Sizing Up Plasmas Using Dimensionless Parameters*

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Since plasmas are complex physical systems, dimensional analysis is a valuable tool for improving our physical understanding and providing scalings (trends) that are compatible with the governing equations. The application of dimensional analysis to magnetically confined plasmas by Kadomtsev was formalized by Connor and Taylor’s method of scale invariance, and since then comprehensive studies have demonstrated the usefulness of dimensionless parameter scaling in designing and interpreting plasma experiments. This talk reviews what the scaling of phenomena with dimensionless parameters has taught us about the physics of magnetically confined plasmas, with emphasis on cross-magnetic-field transport and edge plasma characteristics. An essential step in experimentally applying dimensional analysis is to verify the principle of similarity, which dictates that plasmas with the same dimensionless parameters exhibit the same physical behavior. Similarity in high temperature plasmas was first confirmed by comparing heat transport in tokamaks of different physical size. Tests of similarity for edge plasma phenomena had more mixed results, which suggest that the role of atomic physics or magnetic field ripple may not be negligible. An extensive series of experiments on stellarators and tokamaks have investigated the transport dependence on relative gyroradius, beta, collisionality, safety factor, elongation, and aspect ratio. The weak dependence on beta favors primarily electrostatic turbulent transport, while an increase in transport with collisionality can be explained by collisional damping of zonal flows. Cross-tokamak studies have confirmed the dimensionless parameter scalings found on individual tokamaks. The results of these experiments point to a favorable path for increasing the fusion performance in burning plasma devices.

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