REVIEWS

Plasma Physics. By J. G. LINHART. Amsterdam: North Holland Publishing Co., 1960. 278 pp. 50*s*.

It is curious that the Greek idea of the Universe being built of four elements, earth, water, air and fire, has an interpretation in modern physics. These four 'elements' may be compared with the four states of matter in which most of the matter in the Universe exists, namely, solid, liquid, gaseous and plasma, the last being the state in which matter is ionized and consists of free electrons and ions. Although it is probable that more than 99·9% of the Universe is in the plasma state, the study of plasmas has until the last decade been comparatively neglected and has been one of the backwaters of physics, perhaps because the plasma state occurs rarely in nature on the surface of the earth and then only briefly, for example in lightning and other electrical discharges, and is not easily produced in the laboratory. However, the prospect of unlimited power from thermonuclear fusion and the first steps into outer space, together with a growing realization by astrophysicists of the importance of plasma physics in their field, have given an enormous impetus to the subject. To produce fusion in a power station will require exceedingly high temperatures and low densities in which the hydrogen and its isotopes will be changed from the gaseous to the plasma state. Away from the neighbourhood of the earth's surface, man, or rather his rockets and satellites, is moving through a medium which is naturally in the plasma state. As a result, a flood of papers is coming from an apparently exponentially growing number of research workers, and the subject is now one of the most fashionable.

It might be thought that fluid dynamicists, who have so far been concerned with the liquid and gaseous states, would naturally take up plasma physics but few seem to have gone past the half-way house of magnetohydrodynamics or, as the plasma physicists prefer to call it, hydromagnetics. A reason may be the lack of introductory texts on the subject combined with the fact that a study of plasma physics requires knowledge from a variety of fields including electrodynamics, statistical mechanics, special relativity, and quantum theory, which the fluid dynamicist is not likely to have met since his undergraduate days, if then; whereas for much of magnetohydrodynamics the standard methods and techniques of fluid dynamics will suffice. Any introductory monograph is therefore to be welcomed as likely to help the fluid dynamicist find his feet instead of drowning in the literature and the unfamiliar ideas. The book under review serves this purpose reasonably well. It does not start from first principles, but the basic knowledge required by the reader can be found in degree course textbooks. It is basically on the same lines as the brief monograph by L. Spitzer, *The Physics of Fully Ionized Gases*, but is somewhat fuller and more detailed. In particular, the list of references is excellent and remarkably up-to-date, and includes the Russian literature. On the other hand, it lacks the clarity, elegance and insight of Spitzer's book, which the newcomer to the field would be well advised to read first.

An important difference between the mechanics of a plasma and that of a fluid is the existence of long-range Coulomb forces between the particles. Close collisions may in many cases be relatively unimportant and the motion of the plasma can then be described in terms of the motion of a single charged particle in the electromagnetic field generated by the plasma motion and by external means. This is called the single-particle picture, and is considered in the first chapter where the motion of a charged particle in the electromagnetic fields most likely to be encountered in practice is calculated. The treatment tends to be unduly complicated, but it has the virtue of being complete. An account of the various types of radiation emitted by a moving charged particle, bremsstrahlung, cyclotron radiation and Cerenkov radiation, is also included.

The study of individual particles, although often throwing light on the behaviour of a plasma, is not usually a convenient method for obtaining quantitative information, and the next two chapters are devoted to the more appropriate macroscopic approach which essentially regards the plasma as a mixture of two fluids, the electron gas and the ion gas. Moreover, it is necessary to investigate the distribution of particle velocities in the neighbourhood of a point in space, so that in fact a plasma is represented as a fluid in phase space and the basic equation is the Boltzmann equation. Continuum-type equations for macroscopic variables are then obtained by taking the first two integral moments in phase space of the Boltzmann equation and by making some assumption, appropriate to the circumstances, about the collision term and the momentum transfer or stress terms. Here the account is far from satisfactory, for these terms are simply supposed equivalent to an isotropic pressure and the reader is given little clue about the circumstances under which this is valid or about the difficulties which abound here. Various solutions of these equations are obtained corresponding with steady-state or equilibrium configurations of the plasma and the associated electromagnetic field, the best known being the Bennett pinch.

Waves and instabilities in plasmas are the topic of the next chapter. The whole gamut of linear oscillations is run, from hydromagnetic waves to electrostatic plasma oscillations. It is useful to have the whole variety described together in reasonably compact form, and the author can perhaps be excused for his cursory treatment of Landau damping of the electrostatic oscillations. This particular topic has been the cause of many headaches, and a full investigation may possibly be out of place in an introductory text, especially since there is a tendency for its importance to be inflated owing to it being a new phenomenon with no obvious analogue in fluid mechanics. The chapter ends with an introductory discussion of the main types of instability found in plasma motions, and is followed by a brief one on shock waves in plasmas and on plasmoids, the name given to an isolated cloud of plasma. The main features of the phenomena are described and enough is said to make the reader realize that this is a part of the field where theory is still a matter for conjecture.

The next chapter provides an introduction to the difficult and involved question of collision-dominated transport and relaxation processes in a plasma. The dynamics of binary collisions are studied and also the cumulative effects of

many distant collisions which, because of the long-range effect of the Coulomb forces, are particularly important in a plasma; this is followed by the derivation of the Fokker-Planck equation which describes the diffusion in velocity space, owing to collisions between particles, of a non-equilibrium velocity distribution function. Calculations of the transport coefficients for heat, electricity and momentum are also given.

The remaining two chapters are devoted to the applications of plasma physics to problems of practical importance, and it is a welcome feature of the book that these are included. It is all to the good that the more or less academic theoretician should be aware of the engineering problems which need to be overcome. One chapter discusses the problems of controlled fusion, the outstanding difficulties, and possible methods of overcoming them. Of value to the fluid dynamicist is a review of the sources of nuclear energy and the way in which nuclear energy is released. The other chapter deals with the problems involved in the use of plasmas to convert chemical energy directly into electrical energy and for energy storage, with plasma oscillators and accelerators, and (what is almost science fiction) the plasma rocket motor which, combined with a nuclear power source, may be the eventual means of propulsion of interplanetary space ships.

This book shows signs of having been hastily put together, and sometimes presents an oversimplified picture which will irritate the expert. But on the whole it serves its purpose of providing an introduction to and an up-to-date summary of a rapidly developing field.

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