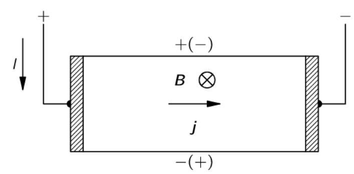
Semiconductors: Hall effect

Electrically charged particles in motion attract or repulse other charged particles. This phenomenon is described as magnetic force. The presence of magnetic force creates a magnetic field which is denoted with B. Magnetic field is defined in terms of force on moving charge in the Lorentz force law which is

$$F = q(v \times B)$$

where q is the numerical value of the charge, v is the velocity of the charged particle, and B is the magnetic field in which the charged particle is moving



In the figure above, the current is traveling to the right and the magnetic field is going into the plane. As a result, any moving carrier will feel a magnetic field. According to the right hand rule, the carriers will feel a magnetic force upward. Under steady conditions, however, there is no upward motion of the carriers because the current can flow only from left to right. What happens is that a few of the charges initially flow upward, producing a surface charge density along the upper surface of the semiconductor—leaving an equal and opposite surface charge density along the bottom surface of the crystal. The charges pile up on the top and bottom surfaces until the electric forces they produce on the moving charges just exactly cancel the magnetic force (on the average) so that the steady current flows horizontally. The charges on the top and bottom surfaces will produce a potential difference vertically across the crystal which is called the Hall effect.

The Hall voltage is calculated by

$$V_H = \frac{IB}{ned}$$

Where I is the current, B is the magnetic field, n is density of mobile charges, e is electron charge, and d is the height of the conducting plate we are using.

In order to ensure the flow of electric current or a charged particle, we need a material with higher electrical conductivity. Electric conductivity is the measure of how well a material will allow electricity to travel through it. [2] Conductivity, σ is the inverse of resistivity, ρ which is measured as

$$\rho = \frac{RA}{l}$$

Where R is the resistance, A is the cross sectional area, and l is the length of the wire the current is flowing through. Additionally, the resistance, $R = V/I$ where V is the voltage and I is the current. So,

$$\rho = \frac{VA}{lI}$$

So, $\sigma = lI/RA$.

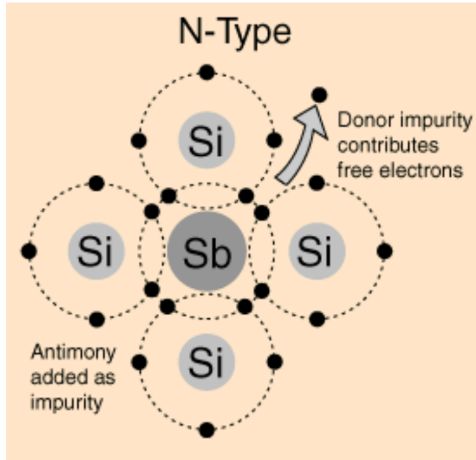
For semiconductors, $\sigma = \sigma_0 \exp(-E_g/2kT)$ where σ_0 is the proportionality constant, E_g is the energy or band gap, k is the Boltzmann's constant and T is the temperature of the plate.

The quantum Hall effect (or integer quantum Hall effect) is a quantized version of the Hall effect which is observed in two-dimensional electron systems subjected to low temperatures and strong magnetic fields. This can also be observed in photons and this effect is created by shooting the light across multiple mirrors. As a result, the photons are routed and gain additional phase proportional to their angular momentum. This creates an effect like they are in a magnetic field.

Semiconductor:

Semiconductors behave as insulators at very low temperature but they conduct electricity somewhat at room temperature. Silicon and germanium are some of the elements widely used as semiconductors. If we add a small percentage of foreign atoms in the regular crystal lattice of any of the two elements, it changes their electrical properties and produces n-type and p-type semiconductors.

N-type: If we add pentavalent impurities such as antimony, arsenic or phosphorus which results in the contribution of free electrons to the material. Therefore, the conductivity of the semiconductor increases.



P-type: If we add trivalent impurities, such as boron, aluminium, or gallum then it creates deficiencies of valence electrons, called “holes”.