BOOKS & JOURNALS
A SPECIAL REPORT

tures (at the University of Colorado and University College London).

The author, a professor of physics at the University of Colorado, has published numerous articles on collision theory. Perhaps his most often referenced work concerned application of variational techniques to calculations of electron scattering by atoms.

I would recommend this book as a text for a graduate "topics" course or to students seeking an introduction to atomic-collision theory. Although the author is patient with his exposition, most readers will wish he had provided more extensive references to the literature. The meager bibliographies at the end of sections are too modest even to give proper credit to the author's own contributions. Serious students of atomic collisions will wish to follow this with the very thorough four-volume treatise by H. S. W. Massey and his coworkers, *Electronic and Ionic Impact Phenomena* (Oxford U. P., 1969).

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The Technology Of Computer Music

By M. V. Mathews
188 pp. MIT Press, Cambridge, Mass., 1969. $12.00

Electrical and electronic musical instruments have been with us for over 75 years, but have yet to achieve a place in the musical world comparable to that of conventional instruments. However, the current generation of electronic musical instruments has gone beyond conventional real-time performable instruments such as the electric organ. We now have a new kind of musical instrument, the programmable instrument, which does not normally work in real time, but contains storage and superposition features that allow complex musical structures to be generated one layer at a time, stored and superposed. The contemporary analog synthesizers, of which the Moog is the best known, are of this type. They now boast a very wide range of musical possibilities and are still undergoing rapid evolution.

Outside this development, in a parallel route, lies the alternative possibility of dispensing entirely with musical hardware, and creating music by generating mathematically-produced waveforms that are later converted to sound. A music-generating computer program does exactly this and, in addition, allows the most precise and detailed control of the sound. In computer-generated sound, every vestige of the technical difficulty of performance on ordinary instruments disappears, and everyone becomes a potential virtuoso, limited only by his imagination and his control over his willing and obedient orchestra.

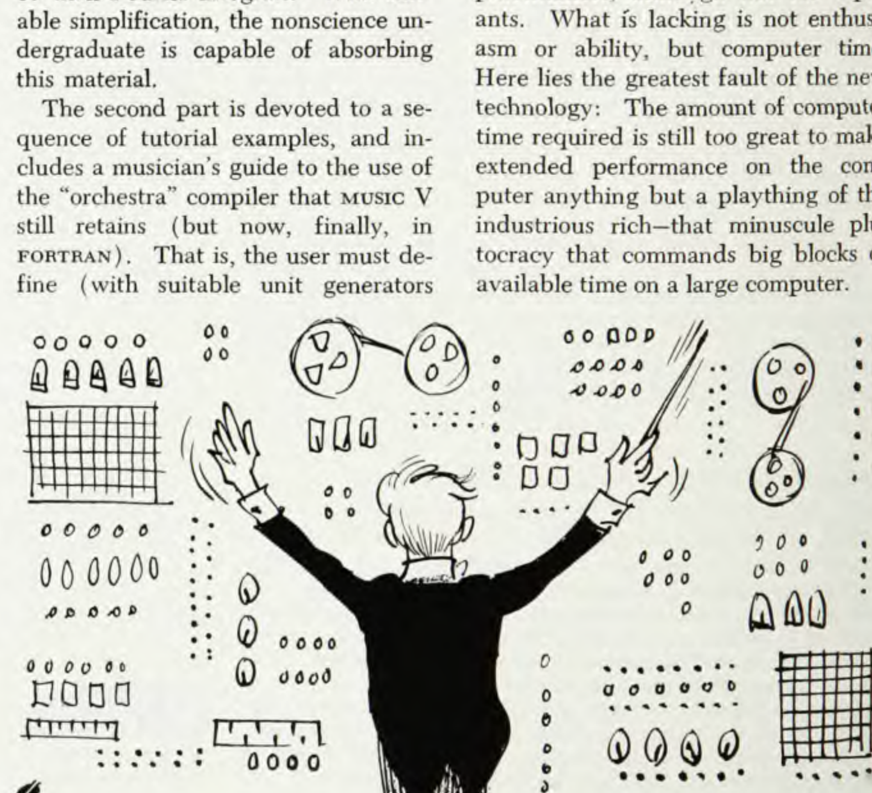
In this book we have for the first time a complete although brief description of the pioneering effort of Max Mathews and his colleagues, which gave the world its first serious and artistically valid music-generating computer program. Mathews here describes the current version, MUSIC V.

The book is divided into three sections. The first is a short exposition of the basic principles of computer generation, in digital form, of a sampled representation of the desired waveform. This part demands the greatest technical sophistication, which is needed for the explanations of the sampling process and its errors. Even here there is nothing more complicated than Fourier integrals. With suitable simplification, the nonscience undergraduate is capable of absorbing this material.

The second part is devoted to a sequence of tutorial examples, and includes a musician's guide to the use of the "orchestra" compiler that MUSIC V still retains (but now, finally, in FORTRAN). That is, the user must define (with suitable unit generators that simulate oscillators, adders, function generators and filters) the software equivalent of the kind of instrument he might patch together with cables on an idealized Moog synthesizer. MUSIC V differs in this respect from ORPHEUS, an earlier all FORTRAN descendant of MUSIC IV, in which there is just one all purpose instrument, defined once and for all.

The third part of the book, called the "MUSIC V Manual," is devoted to an exposition of the program itself and explains its operation in considerable detail. Given a copy of this manual, a printout of the program and a means of providing the digital-to-analog conversion for the computer output tape (any small computer with a magnetic tape input, a clock and a D-to-A converter will suffice), anyone with enough computer time can start his own orchestra.

The potentialities of computer produced music, shown by the existing output, easily exceed those of the much more popular analog synthesizers, such as the Moog. Even so, the world has paid little attention to this new technology; in particular, musicians, for lack of understanding and technical grasp, have tended either to ignore it in the hope that it would go away or to denigrate it as mechanical, or worse as "electronic." The new craft still languishes for want of active practitioners, although not for aspirants. What is lacking is not enthusiasm or ability, but computer time. Here lies the greatest fault of the new technology: The amount of computer time required is still too great to make extended performance on the computer anything but a plaything of the industrious rich—that minuscule plutocracy that commands big blocks of available time on a large computer.



Because the greatest hindrance to further development in this direction is the dependence on open-shop operation of large-scale computers, the next stage of development almost surely lies in freeing the music-generating program from its ties to a large-scale computer. Means must be found for using small or medium-scale computers, probably in a hybrid system that will combine the precision of computer sound definition and the economy of analog sound production. The first beginnings in this direction have already been made.

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Thermal Physics

By Charles Kittel
418 pp. Wiley, New York, 1969. $10.95

Nobody would expect Charles Kittel to write a dull book. After the huge success of his *Introduction to Solid State Physics*, any new work of his makes an immediate claim on our attention and expectations. *Thermal Physics* is not a disappointment; it is a highly stimulating and readable book. There are times when one feels that the difficulties are not being fully disclosed; nevertheless, it remains compulsive reading.

It is essentially a book about statistical mechanics, with classical mechanics reduced to a strictly subordinate role. The statistical treatment is developed for systems with quantized energy states, for, as Kittel says in his preface, "thermal physics is a remarkably easy subject if taught from a consistent quantum viewpoint in which we think of states of an entire system, however large or small."

The development leads swiftly and painlessly through definitions of entropy and temperature in terms of the number of quantum states accessible to the system and to the chemical potential and partition functions, both grand and ordinary. Consideration of special cases then leads to the Fermi–Dirac and Bose–Einstein statistics. There is an excellent discussion of the behavior of quantum systems in the classical limit, and some welcome remarks about the difficulty of trying to construct a truly classical form of statistical mechanics, that is, one where Planck's constant does not appear. An unusually wide range of applications is discussed; it includes biology, chemistry and astronomy as well as the more familiar physical ones. The account of Bose–Einstein condensation is by far the clearest and most useful elementary discussion I have seen. Throughout, a considerable sophistication of physical thought is attempted, but the mathematics is always minimal, so that the subject can be taught at an early stage.

One interesting innovation is the way the student is introduced to the statistical behavior of systems of many particles. Instead of the usual hand-waving arguments, he is given the exact solution of one particular problem, that of a large number N of independent particles, each of which can exist in either of two states corresponding to different orientations of its magnetic moment. The number of states of the system giving the same total magnetic moment is found, and the overwhelmingly high probability of the most probable distribution demonstrated. The same model and the same mathematics are then available for discussions of fluctuation phenomena.

All this is excellent, but there are two major things about the book that I disliked. The first of these is the treatment of classical thermodynamics, which is too condensed and too scattered to give any appreciation of its problems or of its power. It is never quite clear what reliance Kittel is placing on the laws of thermodynamics. In a quotation from Gibbs at a chapter heading we find: "The laws of thermodynamics may easily be obtained from the principles of statistic mechanics, of which they are the incomplete expression." This might lead one to think that he will prove the laws, or at least try to do without them. In fact he appears to use the laws, but without admitting that he does so. In the case of the first law this is very clear; the existence of an energy function for any physical system and the conservation of energy are assumed at an early stage without comment. As for the second law, it never became clear to me whether it had been assumed, proved or rendered redundant. I think the author should have told us.

My second grumble is quite a different one. The experience of many teachers of statistical mechanics is that

ENTROPY. This figure, which shows five factors that increase the entropy of a system, is taken from *Thermal Physics*.