

Tributes to Hans Bethe continue

The October 2005 special issue of PHYSICS TODAY describes the breadth of Hans Bethe's accomplishments and interests in different fields of physics. Here are two additional contributions of his that illustrate his ability to produce new advances in areas outside those for which he was most famous.

In 1929 Bethe employed group theory to examine how the crystalline field would split the energy levels of free ions and determined the symmetry required to fully quench the orbital moment.¹ This area became an active research field only after World War II, with the development of electron paramagnetic resonance and spin Hamiltonians.

Richard Garwin and Kurt Gottfried (PHYSICS TODAY, October 2005, page 52) mention that Bethe invented his hole coupler between two waveguides and developed his "exhaustive theory" of the coupler while at the MIT Radiation Laboratory. A second significant contribution to microwaves and electromagnetic theory by Bethe and Julian Schwinger employed Maxwell's equations in calculating the fractional frequency shift $\Delta f/f$ when a sample is inserted in a resonant cavity. The fractional frequency shift provides a direct connection to the tensor electric permittivity and the tensor magnetic permeability of the sample. Two reports exist about this work.^{2,3} However, the derivation is given by Walter Hauser,⁴ who terms the expression for the fractional frequency shift the Bethe-Schwinger cavity perturbation formula.

This fundamental expression, although known to some microwave experts, is not mentioned in the best-known electricity and magnetism texts. It is also not mentioned in the MIT Ra-

diation Laboratory series that appeared shortly after World War II. John Slater's postwar text⁵ mentions the 1943 MIT report² but doesn't give the Bethe-Schwinger formula. I was unaware of this expression until the early 1990s, even though I'd learned microwave techniques in the 1950s. Why wasn't this result published in an American physics journal? The report dates may provide a clue: Bethe was already at Los Alamos in early 1943.

References

1. H. A. Bethe, *Ann. Phys. (Leipzig)* **3**, 133 (1929).
2. J. Schwinger, MIT Radiation Laboratory rep. no. 43-34, MIT, Cambridge, MA (21 May 1943).
3. H. A. Bethe, J. Schwinger, National Defense Research Council rep. no. D1-117, Cornell U., Ithaca, NY (1943).
4. W. Hauser, *Introduction to the Principles of Electromagnetism*, Addison-Wesley, Reading, MA (1971), p. 511.
5. J. C. Slater, *Microwave Electronics*, Van Nostrand, New York (1950), p. 131.

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Kurt Gottfried wrote, "For almost seven decades, [Hans Bethe's] wife Rose was his constant companion and closest adviser" (PHYSICS TODAY, October 2005, page 36). Sam Schweber (page 38) explained that Bethe's 1928 thesis on electron diffraction in crystals built on previous work by Paul Ewald on the diffraction of x rays by crystals. The two statements are intimately connected.

In his 1981 "Reminiscences of the Early Days of Electron Diffraction," Bethe wrote the following:

On the basis of my thesis, I was invited by P. P. Ewald to give a talk at a small conference on diffraction which he was arranging in Stuttgart in 1928. Apparently my talk pleased him, because a year later he asked me to become his assistant. I had a most enjoyable semester there, with a great deal of research, and close personal contact with Ewald and his family. Out of this I got a wife: Ewald's

daughter, then 12 years old, was already very attractive, but I did not dream of marrying her. Eight years later, I met her again, and in 1939 we got married. So I owe a great deal to electron diffraction.¹

Arnold Sommerfeld had proposed that Bethe make a detailed theory of electron diffraction in a crystal. He recommended as a model the theory by Ewald of the diffraction of x rays, written in 1917. Bethe found that electron diffraction was a great deal simpler. In the x-ray case one has to contend with a vector field. He retained only Ewald's fundamental idea, the expansion of a spherical wave—that is, the wave scattered by an atom—in terms of plane waves. Thence Bethe developed the theory of electron diffraction in first-order perturbation theory.

Reference

1. H. A. Bethe, in *Fifty Years of Electron Diffraction*, P. Goodman, ed., Reidel, Dordrecht, Netherlands (1981), p. 73.

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I very much enjoyed the special issue on Hans Bethe, one of the greatest physicists of our time. However, I was a little disappointed that save for a single sentence on page 36 almost no mention is made of Bethe the teacher. The American Association of Physics Teachers recognized him as a "teacher of teachers as well as students." I had the honor of presenting him with AAPT's 1993 Oersted Medal, which recognizes outstanding contributions to the teaching of physics. Bethe remarked to me that he cherished that medal as much as any he had received. I believe only Bethe and Richard Feynman have received both the Oersted Medal and the Nobel Prize in Physics. Bethe's address as part of the Oersted Award was published in 1993 in the *American Journal of Physics*, volume 61, page 971.

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The special issue celebrating the life of Hans Bethe admirably described his

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