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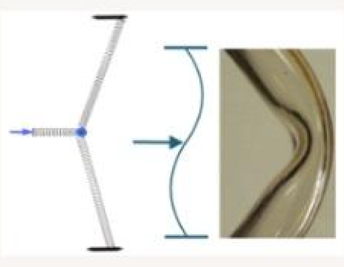


On the Cover

Classical thermodynamic bounds provide constraints on values that are expected in measurements of certain physical properties. In a variety of fields, some measurements exceed these bounds. This apparent violation of thermodynamics arises because the measurements are made in ways that violate the underlying assumptions made when deriving these bounds. This Colloquium describes a wide variety of circumstances where such violations occur and which of the underlying assumptions are violated in each case. It also describes how interesting material properties can be developed using materials designed to violate these assumptions.

From the article:

Colloquium: Materials that exceed classical thermodynamic bounds on properties

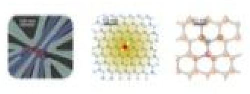
Roderic S. Lakes

Rev. Mod. Phys. **97**, 021002 (2025)

Colloquium: Decoherence of solid-state spin qubits: A computational perspective

Mykyta Onizhuk and Giulia Galli

Rev. Mod. Phys. **97**, 021001 (2025) - Published 4 April, 2025



Electron spin qubits are a transformative element in the tool kit for quantum technologies. Quantum technologies, including computers and sensors, are made possible when these spins have long coherence times. This Colloquium focuses on the growing confidence with which these coherence times can be predicted using *ab initio* methods. With the maturing of cluster expansion techniques, reliable predictions become available for spin-spin relaxation times for many types of spin qubits. Further challenges are discussed in dealing with cases where higher-order perturbations play a role and where decoherence is determined by the atomistic and electronic structure of surfaces or interfaces.

Colloquium: Materials that exceed classical thermodynamic bounds on properties

Roderic S. Lakes

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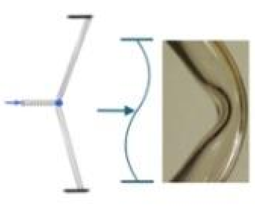

Classical thermodynamic bounds provide constraints on values that are expected in measurements of certain physical properties. In a variety of fields, some measurements exceed these bounds. This apparent violation of thermodynamics arises because the measurements are made in ways that violate the underlying assumptions made when deriving these bounds. This Colloquium describes a wide variety of circumstances where such violations occur and which of the underlying assumptions are violated in each case. It also describes how interesting material properties can be developed using materials designed to violate these assumptions.

Colloquium: Qudits for decomposing multiqubit gates and realizing quantum algorithms

Evgeniy O. Kiktenko, Anastasiia S. Nikolaeva, and Aleksey K. Fedorov

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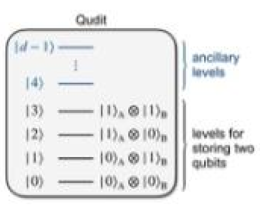

Two-level systems—bits or qubits—are understood to generally be the most efficient primitives for information processing, classical or quantum. But this is not to say that there are no roles to be played by multilevel systems. This Colloquium surveys these possible roles for the quantum case. Here we speak of qudits: *d*-level quantum systems. In one interesting example, the use of just one three-level system permits a drastic simplification of the "Toffoli gate," the basic three-qubit primitive of reversible logic. A survey is given of various qudit-qubit embeddings, and the current state of quantum computing experiments using qudits is reviewed.

Gas bubble dynamics

Dominique Legendre and Roberto Zenit

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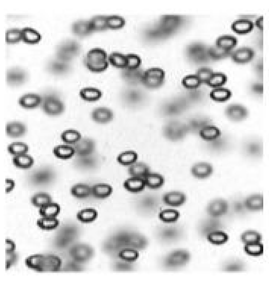

The motion of gas bubbles in liquids plays a vital role in numerous natural, industrial, and everyday phenomena. Unlike solid particles, gas bubbles are nearly weightless and highly responsive to forces from the surrounding fluid. Their dynamics are affected by added mass acceleration and deformable surfaces, and also by interactions with turbulent flows, other bubbles, and walls, with liquid rheology and surfactants further influencing their behavior. This review examines the intricate behavior of noncondensable gas bubbles, highlighting key advances over the past 20 years. Key topics include turbulence, non-Newtonian fluids, and electrolytes, offering insights to enhance modeling and guide future research in two-phase flow systems.

CODATA recommended values of the fundamental physical constants: 2022

Peter J. Mohr, David B. Newell, Barry N. Taylor, and Eite Tiesinga

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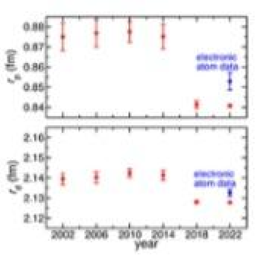

This review contains the 2022 self-consistent set of values of the constants and conversion factors of physics and chemistry recommended by the Committee on Data for Science and Technology (CODATA). The CODATA values are based on a least-squares adjustment that takes into account all data available up to the end of 2022. Details of the data selection and methodology are described.

Quantum physics of stars

M. Wiescher, C. A. Bertulani, C. R. Brune, R. J. deBoer, A. Diaz-Torres, L. R. Gasques, K. Langanke, P. Navrátil, W. Nazarewicz, J. Okołowicz, D. R. Phillips, M. Płoszajczak, S. Quaglioni, and A. Tumino

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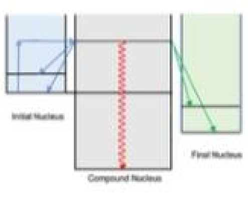

There are many nuclear reactions that are of central importance for stellar burning and element formation. In typical stars, these reactions take place at very low energy, and many of them have very small rates, making it difficult to measure them directly in the laboratory. On the theoretical side, the low-energy regime is governed by quantum-mechanical phenomena like tunneling, near-threshold resonances, and interference effects. This review summarizes the state of the art in the theory of low-energy nuclear reactions in stars and describes new ideas for studying these reactions on Earth.

Universality in driven open quantum matter

Lukas M. Sieberer, Michael Buchhold, Jamir Marino, and Sebastian Diehl

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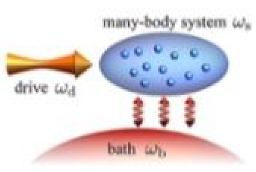

Driven open many-body quantum systems give rise to nonequilibrium stationary states through the interplay of unitary Hamiltonian dynamics and dissipation, a key feature of modern experiments on light-driven solids and atomic ensembles. This review explores the different types of universal behavior that emerge in these states and their theoretical classification within nonequilibrium quantum field theory, emphasizing the role of symmetry, topology, and quantum state purity.

Spin-dependent exotic interactions

Lei Cong, Wei Ji, Pavel Fadeev, Filip Ficek, Min Jiang, Victor V. Flambaum, Haosen Guan, Derek F. Jackson Kimball, Mikhail G. Kozlov, Yevgeny V. Stadnik, and Dmitry Budker

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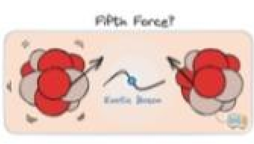

This review presents a comprehensive summary of theoretical investigations and experimental searches for spin-dependent interactions beyond the standard model. These interactions may be mediated by various types of exotic bosons, and their existence and properties may, in turn, explain the nature of dark matter and dark energy. The described experiments also probe the discrete fundamental symmetries of nature.

Order and disorder at the atomic scale: Microscopy applied to semiconductors

Enrico Di Russo, Tom Verstijnen, Paul Koenraad, Konstantinos Pantzas, Gilles Patriarche, and Lorenzo Rigutti

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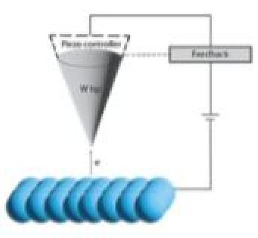

Atomic-scale details, especially those of disorder, are important for material properties, especially in semiconductors, but they are also extremely difficult to measure. Real-space methods can give direct access to this information, but typically, that access is limited. This review reports the application of three real-space techniques for measuring disorder to compound semiconductor materials: scanning tunneling microscopy, transmission electron microscopy, and atom-probe microscopy. Where possible, it emphasizes cases in which the probes have been combined to achieve a more complete picture of the defects.

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