MAR09-2008-000327

Abstract for an Invited Paper
for the MAR09 Meeting of
the American Physical Society

Paramagnetic or diamagnetic persistent currents? A topological point of view

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A persistent current flows at low temperatures in small conducting rings when they are threaded by a magnetic flux. I will discuss the sign of this persistent current (diamagnetic or paramagnetic response) in the special case of N electrons in a one dimensional ring [1]. One dimension is very special in the sense that the sign of the persistent current is entirely controlled by the topology of the system. I will establish lower bounds for the free energy in the presence of arbitrary electron-electron interactions and external potentials. Those bounds are the counterparts of upper bounds derived by Leggett using another topological argument. Rings with odd (even) numbers of polarized electrons are always diamagnetic (paramagnetic). The situation is more interesting with unpolarized electrons where Leggett upper bound breaks down: rings with $N = 4n$ exhibit either paramagnetic behavior or a superconductor-like current-phase relation. The topological argument provides a rigorous justification for the phenomenological Huckel rule which states that cyclic molecules with $4n + 2$ electrons like benzene are aromatic while those with 4n electrons are not.

[1] Xavier Waintal, Geneviève Fleury, Kyryl Kazymyrenko, Manuel Houzet, Peter Schmitteckert, and Dietmar Weinmann *Phys. Rev. Lett.***101**, 106804 (2008).