Stability of pure electron plasmas on magnetic surfaces

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Abstract

The stability of pure electron plasmas is developed for perturbations that are of sufficiently low frequency to preserve force balance and the equality of the electron temperature along the magnetic field lines. These two constraints are shown to imply an otherwise ideal plasma is stable to all perturbations of the electric potential. The source of this robust stability is that these two constraints eliminate plasma flows that cross the magnetic surfaces. Since the magnetic surfaces are rigid, the elimination of plasma flows across the surfaces means the plasma cannot effectively tap the enormous free energy that exists in the repulsive electrostatic potential.

Toroidal plasmas with magnetic surfaces have been used for about half a century to confine quasi-neutral plasmas. Proposals have only recently been made to confine non-neutral plasmas in toroidal systems with magnetic surfaces using either an axisymmetric levitated ring or a stellarator geometry. A stellarator for confining non-neutral plasmas, the Columbia Non-Neutral Torus (CNT), is being built by Prof. Thomas Pedersen. The theory of pure electron plasmas confined on magnetic surfaces differs significantly from that of quasi-neutral plasmas. In pure electron plasmas, the plasma density is sufficiently low that its current has a negligible effect on the magnetic field. Force balance and rapid heat transport along the magnetic field lines determine the form of the electron density, but otherwise force balance in a non-neutral plasma is simple. The primary equilibrium equation is the equation for the electric potential, which is given by Poisson's equation. The ratio of the change in the potential to T/e is approximately the square of plasma radius divided by the Debye length. The CNT stellarator will be used to study not only pure electron plasmas, but also partial neutralized and quasi-neutral plasmas

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