tool in planetary astronomy (chiefly associated with the names of Pierre and Janine Connes) and is becoming increasingly so in stellar astronomy. It is surprising, therefore, to find a figure showing a Fourier spectrometer using cube-corner reflectors described as one using cat's-eye reflectors, a quite different method of constructing a retroreflector. We are also told that Saturn shows 5-micron hot-spots similar to Jupiter's, which it does not, and in a later chapter that "comets journey through the galaxy making a single pass of each star they encounter." One therefore presumes that Allen believes periodic comets to be chimerical.

Despite these criticisms, I enjoyed this book enormously. I particularly liked the uniform style of the essential energy-distribution graphs and the appendix, which updates the book to January 1975. There are a useful index and bibliography, and for its modest price, one can overlook the rather poor quality of the half-tone reproductions.

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Vibrational States

S. Califano
335 pp. Wiley, New York, 1976. $39.95

Salvatore Califano is professor of physical chemistry at the University of Florence, where he and his colleagues have carried on a vigorous program of studies in vibrational molecular spectroscopy. His monograph entitled *Vibrational States* is a timely compendium of the theory essential for the interpretation of this realm of spectroscopy.

Most of the theory necessary for the analysis of vibrational states in polyatomic molecules was complete by 1950. Part of this theory belongs to modern physics in general, but a special segment of it is the formulation of the vibration-rotation Hamiltonian for a polyatomic molecule in terms of a potential function, usually expressed as a power series in the normal coordinates. In this way, vibrational analysis is reduced to the deduction of the potential-energy parameters from the energy-level scheme, which in turn is inferred from infrared and Raman spectra.

The formulation of the molecular Hamiltonian and its orderly expansion to permit perturbation solutions was chiefly the work of E. Bright Wilson Jr and John B. Howard,[1] Byron T. Darling and David M. Dennison,[2] Harald H. Nielsen,[3] and their collaborators. The study of molecular vibration in the harmonic approximation has been greatly facilitated by the introduction of "internal" coordinates and the formulation of the normal-coordinate problem in the famous "FG" form by Wilson.[4] Thus it can be seen that relatively few general developments have occurred since the appearance of the 1945 and 1955 monographs cited by Califano in his preface.[5]

What has happened then, in the last two or three decades, that necessitates a new monograph on the subject?

Obviously, there has been a vast increment to the experimental literature. Moreover, many gaseous molecules have been examined at high resolution, so that a meaningful description of the levels with anharmonicity corrections and careful treatment of Fermi resonance is possible. Califano appropriately devotes a whole chapter to anharmonicity (Chapter 9). Even in the harmonic approximation, using symmetry, the numerology is cumbersome for secular determinants of large order: Here, computer methods have come to the fore, and a good account of such methods may be found in Califano's eighth chapter.

Computers, however, do not overcome the fundamental indeterminacy of the vibrational problem, which arises because there are in general fewer frequencies than force constants. Chapter 8 therefore includes an appropriate development of the relation between Coriolis (vibration-rotation coupling) constants and the potential function, together with a brief account of centrifugal-distortion constants. These quantities (from spectroscopy) together with mean amplitudes of vibration (from diffraction studies) are often combined with the frequency data in an attempt to find a unique solution for the force constants. An obvious advantage of computer calculations is the ease with which, even in a multiparameter problem, the parameter uncertainties can be obtained and reported. . Although several examples of various combinations of data used in refining the potential function are given, one wishes that the author had found space to discuss the relative value of the different observations in fixing the force constants.

What fairly important developments in vibration theory have been omitted? One is quite venerable: the concept[6] of the "molecular symmetry group," which is valuable in understanding the dynamics of molecules with several accessible potential minima. Presumably for this reason, Califano does not describe the remarkable features of vibrational spectra of molecules with inversion splitting (NH_3, for example), or internal rotation with various barrier heights (CH_3OH, CH_3–C=C–CH_3, C_2H_6), or ring puckering (trimethylene oxide and others). Another topic that has received considerable attention in the literature and that follows easily from the subject matter of the first seven chapters is the quantitative intensity theory.

A final topic not treated in the present work is comprised under the general heading of non-linear Raman effects, such as the hyper-Raman effect or CARS (coherent anti-Stokes Raman scattering); this omission is easily justified, because not many results have been reported for the former and the latter is just in its infancy.

I hasten to add that these omissions, partly justified by the aim of keeping the book a reasonable length, in no way detract from the utility and accuracy of the material presented. I strongly commend the volume to all present practitioners and students of vibrational spectroscopy.

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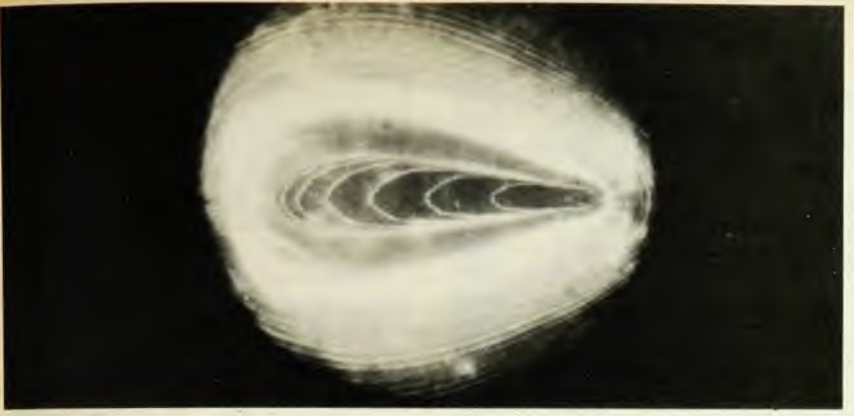
Plasmas and Laser Light

T. P. Hughes
518 pp. Halsted, New York, 1975. $90.00

The interaction of intense laser light with plasma is a rapidly developing interdisciplinary field dependent upon developments in atomic and molecular physics, plasma physics, fluid dynamics, classical optics, nonlinear optics and solid-state physics (in the case of laser plasma formation at surfaces). T. P. Hughes has succeeded nicely in bringing together in one book all the principal topics, with the exception of high-power laser development. We find a sometimes sketchy but usually clear exposition of the material, presented at an in-depth level. The book is comprehensive enough for most readers to proceed with an update using the post-1973 literature. Fifty pages of well chosen references make easy a determination of the names, places and journals one should follow in the field.

The eight chapters of the book divide



Schlieren photograph of plasma formed in argon. Images produced by a train of mode-locked laser pulses are superimposed. The photo (courtesy of A. J. Alcock) appears in Hughes's book.

into two sections separated by a short chapter on basic considerations in laser fusion-reactor design. The common theme binding together the different topics is the application to laser-heated thermonuclear plasmas for the possible future generation of electrical power. The first 130 pages are concerned with the propagation, emission, absorption and scattering of electromagnetic waves by an ionized medium. The last 300 pages of the text deal with the generation of plasmas by laser irradiation, and with the determination of the properties of such plasmas.

The theory of plane-wave propagation in fully ionized homogeneous plasmas is briefly developed from Maxwell's equations. The assumption of small amplitude waves implies that bulk properties of the medium, such as conductivity, don't depend upon the wave itself. In the first chapter the plasma-conductivity term is assumed constant; that is, radiative energy transfer between the plasma and the radiation field is not permitted. First introduced are the concepts of electron-plasma frequency and electron-collisions frequency, useful for waves in cold plasmas where all charges have no motions other than those induced by the wave. An understanding of the Boltzmann equation is assumed at the beginning of a derivation of the dispersion equation that determines the dielectric tensor for a hot plasma in an external, constant magnetic field. A number of special cases of this general problem are then considered, which nicely show how wave propagation in plasma can be frequency resonant on the one hand, or impossible beyond cutoff-frequency limits on the other. A description of the various plasma resonance and damping mechanisms makes the reader familiar with many of the basic effects in wave propagation.

Of greater interest to many of us are those nonlinear interactions of light waves with plasma that set in at high laser intensities. Then inelastic processes occur that involve absorption of the laser light and re-emission of energy at new wavelengths. A number of radiative emission processes can be discussed in terms of the charged-particle motions within the plasma once it is heated. These topics are summarized and the processes then combined in the construction of several plasma models, such as those named "local thermal equilibrium" (where atomic-state populations are controlled completely by electron collisions) and "coronal equilibrium" (where collisional atomic excitation and ionization are balanced by radiative decay and radiative recombination, respectively).

The inverse radiative processes involved in plasma heating by laser light absorption are then considered. It is in discussing these processes, which involve particle collisions in a field, that we find first reference to physics in the strong-field limit, where multiphoton processes are predominant. The reader should be aware that this region is not well understood and that the predictions of existing theory are not yet supported by decisive experiments. At a number of points in this book, the discussion of strong-field limits should be considered more as a status report than the reporting of fact.

The nonlinear effects that arise when large-amplitude laser light propagates through a plasma have only recently been explored, to some extent theoretically and much less so experimentally. Coupling can occur between different waves in the plasma, leading to quite different situations than those arising from the laser-heating and plasma-emission processes separately. Especially near plasma resonance, the laser energy may now couple into electron-plasma waves or ion-acoustic waves in the plasma and from there go efficiently into particle kinetic energy. The plasma waves, once established, can also scatter the laser light out from the plasma efficiently. An informative section on the available experimental information about such matters of course needs updating. Although all-important to laser fusion, much of this field remains unexplored.

A far better established subdiscipline is the incoherent Thomson scattering of light by the density fluctuations of the electrons and ions in the plasma. As only minute amounts of laser energy are absorbed by this process, it is used as an important diagnostic tool in plasma physics. The technique is sensitive to the electron density and temperature, the ion temperature, the magnetic field and the plasma wave spectrum in a way permitting spatial and temporal resolution with pulsed lasers. Electromagnetic theory and plasma kinetic theory are combined to give the reader a feeling for this process for the case of single-particle scattering. For scattering from plasma density fluctuations the reader will have to struggle with some of the references in order to understand Hughes's starting point. After this the theoretical development is both interesting and useful. Practical problems in application to plasma diagnostics are discussed, the details of needed apparatus are presented, and an interesting collection of diagnostics results rounds out this section, nicely balanced between theory and experiment.

The second portion of the book begins with a study of the laser ionization and breakdown of gases. A short and sketchy section on multiphoton ionization theory starts out with the static electric-field ionization of atoms, followed in turn by the adiabatic approximation, Keldysh theory, rate enhancement by resonant intermediate states, and laser-light polarization and other effects treated within perturbation theory. A number of ionization experiments using pulsed ruby, neodymium-glass and CO_2 lasers are described. Numerous results exhibit such interesting features as the variation of ionization with field strength, laser wavelength and atomic species.

The avalanche theory of laser gas breakdown is illuminated in this book through the relationship to microwave breakdown. The measurements of laser-breakdown thresholds are critically viewed in terms of such serious difficulties as the determination of field intensities within a laser-light focal volume. A number of outstanding anomalies within the data are pointed out, along with explanations for some earlier problems that arose from such things as laser mode-beating as well as beam self-focusing due to intensity-dependent variations in the refractive index of the gas.

Breakdown is followed by dynamical plasma phenomena such as shock waves and a macroscopic time-evolution of the electron and ion distributions. At this point the combined importance of the many earlier topics begins to be felt and the great usefulness of Hughes's book becomes apparent. There is a section on diagnostic techniques, such as shadow and Schlieren photography, interferometer and holographic studies, and finally x-ray emission and microwave-absorption measurements. A large amount of data on laser plasma reflectivities, particle densities and particle temperatures is presented as a function of either space or time, with the experiments done at all the different high-power laser wavelengths.

An extensive treatment of plasma formation by laser light incident on solid surfaces parallels that described for gases. The section on spherical implosions is good but needs supplementing due to the great deal of recent effort in this area.

This unique and useful book is almost a must for those interested in lasers coupled to plasmas; it is a single source to pick up whenever an unfamiliar or forgotten aspect comes to mind. The monetary blow associated with buying *Plasmas and Laser Light* will be soon forgotten as you find it interesting reading and rereading through the years.

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Big Ear

J. Kraus
228 pp. Cygnus-Quasar, P.O. Box 85, Powell, Ohio 43065, 1976. $3.25

Anyone who is so fortunate as to live through the birth of a new branch of science usually has an interesting story to tell, and in our non-memoir-oriented age it is a pity that these stories are frequently never told. Fortunately John Kraus has been able to write this very personal account of his career, which spans the growth of radio technology and the birth and development of radio astronomy. His book is written in a casual style close to that of *Popular Science* or *QST* and could be enjoyed by a reader of any age, although some might be put off a bit by its chattiness.

For a young boy growing up in the midwest, such as Kraus, the urge to master technology was powerful indeed. If he needed an earphone to go with his crystal receiver he could steal it from the telephone, hanging a hammer on the hook so Central would never know. Somehow he would always get wind of the newest gadgets at a very early stage and master their use very quickly. As Kraus progressed through the development of ham radio and a college education that trained him both as a physicist and an electrical engineer, he had to make do with what he found, and he did so very well. The stories he tells of his early jobs show a lack of concern for security that might appear remarkable to students of today. Even after he became a professor, not much was provided. For example, when he invented the helical antenna, he had no laboratory space and carried out the pattern measurements in his basement. In recognition of this success, he was granted a plank-covered space in the loft of an old airplane hangar, above the campus radio station. No chance for Parkinson's Law to act in those days!

Kraus is one of the few radio astronomers in the world today who knew Carl Jansky when the first discoveries that founded the science of radio astronomy were made at Bell Laboratories. I do wish that he could have told us a few more anecdotes of the 1930's when he interacted with both Jansky and Grote Reber. Nevertheless, his stories of how he progressed from tiny model antennas to the construction of great radio telescopes is told in detail, with all the troubles as well as the successes.

Our students usually acquire a cosmetic version of how a project is conceived and developed. This seldom coincides with reality, and Kraus's account is a welcome corrective. The wind can blow your antennas down, government funding agencies can stop your funding money at a crucial time, and all these griefs and heartaches never appear in the publications on glossy paper. Kraus's whole life has been marked by ingenuity and persistence, and the examples that he gives should serve as inspiration to any young scientist. His account never flags, his attitude seems to have always been open and optimistic, and he must surely take pleasure in the spectacular quasar discoveries that have been made possible by his Ohio State catalog of radio sources. His textbooks on antennas, electromagnetic theory and radio astronomy are well known, and we can all be grateful that this indefatigable writer has taken the time to write this entertaining contribution to history.

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Introduction to Mathematical Physics

C. Harper
301 pp. Prentice-Hall, Englewood Cliffs, N.J., 1976. $16.50

Charlie Harper has written a useful introduction to the mathematics that is most likely to be encountered in advanced-undergraduate physics courses. The topics have been judiciously chosen so that the book can be comfortably covered in a one-semester undergraduate course. Included are chapters on vector calculus, operator and matrix analysis, complex variables, special functions and Fourier analysis, as well as an excellent chapter on tensor analysis.

The book is mathematically sound, at least as far as I can determine as a physicist by training. Although the proofs would not delight a mathematician, the approach is clear, straightforward and intuitive. Harper tries to relate the mathematics to physics mainly in the examples and problems. Advanced concepts such as vector space and Hilbert space are used in an elementary manner in order to prepare the way for future studies. Several helpful flow diagrams that illustrate the solution of various partial differential equations are included.

Unfortunately, the book has several shortcomings that will require clarification by an instructor. For example, the words "tensor," "tensor of rank zero" and "tensor of rank one" are used on pages 1 and 2, but the reader must refer to page 255 for the definitions of these terms. On page 45, the bra and ket vectors are introduced with no explanation of the bra vector. The term "eigenenergy" is used on page 171 but never defined. The sentence "Geometrically, axial vectors correspond to areas" appears on page 261 with no explanation. Although these are not fatal flaws, the book is not appropriate for self-study by undergraduates.

Harper has a conversational writing style that makes for easy reading. The book has 72 worked examples (more would be welcome) and 256 problems with no solutions or answers. Simple line drawings are used as illustrations. These drawings tend to be small and, in some cases, confusing. The general bibliography is short, as are the reference lists for each chapter. While the books by R. V. Churchill are all mentioned, the standard treatise by Philip Morse and Herman Feshbach is not.

The book can be used profitably as a text for a one-semester undergraduate course. However, it can not be recommended as a graduate text or reference book because of the limited breadth and depth of topics covered.

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book notes

The Second Law of Thermodynamics (Benchmark Papers on Energy, Vol. 5). J. Kestin, ed. 329 pp. Dowden, Hutchinson and Ross, Stroudsberg, Penna. (distributor: Halsted, New York), 1977. $27.50

The Benchmark Papers on Energy are a series of volumes that make readily available important but sometimes hard-to-find articles on the concept of energy—its historical development, applications and role in civilization. This particular book traces the development of the Second Law from Nicolas Sadi Carnot ("Reflections on the Motive Power of Fire, and on Machines Fitted to Develop That Power," 1824), with papers by Max