NORMAN F. RAMSEY

The Nobel Prize in Physics 1989

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I was born August 27, 1915 in Washington, D.C. My mother, daughter of German immigrants, had been a mathematics instructor at the University of Kansas. My father, descended from Scottish refugees and a West Point graduate, was an officer in the Army Ordnance Corps. His frequently changing assignments took us from Washington, DC to Topeka, Kansas, to Paris, France, to Picatinny Arsenal near Dover, New Jersey, and to Fort Leavenworth, Kansas. With two of the moves I skipped a grade and, encouraged by my supportive parents and teachers, I graduated from high school with a high academic record at the age of 15.

My early interest in science was stimulated by reading an article on the quantum theory of the atom. But at that time I did not realize that physics could be a profession. My parents presumed that I would try to follow my father's footsteps to West Point, but I was too young to be admitted there. I was offered a scholarship to Kansas University but my parents again moved - this time to New York City. Thus I entered Columbia College in 1931, during the great depression. Though I started in engineering, I soon learned that I wanted a deeper understanding of nature than was then expected of engineers so I shifted to mathematics. By winning yearly competitive mathematics contests, I was honored in my senior year by being given the mathematics teaching assistantship normally reserved for graduate students. At the time I graduated from Columbia in 1935, I discovered that physics was a possible profession and was the field that most excited my curiosity and interest.

Columbia gave me a Kellett Fellowship to Cambridge University, England, where I enrolled as a physics undergraduate. The Cavendish Laboratory in Cambridge was then an exciting world center for physics with a stellar array of physicists: J.J.. Thomson, Rutherford, Chadwick, Cockcroft, Eddington, Appleton, Born, Fowler, Bullard, Goldhaber and Dirac. An essay I wrote at Cambridge for my tutor, Maurice Goldhaber, first stimulated my interest in molecular beams and in the possibility of later doing my Ph. D. research with I. I. Rabi at Columbia.

After receiving from Cambridge my second bachelors degree, I therefore returned to Columbia to do research with Rabi. At the time I arrived Rabi was rather discouraged about the future of molecular beam research, but this discouragement soon vanished when he invented the molecular beam magnetic resonance method which became a potent source for new fundamental discoveries in physics. This invention gave me the unique opportunity to be the first graduate student to work with Rabi and his associates, Zacharias, Kellogg, Millman and Kusch, in the new field of magnetic resonance and to share in the discovery of the deuteron quadrupole moment.

Following the completion of my Columbia thesis, I went to Washington, D. C. as a Carnegie Institution Fellow, where I studied neutron-proton and proton-helium scattering.

In the summer of 1940 I married Elinor Jameson of Brooklyn, New York, and we went to the University of Illinois with the expectation of spending the rest of our lives there, but our stay was short lived. World War II was rampant in Europe and within a few weeks we left for the MIT Radiation Laboratory. During the next two years I headed the group developing radar at 3 cm wavelength and then went to Washington as a radar consultant to the Secretary of War. In 1943 we went to Los Alamos, New Mexico, to. work on the Manhattan Project.

As soon as the war ended I eagerly returned to Columbia University as a professor and research scientist. Rabi and I immediately set out to revive the molecular beam laboratory which had been abandoned during the war. My first graduate student, William Nierenberg, and I measured a number of nuclear magnetic dipole and electric quadrupole moments and Rabi and I started two other students, Nafe and Nelson, on a fundamental experiment to measure accurately the atomic hydrogen hyperfine separation.. During this period Rabi and I also initiated the actions that led to the establishment of the Brookhaven National Laboratory on Long Island, New York, where in 1946 I became the first head of the Physics Department.

In 1947 I moved to Harvard University where I taught for 40 years except for visiting professorships at Middlebury College, Oxford University, Mt. Holyoke College and the University of Virginia. At Harvard I established a molecular beam laboratory with the intent of doing accurate molecular beam magnetic resonance experiments, but I had difficulty in obtaining magnetic fields of the required uniformity. Inspired by this failure, I invented the separated oscillatory field method which permitted us to achieve the desired accuracy with the available magnets. My graduate students and I then used this method to measure in many different molecules a number of molecular and nuclear properties including nuclear spins, nuclear magnetic dipole and electric quadrupole moments, rotational magnetic moments of molecules, spin-rotational interactions, spin-spin interactions, electron distributions in molecules, etc. Although we studied a wide variety of molecules we concentrated on the diatomic molecules of the hydrogen isotopes since these molecules were most suitable for comparing theory and experiment. During this period I also consulted with various groups that were applying the separated oscillatory field method to atomic clocks and I analyzed the precautions which must be taken to avoid errors. Although our original molecular beam research was only with the magnetic resonance method, we later built a separated oscillatory fields electric resonance apparatus and used it to study polar molecules.

In an effort to attain even greater accuracy and to do so with atomic hydrogen, the simplest fundamental atom, Daniel Kleppner, a former student, and I invented the atomic hydrogen maser. We then used it for accurate measurements of the hyperfine separations of atomic hydrogen, deuterium and tritium and for determining the extent to which the hyperfine structure was modified by the application of external electric and magnetic fields. We also participated with Robert Vessot and others in converting a hydrogen maser to a clock of unprecedented stability.

While these experiments were being carried out with some of my graduate students, I worked with other students and associates to apply similar precision methods to beams of polarized neutrons. At the Institut LaueLangevin In Grenoble, France, we measured accurately the magnetic moment of the neutron, set a low limit to the electric dipole moment of the neutron as a test of time reversal symmetry and discovered and measured the parity non-conserving rotations of the spins of neutrons passing through various materials.

Concurrently with my molecular and neutron beam research, I was also teaching and involved with other scientific activities. I was director of the Harvard Cyclotron during its construction and early operation and participated in proton-proton scattering experiments with that cyclotron. I was later chairman of the joint Harvard-MIT committee managing the construction of the 6 Gev Cambridge Electron Accelerator and used that device for various particle physics experiments including electron-proton scattering. For a year and a half I was on leave from Harvard as the first Assistant Secretary General for Science (Science Advisor) in NATO where I initiated the NATO programs for Advanced Study Institutes, Fellowships and Research Grants. For sixteen exciting years I was on leave half time from Harvard as President of Universities Research Association which exercised its management responsibilities for the construction and operation of the Fermilab accelerator through two outstanding laboratory directors, Robert R. Wilson and Leon Lederman.

Although I am primarily an experimental physicist, theoretical physics is my hobby and I have published several theoretical papers including early discussions of parity and time reversal symmetry, the first successful theory of the NMR chemical shifts, theories of nuclear interactions in molecules and the theory of thermodynamics and statistical mechanics at negative absolute temperatures.

I officially retired from Harvard in 1986, but I have remained active in physics. For one year I was a research fellow at the Joint Institute for Laboratory Astrophysics at the University of Colorado and I now periodically revisit JILA as an Adjunct Research Fellow. Subsequent to our year in Colorado, I have been visiting professors at The University of Chicago, Williams College and the University of Michigan. I continue writing and theoretical calculations in my Harvard office and with my collaborators we are continuing our neutron experiments at Grenoble.

After Elinor died in 1983, I married Ellie Welch of Brookline, Massachusetts and we now have a combined family of seven children and six grandchildren. We enjoy downhill and cross country skiing, hiking, bicycling and trekking as well as musical and cultural events.

I have greatly enjoyed my years as a teacher and research physicist and continue to do so. The research collaborations and close friendships with my eighty-four graduate students have given me especially great pleasure. I hope they have learned as much from me as I have from them.

Books:

Experimental Nuclear Physics, with E. Segre, John Wiley and Sons, Inc. (1953), Nuclear Moments, John Wiley and Sons, Inc. (1953), Molecular Beams, Oxford University Press (1956 and 1985) and Quick Calculus, with D. Kleppner, John Wiley and Sons, Inc. (1965 and 1985).

Honorary D. Sc.:

Case-Western Reserve University, Middlebury College, Oxford University, The Rockefeller University, The University of Chicago and The University of Sussex.

Honors:

E. O Lawrence Award, 1960; Trustee Carnegie Endowment for International Peace, 1962 - 86; Davisson-Germer Prize, 1974; Trustee of The Rockefeller University, 1977 - ; President of the American Physical Society, 1978 - 79; Chairman Board of Governors of American Institute of Physics, 1980 - 86; President of United Chapters of Phi Beta Kappa, 1984 - 88; IEEE Medal of Honor, 1984; Rabi Prize, 1985; Rumford Premium, 1985; Chairman Board of Physics and Astronomy of National Research Council, 1985 - 1989; Compton Medal, 1986; Oersted Medal, 1988; National Medal of Science, 1988.

Principal Publications:

1. Magnetic Moments of Proton and Deuteron. Radiofrequency Spectrum of H2 in Magnetic fields. With J. M. B. Kellogg, I. I. Rabi and J. R. Zacharias, Phys. Rev. 56, 728 (1939).

2. Electrical Quadrupole Moment of the Deuteron. Radiofrequency Spectra of HD and D2 Molecules in a Magnetic Field. With J. M. B. Kellogg, I. I. Rabi and J.. R. Zacharias, Phys. Rev. 57, 677 (1940).

3. Rotational Magnetic Moments of H2, D2 and HD molecules. Phys. Rev. 58, 226 (1940).

4. Molecular Beam Resonance Method with Separated Oscillating Fields. Phys. Rev. 78, 695 (1950).

5. Magnetic Shielding of Nuclei in Molecules. Phys. Rev. 78, 699 (1950).

6. On the Possibility of Electric Dipole Moments for Elementary Particles and Nuclei. With E. M. Purcell, Phys. Rev. 78, 807(L) (1950).

7. Nuclear Audiofrequency Spectroscopy by Resonant Heating of the Nuclear Spin System. With R. V. Pound, Phys. Rev. 81, 278(L) (1951).

8. Proton-Proton Scattering at 105 MeV and 75 MeV. With R. W. Brige and U. E. Kruse, Phys. Rev. 83, 274 (1951).

9. Theory of Molecular Hydrogen and Deuterium in Magnetic Fields. Phys. Rev. 85, 60 (1952).

10. Chemical Effects in Nuclear Magnetic Resonance and in Diamagnetic Susceptibility. Phys. Rev. 86, 243 (1952).

11. Nuclear Radiofrequency Spectra of H2 and D2 in High and Low Magnetic Fields. With H. G. Kolsky, T. E. Phipps, and H. B. Silsbee, Phys. Rev. 87, 395 (1952).

12. Nuclear Radiofrequency Spectra of D2 and H2 in Intermediate and Strong Magnetic Fields. With N. J. Harrick, R. G. Barns and P. J. Bray, Phys. Rev. 90, 260 (1953).

13. Electron Coupled Interations between Nuclear Spins in Molecules. Phys. Rev. 91, 303 (1953).

14. Use of Rotating Coordinates in Magnetic Resonance Problems. With I. I. Rabi andJ. Schwinger, Rev. Mod. Phys. 26, 167 (1954).

15. Resonance Transitions Induced by Perturbations at Two or More Different Frequencies. Phys. Rev. 100, 1191 (1955).

16. Thermodynamics and Statistical Mechanics at Negative Absolute Temperatures, Phys. Rev. 103, 20 (1956).

17. Molecular Beams, Published by Oxford University Press, England (1956).

18. Resonance Experiments in Successive Oscillatory Fields. Rev. Sci. Instr. 28, 57(L) (1957).

19. Experimental Limit to the Electric Dipole Moment of the Neutron. With J. H. Smith and E. M. Purcell, Phys. Rev. 108, 120 (1957).

20. Time Reversal, Charge Conjugation, Magnetic Pole Conjugation, and Parity. Phys. Rev. 109, 225 (1958).

21. Molecular Beam Resonances in Oscillatory Fields of Nonuniform Amplitudes and Phases. Phys. Rev. 109, 822 (1958).

22. Radiofrequency Spectra of Hydrogen Deuteride in Strong Magnetic Fields. With W. E. Quinn, J. M. Baker, J. T. LaTourrette, Phys. Rev. 112, 1929 (1958).

23. On the Significance of Potentials in Quantum Theory. With W. H. Furry, Phys. Rev. 118, 623 (1960).

24. Atomic Hydrogen Maser. With H. M. Goldenberg and D. Kleppner, Phys. Rev. Letters 8, 361 (1960).

25. Theory of the Hydrogen Maser. With D. Kleppner and H. M. Goldenberg, Phys. Rev. 126, 603 (1962).

26. Hyperfine Structure of Ground State of Atomic Hydrogen. With S. B. Crampton, and D. Kleppner, Phys. Rev. Letters 11, 338 (1963).

27. Hydrogen Maser Principles and Techniques. With D. Kleppner, H. C. Berg, S. B. Crampton, R. F. C. Vessot, H. E. Peters and J. Vanier, Phys. Rev. 138, A972 (1965).

28. Measurement of Proton Electromagnetic Form Factors at High Momentum Transfer. With K. W. Chen, J. R. Dunning, Jr., A. A. Cone, J. K. Walker and Richard Wilson, Phys. Rev. 141, 1267 (1966).

29. Absolute Value of the Proton g Factor. With T. Myint, D. Kleppner and H. G. Robinson, Phys. Rev. Lett. 17, 405 (1966).

30. Magnetic Resonance Molecular Beam Spectra of Methane. With C. H. Anderson, Phys. Rev. 149, 14 (1966).

31. Hyperfine Separation of Tritium. With B. S. Mathur, S. B. Crampton, and D. Kleppner, Phys. Rev. 158, 14 (1967).

32. Measurement of the Hydrogen-Deuterium Atomic Magnetic Moment Ratio and of the Deuterium Hyperfine Frequency. With D. J. Larson and P. A. Valberg, Phys. Rev. Letters 23, 1369 (1969).

33. Multiple Region Hydrogen Maser with Reduced Wall Shift. With E. E. Uzgiris, Phys. Rev. Al, 429 (1970).

34. Molecular Beam Magnetic Resonance Studies of HD and D2. With R. F. Code, Phys. Rev. A4, 1945 (1971).

35. Atomic Deuterium Maser With D. J. Wineland, Phys. Rev. A5, 821 (1972).

36. The Molecular Zeeman and Hyperfine Spectra of LiH and LiD by Molecular Beam High Resolution Electric Resonance. With Richard R. Freeman, Abram R. Jacobson, and David W. Johnson, J. of Chem. Physics 63, 2597 (1975).

37. The Tensor Force Between Two Protons at Long Range, Physica 96A, 285 (1979)

38. Measurement of the Neutron Magnetic Moment. With G. L. Green, W. Mampe, J. M. Pendelbury, K. Smith, W. B. Dress, P. D. Miller and P. Perrin, Phys. Rev. D20, 2139 (1979).

39. First Measurement of Parity-Nonconserving Neutron Spin Rotation: The Tin Isotopes. With M. Forte, B. R. Heckel K. Green, and G. L. Greene, Phys. Rev. Lett. 45, 2088 (1980).

40. Search for P and T Violations in the Hyperfine Structure of Thallium Fluoride. With D. A. Wilkening and D. J. Larson, Phys. Rev. A29, 425 (1984).

41. Search for a Neutron Electric Dipole Moment. With J. M. Pendlebury, et al., Phys. Letters 136B, 327 (1984).

42. Neutron Magnetic Resonance Experiments. Physica 137B, 223 (1986).

43. Quantum Mechanics and Precision Measurements, IEEE Transactions on Instrumentation and Measurement IM36, 155 (1987).

44. Precise Measurements of Time. American Scientist 76, 42 (1988).

45. The Electric Dipole Moment of the Neutron. Physical Scripta T22, 40 (1988).