SCIENCE AND THE ENGINEER

Some reflections on the engineer's function in our increasingly complex technological culture

by M. A. Biot

It is a great honor to be associated with the name of Timoshenko, the teacher, the scholar, the great engineer and scientist. It is widely agreed that the high level of instruction and application of solid state mechanics in this country is due to his influence and his teaching.

However, to me the name symbolizes much more than the award and the honor.

It evokes a brilliant phase and tradition in the practice of science and engineering which unfortunately seems to be on the decline. This is the tradition of clarity, simplicity, intuitive understanding, unpretentious depth, and a shunning of the irrelevant.

There is, of course, no merit in sophistication for its own sake. In the understanding of the physical world, and particularly in the area of technological applications, it is important to perceive what is irrelevant. The level of irrelevance involves a value judgment which usually requires rather subtle habits of thought related to natural endowment and previous experience.

We should not overlook the importance of simplicity combined with depth of understanding —not only for its cultural value, but as a technological tool. It leads to quantitative predictions without laborious and costly calculations; it suggests new inventions and simple solutions of engineering problems. Aside from obvious economic advantages, it also provides an important quality in engineering design – namely reliability. In this respect one cannot help but reflect on our dismal record of staggering cost and repeated failures in the field of rocketry.

Deeper physical insight combined with theoretical simplicity provides the short-cut leading immediately to the core of extremely complex problems and to straightforward solutions. This cannot be achieved by methods which are sophisticated and ponderous even in simple cases.

The process of thought which is involved here may be described as "cutting through the scientific red tape" and bypassing the slow-grinding mills of formal scientific knowledge. Of course, formal knowledge is essential but, as for everything in life, the truth involves a matter of balance. The instinctive embodiment of this truth is to be found more often in the politician than in the scientist. However, it is essential to the make-up of a competent engineer.

Doubt about the engineer's function in our increasingly complex technological culture has been expressed by the blunt question, "Is the engineer obsolete? Should he be replaced by the scientist?" Although such a question is the product of ignorance, the situation is such that, in this country at least, it finds a respectable echo.

continued on page 34

"Science and the Engineer" has been adapted from the acceptance speech given by Dr. Maurice Biot when he received the Timoshenko Medal from the American Society of Mechanical Engineers in New York on November 27, 1962. The medal, named in honor of S. Timoshenko, authority in the field of mechanics of materials, is given for "distinguished service or achievement in science or engineering." Dr. Biot, who received his PhD in aeronautics from Caltech in 1932, is a private consultant in physics, mathematics, and engineering in New York.

What about the physicist? Speaking in general, and with due respect for exceptional personalities endowed with outstanding natural ability, I think the physicist has turned away from his own tradition and has tended to become a victim of narrow specialization. Nuclear and particle physics, solid state, spectroscopy, plasma physics, all claim their victims. Many are almost totally ignorant of classical mechanics and are not able to understand the formulation of even a simple problem unless it can be reduced to the solution of a Schroedinger equation.

As for the mathematician, a situation has developed which is a complete reversal of what existed in the past. Many of the great names in the history of mathematics of the nineteenth century have been those of distinguished engineers. An outstanding example is Cauchy, who graduated as a civil engineer and was engaged in the practice of engineering for many years. These men were of a different breed. They had a deeper grasp of scientific knowledge, a much broader outlook than the professional mathematician of today.

Dehumanized mathematics

Whatever the cause of this reversal, we must face the fact that mathematical science has become dominated by abstract formalism. It is increasingly dehumanized and cut off from its roots in the rich and nourishing soil of physics and engineering, and the other natural sciences. What should be referred to as applied mathematics does not exist on its own, but describes essentially a function and a craft by which the science of mathematics finds its nourishment.

Much of the so-called applied mathematics which is practiced today is almost diametrically opposite to this function. It is permeated with legalistic hairsplitting, shrouded in pretentious language, as if the purpose were to obscure and surround with an aura of mystery and profundity what is very often a simple and even trivial subject.

This trend toward a formalism devoid of humanistic content, this emphasis on form at the expense of substance, is found not only in science. It also prevails in our contemporary art and literature and obviously results from deeper, and perhaps self-destructive, undercurrents in our culture.

It constitutes a retrogression toward the abuses of medieval scholasticism and away from that intimate union of craftsmanship and science so characteristic of the Renaissance period. In this connection I recall a quotation from Ortega y Gasset, in his book, *Man and Crisis:*

> "Life is not to be lived for the sake of intelligence, science, culture, but the reverse; intelligence, science, culture, have no other reality than that which accrues to them as tools for life. To believe the former is to fall into the intellectualistic folly which, several times in history, has brought about the downfall of intelligence."

Generally speaking, the professional mathematician has become a specialist in logical systems and rigor. His lack of flexibility makes him unable to exercise one of the very essential functions of mathematics in the natural sciences and engineering, which is to separate the relevant from the irrelevant, to simplify the formulation of complex phenomena, to synthetize and to unify the substance rather than the form.

There is no time here to dwell on the details. For contrast, let me cite only the brilliant treatment of the Navier-Stokes equations by Prandtl in his famous theory of the boundary layer.

There is, however, a more ominous aspect of this situation which brings up the matter of education of scientists and engineers.

We should remember that intuitive ability closely resembles artistic talent. It may be developed or it may be smothered, depending on the environment and the training. Rigor and abstract formalism are technical aspects of mathematics which may actually impede invention. They are for the specialist. The engineering student should be exposed to them only as an experience. They should not pervade his thinking nor exceed the point at which the intuitive faculties become inhibited.

Developing creativity

In many schools the hard core of mathematical and physical knowledge is submerged in a flood of special courses characterized by abstract-formalistic overtones. There is an emphasis on formal knowledge rather than understanding and the climate is not favorable to creative talent. It should be remembered that one of the important functions of a school is to discover, encourage, and develop talent and not only to transmit knowledge.

To make the situation worse, we are now witnessing the introduction of the abstract axiomatic

continued on page 36

approach in high school mathematics. Such a development involves great dangers to our future scientific and technological standing. It has been said that "Learning is the kind of ignorance distinguishing the studious." I don't want to downgrade studiousness, but I don't think knowledge should be an obstacle to understanding.

While I have dwelled on the more gloomy aspects of this situation, I would like to conclude with a more optimistic note.

Let us hope for a revival of humanism and a spirit of synthesis in science. Let us also put new emphasis on engineering as a professional craft, requiring high skill, natural talent, deserving social recognition, and distinctly different from the scientific professions as such. New stirrings are appearing in this direction. I am inclined to believe that engineers and engineering schools will play an important part in restoring the unity and central viewpoint in the natural sciences. This is because modern engineering, by its very nature, must be synthetic. Specialization carried to extremes is a form of death and decay.

One could formulate a principle of degradation of knowledge entirely analogous to the second principle of thermodynamics. It represents a powerful force which can be defeated only by a hard and difficult struggle. The burden of it must be carried, not by teams and organizations, but by a few individuals. In this connection there is much to be said for the smaller schools. They should provide a better environment for unhurried maturing of thought and for the nucleation process by a very small number of qualified people.

It has been customary for the recipient of an award to avail himself of the opportunity to reflect on current problems of professional interest. While I do not pretend to have brought to light any really new ideas, it seems to me that the occasion was most appropriate for their reemphasis in the framework of the Timoshenko tradition.

In this future synthesis and the revival of technological craftsmanship, I think we all agree that in the practice as well as in the teaching, engineers are called upon to play a very fruitful and essential part.