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Physics at the FMQT'08 conference

V. Špička [a,*], Th.M. Nieuwenhuizen [b], P.D. Keefe [c]

[a] *Institute of Physics, Academy of Sciences of the Czech Republic, Na Slovance 2, 182 21 Praha 8, Czech Republic*
[b] *Institute for Theoretical Physics, Valckenierstraat 65, 1018 XE Amsterdam, The Netherlands*
[c] *University of Detroit Mercy, 24405 Gratiot Avenue, Eastpointe, MI 48021, USA*

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ABSTRACT

This paper summarizes the recent state of the art of the following topics presented at the FQMT'08 conference: Foundations of quantum physics, Quantum measurement; Quantum noise, decoherence and dephasing; Cold atoms and Bose–Einstein condensation; Physics of quantum computing and information; Nonequilibrium quantum statistical mechanics; Quantum, mesoscopic and partly classical thermodynamics; Mesoscopic, nano-electro-mechanical systems and optomechanical systems; Spins systems and their dynamics, Brownian motion and molecular motors; Physics of biological systems, and Relevant experiments from the nanoscale to the macroscale.

To all these subjects an introduction is given and the recent literature is overviewed. The paper contains some 680 references in total.

Introduction

Recent progress in nanoscale technologies enables the preparation of well defined artificial structures composed of atoms (molecules) in the number range of between several and hundreds and to measure many characteristics of such systems of nanoscale sizes. At the same time, advances of measurement techniques open the possibility to investigate not only these artificial structures, but also structures of similar nanoscale size occurring in nature, as for example complex molecules, molecular motors in living cells, prions and viruses.

There is thus a growing demand for a better understanding of the (possible phenomenological "quantum thermodynamical") laws which govern the behavior of these systems and insight into the problems and interpretations of quantum physics based upon the methods of condensed matter physics and quantum optics. To find these laws is a challenging task, due to the complexity of these systems, their diversity, and the fact that these systems are on the borderline between different disciplines (i.e., physics, chemistry and biology) where the diverse dynamic behavior of these systems and corresponding various methods of their description (individual and statistical, microscopic and macroscopic, classical and quantum) meet.

In general, the FQMT'08 conference addressed quantum physics and non-equilibrium quantum statistical physics and focused on six main aspect and problem areas:

1. Time evolution of non-equilibrium quantum systems.
2. The role of size and dimension on systems.
3. Many-body effects, disorder.
4. Quantum noise and quantum decoherence.
5. Molecular motors, nanoscale biological systems.
6. Foundations of quantum mechanics and quantum field theory.

These aspects and problems concern many physical situations studied by condensed matter physics (e.g., metals, semiconductors, superconductors, and their various combinations, in artificially created structures), plasma physics, nuclear physics, elementary particle physics, chemistry and biology. A good understanding of the time evolution of quantum systems, both on the short and long time scale is essential for an explanation of many experiments pertaining to mesoscopic systems. The theory of non-equilibrium behavior of quantum systems is, however, far from being complete. There are lasting and extremely important problems related to modern technologies, including questions of irreversible behavior of real systems in comparison with reversible microscopic laws, emergence of classical macroscopic behavior from microscopic quantum behavior and macroscopic quantum systems (such as Bose–Einstein condensates), limits to "phenomenological" thermodynamic descriptions, and the problem of how to describe properly open quantum systems far from

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* Corresponding author.
E-mail address: spicka@fzu.cz (V. Špička).

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equilibrium states (as for example a system under the influence of strong time dependent laser pulses), especially in the case of strong interaction between a small system and reservoirs (contact baths).

The above problems are related to questions of description of dissipation, dephasing and decoherence processes, and, on a very basic level, to the foundations of quantum mechanics and related theories of quantum measurement. The best systems to measure and investigate these problems and questions are mesoscopic systems which are nowadays prepared by technologies which provide artificial structures having well defined parameters. Various systems of nanoscale size are studied by methods of condensed matter physics and quantum optics, using suitable samples, to observe the behavior of quantum systems in order to obtain a deeper understanding of quantum physics, as represented by quantum interference phenomena, decoherence processes, entanglement, the uncertainty principle, nonlocality and quantum measurement.

A better knowledge and insight into the foundations of quantum physics is of principle interest for proper formulation of the fundamental laws of physics in regard to Bell inequalities and quantum gravity. It is also essential for developing a suitable description of small quantum systems and their applications. This applies particularly to quantum optics investigations and physics of quantum computing, where questions of quantum interference, entanglement and decoherence processes together with knowledge of time scales governing the dynamics of the studied systems are essential and mutually beneficial.

Time evolution of mesoscopic systems and accompanied decoherence processes are strongly related to the many body interactions in systems. The strong correlations in systems are, however, far from being understood even in equilibrium. Apart from the properties determined by (electron) charges, spin dynamics of nanoscale systems are also interesting to study, both in terms of basic research and possible applications. An understanding of mesoscopic systems, however, is far from being complete. Another promising contribution to advance the understanding of mesoscopic systems, and at the same time the foundation of quantum physics, comes from a combination of electron transport and mechanical degrees of freedom in so-called nano-electro-mechanical systems (NEMS). These systems not only provide interesting data, but they also bring other possibilities of how to measure and investigate other small systems of various origins.

The last, but not the least, challenging problem is represented by stochastic behavior of quantum systems caused either by innate features of the systems or by noise related to the fact that the studied systems are open. Quantum and temperature fluctuations, as well as quantum noise in mesoscopic systems, created an essential part of the conference contributions. Particularly, spin fluctuations and related dynamics were discussed. Experimental as well as theoretical studies of transport and optical properties, including full counting statistics of systems were considered. The conference dealt also with the physics of Brownian motion and molecular motors, of both artificial and biological systems.

Nowadays, all the above-mentioned problems connect thermodynamics, statistical physics, quantum theory and physics of small systems not only from a theoretical, but also from an experimental point of view, at many levels. This recent state of the art motivated the organization of the FQMT'08 conference and the following choice of its main topics: Foundations of quantum physics, Quantum measurement; Quantum noise, decoherence and dephasing; Cold atoms and Bose–Einstein condensation; Physics of quantum computing and information; Nonequilibrium quantum statistical mechanics; Quantum, mesoscopic and partly classical thermodynamics; Mesoscopic, nano-electro-mechanical systems and optomechanical systems; Spins systems and their dynamics, Brownian motion and molecular motors; Physics of biological systems, and Relevant experiments from the nanoscale to the macroscale.

Many participants have submitted a contribution to these proceedings. These have been grouped in 11 sections:

1. General physics.
2. Foundations of quantum mechanics.
3. Quantum measurement, entanglement, coherence and dissipation.
4. Quantum optics.
5. Cold atoms and Bose–Einstein condensation.
6. Physics of quantum computing and information.
7. Quantum thermodynamics.
8. Non-equilibrium quantum statistical physics.
9. Physics of small quantum systems.
10. Spin systems and their dynamics.
11. Biological systems and molecular motors.

A guide in the bibliography

The details of the recent developments regarding to the subjects of individual sections (together with some very recent development during a period of several months after the conference) can be found in the included literature (ordered mostly by years of publication):

1. General physics: from Refs. [1–39].
2. Foundations of quantum mechanics: from Refs. [40–149].
3. Quantum measurement, entanglement, coherence and dissipation: from Refs. [150–214].
4. Quantum optics: from Refs. [215–236].
5. Cold atoms and Bose–Einstein condensation: from Refs. [237–251].
6. Physics of quantum computing and information: from Refs. [252–298].
7. Quantum thermodynamics: from Ref. [299–347].
8. Non-equilibrium quantum statistical physics: from Refs. [348–486].
9. Physics of small quantum systems: from Refs. [487–602].
10. Spin systems and their dynamics: from Refs. [603–618].
11. Biological systems and molecular motors: from Refs. [619–682].

We note that, apart from some exceptions, only recent books and review articles are referred to. We suppose that the reader will find all other important articles in these books and reviews. Apart from this, we often do not refer in the text to specific books or review articles and leave the reader to find out the more detailed information from the variety of references offered in this article, which are roughly classified above.

Contents

The aim of this article is to summarize the problems discussed at the conference, to introduce main topics of individual contributions and, last but not the least, to point out relations between these topics.

The following 11 sections of this article correspond to the 11 groups of the contributions to these proceedings.

Due to many relations between discussed topics, texts in the following 11 sections partly overlap. The aim is, however, to show common themes from different points of view and levels of generality in different sections.

1. General physics

This section of the proceedings contains papers, which deal with various fundamental concepts of physics. They discuss not only some of basic principles of quantum mechanics (the field of physics connecting most of contributions in the proceedings), but also special and general relativity. Their authors wrote these articles from the point of view to find out new ways to look at some lasting ''puzzles'' of nature, specifically, the concept of time and its direction, the existence of gravitational waves and their measurement, properties of black holes and their relation to formulation of gravity theory and its consequences for observations and its relation with concepts of quantum mechanics. These papers have overlaps with many topics discussed in the other Sections of the proceedings.

Contrary to the following sections, we will not introduce here any themes related to the papers of this section. Apart from information in the articles, readers can find some additional information either in the literature accompanying this section [1–38] or in the following sections and literature to these sections at the end of this article.

2. Foundations of quantum mechanics

The central phenomenon which connects basic topics of the foundations of quantum physics as an interpretation of quantum mechanics, non-locality of quantum mechanics, quantum entanglement and quantum measurement problem with teleportation experiments, possible quantum qubits behavior and studies of various mesoscopic (nano)systems, is the phenomenon of quantum interference and its possible decay by various (decoherence) processes.

2.1. Border between classical and quantum physics

The existence of quantum interference, confirmed experimentally at the microscopic level, brings the natural question about a possibility of quantum interference of macroscopically distinct states. This question is the basis of the famous Schrödinger's cat thought experiment [49], which was formulated soon after another famous thought experiment, the Einstein–Podolsky–Rosen (EPR) paradox [40,49], questioning the completeness and non-locality of quantum mechanics. Both thought experiments ask the question what is the relation between the classical and quantum physics. This leads to other questions: Where is the borderline between the classical and quantum worlds? What does macroscopic and microscopic mean from this point of view? At which level can we still observe superposition of quantum states? The standard Copenhagen interpretation of quantum mechanics just states that microscopic quantum objects are measured by classical macroscopic apparatus. The collapse of the wave function (by some ''stochastic'' unknown process) occurs in the relation with the measurement and we will receive an ''unpredictable'' measured value. At the time of its formulation, experiments, which would enable measurement of the transition between the micro- and macro-worlds under well defined conditions, were not accessible. With the possibility of more sophisticated quantum optics and solid state ''mesoscopic'' experiments, the old questions have re-emerged together with many new questions related to the Copenhagen interpretation of quantum mechanics and other possible schemes for understanding the foundations of quantum mechanics. Nowadays, however, these questions can be discussed together with the relevant experimental results.

The role of quantum interference and its erasing by decoherence processes is still not fully understood, but we are gradually getting better insights in many problems of quantum physics of the micro-worlds and macro-worlds. In addition, we see the old problems, represented by the EPR and Schrödinger's cat paradoxes in a new light. The emerging landscape of foundations of quantum physics and relevant experiments is ever more complex.

2.2. Non-locality of quantum mechanics

Many experiments have attempted to test non-locality of quantum mechanics as well as the quantum complementarity principle. Since interference effects are often seen as the manifestation of non-local behavior, there is sometimes believed to be a direct relationship between tests of quantum non-locality, entanglement and complementarity. After pivotal experiments of Alain Aspects and his group [43–47] investigating the non-locality of quantum theory and Bell's inequalities from the late seventies and early eighties of the last century, other independent experiments testing quantum non-locality appeared. These experiments came from two fields which were also discussed at the FQMT'08 conference: quantum optics and (mesoscopic) solid state physics.

The complementarity principle, which is in contradiction with local theories, was tested via ''which-way'' double slit type experiments. A Gedanken which-way experiment using micromaser cavities was suggested and gradually improved upon by Englert, Rempe, Scully, and Walter [55,56,66,83]. Ideas related to the so-called quantum eraser thought experiments reported in the articles above were experimentally realized in 1995 [69].

All experimental tests of non-locality and complementarity up to now support non-locality of the quantum mechanical picture and seem to exclude the idea of local reality. This is still a heavily debated subject, however, and there are opposing view points, that argue that locality cannot be excluded, see e.g. Ref. [15,93–95,111]. Non-locality is also strongly advocated on the basis of teleportation experiments using entangled states. For the first time, the possibility to teleport a photon was discussed in [61]. Teleportation was then experimentally realized in 1997 [71].

To summarize, apart from well known Bell inequalities, several other inequalities testing the possibility to describe microscopic world by quantum mechanics have been developed and experimentally tested. They are known under the following names: 1. Clauser, Horne, Shimony, and Holt, 3. Clauser and Horne, 3. Carg and Mermin, and 4. Leggett inequalities.

Up to now a possibility exists that all these experiments still suffer from some hidden implicit assumptions (related to possible introduction of additional undesired parameters or even to technical limits of experiment), called loopholes, which can bring serious doubts as for the conclusions from experimental tests on quantum mechanics. Combinations of Locality, Angular-correlation and Detection loopholes can affect the proper interpretation of tests. The ultimate test on ''non-completeness'' of quantum mechanics is still missing: a single experiment that closes all the loopholes at once.

From the theoretical side, it has been put forward that the contextuality loophole cannot be closed, i.e., that the Bell inequalities cannot be derived if one takes proper account of the hidden variables of the detectors, implying that Bell inequality violation has no say on local realism [136]. Along another line of approach, normal (''local'') computer algorithms were designed that mimic the role of detectors and mirrors in a real experiment.

Since they may reproduce the quantum violations of Bell inequalities, this again questions the supposed relation between Bell inequalities and absence of local realism, see Refs. [125,126] and the contributions of the de Raedt group to these proceedings.

2.3. Interpretations of quantum mechanics

Apart from the Copenhagen interpretation of quantum mechanics and its small variations, there are many other interpretations among which it is difficult to distinguish, since they provide, at least in principle, the same description of nature and the same results when applied to concrete physical situations.

We will not discuss these theories here, see many references to this section at the end of this article. We will just briefly comment that the problem of the collapse of the wave function, measurement of microscopic versus macroscopic states and decoherence processes, are related in some of the above-mentioned interpretation of quantum mechanics. Environmentally induced decoherence is one possible explanation of the collapse of the wave function and non-possibility to observe macroscopic superposition of states. In the model for a realistic quantum measurement of Balian et al., there occurs first a dephasing in the off-diagonal elements of the density matrix, that is made permanent on a somewhat longer timescale by decoherence due to the bath [107,181].

2.4. Stochastic electrodynamics

In this section we will briefly mention an alternative approach to explain observations of quantum phenomena: stochastic quantum mechanics [139–149].

This approach is basically based on the postulates of classical mechanics which are combined with only one additional assumption: the existence of the stochastic background which is considered to be a randomly fluctuating electromagnetic field. This all pervasive, so-called Zero point radiation (ZPR), is permanently present even at the absolute zero of temperature at every point of the universe. According to stochastic electrodynamics (SED), it is the presence of ZPR which causes all quantum effects we observe.

Up to now, several quantum effects have been satisfactorily explained in terms of SED, e.g. Black body radiation spectrum, Lamb shift, and Casimir force.

3. Quantum measurement, entanglement, coherence and dissipation

This section deals with some core problems of recent physics, as the measurements on quantum systems, entanglement, quantum interference and related mechanisms of decoherence and dissipation. These are, nowadays, contrary to past thinking, not only posed as theoretical, academic problems, but they also are now more than in the past reflected in recent experiments and even suggested applications.

Investigation of various manifestations of quantum correlations (entanglement), interference, dissipation, dephasing and decoherence in general is a very active area of recent research, since we need to understand quantum correlations and decoherence at microscopic, mesoscopic and macroscopic scales to be able to deal with recent experimental systems, see also Sections 4 and 5. On the other hand, nowadays a huge diversity of investigated systems, with often well controlled parameters, provide us an enormous amount of experimental data to build up a gradually ever more satisfactory picture of quantum correlations and decoherence processes and related theories of their description which would lead to satisfactory theory of measurements on quantum systems. Apart from providing a practical solution for every-day problems encountered when analyzing the behavior of experimentally tested systems, this progress in knowledge about quantum correlations, interference effects and decoherence processes also helps us to improve our understanding of quantum physics at its most fundamental level and emergence of the classical world from the quantum one, as well as macroscopic irreversibility from microscopic reversibility. As already partially discussed in the previous section, interference and decoherence processes play also a crucial role in the interpretation of quantum mechanics and possible alternative theories.

3.1. Quantum measurement problem

Quantum systems exhibit many features different from classical ones and consequently their states are supposed to be described by wave functions, these features being unknown in classical mechanics. Natural questions thus emerge: What we can measure in quantum systems and how do we perform measurements to gain relevant information about the system?

First, to gain some insight into these tasks we have to treat any measurement of the quantum systems as a physical process. This process involves, apart from the measured system itself, also a device (usually macroscopic) which measures the system and shows us the desired information. Both, the system and the device, must be treated as quantum systems; in terms of quantum dynamics (see also Sections 2 and 8) we have to consider the measured system as an open one which interacts with the device and its environment. In addition, the device must behave also classically to provide us definite numbers on its scale or counter. One of the most fundamental tasks of quantum measurement, not yet fully satisfactorily answered, is to understand this dual nature (quantum and classical) of the device. Moreover, this task is combined with a need of (generally non-equilibrium) description of dynamics of the measured open system and its preparation together with the device before the measuring process (the highly non-trivial problem of initial conditions); see also Section 8. Due to openness of the system, we can also look at the process of measurement as a process during which the system loses its quantum coherence, see also the text about decoherence in this section below.

Second, to understand what we can measure in quantum systems we have to return to the basic features of quantum mechanics. As is well known, there is a very basic difference between classical and quantum mechanics regarding measurements of the system: In classical mechanics all observables commute, they can be measured simultaneously and therefore the state of the system is observable, since it is just represented by the set of measured values of observables. In quantum mechanics, however, operators representing observables generally do not commute and therefore the state cannot be represented just by the set of simultaneously measured values. Accordingly, these questions arise: Are information about systems based on non-commuting observables and the standard von Neumann approach to measurement is only possible and sufficient to characterize the quantum system? Can we measure somehow the state of the system as represented by the wave function, i.e. to measure the wave function itself? Can we even ask: Does the quantum wave function exist, does it have some real meaning or is it just our technical tool? We can clearly see that these questions, which have nowadays a practical meaning, see also Section 9, are closely related to the basic questions of the foundation of quantum mechanics and its various interpretations which were discussed in the previous section. The exact solutions of all steps of a model for an ideal measurement favor the statistical interpretation of quantum mechanics [107,181].

von Neumann's original approach to formalize quantum measurement is based on the famous projection postulate and the set of projection operators, commonly called projection-valued measurement (PVM). This traditional definition is too restrictive from the point of view of possibilities of gaining information on quantum systems, so its concept was generalized for well known positive operator valued measurement (POVM) which is related to understanding the measured system as a subsystem of a bigger, composite system. Again, this concept brings us back to fundamental non-separability of quantum systems and their openness, see also the text above and Sections 2 and 8.

Later on, with development of experiments of quantum optics and mesoscopic physics, other concepts dealing with quantum state reconstruction (often using the concept of the Wigner function bearing some semiclassical features) and various possibilities for how to perform measurements on quantum systems have emerged: non-demolition measurement, weak measurement on quantum systems, quantum tomography, and quantum state endoscopy of quantum fields in cavities. As discussions at the FQMT08 conference and contributions to its proceedings show, the question of how to gain information about quantum systems is a very important and lively part of current investigations in physics.

3.2. Entanglement

One of the surprising features of quantum mechanics is its coherence and entanglement. This leads to processes that are rather unexpected from the point of view of classical mechanics. Contrary to classical physics, where non-interacting subsystems can be completely separated, quantum mechanical systems manifest non-classical correlations between subsystems even if these are not mutually interacting. This non-local correlation, which is closely related to tests on non-locality of quantum mechanics mentioned in the previous section, is called entanglement. If all loopholes in tests on non-locality of quantum mechanics are closed, entanglement would just provide us a needed mechanism which prevents Einstein's spooky action at a distance. Recent experiments have even found a lower limit of the speed of this hypothetical spooky action at the distance and have shown that with high probability the non-local correlations in quantum systems are indeed truly non-local.

Apart from its relation to the very foundations of quantum mechanics and its tests the existence of entanglement has also other consequences important for methods of description of quantum systems: Due to entanglement, any quantum system is, in principle, the open system (see also Section 8) via its non-separability caused by non-trivial correlations with its environment.

Quantum entanglement is not only an interesting phenomenon related to foundations of quantum physics, but it also seems to be one of the key concepts of the many branches of recent physics and their applications, e.g., in physics of quantum computers and quantum information science, among others. Several quantum protocols such as teleportation and related quantum communication cannot be in principle realized without the help of entangled states.

The most essential task related to the physics of entanglement is to find algorithms to detect entanglement and methods of how to distinguish separable states from entangled states. Measures of entanglement represent a vast field by itself and involve methods enabling us to quantify bi-particle, three-particle and even many-particle entangled states in many-body systems, at least from the theoretical point of view, see review articles in the end of this article.

Another important question is how to prepare artificially entangled states experimentally on purpose. Artificial entangled states were for the first time prepared in the case of photons by methods of quantum optics. Recent works deal even with entanglements in trapped atomic ions and ultracold atoms in optical lattices. Of course, entanglement is very seriously investigated also in all artificially prepared systems which are supposed to be candidates for working quantum computers, see also the text related to decoherence below in this section and Sections 6 and 8.

Entanglement also offers an interesting possibility to make tests on quantum mechanics without Bell's inequalities or their various generalizations, which were discussed in the previous section.

Since quantum entanglement has became a basic resource in quantum information science and other applications of quantum physics, it is really vital to understand how non-classical correlations decay in a real environment (and classical behavior of the system emerges). So, dynamics of entanglement is another challenging task of recent physics and we immediately see the connection of entanglement with non-equilibrium quantum statistical physics and quantum thermodynamics, especially with decoherence theory.

It is often stated that entanglement is a purely quantum phenomenon. However, Allahverdyan et al. demonstrate that it may also occur in the problem of two classical Brownian particles that have interacted with each other in the past, but are free now [182].

3.3. Decoherence and dissipation

Generally, decoherence can be a candidate for explaining most of the difference between the microscopic world of quantum physics and the macroscopic (classical) world we directly observe. From this point of view, the idea of decoherence can help us in the end to understand, even at the very fundamental level, the relation between quantum statistical physics and thermodynamics. Since the decoherence time is very sensitive to the parameters of the system and to the reservoir with which the system is coupled, its values can change over many orders from the very small (non-measurable nowadays) values for macroscopic objects to the very large values for almost isolated elementary particles. The small, "mesoscopic" systems, see also Sections 9–11, however, provide a possibility to make measurements of decoherence in the time range which is observable by recent techniques.

In general, decoherence is a process of a loss of quantum interference (coherence) due to non-unitary dynamics of the system, which is a consequence of a coupling between the system and the environment (in terms of theory of open systems discussed in Section 2, due to interaction between the open system S and the reservoir B).

Phenomenologically, the transition in time from the quantum (coherent) state into the classical (decoherent) state can be described by a decoherence factor $e^{-t/\tau}$, where τ is the decoherence time. Generally, the decoherence, of course, includes both dephasing and dissipative contributions, sometimes denoted as T_2 and T_1 processes. Dephasing is related to processes randomizing the relative phases of the quantum states. Dissipation corresponds to interaction processes which are changing the populations of quantum states.

The description of the decoherence processes for various systems is a highly non-trivial task which is far from being satisfactorily fulfilled. Many highly successful models have already been introduced for the description of systems with dissipation, e.g., variants of the central spin model (both, system and reservoir are represented by spins), spin-boson model (system composed by spins, reservoir by bosons) not to mention the celebrated Caldeira–Leggett model. However, as the conference talks and discussions revealed, new, more complex and more realistic models are needed to describe the dissipation processes together with improvement of the general theory of open systems, see also Section 2. There are still many unanswered questions related to quantum coherence, the most important, at least as it seems now, are the following ones:

1. *What are the dynamics of decoherence*? In other words, how do the off-diagonal elements of the density matrix of the system evolve in time under various conditions, depending, e.g., on the initial state of the system and the reservoir, and on the strengths of coupling between the system and the reservoir? The realistic determination of decoherence times for various systems is a very useful, but sometimes difficult to fulfill, aim.
2. *What are possible mechanisms of decoherence in various systems*? Apart from this, what is the relation of these mechanisms to other mechanisms in systems, e.g. namely to quantum relaxation processes?
3. *What is the relation of decoherence processes with the transition between quantum and classical behavior*?
4. *How are decoherence processes related to quantum measurement processes*? Namely, a natural question emerges as to whether decoherence can cause collapse of the wave function in relation to the measurement processes. If yes, what is the difference between measurement of microscopic and possible macroscopic coherent states, if any? What is the relation to the possible irreversibility on the microscopic level caused by quantum measurement? In other words, can quantum decoherence satisfactorily solve the “measurement problem” and related collapse of the wave function, if this really occurs?

4. Quantum optics

Quantum optics deals with the quantum aspects of light and its interaction with matter. It is thus connected, via its concepts and rich experimental methods, to many problems discussed in these proceedings. Experimental methods of quantum optics are now commonly used to investigate a very wide range of various quantum systems. They provide us tools to test basic concepts of quantum physics and enable us also to realize experiments on quantum systems which lead to many important applications of quantum physics. There is, of course, already a vast and still very quickly growing literature dealing with many aspects of quantum optics, see the references at the end of this article, so we will only briefly point out and summarize several aspects which are important for consideration in these proceedings.

This is the field of physics which has been closely related not only to foundations of quantum physics (Section 2) and quantum statistical physics (Section 8) just from their very beginnings at the turn of the twentieth century, but it also helps substantially in quickly developing areas, such as the physics of cold atoms and Bose–Einstein condensation (Section 5) and the physics of quantum computing (Section 6).

The mutual relationship of the foundations of quantum physics and quantum optics was started by early works on Blackbody radiation spectrum, photoelectric effect and Compton scattering, which revealed quantum aspects of light and introduced the concept of the photon, a dualistic picture of light, Bose–Einstein statistics and stimulated and spontaneous emission of light. Almost simultaneously, natural and long lasting questions have emerged: What are light quanta? Are photons really necessary? At the same time during investigations of the blackbody radiation, the question of the so-called Zero point fluctuations of electromagnetic field has emerged and this has lead to a parallel formulation of quantum mechanics, so-called Stochastic electrodynamics (see Section 2).

Later on, formal technical means (of the quantized electromagnetic field) and improved experimental methods enabled development of lasers, various forms of interference experiments, “which-path” and delayed-choice experiments, and the formulation of various optical EPR (Einstein, Podolsky, Rosen) experiments. Optical tests of various forms of Bell’s inequalities have not only improved our understanding of the foundations of quantum physics, but have also gradually led to a better understanding of the various light states (coherent, bunched and antibunched light, non-classical, squeezed states) and entanglement. Finally, these achievements opened the way to man-made entangled photons and the experimental possibility of teleportation. This has led to a boost of the physics of quantum computers and communication which we have witnessed in recent years.

In the nineties of the last century, methods of quantum optics have enabled us also to cool down systems of atom gases to extremely low temperatures and thus to create and to observe for the first time Bose–Einstein condensation phenomena in real systems. Quantum optics methods of Doppler, Sysiphos and subrecoil cooling are nowadays commonly used. The techniques of quantum optics can provide us a real possibility to manipulate atoms with photons. There is now even the possibility to entangle photons and cold atoms and use entangling collisions in a Bose–Einstein condensate for the physics of qubits.

The further improvement of theoretical concepts and experimental methods of Quantum optics and its mutual relations with other branches of physics is very much needed to further improve our possibilities to observe properties of quantum systems and to suggest and to realize in practice new schemes for better understanding of the foundations of quantum physics and quantum statistical physics and its following use for dealing with experiments on real quantum systems and their proper interpretation.

5. Cold atoms and Bose–Einstein condensation

This is a field which, from its very beginning, has been strongly related to quantum optics, discussed in the previous section, and, as we will see, not only confined to the methods of laser cooling.

From the point of view of foundations of quantum physics, it is extremely tempting to reach Bose–Einstein condensation (BEC) in real systems, since the Bose–Einstein condensate represents a macroscopic quantum state. To reach experimental conditions under which a diluted gas of atoms creates Bose–Einstein condensate is, however, an extremely demanding task, especially from the point of view of trapping atoms in limited space and at the same time cooling them down to ultra-low temperatures. It is thus not at all surprising that only in 1995 was a real example of Bose–Einstein condensation finally realized. As already mentioned, quantum optics provides methods of cooling a gas of atoms to very low temperatures. To reach even lower temperatures needed for Bose–Einstein condensation, the additional method of evaporative cooling must be used. As the diluted gas of atoms is cooled down, it must be caught in the so-called magnetic trap. The process of developing these magnetic traps is a demanding task in itself.

From the first experimental manifestations of BEC in 1995, the physics of cold atoms has become one of the most active areas of contemporary physics which has strong overlaps not only with quantum optics but also with the foundations of quantum physics (Section 2), the physics of quantum computing (Section 6) and even with Non-equilibrium quantum statistical physics (Section 8). In fact, BEC in ultra cold atoms is also very interesting from the point of view of many particle physics. An ideal Bose–Einstein gas does not express superfluidity. To reach superfluidity we have to have a weakly interacting gas of atoms.

From the point of view of the foundations of physics, very interesting experiments have been performed which demonstrate macroscopic quantum coherence in BEC, showing quantum superposition and interference between systems with macroscopic numbers of particles. Again, we are dealing with the border between the microscopic and the macroscopic realms and the transition from quantum to classical behavior of systems which usually happens at the macroscopic scale.

There are also many experiments with cold atoms which are using other methods of quantum optics to trap atoms, so-called optical lattices. These are created by the periodic modulation of light intensity in a standing wave. By superimposing a number of different laser beams, it is possible to generate potentials which are periodic in one, two or three dimensions, so that we can study the dimensional dependence of the physics of trapped atoms. Recently, experiments were performed with quantum coherence and entanglement with ultracold atoms in optical lattices. The large scale entanglement which could be generated in the large arrays of atoms in the lattice (created by trapping potentials of a laser field) offer possibilities that may lead to quantum information processing in these structures. In addition BEC offers rich opportunities for storing and processing optical signals. So, BEC has already started to be used in the physics of quantum information processing (Section 6).

Last but not the least it is also worth mentioning experiments with rotation of ultracold atom systems and studies of far from equilibrium properties of these systems. So, there are strong overlaps of the field of cold atoms with nonequilibrium quantum statistical physics, see Section 8.

6. Physics of quantum computing and information

Another group of theories and experiments related strongly to both foundations of quantum physics (Section 2), quantum measurement, entanglement, coherence and dissipation (Section 3) and their possible applications, is dealing with the physics of quantum computing, i.e., the physics of qubits. Physics of quantum computing works with all basic principles of quantum physics. We can therefore understand various qubits systems as theoretical and experimental models for understanding and testing properties of quantum mechanics and related concepts independently of a real possibility of creating a working quantum computer—due to various conceptual and experimental problems, especially with decoherence, we are nowadays far from knowing if this is possible in principle, not to mention its practical realization.

We can see difficulties on the way to real implementation of quantum algorithms from the following list of conditions, originally formulated by DiVincenzo in the early nineties of the last century, which a quantum mechanical system must obey if it is to be used as an quantum information processing device:

1. It must be possible to initialize the system into a well-defined quantum state.
2. It must be possible to apply unitary operations to each individual two-level system that serves as a qubit.
3. It must be possible to apply unitary operations to some pairs of qubits.
4. The information stored in the quantum register, in particular the relative phases of all quantum states, must be preserved for a sufficiently large number of logical operations.
5. It must be possible to read out the state of each qubit with high fidelity.

Problems with simultaneous realization of all these conditions can be immediately related to various tasks to be solved which were mentioned in many other sections of this article, namely to the problem of preparation of the initial state and its following measurement (to read out information) during its evolution (Sections 3 and 8) together with problems related to decoherence processes (Section 3).

Physics of quantum computing was motivated by a possibility to use quantum mechanics, especially its superposition principle, coherence and entanglement, for developing quicker and more efficient algorithms for some special tasks within quantum rules than it is possible within the rules of classical mechanics, which is used by common computers. There is a vast literature on quantum algorithms and protocols and the field is quickly growing—so we will not mention any details of this development here, see also the list of books and reviews at the end of this article.

These algorithms and protocols are intended to be developed into forms which enable us to use them for practical quantum information processing, quantum cryptography and quantum communication based on quantum entanglement and teleportation. To deal with them successfully in practice, it is also necessary to develop protocols with high fidelity and quantum error corrections schemes which compensate destructive effects of quantum decoherence processes. All these mentioned fields are nowadays quickly developing and they provide us also ever better insights into the foundations of quantum physics and to the relation of physical processes and quantum information.

The central theme of "qubits physics" is thus the theoretical description and measurement of five closely related phenomena: quantum entanglement, teleportation, decoherence, dissipation and noise.

There are nowadays several ideas being put forward as how to realize quantum qubit systems practically. The most active work is mainly on these systems: quantum optical systems, trapped ions and atoms, liquid and solid state NMR, superconducting systems and semiconductors systems (electron spin qubits and excitons in quantum dots).

The most important task of all the investigations into these various possible systems, which are candidates for qubits, is the fight between quantum coherence (needed for the proper function of qubit systems from the point of view of possible quantum computing algorithms) and decoherence (coming naturally from the environment and being a natural obstacle to a realization of possible "quantum processors" in the future, but is inevitable due to coupling to an environment which enables us to read out information from systems).

7. Quantum thermodynamics

Originally, thermodynamics developed as the phenomenological description of the macroscopic behavior of macroscopic systems. It formulated the most general laws of the macroscopic world as the First and the Second Laws of thermodynamics and introduced such concepts as temperature, heat, entropy and state variables.

Phenomenological theory of heat engines based on thermodynamical behavior of macroscopic systems was also developed.

The real challenge for thermodynamics came with the miniaturization of systems which were the objects of experiments. In addition, discussions about macroscopic quantum effects and possible interference of macroscopically distinct states also contributed to a new emerging view of thermodynamics. The question has become: under which conditions the thermodynamic behavior still manifests? And, of course, whether the thermodynamic laws are still valid. Additional quantum mechanical ingredients, such as quantum interference effects, (coherent) tunneling, quantum non-locality and entanglement, quantum (not only thermal) fluctuations and finite size systems (splitting to system and reservoir) together with possible reduced dimensionality of systems, started to play an important role. All old certainties, as the theory of heat engines, Maxwell's demon problem, its relation to information and thermodynamics laws, appeared suddenly in a new light. Discussions about what is the meaning of quantum thermodynamics started and continue up till today, together with a huge development in the related field of the quantum statistical and mesoscopic physics, see also Sections 8–11. The theoretical considerations have been complemented by more and more sophisticated and sensitive, sometimes really "crafty", experiments. In fact, there is the question up to which extent (size, parameters of systems) thermodynamics can provide a unifying description of "macroscopic objects" based on the laws known from statistical physics (discussed in the Section 8) and quantum mechanics (Sections 2 and 3). Especially, the use of the concept of temperature and its limits were questioned in connection with small quantum systems. The validity of the Second Law of thermodynamics was questioned, too. New suggestions of "heat" engines on the molecular level have been discussed. In addition, concepts developed in these four interrelated disciplines (discussed in Sections 2, 3, 7 and 8 of this article) are nowadays intensively tested and their possible limitations manifested by experiments on small quantum (mesoscopic) systems (Sections 9 and 10), the special case as molecular motors being discussed in Section 11.

8. Non-equilibrium quantum statistical physics

Statistical physics has provided a theoretical basis of the laws of thermodynamics due to its recognition of the molecular structure of matter, and has applications to a diversity of systems with many elements, also outside the range of condensed matter physics, such as star clusters, granular materials, traffic problems, econophysics, risk management, etc.

The basic task of statistical physics is to relate microscopic characteristics of the systems, like interactions and dynamics of their many microscopic parts, with their macroscopically observed properties. It connects the level of description of the dynamics of individual particles, such as electrons, with macroscopic behavior of such complicated structure, such as metals. Special attention must be paid to the description of the systems when the number of particles and other parameters involved are somewhere between those which lead to exhibition of either microscopic or macroscopic features, e.g., systems have mesoscopic features, see also Section 4 and references there.

Non-equilibrium quantum statistical mechanics is our tool to understand at least in part many particle interacting quantum systems out of equilibrium and phenomena related to these systems as are various transient, relaxation, transport and dissipation processes, (thermal) fluctuations and corresponding noise during measurements on systems—in summary to understand all (generally non-linear and non-equilibrium) stochastic processes, linear or non-linear effects, short and long time behavior of systems and dependency of the behavior of an individual system on its initial state, structure, size and dimensionality. This is accompanied by a better understanding of the reversibility of phenomena at the microscopic level and the general irreversibility at the macroscopic level.

The properties of systems where quantum mechanics plays an important role, can be, in addition to classical behavior, strongly influenced mainly by the three essential manifestations of quantum mechanics: the Pauli exclusion principle, quantum interference effects and quantum fluctuations. We have discussed in more detail mainly quantum interference and its relation to quantum decoherence and dissipation in the Section 3. Quantum interference effects also play an essential role in the mesoscopic structured discussed in Sections 9–11.

Considering the huge variety of properties and phenomena related to various systems to find the most feasible methods of their description, statistical physics has developed many methods. Here we will mention only those which are the most relevant to the conference contributions.

8.1. Non-equilibrium Green's functions

The theoretical microscopic description of any quantum system starts from the Hamiltonian of the isolated system which can be, however, driven by some external time dependent field described by the additional time dependent part of the Hamiltonian. Such an isolated externally driven system is then called a closed system. The dynamics of a closed system are governed by the unitary evolution which is described either by the Schrödinger equation for the wave function or the Liouville equation for the density matrix of the system. Very often the needed (relevant) observables are single particle ones and, in this case, a one particle reduced density matrix description is used to find these observables. This reduced one particle matrix is found from approximations of the famous BBGKY chain of equations for reduced density matrices [353,428].

From the point of view of formulation of an approximation scheme, it is often advantageous not to calculate directly the single particle reduced density matrix, but to formulate dynamics within the Nonequilibrium Green's function method [409–469]. This method was extensively used for investigations of many extended systems such as metals, semiconductors, plasma physics and nuclear matter physics systems when the closed system description appears as the natural one and, in consequence, it leads to a solvable description of the system. Similarly to the closed equation for a single particle reduced density matrix obtained by approximations within the BBGKY hierarchy, the irreversibility of the description and the related description of the dissipation phenomena emerge in this description when the asymptotical (approximal) equations are closed either for the single particle Green's functions or related single particle distribution function, as is in the case of the Boltzmann equation.

There are many identities and relations which help to solve the dynamical equations written for closed systems. One special identity, which is worth mentioning here, is the famous fluctuation–dissipation theorem, which, as its name implies, relates fluctuations with the effect of dissipation. This theorem is at the heart of linear response theory and enables us to formulate Kubo–Greenwood formulas for the solution of various linear response problems. As an identity, which must be fulfilled in any linear response theory, the fluctuation–dissipation theorem can also serve us as the control for models involving dissipation. The study of glasses has taught us, however, that it applies only to systems where the largest timescale is less than the observation time [365,367].

8.2. Density matrix approaches to non-equilibrium

For better description of molecular, mesoscopic and quantum optical systems, it can be, however, advantageous (from the point of view of the possibility to find the solution of the dynamics) to introduce the concept of an open system, which can be also useful from the stand point of a more natural description of quantum mechanics itself, due to its principal of non-locality, see Section 2.

Supposing there is a small part of a total system T, which we are preferably interested in. In this case, we divide the total closed system $T=S+B$, which is always governed by unitary evolution, to a so-called (relevant for us) open system S and (irrelevant for us) a bath B named sometimes also a reservoir. The dynamics of the open system S is then governed by the non-unitary dynamics for the reduced density matrix of the system S obtained by projection of the total density matrix to the subspace S and the Liouville equation for the total system T only to the subspace S, too. As a result of a projection technique, e.g. Nakajima–Zwanzig, we will have a generalized master equation (GME) for the reduced density matrix of the open system S [451–466]. Formally, this scheme works fairly well. The first important problem, however, emerges just at the level of this step. There are no essential problems to find a reasonable approximation of the resulting equations when the coupling between the open system S and the bath B is weak, so the separation seems to be quite natural. In this case of weak coupling, we have the very well formulated Davies theory. As soon as the coupling is very strong, problems start and even today no really satisfactory approximations are known. In this respect it is interesting to recall the breakdown of the Landauer inequality for the amount of work to be dispersed in order to erase one bit of information, occurring exactly in this regime [307,308].

Generally, the GME has a very complicated structure, and to find its solution for different systems and conditions is one of the tasks of recent quantum statistical physics. Similar to the situation in the description based on the closed systems, the basic approximation, which essentially simplifies the GME, is the Markovian approximation which removes all memory effects and introduces a local time structure of the equation. In such a case, the memory effects are important for the description of the system, and much more complicated non-markovian approximations are used. From the point of view of behavior of systems we can also formulate the GME in the so-called Brownian motion or Quantum optics limit—the names of approximations and their use are self-explanatory.

Apart from methods based on the density matrix description and related Liouville equation for the quantum mechanical density matrix, there are also methods using the path-integral formulation. Especially, the Feynman–Vernon formulation is often used. The path integral formulation is especially advantageous for formulation of problems with dissipation. On the other hand, we can solve a dissipative quantum dynamical problem with a path integral approach, the GME, or even via a generalized quantum Langevin equation. Special attention to various models with dissipation is given in Section 3.

It is worth mentioning here the existence of various formulations of non-equilibrium fluctuation theorems for open systems [402,404–407]. This is the field where the essential progress has been made very recently regarding generalizations of fluctuation theorems from classical to quantum systems. These theorems formulate fundamental identities for energy exchanges between a non-equilibrium system and its environment, and their formulation is thus very important, e.g., for dealing with non-equilibrium physics of small systems (Section 9).

Finally, we will mention very briefly some special advanced methods of how to deal in practice with very difficult tasks related to the proper description of many-body effects in quantum systems far from equilibrium: Recently, we are witnessing growing interest in improvements and use of methods such as time dependent density functional theory (TDDFT), dynamical mean-field theory (DMFT) and density matrix renormalization group (DMRG). These methods often combine advantages of both basic approaches mentioned above, Non-equilibrium Green's functions and density matrix methods.

9. Physics of small quantum systems

In the context of this section, systems are understood to be small (often also called mesoscopic) when their parameters enable us to observe quantum interference effects manifested, for instance, in the transport characteristics of electrons. Usually these systems are artificially created structures which combine metal, semiconductor or superconductor materials. Various characteristics related to electrons in these structures are studied. The "small" size of the system is not the only one decisive parameter which determines whether quantum interference will be manifested. In fact, what is small from the point of view of manifestations of quantum interference effects depends also on the interactions in the systems. For instance, the quantum coherence of an electron which moves in the sample ballistically without scattering events can be disturbed by its scattering with phonons; of course, with decreasing sample size there is a greater probability that the electron will flow through the sample without any inelastic scattering which disturbs its quantum coherence. On the other hand the increasing temperature drastically increases the probability of electron–phonon scattering. So, when temperature is lower, the size of the sample can be bigger to observe interference effects related to the electron moving without scattering through the sample. Of course, the concentration of electrons is another parameter which influences the quantum behavior because of its relation to the electron–electron interaction.

Physics of "small" (mesoscopic) systems has been a very active area of research already for many years, which brings ever further motivation for investigations due to ever improving technologies. These enable the preparation of ever more interesting samples with very well defined parameters and to measure, in the past inaccessible, details. Nowadays, experiments can measure quantum interference effects in a system and their dependence on various parameters as for example: dimensionality of the sample (quantum dots, quantum wires and various two-dimensional systems are common), size of the sample and its geometry, concentration of impurities (the number of scattering events can be varied), concentration of electrons, temperature of the sample and its environment, and strengths of electric and magnetic fields.

These artificially prepared systems enable us to test various hypotheses, methods and theories developed in the above discussed areas of Quantum thermodynamics (Section 7), Statistical physics (Section 8), Foundations of physics (Section 2) and Physics of quantum measurement, entanglement, coherence and dissipation (Section 3).

In these small systems, many quantum interference and fluctuation phenomena are studied under various conditions, among others, weak electron localization, universal conductance fluctuations, persistent currents, and tunneling (resonant tunneling). Special attention is also paid to the Aharonov–Bohm effect, quantum Hall effects, and quantum chaos [369,491,497,499, 500,509,510,528].

An especially fast developing area is "quantum dots" physics [530,533,534]. Nowadays, quantum dots can be fabricated with a few levels, thus constituting artificial atoms. As their parameters can be manipulated, they yield unprecedented tools to study the dynamics of few level open systems and dissipative processes in a controlled way. Quantum dots systems, as mentioned already in Section 6, are also candidates for creating working qubit systems.

Another very active area of research is dealing with molecular systems and molecular electronics [527,539,535].

"Mesoscopic" systems have also contributed to the development of some special theoretical methods of quantum statistical physics. To describe very effectively linear transport of electrons in mesoscopic systems, the Landauer–Büttiker method was introduced [369,488,497,499,500,506]. This formalism, based on the idea of transport as a scattering problem, is suitable for the description of transport through samples where only elastic scattering (on impurities) takes place. Transport channels are then well described by transmission and reflection coefficients, and we have a simple recipe of how to calculate transport characteristics. In this case, this efficient method is equivalent to the Kubo–Greenwood formula which has to be, however, used when inelastic scatterings must be taken into account [489,490,494]. To describe various transport regimes in the case of disordered systems, random matrix theory [375] and non-linear sigma models [366] are also in use. Many techniques, originally used for the description of bulk (extended) systems, as for example Green's functions [418–420,435,489,494,507,514,515,520,521] or the path integral approach [369], have been also adapted to describe the physics of small systems.

9.1. Physics of nanomechanical and optomechanical devices, quantum limit

In this subsection, we will briefly comment on two categories of small mechanical systems, opto-mechanical and nano-electro-mechanical systems (NEMS).

The central part of both systems is the mechanical resonator of nanometer to micrometer size scale which is coupled to a specially shaped "environment". This coupling enables us to detect vibrational modes of the resonator and also enables these systems to work as "devices".

Due to advances in microfabrication techniques, nanomechanical devices have a great potential, not only in applications, as, e.g., ultrasensitive mass and force detectors at the molecular level, high-speed optical signal processing devices, and electrometers, (e.g., when coupled to a Cooper-pair box) but also in investigations of fundamental concepts of quantum mechanics.

Opto-mechanical systems consist of a resonator coupled to a radiation field by radiation pressure effects. A radiation field serves as a probe to read out information about the state of the resonator (oscillator's frequency and position).

Nano-electro-mechanical systems (*NEMS*) are nanometer to micrometer scale mechanical resonators coupled electrostatically to electronic (mesoscopic) devices of comparable size. In other words, NEMS are micro-electro-mechanical (MEMS) systems scaled to submicron size. As a central part of NEMS, the mechanical resonator, very simple structures, such as a cantilever or a bridge, are commonly used [570,578,585]. A mechanical resonator having submicron size and small mass can vibrate at frequencies from a few megahertz up to around a gigahertz. There is a possibility to detect the displacement of the vibrating part of the resonator (e.g., cantilever) by ultrasensitive displacement detectors. Several working schemes have been suggested [571,578,584]. One of the possibilities for an extremely sensitive motion detectors for a nanomechanical resonator is a single-electron transistor (SET) [568,583,582].

There are plenty of suggested, and even experimentally realized schemes for devices using electro-mechanical coupling to the submicron resonator.

Mass spectrometer: When a small particle (molecule) attaches itself to a resonator, its mass can be determined from the resulting vibrational frequency shift of the resonator [573,574].

Electro-mechanical which-way interferometer: The resonator (cantilever) is electrostatically coupled to a quantum dot situated in one of two arms of an Aharonov–Bohm ring. The vibrating cantilever decides which way the individual electron goes from the dot. At very low temperature a submicron cantilever can be represented by a single quantum mechanical oscillator [564,569].

Systems for solid state quantum information processors: There is a possibility that nano-electro-mechanical systems will play an important role in the development of quantum computer systems, see also Section 3. The task of fabricating physical qubit elements in such a network that will reach sufficiently long quantum decoherence decay times and at the same time will be able to control entanglement of individual elements, is one of the obstacles on our way to a quantum computer. Recently, a promising scheme has been suggested: high frequency nanomechanical resonators could be used to coherently couple two or more current-biased Josephson junction devices to make a solid state quantum information processing architecture [580,586].

Nanomechanical resonators coupled to a Cooper-pair box: The system of a nanomechanical resonator which is electrostatically coupled to a Cooper-pair box has been studied both theoretically and experimentally [566,572,578,585]. There is hope that these systems can be used to test some ideas from the decoherence theory and questions related to the foundation of quantum physics, see the text below.

BioNEMS: With advancing technologies and the huge sensitivity of NEMS to detect small inertial masses (even of individual molecules) and at the same time forces (chemical forces), there is an increasing possibility that NEMS will be effectively used to improve our knowledge of macromolecules existing in living cells by measuring their masses and binding forces. Questions of the type: "Can one realize a nanoscale assay for a single cell?" have already been seriously asked. Biochips involving nanoscale mechanical systems could be quite helpful in biochemistry studies [560].

Nano-electro-mechanical systems represent a great hope for improving our understanding of many aspects of the behavior of small systems. Apart from providing ultra-sensitive measuring techniques and many other possible applications, this also enables us to test basic ideas of quantum statistical physics and conceptual foundations of quantum mechanics mentioned in Sections 2 and 8.

9.1.1. NEMS, statistical physics and foundations of quantum mechanics

Taking into account "mesoscopic" sizes, masses of both the nanomechanical resonator and coupled devices, temperatures involved (NEMS systems operate at very low temperatures) and, in addition, coupling of the whole NEMS into its surroundings, we can see that we have the systems *par excellence* to study all essential questions of the quantum statistical physics of open systems: fluctuations, noise, dissipation and decoherence effects. For example, the analysis of the current noise spectrum can help to distinguish between possible mechanisms of transport of electrons between two contacts of a quantum shuttle device.

Suggested models and approximation schemes can be tested experimentally.

Nano-electro-mechanical systems also offer a possible fascinating insight into the realm of the foundations of quantum physics, since their parameters approach now a possibility to measure not only the crossover between classical and quantum behavior of a nanomechanical resonator, but also to observe interference of macroscopically distinct quantum states and related decoherence times, due to environmentally induced decoherence. In addition, NEMS are promising from the point of view of detailed studies of decoherence theory and of observations of decoherence times which are important not only for the tuning of NEMS and, e.g., their possible use for quantum processor systems, but also for testing alternative approaches to quantum mechanics, where the decoherence times play an essential role, see also Section 3.

A possibility to use NEMS for which-way experiments, one of the essential tests of interference behavior and non-locality nature of quantum mechanics, was already mentioned above.

Testing the Heisenberg Uncertainty Principle is another choice. There is an increasing effort to approach the quantum limit for position detection. The recent [581] ultra-sensitive measurements of positions of a resonator (effectively represented by an oscillator) at very low temperature were made on the NEMS system. The positions of a nanomechanical resonator, a vibrating mechanical beam (with the frequency of about 20 MHz) which was about a hundredth of a millimeter long and cooled down to about 60 mK, were measured by a single-electron transistor coupled electrostatically to the resonator. It is fascinating to realize that this test of the Uncertainty Principle used a mechanical beam, very small from the point of view of human senses, but still macroscopic from the point of view of common conception of the micro-world and the macro-world of quantum mechanics. The beam consists of about 10^{12} atoms. Such a many-particle object definitely is not considered to be microscopic. This experiment is not only trying to approach the Heisenberg Uncertainty limit for a position measurement, but it tries to approach it for a macroscopic object. In other words, this type of experiment aims to find a crossover not only between the quantum and classical worlds but also to find out how this crossover is related to the possible distinction between the micro-world and the macro-world.

Interference of macroscopically distinct states and measurement of decoherence times: At the end of the discussion of NEMS and foundations of quantum mechanics, we will return to the nanomechanical resonator coupled to Cooper-pair box NEMS already introduced above. This NEMS offers a working scheme to produce superpositions of distinct position states and measure their decay due to environmentally induced decoherence [566,572,578]. This scheme is based on the idea of coupling a nano-mechanical resonator to a Cooper-pair box to gain an advantage of coupling the resonator to a well defined two-level system (spin down and spin up states; a Cooper-pair box consists of a small superconducting island which is linked through a Josephson junction to a superconducting reservoir). The aim is to produce entangled states of a mechanical resonator and a Cooper-pair box: As soon as the Cooper-pair box is in a linear superposition of charge states (prepared by using an external gate) the resonator is (due to entanglement) driven in a superposition of spatially separated states. Under some circumstances, the separation of these states is large enough to be distinct states. Since the used resonator (cantilever) contains about $10^{10}-10^{11}$ atoms, we can suppose these states are macroscopically distinct states. There is a possibility to observe decoherence times related to this superposition of macroscopically distinct position states due to their coupling to the "well defined" environment.

10. Spin systems and their dynamics

Physics of spins offers a rich variety of phenomena realized in many different systems and new possibilities to create relatively simple two-level models to study dynamics of spins under various external fields and in various environments. At the same time modern technologies enable us to create well defined artificial structures as quantum dots and their arrays, where dynamics of spins can be well controlled by our choice of the system's parameters and external fields. Spins systems are thus very convenient (both from the theoretical as well as experimental point of view) especially for studies of basic questions of foundations of quantum physics (Section 2), quantum measurement, entanglement, coherence and dissipation (Section 3), quantum information processing (Section 6) and non-equilibrium quantum statistical physics (Section 8). Of course, many theoretical and experimental efforts are concentrated on properties related to spins in small (nanoscopic) systems (previous section). Due to specificity of these small spins systems we will briefly discuss some of their particular properties here.

Since there is a vast amount of activity in all these fields, it is not possible to mention all of them in this very limited space; we will therefore briefly mention only two applications of spin dynamics studies.

10.1. Spin electronics (spintronics)

Contrary to traditional solid state electronics which is based on the charge of electrons, spin electronics, or spintonics, deals with electron spin as an independent degree of freedom. Involvement of spin degree of freedom raises the question of the fundamental character what kind of new physics emerges when the processes related to electron charge and the electron spins are related. Some answers to this question lead to rapid transitions from fundamental studies to device technology of the magnetic memory storage industry; studies on sandwich structures, which consist of alternating ferromagnetic and non-magnetic metal layers lead to phenomenon of Giant magnetic resonance (GMR); its various forms were quickly used for many, nowadays commonly used, devices.

While mainstream spintronics continues with scientific studies of metal based structures and their technological improvements leading to ever better metal based devices, a parallel, more fundamental from the point of view of basic science, effort has now concentrated on semiconductor spintronics. Semiconductor spintronics now aims to understand the details of electron spin dependent transport so as to be able to develop electron devices whose resistance is well controlled by magnetic fields and the spins of charge carriers that flow through them.

There is also a possibility to manipulate carrier spins in semiconductors only by electric fields through spin–orbit coupling which can generate spin polarization through two processes: influencing a geometric phase and via spin-dependent scattering. This possibility has lead recently to an enormous number of studies.

10.2. Spins and quantum information processing

One of most promising candidates for solid state qubit systems is based on semiconductor quantum dots. Coherent control of a quantum system based on electron spins states in quantum dots could allow reasonable state preparation, coherent manipulation and readout. There is the possibility that spin based qubit nanoscopic systems could potentially operate even at room temperature and benefit from single-spin detection schemes. In this context, molecular nanomagnets have been proposed as hardware for quantum computation. The proposals for spin-based quantum information processing have generated a lot of attention with respect to the coherent control and decoherence processes of spins in many environments, and have led to many interesting studies important for both fundamental as well as applied research.

To summarize, in order to cope successfully with manipulation of spin states of quantum dots arrays by electrical means is a highly desirable aim of fundamental importance not only for the development of various spintronic devices such as possible spin transistors, filters and memories, but also for developing working scalable solid state qubits systems. We can also see again that further studies of decoherence processes and in general development of non-equilibrium statistical mechanics dealing with spin degrees of freedom influenced by various environments are urgent tasks.

11. Biological systems and molecular motors

Investigations of properties and behavior of biological systems require concentrated simultaneous efforts of many scientific disciplines due to complexity of these systems and involvement of enormous numbers of mutual interactions of their individual parts not only within, but also between different levels of their complicated hierarchical structures, creating an architecture going from individual atoms over huge biomolecules, through cells and tissues to the whole of a living organism. They are thus representing systems, the different parts of which going from the microscopic through the mesocscopic to the macroscopic world. Apart from hierarchy in space and size scales, we cannot forget about the complicated and rather variable hierarchical structure of time scales which determines the dynamics of individual parts of living organisms and, as a result, their behavior as a whole. In addition, all parts of living organisms are open systems which are very often in states far from equilibrium.

Thus, biological systems offer physics many fascinating possibilities to investigate these systems at various levels of their complexity and present challenging tasks on the way to understanding how the laws of physics work in such complex systems. To understand these living systems at least partially, we have to combine many fields of physics. It is impossible to name all fields of biophysics and biological physics which are nowadays quickly developing, but we can mention modeling brain functions, immune system, structure, solvation and folding of biomolecules, electron and proton transfer in bioenergetics and enzyme catalysis, ultrafast quantum dynamics in photosynthesis, physics of cell membranes, see also the books and reviews related to this section in this article biography.

As for themes discussed up to now in these proceedings we will first mention possible relation of physics of living organisms to Foundations of physics (Section 2) and Quantum measurement, entanglement and dissipation (Section 3). It is generally agreed that chemistry of biomolecules is governed by the laws of quantum mechanics. It is, however, up to now completely unclear whether quantum mechanics plays any significant role in the essential processes which lead to life; the possible role of quantum coherence, entanglement and of decoherence processes in living organisms remains uncertain, together with questions relating to at which levels transition from quantum to classical takes place. Any existence of macroscopic quantum phenomena in living organisms is not supported by any evidence up to now.

Very important overlaps exist between biological physics and non-equilibrium statistical physics (Section 8) together with physics of small systems (Section 9) since cells exhibit exceptional dynamics caused by the presence of ATP driven active motion which is realized along cytoskeleton (semidilute network of biopolymers which guarantees the mechanical stability and integrity of cells and enables active and directed traffic of molecules within cells) with the help of molecular motors of nanoscale sizes.

We will now finish this section by a short discussion of the physics of molecular motors which can be either natural or artificially prepared structures. There is still an undecided question of whether apart from commonly occurring classical molecular motors, quantum molecular motors play some role in living cells.

11.1. Molecular motors and rectified motion

Physics of artificially created and molecular motors occurring in nature create a special branch of physics where physics of small (“mesoscopic”) systems, statistical physics and biological physics mutually overlap. Contrary to the preceding sections, this subsection deals with classical as well as quantum systems. The basic feature of ratchet systems is the existence of a periodic, but asymmetric potential in the presence of an ac driving field. In addition, a system with a ratchet effect must have such parameters that thermal and quantum (in the case of quantum motors) fluctuations play an important role in its dynamics. Under these conditions directed transport can appear both in classical and quantum systems. Due to the essential role that Brownian motion plays in the ratchet effect, systems manifesting this effect are called either ratchet, or equivalently, Brownian motor systems. Due to the importance of fluctuations, ratchet effects appear generally in small systems [652–655,668].

The ratchet effect occurs naturally in biological systems where it creates a base for functioning of so-called molecular motors. These are proteins that take care of transport and muscle contraction in living organisms [644,646,634,648,658,659,664,667]. Apart from these naturally created systems, molecular motors are also studied in artificially shaped systems which, in some sense, mimic functions of molecular motors in living cells [653,668].

The theoretical and experimental study of both classical and quantum molecular motors enables us to develop a better stochastic method of systems description which is in some sense complementary to a fully microscopic description, starting from deterministic Newton or Schrödinger equations. Similarly, as Langevin and Fokker–Planck equations are complementary to the reversible, deterministic Newton equation and irreversible statistical mechanics based on it, the quantum Langevin equation and other quantum stochastic equations are complementary to the irreversible quantum statistical description starting from the “reversible, deterministic” Schrödinger equation. In the end, both approaches, either the one starting from the deterministic description or the one starting from the stochastic description, must provide the same results. Again, natural questions in relation with classical and quantum molecular motors, are “How the irreversibility is emerging?” and ”Where is the crossover between the classical and quantum worlds?

Summary

The FQMT’08 conference and the conference contributions to these proceedings have demonstrated many relations between such areas as foundation of quantum physics, quantum measurement theory, decoherence theory, quantum optics, quantum thermodynamics, non-equilibrium quantum statistical physics and their applications to the physics of quantum computing, cold atoms, physics of mesoscopic systems, biological systems and molecular motors.

Apparently, there is also an increasing tendency for merging theoretical and experimental methods of quantum optics and solid state physics. Similar to the FQMT'04 conference, lectures and discussions during the FQMT'08 conference and contributions to its proceedings have also shown several quite challenging goals of the recent physics which are common to all these areas. From the time of the FQMT'04 conference there have been some important partial successes on the way to solve tasks we formulated in the Proceedings from the FQMT'04 conference, but we are still far from finding their final satisfactory solution. So, in some cases we almost repeat the list of tasks from the conclusion of the FQMT'04 conference, perhaps with a little different stress on their various aspects. For example, over the four years since FQMT'04, it is clear that one of the most urgent tasks of physics is a proper formulation of fully non-equilibrium statistical theory of quantum systems together with a proper dealing with initial conditions suitable for a description of decoherence process under various circumstances. For this task, it is also crucial to improve our understanding the phenomenon of non-separability of quantum mechanical systems and related entanglement and to find out a better way of how to handle open systems so as to get deeper insight into their dynamics.

We now list some goals which the lectures and discussions at the FQMT'08 conference and its conference proceedings reveal to be important for future developments:

1. *To improve methods for the description of (open) systems far from equilibrium*: The need for improvement in this field is being driven by a growing demand to understand details of quick switching-on processes during experiments on nano-size systems which must be, due to their contacts, understood as open systems. These transients, switching-on or off processes, generally start from highly non-equilibrium quantum initial states.

The proper understanding of formulation of the initial state (i.e., the preparation period of systems before their measurement) and its time development (its measurement) is important not only from the point of view of basic science (theory of quantum measurement, quantum transport theory) but this is also crucial for possible applications. This is in fact a really interdisciplinary field where many fundamental questions and possible applications meet: as it was mentioned at various places in previous sections, non-equilibrium theory of open systems relates, via decoherence theory, to all branches of physics discussed at the conference, from the foundations of quantum mechanics, to measurements on quantum systems, to the physics of quantum computing and mesocopic systems.

We need to develop a non-equilibrium theory which will be able to describe (open) systems with various numbers of particles (e.g., from individual electron systems up to many-electron systems) with sufficient accuracy in all time ranges, e.g., covering processes and dynamics of the system from short-time to long-time scales. To this end, we need to find a proper description of initial conditions, interactions in the system, and efficient methods of how to find dynamics beyond both Markovian and linear approximations. A really challenging problem is to develop a theory which describes proper dynamics of the system when the interaction between the system and the reservoir is a strong one, and weak coupling theories are not working properly.

2. *To develop more complex models for dissipation processes*: In "small systems", such as nanonectromechanical systems (NEMS), complicated couplings can be created between various parts of the system and their surroundings. There is a possibility that, e.g., the resonator can be damped via excitations of internal modes of the system. The dissipation can also be mediated via the strong electron–phonon interaction when an adiabatic (Born–Oppenheimer) approach is not sufficient. In other words, we have to study dissipation mechanisms in these new systems and to develop methods for including them in the dynamical description, so that these mechanisms will be still practically treatable within the generalized master equations (GME) framework.

3. *To improve our understanding of decoherence in various* (*microscopic–mesoscopic–macroscopic*) *systems*: There is an increasing need to understand: (a) the relation between decoherence processes and the quantum measurement problem, (b) emergence of classical macroscopic world from the quantum world, and (c) the physics of possible working qubit systems.

4. *To get better insight into entanglement in various* (*microscopic–mesoscopic–macroscopic*) *systems*: Due to basic significance of quantum entanglement in behavior of quantum systems and increasing use of the idea of quantum entanglement in various experiments in many branches of physics it is necessary to improve our algorithms and methods for detecting and quantifying entanglement together with possibilities of how to prepare entangled states artificially in various systems. At the same time, we need to develop methods of how to describe properly the dynamics of entanglement depending on the system environment. This is needed not only from the point of view of final understanding of the transition from quantum to classical classical behavior and as to why macroscopic many body systems have a tendency to behave classically, but also to be able to develop possible real working schemes based on the physics of quantum entanglement, such as various teleportation protocols. Last but not least, better understanding of entanglement can lead us to improved versions of non-equilibrium quantum statistical mechanics and quantum thermodynamics.

5. *To create new methods to analyze noise spectra and to thereby extract useful information from systems such as nano-electromechanical systems* (*NEMS*): There is continuing need to gain more information about "mesoscopic" systems from transport studies as opposed to only from the mean current, which measures the total charge transported via the system. Full counting statistics (FCS), i.e., the knowledge of the whole distribution of transmitted charge through the small system, of course, provides more information about the system than just only the first cumulant of the FCS (mean current). Already the second cumulant, the current noise, can help us to distinguish between the different transport mechanisms which lead to the same mean current. The problem, however, is how to coordinate the choice of a model of the measured small system with a method of how to calculate reliable several first cumulants; calculations heavily depend on an approximation of a generalized master equation (GME). Due to technical difficulties, calculations are up to now limited.

6. *To study intensively physical processes in "small" biological systems, i.e., on the level of cells and their organelles*: Recent nanotechnologies enable us to construct (biomimetic) systems, which mimic at least some features of complicated biological systems and mechanisms in living cells. Apart from the investigation of mimetic systems, nano-devices (e.g. NEMS) provide us a possibility to "follow individual molecules" in cells and manipulate them. This increases the possibility of a "symbiosis" between biology and physics: We can improve our knowledge of how cells work by using physics, but also physics research can be motivated by studies of cellular mechanisms. Molecular motors is the field where physics and biology already mutually cooperate. It is assumed nowadays, that every directed motion in living cells (such as transport of ions through cells' membranes, and kinesin walking along cytoskeletal filaments) is governed by molecular motors. These "microscopic engines" probably operate in the overdamped Brownian motion regime and for a better understanding of their roles in cells, a further development of methods of statistical physics is essential: we deal not only with individual motors in cells, but our challenge is to understand highly

cooperative behavior of many molecular motors, filaments of the cytoskeleton system, transport through membranes, and organelles of the cell. We can encounter such phenomena as traffic flows, traffic jams and pattern formation in cells. In fact, there are many problems where physics can help biology and vice versa. For example, recent investigations show that statistical physics can help us understand biological information processing: the effect of stochastic resonance can explain how weak biological signals are amplified by random fluctuations.

7. *To further improve systems which we can study experimentally, to suggest new experiments for small systems and to investigate various combinations of systems and parameters we have under our control*: There are many promising areas of research, such as Quantum optics, Cold atoms and Bose–Einstein condenastes, Physics of quantum computing, Nano-electro-mechanical and Opto-mechanical systems, Spins systems, Quantum Brownian motion and Molecular motors, which provide us a possibility to test experimentally the developed models and basic theories (as for example the theory of decoherence) in greater detail.

There is hope that working on the above-mentioned problems, in the future we will understand how and when a possible quantum thermodynamic description will appear as a special limit to quantum statistical physics. We will have better explanation for the irreversibility not only from the point of view of how it appears in the macroscopic world when a microscopic description is in principle based on a reversible description, but also in relation to the quantum measurement process which is an irreversible process itself. At the same time, we will understand better when and how the classical macroscopic world which we daily observe is emerging from our quantum statistical picture of the micro-world.

Even small experimental systems (generally far from equilibrium states) are still complicated from the point of view of theoretical description and the interpretation of experiments.

In other words, we need to develop theoretical methods and models we are able to solve, and from which it is possible to extract information comparable with experimental data. At the same time, the model has to be able to describe the actual complexity of the experiment.

To conclude, we can again, as already after the FQMT'04 conference, say that the depth and the diversity of the questions addressed at the FQMT'08 conference were very profound and is reflected in these proceedings.

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References

1. General points

[1] C.W. Misner, K.S. Thorne, J.A. Wheeler, Gravitation, W.H. Freeman and Company, San Francisco, 1973.
[2] C. Itzykson, J.-B. Zuber, Quantum Field Theory, McGraw-Hill, New York, 1980.
[3] R. Penrose, The Emperor's New Mind, Oxford University Press, Oxford, 1989.
[4] W.H. Zurek (Ed.), Complexity, Entropy, and the Physics of Information, SFI Studies in the Science of Complexity, vol. VIII, Addison-Wesley, Reading, MA, 1990.
[5] P. Davies (Ed.), The New Physics, Cambridge University Press, Cambridge, 1993.
[6] S. Weinberg, The Quantum Theory of Fields, vol. I: Foundations, Cambridge University Press, Cambridge, 1995.
[7] S. Weinberg, The Quantum Theory of Fields, vol. II: Modern Applications, Cambridge University Press, Cambridge, 1996.
[8] S. Weinberg, The Quantum Theory of Fields, vol. III: Supersymmetry, Cambridge University Press, Cambridge, 2000.
[9] S.F. Savitt (Ed.), Time's Arrows Today, Recent Physical and Philosophical Work, Cambridge University Press, Cambridge, 1995.
[10] L.S. Schulman, Time's Arrows and Quantum Measurement, Cambridge University Press, Cambridge, 1997.
[11] V.L. Fitch, D.R. Marlow, M.A.E. Dementi (Eds.), Critical Problems in Physics, Princeton University Press, Princeton, 1997.
[12] R. Torretti, The Philosophy of Physics, Cambridge University Press, Cambridge, 1999.
[13] B. Bederson (Ed.), More in Heaven and Earth, A Celebration of Physics at the Millenium, Springer, Berlin, 1999.
[14] S. Adams, Frontiers Twentieth Century Physics, Taylor & Francis, London, 2000.
[15] A. Khrennikov (Ed.), Quantum Probability and White Noise Analysis, vol. XIII: Proceedings of the Conference on Foundations of Probability and Physics, World Scientific, Singapore, 2002.
[16] R.A. Bertlman, A. Zeilinger, Quantum (Un)speakables: From Bell to Quantum Information, Springer, Berlin, 2002.
[17] A.Yu. Khrennikov (Ed.), Quantum Theory: Reconsideration of Foundations, Waxjo University Press, 2002.
[18] L. Castell, O. Ischebeck (Eds.), Time, Quantum, Information, Springer, Berlin, 2003.
[19] Q. Ho-Kim, N. Kumar, C.S. Lam, Invitation to Contemporary Physics, second ed., World Scientific, Singapore, 2004.
[20] M. Rowan-Robinson, Cosmology, fourth ed., Oxford University Press, Oxford, 2004.
[21] A.Yu. Khrennikov, Information Dynamics in Cognitive, Psychological and Anomalous Phenomena, Kluwer, Dordrecht, 2004.
[22] R. Penrose, The Road to Reality, Jonathan Cape, London, 2004.
[23] Th.M. Nieuwenhuizen, P.D. Keefe, V. Špička (Eds.), Proceedings of the International Conference on Frontiers of Quantum and Mesoscopic Thermodynamics (FQMT04), Physica E 29(1–2) (2005).
[24] A.Yu. Khrennikov (Ed.), Foundations of Probability and Physics—3, AIP Conference Proceedings, 2005.
[25] A.J. Leggett, The Problems of Physics, Oxford University Press, Oxford, 2006.
[26] G. Fraser (Ed.), The New Physics for the Twenty-first Century, Cambridge University Press, Cambridge, 2006.
[27] S. Blugel, G. Gompper, E. Koch, H. Muller-Krumhaar, R. Spatschek, R.G. Winkler (Eds.), Computational Condensed Matter Physics, Forschungszentrum Julich, 2006.
[28] G. Adenier, A.Yu. Khrennikov, T.M. Nieuwenhuizen (Eds.), Quantum Theory: Reconsideration of Foundations—3, AIP Conference Proceedings, vol. 810, AIP, Melville, NY, 2006.
[29] G. Adenier, A.Yu. Khrennikov, P. Lahti, V.I. Manko, T.M. Nieuwenhuizen (Eds.), Quantum Theory: Reconsideration of Foundations—4, AIP Conference Proceedings, vol. 962, AIP, Melville, NY, 2007.
[30] Th. Nieuwenhuizen, V. Špička, B. Mehmani, M.J. Aghdami, A.Yu. Khrennikov (Eds.), Beyond the Quantum, World Scientific, Singapore, 2007.
[31] R.J. Scully, The Demon and the Quantum, Wiley-VCH Verlag, 2007.
[32] M. Sachs, Concepts of Modern Physics, Imperial College Press, 2007.
[33] H.D. Zeh, The Physical Basis of the Direction of Time, Springer, Berlin, 2007.
[34] E. Lipparini, Modern Many-Particle Physics, World Scientific, Singapore, 2008.
[35] S. Weinberg, Cosmology, Oxford University Press, Oxford, 2008.
[36] Ch. Roychoudhuri, A.F. Kracklauer, K. Creath (Eds.), The Nature of Light: What is a Photon?, Taylor & Francis, 2008.
[37] G.P. Beretta, A.F. Ghoniem, G.N. Hatsopoulos (Eds.), Meeting the Entropy Challenge, American Institute of Physics, 2008.
[38] K. Maruyama, F. Nori, V. Vedral, Rev. Mod. Phys. 81 (2009).
[39] L. Acardi, G. Adenier, C.A. Fuchs, G. Jaeger, A. Khrennikov, J.A. Larson, S. Stenholm, (Eds.), Foundations of Probability and Physics—5, AIP Conference Proceedings, 2009.

2. Foundations of quantum mechanics

[40] A. Einstein, B. Podolsky, N. Rosen, Phys. Rev. 47 (1935) 777.
[41] J.E. Ballentine, Rev. Mod. Phys. 42 (1970) 358.
[42] H. Everett, The theory of the universal wave function, in: B. de Witt, N. Graham (Eds.), The Many-Worlds Interpretation of Quantum Mechanics, Princeton University Press, New Jersey, 1973.
[43] A. Aspect, Phys. Rev. D 14 (1976) 1944.
[44] A. Aspect, P. Grangier, G. Roger, Phys. Rev. Lett. 47 (1981) 460.
[45] A. Aspect, P. Grangier, G. Roger, Phys. Rev. Lett. 49 (1982) 91.

[46] A. Aspect, J. Dalibard, G. Roger, Phys. Rev. Lett. 49 (1982) 1804.
[47] A. Aspect, Nature 398 (1999) 189.
[48] A.J. Leggett, Suppl. Prog. Theor. Phys. 69 (1980) 80.
[49] J.A. Wheeler, W.H. Zurek (Eds.), Quantum Theory and Measurement, Princeton, New York, 1983.
[50] A.J. Leggett, Quantum measurement at the macroscopic level, in: J. De Boer, E. Dal, O. Ulfbeck (Eds.), The Lessons of Quantum Theory, Elsevier, Amsterdam, 1986, p. 35.
[51] J.S. Bell, Speakable and Unspeakable in Quantum Mechanics, Cambridge University Press, Cambridge, 1987.
[52] D. Bohm, B.J. Hiley, P.N. Kaloyerou, Phys. Rep. 144 (1987) 321.
[53] D.M. Greenberger, M.A. Horne, A. Shimony, A. Zeilinger, Am. J. Phys. 58 (1990) 1131.
[54] N.D. Mermin, Am. J. Phys. 58 (1990) 731.
[55] G. Rempe, M.O. Scully, H. Walter, Phys. Scr. T 54 (1991).
[56] M.O. Scully, B.G. Englert, H. Walter, Nature 351 (1991) 111.
[57] R. Omnes, Rev. Mod. Phys. 64 (1992) 339.
[58] V. Ambegaokar, Phys. Today 46 (1993) 828.
[59] D. Bohm, B. Hiley, Routledge, London, 1993.
[60] N.D. Mermin, Rev. Mod. Phys. 65 (1993) 803.
[61] Ch.H. Bennett, G. Brassard, C. Crepeau, R. Josza, A. Peres, W.K. Wooters, Phys. Rev. Lett. 70 (1993) 1895.
[62] A.H. Cook, The Observational Foundations of Physics, Cambridge University Press, Cambridge, 1994.
[63] B.J. Hiley, F.D. Peat (Eds.), Quantum Implications, Essays in Honour of David Bohm, Routledge, London, 1994.
[64] R. Omnes, Interpretation of Quantum Mechanics, Princeton University Press, Princeton, 1994.
[65] M.P. Silverman, More than one Mystery, Exploration in Quantum Interference, Springer, Berlin, 1994.
[66] B.G. Englert, M.O. Scully, H. Walter, Sci. Am. 271 (1994) 92.
[67] A. Peres, Quantum Theory: Concepts and Methods, Kluwer Academic Publishers, Dordrecht, 1995.
[68] B. d'Espagnat, Veiled Reality, Addison-Wesley, Reading, MA, 1995.
[69] T. Herzog, P. Kwiat, H. Weinfurter, A. Zeilinger, Phys. Rev. Lett. 75 (1995) 3034.
[70] D.M. Greenberger, A. Zeilinger, J.A. Wheeler (Eds.), Fundamental Problems in Quantum Theory (Proceedings of a Conference held in honor of J.A. Wheeler), vol. 755, Annals of the New York Academy of Sciences, New York, 1995.
[71] D. Bouwmeester, J.W. Pan, K. Mattle, M. Eibl, H. Weinfirter, A. Zeilinger, Nature 390 (1997) 575.
[72] C.J. Isham, Lectures on Quantum Theory, Mathematical and Structural Foundations, Imperial College Press, 1995, 1997.
[73] D. Home, M.A.B. Whitaker, Ann. Phys. (Leipzig (1997) 237.
[74] G. Grenstein, A.G. Zajonc, The Quantum Challenge, Jones and Bartlett Publishers, 1997.
[75] J. Bub, Interpreting Quantum World, Cambridge University Press, Cambridge, 1997.
[76] D. Home, Conceptual Foundations of Quantum Physics: An Overview from Modern Perspectives, Plenum Press, New York, 1997.
[77] L.E. Ballentine, Quantum Mechanics, a Modern Development, World Scientific, Singapore, 1998.
[78] Y. Imry, Phys. Scr. T 76 (1998) 171.
[79] L. Hardy, Cont. Phys. 39 (1998) 416.
[80] E.B. Karlsson and E. Brandes (Eds.), Topical Issue, Phys. Scr. T 76 (1998).
[81] A. Zeilinger, Rev. Mod. Phys. 71 (1999) S288.
[82] A. Zeilinger, Found. Phys. 29 (1999) 631.
[83] B.G. Englert, M.O. Scully, H. Walter, Am. J. Phys. 67 (1999) 325.
[84] L. Mandel, Rev. Mod. Phys. 71 (1999) S274.
[85] Found. Phys. 29(4) (1999) the whole issue.
[86] H.A. Bethe, Rev. Mod. Phys. 71 (1999) S1.
[87] A. Chefles, Cont. Phys. 41 (2000) 401.
[88] N. Gisin, V. Scarani, W. Tittel, H. Zbinden, Ann. Phys. (Leipzig) 9 (2000) 831.
[89] J.T. Cushing, Ann. Phys. (Leipzig) 9 (2000) 939.
[90] J. Ellis, D. Amati (Eds.), Quantum Reflections, Cambridge University Press, Cambridge, 2000.
[91] G. Auletta, Foundations and Interpretation of Quantum Mechanics: In the Light of a Critical Historical Analysis of the Problems and of a Synthesis of the Results, World Scientific, Singapore, 2000.
[92] F. Laloe, Am. J. Phys. 69 (2001) 655.
[93] L. Acardi, M. Regoli, The EPR correlations and the chameleon effect, in: A. Khrennikov (Ed.), Quantum Probability and White Noise Analysis, vol. XIII: Proceedings of the Conference Foundations of Probability and Physics, World Scientific, Singapore, 2001, p. 1, quant-ph/0110086.
[94] W.M. de Muynck, Interpretations of quantum mechanics, and interpretation of violation of Bell's inequality, in: A. Khrennikov (Ed.), Quantum Probability and White Noise Analysis, Vol. XIII: Proceedings of the Conference Foundations of Probability and Physics, World Scientific, Singapore, 2001, p. 95, quant-ph/0102066.
[95] I. Volovich, Quantum cryptography in space and Bell's theorem, in: A. Khrennikov (Ed.), Quantum Probability and White Noise Analysis, vol. XIII: Proceedings of the Conference Foundations of Probability and Physics, World Scientific, Singapore, 2001, p. 364.
[96] H.J. Eberly, Am. J. Phys. 70 (2002) 276.
[97] A.J. Leggett, J. Phys. Condens. Mattter 14 (2002) R415.
[98] R.B. Griffith, Consistent Quantum Theory, Cambridge University Press, Cambridge, 2002.
[99] W.M. De Muynck, Foundations of Quantum Mechanics, An Empiricists Approach, Kluwer, Dordrecht, 2002.
[100] A.J. Leggett, Found. Phys. 33 (2003) 1469.
[101] Found. Phys. 33 (10,11,12) (2003) the whole issues.
[102] B. Collett, P. Pearle, Found. Phys. 33 (2003) 1495.
[103] A. Bassi, G.C. Ghirandi, Phys. Rep. 379 (2003) 257.
[104] M. Razavy, Quantum Theory of Tunnelling, World Scientific, Singapore, 2003.
[105] A.Yu. Khrennikov, Ann. Phys. (Leipzig) 12 (2003) 575.
[106] O. Nairz, M. Armdt, A. Zeilinger, Am. J. Phys. 71 (2003) 319.
[107] A.E. Allahverdyan, R. Balian, Th.M. Nieuwenhuizen, Europhys. Lett. 61 (2003) 452.
[108] R.W. Robinett, Phys. Rep. 392 (2004).
[109] D. Dragoman, M. Dragoman, Quantum-Classical Analogies, Springer, Berlin, 2004.
[110] R. Bonifacio, B.G. Englert, and M.G.A. Paris (Eds.), J. Mod. Opt. 51(6/7) (2004).
[111] K. Hess, W. Philipp, Proc. Nat. Acad. Sci. 103 (2004) 1799.
[112] J.J. Halliwell, Cont. Phys. 46 (2005) 93.
[113] Found. Phys. 35(4) (2005) the whole issue.
[114] D. K Ferry, R. Akins, J. Bird, J. Phys. Condens. Matter 17 (2005) S1017.
[115] A. Elitzur, S. Dolev, N. Kolenda (Eds.), Quo Vadis Quantum Mechanics? Springer, Berlin, 2005.
[116] G. Greenstein, A.G. Zajonc, The Quantum Challenge: Modern Research on the Foundations of Quantum Mechanics, Jones and Bartlett Publishers, Sudbury, 2006.
[117] A. Whitaker, Einstein, Bohr and the Quantum Dilemma, Cambridge University Press, Cambridge, UK, 2006.
[118] S. Haroche, J.-M. Raimond, Exploring the Quantum: Atoms, Cavities, and Photons, Oxford University Press, Oxford, 2006.
[119] B. Rosenblum, F. Kuttner, Quantum Enigma: Physics Encounters Consciousness, Oxford University Press, Oxford, 2006.
[120] M. Le Bellac, Quantum Physics, Cambridge University Press, Cambridge, 2006.
[121] W.J. Mullin, R. Krotkov, F. Laloe, Phys. Rev. A 74 (2006) 023610.
[122] F. Laloe, W.J. Mullin, Phys. Rev. Lett. 99 (2007) 150401.
[123] A.J. Leggett, J. Phys. A Math. Theor. 40 (2007) 3141.
[124] A.J. Leggett, Prog. Theor. Phys. Suppl. 170 (2007) 100.
[125] H. De Raedt, K. De Raedt, K. Michielsen, K. Keimpema, S. Miyashita, J. Phys. Soc. Japan 76 (2007) 104005.
[126] S. Zhao, H. De Raedt, K. Michielsen, Found. Phys. 38 (2008) 322.
[127] A.J. Leggett, Rep. Prog. Phys. 71 (2008) 022001.
[128] F. Laloe, W.J. Mullin, Phys. Rev. A 77 (2008) 022108.
[129] W.J. Mullin, F. Laloe, Phys. Rev. A 78 (2008) 061605.
[130] M. Aspelmeyer, A. Zeilinger, Phys. World July (2008) 22.
[131] R. Brunner, R. Akins, D. K Ferry, F. Kuchar, R. Meisels, Phys. Rev. Lett. 101 (2008) 024102.
[132] D.M. Greenberger, M. Horne, A. Zeilinger, M. Zukowski, Phys. Rev. A 78 (2008) 022111.
[133] X.S. Ma, A. Qarry, J. Kofler, T. Jennewein, A. Zeilinger, Phys. Rev. A 79 (2008) 042101.
[134] S. Lloyd, Nat. Phys. 5 (2009) 165.
[135] W.H. Zurek, Nat. Phys. 5 (2009) 181.
[136] T.M. Nieuwenhuizen, Where Bell went wrong, in: L. Acardi, G. Adenier, C.A. Fuchs, G. Jaeger, A. Khrennikov, J.A. Larson, S. Stenholm, (Eds.), Foundations of Probability and Physics—5, AIP Conference Proceedings, 2009, p. 127.
[137] K. Konishi, G. Paffuti, Quantum Mechanics, Oxford University Press, Oxford, 2009.
[138] G. Auletta, M. Fortunato, G. Parisi, Quantum Mechanics, Cambridge University Press, Cambridge, 2009.

Stochastic electrodynamics, Quantum vacuum, Casimir force

[139] D. Bohm, B.J. Hiley, Phys. Rep. 172 (1989) 93.
[140] P.W. Milloni, The Quantum Vacuum—An Introduction to Quantum Electrodynamics, Academic Press, Boston, 1994.
[141] L. de la Pena, A.M. Cetto, The Quantum Dice—An Introduction to Stochastic Electrodynamics, Kluwer Academic Publishers, Kluwer, 1996.
[142] V.M. Mostepanenko, N.N. Trunov, The Casimir Effect and its Applications, Clarendon Press, Oxford, 1997.
[143] M. Kardar, R. Golestanian, Rev. Mod. Phys. 71 (1999) 1233.
[144] L. de la Pena, A.M. Cetto, Found. Phys. 31 (2001) 1703.
[145] K.A. Milton, The Casimir Effect, Physical Manifestation of Zero-Point Energy, World Scientific, Singapore, 2001.
[146] R.G. Barrera, S. Reynaud, New. J. Phys. 9 (2006).
[147] G.L. Klimchitskaya, V.M. Mostepanenko, Cont. Phys. 47 (2006) 131.
[148] B. Geyer, G.L. Klimchitskaya, V.M. Mostepanenko, Ann. Phys. 323 (2008) 291.
[149] S.K. Lamoreaux, Nature 457 (2009) 156.

3. Quantum measurement, entanglement, coherence and dissipation

[150] A.O. Caldeira, A.J. Leggett, Ann. Phys. 149 (1983) 374.
[151] A.J. Leggett, S. Chakravarty, A.T. Dorsey, M.P.A. Fisher, A. Garg, W. Zwerger, Rev. Mod. Phys. 59 (1987) 1.
[152] V.B. Braginsky, F.Ya. Khalili, in: K.S. Thorne (Ed.), Quantum Measurement, Cambridge University Press, Cambridge, 1992, 1995.
[153] U. Weiss, Quantum Dissipative Systems, World Scientific, Singapore, 1993 second ed., 1999, third ed., 2008.
[154] P. Grigolini, Quantum Mechanical Irreversibility and Measurement, World Scientific, Singapore, 1994.
[155] G.Z.K. Horvath, R.C. Thompson, P.L. Knight, Cont. Phys. 38 (1997) 25.
[156] M.G. Raymer, Cont. Phys. 38 (1997) 343.
[157] M.B. Plenio, P.L. Knight, Rev. Mod. Phys. 70 (1998) 101.
[158] W.H. Zurek, Philos. Trans. R. Soc. London A 356 (1998) 1793.
[159] W.H. Zurek, Phys. Scr. T 76 (1998) 186.
[160] R.A. Webb, P. Mohanty, E.M.Q. Jariwala, Prog. Phys. 46 (1998) 779.
[161] M.E. Gershenson, Ann. Phys. (Leipzig) 8 (1999) 559.
[162] P. Blanchard, D. Guilini, E. Joos, C. Keifer, I.O. Stamatescu (Eds.), Decoherence: Theoretical, Experimental and Conceptual Problems, Lecture Notes in Physics, vol. 538, Springer, Berlin, 1999.
[163] W.H. Zurek, Ann. Phys. (Leipzig) 9 (2000) 855.
[164] F. Haake, Quantum Signatures of Chaos, second ed., Springer, Berlin, 2000.
[165] N.V. Prokofev, P.C.E. Stamp, Rep. Prog. Phys. 63 (2000) 669.
[166] Y. Makhlin, G. Schön, A. Shnirman, Rev. Mod. Phys. 73 (2001) 357.
[167] J.M. Raimond, M. Brune, S. Haroche, Rev. Mod. Phys. 73 (2001) 565.
[168] J. Audretsch (Ed.), Entangled World, Wiley-VCH, Weinheim, 2002.
[169] W.H. Zurek, Rev. Mod. Phys. 75 (2003) 715.
[170] D. Giulini, E. Joos, C. Kiefer, J. Kupsch, I.O. Stamatescu (Eds.), Decoherence and the Appearance of a Classical World in Quantum Theory, Springer, Berlin, 1996 second ed., 2003.
[171] M. Schlosshauer, Rev. Mod. Phys. 76 (2004) 1267.
[172] H.T. Elze (Ed.), Decoherence and Entropy in Complex Systems, Lecture Notes in Physics, vol. 633, Springer, Berlin, 2004.
[173] R. Fazio, C. Macchiavello, Ann. Phys. (Leipzig) 14 (2005) 177.
[174] M. Schlosshauer, Decoherence and the Quantum-to-Classical Transition, Springer, Berlin, 2007.
[175] L. Amico, R. Fazio, A. Osterloh, V. Vedral, Rev. Mod. Phys. 80 (2008) 517.
[176] M. Griffoni, E. Paladino, New J. Phys. 10 (2008) 115003.
[177] R. Horodecki, P. Horodecki, M. Horodecki, K. Horodecki, Rev. Mod. Phys. 81 (2009) 865 arXiv: quant-ph/0702225v2.

Regular articles

[178] A.E. Allahverdyan, R. Balian, Th.M. Nieuwenhuizen, Phys. Rev. A 64 (2001) 032108.
[179] A.E. Allahverdyan, R. Balian, Th.M. Nieuwenhuizen, Phys. Rev. Lett. 92 (2004) 120402.
[180] D. K Ferry, R. Akins, J. Bird, Phys. Rev. Lett. 93 (2004) 026803-1.
[181] A.E. Allahverdyan, R. Balian, Th.M. Nieuwenhuizen, Physica E 29 (2005) 261.
[182] A.E. Allahverdyan, A.Yu. Khrennikov, Th.M. Nieuwenhuizen, Phys. Rev. A 72 (2005) 032102.
[183] A.N. Jordan, M. Buttiker, Phys. Rev. Lett. 95 (2005) 220401.
[184] A.N. Jordan, A.N. Korotkov, M. Buttiker, Phys. Rev. Lett. 97 (2006) 026805.
[185] S. Popescu, A.J. Shortm, A. Winter, Nat. Phys. 2 (2006) 754.
[186] A.N. Jordan, B. Trauzettel, G. Burkard, Phys. Rev. B 76 (2007) 155324.
[187] R. Brunner, R. Meisels, F. Kuchar, R. Akins, D. K Ferry, J. Bird, Phys. Rev. Lett. 98 (2007) 204101.
[188] A. Amir, Y. Oreg, Y. Imry, Phys. Rev. A 77 (2008) 050101.
[189] N.S. Williams, A.N. Jordan, Phys. Rev. Lett. 100 (2008) 026804.
[190] K. Jacobs, A.N. Jordan, E.K. Irish, Europhys. Lett. 82 (2008) 18003.
[191] N.S. Williams, A.N. Jordan, Phys. Rev. A 78 (2008) 062322.
[192] B. Kraus, H.P. Buchler, S. Diehl, A. Kantian, A. Micheli, P. Zoller, Phys. Rev. A 78 (2008) 042307.
[193] Ch. Ross, Nat. Phys. 4 (2008) 97.
[194] B. Mehmani, A.E. Allahverdyan, Th.M. Nieuwenhuizen, Phys. Rev. A 77 (2008) 032122.
[195] V. Vedral, Nature 453 (2008) 1004.
[196] C. Branciard, N. Brunner, N. Gisin, Ch. Kurtsiefer, A. Lamas-Linares, A. Ling, V. Scarani, Nature 4 (2008) 685.
[197] D. Kaszlikowski, A. Sen(De), U. Sen, V. Vedral, A. Winter, Phys. Rev. Lett. 101 (2008) 070502-1.
[198] M. Horodecki, Nat. Phys. 4 (2008) 833.
[199] F.G.S.L. Brandao, M.B. Plenio, Nat. Phys. 4 (2008) 873.
[200] R. Blatt, D. Wineland, Nature 453 (2008) 1008.
[201] I. Bloch, Nature 453 (2008) 1016.
[202] A. Zeilinger, Nature 451 (2008) 18.
[203] H.J. Kimble, Nature 453 (2008) 1023.
[204] J. Clarke, F.K. Wilhelm, Nature 453 (2008) 1031.
[205] R. Hanson, D.D. Awschalom, Nature 453 (2008) 1031.
[206] J. Dajka, J. Luczka, P. Hanggi, Phys. Status Solidi B 246 (2009) 936.
[207] L. Gammaitoni, P. Hanggi, P. Jung, F. Marchesoni, European Phys. J. B 69 (2009) 1.
[208] I. Goychuk, P. Hanggi, European Phys. J. B 69 (2009) 29.
[209] G. Galve, D. Zueco, S. Kohler, E. Lutz, P. Hanggi, Phys. Rev. A 79 (2009) 032332.
[210] D. Zueco, P. Hanggi, S. Kohler, New J. Phys. 10 (2009) 115012.
[211] P.B. Dixon, D.J. Starling, A.N. Jordan, J.C. Howell, Phys. Rev. Lett. 102 (2009) 173601.
[212] P. Samuelsson, I. Neder, M. Buttiker, Phys. Rev. Lett. 102 (2009) 106804.
[213] J.C. Howell, Nature 457 (2009) 798.
[214] M. Aspelmeyer, Nat. Phys. 5 (2009) 11.

4. Quantum optics

[215] W.H. Louisell, Quantum Statistical Properties of Radiation, Wiley, New York, 1990.
[216] H.J. Carmichael, An Open Systems Approach to Quantum Optics, Springer, Berlin, 1993.
[217] D.F. Walls, G.J. Milburn, Quantum Optics, Springer, Berlin, 1994 1995.
[218] L. Mandel, E. Wolf, Optical Coherence and Quantum Optics, Cambridge University Press, Cambridge, 1995.
[219] M.O. Scully, M.S. Zubairy, Quantum Optics, Cambridge University Press, Cambridge, 1999.
[220] H.J. Carmichael, Statistical Methods in Quantum Optics 1: Master Equations and Fokker–Planck Equations, Springer, Berlin, 2003.
[221] H.J. Carmichael, Statistical Methods in Quantum Optics 2: Non-Classical Fields, Springer, Berlin, 2007.
[222] C. Cohen-Tannoudji, J. Dupont-Roc, G. Grynberg, Photons and Atoms: Introduction to Quantum Electrodynamics, Wiley-VCH, Wenheim, 2004.
[223] H. Paul, Introduction to Quantum Optics: From Light Quanta to Quantum Teleportation, Cambridge University Press, Cambridge, UK, 2004.
[224] Ch.C. Gerry, S.P.L. Knight, Introductory Quantum Optics, Cambridge University Press, Cambridge, 2005.
[225] V. Vedral, Modern Foundations of Quantum Optics, Imperial College Press, London, 2005.
[226] M. Fox, Quantum Optics, Oxford University Press, Oxford, 2006.
[227] R.J. Glauber, Rev. Mod. Phys. 78 (2006) 1267.
[228] J. Hall, Rev. Mod. Phys. 78 (2006) 1279.
[229] J. Hansch, Rev. Mod. Phys. 78 (2006) 1297.
[230] M. Pessa, A. Tnnermann, New J. Phys. 8 (2006).
[231] J.C. Garrison, R.Y. Chiao, Quantum Optics, Oxford University Press, Oxford, 2008.
[232] I.R. Kenyon, The Light Fantastic, Oxford University Press, Oxford, 2008.
[233] A.D. Bandrauk, F. Krausz, A.F. Starace, New J. Phys. 10 (2008) 025004.
[234] F. Krausz, M. Ivanov, Rev. Mod. Phys. 81 (2009) 163.
[235] A. Ourjoumtsev, F. Ferreyrol, R. Tualle-Brouri, P. Grangier, Nat. Phys. 5 (2009) 189.
[236] D.H. Bradshaw, P.W. Milloni, Nature 457 (2009) 671.

5. Cold atoms and Bose–Einstein condensation

[237] C.J. Pethick, H. Smith, Bose–Einstein Condensation in Dilute Gases, Cambridge University Press, Cambridge, UK, 2002.
[238] L.P. Pitaevskii, S. Stringari, Bose–Einstein Condensation, Oxford University Press, Oxford, 2003.
[239] J.F. Annett, Superconductivity, Superfluidity and Condensates, Oxford University Press, Oxford, 2004.
[240] Ch.J. Foot, Atomic Physics, Oxford University Press, Oxford, 2005.
[241] A.J. Leggett, Quantum Liquids, Oxford University Press, Oxford, 2006.
[242] A. Posazhennikova, Rev. Mod. Phys. 78 (2006) 1111.
[243] I. Bloch, P. Zoller, New J. Phys. 8 (2006).
[244] D.M. Greenberg, N. Erez, M.O. Scully, A.A. Svidzinsky, M.S. Zubairy, Planck, photon statistics and Bose–Einstein condensation, in: E. Wolf (Ed.), Progress in Optics, vol. 50, Elsevier, Amsterdam, 2007, p. 275 arXiv:physics-optics/0712.1367.
[245] I. Bloch, J. Dallibard, W. Zwerger, Rev. Mod. Phys. 80 (2008) 885.
[246] S. Giorgini, L.P. Pitaevskii, S. Stringari, Rev. Mod. Phys. 80 (2008) 1215.
[247] I. Bloch, Nature 453 (2008) 1016.
[248] I. Bloch, Science 319 (2008) 1202.
[249] S. Diehl, A. Micheli, A. Kantian, B. Kraus, H.P. Buchler, P. Zoller, Nat. Phys. 4 (2008) 878.
[250] A. Amo, D. Sanvitto1, F.P. Laussy, D. Ballarini, E. del Valle, M.D. Martin, A. Lemaitre, J. Bloch, D.N. Krizhanovskii, M.S. Skolnick, C. Tejedor, L. Vina, Nature 457 (2009) 291.
[251] C.J. Griffin, T. Nikuni, E. Zaremba, Bose Condensed Gases at Finite Temperatures, Cambridge University Press, Cambridge, 2009.

6. Physics of quantum computing and information

[252] Ch.H. Bennett, Phys. Today 48 (1995) 24.
[253] R.P. Feynman, in: T. Hey, R.W. Allen (Eds.), Feynman Lectures on Computation, Perseus Publishing, 1996.
[254] A. Ekert, R. Jozsa, Rev. Mod. Phys. 68 (1996) 733.
[255] V. Vedral, M.B. Plenio, Prog. Quant. Electronics 22 (1998) 1.
[256] T. Hey, Cont. Phys. 40 (1999) 257.
[257] Ch.H. Bennett, D.P. DiVincenzo, Nature 404 (2000) 247.
[258] M.A. Nielsen, L.I. Chuang, Quantum Computation and Quantum Information, Cambridge University Press, Cambridge, 2000.
[259] H.K. Cummins, J.A. Jones, Cont. Phys. 41 (2000) 383.
[260] D. Bouwmeester, A. Ekert, A. Zeilinger (Eds.), The Physics of Quantum Information, Springer, Berlin, 2000.
[261] M.B. Plenio, V. Vitelli, Cont. Phys. 42 (2001) 25.
[262] A. Gonis, P.A.E. Turchi (Eds.), Decoherence and its Implications in Quantum Computing and Information Transfer, IOS Press, New York, 2001.
[263] D.V. Averin, B. Ruggiero, P. Silvestrini (Eds.), Macroscopic Quantum Coherence and Quantum Computing, Kluwer, New York, 2001.
[264] D. Vion, A. Aassime, A. Cottet, P. Joyez, H. Pothier, C. Urbina, D. Esteve, M.H. Devoret, Science 296 (2002) 886.
[265] A. Galindo, M.A. Martin-Delgado, Rev. Mod. Phys. 74 (2002) 374.
[266] N. Gisin, G. Ribordy, W. Tittel, H. Zbinden, Rev. Mod. Phys. 74 (2002) 145.
[267] V. Vedral, Rev. Mod. Phys. 74 (2002) 197.
[268] D. Heiss (Ed.), Fundamentals of Quantum Information, Quantum Computation, Communication, Decoherence and All That, Lecture Notes in Physics, vol. 587, Springer, Berlin, 2002.
[269] V.P. Belavkin, Rep. Prog. Phys. 65 (2002) 353.
[270] I. Chiorescu, Y. Nakamura, C.J.P.M. Harmans, J.E. Mooij, Science 299 (2003) 1869.
[271] A. Leggett, B. Ruggiero, P. Silvestrini (Eds.), Quantum Computing and Quantum Bits in Mesoscopic Systems, Plenum, New York, 2003.
[272] H. Hirvensalo, Quantum Computing, second ed., Springer, Berlin, 2004.
[273] D. Esteve, J.M. Raimond, J. Dalibard (Eds.), Quantum Entanglement and Information Processing: Proceedings of the Les Houches Summer School 2003, Elsevier Science, 2004.
[274] M.G.A. Paris, J. Řeháček (Eds.), Quantum State Estimation, Lecture Notes in Physics, vol. 649, Springer, Berlin, 2004.
[275] S. Lloyd, Nature 430 (2004) 971.
[276] I. Chiorescu, P. Bertet, K. Semba, Y. Nakamura, C.J.P. Harmans, J.E. Mooij, Nature 431 (2004) 159.
[277] C.W. Gardiner, Opt. Commun. 243 (2004) 57.
[278] P. Walther, K.J. Resch, T. Rudolph, E. Schenck, H. Weinfurter, V. Vedral, M. Aspelmeyer, A. Zeilinger, Nature 434 (2005) 169.
[279] T.P. Spiller, W.J. Munro, S.D. Barrett, P. Kok, Cont. Phys. 46 (2005) 407.
[280] L.M.K. Vandersypen, I.L. Chuang, Rev. Mod. Phys. 76 (2005) 1037.
[281] G. Benetti, G. Casati, G. Strini, Principles of Quantum Computation and Information, vol. I: Basic Concepts, World Scientific, Singapore, 2005.
[282] R. Fazio, New J. Phys. 7 (2005) 11.
[283] V. Bužek, P. Grangier, P. Tombesi (Eds.), Eur. Phys. J. D 32(2) (2005).
[284] V. Vedral, Quantum Information Science, Oxford University Press, Oxford, 2006.
[285] G. Benetti, G. Casati, G. Strini, Principles of Quantum Computation and Information, vol. I: Basic Tools and Special Topics, World Scientific, Singapore, 2007.
[286] T. Rudolph, J.-W. Pan, New J. Phys. 9 (2007).
[287] G. Jaeger, Quantum Information, Springer, New York, 2007.
[288] N.D. Mermin, Quantum Information Science, Cambridge University Press, Cambridge, 2007.
[289] S.D. Bartlett, T. Rudolph, R.W. Spekkens, Rev. Mod. Phys. 79 (2007) 555.
[290] P. Kok, W.J. Munro, K. Nemoto, T.C. Ralph, J.P. Dowling, G.J. Milburn, Rev. Mod. Phys. 79 (2007) 135.
[291] W. van Dam, G.M. D'Ariano, A. Ekert, C. Macchiavello, M. Mosca, Phys. Rev. Lett. 98 (2007) 090501.
[292] A. Ekert, Nature 445 (2007) 366.
[293] T. Calarco, P. Grangier, A. Wallraff, P. Zoller, Nat. Phys. 4 (2008).
[294] A.J. Daley, M.M. Boyd, J. Ye, P. Zoller, Phys. Rev. Lett. 101 (2008) 170504.
[295] J. Stolze, D. Suter, Quantum Computing, Wiley-VCH, Weinheim, 2008.
[296] C. Brukner, A. Zeilinger, Found. Phys. 39 (2009) 677.
[297] R. Prevedel, G. Cronenberg, M.S. Tame, M. Paternostro, P. Walther, M.S. Kim, A. Zeilinger, Phys. Rev. Lett. 103 (2009) 020503.
[298] T. Scheidl, R. Ursin, A. Fedrizzi, S. Ramelow, X.S. Ma, T. Herbst, R. Prevedel, L. Ratschbacher, J. Kofler, T. Jennewein, A. Zeilinger, New J. Phys. 11 (2009) 085002.

7. Quantum thermodynamics

[299] S.G. Brush, The Kind of Motion we Call Heat: Statistical Physics and Irreversible Processes, Elsevier, 1986.
[300] C.H. Bennett, Sci. Am. 257 (1987) 108.
[301] W. Brenig, Statistical Theory of Heat, Nonequilibrium Phenomena, Springer, Berlin, 1989.
[302] H.S. Leff, A.F. Rex (Eds.), Maxwell's Demon: Entropy, Information, Computing, Adam Hilger, Bristol and Princeton University Press, Princeton, 1990.
[303] E. Fick, G. Sauermann, The Quantum Statistics of Dynamic Processes, Springer, Berlin, 1990.
[304] M.B. Plenio, V. Vedral, Cont. Phys. 39 (1998) 431.
[305] A.E. Allahverdyan, Th.M. Nieuwenhuizen, Phys. Rev. Lett. 85 (2000) 1799.
[306] M.O. Scully, Phys. Rev. Lett. 87 (2001) 220601.
[307] A.E. Allahverdyan, Th.M. Nieuwenhuizen, Phys. Rev. E 64 (2001) 056117.
[308] Th.M. Nieuwenhuizen, A.E. Allahverdyan, Phys. Rev. E 66 (2002) 036102.
[309] M.O. Scully, Phys. Rev. Lett. 88 (2002) 050602.
[310] D.J. Evans, D.J. Searles, Adv. Phys. 51 (2002) 1529.
[311] G. Sewell, Quantum Mechanics and its Emergent Macrophysics, Princeton University Press, Princeton, 2002.
[312] A.E. Allahverdyan, Th.M. Nieuwenhuizen, Physica A 305 (2002) 542.
[313] A.E. Allahverdyan, Th.M. Nieuwenhuizen, J. Phys. A Math. Gen. 36 (2003) 875.
[314] Y.V. Rostovtsev, A.B. Matsko, N. Nayak, M.S. Zubairy, M.O. Scully, Phys. Rev. A 67 (2003) 053811.
[315] Computing, H.S. Leff, A.F. Rex (Eds.), Maxwell's Demon 2: Entropy, Classical and Quantum Information, Institute of Physics Publishing, Bristol, 2003.
[316] F. Ritort, Seminaire Poincare 2 (2003) 63.
[317] Ch.H. Bennett, Stud. History Philos. Mod. Phys. 34b (2003) 501.
[318] M.O. Scully, H.S. Zubairy, G.S. Agarwal, H. Walter, Science 299 (2003) 862.
[319] S.G. Brush, Kinetic Theory of Gases: An Anthology of Classic Papers with Historical Commentary, Imperial College Press, 2003.
[320] A. Nikulov, D.P. Sheehan (Eds.), Quantum Limits to the Second Law of Thermodynamics, Entropy (1) (2004).
[321] A.E. Allahverdyan, R. Serral Gracia, Th.M. Nieuwenhuizen, Phys. Rev. Lett. 93 (2004) 260404.
[322] A.E. Allahverdyan, R. Balian, Th.M. Nieuwenhuizen, Europhys. Lett. 67 (2004) 565.
[323] A.E. Allahverdyan, R. Balian, Th.M. Nieuwenhuizen, Entropy 6 (2004) 30.
[324] A.E. Allahverdyan, Th.M. Nieuwenhuizen, Phys. Rev. E 71 (2005) 066102.
[325] A.E. Allahverdyan, Th.M. Nieuwenhuizen, Phys. Rev. E 71 (2005) 046107.
[326] J. Gemmer, M. Michel, G. Mahler, Quantum Thermodynamics, Emergence of Thermodynamic Behavior within Composite Quantum Systems, Lecture Notes in Physics, vol. 657, Springer, Berlin, 2004.
[327] V. Čápek, D.P. Sheehan, Challenges to the Second Law of Thermodynamics: Theory and Experiment, Fundamental Theory of Physics, vol. 146, Springer, Dordrecht, 2005.
[328] J. Šesták, Science of Heat and Thermophysical Study, Elsevier, Amsterdam, 2005.
[329] A.E. Allahverdyan, R.S. Garcia, Th.M. Nieuwenhuizen, Phys. Rev. E 71 (2005) 046106.
[330] M. Hartmann, G. Mahler, O. Hess, Fundamentals of nano-thermodynamics, in: M. Rieth, W. Schommers (Eds.), Handbook of Theoretical and Computational Nanotechnology, American Scientific Publishers, 2005.
[331] C. Bustamante, J. Liphardt, F. Ritort, Phys. Today (July) (2005) 43.
[332] I. Kim, G. Mahler, Eur. Phys. J. B 54 (2006) 405.
[333] R.F. O'Connell, J. Statist. Phys. 124 (2006) 15.
[334] A.E. Allahverdyan, Th.M. Nieuwenhuizen, Phys. Rev. E 73 (066119) (2006).
[335] L. Leuzzi, T.M. Nieuwenhuizen, Thermodynamics of the Glassy State, Taylor & Francis, Boca Raton, FL, 2007.
[336] A.E. Allahverdyan, Th.M. Nieuwenhuizen, Phys. Rev. E 75 (2007) 051124.
[337] E. Bormashenko, A. Shkorbatov, O. Gendelman, Am. J. Phys. 75 (2007) 911.
[338] R.F. O'Connell, Fluctuation Noise Lett. 7 (2007) L483.
[339] G.W. Ford, R.F. O'Connell, Phys. Rev. B 75 (2007) 134301.
[340] M.J. Henrich, G. Mahler, M. Michel, Phys. Rev. E 75 (2007) 051118.
[341] M.J. Henrich, F. Rempp, G. Mahler, Eur. Phys. J. 151 (2007) 157.
[342] A. Allahverdyan, R.S. Johal, G. Mahler, Phys. Rev. E 77 (2008) 041118.
[343] U. Seifert, Eur. Phys. J. B 64 (2008) 423.
[344] I. Birjukov, T. Jahnke, G. Mahler, Eur. Phys. J. B 64 (2008) 105.
[345] A. Allahverdyan, G. Mahler, Eur. Phys. Lett. 84 (2008) 40007.
[346] A. Ben-Naim, Entropy Demystified, World Scientific, Singapore, 2008.
[347] W.T. Grady, Entropy and the Time Evolution of Macroscopic Systems, Oxford University Press, Oxford, 2008.

8. Non-equilibrium quantum statistical physics

[348] P. Hänggi, H. Thomas, Phys. Rep. 88 (1982) 207.
[349] E. Nelson, Quantum Fluctuations, Princeton University Press, Princeton, 1985.
[350] C.W. Gardiner, Handbook of Stochastic Methods for Physics, Chemistry and the Natural Sciences, second ed., Springer, Berlin, 1985, 1997.
[351] H. Smith, H.H. Jensen, Transport Phenomena, Clarendon Press, Oxford, 1989.
[352] S. Chapman, T.G. Cowling, The Mathematical Theory of Non-uniform Gases, third ed., Cambridge University Press, Cambridge, 1990.

[353] R.L. Liboff, Kinetic Theory, Classical, Quantum and Relativistic Descriptions, third ed., Prentice Hall, London, 1990, Springer, Berlin, 2003.
[354] P. Hänggi, P. Talkner, M. Borkovec, Rev. Mod. Phys. 62 (1990) 251.
[355] H.A. Cerdeira, F. Guinea-Lopez, U. Weiss (Eds.), Quantum Fluctuations in Mesoscopic and Macroscopic Systems, World Scientific, Singapore, 1991.
[356] R. Balian, From Microphysics to Macrophysics, Methods and Applications of Statistical Physics, vol. I, Springer, Berlin, 1992.
[357] R. Balian, From Microphysics to Macrophysics, Methods and Applications of Statistical Physics, vol. II, Springer, Berlin, 1992.
[358] D.K. Ferry, C. Jacoboni (Eds.), Quantum Transport in Semiconductors, Plenum Press, 1992.
[359] N.G. van Kampen, Stochastic Processes in Physics and Chemistry, North-Holland, Berlin, 1992.
[360] Y.U. Kagan and A.J. Leggett (Eds.), Quantum Tunnelling in Condensed Matter, Elsevier Publishers, New York, 1993.
[361] S. Hershfield, Phys. Rev. Lett. 70 (1993) 2134.
[362] G. Mahler, V.A. Weberrus, Quantum Networks, Dynamics of Open Nanostructures, Springer, Berlin, 1995.
[363] G. Casati, B.V. Chirikov (Eds.), Quantum Chaos: Between Order and Disorder, Cambridge University Press, Cambridge, 1995.
[364] H. Risken, The Fokker–Planck Equation: Methods of Solution and Applications, Berlin, Springer, 1996.
[365] J.P. Bouchaud, L.F. Cugliandolo, J. Kurchan, M. Mezard, Physica (Amsterdam) 226A (1996) 243.
[366] K. Efetov, Supersymmetry in Disorder and Chaos, Cambridge University Press, Cambridge, 1997.
[367] Th.M. Nieuwenhuizen, Phys. Rev. Lett. 80 (1998) 5580.
[368] R. Dean Astumian, F. Moss (Eds.), The Construction Role of Noise in Fluctuation Driven Transport and Stochastic Resonance, Focus issue, Chaos, vol. 8(3), 1998.
[369] T. Dittrich, P. Hänggi, G.L. Ingold, B. Kramer, G. Schon, W. Zwerger (Eds.), Quantum Transport and Dissipation, Wiley, New York, 1998.
[370] M. Grifoni, P. Hänggi, Phys. Rep. 304 (1998) 229.
[371] L. Gammaitoni, P. Hangi, P. Jung, F. Marchesoni, Rev. Mod. Phys. 70 (1998) 223.
[372] J. Honerkamp, Statistical Physics, An Advanced Approach with Applications, Springer, Berlin, 1998.
[373] Special Issue in Honor of Rolf Landauer, Superlattices Microstruct., vol. 23(3/4), 1998.
[374] J. Garcia-Ojalvo, J.M. Sancho, Noise in Spatially Extended Systems, Springer, Berlin, 1999.
[375] C.W.J. Beenakker, Rev. Mod. Phys. 69 (1999) 731.
[376] C.W. Gardiner, P. Zoller, Quantum Noise, A Handbook of Markovian and Non-Markovian Quantum Stochastic Methods with Applications to Quantum Optics, Springer, Berlin 2000.
[377] J.A. Freund, T. Poschel (Eds.), Stochastic Processes in Physics, Chemistry and Biology, Springer, Berlin, 2000.
[378] G. Lang, U. Weiss, Ann. Phys. (Leipzig) 9 (2000) 804.
[379] A. Schiller, S. Hershfield, Phys. Rev. B 62 (2000) R16271.
[380] R. Zwanzig, Nonequilibrium Statistical Mechanics, Oxford University Press, Oxford, 2001.
[381] H.D. Zeh, The Physical Basis of the Direction of Time, fourth ed., Springer, Berlin, 2001.
[382] V. Pechakus, U. Weiss (Eds.), Quantum Dynamics of Open Systems, special issue, Chem. Phys., vol. 268(1–3), 2001.
[383] G.L. Ingold, Path integrals and their applications to dissipative quantum systems, in: Lecture Notes in Physics, vol. 611, Springer, Berlin, 2002, p. 1.
[384] A. Buchleitner, K. Hornberger (Eds.), Coherent Evolution in Noisy Environments, Lecture Notes in Physics, vol. 611, Springer, Berlin, 2002.
[385] D.S. Lemons, An Introduction to Stochastic Processes in Physics, J. Hopkins Press, Baltimore, 2002.
[386] S.M. Bezrukov, Unsolved Problems of Noise and Fluctuations, AIP Conference Proceedings, vol. 665, Melville, New York, 2003.
[387] P. Garbaczewski, R. Olkiewicz (Eds.), Dynamics of Dissipation, Lecture Notes in Physics, vol. 597, Springer, Berlin, 2003.
[388] P. Bokes, R.W. Godby, Phys. Rev. B 68 (2003) 125414.
[389] P. Coleman, W. Mao, J. Phys: Condens. Matter 16 (2004) L263.
[390] J.L. Garcia-Palacios, D. Zueco, J. Phys. A 37 (2004) 10735.
[391] B. Lindner, J. Garcia-Ojalvo, A. Neiman, L. Schimansky-Geier, Phys. Rep. 392 (2004) 321.
[392] J.J. Mareš, J. Stávek, J. Šesták, J. Chem. Phys. 121 (2004) 1499.
[393] H. Kleinert, Path Integrals in Quantum Mechanics, Statistics, Polymer Physics, and Financial Markets, third ed., World Scientific, Singapore, 2004.
[394] T.D. Franck, Nonlinear Fokker–Planck Equations: Fundamentals and Applications, Springer, Berlin, 2005.
[395] E. Lebanon, P. Coleman, Phys. Rev. Lett. 95 (2005) 046803.
[396] B. Doyon, N. Andrei, Phys. Rev. B 73 (2006) 245326-1.
[397] B. Naser, D.K. Ferry, J. Heeren, J.L. Reno, J.P. Bird, Appl. Phys. Lett. 89 (2006) 083103.
[398] B. Naser, D.K. Ferry, J. Heeren, J.L. Reno, J.P. Bird, Appl. Phys. Lett. 90 (2007) 043103.
[399] F. Saques, J.M. Sancho, J.G. -Ojalvo, Rev. Mod. Phys. 79 (2007) 929.
[400] C.M. Van Vliet, Equilibrium and Non-equilibrium Statistical Mechanics, World Scientific, Singapore, 2008.
[401] H. Schroder, J. Teifel, G. Mahler, Eur. Phys. J. Spec. Top. 151 (2007) 181.
[402] G.E. Crooks, J. Statist. Phys. (2008) P10023.
[403] H. Forster, M. Buttiker, Phys. Rev. Lett. 101 (2008) 136805.
[404] G. Huber, F. Schmidt-Kaler, S. Deffner, E. Lutz, Phys. Rev. Lett. (2008) 070403-1.
[405] I. Junier, A. Mossa, M. Manosas, F. Ritort, Phys. Rev. Lett. (2009) 070602-1.
[406] M. Campisi, P. Talkner, P. Hanggi, Phys. Rev. Lett. (2009) 070602-1.
[407] F. Ritort, Physics 2 (2009) 43.
[408] S. Weiss, J. Eckel, M. Thorwart, R. Egger, Phys. Rev. B 77 (2008) 195316.

Green's functions approach

[409] L.P. Kadanoff, G. Baym, Quantum Statistical Mechanics, Benjamin, New York, 1962.
[410] A.A. Abrikosov, L.P. Gorkov, I.E. Dzyaloshinskii, Methods of Quantum Field Theory in Statistical Physics, Prentice-Hall, Englewood Cliffs, NJ, 1963.
[411] V. Korenman, Ann. Phys. 39 (1966) 72.
[412] P. Danielewicz, Ann. Phys. (N.Y.) 152 (1984) 239.
[413] J. Rammer, H. Smith, Rev. Mod. Phys. 58 (1986) 323.
[414] S. Hershfield, V. Ambegaokar, Phys. Rev. B 34 (1986) 2147.
[415] G.D. Mahan, Many Particle Physics, Plenum Press, New York, 1990, third ed., 2000.
[416] W. Botermans, R. Malfliet, Phys. Rep. 198 (1990) 115.
[417] G. Baym, Ch. Pethick, Landau Fermi-Liquid Theory: Concepts and Applications, Wiley, New York, 1991.
[418] R. Lake, S. Datta, Phys. Rev. B 45 (1992) 6670.
[419] N.S. Wingreen, Y. Meir, Phys. Rev. B 49 (1994) 11040.
[420] A.P. Jauho, N.S. Wingreen, Y. Meir, Phys. Rev. B 50 (1994) 5528.
[421] H. Schoeller, Ann. Phys. 229 (1994) 273.
[422] V. Špička, P. Lipavský, Phys. Rev. B 29 (1995) 14615–14635.
[423] N. Sivan, N.S. Wingreen, Phys. Rev. B 54 (1996) 11622.
[424] V. Špička, P. Lipavský, K. Morawetz, Phys. Rev. B 55 (1997) 5084.
[425] V. Špička, P. Lipavský, K. Morawetz, Phys. Rev. B 55 (1997) 5095.
[426] T.A. Costi, Phys. Rev. B 55 (1997) 3003.
[427] H. Haug, A.P. Jauho, Quantum Kinetics in Transport and Optics of Semiconductors, Springer, Berlin, 1997, second. ed., 2007.
[428] M. Bonitz, Quantum Kinetic Theory, Teubner, Stuttgart, 1998.
[429] A. Kamenev, A. Andreev, Phys. Rev. B 60 (1999) 2218.
[430] C. Chamon, A.W.W. Ludwig, Ch. Nayak, Phys. Rev. B 60 (1999) 2239.
[431] P.C. Martin, Quantum kinetic equations, in: M. Bonitz (Ed.), Progress in Non-equilibrium Green's Functions, World Scientific, Singapore, 2000, p. 2.
[432] G. Baym, Conservation laws and the quantum theory of transport: the early days, in: M. Bonitz (Ed.), Progress in Non-equilibrium Green's Functions, World Scientific, Singapore, 2000, p. 17.
[433] V. Špička, P. Lipavský, K. Morawetz, Phys. Rev. E 64 (2001) 046107.
[434] P. Lipavský, K. Morawetz, V. Špička, Ann. Phys. (France) 26 (2001).
[435] F. Michael, M.D. Johnson, Physica B 339 (2003) 31.
[436] L.V. Keldysh, Real-time nonequilibrium Green's functions, in: M. Bonitz, D. Semkat (Eds.), Progress in Non-equilibrium Green's Functions II, World Scientific, Singapore, 2003, pp. 2–16.
[437] H. Bruus, K. Flensberg, Many Body Quantum Theory in Condensed Matter Physics, Oxford University Press, Oxford, 2004.
[438] A. Kamenev, Many-body theory of non-equilibrium systems, in: Nanoscopic Quantum Transport, Proceedings of the 2004 Les-Houches Summer School, Elsevier, Amsterdam, 2005, cond-mat/0412296.
[439] V. Špička, B. Velický, A. Kalvová, Physica E 29 (2005) 154.
[440] V. Špička, B. Velický, A. Kalvová, Physica E 29 (2005) 175.
[441] V. Špička, B. Velický, A. Kalvová, Physica E 29 (2005) 196.
[442] J. Freericks, Transport in Multirayed Nanostructures, Imperial College Press, London, 2006.
[443] D. Kremp, D. Semkat, Th. Bornath, Condens. Matter Phys. 9 (2006) 431.
[444] L.A. Banyai, Non-equilibrium Theory of Condensed Matter, World Scientific, Singapore, 2006.
[445] A.R. Rocha, V.M. Garcia-Suarez, S. Bailey, C. Lambert, J. Ferrer, S. Sanvito, Phys. Rev. B 73 (2006) 085414.
[446] D. Kremp, D. Semkat, Th. Bornath, J. Phys: Condens. Matter 19 (2007) 376206.
[447] B. Velický, A. Kalvová, V. Špička, Phys. Rev. B 75 (2007) 195125.
[448] B. Velický, A. Kalvová, V. Špička, Phys. Rev. B 77 (2008) 041201 (R).
[449] K.S. Thygesen, A. Rubio, Phys. Rev. B 77 (2008) 115333.
[450] K.S. Thygesen, A. Rubio, Phys. Rev. B 79 (2009) 155110.

Density matrix approach

[451] R. Zwanzig, Physica 30 (1964) 1109.
[452] S. Nakajima, Prog. Theor. Phys. 20 (1958) 948.
[453] H. Mori, Prog. Theor. Phys. 33 (1965) 423.
[454] M. Tokuyama, H. Mori, Prog. Theor. Phys. 20 (1976) 411.
[455] E.B. Davies, Quantum Theory of Open Systems, Academic Press, London, 1976.
[456] H. Grabert, Projection Operator Techniques in Nonlinear Statistical Mechanics, Springer, Berlin, 1982.
[457] W.R. Frensley, Rev. Mod. Phys. 69 (1990) 745.

[458] J. Rau, B. Muller, Phys. Rep. 272 (1996).
[459] K. Blum, Density Matrix Theory and Applications, second ed., Plenum Press, New York, 1996.
[460] K.E. Camill, R.J. Glauber, Phys. Rev. A 59 (1999) 1538.
[461] V. May, O. Kuhn, Charge and Energy Transfer Dynamics in Molecular Systems, Wiley, Berlin, 2000.
[462] H.P. Breuer, F. Petruccione, The Theory of Open Quantum Systems, Oxford, New York, 2002.
[463] F. Benatti, R. Floreanini (Eds.), Irreversible Quantum Dynamics, Lecture Notes in Physics, vol. 622, Springer, Berlin, 2003.
[464] R. Brunetti, S. Monastra, C. Jacoboni, Semicon. Sci. Technol. 19 (2004) S250.
[465] I. Knezevic, D.K. Ferry, Phys. Rev. A 69 (2004) 012104.
[466] I. Knezevic, D.K. Ferry, Sci. Technol. 19 (2004) S220.

Time dependent density functional approach

[467] D. Joubert (Ed.), Density Functionals: Theory and Applications, Lecture Notes in Physics, vol. 500, Springer, Berlin, 1998, p. 116.
[468] R. Van Leeuwen, Int. J. Mod. Phys. B 15 (2001) 1969.
[469] G. Onida, L. Reining, A. Rubio, Rev. Mod. Phys. 74 (2002) 601.
[470] R. van Leeuwen, N.E. Dahlen, G. Stefanucci, C.O. Almbladh, U. von Barth, Introduction to the Keldysh Formalism and Applications to Time-Dependent Density-Functional Theory, cond-mat/0506130.
[471] O. Butriy, H. Ebadi, R. Van Leeuwen, E.K.U. Gross, Phys. Rev. A 98 (2007) 052514.
[472] N.E. Dahlen, R. van Leeuwen, Phys. Rev. Lett. 98 (2007) 153004-1.
[473] M. Myohanen, A. Stan, G. Stefanucci, R. van Leeuwen, European Phys. Lett. 84 (2008) 67001.

Dynamical mean field theory (DMFT)

[474] J.K. Freericks, V.M. Turkowski, V. Zlatic, Phys. Rev. Lett. 97 (2006) 266408.
[475] V.M. Turkowski, J.K. Freericks, Phys. Rev. B 75 (2007) 125110.
[476] O.P. Matveev, A.M. Shvaika, J.K. Freericks, Phys. Rev. B 77 (2008) 035102.
[477] A.V. Joura, J.K. Freericks, T. Pruschke, Phys. Rev. Lett. 101 (2008) 196401.
[478] N. Tsui, T. Oka, H. Aoki, Phys. Rev. B 78 (2008) 235124.

Density matrix renormalization group (DMRG)

[479] T.A. Costi, Phys. Rev. B 55 (1997) 3003.
[480] M. Keil, H. Schoeller, Chem. Phys. 268 (2001) 11.
[481] M.A. Cazalila, J.B. Marston, Phys. Rev. Lett. 88 (2002) 256403.
[482] P. Schmitteckert, Phys. Rev. B 70 (2004) 121302.
[483] F.B. Anders, A. Schiller, Phys. Rev. Lett. 95 (2005) 196801.
[484] D. Bohr, P. Schmitteckert, P. Wolfle, European Lett. 73 (2006) 246.
[485] S.G. Jakobs, V. Meden, H. Schoeller, Phys. Rev. B 70 (2004) 121302.
[486] F.B. Anders, Phys. Rev. Lett. 101 (2008) 066804.

9. Physics of small quantum systems

[487] R.P. Feynman, Eng. Sci. 23 (1966), Lecture Given at the APS Meeting 1959.
[488] G. Grinstein, G. Mazenko, Directions in Condensed Matter Physics, vol. 1, World Scientific, Singapore, 1986.
[489] B. Velický, V. Špička, J. Mašek, Solid State Commun. 72 (1989) 981.
[490] V. Špička, J. Mašek, B. Velický, J. Phys: Condens. Matter 2 (1990) 1569.
[491] B.L. Altshuler, P.A. Lee, R.A. Webb (Eds.), Mesoscopic Phenomena in Solids, North-Holland, Amsterdam, 1991.
[492] J.H. Davies, A.R. Long (Eds.), Physics of Nanostructures, IOP publishing, 1992.
[493] F. Sols, Ann. Phys. 214 (1992) 386.
[494] Y. Meir, N.S. Wingreen, Phys. Rev. Lett. 68 (1992) 2512.
[495] E. Akkermans, G. Montambaux, in: J.L. Pichard, J. Zinn-Justin (Eds.), Mesoscopic Quantum Physics, North-Holland, Amsterdam, 1995.
[496] H.A. Cerdeira, B. Kramer, G. Schon, in: Quantum Dynamics of Submicron Structures, Kluwer Academic Publishers, Dordrecht, 1995.
[497] S. Datta, Electron Transport in Mesoscopic Systems, Cambridge University Press: Cambridge (1995) 2001.
[498] J. Shah, Ultrafast Spectroscopy of Semiconductors and Semiconductor Nanostructures, Springer, Berlin, 1996.
[499] D. Ferry, S.M. Goodnick, Transport in Nanostructures, Cambridge University Press: Cambridge (1997) 2001.
[500] Y. Imry, in: Introduction to mesoscopic physics, Mesoscopic Physics and Nanotechnology, Oxford University Press, Oxford, 1997 second ed., 2002.
[501] L.L. Sohn, L.P. Kouwenhoven, in: G. Schon (Ed.), Mesoscopic Electron Transport, Kluwer Academic Publishers, Dordrecht, 1997.
[502] J.H. Davies, The Physics of Low-Dimensional Semiconductors, Cambridge University Press, Cambridge, 1998.
[503] A. Shik, Quantum Wells, Physics and Electronics of Two-Dimensional Systems, World Scientific, Singapore, 1998.
[504] Special Issue in Honor of Rolf Landauer, S. Datta (editor in chief), Superlattices and Microstructures, vol. 23(3/4), 1998.
[505] Y.V. Nazarov, Ann. Phys. (Leipzig) 8 (1999) 507.
[506] Y. Imry, R. Landauer, Rev. Mod. Phys. 71 (1999) S306.
[507] S. Datta, Superlattices Microstruct. 28 (2000) 253.
[508] Ya.M. Blanter, M. Büttiker, Phys. Rep. 336 (2000) 1.
[509] M. Janssen, Fluctuations and Localization in Mesoscopic Systems, World Scientific, Singapore, 2001.
[510] Y. Murayama, Mesoscopic Systems, Fundamentals and Applications, Wiley, New York, 2002.
[511] Lecture Notes in Physics, vol. 611, Springer, Berlin, 2002.
[512] D. Loss, N. Samarth (Eds.), Semiconductor Spintronics and Quantum Computation, D.D. Awschalom, Springer, Berlin, 2002.
[513] I.V. Lerner, B.L. Altshuler, V.I. Falko, T. Giamarchi (Eds.), Strongly Correlated Fermions and Bosons in Low-Dimensional Disordered Systems, Kluwer Academic Publishers, Dordrecht, 2002.
[514] T. Xue, S. Datta, M.A. Ratner, Chem. Phys. 281 (2002) 151.
[515] A. Wacker, Phys. Rep. 357 (2002) 1.
[516] I.L. Aleiner, P.W. Brouwer, L.I. Glazman, Phys. Rep. 358 (2002) 309.
[517] A.E. Allahverdyan, Th.M. Nieuwenhuizen, Phys. Rev. B 66 (2002) 115309 Selected for: Virtual J. Nanoscale Sci. Technol. 6(13) (2002)..
[518] T. Brandes, S. Ketterman (Eds.), Anderson Localization and its Ramifications, Lecture Notes in Physics, vol. 630, Springer, Berlin, 2003.
[519] R. Fazio, V.F. Gantmakher, Y. Imry (Eds.), New Directions in Mesoscopic Physics (Towards Nanoscience), Kluwer Academic Publishers, Dordrecht, 2003.
[520] Z.Y. Zeng, L. Baowen, F. Claro, Phys. Rev. B 68 (2003) 115319.
[521] A.P. Jauho, Non-equilibrium Green's function modelling of transport in mesoscopic systems, in: M. Bonitz, D. Semkat (Eds.), Progress in Non-equilibrium Green's Functions II, World Scientific, Singapore, 2003, p. 181.
[522] Lecture Notes in Physics, vol. 622, Springer, Berlin, 2003, the whole issue.
[523] V. Balzani, M. Venturi, A. Credi, Molecular Devices and Machines: A Journey into the Nanoworld, Wiley, New York, 2003.
[524] Y.V. Nazarov (ed.), Quantum Noise in Mesoscopic Physics, Kluwer Academic Publishers, Dordrecht, 2003.
[525] B.L. Altshuler, V. Tognett (Eds.), Quantum Phenomena of Mesoscopic Systems, Institute of Physics, 2003.
[526] P.A. Mello, N. Kumar, Quantum Transport in Mesoscopic Systems: Complexity and Statistical Fluctuations: A Maximum Entropy Viewpoint (Mesoscopic Physics and Nanotechnology), Oxford University Press, Oxford, 2004.
[527] K. Goser, P. Glosekotter, J. Dienstuhl, Nanonelectronics and Nanosystems: From Transistors to Molecular and Quantum Devices, Springer, Berlin, 2004.
[528] T. Ihn, Electronic Quantum Transport in Mesoscopic Semiconductor Structures, Springer, Berlin, 2004.
[529] J. Stangl, V. Holý, G. Bauer, Rev. Mod. Phys. 76 (2004) 725.
[530] K. Nakamura, T. Harayma, Quantum Chaos and Quantum Dots (Mesoscopic Physics and Nanotechnology), Oxford University Press, Oxford, 2004.
[531] S. Kohler, J. Lehmann, P. Hänggi, Phys. Rep. 406 (2005) 379.
[532] T. Brandes, Phys. Rep. 408 (2005) 315.
[533] W.D. Heiss (Ed.), Quantum Dots: A Doorway to Nanoscale Physics, Lecture Notes in Physics, vol. 667, Springer, Berlin, 2005.
[534] D.G. Austing, P. Hawrylak, D.J. Lockwood, A.S. Sachrajda (Eds.), Proceedings of the International Conference on Quantum Dots, Physica E, vol. 26(1–4), 2005.
[535] G. Cunibert, G. Fagas, K. Richter (Eds.), Molecular Electronics, Springer, Berlin, 2005.
[536] K. Busch, A. Powell, C. Rö thig, G. Schön, J. Weismüller (Eds.), CFN Lectures on Functional Nanostructures, Springer, Berlin, 2005.
[537] A. Baladin, K.L. Wang (Eds.), Handbook of Semiconductor Nanostructures and Nanodevices, American Scientific Publishers, 2005.
[538] M. Rieth, W. Schommers (Eds.), Handbook of Theoretical and Computational Nanotechnology, American Scientific Publishers, 2005.
[539] D.P. Sheehan, T. Seideman, J. Chem. Phys. 122 (2005) 204713.
[540] E. Akkermans, G. Montambaux, Mesoscopic Physics of Electrons and Photons, Cambridge University Press, Cambridge, 2007.
[541] M. Rey, M. Strass, S. Kohler, P. Hanggi, F. Sols, Phys. Rev. B 76 (2007) 085337.
[542] O. Entin-Wohlman, Y. Imry, S.A. Gurvitz, A. Aharony, Phys. Rev. B 75 (2007) 193308.
[543] Z. Ringel, Y. Imry, O. Entin-Wohlman, Phys. Rev. B 78 (2008) 165304.
[544] O. Entin-Wohlman, Y. Imry, A. Aharony, Phys. Rev. B 78 (2008) 224510.
[545] M. Di Ventra, Electrical Transport in Nanoscale Systems, Cambridge University Press, Cambridge, 2008.
[546] V.V. Mitin, V.A. Kochelap, M.A. Stroncio, Nanoelectronics, Cambridge University Press, Cambridge, 2008.
[547] E. Scheer, P. Reineker, New J. Phys. 10 (2008) 065004.
[548] R. Shankar, Rev. Mod. Phys. 80 (2008) 379.
[549] S.E. Nigg, M. Buttiker, Phys. Rev. B 77 (2008) 085312.
[550] Y.V. Nazarov, Y.M. Blanter, Quantum Transport, Cambridge University Press, Cambridge, 2009.
[551] S.E. Nigg, M. Buttiker, Phys. Rev. Lett. 102 (2009) 236801.

[552] J. Splettstoesser, M. Moskalets, M. Buttiker, Phys. Rev. Lett. 103 (2009) 076804.
[553] M. Moskalets, M. Buttiker, Phys. Rev. B 80 (2009) 081302.
[554] O. Entin-Wohlman, Y. Imry, A. Aharony, Phys. Rev. B 80 (2009) 035417.
[555] M.T. Rakher, N.G. Stoltz, L.A. Coldren, P.M. Petroff, D. Bouwmeester, Phys. Rev. Lett. 102 (2009) 097403.
[556] S.M. Thon, M.T. Rakher, H. Kim, J. Gudat, W.T.M. Irvine, P.M. Petroff, D. Bouwmeester, Appl. Phys. Lett. 94 (2009) 111115.
[557] M.P. van Exter, J. Gudat, G. Nienhuis, D. Bouwmeester, Phys. Rev. A 80 (2009) 023812.
[558] Ch. Santori, Y. Yamamoto, Nat. Phys. 5 (2009) 173.

Nanomechanical and optomechanical devices, quantum limit

[559] K.E. Drexler, Nanosystems Molecular Machinery, Manufacturing, and Computation, Wiley, New York, 1992.
[560] M.L. Roukes, Nano-Electromechanical Systems, in: Technical Digest of Solid-State Sensor and Actuator Workshop, 2000, cond-mat/0008187.
[561] M. Roukes, Sci. Am. 285 (2001) 48.
[562] M. Roukes, Phys. World 14 (2001) 25.
[563] D. Vitali, S. Mancini, P. Tombesi, Phys. Rev. A 64 (2001) 051401.
[564] A.D. Armour, M.P. Blencowe, Phys. Rev. B 64 (2001) 035311.
[565] R.H. Blick, A. Erbe, L. Pescini, A. Kraus, D.V. Scheible, F.W. Beil, E. Hoehberger, A. Hoerner, J. Kirschbaum, H. Lorenz, J.P. Kotthaus, J. Phys: Condens. Matter 14 (2002) R905.
[566] A.D. Armour, M.P. Blencowe, K. Schwab, Phys. Rev. Lett. 88 (2002) 148301.
[567] A.N. Cleland, Foundations of Nanomechanics, Springer, Berlin, 2002.
[568] R.G. Knobel, A.N. Cleland, Nature 424 (2003) 291.
[569] A. MacKinnon, A.D. Armour, Physica E 18 (2003) 235.
[570] A. Husain, J. Hone, H.W.Ch. Postma, X.M.H. Huang, T. Drake, M. Barbic, A. Scherer, M.L. Roukes, Appl. Phys. Lett. 83 (2003) 1240.
[571] I. Bargatin, M.L. Roukes, Phys. Rev. Lett. 91 (2003) 138302.
[572] E.K. Irish, K. Schwab, Phys. Rev. B 68 (2003) 155311.
[573] K.L. Ekinci, X.M.H. Huang, M.L. Roukes, Appl. Phys. Lett. 84 (2004) 4469.
[574] K.L. Ekinci, Y.T. Yang, M.L. Roukes, J. Appl. Phys. 95 (2004) 2682.
[575] R. Fremani, S. Mancini, P. Tombesi, Phys. Rev. A 70 (2004) 045801.
[576] P. Zoller, L. Tian, Phys. Rev. Lett. 93 (2004) 266403.
[577] P. Rabl, A. Shnirman, P. Zoller, Phys. Rev. B 70 (2004) 205304.
[578] M.P. Blencowe, Phys. Rep. 395 (2004) 159.
[579] M. Blencowe, Science 304 (2004) 56.
[580] A.N. Cleland, M.R. Geller, Phys. Rev. Lett. 93 (2004) 07051.
[581] H.D. LaHaye, O. Buu, B. Caharota, K.C. Schwab, Science 304 (2004) 74.
[582] A.D. Armour, M.P. Blencowe, Y. Zhang, Phys. Rev. B 69 (2004) 125313.
[583] A.D. Armour, Phys. Rev. B 70 (2004) 165315.
[584] I. Bargatin, E.B. Myers, J. Arlett, B. Gudlewski, M.L. Roukes, Appl. Phys. Lett. 86 (2005) 133109.
[585] M. Blencowe, Cont. Phys. 46 (2005) 249.
[586] M.R. Geller, A.N. Cleland, Phys. Rev. A 71 (2005) 032311.
[587] R.H. Blick, M. Grifoni (Eds.), New J. Phys. 7 (2006).
[588] S. Gigan, H.R. Bohm, M. Paternostro, F. Blaser, G. Langer, J.B. Hertzberg, K.C. Schwab, D. Bauerle, M. Aspelmeyer, A. Zeilinger, Nature 444 (2006) 67.
[589] T.J. Kippenberg, K.J. Vahala, cavity Opt. Exp. 15 (2007) 17172.
[590] L. Pezze, A. Smerzi, G. Khoury, J.F. Hodelin, D. Bouwmeester, Phys. Rev. Lett. 99 (2007) 223602.
[591] M. Aspelmeyer, K. Schwab (Eds.), New J. Phys. 10 (2008) 095001.
[592] T.J. Kippenberg, K.J. Vahala, Science 321 (2008) 1172.
[593] K.J. Vahala, J. Kerry, Phys. Rev. A 78 (2008) 023832.
[594] D. Kleckner, I. Pikovski, E. Jeffrey, L. Ament, E. Eliel, J. van den Brink, D. Bouwmeester, New J. Phys. 10 (2008) 095020.
[595] J.D. Teufel, J.W. Harlow, C.A. Regal, K.W. Lehnert, Phys. Rev. Lett. 101 (2008) 197203.
[596] J.D. Thompson, B.M. Zwicki, A.M. Jayich, F. Marquardt, S.M. Girvin, J.G.E. Harris, Nature 452 (2008) 72.
[597] F. Marquardt, Nat. Phys. 4 (2008) 513.
[598] M.P. Blencowe, Nat. Phys. 4 (2008) 753.
[599] M. Eichenfield, R. Camacho, J. Chan, K.J. Vahala, O. Painter, Nature 459 (2009) 550.
[600] K. Hammerer, M. Aspelmeyer, E.S. Polzik, P. Zoller, Phys. Rev. Lett. 102 (2009) 020501.
[601] K. Jahne, C. Genes, K. Hammerer, M. Wallquist, E.S. Polzik, P. Zoller, Phys. Rev. A 79 (2009) 063819.
[602] K. Hammerer, M. Wallquist, C. Genes, M. Ludwig, F. Marquardt, P. Treutlein, P. Zoller, J. Ye, H.J. Kimble, Phys. Rev. Lett. 103 (2009) 063005.

10. Spin systems and their dynamics

[603] I. Žutič, J. Fabian, S. Das Sarma, Rev. Mod. Phys. 76 (2004) 323.
[604] T. Jungwirth, J. Sinova, J. Masek, J. Kucera, A.H. MacDonald, Rev. Mod. Phys. 78 (2006) 809.
[605] G.A. Fiete, Rev. Mod. Phys. 79 (2007) 801.
[606] R. Hanson, L.P. Kouwenhoven, J.R. Petta, S. Tarucha, L.M.K. Vandersypen, Rev. Mod. Phys. 79 (2007) 1217.
[607] G.E.W. Bauer, L.W. Molenkamp, New J. Phys. 9 (2007).
[608] K. Hathaway, E. Dan Dahlberg, Am. J. Phys. 75 (2007) 871.
[609] D. Belitz, T.R. Kirkpatrick, Nat. Phys. 3 (2007) 15.
[610] A. Fert, Rev. Mod. Phys. 80 (2008) 1517.
[611] P. Grunberg, Rev. Mod. Phys. 80 (2008) 1531.
[612] M. trif, V.N. Golubev, D. Loss, Phys. Rev. B 77 (2008) 04534.
[613] P. Nagele, G. Campagnano, U. Weiss, New J. Phys. 10 (2008) 115010.
[614] M. Duckheim, D. Loss, Nat. Phys. 4 (2008) 836.
[615] C. Chappert, J.-V. Kim, Nat. Phys. 4 (2008) 837.
[616] N.P. Stern, D.W. Steuerman, S. Mack, A.C. Gossard, D.D. Awschalom, Nat. Phys. 4 (2008) 843.
[617] T. Yang, T. Kimura, Y. Otani, Nat. Phys. 4 (2008) 851.
[618] M. Malinowski, F. Dalla Longa, J.H.H. Rietjens, P.V. Paluskar, R. Hijink, H.J.M. Swagten, B. Koopmans, Nat. Phys. 4 (2008) 855.

11. Biological systems and molecular motors

[619] D.J. Amit, Modeling Brain Function, Cambridge University Press, Cambridge, 1992.
[620] S.A. Kauffman, The Origins of Order, Oxford University Press, Oxford, 1993.
[621] J.D. Murray, Mathematical Biology, second ed., Springer, Berlin, 1993.
[622] E. Schrodinger, What is life?, Cambridge University Press, Cambridge, 1994.
[623] B. Alberts, D. Bray, J. Lewis, M. Raff, K. Roberts, J.D. Watson, Molecular Biology of the Cell, third ed., Garland Publishing Inc., 1994.
[624] M.P. Murphy, L.A.J. ONeill (Eds.), What is life? The Next Fifty Years, Cambridge University Press, Cambridge, 1995.
[625] T.F. Weiss, Cellular Biophysics, vol. 1: Transport, MIT Press, Cambridge, MA, 1996.
[626] T.F. Weiss, Cellular Biophysics, vol. 2: Electrical Properties, MIT Press, Cambridge, MA, 1996.
[627] J.J. Hopfiled, Dynamics, computation, and neurobiology, in: V.L. Fitch, D.R. Marlow, M.A.E. Dementi (Eds.), Critical Problems in Physics, Princeton University Press, Princeton, 1997, p. 29.
[628] A.S. Perelson, G. Weisbuch, Rev. Mod. Phys. 69 (1997) 1219.
[629] B.D. Hames, N.M. Hooper, J.D. Houghton, Instant Notes in Biochemistry, Bios Scientific Publishers, 1997.
[630] H. Frauenfelder, G. Hummer, R. Garcia (Eds.), Biological Physics, American Institute of Physics, 1999.
[631] M. Daune, Molecular Biophysics, Oxford University Press, Oxford, 1999.
[632] H. Frauenfelder, P.G. Wolynes, R.H. Austin, Biological physics, in: B. Bederson (Ed.), More in Heaven and Earth, A Celebration of Physics at the Millenium, Springer, Berlin, 1999, p. 707 .
[633] J. McFadden, Quantum Evolution: Life in the Multiverse, Flamingo, London, 2000.
[634] V. Sayakanit, L. Matson, H. Frauenfelder (Eds.), Biological Physics, 2000, World Scientific, Singapore, 2001.
[635] S. Kauffman, Investigations, Oxford University Press, New York, 2000.
[636] D. Abbott (Ed.), Quantum Aspects of Life, World Scientific, Singapore, 2007.
[637] F. Ritort, Nonequilibrium fluctuations in small systems: from physics to biology, cond-mat 0705.0455, 2007.
[638] F. Jülicher, J. Käs, New J. Phys. 10 (2007) 1367.
[639] H.J. Briegel, S. Popescu, Entanglement and intra-molecular cooling in biological systems?—A quantum thermodynamic perspective, arXiv:quant-phys/0806.4552, 2008.
[640] E.H. Feng, G.E. Crooks, Phys. Rev. Lett. (2008) 090602-1.
[641] R. Philips, J. Kondev, J. Theriot, Physical Biology of the Cell, Garland Science, 2008.

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[642] V. Ambegaokar, Phys. Chem. Chem. Phys. 95 (1991) 400.
[643] R. Dean Astumian, Science 276 (1997) 917.
[644] M. Bier, Cont. Phys. 38 (1997) 371.
[645] F. Jülicher, A. Ajdar, J. Prost, Rev. Mod. Phys. 69 (1997) 1269.
[646] D. Reguear, J.M.G. Vilar, J.M. Rubi (Eds.), Statistical Mechanics of Biocomplexity, Lecture Notes in Physics, vol. 527, Springer, Berlin, 1999.
[647] J. Luczka, M. Matlak (Eds.), Transport Phenomena from Quantum to Classical Regimes, Proceedings of the XXIV International School of Theoretical Physics, Acta Phys. Polonica B, vol. 32(2), 2001.
[648] J. Howard, Mechanics of Motor Protein and Cytoskeleton, Sinauer Associates, Sunderland, 2001.
[649] R. Lipowsky, S. Klumpp, Th.M. Nieuwenhuizen, Phys. Rev. Lett. 87 (2001) 108101.
[650] Th.M. Nieuwenhuizen, R. Lipowsky, S. Klumpp, Europhys. Lett. 58 (2002) 68.
[651] R.M. Mazo, Brownian Motion, Oxford University Press, Oxford, 2002.
[652] R. Dean Astumian, P. Hänggi, Phys. Today 55 (2002) 33.
[653] H. Linke, Appl. Phys. A 75(2) (2002).
[654] P. Reimann, P. Hänggi, Appl. Phys. 75 (2002) 169.

[655] P. Reimann, Phys. Rep. 361 (2002) 57.
[656] P. Reimann, P. Hänggi, Appl. Phys. 75 (2002) 169.
[657] P. Hänggi, Chem. Phys. Chem. 3 (2002) 285.
[658] M. Schliwa (Ed.), Molecular Motors, Wiley, Wenheim, 2003.
[659] J. Howard, F. Gittes, Motor proteins, in: Physics of Biological Systems: From Molecules to Species, Lecture Notes in Physics, vol. 480, Springer, Berlin, 2003.
[660] R. Lipowsky, N. Jaster, J. Statist. Phys. 110 (2003) 1141.
[661] J.M.R. Parrondo, L. Dinis, Cont. Phys. 45 (2004) 147.
[662] Th.M. Nieuwenhuizen, S. Klumpp, R. Lipowsky, Phys. Rev. E 69 (2004) 061911.
[663] S. Klumpp, Th.M. Nieuwenhuizen, R. Lipowsky, Biophys. J. 88 (2005) 3118.
[664] M. Bier, Cont. Phys. 46 (2005) 41.
[665] F. Renzoni, Cont. Phys. 46 (2005) 161.
[666] J. Renn, Ann. Phys. (Leipzig) 14 (Suppl.) (2005) 23.
[667] E. Frey, K. Kroy, Ann. Phys. (Leipzig) 14 (2005) 20.
[668] P. Hänggi, F. Marchesoni, F. Nori, Ann. Phys. (Leipzig) 14 (2005) 51.
[669] P. Hänggi, F. Marchesoni (Eds.), 100 Years of Brownian Motion, Focus Issue of Chaos, vol. 15, 2005, 026101-026117, cond-mat/0502053.
[670] P. Hanggi, J. Luczka, P. Talkner (Eds.), Brownian Motion and Diffusion in the 21st Century, Focus Issue, New Journal of Physics, vol. 7, 2005.
[671] P. Hänggi, G.L. Ingold, Chaos 15 (2005) 026105;
G.W. Ford, R.F. O'Connell, Phys. Rev. A 73 (2006) 032103.
[672] D.S. Grebenkov, Rev. Mod. Phys. 79 (2007) 1077.
[673] G.W. Ford, R.F. O'Connell, Phys. Rev. A 76 (2007) 042122.
[674] R. Lipowsky, S. Liepelt, J. Statist. Phys. 130 (2008) 39.
[675] J. Beeg, S. Klumpp, R. Dimova, R.S. Gracia, E. Unger, R. Lipowsky, Biophys. J. 94 (2008) 532.
[676] J. Kierfeld, K. Frentzel, P. Kraikivski, R. Lipowsky, Eur. Phys. J. Spec. Top. 157 (2008) 123.
[677] S. Klumpp, Y. Chai, R. Lipowsky, Phys. Rev. E 78 (2008) 041909.
[678] S. Liepelt, R. Lipowsky, Phys. Rev. E 79 (2009) 011917.
[679] A.V. Ponomarev, S. Denisov, P. Hanggi, Eur. Phys. Lett. 85 (2009) 40003.
[680] A.V. Ponomarev, S. Denisov, P. Hanggi, Phys. Rev. Lett. 102 (2009) 230601.
[681] S. Denisov, P. Hanggi, J.L. Mateos, Am. J. Phys. 77 (2009) 602.
[682] P. Hänggi, F. Marchesoni, cond-mat 0807.1283v2, Rev. Mod. Phys. 81 (2009) 387.