

mechanics we demonstrate forces in action, state Newton's laws and do playground problems, and we can do the like in quantum physics, using polarizers and analyzers with ψ vectors painted on them Montessori-style to show ψ vectors in action. This Dirac route cuts a century off the historical meander of physics through field theory.

Both authors suggest that quantum physics entails a loss of "objectivity." The alternative to objectivity is subjectivity, but a quantum frame is not just a mind-set, and the orientation of a polarizer is as objective as can be. Perhaps the authors mean that quantum mechanics is nonobjective in the sense of Wassily Kandinsky, who coined the term "non-objective art" in the same Munich where Werner Heisenberg, a decade later, worked out his quantum mechanics; for both renounced classical objects.

I emphasize that these imperfections are not confined to the books under review. Operational studies such as those of D. J. Foulis and C. H. Randall (*Current Issues in Quantum Logic*, Plenum, New York, 1981), Robin Giles (*J. Math. Phys.* **9** (1968) 359; **11** (1970) 2139) and Gunther Ludwig (*Foundations of Quantum Mechanics I&II*, Springer, New York, 1985) have only begun to trickle down to introductory texts; Leslie Ballentine's (*Quantum Mechanics*, Prentice Hall, N.J., 1990) is a praiseworthy exception. At any rate, we learn quantum physics, like any other sport, by doing it, not by talking about it. Both of these books do quantum theory admirably even without saying exactly what it is they do.

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The Andromeda Galaxy

Paul Hodge
Kluwer Academic, Boston,
1992. 358 pp. \$79.00 hc
ISBN 0-7923-1654-1

In this neat little volume, Paul Hodge has provided us with a comprehensive, semipopular survey of the literature on the Andromeda galaxy (Messier 31) from 1885 to 1991. It is the outcome of a ten-year effort, which Hodge undertook with the help of graduate students and most of the active researchers in the field. Many astronomers, both professional and amateur, will turn often to this convenient reference for a quick review of the known data on the nearest large spiral galaxy to our own.

Hodge, of the department of astronomy at the University of Washington,

Seattle and editor of the *Astronomical Journal*, was well qualified to prepare this compendium. He has made substantial contributions to the exploration and mapping of M 31. His work includes studies of the light distribution (which he did with Robert Kennicutt), associations of young stars, open star clusters (he includes a useful catalog of these in the book) and the complex, widespread dust clouds. He has also published the valuable photographic *Atlas of the Andromeda Galaxy* (U. Washington P., 1981).

Hodge's latest book covers the history of the subject from its earliest records and then reviews its optical and radio structure, rotation and mass, star clusters, dust content, variable stars, gaseous nebulae, molecular clouds, x-ray sources and stellar content. A brief final chapter compares M 31 and our Galaxy. The book is abundantly illustrated, generally by reproductions from the original publications. More detailed tables of individual objects, such as variable stars, novae, globular clusters, planetary nebulae and gaseous nebulae, would have made the book more useful to the active researcher, but probably less attractive to the general reader.

The most disappointing chapters are those on variable stars and novae, which fail to cover most of the knowledge acquired during the past 10 to 20 years. One gets the impression that toward the end of this vast undertaking the author became overwhelmed by the ever rising tide of papers to be read (a fact that he mentions in his preface).

For the Russian reader, a useful, somewhat more technical supplement to Hodge's book, may be found in *Туманность Андромеды* (Nauka, Moscow, 1982) by A. S. Sharov.

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Single Charge Tunneling: Coulomb Blockade Phenomena in Nanostructures

H. Grabert and
M. H. Devoret, eds.
Plenum, New York, 1992.
335 pp. \$89.50 hc
ISBN 0-306-44229-9

Since the 1960s it has been known that when electrons tunnel through an insulator containing a small metal particle, the current is suppressed because of the energy required to add charge to the particle. The energy to

add or remove an electron is $e^2/2C$, where C is the capacitance between the particle and the rest of the system; no current can flow if kT is much smaller than $e^2/2C$. This suppression of the current is called the Coulomb blockade. Of course, one can overcome this blockade by applying a large enough voltage, but when current begins to flow, electrons can only tunnel one at a time onto the particle. Otherwise, there would be two extra electrons on the particle at the same time, costing a still larger energy. Thus, the Coulomb blockade leads to single-electron tunneling.

In the 1960s the sizes and positions of metal particles in tunnel junctions could not be controlled. By the 1980s the technique of nanolithography made such control possible. There was a crescendo of activity in the study of single-electron phenomena, and in early 1991 a NATO Advanced Study Institute was held in Les Houches, France, to review the progress in the field. This book is a collection of lectures presented at the institute by leaders in single-electron physics and engineering.

Although the articles are described in the introduction as tutorial, they actually assume a great deal of background knowledge. Much of the theory of the Coulomb blockade is based on ideas developed long ago for the tunneling of Cooper pairs between superconductors, so a familiarity with that subject is very helpful in reading some of the chapters. Certain parts of the discussion assume a familiarity with superconducting electronics as well; for example, it is difficult to understand the chapter on applications of single-charge tunneling without this background.

Because the institute took place in 1991, some exciting recent advances could not be mentioned. One example is the measurement by Ray Ashoori and his colleagues at Bell Labs of capacitance changes resulting from single electron tunneling.

Despite these caveats I recommend the volume to those who wish to become familiar with the physics and potential applications of single-electron phenomena. They will find reviews on tunneling of single electrons in metal and semiconductor nanostructures, and on tunneling of Cooper pairs in superconducting ones. I particularly enjoyed the chapter entitled "Transferring Electrons One by One." In this chapter, D. Esteve discusses a variety of electron devices, including the electron "turnstile" and electron "pump," which provide a current $I = ef$ in response to a radio-frequency or microwave voltage of

frequency f . Esteve discusses the prospects of using these devices for metrology. Although the precision of such frequency-to-current converters is still too crude, they might eventually eliminate the kilogram—from which the ampere is presently derived—from our set of standards.

I expect that single-electron tunneling will continue to be a subject of much attention for the next few years. To my knowledge there are no other monographs on this subject, so those who intend to become experts will find this book quite valuable.

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Interfacial Transport Processes and Rheology

David A. Edwards,
Howard Brenner and
Darsh T. Wasan

Butterworth-Heinemann,
Boston, 1991. 558 pp. \$75.00 hc
ISBN 0-750-69185-9

As this review is being composed, thousands of gallons of light crude oil are spewing into the ocean from a tanker marooned off the Shetland Islands. In a distant time under less disturbing circumstances, Pliny the Elder observed that "divers sprinkle oil from their mouth because it calms the rough element and carries light down with them." Situations that evoke very different emotions often involve the exact same physics. Those currently interested in soft condensed matter, especially complex fluids such as liquid-liquid emulsions and gas-liquid foams, follow Lord Kelvin, J. A. F. Plateau, Lord Rayleigh and Josiah Willard Gibbs by engaging the physics of the interfacial region separating two fluids.

Interfacial Transport Processes and Rheology is a comprehensive graduate-level textbook concerned with the theory, measurement and application of interfacial hydrodynamics. The text is divided into two complementary parts. Part I occupies most of the book and adopts the classical, macroscopic view of fluid interfaces as idealized, two-dimensional singular surfaces. The adsorption of molecular or macromolecular surfactants imparts intrinsic rheological properties to the interface such as interfacial shear and dilatational viscosities (which are two dimensional counterparts of the three dimensional viscosities possessed by bulk-phase fluids) and Gibbs elasticity, which indicates the change in interfacial tension with

area. Gradients in surfactant concentration and temperature cause interfacial tension gradients that produce Marangoni phenomena such as the "tears" of strong wine. This text focuses successfully on predicting and understanding the separate and coupled roles of these intrinsic and extrinsic mechanisms of interfacial response.

The first two chapters of Part I include an illuminating introduction to interfacial phenomena, a short historical review, a qualitative discussion of the physicochemical aspects of interfacial behavior and an overview of important applications. The next three chapters provide a mathematical foundation and develop the field equations that govern the bulk and interfacial transport of momentum, mass, chemical species, energy and so on. These chapters provide deep insight into the physical and mathematical roles of the interface in supplying boundary conditions for the neighboring bulk phases. The text draws parallels and emphasizes differences between the interface and the bulk. The book includes numerous worked examples, questions and suggestions for additional reading at the end of each chapter. (A solution manual for instructors is available from the publisher.)

The next four chapters are devoted to the measurement of interfacial rheological properties. A balanced view is provided of the successes and problems, direct and approximate experimental techniques, and absolute and apparent physical properties that are associated with the condition of interfacial stress. Some highlights of the experimental sections include discussions of light-scattering techniques and the deep-channel viscometer for measuring interfacial shear viscosity. The last five chapters in Part I cover important applications such as Rayleigh and Bénard instabilities, interfacial turbulence, thin-liquid-film hydrodynamics and stability, and the rheology and stability of foams and emulsions. The discussion of the role of disjoining pressure and the use of Derjaguin-Landau-Verwey-Overbeek (DLVO) theory to understand the metastability (as opposed to the retarded but inevitable demise) of complex fluids are of interest to scientists and technologists alike, and they illustrate the broad appeal of the applications chapters.

Part II pursues a more detailed microrheological view of a three-dimensional interfacial region: It uses rigorous perturbation techniques to develop a generic surface-excess theory for nonmaterial interfaces that is

consistent with the classical approach. This theory may elucidate the molecular origins of interfacial phenomena and ultimately unify statistical mechanical and continuum mechanical approaches. The presentation parallels that on field equations in Part I and concludes with a chapter on the three-phase contact line (not covered in Part I but described by the Neumann-Young equation in the classical approach).

I highly recommend this textbook to serious students, teachers, technologists and researchers in this field.

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Exploring Music: The Science and Technology of Tones and Tunes

Charles Taylor

IOP, Bristol, UK (US dist.,
AIP, New York), 1992. 255 pp.
\$35.90 pb ISBN 0-7503-0213-5

The foreword of this book advises us that "Every year, ever since 1826, the Royal Institution has invited an eminent scientist to deliver a course of lectures at Christmastide in a style 'adapted to a juvenile auditory,' to use the words of Michael Faraday, who initiated the tradition." In practice the audience may range in age from under 10 to over 80.

Charles Taylor, a physicist who is an expert in crystal and optical phenomena, author of ten other musical books, and sometime professor of physics at the University of Wales, delivered the Christmas lectures in 1971 and again in 1989. The first series of lectures was published by the BBC as *Sounds of Music*. The book reviewed here is an expanded version of the 1989 lectures.

The book is charming in its descriptions of demonstrations by great men of the past and for illustrations of the apparatus they used. These include three used by John Tyndall, one demonstrating that sound will not travel through a vacuum. It is chastening to be reminded that effective acoustical and musical experiments predated electronic gadgets and computers. But electronics and computers also have their place in this wide-ranging book.

The variety of material covered would challenge the powers of any author. My reading is that Taylor is best in the physics of traditional musical instruments. He refers often to the work of the late Arthur Benade,