Relativistic Kinetic Theory in Heavy-Ion Collisions and Particle & Astrophysics

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The properties of many-particle systems depend essentially upon the interactions of the constituent particles and external constraints. We are generally interested in certain -equilibrium or non-equilibrium – macroscopic properties. These macroscopic quantities, which are functions of the space-time coordinates, should be expressed in terms of the macroscopic state variables (such as particle density, temperature, and in the case of mixtures, the composition) and of the characteristic microscopic parameters of the system.

Kinetic theory uses statistical description in terms of the one-particle distribution function. The one-particle distribution function gives the average number of particles with a certain momentum at each space-time point. In the development of the theory, one derives the relativistic kinetic equation which gives the rate of change of the distribution function in time and space due to particle interactions. One of the purposes of kinetic theory is to derive the macroscopic laws which are the conservation laws and the entropy laws from the kinetic (transport) equation.

Kinetic theory and fluid dynamics descriptions are complementary ways of treating relativistic many-particle systems. Relativistic fluid dynamics can be derived from the relativistic kinetic theory.

Relativistic kinetic theory has widespread applications in nuclear physics, particle physics, astrophysics, and cosmology. In nuclear and particle physics relativistic kinetic theory is used in the description of many elementary particle collisions, hadronic collisions, and heavy ion collisions.

In astrophysics and cosmology, large systems satisfying conditions for kinetic theory applications exist – for example stellar clusters and the gas of galaxies, also the inclusion of gases of photons and neutrinos. In addition, relativistic kinetic theory is applied in the covariant theory of plasma response, thermalization of relativistic plasma, the kinetics of self-gravitating systems, cosmological structure formation and neutrino emission during the gravitational collapse, in accretion processes around compact objects such as black holes.

In this topic, you will

(i) learn/study/review special and general theories of relativity.

(ii) derive relativistic transport equation(s).

(iii) deduce the equations underlying fluid dynamics for a gas in a near-equilibrium state including the equation of state and the terms describing viscosity and heat transport.

(iv) use available relativistic transport models to model/simulate relativistic many-particle systems in nuclear and particle physics, heavy-ion collisions, as well as in astrophysics and cosmology (e.g. during stellar core-collapse and neutron star collisions).