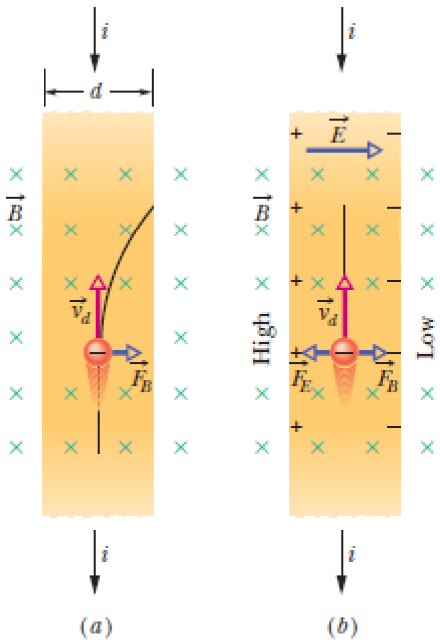
Hall Effect

A beam of electrons in a vacuum can be deflected by a magnetic field. Can the drifting conduction electrons in a copper wire also be deflected by a magnetic field? In 1879, Edwin H. Hall, then a 24-year-old graduate student at the Johns Hopkins University, showed that they can. This **Hall effect** allows us to find out whether the charge carriers in a conductor are positively or negatively charged. Beyond that, we can measure the number of such carriers per unit volume of the conductor.

Figure *a* shows a copper strip of width *d*, carrying a current *i* whose conventional direction is from the top of the figure to the bottom. The charge carriers are electrons and, as we know, they drift (with drift speed *vd*) in the opposite direction, from bottom to top. At the instant shown in Fig. *a*, an external magnetic field B, pointing into the plane of the figure, has just been turned on. From F = qv×B we see that a magnetic deflecting force F_B will act on each drifting electron, pushing it toward the right edge of the strip. As time goes on, electrons move to the right, mostly piling up on the right edge of the strip, leaving uncompensated positive charges in fixed positions at the left edge. The separation of positive charges on the left edge and negative charges on the right edge produces an electric field Ē within the strip, pointing from left to right in Fig. *b*. This field exerts an electric force F_E on each electron, tending to push it to the left. Thus, this electric force on the electrons, which opposes the magnetic force on them, begins to build up.

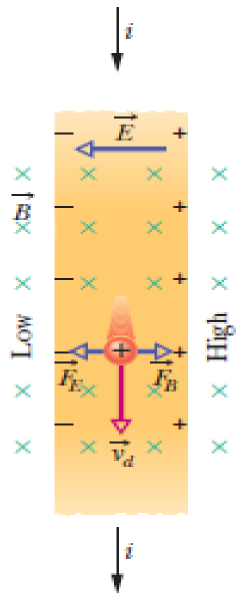


Equilibrium. An equilibrium quickly develops in which the electric force on each electron has increased enough to match the magnetic force. When this happens, as Fig. *b* shows, the force due to B and the force due to F_E are in balance. The drifting electrons then move along the strip toward the top of the page at velocity v_d with no further collection of electrons on the right edge of the strip and thus no further increase in the electric field Ē. A *Hall potential difference V* is associated with the electric field across strip width *d*. The magnitude of that potential difference is

$$V = Ed.$$

By connecting a voltmeter across the width, we can measure the potential difference between the two edges of the strip. Moreover, the voltmeter can tell us which edge is at higher potential.

For the situation of Fig. *b*, we would find that the left edge is at higher potential, which is consistent with our assumption that the charge carriers are negatively charged. For a moment, let us make the opposite assumption, that the charge carriers in current *i* are positively charged (Fig. *c*). Convince yourself that as these charge carriers move from top to bottom in the strip, they are pushed to the right edge by F_B and thus that the *right* edge is at higher potential. Because that last statement is contradicted by our voltmeter reading, the charge carriers must be negatively charged.



(c)