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Self-similarity of flows induced by instabilities

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Flows induced by instabilities are found in many engineering and astrophysical circumstances. Specifically, the instabilities induced by acceleration and shear (Rayleigh-Taylor, Richtmyer-Meshkov, and Kelvin-Helmholtz instabilities) have attracted much attention. While the initial linear, nonlinear, and transient processes are complicated, it is widely suspected that at late time the flow will relax toward a self-similar statistical state where the dominant length scale, i.e., the mixing-layer width, is growing as an algebraic function in time. For the Richtmyer-Meshkov mixing layer, analogies with weakly anisotropic turbulence suggest that both the bubble-side and spike-side widths of the mixing layer should evolve as power-law in time, with the same power-law exponent and virtual time origin for both sides. The analogy also bounds the power-law exponent between 2/7 and 1/2. The implication of full self-similarity of the Rayleigh-Taylor mixing layer and the Kelvin-Helmholtz shear layer are examined using a simplified group-theoretic analysis. The constraints on the behavior and evolution of these layers imposed by rigorous self-similarity are identified, and equations are constructed for the growth rate of these layers based on a total energy balance. This analysis does not prove that such flows will become self-similar. Rather, the analysis demonstrates the behaviors that would arise if these flows were to become fully self-similar.

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