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Hamiltonian mechanics of superfluid helium-4 with numerical applications

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At very low temperatures (less than 2.17 K), helium becomes superfluid. For instance, it flows through narrow capillaries with no resistance. Although traditional models describe superfluid helium as a mixture of a normal component and a superfluid component, helium is actually a pure substance, not a mixture, that exhibits two motions. In order to describe the two motions, we use geometric mechanics, that connects classical continuum mechanics with the underlying quantum mechanics. Another aspect of superfluid helium is the presence of quantum vortices, topological defects of the phase of the wave function. Hamiltonian mechanics helps to include quantum vortices and to formulate a numerical scheme based on smoothed-particle hydrodynamics. As an application, we show a simulation of the superfluid fountain effect, where heating is converted to the motion of helium.

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