Three receive APS plasma physics awards

The Division of Plasma Physics of The American Physical Society in November honored Harold Grad (New York University), John Bryan Taylor (Culham Laboratory, Abingdon, England) and Joel Fajans (University of California, San Diego) for their work in plasma physics.

Grad, who was named to receive the James Clerk Maxwell Prize, died on 17 November (see page 86). The division cited him for his "outstanding contributions to magnetofluid dynamics, plasma physics and magnetic fusion energy. His investigations, using rigorous mathematical methods with advanced analytical and computational techniques, include seminal research on the Boltzmann equation, collisionless shocks, guiding center plasmas, and equilibrium, stability and transport theory." Grad received his MS (1945) and PhD (1948) from NYU. He continued there on the faculty of the Courant Institute of Mathematical Sciences as assistant professor, later becoming associate (1952) and then full professor (1957) of mathematics. As a participant in Project Sherwood, Grad developed a nonrelativistic electromagnetic theory that involved the formulation and solution of Galilean invariant magnetohydrodynamic equations, and led to the curvature criterion and the magnetic well concept for stability. His invention of the cusped geometries for plasma containment and the concept of collisionless shock (before its experimental confirmation) were based on that early work. More recently, by introducing quantities averaged over flux surfaces, he created a new kind of differential equation for the analysis and numerical study of plasma transport. His most recent work consisted largely of the development of fast, accurate iterative techniques, alternating dimension algorithms, for the numerical solution of the transport equations.

Taylor received the Award for Excellence in Plasma Research "for his pioneering theoretical contributions to relaxed energy states in the reversed-field pinch configuration using global helicity conservation. This research has had a profound effect on the general advancement of experimental plasma physics and on the basic understanding of nonlinear resistive MHD phenomena." Taylor received his BSc (1950) and PhD (1955) from Birmingham University. He worked at Atomic Weapons Research (Aldermaston) from 1955 until 1962, when he went to Culham Lab. He was appointed head of the lab's theoretical physics division in 1963. At Culham in the early 1960s Taylor worked with R. J. Hastie on the theory of plasma equilibrium and stability in magnetic wells. In the period 1974–84 Taylor pioneered the theory of plasma relaxation, initially to account for the generation of a spontaneous reversed magnetic field in toroidal pinches and later to predict or interpret phenomena in laboratory plasmas and, recently, in astrophysical plasmas. In addition Taylor, J. W. Connor and Hastie have developed mathematical techniques for describing short wave plasma perturbations in sheared magnetic fields. Taylor was named chief physicist at Culham in 1981.

Fajans received the first Simon Ramo Award, which recognizes outstanding doctoral-thesis research in plasma physics, for work "in which he carried out excellent and detailed studies of many physics aspects of a free electron laser in the linear Raman [collective] regime, thereby making important contributions to the further development of such free electron lasers." Fajans received his BS in phys-

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ics and electrical engineering (1980) and his PhD (1985) from MIT. For his doctoral research he built a free electron laser and made detailed studies of the physics underlying its operation, particularly in the Raman collective regime. He is now working with John Malmberg at San Diego on a cryogenic plasma experiment. The Ramo Award consists of $1500 and a certificate.

obituaries

Harold Grad

The plasma physics community and the scientific world suffered a profound loss upon the death of Harold Grad on 17 November at the age of 63. Only 12 days earlier, his eminent achievements had been recognized by the award of the James Clerk Maxwell Prize of The American Physical Society, at ceremonies he was unable to attend (see page 85). He will be remembered, not only for his scientific accomplishments, but for his intense devotion to the cause of good science. His intolerance of slipshod thinking and his tenacity in pursuit of the truth are legendary, nonetheless he made great efforts to help those who lacked his skill, insight and knowledge. He was gentle toward his students and junior associates, and he was enormously exciting to work with. His stimulation and unstinting willingness to share carried far beyond his close associates. Few of us will forget his quick wit, for he was often wonderfully funny.

Grad began as an electrical engineer, receiving his degree from Cooper Union during World War II. After that, while working as an engineer in a defense industry, he took evening graduate courses at the Courant Institute (then the Institute for Mathemaics and Mechanics) at New York University. With Richard Courant's encouragement and help, he left his job to complete his graduate work at NYU where he pursued his entire professional career, achieving full professorial rank early. He founded the magnetofluid dynamics division of the Courant Institute in 1956 and remained its director for 25 years.

Grad was a founder of the Society of Engineering Sciences. He was an active member of the New York Academy of Sciences, and served on its Board of Governors (1978-81). He was elected to the National Academy of Sciences in 1970. Much of Grad's energy was devoted to the activities of APS. He found it amusing that he was the only living person who had been chairman of two society divisions, the Fluid Dynamics Division and the Plasma Physics Division.

Courant, in trying to capture the essence of Grad's genius, said that Grad had the rare ability to understand and interpret the physical world as a mathematician. It is also true that, as a physicist, Grad had the unusual talent to find the mathematics that most appropriately models the physical world. This he did, working first in fluid dynamics, statistical mechanics and kinetic theory, to prepare himself, finally, to be a master of the budding science of plasma physics.

The basic quality of Grad's work was already visible in his 1948 doctoral thesis on the kinetic theory of rarefied gases. In this seminal work, Grad explicitly introduced the concept of a hierarchy of models interpolating between kinetic theory and fluid dynamics, and he exploited the concept to go a level higher than the Navier–Stokes system, to the so-called thirteen-moment equations. Thus, Grad made his mark early as an architect of general systems. Within a few years he was recognized as a leader in kinetic theory. His 1958 monograph in the *Handbuch der Physik*, *Principles of the Kinetic Theory of Gases*, laid down new foundations for the subject.

In 1958, he presented in outline a derivation of the Boltzmann equation as a singular limit. This outline was finally filled in rigorously in 1975 by Oscar Lanford (Institut des Hautes Études Scientifiques, Vures-Sur-Yvette, France). Also in statistical mechanics, he contributed fundamental clarifications of the concepts of entropy and molecular chaos. In kinetic theory, his two major papers in 1963 on the asymptotic theory of the Boltzmann equation, together with his earlier work, have been a springboard for most further development. It is said that Grad was invited to participate in the development of the hydrogen bomb; instead he made a conscientious decision to work on the peaceful use of fusion energy. In 1955, he joined the fusion power program, then classified under the code name Project Sherwood. He became a preeminent plasma physicist, masterfully deploying his method of looking at the field through a hierarchy of models from magnetofluid dynamics through guiding center fluid and guiding center plasma to fully kinetic models. Much of this development is summarized in his 1967 monograph, *The Guiding Center Plasma*. He was an avid practitioner as well as a generalist: He introduced the curvature criterion for magnetohydrodynamic stability, and from that developed the first known stable plasma configurations—cusped geometries—which formed the basis of a patent by Grad and Kurt O. Friedrichs (Courant Institute).

Grad's work touched on virtually every aspect of plasma physics: He systematically explored variational methods, formulating and applying them to problems of equilibrium and stability, for both fluid magnetic and plasma models. (An example is the magnetic-well principle underlying the stability of cusped geometries.) In orbit theory, he investigated nonadiabatic orbits in a cusped magnetic field and he fully examined the consequences of the pathological long term behavior of orbits in toroidal geometries. He developed the concept of collisionless shock prior to its confirmation by experiment. In equilibrium theory, Grad pointed out the necessity of symmetry for the mere existence of exact toroidal equilibria, and he was the first to seriously consider the appearance of mathematical pathology in toroidal geometries. In addition he created a new approach to transport that permits two- and three-dimensional problems to be solved without an enormous increase in difficulty over one-dimensional problems. Grad based this work on his theoretical development of, and numerical experimentation with, a new type of equation, the "queer" differential equation, which he introduced in 1970.

Toward the end, Grad concentrated his efforts on the development of algorithms and codes for solving transport problems that arise in the magnetic fusion program. Despite his flagging energies, he pursued this work with the same youthful zest and desire to expand the boundaries of knowledge that marked his entire scientific career. Overcoming the difficulties caused by his ill health, he still maintained his concern and efforts for those around him, and he continued to support and advance the interests of his junior colleagues. The many who benefited from his wisdom and caring will miss him keenly.

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Clifford Keith Beck

Clifford Beck died on 17 April 1986 after a protracted illness. He was born on 12 April 1913 in Salisbury, North Carolina, and received his undergradu-