Meetings

Nonequilibrium Thermodynamics, Variational Techniques, and Stability

Nonequilibrium thermodynamics is a relatively recent branch of thermodynamics which was founded about 20 years ago when two different schools of thought merged to form a new discipline. One was based on the extension of conservation equations and entropy balance, as developed originally by the French and Belgian schools of thermodynamics (Duhem, de Donder); the other was based on the theory of fluctuations, culminating in the derivation by Onsager of the basic reciprocity relations. A symposium was held 17–19 May 1965 at the Center for Continuing Education, University of Chicago, to discuss and review concepts and methods of nonequilibrium thermodynamics and of macroscopic physics as a whole. The program included discussions of variational techniques for continuum systems and several contributions on hydrodynamic stability.

Nonequilibrium thermodynamics has two major goals: first, to provide general relations between experimental effects which would be independent of molecular models; in this case, Onsager's reciprocity relations (1931) play an essential role; second, to introduce evolution criteria which would remain valid for dissipative systems which are not in equilibrium. A first step was Prigogine's formulation of the theorem of minimum entropy production (1945), which is valid only for strictly linear systems.

I. Prigogine and P. Glansdorff (Université Libre, Brussels) have recently attempted to extend the theorem of minimum entropy production to the whole range of macroscopic physics. The three main steps of this theory are the following:

1) Using thermodynamic stability theory one can establish an inequality in the form of a nontotal, semidefinite differential, valid both for dissipative and mechanical flow processes.

2) This nontotal differential cannot, in general, be expressed as the differential of some potential (precisely because most problems of heat or mass transfer are not self-adjoint); however, it is possible to extract a so-called "local potential" in which each thermodynamic variable (for example, temperature) appears twice.

3) The meaning of this procedure becomes clear by comparison with macroscopic fluctuation theory. One set of variables represents the average value of these variables (which satisfy the macroscopic conservation equation); the other set represents fluctuating variables. This method leads to a generalized Lagrangian formalism. The macroscopic conservation equations are recovered as the Euler-Lagrange equations for fluctuating variables, the most probable distribution being identified at the end of the calculation with the average one.

Prigogine and Glansdorff presented their theory, and D. F. Hays (General Motors Research Laboratories) discussed the application of their technique to three problems in the conduction of heat with temperature-dependent thermal conductivity. One of these examples had time-dependent boundary conditions. A survey of variational principles for continuum systems was given by R. Schechter (University of Texas); he evaluated the relationships, theoretical significance, and practical value of such principles.

J. Meixner (Institut for Theoretische Physik, Aachen) discussed the thermodynamics of relaxation processes. Because of their linear character, relaxation processes can be discussed in great detail. Meixner described a variety of such processes, including acoustical and dielectric relaxation and internal processes in solids related to mechanical deformation.

In his lecture, on the application of the thermodynamics of irreversible processes to continuum mechanics, G. A. Kluitenberg (University of Eindhoven) showed how materials with very different rheological and mechanical behavior may be treated from the point of view of the balance equations of nonequilibrium thermodynamics and relations between generalized forces and rates. Many phenomenological equations follow in a natural way.

C. Truesdell (Johns Hopkins University) argued that a true thermodynamics of general materials in large and rapid deformation is needed. He outlined as an example the recent work of B. D. Coleman on the thermodynamics of materials with fading memory.

The lecture by A. Katchalsky (Weizmann Institute), "Biophysics and thermodynamics of irreversible processes," dealt with some of the most fascinating aspects of biological membrane structure and their function in the organism, especially from the point of view of coupled processes.

In the opening lecture of the sessions on hydrodynamic stability, W. H. Reid (University of Chicago) reviewed a number of the classical problems of hydrodynamic stability; he included the Bénard (thermal convection) problem, Couette flow, and parallel shear flows. In each case he discussed the use of asymptotic techniques for problems of this type.

P. H. Roberts (University of Newcastle-upon-Tyne) discussed the problem of the preferred mode in Bénard convection using the Prigogine-Glansdorff technique of local potentials. The results, applied to such a difficult problem as nonlinear convection, constituted one of the most interesting applications of this technique.

A second session on stability was opened by L. Segel (Rensselaer Polytechnic Institute) with a comprehensive survey of several of the current problems in nonlinear stability theory. He discussed in particular the Landau-Stuart approach in thermal convection and Couette flow, including some recent experimental examples. N. R. Lebovitz (University of Chicago) reported on convective instability in stars. In particular, he gave an analytical proof of the validity of the Schwarzchild criterion for the onset of convection. M. Clement (University of Chicago) noted the inhibiting influence of a slow rotation of a star on the onset of convection. G. Nicolis (Université Libre) showed how the Prigogine-Glansdorff method could be used to study a problem of stability in phase space. He discussed mainly the run-away problem in plasmas, and compared the results obtained by the variational technique to the well-known results of Driecer.

One of the sessions was concerned

with statistical physical aspects. The formulation of a general statistical mechanical theory for nonequilibrium problems will probably be considered one of the major theoretical developments of our time, exactly as the formulation of equilibrium statistical mechanics appears now as one of the major achievements of the 19th century. It is clear why about 50 years separate the general formulation of equilibrium statistical mechanics by Gibbs and work of similar generality in nonequilibrium studies (Bogoliubov, Van Hove, and Prigogine). The nonequilibrium problem is an order of magnitude more difficult, and only general progress in many-body problems could lead finally to the elaboration of the necessary methods.

The first two lectures in this session, "Theory of fluctuations" by H. Callen (University of Pennsylvania) and "Entropy and irreversibility" by P. Resibois (Université Libre), gave a condensed, but fairly complete, survey of the main aspects of dissipative processes when studied from a statistical point of view. R. Balescu (Université Libre) and B. Coppi (University of California) discussed more precisely the statistical problem of plasma instability. This is a problem in which the long-range character of the Coulomb force plays an essential role. As a consequence, characteristic nonlinearities appear in the kinetic equation of evolution, thus giving rise to new stability problems. While these problems are becoming clearer in terms of the physical mechanisms involved, much remains to done from the mathematical point of view.

Short contributions and discussion remarks comprised the last session—J. S. Kirkaldy (McMaster University) on thermodynamic effects in the nucleation of new phases, H. Frisch (Bell Telephone Laboratories) on nonequilibrium thermodynamics of systems with internally relaxing parameters, S. Prager (University of Minnesota) on diffusion-controlled chemical reactions, and R. J. Donnelly (University of Chicago) on hydrodynamic stability in quantum fluids. During the second part of this session, S. Kline (Stanford University), M. Kruskal (Princeton University), I. Prigogine, P. H. Roberts, L. E. Scriven (University of Minnesota), R. Schechter, and P. Weiss (Wayne State University) presented remarks about the Prigogine-Glansdorff theory. For physicists, the content of a variational theory is essentially expressed by its Lagrangian. However, as clearly shown by the existence of approximation techniques of the Galerkin type, a Lagrangian is not necessary to provide us with a variational technique. Further investigations are certainly necessary to make more precise to what extent nonequilibrium thermodynamics can provide us with new calculational tools.

The symposium was sponsored by the Université Libre of Brussels (through the Instituts Internationaux de Physique et de Chimie, founded by E. Solvay), by the General Motors Research Laboratories, and by the University of Chicago. The organizing committee consisted of I. Prigogine and P. Glansdorff (Université Libre), J. M. Campbell, D. F. Hays, and R. Herman (General Motors), P. F. Chenea (Purdue University), and S. A. Rice and R. J. Donnelly (University of Chicago). The proceedings of the symposium are to be published by the University of Chicago Press.

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Forthcoming Events

September

9–11. **Industrial Electronics and Control Instrumentation**, conf., Philadelphia, Pa. (L. Winner, 152 W. 42 St., New York 10025)

9–11. **Parapsychological** Assoc., 8th annual conv., New York, N.Y. (J. G. Pratt, Box 152, Univ. of Virginia Hospital, Charlottesville)

9–11. **Phlebology**, 2nd intern. congr., Wiesbaden, Germany. (H. L. Biegeleisen, Phlebology Soc. of America, 155 E. 72 St., New York 10021)

9–12. Canadian **Agricultural Chemicals** Assoc., 13th annual, Banff, Alberta, Canada. (CACA, 3405 Code des Neiges Rd., Montreal 25, Que.)

9–12. **Mass Spectrometry**, Euchem conf., Sarlat, France. (Gesellschaft Deutscher Chemiker, Postfach 9075, 6 Frankfurt am Main, Germany)

9–13. Association of European **Anesthetists**, congr., Athens, Greece. (P. Maestracci, Centre de Transfusion Sanguine, Rue Delille, Nice, France)

9–13. International Soc. for **Clinical Electroretinography**, 4th symp., Tokyo, Japan. (A. Nakajama, Dept. of Ophthalmology, Juntendo Univ., Tokyo)

10. **Manned Space Stations**, intern. symp., Munich, Germany. (German Soc. for Rocket Technology and Travel, Neuensteiner str. 19, Stuttgart-Zuffenhausen, Germany)

10–12. **Comparative Neurophysiology**, symp., Tokyo, Japan. (Yasuji Katsuki, Tokyo Medical and Dental Univ., 3-Chome, Yusima, Bunkyo-ku, Tokyo)

10–12. Structure and Function of the **Limbic System**, symp., Hakone, Japan. (T. Tokizane, Inst. of Brain Research, Univ. of Tokyo, Hongo, Tokyo, Japan)

11–12. **Brain Edema**, symp., Vienna, Austria. (F. Seitelberger, World Federation of Neurology, Schwarzspanierstr. 17, Vienna)

11–18. International **Cardiovascular** Soc., 7th congr., Philadelphia, Pa. (R. A. Deterling, Jr., 171 Harrison Ave., Boston, Mass. 02111)

11–18. **Plant Environment** in Glasshouses, symp., Bedfordshire, England. (Secretariat, P.O. Box 38, Wageningen, Netherlands)

11–18. International Soc. of **Surgery**, 21st congr., Philadelphia, Pa. (P. Martin, 43, rue des Champs-Elysees, Brussels 5, Belgium)

11–26. **Chemistry in Industry and Agriculture**, intern. conf., Moscow, U.S.S.R. (Central Office of Information, Reference Div., London, England)

12–15. International Assoc. of **Milk, Food, and Environmental Sanitarians**, Hartford, Conn. (H. L. Thomasson, P.O. Box 437, Shelbyville, Ind.)

12–17. International **Aeronautic** Federation, 58th annual general conf., Munich, Germany. (Natl. Aeronautic Federation, 1025 Connecticut Ave., NW., Washington, D.C. 20036)

12–17. American **Chemical** Soc., 150th annual, Atlantic City, N.J. (B. S. Baker, Inst. of Gas Technology, 3424 S. State St., Chicago, Ill. 60616)

12–17. **Fracture**, intern. conf., Sendai, Japan. (T. Yokobori, Dept. of Mechanical Engineering, Tohoku Univ., Sendai)

12–17. **Highspeed Photography**, 7th intern. conf., Zurich, Switzerland. (K. Pfister, Secretariat, Postfach 189, 8033 Zurich)

12–18. **Astronautics**, 16th intern. congr., Athens, Greece. (A. L. Jaumotte, Inst. de Mécanique Appliquée, Université Libre de Bruxelles, 50, avenue F. D. Roosevelt, Brussells, Belgium)

12–18. **Radiology**, 10th Brazilian congr., first Portuguese-Brazilian congr., Rio de Janeiro, Brazil. (A. Arantes Pereira, Av. Churchill 97, S/508, Rio de Janeiro)

12–19. Mechanisms of **Viral Carcinogenesis**, symp., Rehovoth, Israel. (Weizman Inst., Rehovoth)

12–25. **Speleology**, 4th intern. congr., Ljubljana and other cities, Yugoslavia. (W. Bohinec, Titova 17a, Ljubljana)

13–15. **Drugs Affecting Lipid Metabolism**, 2nd intern. symp., Milan, Italy. (R. Paoletti, Inst. of Pharmacology, Univ. of Milan, Via Andrea del Sarto 21, Milan)

13–15. Mechanism and Control of **Gastric Secretion**, Univ. of Alberta, Edmonton, Alta., Canada. (Gastric Secretion Symp. Committee, Rm. C148, University Hospital, Edmonton)

13–15. Association of French-Speaking **Pediatricians**, 20th congr., Nancy, France. (Prof. Pierson, Hôpital Général, Nancy)

13–16. **Cancer**, Latin American congr., Bogota, Colombia. (A. Buendia-Ferro, Avenida 1ª no. 9-85, Bogota)

13–16. Optical Properties and Electronic Structure of **Metals and Alloys**, intern., Paris, France. (F. Abelès, Institut d'Optique, 3 Boulevard Pasteur, Paris)

13–16. **Natural Mammalian Hibernation**, 3rd intern. symp., Univ. of Toronto,