ENGINEERING AND ENGINEERING SCIENCES*

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Introduction

When one reviews the development of human society in the last half of century, one, is, certainly struck by the phenomenal growth of the importance of technical and scientific research as a determining factor in national and international affairs. It is quite clear that while technical and scientific research was pursued in an unplanned individualistic manner during the earlier days, such research is now carefully controlled in any major nation. Thus technical and scientific research has become a matter of state along with the age old matters such as the agriculture, financial policy, or the foreign relations. A closer examination for the reason of such growth of the importance of research would naturally yield the answer that research is now an integral part of modern industry and we cannot speak of a modern industry without mentioning research. Since industry is now the foundation of a nation's strength and welfare, technical and scientific research is then the key to a nation's strength and welfare.

But then one might argue that since the pioneering days of industrial age, technical and scientific research was related to the industrial development, then what is exactly the reason for making the research so important today? The answer to this question is the rate at which the modern industry is forced to develop due to national and international competition. At this rapid rate of development, research must be greatly intensified with the almost immediate application of basic scientific findings. Perhaps, nothing is so dramatic as an illustration as the wartime development of radar and nuclear energy. That the successful development of radar and nuclear energy contributed much to the victorious conclusion of the World War II in the side of Democracy is an established fact. Thus here intensive research has brought the findings of the basic science of physics through practical engineering and to successful applications to weapons of war in the short interval of a few years. Thus the distance between a pure scientific fact and industrial application is now very short. In other words, the difference between a long-haired pure scientist and a short-haired practical engineer is very small indeed, and a close cooperation

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between them is essential for the successful development of the industry.

This need for close cooperation of the pure scientist and the practical engineer produced a new profession—the engineering research men or engineering scientist. They form the bridge between the pure science and the engineering. They are the men who apply the basic scientific knowledge to engineering problems. The purpose of the present article is to discuss what the engineering scientist can do, what is their job, in engineering, and then what kind of education and training he needs in order to do the job assigned to him.

Contributions of an Engineering Scientist to Engineering Development

The contributions of a engineering scientist to engineering development can be briefly stated as the economy in effort both in manpower and in money. This economy is achieved through a sound and general analysis of the problem on hand to point out 1) whether a proposed engineering scheme is at all possible 2) if feasible, what would be the best way of carrying out the proposal and finally 3) if a certain project failed, what is the cause of failure and what would be the remedy. It is needless to say that if an engineering scientist can fulfill these assignments then the cut and try in any research and development is to a large extent eliminated. All the effort and money can then be concentrated on the best approach or the few better methods of attacking the problem having the best chance of success.

It might be argued, nevertheless, that these three main problems assigned to the engineering scientist are really the three basic problems in engineering. What is that an engineering scientist can do which an engineer cannot do? The answer to this question is that as the engineering profession becomes more and more ocomplex, there is a need for specialization. The present requirement of knowledge for a satisfactory solution of its three problems stated includes a good training not only in engineering but also in mathematics, physics and chemistry, as will be discussed in greater detail in the subsequent paragraphs. Therefore the training of an engineering scientist is quite different from the conventional training of an engineer. In other words, he must be the specialist to solve just the three basic problems of engineering development.

The Feasibility of a Proposal—Long Range Rockets

To gain a better understanding of the way in which an engineering scientist solves the three basic problems of engineering development, a few illustrative examples will be described. The first example is the investigation of the possibility of extremely long range rocket. A rocket is propelled by the reaction of the exhaust jet obtained through the combustion of the propellent carried. The performance of the rocket motor is expressed as the specific propellant consumption in pounds of propellant per hour required to generate one pound of thrust. This figure is slightly modified by the change of the atmospheric pressure, but can be generally taken to be constant and equal to an average value. The specific propellant consumption then fixes the motor performance. The range of the rocket will evidently depend upon the amount of propellant carried, i.e., the ratio of the propellant weight to the gross weight of the rocket. This is the propellant loading ratio. The rocket, during its flight, is opposed by the air resistance. We see thus that for an engineering scientist to solve the problem of the possibilities of long range rocket he has to have three kinds of basic information: the rocket motor performance, the structural efficiency and the aerodynamic forces at high speeds. For rocket motor performance he will depend upon the rocket engineer for test data. For the structural efficiency he will depend upon the stress man for data. For aerodynamic forces at high speeds, he will depend upon the high speed wind tunnel testing for data. The engineering scientist on the job must then synthesize these informations by good engineering judgment, by the application of the laws of dynamics and the skill of solving differential equations. The result is the calculated range of the rocket. If he uses the best rocket motor performance, the lowest practical value of specific fuel consumption, if he uses the best construction to achieve the highest propellant loading ratio and if he uses the best aerodynamic design of the shape of the rocket to minimize the air resistance, he will then obtain the largest range that can be achieved by a rocket.

This formulation of the problem of long range rocket assumes that the best motor performance, best structural efficiency and best aerodynamic shape are known to the analyst. But the real situation may not be so easy. An engineering scientist will find that while previous experience shows that the performance of the propellant can be predicted to within 10% accuracy by making a careful calculation of the combustion temperatures and the composition of the exhaust gas using chemical and thermodynamic equilibrium in the motor combustion chamber and by then calculating the exhaust velocity of the rocket using the dynamics of gaseous flow, the types of propellant actually tested are very few. In searching for the best possible motor performance, he may wish to know the probable specific propellant consumption for more energetic chemical reactions hitherto untried. This means the engineering scientist has made the theoretical estimate of these untried propellants. For instance, he may wish to calculate the performance of the liquid fluorine and liquid hydrogen rocket. If he does this kind of calculations, he will find two important facts about chemical rocket propellants. These are:

1) There is a strong tendency for the ordinary combustion

products such as carbon dioxide, and water to dissociate at the extremely high temperature of the combustion chamber and these dissociations absorb heat. Therefore calculations on the propellant performance using low temperature calorimeter data is totally unreliable. In other words, thermodynamics and chemical equilibrium are matters of primary importance here.

2) There is no "wonder" propellant which will give a tenfold increase in the performance, i.e., lower the specific consumption to one tenth of the value for present propellant. This is easily seen in the following table (Ref. 1) which shows that the best propellant is the combustion fluorine and hydrogen which gives a specific consumption not less than one half of the more conventional nitric acid and aniline combination.

Hence by this kind of investigation, the engineering scientist can achieve a broad orientation in an entire new field of engineering. He knows what to expect and is able to judge critically the validity of claims made by any inventors. Such ability of judgment generally requires years to achieve, if try and error is the only method used. Engineering science is then the useful tool to shorten this crucial process of "learning the trade".

Similarly, the engineering scientist may find the information and structural efficiency and aerodynamic forces quite incomplete. He is then forced to investigate a particular promising type of structure or to investigate a high speed flows over aerodynamic shapes to determine the probable air resistances at high speeds. In other words, to solve the problem of the possibility of long range rocket, the engineering scientist may be required not only to solve a very difficult problem in exterior ballistics but may also have to solve problems in thermodynamics and combustion, in elasticity and strength of materials and in fluid mechanics. His problem is thus not easy, but his reward is also large.

Rocket Propellants

CALCULATED PERFORMANCE AT SEA-LEVEL, CHAMBER PRESSURE IS 20 ATMOSPHERES

Oxidizer	Fuel	Oxidizer/Fuel Weight ratio	Chamber Temperature ° Rankine	Specific Consumption lbs. per hr. per lb. thrust
Fluorine	Hydrazine	1.186	6,970	12.33
	Hydrazine	2.371	9,500	11.50
	Hydrogen	18.85	10,210	10.20
	Hydrogen	9.42	8,530	9.71
	Hydrogen	6.28	6,296	10.20
Oxygen	Ethyl Alcohol (75%+Water 25%)	1.275	5,530	15.45
	Gasoline	2.62	5,930	14.95
	Hydrogen	3.80	5,500	10.20
Red Fuming Nitric Acid	Aniline	3.000	5,525	16.30

Best Method of Attack—Manufacture of Fissionable Material

Very often in engineering practice, one is confronted with the problem of choosing the best method of attack among a possible few. Here again the services of the engineering scientist is invaluable. Let us take the example of the manufacture of fissionable material. According to H. D. Smyth (Ref. 2), the different possible methods are:

1) Manufacture of plutonium—239 by the slow neutron pile using natural uranium and the chemical separation of plutonium.

2) Manufacture of uranium—235 by electro-magnetic separation from the inert uranium—238 in the natural uranium.

3) Manufacture of uranium—235 by separation from uranium—238 utilizing thermal diffusion.

4) Manufacture of uranium—235 by isotope separation utilizing gaseous diffusion.

All methods except the first are involved in a physical process in that the materials to be separated have "identical" chemical properties. During the development of nuclear energy for the atomic bomb by the United States, all four methods were pursued. This way of attacking all possible methods simultaneously is certainly a wartime expedient when the time is very limited and the success of the project is a dire necessity. In normal times, engineering scientists should be called into service to analyze the four different processes to determine which one of them is the most economical. Of course, the engineering scientists will need much detailed information which must be obtained by either theoretical analysis or experimentations. For instance, in the first method, he would have to determine the fission cross-section, or fission probability, of uranium-235, the resonant absorption cross-section of the moderator, etc. Then by the known principles of nuclear physics, he has to work out the process of the diffusion of neutrons in the pile, the distribution of neutron density in the pile, and finally the critical size of the pile. He has also to find the best method of constructing the pile by trying out in his calculations the different ways of placing the pieces of the uranium and the moderator. After all this investigation, the engineering scientist is able to say that the probable economy of the manufacture of plutonium-239 is by the slow neutron pile method.

Now by a similar approach with laboratory experiment and theoretical calculation, the engineering scientist would be able to estimate the economy of all other proposed methods. Then the question of the best method to manufacture the fissionable material can be answered. It is quite evident now that if such an analysis of the relative economy of the different processes were possible, the plutonium process, or method 1), will be the chosen method. General Leslie R. Groves has revealed to the McMahan Committee that as of June 1945, the monthly operating cost of the processes were:

Hanford Plutonium Plant	$ 3,500,000
Oak Ridge Diffusion Plant	6,000,000
" " Electro-Magnetic Plant	12,000,000

Thus the Hanford Plutonium Plant is the most economical one in spite of the fact that it must be the one with the largest capacity for the fissionable materials.

Now suppose the preliminary analysis by the engineering scientist decides on the plutonium process, what would be the consequences? According to General Groves again, the investment spent and committed for plants and facilities as of June 30, 1945 is as follows:

Manufacturing facilities:			
	Hanford Plant	$350,000,000	
	Others	892,000,000	
			$1,242,000,000
Housing for workers:			
	Hanford Palnt	$ 48,000,000	
	Others	114,500,000	
			162,500,000
Research			186,000,000
Workmen's compensation and medical care			4,500,000
Total			$1,595,000,000

Therefore if the authority that directed the development of nuclear energy for the United States during wartime were able to decide on the plutonium process, then approximately one billion dollars could have been saved. In other words, two thirds of the investment could have been saved, if it were possible to use fully the services of engineering scientists.

Reason and Remedy for a Failure—the Tacoma Narrows Bridge

The third problem which may require the attention of an engineering scientist is the discovery of the reason and method of remedy for a failure. While the two previous problems the investigation of the feasibility and the best method of attacking a new development, are work to be done before starting the main part of the engineering, the third problem is, of course, something to be done afterwards. Let us take the example of the Tacoma Narrows Bridge. This bridge was first opened to traffic on July 1, 1940, and it was a suspension bridge of extremely narrow roadbed, as can be seen in the following table of dimensions:

Dimensions of the First Tacoma Narrows Bridge, Washington, U. S. A.

Center Span	2800 ft.
Side Span, West Side	1100 ft.
Side Span, East Side	1100 ft.
West Side, Back Stay	497 ft.
East Side, Back Stay	261.8 ft.
Total Length	4759.2 ft.
Width of Roadway	26 ft.
Total Width including sidewalks	39 ft.

After this bridge was built, it was found that the bridge was extremely flexible. During windy nights, a ghost effect often occurred as the head lights of approaching cars appear and then disappear caused by the lateral and longitudinal oscillation of the roadway. On 10:00 A. M., November 7, 1940 the bridge started to oscillate rather violently in torsion by the prevailing strong wind. This oscillation increased its amplitude and finally an hour later the bridge broke at approximately the mid-span. Of course, there is then developed among civil engineers great interest as to the cause of failure of the bridgé, a kind never observed before. Civil engineers normally deal with static forces of rather large magnitudes. For instance, the stress in the bridge member is generally of the order of tens of tons per square inch. Now the air or wind forces on a surface is probably of the order of one fifth of a pound per square inch. It was rather difficult at first for the civil engineers to understand how such small wind forces could have broke the strong bridge.

The true mechanism of failure was finally explained by a Committee composed of O. H. Armann, Th. von Kármán and G. B. Woodruff (Ref. 3). The report was a typical example of investigation by engineering scientists. It consisted of model testing and theoretical computation. The true reason for the failure of the bridge was the resonant oscillation excited by the wind forces. A phenomena well-known to aeronautical engineers as the flutter, but quite outside the experience of a civil engineer. The wind forces although small have the same period or is always in phase with the oscillation of the roadbed and therefore can build up the amplitude of oscillation to ruinous magnitude. It is seen then that by incorporating damping and by stiffening the bridge to increase the natural frequency the failure can be avoided. This is the principle for the design of the new bridge.

Here again, the services of an engineering scientist is able to clear up a most perplexing engineering question, and can be used to avoid further mistakes in an engineering design.

Unification—Basic Research in Engineering Science

From the above discussion, it might be construed that the problems in engineering science are individual problems and the engineering scientist is to deal with particular case without much generalized scheme. This impression is however not correct. Among the multitude of problems in the current development of engineering there are phenomena which occur repeatedly in many branches of engineering. These phenomena can then be abstracted out of the direct routine problems which the engineering scientist has to solve and be formulated into individual fields of research. The results of such research will then not only benefit one field of engineering, but to all of them. This is the basic research in engineering sciences, through which the greatly diversified engineering activities are united.

Historically, such basic research in engineering sciences was started by the great mathematician F. Kelin in the Göttingen University, Germany, shortly before the World War I. His school has produced such eminent engineering scientists as Th. von Kármán and S. Timoshenko. At that time, the main fields of engineering activity had to deal with mechanics. It is thus natural that the basic research in engineering science was simply called "applied mechanics" (angewandte Mechanik). However the ever-widening fields of engineering now extend to subjects which are not treated in the applied mechanics as first conceived by the German school. Let us then divide the current topics of basic research in engineering sciences into three catagories: 1) Research in the field which are not within the old boundary of applied mechanics; 2) Research in field which are near the old boundary of applied mechanics, and 3) Research in the fields which are within the old boundary of applied mechanics. To understand what is the character of basic research in engineering sciences, its ramifications and relations with different engineering problems, it will be profitable to examine these fields of research in greater detail:

1. Research in the Fields Which Are Not Within the Old Boundary of Applied Mechanics

a) *Solid State of Matter*

The engineering science of metallurgy has really progressed very little beyond the application of Gibb's phase rule. In fact, the present knowledge of materials is obtained through a tremendous amount of tedious laboratory tests. This large body of empirical data has practically no coordination or systematic interpretation. On the other hand, the physical theory of solid state, based upon quantum mechanics, is developed generally by physicists as a branch of pure science. In other words, there is a wide gap between the practical engineering and the scientific investigation. This gap has to be bridged. This effort of unitizing the physical theory with metallurgy will bring about not only a systematic interpretation of the accumulated empirical data but certainly will also indicate new possibilities in the field of development of materials. It is also certain that after a satisfactory engineering science of materials is developed, the search for an engineering material to satisfy a given specification will be greatly facilitated.

Another field of investigation is the ceramic materials. The present engineering materials are dominated by metals which consist of atomic crystals. There is no reason to believe that the other types of material, consisting of ionic crystals such as the ceramic materials, cannot be utilized as engineering materials for machine construction. In fact the recent demand for materials to withstand extremely high temperatures naturally points research in this direction.

b) *Electronics*

The electronics engineering can be divided into two main divisions: The division which deals with electronic tubes themselves and the division which treats the circuits and the radiation fields. The second division mainly involves an application of the classical Maxwell theory. The general character of the results is expected, in spite of the fact that such calculations may be very complicated and may require advance mathematical technique. The performance of tubes is, however, seldom comprehensively analyzed. The design of these tubes is generally worked out by numerous tests, guided by a few basic principles. However, the electronics engineering has now passed its heroic age of invention and creation and has entered the age of engineering development. The empirical approach may not be the most economical one in this new situation where detailed improvement of the various devices has to be carried out. This is especially true for very high frequency tubes where the electron inertia effect can no longer be neglected. It seems necessary to develop an engineering method of calculating such flow fields of electron cloud under the combined effect of rapidly varying external electric and magnetic fields. If this is done, then the characteristics of electronic tubes or other similar devices can be analyzed and the experimental data coordinated.

c) *Nuclear Engineering*

While the understanding of the nuclear structure is yet to be achieved, a general interpretation of the nuclear reaction seems to have developed to a satisfactory degree. In fact, the elementary processes of nuclei reactions such as collision, capture, excitation, and emission of new particles from the compound nuclei could be measured and studied individually. If these empirical data are available, then the overall microscopic performance of the reaction can be predicted by applying the methods of chemical kinetics. Impossible and undesirable processes can then be eliminated from further consideration and large scale tests. This approach to the utilization of atomic energy, or atomic engineering, seems to be able to lead to fruitful results without the danger of uncontrolled experiments. In other words, the stage seems to be set for the rapid development of utilization of nuclear reactions similar to the utilization of molecular reactions such as combustion.

2. Research in the Fields Which Are Near the Old Boundary of Applied Mechanics

a) *Combustion*

The theory of combustion has been studied by chemists mainly from the point of view of chemical kinetics. However, the problems which grow out of the recent development of jet propulsion generally involve very high speeds of flow. In such problems the effect of the inertia of the fluid elements certainly cannot be neglected. In fact, a study of a simple one dimensional problem has shown rather unexpected results due to this inertia effect. Then a complete and satisfactory solution of combustion problems must combine the science of fluid motion, i.e., hydrodynamics with the science of chemical kinetics. As an initial approach to this problem the effect of diffusion and turbulence on combustion must be studied.

b) *Metal Forming by Plastic Deformation*

The large number of metal forming processes is based upon the plastic deformation of the material. For instance, the widely used process of sheet metal forming is by pressing. This process, until recently, was practically carried out purely by experience. During the design of the dies for this process one has to use the cut and try method guided by a few empirical principles. This method is generally very uneconomical. It then seems necessary to develop a satisfactory theory so that such dies can be designed for each individual problem without resorting to numerous experiments. This new science of plastic forming, of course, will be based upon the methods of the theory of elasticity and a complete knowledge of the solid state of matter which is another topic of research as stated in the previous section.

3. Research in the Fields Which Are Within the Old Boundary of Applied Mechanics

a) *Turbulence*

During the last 15 years the problem of turbulence in fluid flows has been studied intensively and simple rules have been developed for satisfactory solutions of engineering problems in this field. However, the theory still lacks an explanation of the fundamentally important fact that the exchange coefficient in turbulent flows is enormous, as compared with that of laminar flows. The correct understanding of this phenomenon is the nub of the turbulence problem. It is believed that this understanding can only be achieved through a detailed survey of the turbulent fluid field together with theoretical analysis. Measurements on the turbulent velocities, the correlation coefficients and diffusion characteristics must be carried out.

Another possible field of investigation would be the application of the presently known knowledge of turbulence to the other fields of engineering such as combustion and the mixing problems in chemical engineering. Such applications are believed to be extremely useful.

b) *Gasdynamics*

The recent advance in aeronautics makes the science of gasdynamics one of the most important and urgently needed knowledges. The fundamental problems are connected with the interaction of viscosity and compressibility of the fluid. It was believed that the effects of viscosity, or Reynolds number, and the effect of compressibility, or Mach number, can be separated. However, it is now realized that such separation is impossible. On the other hand, the problem of the interaction is very complex, particularly due to the possible appearance of turbulence in the fluid. The detailed phenomenon must be studied simultaneously by both theoretical analysis and by experiment. In conjunction with this investigation, the effects of second viscosity coefficient and the relaxation time should be considered.

The possibility of flight at extreme speeds presents another very interesting problem of fluid dynamics at a very high Mach number. It is known that at such high Mach numbers, say, Mach number greater than 5, the fluid behaves very similarly to a stream of particles. In other words, the fluid reaction on a moving body will be very similar to that predicted by Newton on the assumption of no interaction between the particles of the fluid. The question of flying at extremely high altitudes leads to another interesting problem. This is the problem of fluid motion at extremely low density, i.e., the fluid flow in which the mean free path of the molecules is comparable to the dimension of the body moving in it. The solution of these problems is believed to be essential for the next assignment of aviation, the trans-oceanic flight at velocities faster than the velocity of sound.

From the above discussion on the different fields of basic research in engineering sciences, it would seem that the subjects are well within the general field of physics. But then why should they be called research topics in engineering science? The reasons are twofold: Firstly, there is a fundamental difference between the point of view of a physicist and the point of view of an engineering scientist. The physicist's point of view is that of a pure scientist, interested essentially in simplifying the problem to such an extent that an "exact" solution can be made. The engineering scientist is more interested to solve the problem as given to him. It will be complicated, so only approximate solutions, though sufficiently accurate for engineering purposes, will be attempted. Thus physicist will give exact solutions of an over simplified problem while engineering scientist wants the approximate solutions of the realistic problem. The work of a physicist may be at times impractical, but that of an engineering scientist must always be practical. The second reason for separating the engineering science from the general field of physics is simply that physicist has no deep interest in engineering problems. Because of these two reasons, the engineering scientist is forced to pick up where the physicist has left it and develop the physical principles into tools of practical engineering.

Training of an Engineering Scientist

For the engineering scientist to solve the problems assigned to them and to carry out research in the basic engineering science he needs definitely an education quite different from the education of an engineer. Then what is exactly the necessary training of an engineering scientist? It would perhaps be best to first see that is the necessary tools for an engineering scientist. He must have these tools. These are:

1) Principles of engineering design and practice.
2) Scientific foundations of engineering.
3) Mathematical method of engineering analysis.

In the first group of tools, is the conventional engineering subjects such as mechanical drawing, drafting and machine design, engineering materials and processes, shop practice. In the second group of subjects, is the physics and the chemistry which is generally contained in a good engineering curriculum. But here the training of an engineer scientist would be different from the conventional engineer in that he must know much more about physics and chemistry. For instance, his knowledge about mechanics must not stop at the statics and dynamics of rigid bodies and the stress in simple beams and columns. He must learn the principles of the theory of elasticity and plasticity. His knowledge about fluid motion must not stop at the hydraulics. He must learn the principles of hydrodynamics and fluid mechanics. His knowledge in thermodynamics must not stop at the first law and the second law or calculation of the idealized Otto cycle or Diesel cycle. He must learn the physical meaning of entropy from the point of view of statistical mechanics and the broad concept of thermodynamical equilibrium. Then he must know the elementary structure of matter from the nucleus up to molecules. In other words, he must know many subjects which a physicist or a chemist has to learn.

The third group of subjects is mathematical methods and principles of mathematics which would help the understanding of the use of mathematical methods. Thus it includes subjects such as advanced calculus, functions of complex variable, principles of mathematical analysis, ordinary differential equations, partial differential equations. In other words, he must know most of the subjects which an applied mathematician should know.

It is quite evident that the prospective engineering scientist cannot hope to cram all his learning into four years of college. In fact he has to be first trained in general engineering which may take three years in a good engineering school after high school, and then he has to spend approximately another three years to learn the science and the mathematics. Therefore it takes at least six years after high school to train an engineering scientist while the general practice now to train the conventional requires only four years. Engineering scientists are then definitely specialists who form only a few percent among the total personnel engaged in engineering and industry and which has to be trained from persons having the particular talent and inclination.

However as yet, only the necessary tools of the engineering scientists has been discussed. The fact that he is given these tools does not necessarily mean that he is trained in using these tools. How can he be trained to use these tools? Here the degree of training cannot be measured in the number of courses the student takes or the number of years he spent in the school. Learning how to use the tools effectively can be only achieved by experiencing the use of tools. Of course, the process can be accelerated with the aid of expert guidance. Therefore to complete the training of an engineering scientist after six years of schooling, the prospective specialist must spend one to two years working on a specific problem under the supervision of an experienced senior man. A good way of realizing this would be to study for a doctor's degree with an authoritative instructor in a well-equipped university. The unhurried academic atmosphere in an educational institution is certainly conductive to thinking which is, after all, the only way to gain wisdom. Wisdom gives insight to a complex problem and insight to a problem is the key to its successful solution.

Concluding Remarks

The training of a competent engineering scientist is a long process of seven to eight years, and the effort and ability required to complete such training is also proportionately great. Fortunately the reward is also large. From the discussion on the character of work performed by engineering scientist, it can be seen that they form the nucleus of men in any engineering development, they are the pioneers of new frontiers in industry. In fact the very essence of engineering science—the technique of transforming a basic scientific truth to practical means of human welfare really goes beyond the realm of present industry. Medicine is the application of chemistry, physics and physiology to cure and to prevent diseases. Agriculture is the application of chemistry, physics and plant physiology to produce food. Both are then engineering in the broad sense of the word and both will then benefit from the methods of engineering science. Hence it is appropriate to call the engineering scientists the most immediate and direct workers towards the goal of the pursuit of science, so aptly expressed by Professor Harold C. Urey: "We wish to abolish drudgery, discomfort, and want from the lives of men and bring them pleasure, leisure and beauty".

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