Research at an Undergraduate Institution to Roger W. Bland (San Francisco State University) for his "outstanding research in the search for free quarks and for his energetic guidance of undergraduate students of San Francisco State University who have fully participated in the research." He and his students have been using a Millikan apparatus to search for free quarks in a wide variety of materials since the late 1970s.

Bland received his BS from Caltech (1961) and his PhD from the University of California, Berkeley (1968). He held research positions at the Lawrence Berkeley Laboratory; the Ecole Polytechnique, Paris; and Glasgow University before going to San Francisco State as a lecturer in physics and astronomy in 1975. He became a full professor at San Francisco State in 1984.

## GRAVITY RESEARCH FOUNDATION ANNOUNCES AWARDS

The Gravity Research Foundation has announced the winners of its 1988 essay competition. Itzhak Bars and Christopher N. Pope (University of Southern California, Los Angeles) received the first prize of $1500 for "Is There a Unique Consistent Theory of Quantum Gravity?" Pawel O. Mazur (Syracuse University) was awarded the second prize of $500 for "An Interacting Geometry Model and Induced Gravity." The third prize of $200 went to Minos Axenides (University of Washington, Seattle) for "On the Phase Transition to Space–Time in String Cosmology." Fourth prize went to Robert C. Myers and Jonathan Z. Simon (University of California, Santa Barbara), and fifth prize went to Ilya Prigogine (University of Texas, Austin, and Free University of Brussels) and J. Geheniau, E. Gunzig and P. Nardone (Free University of Brussels).

## OBITUARIES

### I. I. Rabi

On 11 January 1988, I. I. Rabi, a creative scientist, an innovative statesman and a philosopher, died at the age of 89. He had received numerous awards and honors, including the 1944 Nobel Prize in physics for inventing the molecular-beam magnetic resonance method and for using it to measure the magnetic, electrical and structural properties of atoms, molecules and nuclei.

Rabi was born on 29 July 1898 in Rymanow, Austria, to an Orthodox Jewish family who soon thereafter moved to New York City, where they lived initially on the Lower East Side, but later in the Brownsville section of Brooklyn. He attended New York public schools and, as an avid reader, gained much of his education and interest in science through books borrowed from the public library. In 1916, after graduating from the Manual Training High School in Brooklyn, Rabi entered Cornell University. He started in electrical engineering, but graduated in chemistry. After three years of uninteresting jobs he returned to Cornell to do graduate work in chemistry; a year later he moved to Columbia University, and to physics. At Columbia, Rabi did his doctoral research on magnetic susceptibility with Albert P. Wills, but, characteristically, it was on a subject of Rabi's own choosing and employed a novel technique that greatly simplified the experiments. The day after he sent in his doctoral thesis, he married Helen Newmark, who remained his lifelong companion.

Rabi soon went to Europe on a traveling fellowship, where he worked intermittently with Arnold Sommerfeld, Werner Heisenberg, Niels Bohr and Wolfgang Pauli. The Stern–Gerlach experiment demonstrating the reality of space quantization had earlier sparked Rabi's interest in quantum mechanics, so he became a frequent visitor to Otto Stern's molecular-beam laboratory in Hamburg while working there with Pauli. During one of these visits Rabi suggested a new form of deflecting magnetic field, and Stern invited Rabi to work on it in his laboratory. Rabi's acceptance of this invitation was decisive in turning his interest toward molecular-beam research.

Rabi returned from Europe to join the faculty at Columbia and to begin atomic-beam research in his own laboratory. In 1931 he and Gregory Breit developed the important Breit–Rabi formula, which showed how the magnetic energy of an atom and its effective magnetic moment vary with the strength of the external magnetic field. These changes occur because the atomic configuration varies from the electron's being coupled primarily to the nucleus at a low external field to its being coupled primarily to the external magnetic field at a high field.

Using the Breit–Rabi formula and an atomic-beam apparatus with inhomogeneous magnetic fields, Rabi, Victor Cohen and others were able to determine the strengths of electron–nucleus interactions and the magnitudes of nuclear spins and magnetic moments. Rabi further improved the precision of the measurements by noting from the Breit–Rabi formula that the effective magnetic moments are zero at certain magnetic fields, which give a marked rise in the intensity of the undeflected atoms passing through an inhomogeneous field. By measuring these zero-moment magnetic fields, Rabi's students and associates determined a number of hyperfine interactions. Although the zero-moment method did not work for atoms with nuclear spin $\frac{1}{2}$, Rabi devised an alternative refocusing technique that did.

Rabi also showed that one could adapt the molecular-beam deflection method to measure the signs of nuclear magnetic moments by determining which transitions occurred when atoms went through a region of space in which the directions of the magnetic fields were successively reversed.

Rabi developed the theory of such transitions in his important paper entitled "Space Quantization in a Gyrating Magnetic Field" (*Physical Review* **51**, 652, 1937). In this paper Rabi assumed for simplicity that the applied field changed its direction ("gyrated") at a fixed frequency. As a result this paper has provided the theoretical basis for all subsequent magnetic resonance experiments.

Rabi initially applied his theory to fields that changed only in space rather than in time. A few months after the publication of that paper, following a visit by C. J. Gorter, Rabi directed the major efforts of his laboratory toward the development of molecular-beam magnetic resonance, with the magnetic fields oscillating in time. A molecular beam was deflected by one inhomogeneous magnetic field and refocused by a similar field. In passing between the two fields the molecules were subjected to a weak oscillatory magnetic field at frequency $\nu$. When $\nu$ was equal to the Bohr frequency $\nu_0 = (W_i - W_f)/h$ (where $W_f$ and $W_i$ are the energies of the final and initial states), transitions could take place, with a consequent refocusing failure and a reduction in beam intensity. By measuring the beam intensity as a function of frequency one could thereby determine the spacing of the molecular energy levels.

The first successful molecular-beam experiment was that of Rabi, Sidney Millman, Polykarp Kusch and Jerrold R. Zacharias in 1938, which