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Conduction Theories in Gaseous Plasmas and Solids: Final Report, 1961

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CONDUCTION THEORIES IN GASEOUS PLASMAS AND SOLIDS

Contract Number AF49 (638) 687

FINAL REPORT

(October 1, 1959 - October 31, 1961

Department of Physics
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I. Summary of Research Effort

The theoretical studies on the transport properties of ionized media performed on this contract have been based entirely on the effective particle approach and have ignored all correlation effects as well as quantum corrections. Within this approximation several specific problems have been treated: the anomalous skin effect, the magneto-acoustic effect, magneto-galvanic resistance, and certain aspects of microwave diagnostics. The first two effects are of considerable interest in metals and semi-metals and were studied and extended so as to apply to plasmas. The microwave diagnostic techniques developed here were originally aimed at the interpretation of a specific problem in plasma physics but are of sufficient generality to treat a class of problems involving magneto-hydrodynamic fluids, semi-metals, as well as semi-conductors.

a. The anomalous skin effect (L. Mower and J. E. Mulhern)

The anomalous skin effect refers to the treatment of the electro-magnetic properties of a semi-infinite plasma in which the effect of the boundary on the trajectories of the electrons is taken into account. The "classical" skin effect ignores the influence of the boundary on the trajectories of the electrons entirely. Whereas under classical skin effect conditions the reflection coefficient of a semi-infinite plasma gives information concerning the electron density, under anomalous skin effect conditions the reflection coefficient gives information concerning the temperature of the plasma as well. For this reason the case of a circularly polarized electromagnetic wave incident normally onto a semi-infinite, anisotropic plasma with the dc magnetic field parallel to the direction of incidence has been examined. The anomalous properties were found to be important only in the region of cyclotron resonance. It is questionable whether or not this effect could be observed in an actual plasma inasmuch as diffusion effects might mask the anomalous properties. The important problems to be solved here involve the propagation across the direction of the impressed dc magnetic field in the presence of boundaries.

(Project status: temporarily suspended)

b. The magneto-accoustic effect (R. Brooks and L. Mower)

As an introduction to the literature and the field of both plasma physics and solid state physics, a brief survey of the magneto-acoustic effect in solids was completed. This effect gives a measure of the Fermi velocity in the case of metals and semi-metals; for this reason the theory was extended so as to apply to non-degenerate, high temperature electron plasmas with the hope of obtaining an additional measure of the temperature of a plasma. The results were negative; that is, little information concerning the structure of an electron plasma can be found from the attenuation of sound waves except in the very low frequency range. It is suggested that a multi-ion plasma might be a more fruitful and more physical problem to study provided the motion of the heavy ions is included.

(Project status: temporarily suspended; one publication: a M.S. thesis)

c. Magnetoresistance of semi-conductors (J. E. Mulhern and G. Adams)

An examination of the assumptions underlying the familiar Boltzmann transport equation shows that for semi-conductors it is probably invalid for either $\omega\tau \sim 1$ or $\omega\tau \gg 1$, where $\omega \propto H$, the impressed dc magnetic field and τ is the relaxation time. To study the range of validity, a careful examination of the dc magnetoresistance of germanium was initiated in association with the solid state physics group at Raytheon. (The selection of germanium was made as its energy surfaces are known with more assurance than those of other semi-conductors.) It is the intent of the experimental group at Raytheon to vary both the magnetic field strength and the relaxation time so as to make a smooth transistion from the classical to quantum regions. By stressing experimental accuracy, it is hoped to obtain some insight into the extension of the Boltzmann equation.
(Project status: curently active)

d. Interaction between electromagnetic waves and cold plasmas (L. Mower)

Two parts of a study of the interaction between electromagnetic waves and bounded, cold plasmas have been completed. A general formulation has been developed and applied to treat magneto-active plasmas possessing cylindrical symmetry. Specific applications were made to cavities containing co-axial plasma filaments. A number of modes were studied with the greatest emphasis placed on that mode, TE_{OMN}, for which the effects of the finite boundaries on the properties of the system may be minimized: the electromagnetic properties of the plasma-cavity system for this class of modes are remarkably similar to those of an unbounded plasma. In addition, the formulation was extended so as to apply to hydromagnetic fluids as well as magneto-active dielectrics. (Project status: completed; one publication and one article to be submitted for publication)

II. Administration Notes

a. Theses and publications

"On the Magneto-Acoustic Effect in Metals," a thesis by Richard Brooks was submitted in partial fulfillment of the requirements for the degree of Master of Science in the Graduate School, University of New Hampshire.

"Interaction between Cold Plasmas and Guided Electromagnetic Waves," S. J. Buchsbaum, L. Mower, and S. C. Brown, Physics of Fluids 3, 806 (1960).

b. Personnel and personnel changes

Professor L. Mower (principal investigator)

Professor J. E. Mulhern, Jr.

Mr. Richard Brooks (research assistant)

Mr. Richard Hohly (part-time project assistant, summer 1960)

Miss Elizabeth R. Tuttle (project assistant, summer 1960)

Mr. Gene Adams (research assistant, summer 1961)

Mr. Brooks will continue on in this subject area of physics as a candidate for a Ph. D. degree in Physics at the University of New Hampshire.