

Iordanskii and Lifshitz-Pitaevskii Forces in the Two-Fluid Model

M. R. Geller,¹ D. J. Thouless,² S. W. Rhee,² and W. F. Vinen³

¹*Department of Physics, University of Georgia, Athens GA 30602, USA*

²*Department of Physics, University of Washington, Seattle, WA 98195, USA*

³*School of Physics, University of Birmingham, Birmingham B15 2TT, UK*

It has been known since the pioneering work of Onsager and Feynman that the statistical mechanics and dynamics of vortices play an essential role in the behavior of superfluids and superconductors. However, the theory of vortices in quantum fluids remains in a most unsatisfactory state, with many conflicting results in the literature. In this paper we review the theory of Thouless, Ao and Niu, which gives an expression for the total transverse force acting on a quantized vortex that is in apparent disagreement with the work of Iordanskii and of Lifshitz and Pitaevskii. In particular, no transverse force proportional to the asymptotic normal fluid velocity was found. We use two-fluid hydrodynamics to study this discrepancy.

PACS numbers: 67.40.Vs, 74.60.Ge, 47.37.+q

1. A HIERARCHY OF LENGTH SCALES

A comprehensive theory of vortex dynamics in quantum fluids must address phenomena occurring at three different length scales. At the smallest, most microscopic scale, a fully quantum mechanical treatment of a vortex, including its internal structure, interaction with elementary excitations such as phonons and rotons, and interaction with disorder, is required

At the next—what we shall refer to as intermediate—length scale, one would like to regard a vortex as a classical object, subject to a classical equation of motion. Of course, there is no guarantee that we can do this, and, indeed, certain pathologies result from our insistence in doing so, but experience has shown that this classical picture is extremely successful.¹

There are different ways to formulate the classical approach. If we let $\mathbf{R}(t)$ denote the position in the xy plane of the center of an isolated straight