

# Physics of Inducing of Electric Current

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**Abstract.** This article reveals the physical phenomena which occur in the process of inducing electric current in a conductor located in variable magnetic field and in a conductor moving across a magnetic field .

## 1 Induced Electric Current in a Conductor Located in a Variable Magnetic Field.

Free electrons are distributed uniformly over the conductor where they either oscillate or slowly move in it between the nuclei in various directions depending on the action of nuclear and magnetic fields, as well as their collisions with each other. If the length of a conductor is considerably greater than its diameter, free electron move mostly along and not across the conductor, since in the latter case, having reached the conductor's surface, electrons are pushed back by the surface nuclear field.

If a conductor is located in a magnetic field, then free electrons will be subjected to the action of the Lorentz force in different directions with different strength depending on the direction of electrons' motion with respect to the direction of magnetic force lines. In electrons whose axis of rotation cross these lines at a significant angle, the Lorentz force is formed which pushes these electrons in direction of a circle perpendicularly to the magnetic field, thus forming their circular motion in a direction perpendicular to the axis of electrons' rotation, as is shown in Fig. ???. In electrons whose axis of rotation pass along the lines of the magnetic field the Lorentz force is not formed.

If the magnetic field is directed across a long and thin enough conductor, then electrons engaged in circular motion under the action of the Lorentz force collide with nuclei lying in the surface layer of the conductor. These electrons remain pressed to the conductor's surface, since they cannot leave outside due to the counteraction of the surface nuclear field. Since in a long

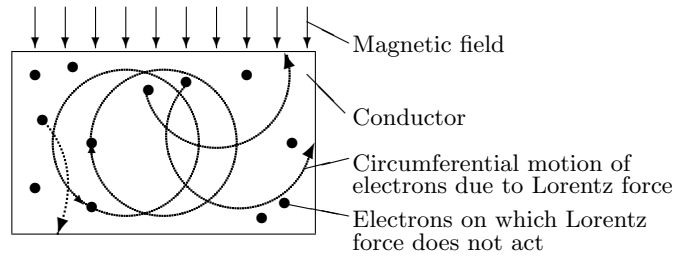


Figure 1: Action of Lorentz force on electrons

conductor free electrons move mostly in two directions along the conductor, then under the action of the magnetic field in the transversal direction part of these electrons will be pushed back towards the conductor's surface under the influence of the Lorentz force in one direction, while another part of electrons will be pushed back in the opposite direction depending on the prior direction of electrons' motion along the conductor. The electrons that were pushed back towards the two opposite surfaces of the conductor have aligned axes of rotation and opposite direction of rotation with respect to the direction of the magnetic field, as is shown in Fig. ??.

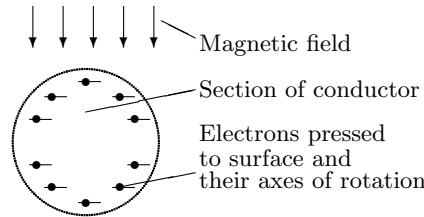


Figure 2: Action of Lorentz force on electrons

The magnetic field acts not only on free electrons inside of a conductor, but also on electrons, which located nearby the surface, where the magnetic field acts from the outside. Herewith the electrons will move circularly along of the conductor to the opposite surface of the conductor. If to change the direction of action of the magnetic field on opposite, then the magnetic field will act on these electrons, moving them in an opposite direction along the conductor. The motion of electrons under the action of the Lorentz force occurs only in that part of the conductor which is located in the magnetic field. The electrons which move under action of a magnetic field, push others

free electrons. At periodic change of a direction of a magnetic field *variable electric current* is formed.

If the dimensions of the conductor greatly exceed the diameter of the circular motion of electrons on which acts the Lorentz force, then the circular motion of an electron may continue until the electron approaches the surface of the conductor's surface. Circular motions of electrons in a conductor having a large mass located in a magnetic field are called *Foucault currents*. does not act. Due to frequent collisions of electrons subjected to the action of the Lorentz force with the nuclei, the conducting body warms up.

## 2 Induced Electric Current in a Conductor Moving Across a Magnetic Field

In a conductor moving at a sufficiently high speed, free electrons are being pushed by the nuclei of atoms along the direction of motion of the conductor; as a result, the electrons not only move along the direction of motion of the conductor, but overtake them, since the mobility of electrons is higher than the mobility of the nuclei of atoms. Due to the fact that free electrons are predominantly moving in the direction of motion of the conductor, the axis of rotation of free electrons turn and stabilize in the same direction.

If a conductor is in transversal motion, that is, is moving transversally its length and not along its length, and if the conductor moves in the magnetic field across the direction of the field as is shown in Fig. ??, then the axis of rotation of electrons are perpendicular to the direction of the magnetic field and perpendicular to the conductor.

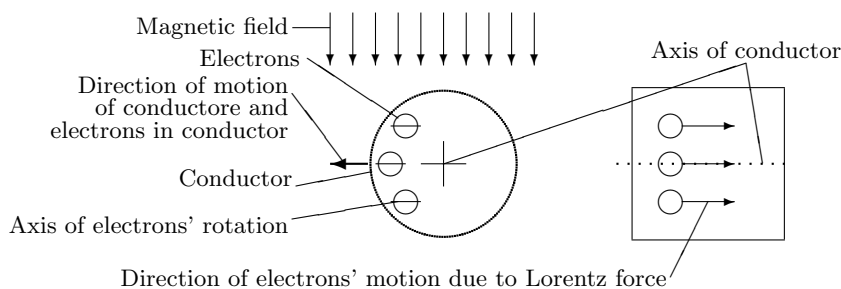


Figure 3: Induced current in moving conductor

If the cross-section of the conductor is sufficiently small, the under the

action of the magnetic field on the rotating electrons whose axes of rotation are perpendicular to the conductor, then the Lorentz force acts on these electrons; due to this, the electrons move according to the left-hand rule, forming electric current. The electric current formed in a conductor moving across the magnetic field is called *induced current*, as is the current formed in a conductor located in a variable magnetic field.

### 3 Action of Magnetic Field on Conductor (Ampere Force)

If a current-carrying conductor in a magnetic field is perpendicular to the force line of this field (see Fig. ??), then the axes of rotation of the current electrons are also perpendicular to the force lines; due to this the Lorentz force acts on the electrons which makes them move along a circumference. In it the electrons move in the direction that can be determined according to the left-hand rule. The direction of motion of the electrons is perpendicular to the direction of the current in the conductor.

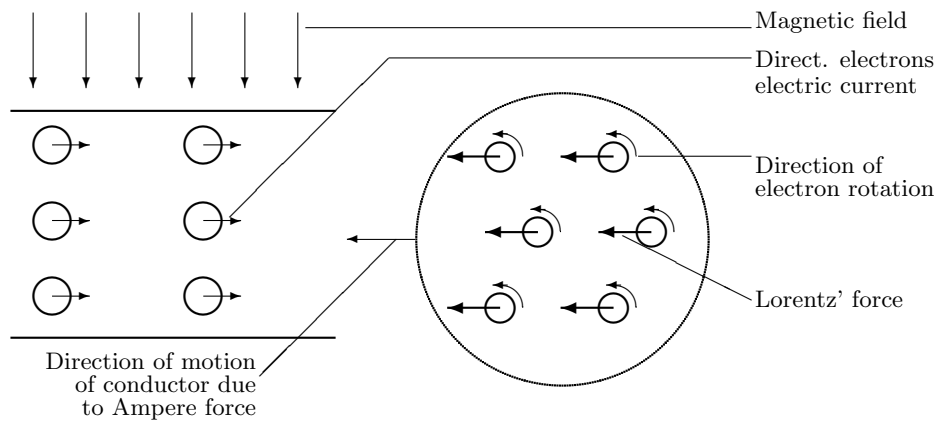


Figure 4: Action of Ampere force

The current electrons displaced by the Lorentz force towards one side of the conductor's cross-section collide with the nuclei of the conductor and push them in the same direction. Since the nuclei cannot move within the conductor, the latter moves as a whole in the direction of action of the

Lorentz force. The action of a magnetic field on a current-carrying conductor ] due to the action of the field on the current electrons and through them on the nuclei is called the *Ampere force* which is defined by the left-hand rule, as the Lorentz force.

## Conclusions

1. If conductor has small diameter and located in changing magnetic field, then on free electrons, which have axis of rotation are perpendicular to lines of the magnetic field, Lorentz's force acts, due to that these electrons are pushed to the surface of the conductor from two sides. Axis of rotation of the electrons are perpendicular to the direction of the magnetic field, but the magnetic field acts only on electrons which are located on a surface, where the magnetic field enter. So is forming short-term an electric current to one side.

2. If the conductor moves across a magnetic field, then the free electrons move faster than the conductor, turn their axis of rotations in the direction of the magnetic field and are located near the surface of the conductor, whence under action of force of Lorentz, the electrons move only to one side along the conductor, forming electric charge which extends on all length of the conductor, forming an electric current.

3. Inducing of electric current under the action of magnetic field can occur only in a sufficiently thin conductor, since in conductors with large cross-sections most of electrons are in circumferential motion and do not move along the conductor.