

devotion to science, and his personal qualities of kindness, modesty, cheerfulness, natural affinity for people, and total absence of self-promotion. He is sorely missed by his family, friends, the scientific community, and others who knew him.

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Roy Middleton

Roy Middleton

Roy Middleton, emeritus professor of physics at the University of Pennsylvania, died at home in Media, Pennsylvania, on 23 June 2004 after a prolonged illness.

Middleton was born on 3 October 1927 in Atherton, a suburb of Manchester, England. He took his first steps toward a scientific career at the nearby Wigan Technical College, a direction that in the English system of the time would have taken him into industry. The University of London recognized his ability, which gained him enrollment there. He received his BSc in physics in 1948 and earned a PhD in physics from Liverpool University three years later under the supervision of Leslie L. Green, who later became director of the Nuclear Structure Facility at Daresbury, UK.

The 8-MeV deuteron cyclotron at Liverpool was used for some of the earliest studies of direct nuclear reactions, and Middleton, first as a graduate student and then as a research associate, enthusiastically measured (d,p) angular distributions using photographic plates. That work led to his studying (d,n) reactions for his PhD thesis using recoil protons in nuclear emulsions as the detection method. He remained at Liverpool as a research associate until 1955.

That same year, Middleton accepted a position as scientific officer at the Atomic Weapons Research Establishment at Aldermaston, soon after it had acquired one of the first tandem Van de Graaff accelerators, an instrument ideal for exciting direct reactions. He was a supremely creative experimentalist, both in the planning and execution of experiments and in the development and use of accelera-

tor peripheral equipment. Of particular significance was his use of a multiple-gap charged-particle spectrometer for observing the products of nuclear reactions. The instrument allowed rapid accumulation of large amounts of data that unraveled the structures of scores of nuclei. The University of Pennsylvania took notice of that work and Middleton's skills with the then new tandem accelerator, and invited him to direct the new Tandem Accelerator Laboratory. He joined the faculty there in 1965 as a professor of physics.

Tandem accelerators achieved a new versatility and ease of operation through Middleton's development of a negative-ion source capable of producing useful currents from a large fraction of the periodic table. His related resource document, which he called the "Negative-Ion Cookbook," circulated as the bible of the nuclear physics and, later, accelerator mass spectrometry communities. He was later (1979) awarded the American Physical Society's Tom W. Bonner Prize for his work on the development and use of ion sources.

Middleton entered the field of accelerator mass spectrometry very early and collaborated with Jeffrey Klein of Penn and with Fouad Tera, Selwyn Sacks, and Julie Morris at the Carnegie Institution of Washington's Department of Terrestrial Magnetism. Using beryllium-10, they demonstrated that lava from island-arc volcanoes had components that had once been on the ocean floor and had been subducted to the roots of volcanoes in transport processes lasting millions of years. Their results were reported in *Geochimica et Cosmochimica Acta* in 1986. Middleton developed or refined

the accelerator method for the other cosmogenically generated isotopes carbon-14, aluminum-26, chlorine-36, and calcium-41. He actively participated in the science resulting from the use of those isotopes in a range of studies involving lunar samples, meteorites, tectites, and the erosion of rock surfaces and soils.

In collaboration with the Hospital of the University of Pennsylvania, Middleton produced the short-lived positron-emitting isotopes carbon-11, oxygen-15, and fluorine-18 for diagnostic studies of patients. The tracers were immediately transmitted to the hospital in gaseous form through tubing. That approach proved so successful that the hospital acquired a cyclotron to open the door to continued medical opportunities.

From 1986 to 1991, Middleton held the Andrew W. Mellon Foundation Professorship in physics at Penn. In his final years at university, he did outstanding work on negative ions, particularly on dianions, work often referred to in the literature of theoretical chemistry. He retired from Penn in 1996.

For thousands of undergraduate students, Middleton was an exceptionally effective, patient, and supportive teacher. If a student from his class in introductory physics needed his help, Middleton would, without complaint, interrupt his work at the tandem accelerator to provide that assistance. Although he taught the same course many times, he captured his students' full attention with new notes and ideas. He brought to the classroom the same freshness and enthusiasm with which he approached his research. In 1969, the Lindback Foundation awarded him the Christian R. and Mary F. Lindback Award for Distinguished Teaching.

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University of Toronto

Kenneth H. Purser

Lexington, Massachusetts

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[Editor's Note: Louis Brown, one of the authors of this obituary, did not live to see it published; he died on 25 September 2004. See his obituary on page 81 of this issue.]

William Craig Reynolds

William Craig Reynolds died of a malignant brain tumor at his

home in Los Altos, California, on 3 January 2004, after 53 years at Stanford University. He was an undergraduate student, a graduate student, and a professor of mechanical engineering at Stanford. His main interest was in turbulent flow, but he worked in nearly all branches and extensions of fluid mechanics, and used experimental, theoretical, and computational methods with equal facility.

Born on 16 March 1933 in Berkeley, California, Reynolds obtained his BS (1954), MS (1955), and PhD (1957), all in mechanical engineering, from Stanford. His doctoral dissertation, cosupervised by William Kays and Stephen Kline, was entitled "Heat Transfer in the Turbulent Incompressible Boundary Layer with Constant and Variable Wall Temperature."

Reynolds was appointed assistant professor in the Stanford mechanical engineering department immediately after finishing his PhD, a rapidity that few could equal. Apart from three sabbaticals, he spent the rest of his career at Stanford, nominally (but not actually) retiring a year or so before his death. Six weeks before he died, he participated in the examination of the last of his more than 40 PhD students.

One of Reynolds's enduring interests was turbulence modeling, the development of approximate methods of calculating fluid turbulence that are simple enough for everyday use. He was one of the founders of the NASA Ames/Stanford Center for Turbulence Research. His first, elegantly simple, model was developed with student Eric Hirst in the mid-1960s, when computers were too slow for elaborate calculations. His last model, conceived a few years before his death, is still being developed by two of his former students.

Not above initiating and participating in "fun" projects, he was noted



William Craig Reynolds

for his spectacular blooming jets project. Manipulation of the jet orifice produced vortex rings whose mutual repulsion turned the jet into something that looked remarkably like a rapidly growing rose bush. Besides being fun, that mechanism was an effective way of augmenting jet mixing.

The list of titles of research programs—not merely individual investigations—in which he participated occupies more than six lines of small print in his curriculum vitae. He wrote or collaborated on hundreds of scientific papers and several books, including the highly innovative textbook *Thermodynamics* (McGraw-Hill, 1965). He won teaching awards from the American Society of Engineering Education, the Society of Women Engineers, and Tau Beta Pi.

Reynolds's great enthusiasm and research infected his students and colleagues. In addition to being an outstanding research scientist and teacher, he has been described as "a classic do-it-yourself person" in the

great tradition of American engineering. He frequented the department workshop on weekends to work on some piece of hardware, academic or domestic. He designed and supervised the building of his home, the air-conditioning system of the Center for Turbulence, and the air cannon (impulse horn) used to signal touchdowns at the university's football games. As in his research work, "supervised" meant "played a large part in."

Latecomers to Reynolds's memorial service in the Stanford church had to stand at the back; an estimated 700 people attended. An unknown hand has inscribed Reynolds's initials on wet concrete at the entrance to the building where he worked for many years. His scientific reputation will doubtless outlast the concrete.

Peter Bradshaw
Stanford University
Stanford, California ■

Hans Albrecht Bethe 1906–2005

Hans Bethe, prolific contributor to many fields of physics, key member of the Manhattan Project, winner of the 1967 Nobel Prize in Physics, and advocate of nuclear arms control, died on 6 March 2005 in Ithaca, New York.

A few of his many contributions are highlighted at <http://www.physicstoday.org>. PHYSICS TODAY will focus on Bethe's work and life in more depth in a future issue.



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