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In this issue: February 2022

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B. Cameron Reed ; Jan Tobochnik

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Joseph Amato, John Essick, Harvey Gould, Claire A. Marrache-Kikuchi, Beth Parks, B. Cameron Reed, and Jan Tobochnik, *Editors*

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These brief summaries are designed to help readers easily see which articles will be most valuable to them. The online version contains links to the articles.

Making digital aquatint with the Ising model

Yannick Meurice
90(2), p. 87
https://doi.org/10.1119/10.0006525

Calling all art-lovers! The mathematical machinery of the Ising model, familiar as a theoretical description of ferromagnetism, is employed to add interesting "texture" to an existing work of art, such as a painting or photograph, mimicking the chemically-based "aquatint" technique developed by Francisco Goya (*The Disasters of War*), Pablo Picasso, and others. Best of all, the materials described herein have been successfully used by the author in first year seminar classes, spurring interest in physics and computer science among artistically-inclined students.

Band formation and defects in a finite periodic quantum potential

Todd K. Timberlake and Neilson Woodfield
90(2), p. 93
https://doi.org/10.1119/10.0006391

Periodic quantum systems, such as regularly spaced atoms in a solid, are characterized by energy spectra with well-defined bands of energy levels separated by gaps. The formation of band structures is usually analyzed with Bloch's theorem, but this can be abstract for beginning students. This paper examines the energy states of a one-dimensional system comprising Dirac delta-function wells embedded in an infinite square well. The spacing and strength of the Dirac wells can be varied to show how bands and gaps respond and to simulate the presence of defects in an otherwise periodic structure. In the following companion paper by Carr *et al.*, a similar topic is dealt with in a very different way: an experimental demonstration of defects and band formation using a classical analog system with coupled harmonic oscillators. Both papers are appropriate for intermediate and upper-level students.

A classical analog for defects in quantum band formation

Paolo Francisco, Tadan Cobb, Shawn A. Hilbert, and Scott Carr
90(2), p. 103
https://doi.org/10.1119/10.0009053

The collective mechanical behavior of a linear system of masses and springs can mimic that of a one-dimensional crystal. In particular, the resonance frequencies of the mechanical system are analogous to the crystal's electronic energies, and there is a frequency gap akin to a bandgap in a semiconductor. In this paper, the authors examine the effect of changing the mass or the spring constant in one of the mechanical oscillators and thus simulate the introduction of a defect in the crystal. The defect's resonance frequency can be theoretically calculated and compared with experiment. This work shows how a macroscopic mechanical system can serve as proxy for a microscopic quantum system. It could be used in an undergraduate advanced mechanics class, building a connection with condensed matter physics.

Investigating and improving student understanding of the basics for a system of identical particles

Christof Keebaugh, Emily Marshman, and Chandralekha Singh
90(2), p. 110
https://doi.org/10.1119/10.0006910

Systems of identical particles are notoriously difficult for students to understand. This paper describes student difficulties and presents a series of reflective exercises, a QuILT, that guide students to a greatly increased understanding, both at the undergraduate and graduate level.

Illustrations of loosely bound and resonant states in atomic nuclei

A. C. Dassie, F. Gerdau, F. J. Gonzalez, M. Moyano, and R. M. Id Betan
90(2), p. 118
https://doi.org/10.1119/10.0007045

The use of S-matrices is essential in analyzing nuclear physics experiments, but their meanings can be opaque. This paper seeks to help physicists develop a better understanding of these matrices by applying them to classical and quantum mechanical scattering problems.

Velocity reciprocity and the relativity principle

Patrick Moylan
90(2), p. 126
https://doi.org/10.1119/10.0009219

Velocity reciprocity is the property that pairs of inertial reference frames will measure each other to have equal and opposite relative velocities. While this is true for the Galilean and Lorentz transformations, it need not be true in general. This paper analyses the group-theoretic foundations of relativity theory to explore what additional assumptions must be made for velocity reciprocity to hold, and also explores the misconception that velocity reciprocity follows from the relativity of motion principle. In particular, the underappreciated importance of Henri Poincaré's demand that the principle of relativity be accorded universal validity is emphasized. Appropriate for students of modern physics and mathematics familiar with the rudiments of group theory.

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Subtle features in projectile motion with quadratic drag found through Taylor series expansions

Antonio Corvo
90(2), p. 135
https://doi.org/10.1119/10.0009227

The problem of projectile motion with air drag is notoriously difficult to approximate. The author presents an insightful trick: Expand the horizonal velocity in powers of inverse velocity. The result provides useful theoretical comparisons for data collected in the teaching lab and also a lesson in applications of the Taylor expansion.

Exploring complex pattern formation with convolutional neural networks

Christian Scholz and Sandy Scholz
90(2), p. 141
https://doi.org/10.1119/5.0065458

Machine learning is becoming more and more important in the analysis of data in many fields including physics. In this paper, the authors provide a pedagogical introduction to how a convolutional neural network can be used to classify the complex patterns created by simulations of a coupled reaction-diffusion system.

Theoretical and experimental examination of simple coaxial photonic crystals for undergraduate teaching

Xubo Guo, Yingying Liu, Ying Chang, Meihong Zhu, and Liuwan Zhang
90(2), p. 152
https://doi.org/10.1119/5.0059320

A coaxial photonic crystal, composed of a single type of coaxial cable, is used to study fundamental properties of photonic crystals. Using only a function generator and oscilloscope, photonic crystal effects, including photonic bandgap, highly superluminal group velocity, and the influence of defects, are investigated. Experimental results are compared to a theory based on transfer matrices. The work described here offers an affordable addition to the undergraduate instructional laboratory.

Book review—Beyond global warming: How numerical models revealed the secrets of climate change

John Chiang, Reviewer
90(2), p. 159
https://doi.org/10.1119/5.0084647

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