REVIEWS of MODERN PHYSICS

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Author guidelines

1 **Editorial: Which Wei Wang?** Gene D. Sprouse

3 **Orbital-dependent density functionals: Theory and applications** Stephan Kümmel, Leeor Kronik

Density-functional theory is widely used for electronic structure calculations. It is based on a very simple, density-based variational principle discovered by Kohn and Hohenberg. However, many physical effects are hard to describe using the density, yet are easily described using orbitals. This article describes how orbital-dependent functionals are incorporated into density-functional theory and how they resolve formal and practical difficulties of the theory.

61 **Disclinations, dislocations, and continuous defects: A reappraisal** M. Kleman, J. Friedel

Defects play a central role in the study of materials, phase transitions, and frustrated systems. The topological approach, familiar in, for instance, the theory of vortices in superfluids and superconductors, is complemented in the materials context by Volterra construction of defects. This review, which brings these two approaches together, delves into the theory of relaxation of elastic distortions in ordered and ill-ordered media in which the concept of the extended Volterra process is developed. This approach is well suited to discuss defects in liquid crystals but also in amorphous systems, polynanocrystals, and in curved space crystals which can be used to understand complex defect-riddled phases, such as the liquid crystalline blue phases and other geometrically frustrated structures.

117 ***Colloquium*: Optimal control of high-harmonic generation** Carsten Winterfeldt, Christian Spielmann, Gustav Gerber

Contemporary interest in observing and controlling molecular and electronic dynamics with subfemtosecond time scale resolution has created a need for short pulses of extreme ultraviolet or soft x-ray coherent radiation. This Colloquium describes the mechanism underlying high harmonic generation, both with single atoms and from media confined within a narrow channel. It then discusses in detail possible techniques for controlling or optimizing the properties of the harmonics, through temporal shaping of the driving laser pulse or through engineering details of the vapor confinement, e.g., a hollow fiber.

141 ***Colloquium*: Physical approaches to DNA sequencing and detection**

Michael Zwolak
Massimiliano Di Ventra

Techniques for identifying the sequence of bases in a DNA strand have become sufficiently commonplace that they serve as tools for many practical applications in medicine, agriculture, and forensic science. In turn, the growth of applications motivate still further attempts to increase the speed and accuracy of sequencing, while also cutting the cost. To this end, there are several promising novel physical techniques that detect and probe DNA at the single molecule level. In particular, this Colloquium focuses on techniques based on nanochannels and nanopores, identifies outstanding current questions that require attention, and discusses opportunities to study fundamental physics at the interface between solids, liquids, and biomolecules in the nanometer range.

167 **Phase transitions and configuration space topology**

Michael Kastner

Phase transitions in thermodynamic equilibrium are characterized by a nonanalyticity in the free energy. An obvious question is which properties of a given system can lead to the existence of such a nonanalyticity. In this article a particular approach is discussed to answer this question, namely, the study of topology changes of configuration space.

189 **Inclusive quasielastic electron-nucleus scattering**

Omar Benhar
Donal Day
Ingo Sick

The response of the nucleus to the scattering of electrons exhibits at momentum transfers larger than 500 MeV/c a broad peak. This peak in the energy spectrum is due to processes where the electron is scattered from an individual moving nucleon in the nucleus which, after interaction with other nucleons, is ejected. The process is generally called quasielastic electron-nucleus scattering. This article reviews existing experimental data and their interpretation in terms of various theoretical approaches with particular emphasis on the width and shape of the quasielastic peak, from which the spectral function describing the distribution of energy and momentum of initially bound nucleons can be derived. Furthermore, processes more complicated than simple nucleon-knockout involving nonnucleonic degrees of freedom and meson exchange currents, and the unique property of scaling of quasielastic scattering, are discussed. Finally, analogies and differences to a variety of other fields of physics exploiting quasielastic scattering of probes from composite systems are pointed out.

225 ***Colloquium*: Theory of drag reduction by polymers in wall-bounded turbulence**

Itamar Procaccia
Victor S. L'vov
Roberto Benzi

Fluids flowing through pipelines, or past the hulls of ships or aircraft, are hindered by drag forces that add to the expense of the transport. It has been known for nearly 60 years that drag of wall-bounded turbulent flow could be substantially reduced by minute concentrations of polymers in the fluid; these agents reduce the momentum flux to the wall from the bulk fluid. Economic motivations have prompted extensive research on this phenomenon, but puzzles and controversy have remained. This Colloquium summarizes the considerable information now available, from recent theoretical advances as well as experiments and numerical simulations of the appropriate fluid equations.

249 **Four-body methods for high-energy ion-atom collisions**

Dževad Belkić
Ivan Mančev
Jocelyn Hanssen

This review presents a thorough overview of the current status and a critical assessment of the existing quantum-mechanical four-body theories for energetic ion atom collisions. A proper description of these collisions with two active electrons requires the solution of the pertinent four-body problems. The analysis considers a number of inelastic collisions with special attention focused on single electron capture, double electron capture, transfer ionization, and transfer excitation. Working within the four-body framework of scattering theory and imposing proper Coulomb boundary conditions in the entrance and exit channels, the review analyzes a number of the leading quantum-mechanical theories. The scope of the review is limited to intermediate and high nonrelativistic impact energies.

Forthcoming articles