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Deriving Kelvin's argument through the principle of "virtual vortex work" P. LUZZATTO-FEGIZ, C.H.K. WILLIAMSON, Cornell University — In 1875, Lord Kelvin proposed an energy argument to define equilibrium and stability in fluid flow. Kelvin stated that steady flows would realize a stationary point of the energy, for given vorticity and impulse. Intriguingly, Kelvin proposed this idea without proof; analytical confirmation was presented a century later by Benjamin (1975). Unfortunately, to this date, we have no indication as to how Kelvin's argument may be derived from a fundamental physical principle. Indeed, the path that led Kelvin to his statement remains unknown. A derivation based on a fundamental principle may enable generalizations to novel applications, which cannot be investigated by the current formulation of Kelvin's argument. In this presentation, we employ the fundamental principle of virtual work, and show that the requirement for a system to be stationary in a *moving* frame leads naturally to a constraint on the impulse. In the context of fluid flow, formulating the principle leads us to introduce the concept of *virtual vortex work*. We show this to be equivalent to Kelvin's argument. We exploit our derivation to devise generalizations of Kelvin's argument for a variety of fluid flows, including vortical flows, gravity waves and compressible flows. This, in turn, allows us to instantly deduce stability properties in 2D and 3D through an "imperfect-velocity-impulse" approach (which takes the form of "IVI" diagrams) recently proposed by the authors.

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