# REVIEWS of MODERN PHYSICS

**Volume 82** **Number 1** **January–March 2010**

**Author guidelines**

**1** **Quantum algorithms for algebraic problems** — Andrew M. Childs, Wim van Dam

A quantum computer may solve some kinds of problems in a much more efficient way than a classical one. But, which are those problems? Until recent years very few of them were known to exist. Recently, however, new quantum algorithms have been developed and the list of problems a quantum computer could efficiently solve has been significantly enlarged. This review presents an introduction into the subject of quantum algorithms, extensively discussing most of the known quantum algorithms which provide a superpolynomial speed up with respect to their classical counterparts.

**53** **Magnetic pyrochlore oxides** — Jason S. Gardner, Michel J. P. Gingras, John E. Greedan

Pyrochlore oxides are prime examples for geometrically frustrated magnets, where long-range magnetic order is suppressed in favor of short-range order. This gives rise to unusual states such as spin ices, spin liquids, or spin glasses. This article gives an overview of this important field, and stresses both materials aspects and the current theoretical understanding of the topic.

**109** **Ginzburg-Landau theory of type II superconductors in magnetic field** — Baruch Rosenstein, Dingping Li

The topic of Abrikosov vortices has seen a strong revival of interest as a result of discoveries in new type II superconductors like the high- $T_c$ superconductors, pnictides, etc. This review gives an up-to-date and systematic overview of this topic, including diverse states of the vortex matter such as the vortex liquid and vortex glass.

**169** **Influence of global cosmological expansion on local dynamics and kinematics** — Matteo Carrera, Domenico Giulini

The influence of global cosmological expansion on the dynamics and kinematics of local systems, related to much smaller sizes of systems than cosmologically relevant scales, includes orbital motions in planetary systems or the configurations of compact objects, like black holes. How can the expansion influence the behavior on such scales? Are measurements of distances, velocities, etc. affected, being based on the exchange of electromagnetic signals from moving objects? This article compares estimates of such effects, e.g., with the scale of the apparently anomalous acceleration of the Pioneer 10 and 11 spacecrafts and reviews the challenging problem how cosmological dynamics has an impact on local systems.

**209** **Optical excitations in electron microscopy** F. J. García de Abajo

Electron microscopes utilize the focusing of electron beams on subnanometer spots to probe metal and/or dielectric response either by analyzing electron energy loss or by detecting emitted radiation. This review discusses the interaction of energetic electrons with matter using classical and quantum formulations and then describes the underlying phenomenology giving rise to unmatched spatial and energy resolution of both localized and extended optical excitations, including plasmons.

**277** ***Colloquium*: Area laws for the entanglement entropy** J. Eisert, M. Cramer, M. B. Plenio

Entanglement or geometric entropy—the entropy of a subregion—typically grows in direct proportion to the subregion's volume. However, for typical ground and thermal states of many-body systems, and for certain systems at critical points, the entanglement entropy increases proportionally to the boundary area. This Colloquium discusses examples of general lattice systems, classical and quantum in one or more dimensions, which such area laws hold, stressing rigorous analytical results; it notes application to the physics of black holes, quantum information theory, and the complexity of many-body systems.

**307** ***Colloquium*: Electronic instabilities in self-assembled atom wires** Paul C. Snijders, Hanno H. Weitering

Low dimensional systems have fascinated physicists for a long time due to their unusual properties such as charge fractionalization, semionic statistics, and Luttinger liquid behavior among others. In nature, however, low dimensional systems often suffer from thermal fluctuations that can make these systems structurally unstable. Human beings, however, can trick nature by producing artificial structures which are not naturally produced. This Colloquium reviews the problem of self-assembled atomic wires on solid surfaces from an experimental and theoretical point of view. These materials represent a class of one-dimensional systems with very unusual properties that can open doors to the study of exotic physics that cannot be studied otherwise.

**331** **The dark Universe** Matthias Bartelmann

The dark universe, the standard model of cosmology, provides a theoretical background for coherent explanations of the vast majority of cosmological phenomena, i.e., the expansion of the Universe, the cosmic microwave background, structure formation and galaxy rotation curves requiring dark matter , the solution of the horizon and flatness problem requiring a period of inflation , and the observed accelerated expansion pointing towards dark energy . This review summarizes the standard cosmological model and discusses what we know from observations about the evolution of the Universe and its contents, and what can be concluded about its origin and future and the structures it contains.

383 **Heavy-ion tumor therapy: Physical and radiobiological benefits**

Dieter Schardt
Thilo Elsässer
Daniela Schulz-Ertner

In recent years the range of available radiological approaches to cancer treatment has been extended from the traditional photon therapy to include novel methods using heavy ions. Progress in this area has been achieved through a combination of technical advances in accelerator design and improved understanding of the biological effects of such treatments. This review provides an overview of both of these areas, along with an outlook for future advances in the field.

427 ***Colloquium*: Structural, electronic, and transport properties of silicon nanowires**

Riccardo Rurali

The control of matter at the atomic-molecular scale is one of the key targets of modern nanotechnology. Within the broad range of devices and structures, nanowires and nanoribbons play an important role, not only because these structures may become useful in future applications, but also because of new quantum effects present. This Colloquium reviews some of the main aspects of Si nanowires from crystal properties to electronic behavior. The Colloquium is essential reading for anyone interested in the recent developments in this fast growing field.

451 ***f*(*R*) theories of gravity**

Thomas P. Sotiriou
Valerio Faraoni

Alternatives to Einstein's theory of gravity have lately received a boost from new developments in high-energy physics, cosmology, and astrophysics. This article focuses on the particular class of so-called $f\,R$ theories which include higher order curvature invariants. The authors review the most important aspects of these theories, point out their equivalence with other theories of gravitation, and discuss topics like actions, field equations, viability criteria, and cosmological and astrophysical applications.

499 **Failure processes in elastic fiber bundles**

Srutarshi Pradhan
Alex Hansen
Bikas K. Chakrabarti

Understanding and predicting the failure of materials is an essential part of technological progress. Both da Vinci and Galileo studied load failure back in their day. This review brings the reader up to date on the current understanding of fiber bundle models—simple models that exhibit rich, critical behavior, can be used to study real materials, and are connected to models of jamming and breakdown in traffic flow and network communications.

557 **Axions and the strong *CP* problem**

Jihn E. Kim
Gianpaolo Carosi

This article surveys the strong *CP* problem and its possible solutions, especially those involving a Peccei-Quinn symmetry and the associated light pseudo-Goldstone boson known as the axion. The theoretical expectations in nonsupersymmetric, supersymmetric, and string contexts, and the experimental, astrophysical, and cosmological implications are discussed.

**603** **Magnetic reconnection**

Masaaki Yamada
Russell Kulsrud
Hantao Ji

Magnetic resonance is ubiquitous in the Universe, observed in laboratory plasmas, solar flares, the Earth's magnetosphere, and on astrophysical scales. In the simplest picture, if plasmas with magnetic field lines in opposing directions are forced together, the magnetic field lines can break and reconnect with one another. More generally, magnetic reconnection involves a topology change of a set of field lines that leads to a new equilibrium configuration of lower magnetic field energy. The excess energy is converted to kinetic energy through acceleration or heating of particles. This article reviews observations of magnetic reconnection, including from dedicated experiments, and the parallel development of its theoretical understanding.

**665** **Nonlocality and communication complexity**

Harry Buhrman
Richard Cleve
Serge Massar
Ronald de Wolf

It is well known that, with the help of quantum mechanics, communication can be made completely secure against eavesdropping. What is not so well known is that, in some contexts, communication can also be made much more efficient. For instance, with the help of entangled states one can dramatically reduce the number of signals that need to be exchanged to perform certain communication tasks. This review explains how this is possible, and enumerates the particular problems where this reduction can occur. The intimate connection between these problems and nonlocality is discussed in detail. Current and future prospects for the experimental realization of these predictions are also discussed.

**699** **Searches for supersymmetry at high-energy colliders**

Jonathan L. Feng
Jean-François Grivaz
Jane Nachtman

Particle physics is at a crossroads. In the past three decades the standard model SM has been successful in describing all known elementary particles and their interactions. Ahead of us is the CERN Large Hadron Collider offering great possibilities to search for and study new phenomena, in the mass range from 100 GeV to several TeV. This article reviews the current state of experimental searches for supersymmetry, the most widely studied extension of the SM. Beyond the Higgs boson that has yet to be discovered, there are strong motivations for supersymmetry, including the need to explain dark matter and the desire for unification of all fundamental forces.

**729** **Light passing through subwavelength apertures**

F. J. Garcia-Vidal
L. Martin-Moreno
T. W. Ebbesen
L. Kuipers

The discovery of extraordinary optical transmission EOT of light through periodic arrays of subwavelength diameter holes in metal films, with transmission coefficients that can exceed unity when normalized to the aperture area, has inspired numerous studies. This paper summarizes the theoretical and experimental results, for both 1D and 2D structures, and several EOT phenomena are considered. The analysis is performed with a unifying theoretical approach which can be applied to the various geometries, ranging from arrays of apertures to the case of a single one.

**789** **Mean-field theory of hard sphere glasses and jamming**

Giorgio Parisi
Francesco Zamponi

When a material fails to crystallize but also fails to flow, we describe it as amorphous or glassy. Can a state which seems to be defined by a dynamic criterion be understood as an equilibrium phenomenon? In this review, the authors summarize the state of the art in the theory of this transition for the idealized system of frictionless hard spheres. In addition to reviewing current thinking, they outline shortcomings of our understanding of these enigmatic organizations of matter.

**847** **Inelastic x-ray scattering by electronic excitations under high pressure**

Jean-Pascal Rueff
Abhay Shukla

Inelastic x-ray scattering, used in tandem with high pressure, has become a powerful all-photon spectroscopic tool with the development of insertion devices on third generation synchrotrons. This review of experimental results focuses on the effects of extreme pressure on electronic transitions especially in strongly correlated electronic materials. The emphasis is on understanding the nature of *d* and *f* electronic states, magnetic transitions in 3D transition metal compounds, metal-insulator transitions, and electron delocalization in mixed valence materials. Local structure changes and electronic transitions under pressure in materials containing light elements are also reviewed.

**897** **Antiferroelectric liquid crystals: Interplay of simplicity and complexity**

Hideo Takezoe
Ewa Gorecka
Mojca ¨epiŁ

The alignment of electric dipoles is often thwarted by their own tendency to cancel the net dipole moment. However, when liquid crystalline phases form out of polar mesogens, their orientational order can be imparted on the dipole moments. The interplay between these two orders leads to remarkably complex phases, many of which are chiral. This article covers the history of antiferroelectric liquid crystals and reviews current thinking in their theoretical underpinnings.

**939** **Photon and graviton mass limits**

Alfred Scharff Goldhaber
Michael Martin Nieto

Standard quantum electrodynamics and general relativity assume that the photon and graviton are massless. It is of fundamental interest to examine whether small masses are possible theoretically and to determine experimental limits. This article reviews the substantial advances that have been made over the years on both fronts.

**981** **Crystal surfaces in and out of equilibrium: A modern view**

Chaouqi Misbah
Olivier Pierre-Louis
Yukio Saito

The growth of crystal surfaces is a complicated process with important practical implications. This paper reviews recent developments in deriving and solving evolution equations for this problem, with a special emphasis on instabilities that can be encountered during the growth process.

**Forthcoming articles**