Growing Waves

The talented or lucky physicist who discovers broad new laws escapes a good deal of the grief that comes to him who tries to work out their consequences. Certainly, Maxwell's equations and the equations of motion, relativistic or nonrelativistic, are simpler and more memorable than the organized interaction of clouds of charged particles with electromagnetic fields.

Perhaps the study of such interactions began in 1929 with Langmuir's and Tonks' theory of plasma oscillations. Later, Hahn and Ramo applied similar concepts of small, linearized perturbations of a smoothed-out cloud of charge in dealing with the signal on the electron beam of a klystron. Still later, similar calculations were made in connection with traveling-wave tubes and electron-wave amplifiers, in which a beam of electrons interacts with a wave traveling along either an electromagnetic circuit or another cloud of charged particles. Such calculations disclosed "growing" waves, waves whose amplitudes change exponentially with distance.

If waves in electron tubes, why not waves elsewhere, and especially, growing waves? Such waves have been invoked to explain the generation of radio noise in the sun's atmosphere, phenomena in interstellar space, noise in magnetrons, and assorted behavior of plasmas in gas tubes. The mathematical mill grinds swiftly and pours out results quicker than any one person can assimilate them. While it is very well to deduce "waves," it is also essential to understand them.

For one thing, a first-order perturbation theory is usually meaningful only if the unperturbed state exists at some time or place. Certainly, essentially unperturbed electron streams of moderate current can be produced. Perturbation calculations themselves show that beams of higher current would be unstable, but such calculations cannot show what happens when a uniform beam does become unstable. It is not at all clear that unperturbed plasmas exist anywhere or anywhen in direct current gas discharges. The concept of a homogeneous, infinitely extensive cloud of charge, in the sun's atmosphere or elsewhere, surely requires some justification.

But suppose we accept the unperturbed state and seek solutions of the linear partial differential equations to which perturbation theory leads us. There may still be trouble ahead. Especially, velocity distributions are awkward. For instance, it can be shown that strictly there are no wavelike solutions in the case of a Maxwellian distribution of velocities, despite the fact that in a recent paper the equation is "solved" in series form.

Let us, then, consider cases in which the equations do have wave solutions, that is, solutions in which everything everywhere and everywhen varies exponentially (with a complex argument) with time and distance, or at least with time and with one coordinate. The solution of a physical problem requires more than finding special solutions of the partial differential equation; it requires fitting boundary conditions as well. That the gain of a traveling-wave or a double-stream amplifier can be obtained approximately by considering the behavior of one "growing wave" is something of a lucky happenstance. Some apparently "growing waves" do not lead to any gain directly related to their change in amplitude with distance.

Deeper below the surface, there are other things to worry about. When is one justified in smoothing out the cloud of particles into a jelly of charge, and just what error is made in doing so? How is one to take the fine-grained interaction of particles into account? Can one justify the concept of collisions rigorously in dealing with square-law forces?

Papers in the field refer to a variety of earlier work. Oddly, different papers have largely non-overlapping sets of references. Perhaps, some happy day, a Lamb or a Love or a Rayleigh will survey the field of interaction of clouds of charge particles with electromagnetic waves, will reduce matters to order, and will write a book. In the happy thereafter, the perplexed worker will be able to justify and understand his assumptions. The proper connection will have been made with magneto-hydrodynamics. The concepts involved and the methods used will have been related to analogous concepts and methods of other fields, and perhaps particularly of hydrodynamics. In the here and now, confusion reigns. Wary workers advance with great trepidation and some others, seemingly, with none at all.

J. R. Pierce

Notes and Comments

Critical Tables

The critical tables published in this country by the National Research Council (International Critical Tables) are over 20 years old without having had any new additions. It goes without saying that they need complete revision to be useful at the present time. However, during the war photostatic reprints of the latest editions of "Landolt-Boernstein, Physikalisch-Chemische Tabellen" were published and sold in this country at a very high price, thus showing that there is a true demand for this type of scientific publication.

The announcement just recently reached us that there will be starting in 1950 a completely new *sixth* edition of the "Landolt-Boernstein", edited by A. Eucken, published once more by Springer, Berlin-Goettingen-Heidelberg, revised and enlarged to four volumes with the following program:

1st Volume, Atomic and Molecular Physics (part 1, atoms and ions; part 2, molecules, molecular ions, and radicals; part 3, crystals; part 4, nuclei).

2nd Volume, Macrophysics and Chemistry.

3rd Volume, Astronomy and Geophysics.

4th Volume, Technique.

To give an idea about the scope of the whole undertaking it is enough to state that Volume I will cover about 2000 pages and Volume III about 400 pages.

We consider this truly scientific event as a very serious challenge and warning for all scientists in this country who live in the dream-world of belief that they are leading in the scientific world, because they have the biggest atom-smashers and the best-equipped laboratories. One of us (HSJ) has been working for a long time trying to interest all those groups in this country who are supposed to be concerned about scientific research, including government departments, scientific societies, publishers, and research foundations, in undertaking both the revision of the International Critical Tables and, of even greater importance, the translation into English of scientific publications which are absolutely essential for truly fundamental research but which are just non-existent in the United States. The answer from all scientists approached invariably has been that while such a work is very much needed, and the suggested ambitious program would be feasible, still there is no money available for it.

We, therefore, want to ask the following questions:

1. Is it really necessary to depend upon Germany, where money is scarce and paper scarcer, to do this monumental work?

2. What is lacking in the attitude of all the American groups who are responsible for scientific publications?

3. What will and must be the reaction of the European, Russian, South American, Indian, Japanese and all other scientists in the world, when they can throw the "American Tables" into the scrap heap and will replace them by a brand new German edition?

4. Are we still in the adolescent stage where, although we have assembled here most of the best scientists in the world in all fields, we rely on European publishers for this work?

5. (Perhaps the most interesting question) Could it be that all the American publishers make a grave mistake in their calculations, that, after all, the publication of such an expensive work as the new "Landolt-Boernstein" is not a "bad business" at all, that in the long run it pays out high dividends? Surely, publishing houses like Gauthiers-Villars, Springer, and Teubner understand their "business" at least as well as their American colleagues, and we cannot imagine that they would undertake any great publishing venture if they knew beforehand that they would lose hundreds of thousands of dollars.

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