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015001 **The climate system and the second law of thermodynamics**

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While the first law of thermodynamics is a well-established principle underlying all models of Earth's climate system, applications of the second law in climate science are active areas of research. This review summarizes how the relationships between Earth's entropy export and internal entropy production provide insights into Earth's climate. These applications include heat-engine analogs for atmospheric convection, tropical cyclones, and large-scale atmospheric heat transport. Open issues addressed include the ongoing debate on whether the climate system maximizes entropy production.

015002 **The proton charge radius**

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The proton is responsible for about half the mass in our personal lives. So it is perhaps surprising that little is known about how it got here or how it is bound from its fundamental quark and gluon constituents. This uncertainty is the largest source of error to extracting some fundamental constants of nature. One observable that probes the internal structure of the proton and tests our theoretical description of it is the proton charge radius. The radius is sensitive to quantum electrodynamics and quantum chromodynamics and helps to constrain new physics. This review presents the current status among the four types of experiments to measure the radius: electron scattering, muon scattering, electronic hydrogen spectroscopy, and muonic hydrogen spectroscopy.

015003 **Semitauonic b-hadron decays: A lepton flavor universality laboratory**

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While searches for interactions at high-energy experiments have yielded more stringent bounds on new physics, the discovery potential of indirect searches has drawn renewed attention. The standard model predicts that physical processes involving charged leptons should feature lepton flavor universality relations among physical observables. Observation of lepton flavor universality violation would thus establish the presence of new physics beyond the standard model. This article provides a review of lepton flavor universality violation in semileptonic b-hadron decays. It investigates the current measurements and their world averages, and examines the future, outlining the expected evolution of the experimental uncertainties and the prospects for future discoveries.

015004 **Noisy intermediate-scale quantum algorithms**

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Noisy quantum computers can in principle perform reliable quantum computations, but truly scalable systems require noise levels lower than are presently achieved. Still, moderate-complexity computations can be performed. This review discusses what is possible in this "noisy intermediate scale" quantum (NISQ) era. Topic areas include the simulation of many-body physics and chemistry, combinatorial optimization, and machine learning. It is evident that the NISQ era has produced new paradigms for programming that will be built upon as quantum computers are further perfected.

015005 **Collective nonlinear dynamics and self-organization in decentralized power grids**

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The rapid increase in renewable energy production facilities, domestic installations injecting energy back onto the grid, and the surge in electric vehicle adoption and associated high voltage charging stations are all placing unprecedented demands on the electric power grid. This article summarizes the physics that can inform the design and operation principles for future compliant power grids. The authors show that mathematically modeling grids as coupled nonlinear dynamical systems and networks and utilizing concepts from statistical physics and graph theory provide a comprehensive framework to understanding and controlling their collective behavior as a system of many interacting units. The article covers key topics including the synchronization dynamics and structural stability of power grids as well as methods to control dynamics and mitigate cascades of failures and large-scale blackouts.

015006 **Complex paths around the sign problem**

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A promising path to solving QCD is on a computer by discretizing spacetime, rewriting the QCD Lagrangian to fit in that discretization, and then taking the appropriate continuum and infinite volume limits. A problem with this method is that the calculation of certain quantities of interest is numerically intractable because of a "sign problem." A sign problem appears whenever large cancellations make it impractical to obtain reliable numerical results. This review discusses a potential solution: deformation of the manifold on which the problem is defined in order to reduce these instabilities.

015007 **Power functional theory for many-body dynamics** Matthias Schmidt

In equilibrium, the unifying framework of density-functional theory provides a variational scheme to determine both the thermodynamics and correlation functions of classical systems in the presence of an external potential field. Density-functional theory has found a range of application and nowadays forms a central pillar of liquid state and soft matter theory. Given the many successes it is natural to seek a variational approach to treat systems out of equilibrium. This was achieved with the development of the power functional theory. This review describes the approach of power functional theory, which is based on an exact one-body principle to describe the dynamics of overdamped, inertial classical, and quantum many-body systems.