Further investigation on Faraday’s law of induction

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Abstract

In this paper, Faraday’s law of induction was further investigated. The purpose is to see that besides there is the change of magnetic flux through the region enclosed by a conductor loop, if the magnetic flus change inside the wire of the loop is also required to generate an induction current in the conductor loop. An experiment is design and performed. The result shows that it is also a necessary condition that there is magnetic flux change inside the wire of the loop to generate an induction current in the conductor loop.

Key words: Faraday’s law of induction; electromagnetic induction.

Introduction

Faraday's law of induction is a basic law of electromagnetism. The law states that the electromotive force (EMF) around a closed path is equal to the negative of the time rate of change of magnetic flux enclosed by the path. The magnetic flux is that flux which passes through any and every surface whose perimeter is the closed path. [1, 2, 3] As this law, whichever ways there is variation through the surface of the wire loop, an EMF will be generated within the loop. If it is a conductor loop, an electric current will be generated within the loop. The Electromagnetic induction law was discovered by Michael Faraday in 1831. It was later generalized to become the Maxwell-Faraday equation, one of the four Maxwell’s equations in Maxwell’s theory of electromagnetism.[4]

The law does not clarify if the region of the wire loop, where the change of magnetic flux happens, includes the wire loop itself. That is, if there is variation of magnetic flux inside the wire of the loop. If there is only the change of magnetic flux through the region enclosed by a conductor loop, but the loop itself is not placed within the changing magnetic field, will an induction current still be generated in the loop, or not? In order to answer this question, an experiment is designed and performed in this paper. In this experimental design, there is magnetic flux change through the region enclosed by a conductor loop, but the loop itself is not placed within the changing magnetic field. That is, there is no variation of magnetic flux inside the wire of the loop. According to the result of the experiment, if the loop itself is not placed within the changing magnetic field, there will be no induction current generated in the conductor loop even if there is the change of magnetic flux through the region enclosed by the loop.

Experiments

Two parallel experiments are performed here. In experiment 1, a magnetic source is placed in the middle of a conductor loop, as shown in figure 1. The magnetic source is a solenoid which is connected to a DC power supply. As the electric current within the solenoid varies, the change of magnetic flux through the region enclosed by the loop happens, so an induction electric current is generated within the loop. In experiment 2, the solenoid is still placed in the middle of the conductor loop, but the solenoid is covered with a hollow column made of magnetic shielding material. The magnetic field of the solenoid is effectively shielded by the hollow column, so the magnetic field of the solenoid cannot reach the conductor loop itself. In experiment 2, if the induction current is not generated within the conductor loop or the current is distinctly smaller than that in the experiment 1, it will indicate that if the conductor loop itself is not placed within the changing magnetic field (or no changing magnetic flux inside the wire of the loop), an induction electric current cannot be generated within the loop, even if there is the change of magnetic flux through the region enclosed by the loop.

In the experimental design, the solenoid and conductor loop are made of copper wire. The hollow column is made of multi layers of permalloy sheet.

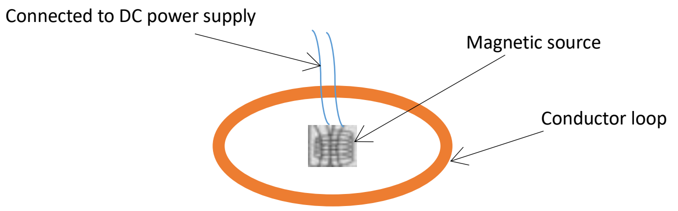

Fig.1. A magnetic source is located in the middle of a conductor loop

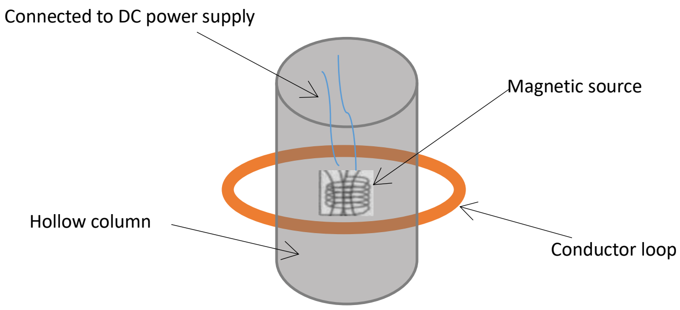

Fig.2. A magnetic source is located in the middle of a conductor loop. The magnetic Source is surrounded by a hollow column made of magnetic shielding material

Results and discussion

During the experiments, we rapidly rotate the current adjusting knob of the DC power supply making the electric current in the wire of the solenoid change from 0 to 10 A. In experiment 1, an average 3.0 μA induction current is observed in the conductor loop. However in experiment 2, almost no induction current (less than 0.2 μA) is observed in the conductor loop. We know that the magnetic field of the solenoid is effectively shielded by the hollow column and make it cannot reach the wire of the loop. Thus, the conductor loop itself is not in the changing magnetic field of the solenoid. This means that there is no magnetic flux change inside the wire of the loop.

The experimental results indicate: if there is no the change of magnetic flux inside the wire of the loop, an induction current will not be generated in the loop even if there is the change of magnetic flux through the region enclosed by the loop. Thus, to generate an induction current in a conductor loop, not only a changing magnetic flux through the region enclosed by the loop is needed, but also the changing magnetic flux inside the wire of the loop is required as well. So, the Faraday's law of induction needs revising. Another necessary condition (i.e. changing magnetic flux inside the wire of the loop) is required in order to generate an induction current in a conductor loop.

Conclusion

The experiment result shows that two necessary conditions are required to generate an induction current in a conductor loop: (1) there is magnetic flux change through the region enclosed by the loop; (2) there is the changing of magnetic flux going through the wire of the loop, i.e., $\frac{\partial B}{\partial t} \neq 0$ inside the wire of the loop.

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