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On the voltage measurements in the presence of varying magnetic fields

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The electromagnetic field behavior is described by the set of Maxwell equations relating the electric and magnetic fields, charge density and current density. The electric and magnetic fields E and B can be written in terms of scalar and vector potentials.

Faraday's law of induction is fundamental to understanding how electric and magnetic fields interact. Time-varying magnetic field give rise to electric field, the induced electric field, which is different from the electrostatic field. The electrostatic field is a conservative field with zero curls and a given divergence, while an induced electric field is a vector field with nonzero curl and zero divergences. The induced electric field is non-conservative and is described by vector potential.

In this work we discuss on didactic aspect of Faraday's law and the induced electric field. We consider the following example: a time-dependent current flowing in an ideal solenoid produces a varying magnetic field. If a wire loop surrounds the solenoid, there is an induced current through the loop. Electric charges move in response to electric fields, which means that an induced electric field is associated with a changing magnetic field. Experiments show that the changing magnetic field is confined inside the solenoid and vanishes outside. How can an induced electric field exist at positions where the magnetic field is zero? What is induced emf? Does induced emf produce any potential difference? What does the voltmeter measure in the presence of varying magnetic fields? Discussions around these issues are presented here.

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