SIAM NEWS

Obituaries: **George Francis Carrier**

June 3, 2002

George Carrier, shown in 1990, accepting the National Medal of Science from President George H.W. Bush. Carrier was recognized for a lifetime's creative use of mathematics to solve an exceptionally wide range of scientific and engineering problems.

George Francis Carrier, one of the world's preeminent applied mathematicians and the T. Jefferson Coolidge Professor of Applied Mathematics Emeritus at Harvard University, died of cancer in a Boston hospital on March 8, 2002, at the age of 83. He had been a resident of Wayland, Massachusetts.

George had a special talent for describing complicated physical phenomena mathematically. He would then deduce approximate analytic solutions that accurately described the behavior of the phenomena and permitted useful predictions. The rapidity with which he executed the analysis was often exceptional, and was facilitated by his ability to extend mathematical methods to serve his immediate needs.

He applied his talents in many fields, with emphasis on fluid dynamics, combustion, and natural hazards (including hurricanes, tornadoes, fires, and tsunamis---destructive ocean waves generated by earthquakes). Typically, he did not contrive the problems on which he worked; they were often brought to him by engineers and researchers who needed technical help, and were aware of his ability to contribute to almost any problem in continuum mechanics put before him. Carrier's work exemplified the application of mathematics to the solution of practical problems, to the benefit of sponsors; at a 1991 workshop on Catalina Island, Cliff Astill, the program manager at the National Science Foundation who funded the tsunami project in which Carrier participated, memorably described him as a "national treasure."

George's modeling and mathematical abilities were so remarkable that Bernard Budiansky, a colleague in Harvard's Division of Engineering and Applied Sciences (DEAS), described him as a magician. Because of his ingenuity in finding ways to overcome formidable difficulties, a legend among his research collaborators was that he had a special pact with the devil. In his early days at Harvard, some doctoral students were reluctant to ask him for mathematical help, for fear that he would go to the blackboard in his office and proceed to solve the problem under discussion. Soon, however, his generosity in dispensing excellent guidance without regard for credit became well known. The result was a steady stream of students, faculty members, and professional colleagues parading through his always open door to seek assistance with wide-ranging problems; to get time for his own research, George had to work quickly.

Carrier was born in 1918 in Millinocket, Maine. At the time, his father was superintendent of the Great Northern papermaking plant in Millinocket, and George often visited the mills with his father. These visits provided early contacts with physical problems involving structures and fluid flow. They also provided a dose of reality about engineering in industry---the company chose to ignore two recommendations he made for process improvement. Turning to another local industry, George became a guide for tourists wanting to climb the nearby Mt. Katahdin and to find the best blueberry-picking sites.

In accord with a family tradition, he attended Cornell University, receiving a master's in engineering degree in 1939, and a PhD under the supervision of G.N. Goodier in 1944. Although he made a major positive impression on the faculty during his first semester as a fresh-man, his formal academic record was not exceptional; he did not believe that know-ledge gained by cramming for examinations would be retained. His doctoral thesis, a compilation of three distinct problems in structural mechanics, provides early indication of his penchant for problem-solving. One of the problems deals with desirable properties (intermediate "softness") of a matrix material in an anisotropic composite so that the stress of a rotating cylindrical flywheel is well distributed over all the fibers---a design concept perhaps yet to be fully appreciated.

Inspired by the artistry of Benny Goodman, George gave thought to becoming a clarinet player in a big band; though he retained an enthusiasm for up tempo swing-era jazz throughout his life, he ultimately decided he had a "tin ear." Accordingly, a two-year postdoctoral appointment at the Harvard Engineering School (later renamed DEAS) was followed by a rapid succession of appointments at Brown University: assistant professor in 1946, associate professor in 1947, and professor in 1948. At Brown, Carrier participated in a program, sponsored by the Air Force, to review all current literature in the field of supersonic flow; he helped to edit a hardbound collection drawn from this literature. He also managed to embarrass William Prager, who wanted to introduce George and another young professor to a highly formal German colleague visiting Brown; Prager found his young lions engaged in a childish, mock-Western "shootout" in the corridors ("OK, Carrier, go for your gun . . . bang, bang, bang!").

In 1952, Carrier was appointed Gordon McKay Professor of Mechanical Engineering at Harvard, where he was to spend the remainder of his career. In 1972, he was awarded the T. Jefferson Coolidge chair in Applied Mathematics.

Carrier is co-author of the mathematical texts *Functions of a Complex Variable---Theory and Technique* (with Max Krook and Carl E. Pearson, 1966); *Partial Differential Equations---Theory and Technique* (with Carl E. Pearson; 1st ed., 1976; 2nd ed., 1988); and *Ordinary Differential Equations* (with Carl E. Pearson, 1968; reprinted in 1991 as Volume 6 in the SIAM's Classics in Applied Mathematics series).

The PDE book may be the most accessible, and the complex variables book the most demanding. (George delighted in quoting a Caltech undergraduate who told him, "If you're the Carrier who wrote the complex variables book, you ought to be shot.") But perhaps the book with which he was most pleased was the one on ODEs: a minimum of exposition, a maximum of guidance, leaving students to derive key results for themselves and then infer how to proceed from there. This is the way George taught himself complex variables, essentially developing the subject for himself, with minimal reference to any text; he felt that he thereby achieved a depth of understanding that accounted for his exceptional facility with integral transforms, contour integration, steepest-descent methods, etc. If he had found the time, a fourth book might have been added to the list. George spoke of enlisting the collaboration of his former doctoral student Howard Baum, now at the National Institute of Standards and Technology, on a collection of simple brief analyses of phenomena in fluid mechanics, especially those encountered in everyday experience. This intention characterizes his steadfast pursuit of applications-oriented solution of specific practical problems as a dependable road to ever greater insight into nonlinear phenomenology.

George Batchelor was assisted by George Carrier and Wayland Griffith in initiating the *Journal of Fluid Mechanics*, and Carrier served as an associate editor during its first 30 years. Carrier often remarked on the anomalous divergence of opinion among reviewers of manuscripts on turbulence. Carrier also was an associate editor of the *Quarterly of Applied Mathematics* and *SIAM Journal on Applied Mathematics*. He authored or co-authored more than 100 technical papers published in various journals. He disliked rehashing old material; when asked to prepare a review paper or plenum lecture, he generally presented newly executed solutions. In truth, Carrier

preferred the candor of informal conversation and seminars to the polish and formality of publications.

From observation, George felt the most valuable part of a journal issue was its table of contents: Since journals do not knowingly publish failure, the titles reveal what topics are amenable to treatment, by one means or another. If motivated, he might treat the topic mentioned in a title in his own fashion, and then ask someone to compare his own approach with that of the author(s). If he did "read" an article, he typically scanned just the abstract and the figures plus captions (which he thought should be self-contained). Obviously prizing brevity above all, he was terse in his own manuscripts; citations were limited to those that would materially assist the reader (only review papers, he believed, need exhaustive lists of references). He published only what he thought would be of interest to others; he did not regard journal pages as intended for documenting every problem a researcher had solved. Not one to polish text, or to pursue a subject beyond the essence of what he wanted to know, he was nevertheless pleased when the late Sydney Goldstein (who, he said, introduced him to the use of the semicolon) praised his writing as concise and precise. He brought much the same goal-oriented approach and spare presentation to geophysical systems (e.g., a firestorm), which have no behavior "specifications," that he brought to topics involving engineering design (e.g., a rapid gas centrifuge for isotope separation).

He was honored for his scientific accomplishments by election to the National Academy of Sciences (1967), the National Academy of Engineering (1974), the American Academy of Arts and Sciences, and the American Philosophical Society. He was the first foreign honorary fellow of the (British) Institute of Mathematics and Its Applications. Carrier also served as a member of the board of trustees of the Rensselaer Polytechnic Institute, the council for the engineering college of Cornell University, the U.S. National Committee of Theoretical and Applied Mechanics, and the Corporation of the Woods Hole Oceanographic Institute. He received scientific awards and medals from more than a dozen professional societies and organizations, including SIAM, which named him the John von Neumann Lecturer in 1969 and awarded him its von Kármán Prize in 1979. In 1990, President George H. W. Bush presented him with the National Medal of Science, the nation's highest scientific award, in recognition of his contributions to the natural sciences and to the nation.

Carrier served on 27 committees or panels of the National Academies, and chaired committees on the Policy Implications of Greenhouse Warming, the Atmospheric Effects of Nuclear Explosions, and the Panel on Modeling and Simulation. These activities attest to the wide recognition of his technical expertise, and of his wisdom, judgment, and objectivity. His long-term service on the Naval Studies Board of the National Research Council warrants special mention, and he contributed to recommendations concerning the education of personnel in the Navy Century 21 study.

Carrier was the sixth consultant hired by what is now TRW; it was TRW co-founder Simon Ramo himself who first sought his services. (Carrier's repeated requests that his badge number be changed from C006 to C007 were always denied.) His versatility, swiftness, and practicality resulted in his being invited to be in residence as a technical "rescue service" at the TRW Space Park facility in Redondo Beach, California, virtually every summer for nearly four decades. His contributions there included tuned liquid dampers for controlling the rotation of a satellite, accounting for the bath-tub vortex generated during the draining of a liquid-fuel tank of a rocket engine, interpreting pressure/time traces measured during the rapid inflation of automotive airbags via gases generated by combustion, and the fate of an accidental ground spill of liquid chlorine from a high-power chemical-laser system. George's summer office for many years was located amidst an ocean-physics group, which was managed by his friend Bruce Lake but had been spawned by George's contributions to theory coupling internal waves and surface gravity waves. The group had to endure George's enjoyment in telling (and retelling) horrendously bad jokes and puns.

Few faculty members were more informal than George; he invariably lectured in rolled-up shirt sleeves, and that is how he appears in the portrait hanging in the faculty coffee room in Harvard's Pierce Hall. In 1970, then Harvard University president Derek C. Bok held a black-tie banquet in Carrier's honor, just (Bok joked) to see Carrier wearing a tie and tuxedo. George must have had an amazing metabolism, because he often wore no jacket, even in a Massachusetts winter, and rarely donned more than a light raincoat. Without adding a pound, he could consume meals that would pack weight on his dining companions. His friends were pleased when age finally slowed him to a normal walking pace, allowing them to keep up with him more easily.

What was the experience of attending one of George's classes, and what advice did he have for young investigators? He taught energetically, usually without notes, at break-neck pace (drop your pencil and you missed Fourier series), and cared little for algebraic precision. If the topic were (say) boundary-layer methods, he dwelled only briefly on theory, and concentrated on demonstrating technique. Problem formulation, solution methodology, and engineering interpretation were a seamless fusion, whether the course was billed as applied mathematics or fluid mechanics or wave motion. Reworking of the notes from his lectures was a major, mandatory activity for any serious student. He slowed only if he found that he had said one thing, written a second, and meant a third. He was bemused by any student who asked him to change the symbol for a function merely because he had transformed the independent variable. He disliked rules specifying when a technique was appropriate; there were just rough guidelines and surprises that benefited the venturesome. He emphasized optimism---try something simple first---but never led his students to believe that every plausible approach would bear fruit. Introduction of some empiricism might well be the judicious path in a particular context, and was not looked at askance.

As a thesis adviser, he did not arrange regular meetings; presumably the student would drop by when ready to talk. He cautioned against young engineers seeking too much freedom to pursue whatever topics they wanted, because few had mature judgment concerning choice of problem. He thought that consulting-for-industry experience substantially benefited the lectures of an applied mathematics professor. His accounts of his own such activities enhanced his students' intuition about which techniques suited a particular problem.

For much of the year, when his professional colleagues contacted George at home, he had to be called away from a favorite pastime, gardening. On other occasions he was off assisting his middle son as a jack-of-all-trades for house-renovation projects---except that this was a skilled carpenter and stone mason, with practical knowledge about beams, buckling, vibrations, and such, who had completed major construction projects for his own house.

He is survived by his wife, Mary, and sons Kenneth, Robert, and Mark. A memorial service is to be held at the Harvard Memorial Church at 2 p.m. on September 13, 2002.

Contributed by *Frederick Abernathy, Harvard University, and Francis Fendell, TRW.*