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Reynolds similitude of a pure superfluid at low temperatures

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The Reynolds similitude, a key concept in hydrodynamics, states that two phenomena of different length scales with a similar geometry are physically identical. Flow properties are universally determined in a unified way in terms of the Reynolds number $calR$ (dimensionless, ratio of inertial to viscous forces in incompressible fluids). For example, the drag coefficient c_D of objects with similar shapes moving in fluids is expressed by a universal function of $calR$.
Certain studies introduced similar dimensionless numbers, that is, the superfluid Reynolds number $calR_s$, to characterize turbulent flows in superfluids. However, the applicablity of the similitude to inviscid quantum fluids is nontrivial as the original theory is applicable to viscous fluids. This study proposes a method to verify the similitude using current experimental techniques in quantum liquid He-II. A highly precise relation between c_D and $calR_s$ was obtained in terms of the terminal speed of a macroscopic body falling in He-II at finite temperatures across the Knudsen (ballistic) and hydrodynamic regimes of thermal excitations. The Reynolds similitude in superfluids proves the quantum viscosity of a pure superfluid and can facilitate a unified mutual development of classical and quantum hydrodynamics; the concept of quantum viscosity provides a practical correspondence between classical and quantum turbulence as a dissipative phenomenon.

References

[1] Hiromitsu Takeuchi, Phys. Rev. B 109, L020502 (2024)

Short bio (50 words) or link to website

http://hiromitsu-takeuchi.appspot.com

Relevant publications (optional)

Career stage

Professor

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