Physics and Engineering in a Free Society

2. INDUSTRY

By E. R. Piore

THESE days there is a strong coupling between science and technology, between physics and engineering, and we tend to forget that this coupling in our free society is relatively recent. Going back to the eighteenth century and the beginning of the nineteenth century, one finds that science and technology—and today in this room it is physics and engineering—were two independent activities. The industrial revolution of the eighteenth century occurred without the benefit of science. We had in the eighteenth century a metallurgical industry, we had the steam engine, we had other complex (complex for those days) industrial activities, and they had their own independent intellectual dynamics. Science also had its own independent drive, motivation, and creativity. Science—physics—does enter into the picture as we examine the events of the nineteenth century. Watt invented and produced a workable steam engine, but the whole science of thermodynamics—the first law, the second law, the Carnot cycle—became part of our scientific structure much later in the nineteenth century. These scientific concepts then became the basis of further improvement of the steam engine, the internal combustion engine, the new sources of power in that century. Thus we see an example where, first, an inventor comes up with a useful concept for industry and where its further development and its further utilization then depend on creative work in science. This role of physics, I think, characterizes the nineteenth century.

Another example is the transmission of information over wires. The initial effort in this country was the construction of a telegraph line between Washington and Baltimore. Among the names that come to mind are Morse and Cornell, both of whom participated in what was a great engineering achievement. However, the realization of a workable cable between Europe and this continent required the intellectual intervention of the best that contemporary physics could offer. If my memory serves me right, Lord Kelvin was one of the principal contributors to the final design of the first Atlantic cable.

Another classic example is the incandescent light. It was invented, but it required the genius of people like Langmuir and the group immediately around him at General Electric to do some real physics in order to make an incandescent lamp, a common article in our contemporary civilization. One saw this role of the physicist in some areas in the last War. The magnetron as an invention was studied with some intensity by engineers prior to 1939–40. It became a practical component of a very real engineering system when physicists moved in, and this is symbolized by the Radiation Laboratory at MIT.

Thus we see one historical function of the physicist in relation to engineering: that of his taking inventions —initial engineering concepts—and bringing to bear on those inventions the best that science can contribute. This then becomes the jumping-off point for the engineer to make the economical and marketable products which we see around us in our complex industrial civilization.

Physicists have made other contributions independent of engineers, of which the two best examples are the nuclear bomb—nuclear energy—and the transistor. These were technical achievements that were created out of science without any reference to prior invention or engineering.

In our contemporary society we therefore see two functions of the physicist: one (to put it in less glamorous words) has to do with product improvement, and the other with the introduction of new and "exotic" products, or product innovation. The examples that I have cited had their impact on the employment of physicists in American industry. Starting from a modest beginning (before 1935) with a few industrial laboratories such as General Electric and Bell Telephone Laboratories, one finds an expanding demand by industry for physicists and the creation of numbers of industrial laboratories employing physicists.

THE question I would like to pose now is whether this demand for physicists by industry will continue. Engineering training has gone through what might almost be described as a revolution, and the training that a physicist receives these days has been modified profoundly from the days prior to and immediately after the War. I would like to examine this briefly. In order to make this point, I'd like to draw on my

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personal experience, and I'm sure you will be tolerant of these reminiscences. I received my graduate degree in the middle thirties. In those days each graduate student had a thesis problem, and conducted his own research. The totality of research among the graduate students covered many fields of physics. There was a community of spirit, a community of junior scholars in the graduate group, that was small compared to present standards. This daily contact, this daily conversation, broadened each graduate student. At the very least, he acquired the vocabulary and the jargon of many fields of physics. He became aware of the experimental problems, experimental techniques, and the headaches that his colleagues faced. And thus this community of junior scholars living together, rubbing shoulders with each other, broadened the individual graduate student and gave him some feeling and understanding of the broad field of contemporary physics.

By now our graduate schools in physics have increased by a factor of five or more. Special laboratories have been built for very specific fields and the graduate student is now associated with these special laboratories and gets his broader view of physics only in the lecture hall or at the colloquium. It remains to be seen whether he comes out as broad-gauged as the graduate student of twenty-five years ago. He certainly knows more physics, he certainly knows his specialty more thoroughly, but he certainly has lost the direct contact with the experience that did the broadening years ago.

In contrast, going back twenty-five years to the graduate training of engineers, first one finds that there were very few men who did graduate work in engineering. There was a high degree of compartmentalization among departments in engineering schools. So the PhD in engineering in those days obtained a very narrow training, unless he somehow got drawn in with the graduate students in the physics department. On the contemporary scene one finds an increase in the number of graduate students in engineering; one finds the melting away of the narrow boundary lines between the engineering departments; one finds a renewed emphasis on fundamentals; one finds that the engineering graduate schools are reaching critical size. So one does broaden himself by being in contact with one's contemporaries.

For these reasons I raise the question of whether men trained in engineering may not be able to make a greater contribution than those trained in physics. I do not know the answer, and I just raise this question in this assembly.

MY final observations deal with the question of what industry needs for continued technical growth. At the beginning of the talk I cited the requirement for product improvement, symbolized by such examples as the steam engine, the Atlantic cable, and the incandescent lamp. This will be a continuing need. Pragmatically, industry will determine whether physicists are more useful or whether engineers are more useful in terms of their contemporary training.

The second need is to evolve new products—I am using the word "products" here very broadly. This requires an element of inventiveness, an element of risk-taking. The inventor in the classical sense does not have the intellectual background necessary at present to make a very important contribution, and we will have to continue to look to the physicist or the engineer who has the instincts of an entrepreneur. In this area it is not training but a certain quality of mind that is the most important single attribute. And it remains to be seen whether the young people with this special gift will be attracted to physics or to engineering during their academic days.

Finally, there is a new area that everyone talks about, and this is what is known as systems and systems engineering. One of the reasons for the great success of the radar systems that came out of the Radiation Laboratory of MIT was the training that nuclear physicists had previously acquired in building particle accelerators, which are complex systems. Nuclear physicists, or machine designers and builders, are now engaged in some of the most complex systems design that is going on anywhere in the world.

As to the place of origin of the needed systems experts of the future, I can make no prediction. Possibly they will also come from nuclear physics. In all likelihood, they will have to be trained in the industrial laboratories.

I am sorry that I was able only to raise problems, and not give their solutions. In the final analysis, universities must have very firm convictions as to what type of people they want to turn out, and we in industry can make certain observations that may be helpful to our great academic institutions.