

Relativity and Gravitation Society, which organizes triennial conferences and publishes the journal *General Relativity & Gravitation*. Peter played a central role in that growth through his research and teaching. He also devoted time to the society through the informal international committee by helping to draft the constitution and structure of the present formal organization, through his membership on the executive committee, and by service to the journal's editorial board. In 1963, Peter, with one of us (Schucking), Ivor Robinson, and Alfred Schild, helped organize the inaugural Texas Symposium on Relativistic Astrophysics.

Peter kept up an interest in thermodynamics and statistical mechanics and in epistemological questions, particularly the theory of measurement. He studied the measurement process in quantum theory and introduced the notion of an ensemble corresponding to time symmetry by selecting a sample using both initial and final states rather than just the fixing of the initial state. He extended to general relativity the Bohr–Rosenfeld argument on the measurement of field strengths. His result showed that the Riemann tensor is the measurable field and that its measurement with infinite precision requires a lattice of infinite rigidity. Peter carried out that work with one of his last students when he was a research professor at New York University.

Peter the teacher, research scientist, colleague, and friend touched and inspired a large number of physicists. During his 40 years at Syracuse, he guided 32 people through their dissertations and contributed actively to the research efforts of many more. In addition, a comparable number of postdocs spent up to two years at Syracuse, either as research associates or visiting professors. They were stimulated by his clear, sharp physical insights and by his personal warmth. His reputation as an outstanding teacher came from the thoughtful individual attention that he gave to students. He always had time for those who were serious in their study and research. His sensitivity to students and their need for support is demonstrated by the following anecdote. Once, during a faculty meeting, Peter was asked how he came to give an A grade to a student who was failing most of his other courses. Peter left the meeting, examined his grade book, returned, and responded, “It was a low A.”

At the end of September 2002, Peter, together with John Wheeler,

was awarded the Einstein Prize by the American Physical Society for “pioneering investigations in general relativity, including gravitational radiation, black holes, spacetime singularities, and symmetries in Einstein’s equations, and for leadership and inspiration to generations of researchers in general relativity.” He learned about the award shortly before his death.

Joshua N. Goldberg

*Syracuse University
Syracuse, New York*

Engelbert L. Schucking

*New York University
New York City*

Robert Lull Forward

Physicist and science-fiction author Robert Lull Forward died on 21 September 2002 in Seattle, Washington, from brain cancer. A leader in gravitational radiation astronomy and advanced space propulsion, he contributed particularly to gravitational and inertial sensors and low-loss electronics.

Forward was born on 15 August 1932 in Geneva, New York. He obtained his BS in physics from the University of Maryland in 1954, an MS in applied physics from UCLA in 1958, and his PhD from the University of Maryland in 1965. For his thesis, he built and operated the first bar antenna for gravitational wave detection; he did this work under the direction of Joseph Weber and David Zipoy. His antenna was on display in a Smithsonian Institution museum and is now in storage there.

Beginning in 1956 and for the next 31 years, Forward worked at the Hughes Aircraft Research Laboratories in Malibu, California, rising to senior scientist on the director’s staff. In his early years at Hughes, he invented and developed gravitational radiation detectors and explored many new ideas in space applications. One such invention was the rotating cruciform gravity gradiometer mass detector, which measures Earth’s subsurface mass variations or gravitational multipole moments. In 1960, he was the first to point out that a laser interferometer gravity-wave detector could be built to be photon noise limited, and that scaling it up would make extreme events in the universe detectable.

Retirement for Forward was a simply a new category of innovation and activity. He took early retirement in 1987 and founded Forward Unlimited. The appropriately named company emphasized space propulsion



MARTHA FORWARD

Robert Lull Forward

methods, including using laser- and microwave-driven sails and antimatter propulsion for high velocities.

Through his concepts for matter and antimatter rockets and laser- and microwave-driven sails, he explored the only technically credible ways of sending probes to the stars; such craft can reach speeds necessary for those vast gulfs. His book *Mirror Matter: Pioneering Antimatter Physics* (Wiley, 1988), written with Joel Davis, presents his ideas on matter and antimatter rockets.

In 1992, Forward formed Tethers Unlimited Inc with Robert Hoyt. The company specializes in innovations for space travel using elegant mechanical methods. He retired again just before his death.

Forward’s written work consists of 157 technical publications and 71 popular science articles. His 14 book-length works include science fact and science fiction. His best known novels are *Dragon’s Egg* (Ballantine, 2000), which is about life on a neutron star and is still used in astrophysics courses, and *Rocheworld* (Baen Books, 1990), which is based on his concept for propulsion using laser-driven sails. He was among the most rigorous of the “hard” science fiction writers. His best nonfiction summary work is *Indistinguishable From Magic* (Baen Books, 1995), based on Arthur C. Clarke’s Third Law, “Any sufficiently advanced technology is indistinguishable from magic.”

Elegance of concept marked his many inventions; in all, Forward obtained 20 patents. Orbital tethers will be both graceful and useful. In a long series of papers, many with Hoyt, he calculated how light cables could be used to transfer energy and momen-

tum between spacecraft; that effort opened new methods of orbit changing. Cables carrying electrical currents can raise or lower orbits by using the $\mathbf{J} \times \mathbf{B}$ force, available from Earth's magnetic field. Forward believed that antimatter could provide the most fundamental method of containing energy. In the 1980s, he published 18 issues of his privately circulated journal, *Mirror Matter Newsletter*, to stimulate the field. He saw how magnetic traps could make antimatter useful in medicine, principally in tumor treatment.

Forward lived up to his name: His thinking was well ahead of his time, and he was known for a positive, supportive, and playful manner. We knew him primarily as a pioneer of beam-driven sails, but he had a thousand other interests. Some of his papers have amusing titles, such as "Laser Weapon Target Practice With Gee-Whiz Targets." He fancied wearing colorful vests to go with his exciting ideas, concepts nonetheless developed with full conservative scientific rigor. Knowing of his fatal illness, he devoted his last months to writing out his newest, partially explored scientific ideas.

Of Forward's many innovations, some were realized in his life, but most will likely emerge in 21st-century space propulsion and gravitational wave detection. Now that the first solar sails are about to be launched and plans are being made to beam microwaves at them to demonstrate photon propulsion, Forward's ideas are starting to become real. He was fond of saying that he wrote science fiction to advance ideas that he couldn't get into the scientific journals. He usually coupled his science-fiction writing to his science papers and thus gave concepts a wider publicity and advanced public understanding of what the consequences of these ideas could mean.

Gregory Benford
*University of California
Irvine*

James Benford
*Microwave Sciences
Lafayette, California*

Frank Slagle Ham

Frank Slagle Ham, a theoretical solid-state physicist best known for his many contributions to the understanding of the Jahn-Teller (JT) effect in condensed matter, died on 12 December 2002 in Schenectady, New York. While being treated for a stroke he had suffered in May 2002,



Frank Slagle Ham

Frank—though never a smoker—was diagnosed with lung cancer, which eventually led to his death.

Born in Bronxville, New York, on 15 August 1928, Frank grew up in Washington, DC, and obtained both his AB (1950) and PhD (1955) in physics at Harvard University. His doctoral dissertation, under Harvey Brooks, represented an early application of the quantum defect method to the study of the electronic structure of solids.

After a postdoctoral period at the University of Illinois, he joined the General Electric Research Laboratory in Schenectady in 1955; he was employed at the lab until his retirement in 1988. During that 33-year period, he spent a year (1971–72) on a Guggenheim fellowship at Oxford University's Clarendon Laboratory in England and a year (1976–77) as visiting professor at Clemson University. He also held adjunct and visiting professorships at Rensselaer Polytechnic Institute (1968–69, 1980–91) and at Lehigh University, where he was active in research from 1983 until his death.

At GE, Frank expanded his energy-band calculations to provide the first practical application of the KKR (Korringa-Kohn-Rostoker) Green's function method to such problems. He subsequently published several articles that contained analytic solutions for the diffusion and aggregation of impurities in crystalline solids and made contributions to the interpretation of luminescence energy-transfer mechanisms in crystals.

In the mid-1960s, Frank, like other theorists at the time, was concerned about electron paramagnetic resonance (EPR) spectra of many impurity ions that have orbitally degener-

ate ground states. The states appeared to show no evidence of the symmetry-lowering JT distortions predicted by theory. Frank was the first to recognize that the JT effect was actually present all along—not static but dynamic—with rapid tunneling from one distortion direction to another. Hence, an average was being observed in the EPR spectrum and the system superficially appeared undistorted. Frank showed that predictable telltale changes in the spectra's parameters provided a direct quantitative determination of the distortions' symmetry and magnitude. In subsequent years, he further demonstrated that the dynamic JT effect can have important consequences in all forms of spectroscopy. Terms such as the "Ham effect" and the various "Ham reduction factors" for spin-orbit interaction, orbital angular momentum, and magnetic and strain perturbations are now essential parlance among spectroscopists.

Throughout his career, Frank was interested in the vibronic coupling between the surrounding lattice and an impurity ion or lattice defect. He made important contributions to a number of problems, including the relaxed excited state of the F-center in alkali halides; the EPR, acoustic, optical, and Mössbauer spectra of transition element ions in a variety of ionic and semiconductor hosts; and the unusual EPR spectra of interstitial lithium and the negatively charged states of the lattice vacancy and substitutional platinum in silicon. He also worked on the inverted level ordering for double acceptors and acceptor-bound excitons in semiconductors, the Zeeman effect on double-donor spin-triplet levels in silicon, and the effect of Berry's phase on the sequence of vibronic states for a defect.

Frank made many important but less visible contributions by generously sharing his knowledge and guiding others in interpreting their data. If one was wrong, Frank's criticism was incisive, but he delivered it with such patience and courtesy that one's pleasure in finally seeing the point was unclouded by any feeling of inferiority. Whether graduate student or senior scientist, one would emerge grateful, more knowledgeable, and much closer to the correct interpretation.

Frank served on the executive committee of the American Physical Society's division of condensed matter physics from 1976 to 1978 and on APS's Apker Award committee from 1983 to 1985. He was a member of the editorial board for *Physical Review B* from 1978 to 1982.