

Collisional and collisionless shocks

D.D. Ryutov

Lawrence Livermore National Laboratory, Livermore CA 94550, USA

Shock waves are one of the most common plasma phenomena. They play a significant role in astrophysical and magnetospheric environments, as well as in laboratory plasmas. The classical collisional shocks usually connect two well-defined equilibrium states (those before and after the shock transition). Each of these equilibrium states is characterized by the thermodynamic parameters of density, temperature, and pressure, whose upstream and downstream values are related by the continuity of mass, momentum, and energy flux. In the collisionless plasmas, however, the initial state can be any of the much broader class of states as long as constrained only by the requirement of being micro-stable. To find a final state (which is micro-stable but, generally, non-Maxwellian) one now has to follow the evolution of the system through the whole transition, and a lot of universality is lost. Despite this important conceptual difference, there are also many similarities between the two types of shocks: i) a formation mechanism by the hydrodynamic overtaking, ii) an important role of the electron and ion mass disparity, iii) the presence of several sub-scales in the shock transition, and iv) the composition variation within the shock transition. These general features will be illustrated by examples from laboratory astrophysics, high-energy-density fusion experiments, and edge plasmas of toroidal devices. A special class of shock-like transitions in the form of double layers will also be discussed. Taken together, these phenomena reveal a fascinating interplay of hydrodynamics, statistical mechanics, and plasma physics. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory (LLNL) under Contract DE-AC52-07NA27344.