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Physics of Tokamak Disruption Simulations

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Disruption simulations address two fundamental questions: (1) When is a tokamak operating in a metastable state in which loss of control is credible (avoidance question)? (2) What is the worst credible level of destructive effects when plasma control lost and how can these effects be mitigated (effects question)? The success of ITER and the future of tokamaks as fusion systems depend on the precision with which these questions can be answered. Existing capabilities are far from those desired. Nevertheless, physical constraints on the answers can be given and further important constraints could be obtained through a relatively limited theoretical effort interacting with ongoing experiments. The nature of the physical constraints and procedures for deriving further constraints will be discussed. Throughout a disruption, the plasma evolves through force-balance equilibria. The fastest time scale, roughly a millisecond, is about a thousand times longer than an Alfvén time, and the longest is of order a second. Disruption effects include forces and heat loads on surrounding structures and the production of relativistic electrons, which can burn holes through structures. Although the spatially averaged force that can be exerted by a disruption can be easily estimated, the determination of the localization and duration of force and heat loads is far more subtle. The physics and critical issues in constraining these loads will be discussed. The danger posed by relativistic electrons depends on the quality of the magnetic surfaces when large voltages arise in the disruption evolution. Issues and mitigation methods for relativistic electrons will be discussed.