"I see . . . a physicist is a kind of an electrician!"

Early in May, 1949 the Acoustical Society of America held its twentieth anniversary meeting and in recognition of current attitudes grouped its papers functionally. With the main theme "Acoustics and Man," acoustics was discussed in relation to the arts, to health and comfort, to communications, and to research. This article is taken from an invited paper.

ACOUSTICS and MODERN PHYSICS

*by **Philip M. Morse***

Before the war it was always hard for a physicist to know what to answer when asked what he did. Any answer which included the word "physics" resulted either in complete lack of recognition or in some form of medical humor. I am reminded of a friend who spent a confused and confusing time with a local draft board, some seven years ago, in a small middle western town, trying to explain why a young physicist should not be transformed into a G.I. just then. After a series of dissertations and questions and explanations on the subject of "what is a physicist?" my friend saw a gleam of understanding appear in one pair of eyes. "I see," said one of the board members, "a physicist is a kind of an electrician! Why didn't you say so?"

Nowadays it is different, though I must say I haven't got used to it yet. As before, I try to avoid the question of what I do, and I still get astonished when people know what I mean (or think they do anyway) when I finally admit I'm a physicist.

I wonder if this new public awareness will have any effect on inhibiting the tendency of the various branches of applied physics to dissociate themselves from the main stem. I forget who it was said that the difference between chemistry and physics was that no matter how practical the chemist became he was still a chemist, but as soon as a physicist became practical he called himself an engineer. At any rate the implication that most of the branches of engineering are really branches of physics, and that the engineers haven't cared to admit it till recently, is one to ponder over.

Give and Take

We in acoustics are certainly aware of the close connection between our specialized field and the rest of physics. Our "bible" was written by Lord Rayleigh, who left his mark on nearly all branches of physics of his day. Our experimental techniques are by now completely dependent on the electronics specialists and our terminology is close to that of a communications engineer. We show our awareness of this interdependence by being members of the American Institute of Physics and by many of us being members of other affiliated societies.

The interdependence between acoustics and electrical engineering is obvious. Electrical engineering is of course a recent offshoot from the main trunk: the electrical engineering course at the Massachusetts Institute of Technology, for example, was given by the Physics Department until after 1900; and the subject of electronics is still in the process of being transferred from physics to the engineers. Early in life electrical engineering borrowed many of its concepts and techniques of calculation from the theory of vibrations and of sound. Nowadays we borrow many of the concepts and terminology of AC circuits.

The exchange is not all one way, even now. During the war, as radar was developed and electromagnetic waves shrank to the size of usual sonic waves, the theory of sound transmission in pipes and radiation out of horns suddenly became applicable to wave guides and microwave antennas. By now, I believe, acoustical engineers could learn from the microwave specialists a number of useful techniques for measuring impedances and for testing and rating power generators. Some of the idiosyncracies of magnetrons are similar to those of loud speakers, for instance.

The interrelation between the theoretical techniques of various branches of physics is quite close. Characteristic value problems, with quantized states and eigen functions, were first encountered in acoustics and vibration problems, and only later taken over by wave mechanics. Although Fourier perfected his famous series to compute the flow of heat, it has been used, before and since, for calculating the vibrating string. Once the governing equations are shown to be the same, the theoretical analysis is indifferent as to whether it is dealing with compressional waves in air or meson waves of probability, with the flow of heat in a solid or the flow of neutrons in a nuclear reactor. Consequently it is always useful for workers in any field to keep in touch with theoretical advances in other fields.

Experimental techniques are also important in cross-fertilizing the various branches of physics. All of them now use electronics as a tool. Many of them are using ultrasonic echo-ranging as means of exploration. The measurement of the speed and attenuation of first and second sound in liquid helium, for instance, has proved to be a sensitive means of determining the properties of this peculiar substance. The natural frequencies of standing compressional and shear waves in a crystal provide one of the most accurate means of determining the elastic constants and internal friction of the crystal and are good indicators of the various phase changes at different temperatures. It is always wise for us to be familiar with new techniques, for they often turn out useful in many branches.

It is the cumulative advantage of this cross-fertilization which forms the most convincing argument against the interposing of secrecy barriers and the military or political control of scientific publication. Discoveries in one field inevitably affect other fields, and the throttling of interchange of ideas inevitably slows progress.

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Needed: A Stockpile of Data

The two branches of physics undergoing the most intensive development at present are those of nuclear structure and of solid structure. Both of these fields are using the techniques and knowledge of all the rest of physics in their progress and, vice versa, discoveries in these fields will prove useful in all others.

Bell Telephone Laboratories.

Nuclear physics has reached a stage where more experiments, of greater accuracy, are needed before theory can progress. The equipment needed to obtain data about the smallest particle turns out, paradoxically, to be immensely large and expensive. Thus many nuclear scientists have temporarily become engineers, designing and building installations more powerful than many hydroelectric plants and more complex than many telephone exchanges.

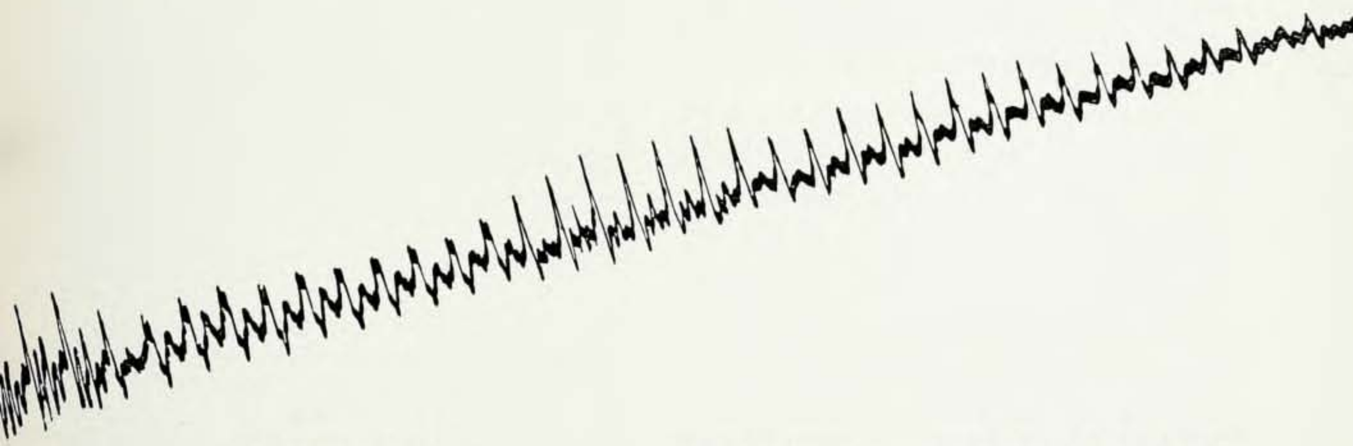
The control mechanisms in the Brookhaven reactor, for instance, must be able to move several feet in less than a second and yet have an accuracy of fractions of a millimeter. They must respond continuously to small changes in temperature, neutron density, and many other properties of various parts of the huge structure. The electrical connections, relays, and other equipment for this control fill a good-sized room and yet the pertinent information concerning the state of affairs must be clearly presented to the master operator at all times. It must be possible to place material at a predetermined spot inside the reactor, and then to remove it, sometimes within fractions of a second. All of the uranium fuel must be capable of continual check and of removal and replacement if necessary. Yet once the reactor has come to full output power no person can ever thereafter go inside the encasing shield to repair, adjust, or lubricate any part of the structure. All this must be done by remote control.

The cooling air will be drawn through the pile at rates of speed and in quantities requiring careful aerodynamic design to maintain efficiency. The blower fans pulling this air through the reactor and pushing it out the three hundred foot stack will use several thousand kilowatts at full load. Thought has been given to silencing the fans and an acoustic supermuffler has been inserted in the output tunnel to prevent the stack from becoming a huge loudspeaker, broadcasting the fan fundamental over the country side.

Certainly the techniques and knowledge of all physics and engineering are needed to make this huge laboratory instrument efficient, effective, and safe. Conversely the results flowing from experiments made with the reactor will affect all the sciences. A pile of this size creates neutrons literally by the pound, and these chargeless particles are highly useful in exploring matter. Neutron diffraction shows up details of molecular or crystal structure unobservable by x-rays. And, of course, neutrons can be added to nearly any ordinary nucleus to produce radioactive isotopes, which are already revolutionizing the techniques of following chemical or biological reactions and which give promise of therapeutic uses in medicine. The effect of all this on acoustics will probably be indirect, but will be as definite as the effects of discoveries in electronics have already been.

Turning now to the other sector of physics in which major advances are being made, that of the structure of solids, we find the cross linkages with acoustics much more direct. The techniques of ultrasonics, developed during the war, turn out to provide an extremely useful tool for measuring the forces between atoms in the structure and for determining their dependence on temperature and pressure. Only recently have these techniques been used in the fascinating region of very low temperatures, and it is to be hoped that they may help in unravelling some of the mysteries of this region.

Bordoni has measured the speed and attenuation of sound in a superconductive metal and has found variations in these quantities as the temperature is lowered through the superconducting point. These results, plus the interesting interrelations between first and second sound which have recently been found in liquid helium, give hope that detailed acoustical measurements at very low temperatures may help to explain phenomena there.



Hand in Hand

But in spite of these and other examples of cross-fertilization of techniques and ideas in modern physics, the problem of holding together the increasing varieties of activity in physics is becoming more and more difficult. The American Institute of Physics now publishes nine journals. The last annual meeting of the American Physical Society, in New York last January, had a program comprising over three hundred papers, with at times as many as seven concurrent sessions. With so much going on it is impossible to keep up with everything and there is temptation for workers in various fields to drift further apart.

Further fragmentation of the field of physics would, I feel, be detrimental to all the fragments, and should be resisted actively. One of the major lessons of our war research was the immense value of close cooperation between specialists in varied fields. The American Institute of Physics is a symbol of our desire to maintain this cross-fertilization and its activities constitute an offer to improve intercommunication between the various specialties.

There is, of course, a broader aspect to this cooperative effort related to our duties as citizens. Scientists are not uniquely capable of running the country and deciding what the world should do. But, with our special knowledge of techniques and with our habits of impartial, nonemotional thinking, we can help this country make wise decisions in the many crucial military and economic problems which we now face. The crucial question of this century, the problem of balancing the availability of power and food with the continued increase of population, is one which needs continual thought and help from all branches of science.

We have no iron curtains in science in this country, nor will we as long as we keep our channels of intercommunication open and busy. We are not told what science should do, what it should be, and what it should not be, nor will this happen as long as we are aware, in all branches of science, that the struggle for truth and knowledge is a cooperative struggle.