On a Kinetic Equation
for and the Dynamical Friction of a Particle in a Plasma-A Phenomenological Approach*

By
S. V. YADAVALLI

(Received January 29, 1962)

Based on phenomenological considerations, a one particle distribution function consisting of two parts accounting for the effects of “distant” particles and the “nearest” neighbors is suggested. Employing the above distribution function and the Liouville theorem, dynamical friction of a particle in, and a kinetic equation for a plasma are demonstrated.

I. Introduction

The object of this paper is to obtain a kinetic equation and a simpler equation similar to the Langevin and Fokker-Planck equations for the one particle distribution function in a plasma, employing a phenomenological approach.

In recent years, there have been many treatments concerning the dynamical friction of “test” particles in a plasma. Although one may follow the treatments given in the literature, it is felt that a phenomenological approach given here will be of some value in appreciating the results of the more rigorous mathematical efforts.

The notion of dynamical friction was introduced by Chandrasekhar in astrophysics some time ago. Since then, similar and other treatments applicable to charged particles in a medium composed of charged particles have been given to illustrate and evaluate the dynamical friction of a charged particle, moving in, say, a plasma. Simply stated, it is equivalent in a sense to saying that when an electron moves in a plasma, there will obtain an excess (accumulation) of electrons in front (in the direction of motion) of the “test” particle and a depletion of electrons.

* This research was supported in part by the U.S. Government under Contracts AF 19 (604)—7396 and Nonr 2728(00) with the Stanford Research Institute.

behind it*; this will become clearer when we note that the ions are extremely heavy in comparison with the electrons, and over-all charge neutrality in the plasma medium (implicitly assumed) is maintained.

The connection between the phenomenological approach given here and the methods of KADOMSTEV, TCHEN, ROSTOKER and ROSENBLUTH, SIMON and HARRIS will become clear in the ensuing discussion. The methods of References 5 to 8 employ a form of B-B-G-K-Y (BOGOLOUBOV, BORN, GREEN, KIRKWOOD and YVON) treatment of the general nonequilibrium situation starting with the Liouville equation and the N-body distribution function and integrating out successively the coordinates of all but one particle, all but two particles, and so on. The one body function treatment yields the familiar Boltzmann equation, and the two body function (when represented by means of terms in a cluster expansion as done by ROSTOKER and ROSENBLUTH and extended later by SIMON and HARRIS to include a radiation field) yields a form of Fokker-Planck equation. KADOMSTEV and TCHEN have considered the non-Markovian character of the behavior of a system of charged particles in some detail and obtained again an equation similar to the Fokker-Planck equation. GASIOROWICZ, NEUMAN and RIDDLE have considered a "test" particle problem where the frictional drag was determined from the response of the surrounding plasma to a test particle; in the above treatment, collisions between plasma particles that produce large deflections were neglected and small angle deflections (considered as fluctuation effects) were treated by a modified Holtzmark type calculation. ROSENBLUTH, MACDONALD and JUDD on the other hand, treated the infrequent large angle scatterings as collisions and the (many) small angle deflections were accounted for by a macroscopic

* It may be added here that a physical picture giving rise to dynamical friction may be given (in a similar manner) in the case of a "test" particle moving in a medium consisting of particles where attractive forces are present. See, for instance, Reference 4.