Generalization of Faraday's law of induction: some examples

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Abstract

A general form of the induced electromotive force due to time-varying magnetic field is derived. It is shown that the integral form of Faraday's law of induction is more conveniently written in the covering space. The method used in this work relies of finding the modified magnetic field each time the circular path is traversed. This amounts to an additional time derivative of the magnetic field. Therefore, the induced electromotive force comes from the sum of all contributions coming from all winding numbers. Thus the differential form is shown to relate the induced electric field in the n^{th} winding number to the $(n+1)^{th}$ time- derivative of the magnetic field. It is also shown that the higher order terms are modulated by the self-inductance and resistance of the circuit. Some illustrative examples for time-dependent magnetic fields are presented: Sinusoidal, exponential, and step-function fields. In each of these examples, it is shown that the induced electromotive force could be written in closed analytical form that depends (among other things) on the ratio between the self-inductance and resistance of the circuit. Furthermore, in all these examples it is demonstrated that our result for the induced electromotive reduces to the well-known result in the limit of the ratio of the self-inductance and resistance goes to zero. The conclusion of this work shows that Maxwell's equation of Faraday's law of induction can be written in a more general form in the physical space.