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Gradient Flow in the Ginzburg-Landau Model of Superconductivity

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The Ginzburg-Landau model for superconductivity provides a phenomenological description of superconductors near the critical temperature where a phase transition between superconducting and regular states occurs. The model has a single dimensionless free parameter, κ, that has a critical value separating type I and type II superconductors. Of particular interest are the vortex solutions (which are known to occur in type II superconductors) where we have some quantized magnetic flux through the material. We study the dynamics of the vortices using the gradient flow of the free energy. The gradient flow gives a system of coupled partial differential equations whose stationary points are given by the solutions to the Ginzburg-Landau equations. Far from equilibrium, the flow equations provide a description of the dynamics of a configuration with multiple vortices that evolves as quickly as possible to minimize the energy. Close to equilibrium the flow equations tell us about the stability of the vortices. We solve the equations numerically to study the interactions between vortices as well as the decay of larger vortices into multiple smaller ones. We find two different time-scales, a short time-scale where vortices form, and a longer time-scale where the vortices interact with eachother.

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