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Mechanical Analogy of the Hall Effect

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We consider two infinitely conductive plates, normal to the z axis. A magnetic field B_0 in z direction is applied. A gas with conductivity σ is driven through the plate by a volume force $P=-(\partial p/\partial x)$ in x direction.

On using one-component magneto-fluid dynamics, it is found readily that the gas moves in the x direction with a velocity $V_x=P/\sigma B^2$. The current density is $J_y=-(P/B_0)$ when the electric field is put equal to zero. This means that the gas is short-circuited by the plates which carry the return current.

When we use the two-component theory in the form given by Spitzer[1] we find that V_x and J_y are the same in this case, but that now a mass flow in y direction, $V_y=-(P/2neB_0)$ occurs. This essentially is caused by the fact that ions and electrons each carry one-half of the electric current, resulting in a net mass flow due to the mass difference.

The result stated means that there is an angle θ between force and flow. Clearly, to $\tan\theta=V_y/V_x=\sigma B_0/2ne=\omega t/2$, where $\omega=eB_0/m$ is the cyclotron frequency and $\tau=\sigma m/2$ is an effective collision time. The component of P normal to the resultant flow can be considered as an analogy to the Hall effect. A more extended treatment is forthcoming.[2]

[1] L. Spitzer, Jr., *Physics of Fully Ionized Gases* (Interscience Publishers, Inc., New York, 1956).

[2] L. J. F. Broer, L. A. Peletier, and L. van Wijngaarden, Appl. Sci. Research **B8**, 259 (1960).