AIP
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Revisiting the electric potential

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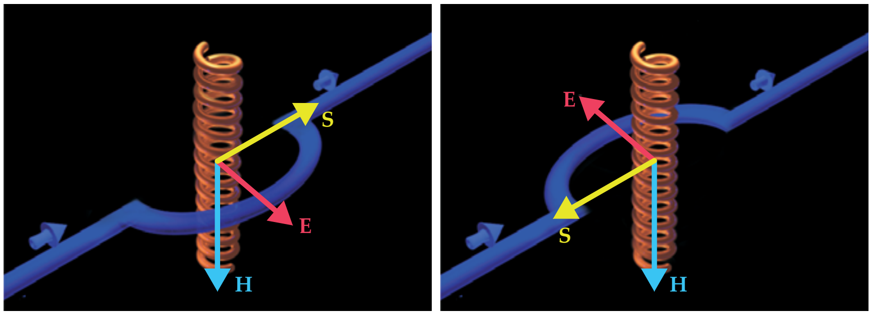

Revisiting the electric potential

In the Quick Study by Eve Vavagiakis, Thomas Bachlechner, and Matthew Kleban (Physics Today, August 2021, page 62), the authors' claim about the ontology of the electromagnetic vector fields seems too simple. As indicated in the figure above (adapted from the authors'), an electron taking either of the paths around the solenoid has an electric field **E** extending into the solenoid, where there is a nonzero magnetic field **H**. For a short time, the electron creates a Poynting vector **S** carrying momentum. That momentum has to be taken away from the initial momenta and thus affects the phase difference between the paths. That quantum mechanical phenomenon, called the magnetic Aharonov–Bohm effect, depends on only the magnetic flux. The obtained phase change does not depend on the distance to the solenoid. Its size is easy to calculate for an infinite solenoid.

Usually, a properly renormalized electron can be thought of in quantum mechanics without considering the constantly emitted and absorbed photons building up the electric field. But for an electron passing around a solenoid, there is an exception, as noted by Lev Vaidman.[1]

The electrostatic version nicely described by J. J. Sakurai and Jim Napolitano is more straightforward.[2] At some point, the electrostatic potential has to be switched on, which, independent of the geometric details, has to involve an electric field. That electric field crosses the particle path and takes away or adds momentum, resulting in the observed phase difference between both paths.

References

1. L. Vaidman, *Phys. Rev. A* **86**, 040101(R) (2012).
2. J. J. Sakurai, J. Napolitano, *Modern Quantum Mechanics*, 2nd ed., Addison-Wesley (2011).

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▶Vavagiakis, Bachlechner, and Kleban reply: Fritz Bopp correctly points out that creating a potential difference necessitates a nonzero electric field. He goes on to assert that the field must cross the particles' paths, differentially accelerating them. If that were the case, the difference in phase could indeed be explained by the interaction of the particles with the electric field. As we describe in our Quick Study, however, the field could be switched on for a while and then off again while the particles are deep inside two long, tubular Faraday cages. Those cages shield the particles from contact with the nonzero field, yet while the field is on, there is a potential difference between the interiors of the two cages. That potential difference is therefore responsible for the difference in phase.

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Correction

July 2022, page 5—The last sentence of the "On the cover" description should read "the world's largest cryogenic particle detector." PT