Magnetization cooling of an electron gas

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We propose an adiabatic magnetization process for cooling the Fermi electron gas to ultra-low temperatures. As was shown by Landau, the motion of electrons in a plane perpendicular to the magnetic field lines is finite, i.e., transverse component of energy is quantized. We have derived the thermodynamic potential Ω of the electron gas with an arbitrary magnetic field H and temperature T and investigated all the thermodynamic quantities as a function of density n, temperature and magnetic field,

pressure $\quad P = -\dfrac{\Omega}{V}\quad$, $\quad$ entropy $\quad S = -\left(\dfrac{\partial \Omega}{\partial T}\right)_{V,\mu}\quad$ and heat capacity $\quad C_V = T\left(\dfrac{\partial S}{\partial T}\right)_{V,\mu}$

We have obtained a novel set of adiabatic equations. Specifically, if

$$\hbar e H / m_e c > \varepsilon_F$$

the adiabatic equation takes the form

$$\frac{TH^2}{n^2} = const.$$

$$(1)$$

where $\hbar$ is Planck's constant, e -electron charge, m_e -electron mass, c -speed of light and ε_F - the Fermi limit energy.

This adiabatic Eq. (1) contains three unknowns (density, temperature, magnetic field) instead of two as in ordinary thermodynamics. Equation (1) is our novel adiabatic equation implying that at fixed density an increase of the magnetic field correspondingly leads to the temperature decrease as

$$T \propto \frac{1}{H^2}.$$