ditions, and for making fundamental research a popular enterprise and for helping to popularize physics and science through the media.

Leprince-Ringuet was a devoted Christian, and a painter who presented several exhibitions. On one such occasion, he had to compare the creative work of the artist to that of the scientist. It seems proper to conclude with his view of science, his first and main love all along, which he repeated at the celebration of his 96th birthday:

> Our work is part of a never-ending study of natural phenomena, of their understanding, and of finding their relationship through a formalism that we have to invent for that purpose. Even if our work relies on imagination, critical thinking, tenacity, and creative spirit, it reveals little and very seldom the deepest and most private reality of our own self. In that sense we are not poets but we sing in wide choirs the greatness of nature and the power of humankind.

MAURICE JACOB
CERN
Geneva, Switzerland

Harold Walter Lewis

Harold Walter Lewis, a former vice provost and dean of arts and sciences at Duke University, died from cancer in Durham, North Carolina, on 17 October 2000.

Lewis was born in Keene, New Hampshire, on 7 May 1917. He obtained his bachelor's degree in physics in 1938 from Middlebury College, received his master's in physics at the University of Buffalo in 1940, and then continued graduate studies at Duke University. At the beginning of World War II, he joined the Naval Ordnance Laboratory and the Navy Bureau of Ordnance as an expert on magnetic fields and mine detection, dividing his time between Washington, DC, and Pearl Harbor, Hawaii.

Lewis returned to Duke in 1946. He obtained his PhD in physics in 1950; his thesis was on cosmic-ray bursts in ionization chambers. That same year, he also became assistant project leader for Duke's nuclear physics program, directed by Henry Newson. He joined the Duke faculty in 1949 as an assistant professor.

In 1953, Lewis realized that nuclear accelerators and nuclear physics detection techniques could be used for the first accurate, absolute cross-section measurements of characteristic atomic x rays produced after inner-shell ionization of high-Z atoms by protons in the MeV range. This work advanced the growth of accelerator-related atomic physics and eventually gave rise to a much-used analytical tool: proton-induced x-ray emission, or PIXE. In a 1958 review entitled "X-Ray Production by Heavy Charged Particles" in the *Encyclopedia of Physics* (Springer, 1958), Lewis gave a comprehensive account of the results that he and his graduate students had obtained in a series of benchmark measurements. The atomic x-ray measurements proved to be valuable in the analysis of gamma-ray yields from the early nuclear Coulomb excitation experiments, to which Lewis contributed. Lewis also collaborated at Duke with Willy Haeberli (later of the University of Wisconsin); this collaboration led to publication of the experimental determination of the nuclear levels of phosphorus-29 in *Physical Review* in 1959.

HAROLD WALTER LEWIS

In 1959, Lewis became a professor of physics at Duke. From 1960 to 1961, he served as a visiting professor at the American University of Beirut in Lebanon under a Smith–Mundt Fellowship. He was appointed in 1961 as associate director of the Nuclear Structure Laboratory at Duke; the lab later was renamed the Triangle Universities Nuclear Laboratory (TUNL).

After a very productive period of research in nuclear physics, Lewis was appointed vice provost and dean of arts and sciences in 1963, and was named dean of faculty in 1969. He returned to the physics department in 1981 as chairman and was named University Distinguished Service Professor. He was also a trustee of the Southeastern Universities Research Association and a councilor of the Oak Ridge Associated Universities.

After he retired from teaching and university administration in 1986, Lewis joined a team of TUNL physicists, led by Thomas Clegg and William Hooke, to construct a new high-intensity polarized ion source using atomic beams of hydrogen and deuterium. Lewis's efforts centered on the design, fabrication, and testing of a system of electromagnetic sextupoles for this source. He worked closely and patiently with several students and young technical staff as their mentor who, by his example, assured that their measurements were carefully made and meticulously logged. Their sextupole designs are still used today at TUNL and were later adapted for an ion source at the Indiana University Cyclotron Facility.

Lewis was a quiet but exceedingly effective leader in his field of research who contributed significantly to physics even after a long term in university administration. As an experimental physicist, he was hardworking and resourceful. As an administrator, both at the university and the physics department levels, he was a respected and beloved person. He was deeply and genuinely concerned for people and respected for his fairness and honest approach to problems. His contributions to science and to Duke, his gracious personality, and his cooperative nature will long be remembered by those who knew him.

HORST MEYER
EDWARD G. BILPUCH
Duke University
Durham, North Carolina
EUGEN MERZBACHER
University of North Carolina at Chapel Hill

Emanuel Maxwell

Emanuel Maxwell, widely known for his research on superconductivity and low-temperature physics, died of heart failure in Cambridge, Massachusetts, on 6 October 2000.

Maxwell was born in Brooklyn, New York, on 16 December 1912 of parents who had emigrated from Russia. As a child, he built radios and became an amateur radio operator; he credited his teachers at Erasmus Hall High School for stimulating his interest in science. He received a BS (1934) and an MS (1935), both in electrical engineering, from Columbia University.

In the depression year of 1935, Maxwell's first job was with RCA at the telegraph receiving station on Long Island, New York, where he

EMANUEL MAXWELL

relayed Morse code originating in Europe to New York City. In 1937, after seven months as a patent examiner in Washington, DC, he worked for Shell Oil in Texas, developing electrical prospecting techniques.

In 1941, he joined the MIT Radiation Laboratory and, during World War II, worked in the fundamental development group of the research division. This group of scientists and engineers, led by Edward Purcell, was assigned the task of making an X-band system to obtain higher resolution radar for aircraft and submarine location. The project was completed that summer and was of great importance to the allied forces. The even higher resolution K-band system was completed before the end of the war. Maxwell then began graduate work at MIT, receiving a PhD in physics in 1948. His thesis adviser was John Slater and his thesis topic was superconducting microwave resonators.

In 1948, Maxwell joined the cryogenics section of the National Bureau of Standards in Washington, DC. At that time, superconductivity remained unexplained. Suspecting that the metal lattice was related to superconductivity, Maxwell decided to test this conjecture, even though two previous experiments had found no dependence. The experiment consisted of measuring the superconducting transition temperature T_c of mercury-198, a pure isotope, and that of natural Hg, which has an average mass number M of 200.6. The small difference in M required precise measurement of the temperature and the magnetic field, but the result clearly showed that the transition temperature of the lighter isotope was 0.021 K above that of natural Hg (T_c = 4.156 K).

Almost simultaneously, a group led by Charles Reynolds and Bernard Serin found similar results with other mercury isotopes. The data fitted a simple relation: $T_c \propto M^{-\alpha}$. Further measurements showed $\alpha \cong 0.5$, not only for Hg, but also for tin and thallium. Maxwell described his discovery—now known as the isotope effect— in an article he wrote for the December 1952 issue of PHYSICS TODAY. The results suggested to theorists that an electron–phonon interaction caused superconductivity. Indeed, Herbert Fröhlich had previously developed such a theory without knowing about the experiments, but his theory and others proved unsatisfactory until the Bardeen-Cooper-Schrieffer (BCS) theory appeared in 1957. This theory, with extensions by other theorists, explained superconductivity as a time-retarded Coulomb interaction between electrons through lattice vibrations. Maxwell analyzed the thermodynamic implications of the isotope effect and the nonparabolic shape of the critical field, which he measured with Olin Lutes. With Paul Marcus, he generalized the two-fluid model of superconductivity.

In 1953, Maxwell returned to MIT, working at the Lincoln Laboratory. There he extended his work on radar components and superconducting microwave resonators, was active in the MIT low-temperature group, and started a low-temperature group at Lincoln to study fundamental properties of superconductors and liquid helium. With Charles Chase and Walter Millett, he determined the density of helium-4 through the λ-point to within 10^{-4} K of the singularity. With Myron Strongin and Thomas Reed, he showed that, for rhenium, $\alpha = 0.356$, adding to the evidence that the BCS analysis of the isotope effect needed generalization.

Maxwell brought his low-temperature group to MIT's Francis Bitter National Magnet Laboratory in 1963. Cerium magnesium nitrate was confirmed to have an antiferromagnetic transition at low temperature, a result of importance to temperature measurement in the millikelvin region (see *Physics Review Letters*, volume 6, page 308, 1969). With Brian Schwartz and Y. B. Kim, he studied flux flow near the critical field of superconductors. Maxwell's knowledge of superconductivity and low-temperature physics was essential to the success of the program in spin-polarized electron tunneling carried out by Paul Tedrow and one of us (Meservey).

In the 1970s, Maxwell joined Henry Kolm, one of us (Kelland), and Israel Jacobs in the development of high-gradient magnetic separation techniques for coal, mineral ores, and water. Perhaps the most significant result was a process of microwave conversion of pyritic sulfur to magnetic pyrrhotite, which then was removed from ground coal.

"Mannie," as he was called, was well informed and serious, but friendly with a subtle sense of humor. His many friends, students, and associates benefited from his insightful advice on physics and life, but often only realized later that he had given it. Tolerant of others, Mannie held himself to very high standards in his personal life and in science.

ROBERT MESERVEY
DAVID R. KELLAND
Massachusetts Institute of Technology
Cambridge, Massachusetts

John Wilder Tukey

John Wilder Tukey, Donner Professor Emeritus of Science at Princeton University and one of the most important contributors to the field of statistics, died 26 July 2000 in New Brunswick, New Jersey, following a heart attack.

Born on 16 June 1915 in New Bedford, Massachusetts, Tukey received an ScB in chemistry (1936) and an ScM in chemistry (1937) from Brown University and an MA in mathematics (1938) and a PhD in mathematics (1939) from Princeton University. He joined the faculty of Princeton in 1939 and remained there until his retirement in 1985. In his thesis on abstract topology, Tukey introduced terminology to describe some properties of sets. In mathematical foundations, the Axiom of Choice has two standard alternate forms: Zermelo's Theorem and Tukey's Lemma. The latter is often said to be the useful version of the Axiom of Choice.

The introduction of new terminology to capture distinctive concepts would become a Tukey trademark. For example, he coined the contraction "bit" for binary digit. Tukey is credited with the first printed use of the word "software" to refer to computer programs; he observed that the software might well prove to become more valuable than the hardware. The saying that "an approximate solution of the exact problem is often more useful than the exact solution of an approximate problem" has often been attributed to Tukey.

Tukey did not follow up on his the-