
Report of the Second Referee -- WJ10056/Hirsch

In this paper, the author claims that the "conventional" BCS theory fails to explain the dynamics of the Meissner effect. However, the arguments advanced by the author are not very convincing. His reasoning relies on the application of classical laws of physics, such as Maxwell's equations. However, it has been known for a long time that Maxwell's equations cannot fully describe the dynamics of the electromagnetic field in superconductors: these equations must be supplemented with London's equations (which, in turn, can be deduced from the BCS theory). Similarly, electrons in superconductors do not follow the classical hydrodynamic equations of a perfect fluid, as assumed here. As first discussed by Gorter and Casimir in Physica C 153, 1405 (1934), a superconductor consists of two distinct components: in addition to the superconducting electrons, one should also consider the "normal" component that carries entropy (similar ideas were later very successfully adapted to superfluid helium by Tisza and Landau). As a superconducting material is cooled below the critical temperature, the normal component is progressively replaced by the superconducting component such that all electrons eventually become superconducting at T=0. The existence of superconducting and normal components arises naturally in the BCS theory. These two components are intimately coupled and therefore cannot be simply treated as two distinct fluids, as implicitly assumed here (in the same way that superfluid helium does not follow the hydrodynamic equations of a perfect fluid but is described by Landau-Khalatnikov two-fluid equations). For this reason, I do not see the relevance of the present considerations based on Alfen's theorem and perfect fluid dynamics. The "puzzle" discussed by the author mainly stems from the application of classical laws beyond their domain of validity. The author's statement "It is important to remember that the laws of author's statement "It is important to remember that the laws of classical physics that we used in this paper always act, whether or not `quantum mechanics' also plays a role" is contradicted by the current understanding of superconductivity, and more importantly by experiments.

It is also not clear what the author means by "conventional" theory of superconductivity. Quite generally, the dynamics of a superconductor with spatially varying fields (such as the magnetic field in the present context) can be described by the time-dependent Bogoliubov-de Gennes equations. These equations (which reduce to those originally introduced by BCS in the limit of homogeneous and time-independent systems) are discussed in standard textbooks and are thus part of the "conventional" theory of superconductivity. Instead, the author proposes an alternative interpretation of the Meissner effect based on a semiclassical approximation for the motions of electrons and holes. But this picture only makes sense in the normal phase, where the concept of a Fermi surface is well-defined. As soon as the temperature falls below the critical temperature, the Fermi surface becomes unstable due to the formation of Cooper pairs. The neglect of this basic phenomenon in the present analysis about the dynamics of electrons in a superconductor is quite dubious.

Finally, the discussion about a transport of effective mass is totally obscure. In particular, the continuity equations (68) imply that the effective mass density and currents are time and space dependent fields, whereas they should not have such dependencies in view of their definition from Bloch states. Moreover, I do not see why the effective mass density should vanish for a full band: this is only true for the integral of the *inverse* effective mass (61) - not the integral of the effective mass itself (see, e.g., appendix I in the standard textbook of Ashcroft&Mermin, Solid State Physics). Incidentally, equation (67) only holds in 1D but is wrong in higher dimensions: depsilon/dk_i /(sum_j dv_j/dk_j) is not equivalent to depsilon/dv_i.

In summary, the arguments advanced in this paper are fallacious or even wrong, and rely on studies previously published by the same author in different journals. Despite the vast literature on superconductivity, about 2/3 of the references actually come from the present author. For all these reasons, I cannot recommend this paper for publication.