Fast Magnetic Field Penetration into Plasmas due to Hall Resistivity

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A dissipationless mechanism, the Hall resistivity, is shown to enhance the penetration of a magnetic field into plasmas. Two cases are described. In the first case the magnetic field is shown, in a one-dimensional model problem, to be governed by a diffusion equation with a complex diffusion coefficient, the imaginary part of which is proportional to the Hall resistivity associated with the magnetic field in the direction of penetration. In the collisionless limit the governing equation is equivalent to the Schrodinger equation for a free particle, and the magnetic field propagates the way a free particle wave packet expands. The magnetic field penetration is enhanced by the ratio of the cyclotron frequency to the collision frequency, and is accompanied by oscillations. In the second case, the magnetic field evolution is governed by Burgers' equation. In this case, for a certain geometry the magnetic field penetrates the plasma as a shock, while in a different geometry the Hall resistivity can expel the magnetic field from an intially magnetized plasma. The enhanced magnetic field penetration induced by the Hall resisitivity might be relevant to the enhanced magnetic field penetration observed in plasmas in pulsed-power devices.

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