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Aspect-Ratio-Dependent Upper Bounds for Two-Dimensional Rayleigh–Bénard Convection between Stress-Free Isothermal Boundaries

GREGORY CHINI, BAOLE WEN, University of New Hampshire, CHARLES DOERING, University of Michigan — One of the central challenges in studies of Rayleigh–Bénard convection is the determination of the heat transport enhancement factor, i.e. the Nusselt number Nu, as a function of the Rayleigh number Ra, Prandtl number Pr, and domain aspect ratio L. Although the functional relation between Nu, Pr and Ra is usually presumed to be $Nu \sim Pr^{\alpha} Ra^{\beta}$ in the "ultimate" high-Ra regime, experiments and simulations have yielded different scaling exponents. Here, we investigate this scaling relationship for two-dimensional Rayleigh–Bénard convection between stress-free isothermal boundaries by computing rigorous upper bounds on the heat transport in domains of varying aspect ratio. Using a novel two-step algorithm (Wen et al. PLA 2013), we numerically solve the full "background field" variational problem arising from the upper bound analysis of Whitehead & Doering (PRL 2011) to obtain the optimal bound for $Ra \leq 10^{10}$ as a function of L. Our results show that $Nu \leq 0.106 Ra^{5/12}$ at fixed $L = 2\sqrt{2}$ uniformly in Pr, confirming that molecular transport *cannot* be neglected even at extreme values of Ra. Moreover, for large Ra, the aspect ratio has little impact on the bounds until the domain becomes sufficiently small.

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