REVIEWS

International Summer Course in Plasma Physics. Danish Atomic Energy Commission, 1960. 645 pp. Dan.kr. 60,00.

In August 1960, the Danish Atomic Energy Commission organized a two-week course on plasma physics at their research establishment Risö. A distinguished team of a dozen lecturers was assembled from half a dozen countries, and over 130 students were enrolled. Only three months later the text of the lectures was published, in a report containing about 200,000 words. Evidently there is much interest in plasma physics these days, and there also seems to be a great deal to say about it. A brief reference, at the end of the report, lists the titles of fifteen additional seminars which took place, but whose text is not reproduced. Surely no group of students or lecturers can ever have worked harder.

Now the study of plasmas is interesting, for many reasons. At first sight a plasma may appear to resemble a gas, for it is compressible and has no structure. But the forces between the charged particles in a plasma are electromagnetic, and act over longer ranges than the forces between the molecules in a gas. Therefore we can normally consider that molecules interact only intermittently, when they approach close enough to each other, and that then they interact strongly. But it is more profitable to think of the particles in a plasma as interacting with each other the whole time, though in most cases the interaction between any pair of plasma particles is weak. Here lies the basic difference between these two states of matter: where close collisions dominate, the outcome of a particular encounter is rather uncertain, and this introduces a randomness into the mechanics of a gas, which is less pronounced in a plasma. A plasma particle interacts, essentially, with a continuum, whose behaviour is more predictable than that of a single molecule. We can therefore follow its progress in phase space more easily. A plasma thus tends to be more internally coherent, and a whole spectrum of waves becomes possible which is absent in a gas. The waves are important because they can lead to the growth of non-uniform electric and magnetic fields.

A plasma will respond strongly to an applied electric or magnetic field, and will at first try to exclude it from its interior, though in the case of a magnetic field this often leads to unstable configurations. In a plasma laced with a magnetic field the paths of the charged particles twist around the lines of force. If high-energy electrons are present, and they seem readily to be produced in such an active medium, they become powerful emitters of electromagnetic radiation.

Even the process of turning a gas into a plasma raises intriguing problems. Though they may have energy enough to detach electrons from one another, atoms and molecules are inefficient in producing ionization. But once a few free electrons exist and have picked up enough energy, the ionization sweeps on like an avalanche. Other interesting effects are the process by which neutrals and ions can exchange electrons, and the way in which contaminants, particularly

ions with one or three electrons, can be excited and then radiate. These are both important mechanisms for cooling a plasma.

Plasmas can be studied in many and widely different physical situations. They occur, for example, in radio stars and in the tails of comets, in the Van Allen belts and the curtains of the polar aurora, in lightning flashes and in television tubes. Yet none of these applications provoked the intensive modern work on plasmas. This is due to the hope that somehow one might be able to confine for a long enough time a plasma which is sufficiently hot, say at a temperature of about 10^8 degrees K. One could then set up a controlled thermonuclear reaction (C.T.R.), make helium from deuterium or tritium, and thus release a vast amount of energy. The confinement must be achieved by a skilfully designed magnetic field. The background to the Risö lectures is the question whether this can be done.

Here must be the hardest technical problem that man has yet set for himself. It is worth thinking about, for after its solution our fuel requirements will be met for the indefinite future. Though no one can reasonably maintain that it is an urgent question, it was, in the curious political circumstances of the last decade, turned into the theme of an international competition, rather like the race towards the moon. Fortunately it has now been realized that the fundamental physics must first be understood. This is quite well reflected in the various lectures. The exception is one contribution, describing a thermonuclear reactor, whose author first disarms his potential critics by admitting that plasmas are too unstable for his liking. His machine is therefore so designed that the plasma is not given time to perform its tricks properly, and by hurrying to forestall it, his machine might just scrape by with a very slight profit. It is all rather touch-and-go, like the old problem of filling a leaky bath tub with both taps full on.

In general the lecturers did not take such a point of view. They may have been thinking about thermonuclear reactors, but in doing so they felt obliged to consider almost all the different aspects of the behaviour of a plasma.

The contributors seem to have had different ideas of their responsibility to the audience. Some are represented in the report by photographic copies of papers published in well-known and highly accessible journals, none of them less than two years old at the time. Should these have been reproduced in the report? Surely anyone who wishes to read them can go to a library and do so. Surely also it is the duty of a lecturer to do more than read to his students extracts from the classics. He should produce the occasional enlightening example, point out the critical stages in an argument, be less insistent on rigour and completeness, and in general make the audience think.

Others again reported on very special studies, recently completed in their laboratories. These may indeed be most significant, but the reader does not know why and the audience was probably not certain either.

Such criticisms apply only to the minority, however. The majority of the lecturers seem to have given accounts of their subjects as proper and as balanced as our present knowledge allows. It is an engaging feature of this book that in some cases the reports reproduce the lectures almost as they must have been given, complete with the occasional slip in algebra or in spelling, and including

a few samples of typical lecture jokes. After reading them for a while one feels as though one were present oneself in the classroom at Risö.

Some of the contributions cause one to feel the same excitement that the audience must have felt on hearing physical problems discussed so lucidly and so graphically. Thus in the first lecture Rosenbluth describes, very briefly but with much insight, the basic dynamical processes of a plasma, and evaluates the characteristic quantities one has to watch. This must be the best introduction anywhere to these topics, and should be compulsory reading for all future plasma physicists.

This exceptionally high level of presentation is not reached again—after all, how could it be? But Rosenbluth scores again in an excellent account of micro-instabilities; other first-class contributions include Thompson's survey of instabilities, Simon's discussion of the collisionless Boltzmann Equation, and Wharton's three lectures on plasma waves and diagnostics.

After digesting the various reports one is deeply grateful to the lecturers for all the new points of view and amazed at the number of physical problems they have raised. Then one begins to wonder whether the material is not too much biased towards the interests of the C.T.R. physicist. To think so would be an unfair criticism. Suppose that a dozen astrophysicists had organized the course. In essence they would have had to discuss the same types of problem, for the nature of the Coulomb interaction, the Boltzmann Equation, the processes of ionization and charge exchange are quite universal. The main difference is that C.T.R. work has sometimes tended to concentrate on the study of some very special configurations, and has thereby distorted the development of the subject. Let a C.T.R. physicist have the last word (Bickerton, on page 453). 'The past experiments have been carried out in systems which were known or are now known to be unstable so that plasma behaviour has been complex and in detail incomprehensible. In the future it is to be hoped that by shifting the complexity to the external apparatus and by making a serious attempt to set up stable conditions in the plasma the resulting phenomena will be simpler and more pleasing.'

F. D. KAHN