The Hall Effect

Is there a flux of charge carriers in an electric current?

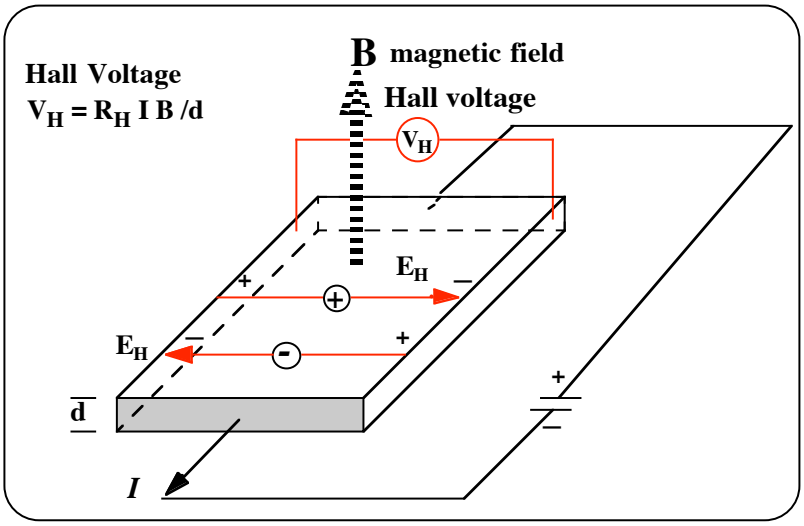
Do moving charge carriers define electrical conduction?

Theory of moving charge carriers cannot explain electrical conduction of the Hall effect

By Johann Marinsek 2005

johann@marinsek.com

When a current carrying thin sheet (Hall element) is placed in a magnetic field that is perpendicular to the direction of the current ***I*** then a transverse electrical field E_H occurs in the Hall element.



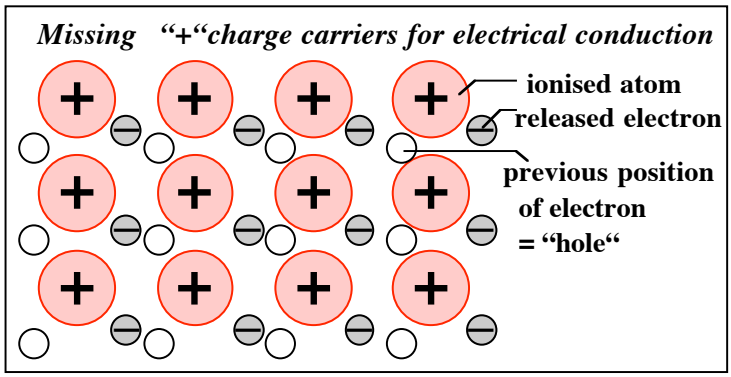
The most important feature of the Hall effect is that the direction of the transverse electrical field E_H depends on the conducting or semiconducting material of the used Hall element. Therefore the so-called Hall coefficient R_H has either a positive sign or a negative sign. The Hall coefficient for the metals Li, Na, K, Cu, Ag, Al, Au and Bi has a negative sign, whereas the sign is positive for W, Zn, Cd and Fe. But there is a temperature dependence of the Hall coefficient: at low temperatures the Hall coefficient for Al has a positive sign for example. See below: electrical conduction and crystal structure.
Quantum physics claims that the different directions of the transverse electrical Hall field are due to different charge carriers, positive and negative ones. The negative charge carriers are allegedly the electrons of an electron cloud in the conductor.
According to this theory every atom of the metal can deliver almost one electron for this purpose. But where do the positive charge carriers come from? Are they the nuclei? Or the ionised atoms, which have a positive net charge? Impossible.

The solution for the charge flux theory of electricity was the concept of moving "holes". Thermal vibrations of the crystal can rupture a bond and release an electron. In the place where the electron has been a "hole" has been left behind. Now the claim is that this *hole has an effective positive charge!* Obviously a neighbouring electron can fill the hole, therefore a new hole was created and so on… Note the *ontological* statement that a missing negative charge is equivalent to a positive charge! So empty locations or "holes" were transubstantiated to a positron!

The charge carrier theory of electrical conduction explains the physical process of conduction as follows: *When a field is applied both holes and electrons contribute to electrical conduction.[nd]*

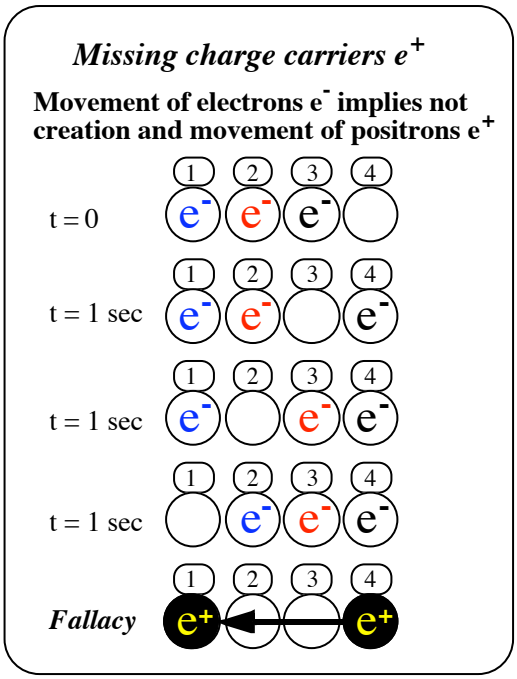
The holes are therefore really assumed to be positive charges and the calculation of the Hall voltage goes on [carr]: *When electrons (or holes) move in a conducting plate that is immersed in a magnetic field, they experience a Lorentz force…*
The Hall voltage can be written in terms of the current as…
$V_H = R_H I B/d$
(I…current in amps, B… magnetic field in Tesla, d… thickness of the Hall element in meters, R_H … Hall coefficient in m^3/C)
There is a category mistake: a successive occurrence of different holes is not identical with the movement of one hole. A "hole" is a previous location of the electron. Only if the atom moves one could say that this location also made locomotion, but this is not supposed by the theory of moving holes.

But the claim of quantum theory is that the holes migrate in the direction opposite to that of the electrons. And the hole is solely an empty place that cannot have a positive sign for charge without a charge carrier. In the metal there are only electrons as carriers of negative charge and the ionised atoms with a positive net charge. But the immobile ionised atoms (or the nuclei) cannot serve as charge carriers for electrical conduction! (Below I will show that a flux of electrons does not define an electrical current. But now the arguments concern charge carriers with positive charge.)



Not convinced? Quantum theory of electrical conduction uses an analogue to make plain the mysterious creation of positrons. See for example [wik]

Imagine a row of seats with #1, #2, #3 and #4. At the time t = 0 the seats #1-3 are occupied by 3 people. Seat #1 is occupied by a blue electron e^-, seat #2 by a red e^- and seat #3 by a black e^-.
Then at t =1 sec the black e^-, which is the person next to the empty seat #4 moves along and sits in it, leaving an empty seat #3 one spot closer to the left edge.
At time t = 2 the red e^- is next to the empty seat #3 and sits in it, leaving an empty seat #2 again on spot closer to the left edge.
At time t = 3 the blue e^- is next to the empty seat #2 and sits in it, leaving an empty seat #1 at the edge.
Now note a category mistake in the argument: *One could say that the empty seat moves*



towards the edge of the row. Obviously the seat #4 does not move towards the left edge of the row! One could only say that there is a succession of empty seats in the row. This has nothing to do with a movement of a seat! Analogously, a former location of an electron does not move when there is a succession of empty locations. Next step concerns the *creatio ex nihilo* of quantum mechanics, namely the creation of a positron: *At the empty "seats" of the electrons physicists propose an imaginary particle called a "hole"… that the hole is simply a positive charge.*
(It doesn't matter how the mass $0{,}81m_e$ for Si was calculated.) The essence of this materialisation is: *the absence of an electron from a normally-filled state is called a "hole" and is treated as a particle…*

Summary: "holes" don't move, "holes" are not particles. Holes cannot be treated neither "as if"- moving seats nor "as if"-particles with positive charge too. Positive charge carriers are missing! Positrons of the nuclei cannot be released for that purpose.

For an explanation of the Hall effect in terms of a flux of charge carriers there is a missing charge carrier for a charge with a *positive* sign. Positrons with a "+"-charge are not available. A "hole", namely the place where an electron had previously its position cannot be a positron substitute. Conclusion: the theory that electrical conduction is a flux of charge carriers cannot explain the Hall effect because charge carriers with positive signs are missing.

Electrical conduction and crystal structure considering the Hall effect

There is a relationship between the electric conductivity and crystal structure. For the Hall effect there should also be a relationship between crystal structure and different directions of the occurring electric Hall field in the thin metal piece. The direction of the electric Hall field (or the sign of the Hall coefficient $\pm R_H$) depends on the specific metal of the Hall element. Please see also the tables in the *Electricity* article!

Let us compare metals with a **bcc-structure and + R_H:** Cr, Fe, Nb, Mo, Ta, W
with metals with **bcc-structure and — R_H:** Li, Na, K, Rb, Cs.
We see that bcc-structure and — R_H is a feature of the alkali metals solely.

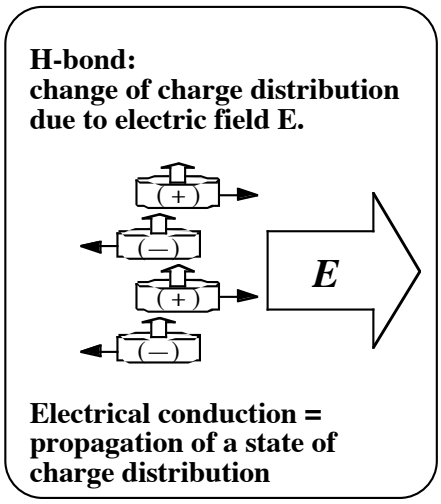
Next let us compare metals with **fcc-structure and + R_H:** Ir, Pb, Ce, Yb
with metals with **fcc-structure and — R_H:** Al, Ca, Ni, Cu, Pd, Ag, Pt, Au, Th.
In the $-R_H$ group there are predominantly noble metals, the lathanides Ce, Yb are in the $+R_H$ group.

Now we compare **hcp-structure and + R_H:** Cd, Be, Zn, Zr, Ru, Hf, Re, Tl
with **hcp-structure and — R_H:** Mg, Sc, Co, Y.

Note that the $-R_H$ for Al and In at room temperatures changes to $+R_H$ at low temperatures.
The $+R_H$ Hall coefficients for α-Pu, β-Pu and δ-Pu are
0,7; 0,3; 1,11 [$10^{-4}cm^3/C$], respectively. α-Pu, β-Pu and δ-Pu are allotropies of Pu.

Polymorphism or allotropy is the ability to arrange the atoms in more than one crystal arrangement. Allotropy depends on temperature.

These regularities are possibly indications for a partial explanation of the Hall coefficient ± R_H in terms of crystal structures. Imagine that a crystal is a 3-dimensional mattress. Bonds and the cores of the atoms consist of hydrogen atoms. (See please the article on chemical bonding.)
Hydrogen has zero net charge but consists of positively and negatively charged subparticles, namely electrons and positrons. So the atoms and the bonds constitute a charge grouping that depends also on the crystal structure. A H-bond is not rigid but deformable by electric or magnetic fields. An electric field causes a displacement of the subparticles.



The direction of the displacement depends on the sign of the charge. (See the graph.) Electrons and positrons, the constituents of hydrogen are also tiny elementary magnets. If a magnet is placed in an external magnetic field B, it will experience a torque. This torque probably causes also a little displacement of the charges. Electrical conduction is explained as the propagation of a state of charge distribution. Then the manner of charge grouping is the cause for the direction of the electric Hall field…

The initial charge grouping has do to with crystal structure.
The results of an external B field on the Hall element are tiny displacements of the positive and negative charges and a potential *difference* appears. This is the Hall voltage.
The conduction "current" is not a flow of charges, therefore
$I \neq Q/t$. This formula should be interpreted as $I = Q\nu$ where ν is the frequency of charges. See please the *Electricity* article!

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