines such as atomic physics, quantum optics, statistical mechanics and solid state physics, all working on different and complementary aspects of QIPC. This publication covers the following topics: Introduction to quantum computing; Quantum logic, information and entanglement; Quantum algorithms; Error-correcting codes for quantum computations; Quantum measurements and control; Quantum communication; Quantum optics and cold atoms for quantum information; Quantum computing with solid state devices; Theory and experiments for superconducting qubits; Interactions in many-body systems: quantum chaos, disorder and random matrices; Decoherence effects for quantum computing; and Flature prospects of quantum information processing.

The physics of strong light-matter coupling has been addressed in different scientific communities over the last three decades. Since the early eighties, atoms coupled to optical and microwave cavities have led to pioneering demonstrations of cavity quantum electrodynamics, Gedanken experiments, and building blocks for quantum information processing, for which the Nobel Prize in Physics was awarded in 2012. In the framework of semiconducting devices, strong coupling has allowed investigations into the physics of Bose gases in solid-state environments, and the latter holds promise for exploiting light-matter interaction at the single-photon level in scalable architectures. More recently, impressive developments in the so-called superconducting circuit QED have opened another fundamental playground to revisit cavity quantum electrodynamics for practical and fundamental purposes. This book aims at developing the necessary interface between these communities, by providing future researchers with a robust conceptual, theoretical and experimental basis on strong light-matter coupling, both in the classical and in the quantum regimes. In addition, the emphasis is on new forefront research topics currently developed around the physics of strong light-matter interaction in the atomic and solid-state scenarios.

The book gathers lecture notes of courses given at the 2014 summer school on integrated biology in Les Houches, France, Session CII. It addresses an emerging field ranging from molecules to cells and to organisms. Through examples it presents a new way of thinking using a combination of interdisciplinary and cutting-edge methods, bridging physics and biology beyond current biophysics. Important novel developments are expected in the coming years that may well introduce paradigm shifts in biological science. The school had the ambition to prepare participants to become major actors in these breakthroughs. The power of integrated approaches is illustrated through two cases: interactions between viruses and host cells, and flower development. The role of forces in biology, as well as their mathematical modeling, is illustrated in both processes: how they allow flower organs to emerge or how they control membrane fusion during virus budding. The book also underlines the importance of conformational changes and dynamics of proteins particularly during membrane processes. It explains how membrane proteins can be handled and studied by molecular simulations. Finally, the book also contains concepts in cell biology, in thermodynamics and several novel approaches such as in-cell NMR. Altogether, the chapters show how examining a biological system from different viewpoints based on multidisciplinary aspects often leads to enriching controversial arguments.

In the last decade, there has been an increasing convergence of interest and methods between theoretical physics and fields as diverse as probability, machine learning, optimization and compressed sensing. In particular, many theoretical and applied works in statistical physics and computer science have relied on the use of message passing algorithms and their connection to statistical physics of spin glasses. The aim of this book, especially adapted to PhD students, post-docs, and young researchers, is to present the background necessary for entering this fast developing field.

First-ever comprehensive introduction to the major new subject of quantum computing and quantum information.

This book gathers the lecture notes of the 100th Les Houches Summer School, which was held in July 2013. These lectures represent a comprehensive pedagogical survey of the frontier of theoretical and observational cosmology just after the release of the first cosmological results of the Planck mission. The Cosmic Microwave Background is discussed as a possible window on the still unknown laws of physics at very high energy and as a backlight for studying the late-time Universe. Other lectures highlight connections of fundamental physics with other areas of cosmology and astrophysics, the successes and fundamental puzzles of the inflationary paradigm of cosmic beginning, the themes of dark energy and dark matter, and the theoretical developments and observational probes that will shed light on these cosmic conundrums in the years to come.

Recent experimental advances in the control of quantum superconducting circuits, nano-mechanical resonators and photonic crystals has meant that quantum measurement theory is now an indispensable part of the modelling and design of experimental technologies. This book, aimed at graduate students and researchers in physics, gives a thorough introduction to the basic theory of quantum measurement and many of its important modern applications. Measurement and control is explicitly treated in superconducting circuits and optical and opto-mechanical systems, and methods for deriving the Hamiltonians of superconducting circuits are introduced in detail. Further applications covered include feedback control, metrology, open systems and thermal environments, Maxwell's demon, and the quantum-to-classical transition.

The authors provide an introduction to quantum computing. Aimed at advanced undergraduate and beginning graduate students in these disciplines, this text is illustrated with diagrams and exercises.

This book gathers the lecture notes of courses given at Session CVII of the summer school in physics, entitled "Current Trends in Atomic Physics" and held in July, 2016 in Les Houches, France. Atomic physics provides a paradigm for exploring few-body quantum systems with unparalleled control. In recent years, this ability has been applied in diverse areas including condensed matter physics, high energy physics, chemistry and ultra-fast phenomena as well as foundational aspects of quantum physics. This book addresses these topics by presenting developments and current trends via a series of tutorials and lectures presented by international leading investigators.

This book presents the latest results in the most fundamental field of quantum state preparation and control. At this unique conference researchers, both from the academic and industrial world, presented their work. A variety of crucial experiments under controlled, novel conditions, and theoretical checks from novel points of view are reported. Highlighted are new schemes for quantum interference, single particle behaviour, gravitational waves, electron holography and semiconductor microlasers. Containing all the recent results available in the field, this volume points the direction for further experimental and theoretical work in the foundations of physics.

New Trends in Control Theory is a graduate-level monographic textbook. It is a contemporary overview of modern trends in control theory. The introductory chapter gives the geometrical and quantum background, which is a necessary minimum for comprehensive reading of the book. The second chapter gives the basics of classical control theory, both linear and nonlinear. The third chapter shows the key role that Euclidean group of rigid motions plays in modern robotics and biomechanics. The fourth chapter gives an overview of modern quantum control, from both theoretical and measurement perspectives. The fifth chapter presents modern control and synchronization methods in complex systems and human crowds. The appendix provides the rest of the background material complementary to the introductory chapter. The book is designed as a one-semester course for engineers, applied mathematicians, computer scientists and physicists, both in industry and academia. It includes a most relevant bibliography on the subject and detailed index.

In many applications of geophysics (weather forecast, study of climate evolution and variability), it is necessary to get the best possible estimate of the state of the system under study. In general, information about this system comes from observations and numerical models. However, none of these sources is perfect. Data assimilation designates the set of mathematical methods used to optimally combine observations with models, to fulfil the need of an accurateestimate of the system state. Because of the weather forecast problem in particular, the geophysical sciences have shaped a long history and a strong background on data assimilation, particularly with big and complex systems such as the atmosphere and the ocean. This book gathers notes from lecturesgiven during a three-week summer school on the fundamentals and the most recent developments of geophysical data assimilation.

The introduction of control theory in quantum mechanics has created a rich, new interdisciplinary scientific field, which is producing novel insight into important theoretical questions at the heart of quantum physics. Exploring this emerging subject, Introduction to Quantum Control and Dynamics presents the mathematical concepts and fundamental physics behind the analysis and control of quantum dynamics, emphasizing the application of Lie algebra and Lie group theory. To advantage students, instructors and practitioners, and since the field is highly interdisciplinary, this book presents an introduction with all the basic notions in the same place. The field has seen a large development in parallel with the neighboring fields of quantum information, computation and communication. The author has maintained an introductory level to encourage course use. After introducing the basics of quantum mechanics, the book derives a class of models for quantum control systems from fundamental physics. It examines the controllability and observability of quantum systems and the related problem of quantum state determination and measurement. The author also uses Lie group decompositions as tools to analyze dynamics and to design control algorithms. In addition, he describes various other control methods and discusses topics in quantum information theory that include entanglement and entanglement dynamics. Changes to the New Edition: New Chapter 4: Uncontrollable Systems and Dynamical Decomposition New section on quantum control landscapes A brief discussion of the experiments that earned the 2012 Nobel Prize in Physics Corrections and revised concepts are made to improve accuracy Armed with the basics of quantum control and dynamics, readers will invariably use this interdisciplinary knowledge in their mathematics, physics and engineering work.

Many of the distinctive and useful phenomena of soft matter come from its interaction with interfaces. Examples are the peeling of a strip of adhesive tape, the coating of a surface, the curling of a fiber via capillary forces, or the collapse of a porous sponge. These interfacial phenomena are distinct from the intrinsic behavior of a soft material like a gel or a microemulsion. Yet many forms of interfacial phenomena can be understood via common principles valid for many forms of soft matter. Our goal in organizing this school was to give students a grasp of these common principles and their many ramifications and possibilities. The Les Houches Summer School comprised over fifty 90-minute lectures over four weeks. Four four-lecture courses by Howard Stone, Michael Cates, David Nelson and L. Mahadevan served as an anchor for the program. A number of shorter courses and seminars rounded out the school. This volume collects the lecture notes of the school.

This book addresses and introduces new developments in the field of Quantum Information and Computing (QIC) for a primary audience of undergraduate students. Developments over the past few decades have spurred the need for QIC courseware at major research institutions. This book broadens the exposure of QIC science to the undergraduate market. The subject matter is introduced in such a way so that it is accessible to students with only a first-year calculus background. Greater accessibility allows a broader range of academic offerings. Courses, based on this book, could be offered in the Physics, Engineering, Math and Computer Science departments. This textbook incorporates Mathematica-based examples into the book. In this way students are allowed a hands-on experience in which difficult abstract concepts are actualized by simulations. The students can ‘turn knobs" in parameter space and explore how the system under study responds. The incorporation of symbolic manipulation software into course-ware allows a more holistic approach to the teaching of difficult concepts. Mathematica software is used here because it is easy to use and allows a fast learning curve for students who have limited experience with scientific programming.

This book targets computer scientists and engineers who are familiar with concepts in classical computer systems but are curious to learn the general architecture of quantum computing systems. It gives a concise presentation of this new paradigm of computing from a computer systems' point of view without assuming any background in quantum mechanics. As such, it is divided into two parts. The first part of the book provides a gentle overview on the fundamental principles of the quantum theory and their implications for computing. The second part is devoted to state-of-the-art research in designing practical quantum programs, building a scalable software systems stack, and controlling quantum hardware components. Most chapters end with a summary and an outlook for future directions. This book celebrates the remarkable progress that scientists across disciplines have made in the past decades and reveals what roles computer scientists and engineers can play to enable practical-scale quantum computing.

Over the last decade new experimental tools and theoretical concepts are providing new insights into collective nonequilibrium behavior of quantum systems. The exquisite control provided by laser trapping and cooling techniques allows us to observe the behavior of condensed bose and degenerate Fermi gases under nonequilibrium drive or after `quenches' in which a Hamiltonian parameter is suddenly or slowly changed. On the solid state front, high intensity short-time pulses and fast (femtosecond) probes allow solids to be put into highly excited states and probed before relaxation and dissipation occur. Experimental developments are matched by progress in theoretical techniques ranging from exact solutions of strongly interacting nonequilibrium models to new approaches to nonequilibrium numerics. The summer school `Strongly interacting quantum systems out of equilibrium' held at the Les Houches School of Physics as its XCIX session was designed to summarize this progress, lay out the open questions and define directions for future work. This books collects the lecture notes of the main courses given in this summer school.

The book gathers the lecture notes of the Les Houches Summer School that was held in August 2011 for an audience of advanced graduate students and post-doctoral fellows in particle physics, theoretical physics, and cosmology, areas where new experimental results were on the verge of being discovered at CERN. The lectures by theoreticians covered many directions in the theory of elementary particles, from classics such as the Supersymmetric Standard Model to veryrecent ideas such as the relation between black holes, hydrodynamics, and gauge-gravity duality. The lectures by experimentalists explained in detail how intensively and how precisely the LHC colliderhas verified the theoretical predictions of the Standard Model, predictions that were at the front lines of experimental discovery during the 70's, 80's and 90's, and how the LHC is ready to make new discoveries. They described many of the ingenious and pioneering techniques developed at CERN for the detection and the data analysis of billions of billions of proton-proton collisions.

This collection includes summaries of presentations given at the NAE Symposium in September 2002. Topics include chemical and molecular engineering in the 21st century, human factors engineering, the future of nuclear energy, and engineering challenges for quantum information technology.

This volume, 106 of the Les Houches Summer School series, brings together applications of integrability to supersymmetric gauge and string theory. The book focuses on the application of integrability and problems in quantum field theory. Particular emphasis is given to the exact solution of planar N=4 super-Yang-Mills theory and its relation with string theory on the one hand, and the exact determination of the low-energy physics of N=2 super-Yang-Mills theories on the other; links with other domains are also explored. The purpose of the Les Houches Summer School was to bring together young researchers and specialists from statistical physics, condensed matter physics, gauge and string theory, and mathematics, to stimulate discussion across these different research areas.

The field of stochastic processes and Random Matrix Theory (RMT) has been a rapidly evolving subject during the last fifteen years. The continuous development and discovery of new tools, connections and ideas have led to an avalanche of new results. These breakthroughs have been made possible thanks, to a large extent, to the recent development of various new techniques in RMT. Matrix models have been playing an important role in theoretical physics for a long time and they are currently also a very active domain of research in mathematics. An emblematic example of these recent advances concerns the theory of growth phenomena in the Kardar-Parisi-Zhang (KPZ) universality class where the joint efforts of physicists and mathematicians during the last twenty years have unveiled the beautiful connections between this fundamental problem of statistical mechanics and the theory of random matrices, namely the fluctuations of the largest eigenvalue of certain ensembles of random matrices. This text not only covers this topic in detail but also presents more recent developments that have emerged from these discoveries, for instance in the context of low dimensional heat transport (on the physics side) or integrable probability (on the mathematical side).

Quantum MachinesMeasurement Control of Engineered Quantum SystemsQuantum Machines: Measurement and Control of Engineered Quantum SystemsLecture Notes of the Les Houches Summer School: Volume 96, July 2011OUP Oxford

Modern Condensed Matter Physics brings together the most important advances in the field of recent decades. It provides instructors teaching graduate-level condensed matter courses with a comprehensive and in-depth textbook that will prepare graduate students for research or further study as well as reading more advanced and specialized books and research literature in the field. This textbook covers the basics of crystalline solids as well as analogous optical lattices and photonic crystals, while discussing cutting-edge topics such as disordered systems, mesoscopic systems, many-body systems, quantum magnetism, Bose–Einstein condensates, quantum entanglement, and superconducting quantum bits. Students are provided with the appropriate mathematical background to understand the topological concepts that have been permeating the field, together with numerous physical examples ranging from the fractional quantum Hall effect to topological insulators, the toric code, and majorana fermions. Exercises, commentary boxes, and appendices afford guidance and feedback for beginners and experts alike.

Quantum Optics and Nanophotonics consists of the lecture notes of the Les Houches Summer School 101 held in August 2013. Some of the most eminent experts in this flourishing area of research have contributed chapters lying at the intersection of basic quantum science and advanced nanotechnology. The book is part of the renowned series of tutorial books that contain the lecture notes of all the Les Houches Summer Schools since the 1950's and cover the latest developments in physics and related fields.

The topic of the CVIII session of the Ecole de Physique des Houches, held in July 2017, was Effective Field Theory in

Particle Physics and Cosmology. Effective Field Theory (EFT) is a general method for describing quantum systems with multiple length scales in a tractable fashion. It allows to perform precise calculations in established models (such as the Standard Models of particle physics and cosmology), as well as to concisely parametrise possible effects from physics beyond the Standard Models. The goal of this school was to offer a broad introduction to the foundations and modern applications of Effective Field Theory in many of its incarnations. This is all the more important as there are preciously few textbooks covering the subject, none of them in a complete way. In this book, the lecturers present the concepts in a pedagogical way so that readers can adapt some of the latest developments to their own problems. The chapters cover almost all the lectures given at the school and will serve as an introduction to the topic and as a reference manual to students and researchers.

The beginning of the 20th century saw a revolution in Physics with the discovery that the fundamental constituents of matter and radiation do not obey Newtonian laws, but those of an entirely new theory of motion and its measurement: quantum mechanics. After a century of experimentation in the world of photons, atoms, molecules, and other microscopic particles, the application of quantum laws is presently being extended to the world of macroscopic, engineeredsystems, whose complexity is such that an exhaustive, bottom-up description is both impossible and fruitless. In these so-called quantum machines, the very level of control signals that govern theevolution of the system operates quantum-mechanically. Quantum machines are based on artificial structures like superconducting tunnel junction circuits or semiconductor quantum dots, and this book provides the conceptual tools to build and utilize them.

In this book, hybrid systems based on yttrium-iron-garnet (YIG), three dimensional microwave cavity resonators, and superconducting transmon qubits, are investigated by continuous wave and pulsed microwave spectroscopy. Limitations to the magnetic linewidth in the quantum regime are identified and coherent exchange between a magnon and a superconducting qubit are demonstrated. Finally, a first step towards a strongly coupled hybrid system containing all three components is demonstrated.

Modern quantum measurement for graduate students and researchers in quantum information, quantum metrology, quantum control and related fields.

A thorough exposition of quantum computing and the underlying concepts of quantum physics, with explanations of the relevant mathematics and numerous examples. The combination of two of the twentieth century's most influential and revolutionary scientific theories, information theory and quantum mechanics, gave rise to a radically new view of computing and information. Quantum information processing explores the implications of using quantum mechanics instead of classical mechanics to model information and its processing. Quantum computing is not about changing the physical substrate on which computation is done from classical to quantum but about changing the notion of computation itself, at the most basic level. The fundamental unit of computation is no longer the bit but the quantum bit or qubit. This comprehensive introduction to the field offers a thorough exposition of quantum computing and the underlying concepts of quantum physics, explaining all the relevant mathematics and offering numerous examples. With its careful development of concepts and thorough explanations, the book makes quantum computing accessible to students and professionals in mathematics, computer science, and engineering. A reader with no prior knowledge of quantum physics (but with sufficient knowledge of linear algebra) will be able to gain a fluent understanding by working through the book.

"During the last ten years Quantum Information Processing and Communication (QIPC) has established itself as one of the new hot topic fields in physics, with the potential to revolutionize many areas of science and technology. QIPC replaces the laws of classical physics applied to computation and communication with the more fundamental laws of quantum mechanics. This becomes increasingly important due to technological progress going down to smaller and smaller scales where quantum effects start to be dominant. In addition to its fundamental nature, QIPC promises to advance computing power beyond the capabilities of any classical computer, to guarantee secure communication and establish direct links to emerging quantum technologies, such as, for example, quantum based sensors and clocks. One of the outstanding feature of QIPC is its interdisciplinary character: it brings together researchers from physics, mathematics and computer science. In particular, within physics we have seen the emergence of a new QIPC community, which ranges from theoretical to experimental physics, and crosses boundaries of traditionally separated disciplines such as atomic physics, quantum optics, statistical mechanics and solid state physics, all working on different and complementary aspects of QIPC. This publication covers the following topics: Introduction to quantum computing; Quantum logic, information and entanglement; Quantum algorithms; Error-correcting codes for quantum computations; Quantum measurements and control; Quantum communication; Quantum optics and cold atoms for quantum information; Quantum computing with solid state devices; Theory and experiments for superconducting qubits; Interactions in many-body systems: quantum chaos, disorder and random matrices; Decoherence effects for quantum computing; and Flature prospects of quantum information processing."

This volume, number 109 of the Les Houches Summer School series, presents the lectures held in August 2017 on the subject of turbulent flows in climate dynamics. Leading scientists in the fields of climate dynamics, atmosphere and ocean dynamics, geophysical fluid dynamics, physics and non-linear sciences present their views on this fast growing and interdisciplinary field of research, by venturing upon fundamental problems of atmospheric convection, clouds, large scale circulation, and predictability. Climate is controlled by turbulent flows. Turbulent motions are responsible for the bulk of the transport of energy, momentum, and water vapor in the atmosphere, which determine the distribution of temperature, winds, and precipitation on Earth. The aim of this book is to survey what is known about how turbulent flows control climate, what role they may play in climate change, and to outline where progress in this important area can be expected, given today's computational and observational capabilities. This book reviews the state-of-the-art developments in this field and provides an essential background to future studies. All chapters are written from a pedagogical perspective, making the book accessible to masters and PhD students and all researchers wishing to enter this field.

This book gathers the lecture notes of courses given at the 2011 summer school in theoretical physics in Les Houches, France, Session XCVI. What is a quantum machine? Can we say that lasers and transistors are quantum machines? After all, physicists advertise these devices as the two main spin-offs of the understanding of quantum mechanical phenomena. However, while quantum mechanics must be used to predict the wavelength of a laser and the operation voltage of a transistor, it does not intervene at the level of the signals processed by these systems. Signals involve macroscopic collective variables like voltages and currents in a circuit or the amplitude of the oscillating electric field in an electromagnetic cavity resonator. In a true quantum machine, the signal collective variables, which both inform the outside on the state of the machine and receive controlling instructions, must themselves be treated as quantum operators, just as the position of the electron in a hydrogen atom. Quantum superconducting circuits, quantum dots, and quantum nanomechanical resonators satisfy the definition of quantum machines. These mesoscopic systems exhibit a few collective dynamical variables, whose fluctuations are well in the quantum regime and whose measurement is essentially limited in precision by the Heisenberg uncertainty principle. Other engineered quantum systems based on natural, rather than artificial degrees of freedom can also qualify as quantum machines: trapped ions, single Rydberg atoms in superconducting cavities, and lattices of ultracold atoms. This book provides the basic knowledge needed to understand and investigate the physics of these novel systems.

The Les Houches Summer School in August 2015 covered the emerging fields of cavity optomechanics and quantum nanomechanics. Optomechanics is flourishing and its concepts and techniques are now applied to a wide range of topics. Modern quantum optomechanics was born in the late 1970s in the framework of gravitational wave interferometry, with an initial focus on the quantum limits of displacement measurements. Carlton Caves, Vladimir Braginsky, and others realized that the sensitivity of the anticipated large-scale gravitational-wave interferometers (GWI) was fundamentally limited by the quantum fluctuations of the measurement laser beam. After tremendous experimental progress, the sensitivity of the upcoming next generation of GWI will effectively be limited by quantum noise. In this way, quantum-optomechanical effects will directly affect the operation of what is arguably the world's most impressive precision experiment. However, optomechanics has also gained a life of its own with a focus on the quantum aspects of moving mirrors. Laser light can be used to cool mechanical resonators well below the temperature of its environment. After proof-of-principle demonstrations of this cooling in 2006, a number of systems were used as the field gradually merged with its condensed matter cousin (nanomechanical systems) to try to reach the mechanical quantum ground state, eventually demonstrated in 2010 by pure cryogenic techniques and just one year later by a combination of cryogenic and radiation-pressure cooling. The book covers all aspects -- historical, theoretical, experimental -- of the field, with its applications to quantum measurement, foundations of quantum mechanics and quantum information. It is an essential read for any new researcher in the field.

This book contains lecture notes by world experts on one of the most rapidly growing fields of research in physics. Topological quantum phenomena are being uncovered at unprecedented rates in novel material systems. The consequences are far reaching, from the possibility of carrying currents and performing computations without dissipation of energy, to the possibility of realizing platforms for topological quantum computation.The pedagogical lectures contained in this book are an excellent introduction to this blooming field. The lecture notes are intended for graduate students or advanced undergraduate students in physics and mathematics who want to immerse in this exciting XXI century physics topic. This Les Houches Summer School presents an overview of this field, along with a sense of its origins and its placement on the map of fundamental physics advancements. The School comprised a set of basic lectures (part 1) aimed at a pedagogical introduction of the fundamental concepts, which was accompanied by more advanced lectures (part 2) covering individual topics at the forefront of today's research in condensed-matter physics.

This book offers an introduction into quantum machine learning research, covering approaches that range from "near-term" to fault-tolerant quantum machine learning algorithms, and from theoretical to practical techniques that help us understand how quantum computers can learn from data. Among the topics discussed are parameterized quantum circuits, hybrid optimization, data encoding, quantum feature maps and kernel methods, quantum learning theory, as well as quantum neural networks. The book aims at an audience of computer scientists and physicists at the graduate level onwards. The second edition extends the material beyond supervised learning and puts a special focus on the developments in near-term quantum machine learning seen over the past few years.