letters

More variations on Aharonov–Bohm

Having read "The Aharonov–Bohm Effects: Variations on a Subtle Theme" by Herman Batelaan and Akira Tonomura (PHYSICS TODAY, September 2009, page 38), we note with some dismay that the principal effect, that related to magnetic flux, continues to be attributed to its re-discoverers rather than to the original discoverers. Batelaan and Tonomura write, "The AB effect was already implicit in the 1926 Schrödinger equation, but it would be another three decades before theorists Yakir Aharonov and David Bohm pointed it out."[1] That is incorrect: It took only two decades before the effect was pointed out, not by Aharonov and Bohm but by Werner Ehrenberg and Raymond "Rory" Siday.[2] Aharonov and Bohm cited that prior publication in their second article.[3]

According to Bohm's biographer F. David Peat, "After their first paper had been published, Bohm learned that the effect had already been postulated by a maverick physicist called Rory E. Siday."[4] It seems curious that the biographer should use the term "postulated" rather than "proposed" and that he should comment on Siday's personality but not on Ehrenberg's. One of us (Sturrock) knew them both: Raymond was very smart but somewhat brash; Werner was erudite and a model of propriety, who would never have subscribed his name to an article unless he was convinced it was correct.

It seems that the main scientific, rather than sociological, reason that the AB proposal was taken more seriously than the ES proposal is that the former was presented in the context of quantum mechanics, the latter in the context of electron optics. Aharonov and Bohm made a rapid transition from quantum mechanics to wave theory. Ehrenberg and Siday made a more detailed transition from geometrical optics to wave theory. For the case of magnetic flux, the two articles presented identical theoretical predictions. Our view is that the ES article was tedious but conceptually sound, whereas the AB article was lively but involved a questionable conceptual leap—namely, a relativistic generalization based on a noncovariant analysis.

Soon after Sturrock arrived at Stanford University in 1955, and before the Aharonov–Bohm publication, he asked Leonard Schiff, Stanford's quantum mechanics expert, whether Schiff found the Ehrenberg–Siday proposal convincing. He did.

In the interests of accuracy and of giving credit where credit is due, we think it would be appropriate to use "Ehrenberg–Siday effect" for the case of magnetic interference and to reserve "Aharonov–Bohm effect" for electrical interference.

We are indebted to Elliott Bloom, Dieter Kern, Walt Harrison, Peter Hawkes, Garret Moddel, Fabian Pease, Jeff Scargle, and Lenny Susskind for helpful discussions on this matter.

References

1. Y. Aharonov, D. Bohm, *Phys. Rev.* **115**, 485 (1959).
2. W. Ehrenberg, R. E. Siday, *Proc. Phys. Soc. B* **62**, 8 (1949).
3. Y. Aharonov, D. Bohm, *Phys. Rev.* **123**, 1511 (1961).
4. F. D. Peat, *Infinite Potential: The Life and Times of David Bohm*, Addison-Wesley, Reading, MA (1997), p. 192.

Peter A. Sturrock
(sturrock@stanford.edu)
Stanford University
Stanford, California

Timothy R. Groves
(tgroves@uamail.albany.edu)
University at Albany
Albany, New York

The article about Aharonov–Bohm effects is interesting and comprehensive. The primary and best-known effect shows that the vector potential **A** of the electromagnetic field is a physical reality rather than a mathematical artifice. That reality was implicit in the Schrödinger equation, as the Hamiltonian H depends on **A** instead of the electric field **E** and magnetic field $\mathbf{B} = \nabla \times \mathbf{A}$. But the same statement also refers to the Hamilton–Jacobi equation in classical mechanics, so one may expect that a similar effect exists in classical physics as well.

Indeed, classical mechanics is governed by the fundamental Hamilton–Jacobi equation for the action S: $\partial S/\partial t + H = 0$, which naturally follows from William Hamilton's principle of least action. Both H and S depend on **A** (even with $\mathbf{E} = \mathbf{B} = 0$). Thus it is quite possible that the vector potential is also a physical reality in classical physics. Erwin Schrödinger arrived at his famous equation in 1926 by using a mechanics–optics analogy, the so-called eikonal equation. Hamilton in 1834 proved that eikonal and Hamilton–Jacobi equations are equivalent, so that the Schrödinger equation actually follows from Hamilton–Jacobi.

Had Hamilton known that classical mechanics does not always hold, quantum mechanics might have appeared a century earlier.[1] The analogy between the equations of classical and quantum mechanics provides a reason to search for experiments that might prove whether a classical analogue of the Aharonov–Bohm effect exists.

Reference

1. H. Goldstein, C. Poole, J. Safko, *Classical Mechanics*, 2nd ed., Addison-Wesley, Reading, MA (1980), p. 484.

Alexander Ershkovich
(alexer@post.tau.ac.il)
Tel Aviv University
Tel Aviv, Israel

The article by Herman Batelaan and Akira Tonomura on the Aharonov–Bohm effect brought back memories of a conference I attended at the University of South Carolina in 1989 commemorating both the 30th anniversary of the Aharonov–Bohm paper and the 5th anniversary of the 1984 paper by Michael

Letters and opinions are encouraged and should be sent by e-mail to ptletters@aip.org (using your surname as "Subject"), or by standard mail to Letters, PHYSICS TODAY, American Center for Physics, One Physics Ellipse, College Park, MD 20740-3842. Please include your name, affiliation, mailing address, e-mail address, and daytime phone number on your attachment or letter. You can also contact us online at http://www.physicstoday.org/pt/contactus.jsp. We reserve the right to edit submissions.