remarkable images of these glowing gas clouds obtained by the Hubble Space Telescope (HST) are seen in textbooks, magazines, and newspapers (see http://oposite.stsci.edu/pubinfo/pictures.html).

The name "planetary nebula" is in fact a misnomer, arising from their superficial similarity (through early telescopes of poor optical quality) to the outer planets Uranus and Neptune, which gave the nebulae the appearance of small, greenish disks. Today we know that planetary nebulae represent a transitional stage in the life cycles of many stars, during which a formerly cool, distended red giant star sheds much of its mass, barin the hot stellar core, which in turn illuminates, ionizes, and heats the newly created circumstellar gas cloud. This phase lasts only 10 000–100 000 years, a mere blink of an eye in the typical lifetime of a star, which is measured in millions or billions of years.

Planetary nebulae lie at the crossroads of several disciplines (stellar, interstellar, and galactic astronomy, as well as several branches of physics). The physical state of the gas and the emerging spectrum of radiation (best described using the tools of interstellar-medium astrophysics—the study of diffuse gas in space). Yet, because planetary nebulae comprise material cast off by aging stars near the end of their lives, they carry not only the imprint of the star's initial composition but also the signatures of internal nuclear reactions and mixing processes that bring freshly-made heavy nuclei to the surface during its lifetime (stellar evolution). Planetary nebulae show us stars caught in the act of changing the composition of their environment by enriching it in stellar nuclear ashes, a one-way cosmic evolutionary process as inexorable as entropy (galactic evolution).

Planetary nebulae have served as remote laboratories for matter under conditions that cannot be duplicated on Earth; from the mid-19th century to the mid-20th and beyond, they were premier sites for the study of atomic-level processes and photon–atom interactions (atomic physics). In the past two decades, they have taken on additional roles as laboratories for gas hydrodynamics (plasma physics) and as probes of the distances and masses of galaxies (extragalactic astronomy).

This slim volume by Sun Kwok, a major player in the field of planetary nebula research and the originator of the current structural paradigm (the "interacting stellar winds" scenario), represents a valuable contribution to the literature. It offers the most complete, accessible, and up-to-date entry to this subject for the newcomer with a strong general background in physics and astronomy at the advanced undergraduate level or above. It is more suitable for this purpose than the proceedings of symposia of the International Astronomical Union (the most recent is Planetary Nebulae, IAU Symposium 180, Kluwer, 1997), edited by H. J. Habing and H. J. G. L. Lamers, which are intended for the specialist. Kwok has wisely chosen not to attempt to fill the same niche as Donald Osterbrock's Astrophysics of Gaseous Nebulae and Active Galactic Nuclei (University Science Books, 1989) or Lawrence Aller's Physics of Thermal Gaseous Nebulae (Reidel, 1984), which are comprehensive reference works on physical processes in nebulae.

Instead, The Origin and Evolution of Planetary Nebulae emphasizes recent developments and the broader astrophysical context, while still including enough nebular physics to orient the novice. The book's modular arrangement enables the reader to choose between two options: Those interested in the detailed nebular physics can progress sequentially through the book, while those more interested in origin and evolution can skip directly from the introductory chapter to chapter 10.

Some minor omissions are noticeable. I would have liked to have seen more material on the neutral atomic as opposed to molecular gas, on results from polarimetry, and on the properties of white dwarfs—the descendants of the central stars of planetary nebulae. More significant is the lack of coverage of the raging current controversy over whether the bipolar morphology of some planetary nebulae is caused by the originating star having evolved within a binary system. This topic deserves its own chapter, and has recently inspired a new series of conferences under the heading of "Asymmetrical Planetary Nebulae." Two volumes are out, a third conference is planned for some time in 2002. Kwok's book would also have benefited from more careful proofreading to eliminate minor grammatical and spelling errors, some of which appear in section headings or in the spelling of author names in the citations.

Overall, The Origin and Evolution of Planetary Nebulae is a significant achievement, drawing together both traditional and modern ideas about the nature of planetary nebulae and their place in stellar and galactic astronomy. The reader who is inspired by the images of planetary nebulae to go beyond aesthetic appreciation, to delve into the physics and astrophysics of these fascinating structures in space, cannot do better than to start with this book.

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Solid State Physics

Mircea S. Rogalski and Stuart B. Palmer
Gordon and Breach, Amsterdam, the Netherlands, 2000. $80.00, $45.00 paper (467 pp.).

Solid State Physics

Giuseppe Grosso and Giuseppe Pastori Parravicini
Academic Press, San Diego, Calif., 2000. $79.95 (727 pp.).
ISBN 0-12-304460-X

Solid-state physics is an essentially modern subject intermeshed with technology and providing the basis for the explosive growth of the information age. Unlike quantum mechanics or statistical mechanics, which have origins going back a century or more, solid-state physics is a post–World War II development, dating symbolically, perhaps, from the invention of the transistor in 1947. In recent years, the sheer difficulty of imagining our life before computers has indicated the revolution that knowledge and control of the properties of materials has wrought. Indeed, not until similar control is inevitably obtained over the materials of life will a transformation of comparable magnitude take place.
In the volatile solid-state area, experimentalists have found rich hunting grounds in the novelties of diverse solids assembled from atoms of the periodic table. Theorists, at the same time, have explored an intellectual playground in which the reality of material systems has often proved more stunning and stimulating than the predictions of their models. How should a textbook introduce students to such a rapidly changing subject? Should it focus on the fundamentals of lattice structures and vibrations, band structure, optics, and transport, plus, say, traditional magnetism and superconductivity? Or should it also try to cover the latest phenomena and techniques: quantum Hall effect, density functional theory, Kondo effect, renormalization group, and superconductivity in copper oxide layers, to name a few? In a field historically dominated by traditional texts like Charles Kittel's *Introduction to Solid State Physics* (Wiley, 1996) at the undergraduate level and Neil Ashcroft and David Mermin's *Solid State Physics* (Holt, Rinehart, and Winston, 1976) at the graduate level, two distinct answers are provided by new offerings: *Solid State Physics* by Mircea Rogalski and Stuart Palmer, and an identically titled book by Giuseppe Grosso and Giuseppe Pastori Parravicini.

The briefer book, by Rogalski and Palmer, active scientists in the areas of thin films and magnetism, develops the subject along admirably clean and pedagogical lines, devoid of the distraction of experimental tables, charts, and graphs, which illustrate the classic texts. The authors address the many-body problem at the start with the separation of the ionic and electronic degrees of freedom provided by the adiabatic approximation, then proceed through lattice symmetry, structure, and dynamics, followed by electronic variables in transport, magnetic fields, and dynamics. The book includes brief chapters on semiconductors, dielectrics, magnetism, and superconductivity, then closes with a useful introduction to surfaces. A contemporary tone comes through in the treatment of bonding states, the serious development of one- and especially two-dimensional examples, and the mention of high-temperature superconductors. A unique feature of the expository development is the extensive use of worked problems with solutions or answers. A student challenged to work out each problem before reading the solution would learn much. This book could be used as a review, as a self-study text, or in a senior undergraduate or introductory graduate course. It should go together with an experimentally oriented survey, since, ultimately, a purely theoretical treatment misses the wonders of combining regular arrangements of atomic elements. Thus I would still find myself opening Kittel, or Ashcroft and Mermin, looking for the physical insight inherent in some pattern in a table of lattice constants, work functions, or Néel temperatures.

The work from Grosso and Pastori Parravicini, well-known researchers with interests that range from electronic and optical properties to layered crystals and polymers, is aimed at a more advanced level. The book is almost 300 pages longer and much more comprehensive than Rogalski and Palmer. Each chapter is self-contained enough to be dipped into independently, but the progression towards the research frontier is steady: electron interactions include density functional theory; magnetic fields up to the integer quantum Hall effect; transport includes linear response; and localized moments incorporate the Kondo effect. Again, the adiabatic principle is treated in detail, but not until the middle of the book, where it is discussed in a fascinating chapter along with potential-energy surfaces, Jahn–Teller systems, parametric Hamiltonians, and Berry phase. A novel research flavor is added by discussions of tridiagonal matrices, continued fractions, and the Lanczos method.

Numerous references to classic experiments and compiled tables of data root this book firmly in the real world, while the extensive theoretical treatment gives a rich compendium of applications. This book is reminiscent of a contemporary and slightly less encyclopedic *Theoretical Solid State Physics*, by William Jones and Norman H. March (Dover, 1985), to which one could send students for orientation on almost any topic. The absence of problems makes this more likely to be used as a reference than as a text, but for an advanced course or research seminar the flexibility and coverage of material could be ideal.

These two books represent invigorating contributions to the inevitable development of a technologically rich area like solid-state physics. Rogalski and Palmer will be especially attractive to students (and teachers) wishing a clear and rigorous introduction to the physical and mathematical basis of solid-state physics, at the expense of a survey of experimental systems and data. Grosso and Pastori Parravicini have provided a major
The Dating Game:
One Man’s Search for the Age of the Earth

Cherry Lewis

The beginning of the 20th century was a time of ferment in geology as it was in physics. Lord Kelvin had weighed in on the centuries-old debate about the age of Earth, and his estimates of 10 million to 100 million years were highly influential in educated secular society. The discovery of radioactivity abruptly revealed a flaw in Lord Kelvin’s assumptions; it also provided the means to date rocks directly and thereby confront the problem empirically.

Arthur Holmes (1890–1965) played a leading role in these efforts over the first half of the 20th century. As early as 1910, Holmes’s work suggested that Lord Kelvin was wrong by at least an order of magnitude, placing the young Holmes in the daunting position of challenging perhaps the most influential scientist of his time. By the time of his death, Holmes had added another order of magnitude to Lord Kelvin’s error. In The Dating Game, Cherry Lewis chronicles Holmes’s dogged pursuit, over five decades, of a quantitative geologic time scale. In the process, she provides unique insight into some intriguing digressions from this pursuit.

Holmes’s early work was remarkable in that much of it was done before the theory of isotopes. Shortly after Bertram B. Boltwood’s discovery in 1907 that uranium decayed slowly to stable lead, Holmes was smitten by the geological implications: they drove him to switch from physics to geology as a student at University College of London. By 1911, using only analytical chemistry applied to a few mineral samples, Holmes established a framework for the geologic time scale that turns out to have been uncannily accurate, considering the deficiencies of his approach. Without belaboring details of his experimental and theoretical approaches, Lewis reveals Holmes’s continual updating of his methodology to match the blistering pace of discoveries in the new physics. After the discovery of the neutron and the recognition of isotopes, Holmes refined his computational approach. But he was no longer able to make the relevant laboratory measurements himself; he relied instead on collaborators at the Vienna Radium Institute and, eventually, on others. His reliance on better-funded colleagues abroad to provide data is well illustrated by his correspondence, notably with the eminent American experimentalist Alfred Nier. Holmes’s nearly lifelong financial struggles, exemplified by his storied plea for funds to buy a calculating machine, are a continuous theme.

Lewis deftly highlights some of Holmes’s significant contributions to Earth science, such as his precocious advocacy of continental drift, including a proposal for mantle convection, and some of his ideas about using isotopes as tracers of geologic processes. Holmes’s work in these areas is less widely known than his seminal work in geochronology, and Lewis thus makes an important contribution by documenting them. Holmes’s impact as an educator is also given just acclaim; his textbook, Principles of Physical Geology (Thomas Nelson and Sons, 1944), was perhaps the most popular introductory text on Earth science ever published.

The picture of Holmes that emerges is curiously schizophrenic: on the one hand a scientific visionary and pedagogical leader, on the other a daring adventurer making extended forays to exotic lands (Mozambique and Burma, in mineral exploration and petroleum production respectively) to ease chronic financial need. These diverse dimensions of Holmes’s personality and their interplay with events of his times are the distinctive emphases of this biography. For example, Holmes’s extra-marital romance with the irascible Doris Reynolds (also a geologist, and leading proponent of the ill-fated theory of “granitisation”), and the disappointing reception this relationship received at the staid University of Durham, emerge among the factors that led to his acceptance of the Regius Professorship that took him to the University of Edinburgh.

Lewis’s book is accessible to anyone with a high-school physics and chemistry background. It provides unique insight into the life and times of a man who was indisputably one of the three most important figures in Earth science of the last century. The book may disappoint those who seek much depth in the evolving physics employed by Holmes and his contemporaries, but this was clearly not Lewis’s aim in writing it. It makes lively reading and is recommended as an absorbing historical biography.

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Small Scale Processes in Geophysical Fluid Flows

Lakshmi H. Kantha and Carol Anne Clayson

The complexity in the motions of fluids flowing over Earth’s surface (in both atmosphere and ocean) is the result in large part of the great range of physical scales at play. The largest length scales are planetary, and the largest time scales are unknown (but certainly many tens of years). The smallest scales (millimeters-to-centimeters, and seconds) are those dominated by three-dimensional turbulence and at which irreversible thermodynamic transfers occur. Although the highly nonlinear equations governing fluid flow (the Navier–Stokes equations) have been well known for over a century, and can be solved numerically, they cannot be solved simultaneously at all geophysical scales. This means that any attempt to model geophysical flows on the scales important for weather patterns or climatic variations requires parameterization of processes occurring at smaller scales. These processes are the focus of Small Scale Processes in Geophysical Fluid Flows, by Lakshmi H. Kantha and Carol Anne Clayson.

The authors discuss a range of phenomena involving small-scale processes in geophysical flows. These include 3D turbulence and the various instability mechanisms leading to turbulence. One example is convective instability, caused by heating the fluid from below (as in the lower atmosphere during the day), or by cooling from above (as in the upper ocean at night). Another example is the breaking of gravity waves either at the surface of the ocean or in the interior of the ocean or atmosphere. While all are governed by the same set of equations, some understanding of the physics of each process can be gained by simplification, leading to a categorization of small scale motions.