# Hydrodynamics, Magnetohydrodynamics, and Electric Circuit Analogs

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The large-scale bulk dynamics of a magnetized plasma is generally treated within the concepts of hydrodynamics (HD) and magnetohydrodynamics (MHD). Yet questions are sometimes raised about the applicability of HD and MHD and suggesting that electric currents are a better representation, from which there has grown a popular belief in an electric circuit analog for the dynamics.

We begin by showing in a collisionless gas how HD follows directly (using Gauss?f theorem) from conservation of particles, momentum, and energy, given only that there are enough particles that the local mean particle density is statistically well defined.

Then, if there are enough free electrons and ions in the gas to neutralize any significant electric field in the moving local reference frame of the gas, MHD is an immediate consequence. The magnetic field is transported bodily with the gas, and electric fields play no dynamic role.

The effects (Hall current, Pedersen resistivity, Ohmic dissipation) arising in a partially ionized gas are small-scale, becoming negligible under most circumstances in any large-scale setting, but important in the local structure of shock fronts and rapid reconnection, of course.

Finally, it is shown that the inductive effects in the conventional current analog do not apply to the currents flowing in a swirling magnetized plasma, because the plasma moves in the frame of reference in which there is no significant electric field