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Department of Physics

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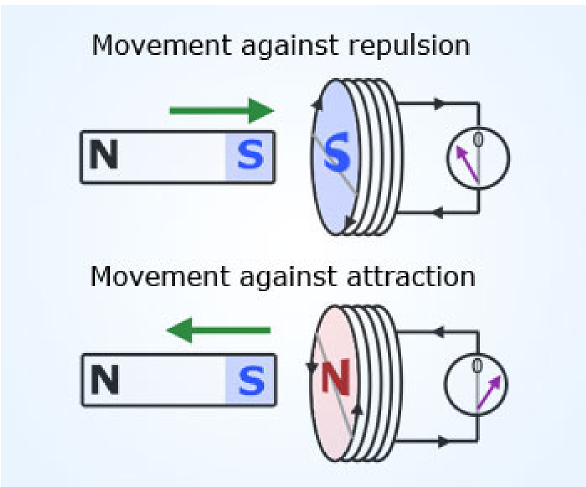
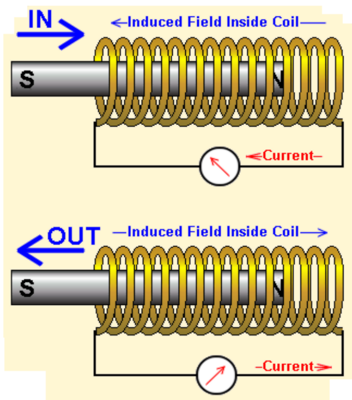
FARADAY'S LAWS OF ELECTROMAGNETIC INDUCTION

(విద్యుదయస్కాంత ప్రేరణా ఫారడే నియమములు)

Some basic points:

Oersted proved that there will be magnetic field around a current carrying conductor. Faraday discovered that whenever magnetic lines of force are cut by a closed circuit are changing, an induced current flows in the circuit. If there is no change in the magnetic field, there is no current as shown in the following figure. The induced current gives rise to electromotive force which is said to be induced electromotive force. This phenomenon is called as 'electromagnetic induction.





Similarly, when a primary coil is connected at battery and the secondary coil is connected to a galvanometer, the Galvanometer shows deflection when the current in the primary coil changes. Further, it observed that the deflection is not observed as long as there is steady current in the primary circuit. This gives evidence for changing current produces changing magnetic field which leads to the production of induced e.m.f.

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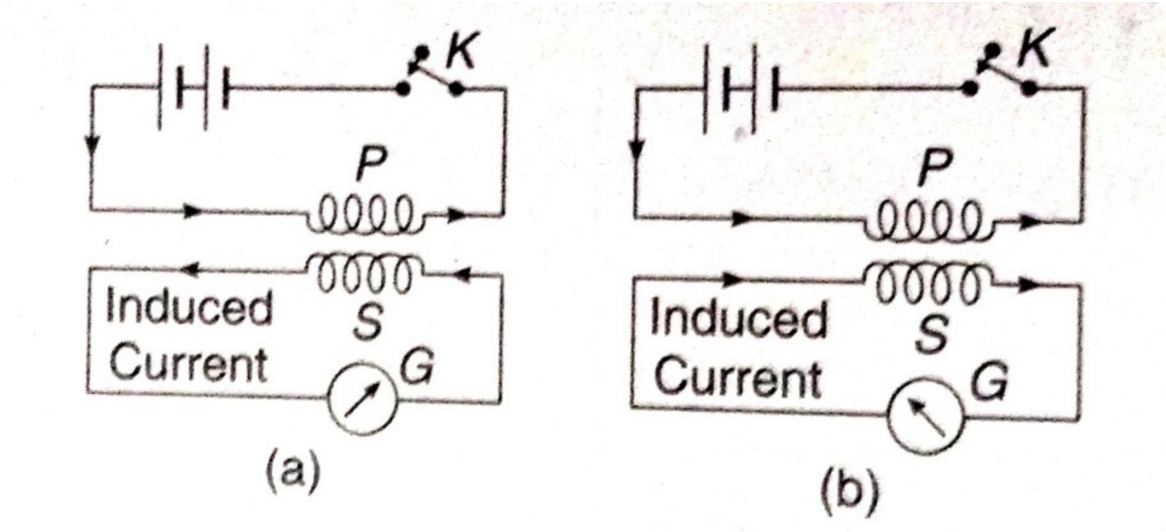

Faraday's laws of electromagnetic induction

There are two laws of electromagnetic induction:

1. Whenever the magnetic flux linked with a circuit is changed, an e.m.f. is induced in the circuit
2. The magnitude of induced e.m.f. is directly proportional to the negative rate of variation of magnetic flux linked with the circuit. Let Φ_B the magnetic flux linked with a circuit at any instant and 'e' be the induced e.m.f., , then

   $e = -\left(\frac{d\Phi_B}{dt}\right), if\ there\ are\ N\ turns\ in\ the\ coil, e = -N\left(\frac{d\Phi_B}{dt}\right)$ ------(1)

   It is also known as Neumann's law.

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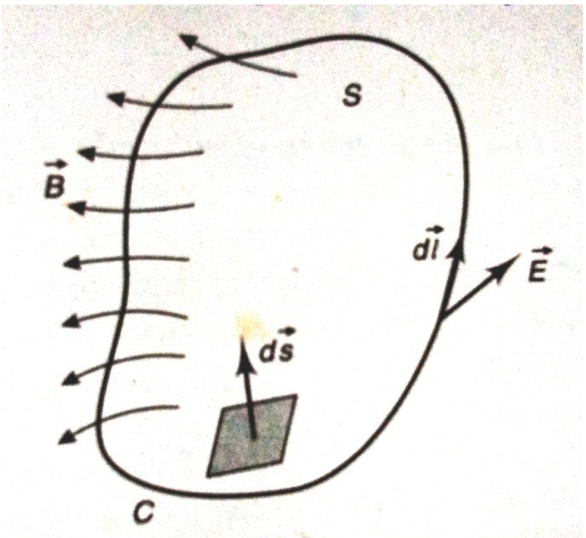
Vector from of Faraday's law (Integral and differential forms)

(ఫారడే నియమముల సదిశా రూపములు(సంకలన మరియు అవకలన రూపములు}



Consider, a magnetic field is produced by a stationary magnet or a current carrying coil as shown in the adjacent figure. Further, consider a closed circuit of area 'A' of any shape in the magnetic field. Let 'B' be the magnetic flux density near the circuit. The flux through the small area dS will be B.dS.

Now, the flux through the entire circuit is given by

$\Phi_B = \iint B.dS$ ------(2)

When magnetic flux changes, an induced electric field is developed around the circuit. The line integral of electric field gives amount of induced e.m.f. in the closed circuit. Thus,

$e = \oint E.dl$ ------(3)

Here, E is the electric field at an element 'dl' of the circuit. Substituting the values of 'e' and Φ_B from equations (2) & (3), in equation (1) one can get

$\oint E.dl = -\frac{d}{dt}\iint B.dS$ -------(4)

This is the integral form of Faraday's law

Therefore, the line integral of electric field around any closed circuit is equal to the negative rate of change of magnetic flux through the circuit.

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From Stoke's theorem, $\oint E.dl = \iint(\nabla \times E).dS$ ------(5)

From equations (4), (5)

$\iint(\nabla \times E).dS = -\frac{d}{dt}\iint B.dS \Rightarrow \iint(\nabla \times E).dS = -\iint \frac{\partial B}{\partial t}.dS$

Therefore, $(\nabla \times E) = -\frac{\partial B}{\partial t}$, This is differential form of Faraday's law.

LENZ'S LAW (లెంజ్ నియమము)

According to this law, the direction of induced e.m.f. or current in a closed circuit is such that it oppose the original cause that produces it.

It is based on the law of conservation of energy. When the applied flux density 'B' in a closed circuit increases, an e.m.f. or a current is induced in the closed circuit in such a direction to oppose a field which tends decrease 'B'. similarly, when the field decreases, an e.m.f. or current is induced in the closed circuit in such a direction to oppose a field which tends to increase 'B'. Therefore , the circuit produces flux which tends to oppose the original cause i.e., it tries to keep the flux constant in the circuit.

As shown in the following figure, if a north pole of a magnet is moved towards coil connected to a galvanometer, an induced e.m.f. is set up in the coil.

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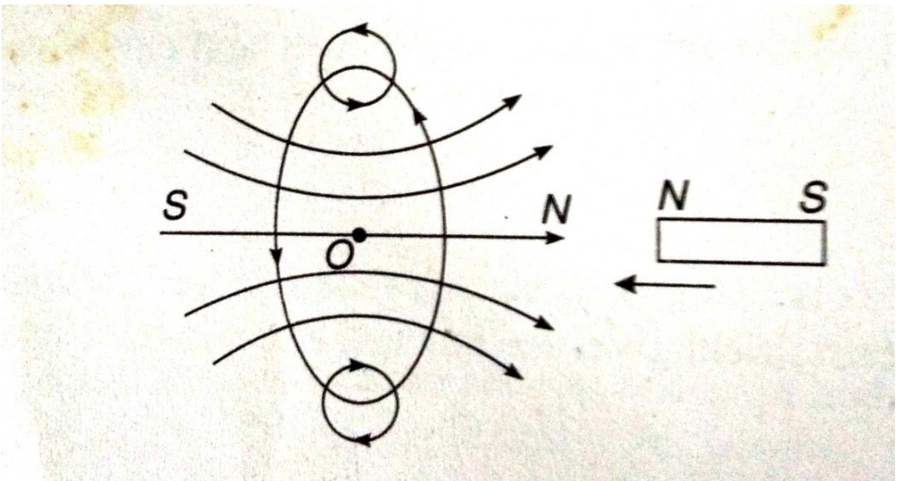

The induced current produces it own magnetic field. As a result, the coil itself behaves as a magnet. Therefore, there will be a force of repulsion. Due to this repulsion, the motion of the magnet is opposed which causes change in the magnetic flux of the coil.

Thus, the direction of induced e.m.f. is such that it opposes the original cause that produces it.

Model Questions(మాదిరి ప్రశ్నలు)

1. Write a short note on electromagnetic induction
2. What is electromagnetic induction? State Faraday's law of electromagnetic induction.
3. State and explain Lenz's law of electromagnetic induction.
4. Explain the term e.m.f.
5. What is meant by electromagnetic induction and derive an expression for induced e.m.f?

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6. State Faraday's law of electromagnetic induction. Derive the integral and differential forms of Faraday's law.

References:

1. Unified Physics, Volume III, Jai Prakash Nath Publications, Meerut

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