electrons in a metal, which move quickly to balance any change in their environment. The introduction of a surface makes these many-body effects particularly subtle. Yet it is at surfaces that processes of great technological interest such as chemical reactions and catalysis take place.

The book's six sections reflect the current state of work in the field, which varies from remarkable progress on, say, the theory of ground-state properties, to much semi-empiricism, for chemical and catalytic reactions. Not every major topic in surface many-body phenomena is covered, a notable missing example being surface electronic band structure calculations.

Section 1 is devoted to the current theoretical framework for ground-state properties, density functional theory. The inspiration of Kohn, Hohenberg, and Sham, this theory turns the full (insoluble) many-body problem into a tractable one-particle theory in which the electronic density (rather than the Schrödinger wave function) is the basic variable. All the complexity is cleanly buried in the effective potential in which the electrons move. Occasionally ideas in theoretical physics work as if by magic, and this theory strikes one as the work of a conjurer. To quote von Barth, "Almost as if by a stroke of luck, already the simplest possible approximation to the full theory—the predominantly used local-density (LD) approximation—gives remarkably accurate results in a variety of systems." The magic is just beginning to be understood, one can see from a paper by Perdew and Levy. However, as Langreth notes, every topic covered in his review of density functional theory (subtitled "From fact! to fantasy?") requires more work. Section 2 discusses the binding of atoms to surfaces. Lundqvist's paper reveals that substantial progress has been made on this difficult problem and makes the understated claim that some results "indicate a degree of convergence between theory and experiment." A remarkable finding is that the shape of the curve of binding energy for chemisorbed metal atoms is almost universal. Much of the progress here rests on density functional theory. If there is discontent it is with excitation energies, for which, as Jones points out, there are unacceptable deviations from experiment.

Section 3 is less specific. It concentrates on a variety of spectroscopic techniques that have evolved for experimental studies of surfaces. Many of the topics in this section are relevant to dynamic many-body phenomena at surfaces, which is the subject of part 4. The treatment of such intrinsically many-body processes as dissipation and inelastic loss has led to a number of sophisticated new theories. Some are perhaps unexpected; for example, the messy-sounding process of sputtering is now explained by an elegant theory developed by Lang. The short sections on reactions and catalysis seem to have been included primarily as a challenge, for these subjects are the real problems toward which the fundamental studies covered in the rest of the book are ultimately directed. Their solutions seem very far off.

The book succeeds in conveying the revolutionary progress that has been made in fundamental surface science, particularly over the past decade. Advances ranging from new theories to ultra-high–vacuum surface experiments have brought this about. The reader will welcome especially the pedagogical spirit of many of the reviews presented. These give an up-to-date survey of the literature and also serve to make this highly technical, high-tech field understandable.

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General Relativity

General Relativity and Gravitation. B. BERTOTTI, F. DE FELICE, and A. PASCOLINI, Eds. Reidel, Boston, 1984 (distributor, Kluwer, Hingham, Mass.). xvi, 517 pp. $69. Fundamental Theories of Physics. From a conference, Padua, Italy, July 1983.

Physicists and mathematicians working on general relativity convene every three years for an international conference that has been held in a succession of pleasant cities all over the world for the last 30 years. The tenth and most recent of these—"GR 10"—took place at the University of Padua, where Galileo once taught. More than 750 relativists from all over the world attended.

The book under consideration consists of the invited papers and the reports of the various workshops of GR 10. It is a rich source of information on current research in the four main divisions of the subject: classical relativity, relativistic astrophysics, experimental general relativity, and quantum gravity.

It begins with a paper on some aspects of classical black-hole theory, especially the interaction of incident gravitational waves with Schwarzschild and Kerr black holes, by S. Chandrasekhar (who later in 1983 won a Nobel prize in physics). In a report from the workshop on black holes, R. M. Wald describes other recent developments. Among these are the discovery of a second real-life candidate for a stellar black hole (this one in the Large Magellanic Cloud), progress in the thermodynamics of black holes, and work on the so-called cosmic censorship hypothesis (that there are no "naked" singularities), on which much of black-hole theory rests. In a related paper D. Christodoulou gives, from initial data, a complete analysis of the evolution under their own gravity of spherically symmetric dust clouds, which contains a counterexample to the censorship hypothesis. The reaction of the experts, that this counterexample, like some earlier ones, is too specialized, only emphasizes the need for a tighter formulation of the hypothesis.

The longest paper in the book (74 pages) is one by G. F. R. Ellis on relativistic cosmology. It contains a very careful assessment of the extent to which the observations—in principle and in fact—support the currently used model universes. It makes clear that there are still many open questions, among them questions about the relation of the local physics to the distant galaxies and the validity in a nonlinear theory like general relativity of the various "smoothing out" techniques applied in dealing mathematically with a very lumpy universe. It should be noted that the currently fashionable inflationary approach to early cosmology is not discussed much in this book.

In another major paper R. W. Hellings reports on the results of a computer analysis of a very large quantity of data concerning the solar system and relevant to general relativity. A great jump in accuracy over previously analyzed data was possible mainly because of the use of spacecraft, especially the landers on Mars. (The latter made it possible to model the Earth-Mars distance to ± 10 meters during their six-year period of operation.) The results now confirm (the post-Newtonian parameters of) Einstein's theory to an impressive accuracy of one-tenth of one percent. Evidently this was of central importance to all participants, though one told Helling, "Well, I'm not surprised." Helling answered, "You may be pleasantly surprised, if you wish, but you must always be surprised!" Further details on space experiments can be found in the report from the workshop on this subject.

Intensive work on the detection of gravitational waves incident on Earth is going on in many laboratories around the world and is duly reported in the book. Detectors based on laser interferometry are now racing against the older Weber type of resonant cylinders weighing several tons. As R. W. P. Drever says, a little self-encouragingly perhaps, the outlook for both is "very promising indeed." The long-simmering controversy over the correct gravitational radiation quadrupole formula is a notorious example of how people's feelings sometimes get mixed up with their science. J. Ehlers and M. Walker here present a most fair and balanced account of the present state of the debate. They conclude that all that is missing is "one coherent treatment which combines the strengths of the various approaches and avoids their weaknesses," and their report is in fact such a treatment in outline already.

One of my own favorites is a brief but most enlightening paper in which E. Witten discusses the positivity of global gravitational energy in general relativity and its extension to Kaluza-Klein theory—with some surprising implications. R. Penrose's quasi-local definition of energy, momentum, and angular momentum was elaborated on by P. Tod in one of the workshops. Reporting on this, E. T. Newman writes: "It appears to me that the most interesting and potentially most important [of recent theoretical developments] is the introduction of spinors into the classical theory of gravity. . . . [In the case of Witten's positivity-of-energy proof and Penrose's quasi-local definitions], in spite of much effort, there has been no means of giving them a tensorial reformulation. There is thus the hint that perhaps a deeper structure underlies classical general relativity." Here Newman is referring to Penrose's well-known contention, and GR 10 may be a milestone on the road to its general appreciation.

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