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# Hall effect as one of the methods for studying the properties of a solid

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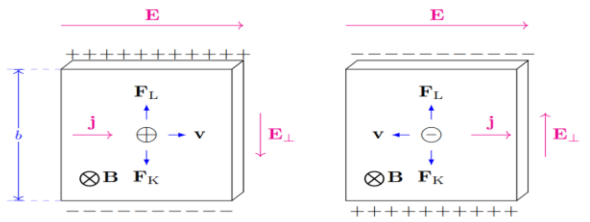
**Abstract:** The article describes the scientific, pedagogical and methodological aspects of studying the Hall effect, the essence of the conduction processes in semiconductors, the boundaries between semiconductors and other types of weakly conducting materials, and also shows its practical significance in the creation of a number of devices including devices with valuable, unique properties that have an important role in automation, radio, measuring and computer technology.

**Keywords**: Hall effect, kinetic and galvanomagnetic phenomena, electron, drift, Lorentz force, potential difference, Hall field, Hall mobility, concentration and sign of charge carriers, anomalous Hall effect, quantum Hall effect, spin Hall effect, devices created Hall effect based Hall sensors.

## Introduction

The study of the scientific, educational and methodological foundations of the Hall effect is of interest not only from the point of view of kinetic and galvanomagnetic phenomena, but also from its practical application. The Hall effect is the phenomenon of a transverse potential difference (also called Hall voltage) when a direct current conductor is placed in a magnetic field. It was discovered by the American physicist Edwin Hall in 1879 in thin plates of gold [1-3].

From Lorenz to Hall. The Hall effect is an extension of the Lorentz force, which describes the force acting on charged particles - such as an electron - moving in a magnetic field. If the magnetic field is directed perpendicular to the direction of motion of the electrons, a force acts on the electron that is perpendicular to both the direction of motion and the direction of the magnetic field.




Due to the action of the Lorentz force, the transverse magnetic field deflects the charge carriers in the direction perpendicular to the drift. After the imposition of a magnetic field, when an electric Hall field has not yet been created, a change in the direction of movement of charge carriers is observed, so that the current density vector rotates through the Hall angle. Accordingly, a charge appears on the lateral edges of the plate, creating a Hall field. The latter compensates, on average, for the action of the Lorentz force.

With mixed electrical conductivity, the vectors of the current density of electrons and holes rotate in different directions, although the electrons and holes themselves are deflected towards the same face of the plate. In this case, the Hall coefficient is determined by the concentration and drift mobility of charge carriers. The Hall effect is described in detail and in a very original way in the tutorial by P.T. Oreshkin [4].

With the help of the Hall effect, it became possible to understand the essence of conduction processes in semiconductors and to draw a line between semiconductors and other types of poorly conductive materials. This is due to the fact that the measurement of the Hall EMF (potential difference) arising in the material perpendicular to the direction of the electric current and external magnetic field, makes it possible to directly determine the concentration and sign of charge carriers. The latter makes it possible to determine whether a

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material belongs to one or another type of semiconductor (p or n-type). Hall effect measurements make it possible to separate the case of ionic conduction from the case of electronic conduction. The presence of the Hall effect in conductors and semiconductors indicates the electronic nature of conductivity. With the help of the Hall effect, it is possible to obtain data on the mobility of charge carriers (the so-called "Hall" mobility). Thus, we can assume that the Hall effect is one of the most effective methods for studying the electrical properties of semiconductor materials and some metals [5-7].

**Abnormal Hall effect.** There are times when the Hall effect is found in the plate without passing a magnetic flux through it. This can only happen when the symmetry with respect to the time reversal in the system is broken. In particular, the anomalous Hall effect can manifest itself in magnetized materials.

**Quantum Hall effect.** In two-dimensional gases, in which the average distance between particles is reduced to commensurate with the de Broglie length, resistance plateaus appear in the crossbar on the dependence of the transverse resistance to the effect of a magnetic field. The Hall effect is quantized only in strong magnetic fields. In magnetic fluxes with an even greater induction force, the fractional quantum Hall effect is found. It is interconnected with the rearrangement of the internal structure of a two-dimensional electron liquid.

**Spin Hall effect.** The spin Hall effect can be observed on non-magnetized conductors that are not placed in the field of action of the lines of force of the magnet. The effect consists in the deflection of electrons with antiparallel spins to the opposite edges of the plate [8].

Based on the Hall effect, it is possible to create a number of devices and devices with valuable and even unique properties and occupying an important place in automation, radio, measuring and computer technology, in particular: in electronic ignition systems for internal combustion engines, in disk drive drives and fan motors in computer technology , in magnetometers of smartphones as a physical basis for the operation of an electronic compass, in electrical measuring instruments (clamp meters, current probes) for contactless measurement of current strength, some types of ion jet engines work on the basis of the Hall effect, etc. [9-18]. Hall effect devices are called Hall sensors.

Hall sensors measure the magnitude of the magnetic field. At a constant value of the current EDS. Hall effect is directly proportional to magnetic induction. The linear dependence of these values for Hall sensors is an advantage over induction meters based on magnetoresistance. Hall sensors also measure the electrical and magnetic characteristics of metals and semiconductors. At present, due to their high accuracy, constancy of data, and reliability, they have found wide application in various branches of science and technology. Hall sensors can be used to measure forces, pressures, angles, displacements and other non-electrical quantities. In the manufacture of semiconductor materials, the Hall effect is used to measure the mobility and carrier concentration in them. For this purpose, e is measured on a specially prepared sample. etc. with. Hall and by its value are judged on the mobility and concentration of charge carriers of the material used for the manufacture of semiconductor devices. Hall sensors are used in automobiles because of their low cost, quality, reliability and ability to withstand harsh environmental conditions. Hall sensors are used to create non-contact unipolar and bipolar switches and switches. The main advantages of Hall sensors are contactlessness, absence of any mechanical stress and contamination.

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