21.5: The Hall Effect

Figure $21.5.1$ shows a simple circuit to illustrate the Hall effect. A flat slab of metal, with width, w, is connected to a battery, so that current flows through the slab. The slab is immersed in a uniform magnetic field, $\vec{B}$, that is perpendicular to the plane of the slab.

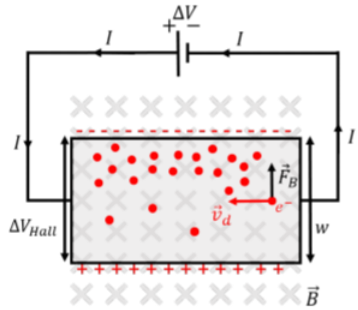

Figure $21.5.1$: Illustration of the Hall effect, as electrons flow through a slab that is immersed in a magnetic field, the magnetic force pushes them to one side, creating an electric potential difference, ΔV_{Hall}, transverse to the motion of the current through the slab.

As the electrons enter the right-hand side of the slab (Figure $21.5.1$) and drift towards the left, they will experience an upwards force from the magnetic field. As they move to the left through the slab, they also move upwards and "pile up" on that side of the slab. There will thus be an excess of negative charge on the top side of the slab, leading to an electric potential difference between the top and the bottom of the slab. This potential difference is called the "Hall potential", ΔV_{Hall}. An equilibrium between the magnetic force and the electric force associated with the Hall potential is quickly reached, so that the Hall potential remains constant.

If we model the slab as two parallel plates, with a potential difference, ΔV_{Hall}, between them, the electric field in the slab is constant and given by:

$$E = \frac{\Delta V_{Hall}}{w}$$

The equilibrium condition (that the electric force on an electron is equal to the magnetic force) is given by:

$$\begin{aligned} F_E &= F_B \\ eE &= ev_dB \\ \frac{\Delta V_{Hall}}{w} &= v_dB \\ \therefore \Delta V_{Hall} &= v_dwB \end{aligned}$$

If the drift velocity of electrons is known, then the Hall effect can be used to measure the strength of the magnetic field by simply measuring the Hall voltage. This is the most common way to measure the strength of a magnetic field (and the device to do so is called a Hall probe). Conversely, if the magnetic field is known, the Hall effect can be used to characterize the drift velocity of electrons and other microscopic quantities for the material from which the Hall probe is made.

The Hall effect allows us to determine that it is negative charges that flow, and not positive charges. Indeed, consider Figure $21.5.1$, but replace the electrons with positive charges flowing to the right, which is equivalent as far as analysing the circuit goes. In this case, those positive charges will be deflected upwards. Thus, if positive charges flow, the top side of the Hall probe becomes positive, whereas it becomes negative if it is negative charges that flow. By measuring the sign of the Hall potential, one can show that it is electrons that flow in an electric current.