

at Chalk River, Bert mentored many students who have gone on to have significant careers in physics.

Although greatly admired for his intellect and novel ways of approaching problems, Bert is remembered for his affection and his humble, gracious manner. Shortly after the announcement that he was a winner of the Nobel Prize, for example, Bert told a gathering of Canadian undergraduate physics students at McMaster that he used to think that his work was not so important, but recent events had forced him to reconsider. He is also remembered for his love of the arts: He often sang opera at work and he appeared in a number of amateur theater productions including a George Bernard Shaw play and Gilbert and Sullivan operettas. Even during the most hectic and productive time in his career, Bert found time to be a devoted family man with six children and, ultimately, 10 grandchildren.

Although Bert's passing is mourned by his many friends and colleagues, we have been inspired by a life of great accomplishment.

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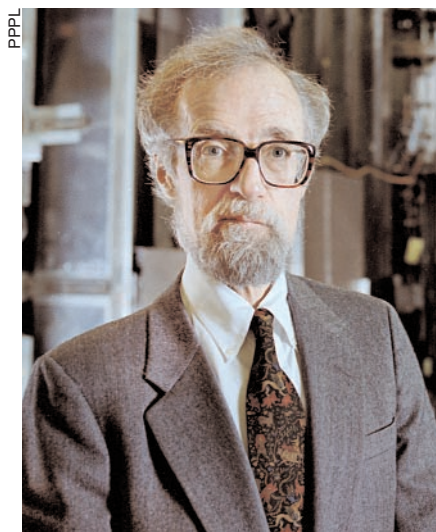
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Harold Paul Furth

Harold Paul Furth, professor emeritus of astrophysical sciences at Princeton University in Princeton, New Jersey, died of heart failure on 21 February 2002 in Philadelphia. Harold was a highly original thinker, an inventor, and a major figure in the field of plasma physics. His life's passion was to produce energy through nuclear fusion. For a quarter of a century, Harold was the architect, authority, and driving force behind the US effort in nuclear fusion for peacetime use.

Harold was born in Vienna, Austria, on 13 January 1930. His father had escaped from a prisoner-of-war camp during World War I, and, via China, had returned to Vienna. There, he ran the successful family hat-making business "Fefzfabriken" ("Fefz Factory"), but his real love was literature. Harold's uncle was Paul Harteck, codiscoverer of the deuterium-deuterium fusion reaction. In the summer of 1939, Harold's father, whose family was of Jewish origin, escaped to Switzerland. In the end, Fefzfabriken was lost in World War II, and Harold inherited instead a love of both physics and literature.



Harold Paul Furth

After studying at the French-speaking Ecole Internationale in Geneva, Harold went to New York City in 1941. In 1947, he graduated at the head of his class from the Hill School in Pottstown, Pennsylvania. He then attended Harvard University until 1951, when he earned his BS in physics. After a year at Cornell University, he returned to Harvard as a graduate student from 1952 to 1956.

In 1956, while still a student at Harvard, Harold joined the University of California Radiation Laboratory, first in Berkeley and later at the Livermore branch (now Lawrence Livermore National Laboratory). His wit and literary prowess, along with his skills in physics, quickly became evident. That year, he published an irreverent poem in the *New Yorker* called "Perils of Modern Living." In it, he imagined "Dr Edward Teller," his laboratory mentor, encountering "Dr Edward Anti-Teller." Teller had explained that, on contact, matter with antimatter would explode, and in Harold's poem, that indeed was the result:

Then shouting gladly oe'r the
sands,
Met two who in their alien
ways
Were like as lentils. Their right
hands
Clasped and the rest was
gamma rays.

In 1960, Harold submitted to Harvard his thesis on magnetic analysis of K meson interactions in emulsion nuclei. Meanwhile, together with Stirling Colgate at Livermore, he invented methods of confining hot plasma, which included numerous pinch configurations and the levitron, a device in which a large current-carrying ring

was levitated within a vacuum chamber. Those early devices were plagued by plasma instabilities that defied conventional explanation. The prevailing paradigms imagined the plasma as a perfectly conducting fluid. However, visualizing what happens when twisting plasma columns in turn twist the magnetic lines of force imbedded in them, Harold recognized how even the small electrical resistance of plasma could alter the gross structure and stability of magnetic traps. In 1963, together with Marshall Rosenbluth and John Killeen, Harold published in *Physics of Fluids* the influential paper "Finite Resistive Instabilities of a Sheet Pinch"—one of the most cited papers in modern plasma literature—that explained the underlying physics of both manmade plasma traps and natural phenomena such as Earth's magnetotail.

Harold joined Princeton in 1967 as a professor of astrophysical sciences and co-head of the experimental division at the Princeton Plasma Physics Laboratory (PPPL). Harold showed, in increasingly larger and more sophisticated devices, how powerful magnetic fields can confine plasma, even as the plasma is heated to thermonuclear temperatures, or tens of millions of degrees Kelvin. In 1969, he immediately recognized the significance of the Russian success in confining plasma using the tokamak configuration. Quickly confirming the favorable Russian results, Harold redirected the Princeton program to explore a series of innovative tokamak variations.

Following the oil embargo in 1973, when the escalating prices and the perceived scarcity of fossil fuels threatened national security, the time was ripe for the US to vigorously explore new energy sources. It was Harold who articulated for the nation the very real promise in harnessing nuclear fusion as an alternative energy source.

When more expensive options were being proposed at a historical meeting of the Atomic Energy Commission in late 1973, Harold went to the blackboard and said, "Well, if this is what you want to do, I will tell you how to do it." Thus, Harold put forth the basic ideas behind the Tokamak Fusion Test Reactor (TFTR). His approach prevailed as the cheapest and surest one, relying on his recent idea of exploiting fusion reactions that arise from injected energetic ions. With colleagues John Dawson and Fred Tenney, Harold had earlier (1971) predicted that, because of the reactions caused before the ions reached equilibrium

with the background plasma, energetic ions injected into confined plasma could significantly increase the number of fusion reactions at a given temperature.

Harold directed PPPL from 1981 to 1990. He supervised the completion of and early experiments on TFTR, the largest American enterprise in controlled nuclear fusion to date. As director, he was intensely engaged both in the TFTR discoveries and in the imagining of different approaches to confining plasma. In 1994, TFTR produced for one-third of a second a record 11 megawatts of fusion power in plasma of deuterium and tritium, and thereby demonstrated the promise of future fusion reactors.

Harold received numerous awards, including the E. O. Lawrence Award from the US Atomic Energy Commission in 1974, the American Physical Society's James Clerk Maxwell Prize for Plasma Physics in 1983, and the Delmer S. Fahrney Medal from the Franklin Institute in 1992. He was a fellow of the American Academy of Arts and Sciences and a member of the National Academy of Sciences.

Harold's charge to himself and to his colleagues was to take on only the lofty goals worthy of precious time, or as Harold put it, "not to take in laundry." For his colleagues, Harold was a true inspiration: He embodied leadership, purpose, personal integrity, brilliant wit, refreshing humor, and monumental accomplishment.

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Vernon Willard Hughes

Vernon Willard Hughes, Sterling Professor Emeritus and Senior Research Associate at Yale University, died 25 March 2003 in New Haven, Connecticut, from medical complications following an operation for an aneurysm. Hughes began research in physics in 1942 at the MIT Radiation Laboratory. During his terminal stay in the hospital, he wrote recommendation letters for a postdoc who worked with him. Thus Hughes worked at physics research—largely at the cutting edge of atomic, nuclear,

and particle physics—for 61 years.

Hughes was born in Kankakee, Illinois, on 28 May 1921. After his father died when he was three, Hughes was raised in New York City by his mother, a librarian at Teachers College of Columbia University. Having entered Columbia as a pre-law student with the intention, he wrote, "of doing good things for the world," he found mathematics and physics more interesting than law. After completing a heavy academic schedule in only three years and winning the Van Buren Math Prize, Hughes graduated from Columbia as a physics major and enrolled as a graduate student at Caltech in 1941. He received his MSc in 1942.

With the nation at war, Hughes worked on radar at the MIT Radiation Laboratory. After the war, he began research at Columbia, under I. I. Rabi, on nuclear electric quadrupole moments and received his PhD in 1950. Following two years as a postdoc at Columbia and two years at the University of Pennsylvania, Hughes came to Yale in 1954.

Although much of Hughes's work was on the properties of atoms, he regarded atoms primarily as laboratories for studies of the fundamentals of electromagnetism. Thus he concentrated on the helium atom, on positronium, and then—arguably his unique contribution to physics—on muonium, the muon–electron atom that, in 1960, he was the first to identify. His next 40 years of experimentation on that atom verified to high precision that the muon is indeed a "heavy electron," gave us new avenues into the experimental study of quantum electrodynamics, and created a tool to probe the highest energy scales of elementary particle physics.

Hughes's deep interest in fundamentals was manifest in his 1957 and 1988 measurements, in which he established limits of the electron–proton charge difference, and his 1960 measurements that limited the anisotropy of the inertial mass of a proton moving in the lithium nucleus. From Mach's principle, that observation established the isotropy of the universe to better than one part in 10^{22} .

In 1958 at Yale, Hughes initiated a design study of a proton linear accelerator "meson factory" to produce meson and muon fluxes a thousand times greater than those available at the time. Beginning in the mid-1960s, he began working on muonium physics at Los Alamos using the Los Alamos Meson Physics Facility accelerator that was based partially on the Yale design. His summers at LAMPF led to his long-time friendship with

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