CONTRIBUTIONS OF THE PHYSICAL SCIENCES TO HUMAN WELFARE*

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I wish to address myself to the high school students attending the Junior Science Section on the general topic: Contributions of the Physical Sciences to Human Welfare.

You will at once agree with me that this is, in a considerable sense, a mechanical age—an age of machines. You accept our wonderful labor-saving machines, our rapid transit, our practically instantaneous radio communication, our innumerable electrical devices; you accept all these and more, I dare say, as essentials to your very existence and happiness. You are not particularly excited by the radio. From your standpoint it has always been with us. Similarly, as far as you are concerned, electricity itself with its many applications has always been with you. And the automobile, how commonplace it is! Most of you do not realize that your parents and grandparents scarcely drove more than twenty-five miles in one day, and that their radius of visiting (by horse and buggy) scarcely ever exceeded forty miles. Compare this with driving four hundred to five hundred miles by auto between sunrise and sunset! And with a touring radius limited only by the confines of this continent! Most of you have never had a pair of reins in your hands. A three hundred dollar team of fine Percheron draft horses excites your interest, while a five thousand dollar automobile passes unnoticed. What brought about this wonderful change in our manner of locomotion? It was the result of scientific inquiry, whether that has been in the university, in the factory, or on the farm. It was the application of the principles of physics and chemistry to the perfection of our methods of travel in response to the general present-day speeding up of human activities. The application of the principles of physics in the development of the automobile unit as a whole, and of chemistry in the extraction of the high test gasolines that are so efficiently used as fuels. By the combined efforts of the mechanical and chemical engineers (we call their work applied science) an auto weighing one ton may readily be transported a distance of twenty-five miles on one gallon of gasoline. Fifteen or twenty years ago the dis-

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tance was but half of this. Through further research the distance may reach fifty miles per gallon.

Thinking seriously of the wonderful mechanism located under the hood, sensitive to the slightest touch of the hand, yet powerful in extent to the combined efforts of twenty-five to fifty horses—there is the carburetor unerring in supplying the fuel in just the right mixture, the engine itself with its cycles of compression, the ignition supplied by a storage battery which really is the very heart of the whole contrivance, the generator, the clutch, the transmission, the differential, the electric starter, the oiling system, the radiator, fan, speedometer, lights, steering device, horn, and, possibly as important as any in preventing accidents, a full set of brakes. In short, we have in the modern automobile a power plant designed for continuous service and rough usage, designed to be driven by people who have no knowledge of the factors involved, yet which will give service for weeks and months without attention from the owner other than supplying oil and fuel.

Such results did not come by chance. Each mechanical part, every principle involved, and the perfect functioning of the whole as a unit are the result of years of scientific investigations—in fact are the result of everything that has gone before for at least one hundred years. Take for instance the part that electricity plays in the automobile. If it were not for electricity the automobile would be next to impossible. How would the compressed gas in the engine cylinders be exploded except by the electric spark? How would the engine be started except by the motor driven in turn by the current drawn from the storage battery? And further how would the storage battery be replenished (charged) except by a dynamo generating the charging current?

We thus see that the auto is very much dependent on an electric current, but whence electricity, and what is it? To discuss this takes us back three or more generations, back to the first half of the nineteenth century and further, to the time of Faraday in England, and to Franklin and Henry in America. Before this, electricity was the mystery of the ages. Trees were rent asunder by the lightning and the thunder rolled, but no one knew aught of its source, nature, or possible utility to man. Benjamin Franklin was the first to show that lightning and the electric spark that one gets when stroking a cat's back are one and the same thing, differing only in intensity. The Italian physicist, Volta, was the first to demonstrate that the electric current that results when certain metals are placed in a chemical solution is the same as the lightning bolt or the spark that may be had by stroking cat fur.

Let us look still more closely into the general subject of electricity, this wonderful entity that is so much used in this electro-mechanical age, the manifestations and uses of which we accept in such a matter-of-fact way. The present advance in electricity and in electrical discharges dates back only about thirty-five or forty years. Sir J. J. Thomson, of the Cavendish Laboratory, Cambridge, England, was the pioneer investigator in the discharge of electricity through gases. Examples of such discharges are the many neon signs that one sees on business streets. He identified the electron as a distinct entity, having a negative charge of electricity, and present in all matter. He showed that these electrons may be made to flow through a wire by connecting that wire to a battery or dynamo. Thus the electron in motion constitutes an electric current. By rubbing an ebonite rod with cat fur electrons are separated out and remain on the rod giving it a negative charge, while at the same time the same number of electrons leave the cat fur. This absence of electrons in a body leaves it with a positive charge. The interaction between positive and negative charges is nicely shown with an ordinary gold-leaf electroscope.

Twenty-five years ago Thomson stated that "we know more nearly what electricity is from the study of the current flowing through gases than from its flow through solids or through liquids." Great advances have been made since that time, and it may now be stated that we are beginning to know vaguely what electricity is though many enigmas remain to be solved. We know much regarding its properties and the laws governing its flow. We can construct electrical circuits and predict the resultant current flowing under given conditions, we can design dynamos and transformers that will give you exactly 110 volts at your lamp sockets. We can do all these and more, but at bottom we do not know the why and wherefore of electricity itself.

The smallest charge of electricity, as stated above, is the electron. Its mass is very small, about 1/1800 that of the hydrogen atom. Each atom of hydrogen has associated with it one, and only one, electron. If the electron is taken away we no longer have a hydrogen atom but an entity carrying a positive charge. This entity is styled a proton. Sir Ernest Rutherford, also of the Cavendish Laboratory, was the first to discover its dimensions and density. The proton is a hard nucleus—but of what? That is the question. It has ponderable mass. It, like the electron, has a charge except that it is positive. These two charges are equal but opposite in sign. Each taken by itself would behave like a charged pith ball. If we allow one proton to unite with one electron we have an uncharged (or neutral) atom called an atom of hydrogen, the first in our series of the ninety-three known elements.

These electrons and protons are building stones. These two entities in various combinations make up everything that we see about us, be that living matter or inert objects.

I have traced hurriedly and in rather rambling fashion one outstanding development—the automobile—in this mechanical age, and called attention to the part that electricity plays in the finished machine, dwelling for a moment on the why and wherefore of electricity itself. The above is but one of many important developments that may be traced down to the present time. Possibly more wonderful in its speed of development is the general subject of radio communication. The mathematical theory predicting electromagnetic waves was made by Maxwell, an English physicist, in 1865. The experimental verification of this theory was made by Heinrich Hertz, a German physicist, in 1888. Wireless telegraphy became a means of communication in the late nineties, and radio, as we know it now, became a fact with the invention of the three-electrode tube in 1907. Since then the development was rapid resulting in the talking movies and radio television installations of today in which the photo-electric cell plays such an important part.

Other lines are equally important and their historical development equally fascinating.

It is worthwhile to note the intense interest that has sprung up and is continuing in science throughout this country and throughout the world. Universities everywhere are active in research, even the colleges and some of the larger high schools have caught the "spirit of inquiry." It is significant that the industries have long ago abandoned the rule of thumb method and now have large research staffs in their employ. Some of our larger electrical corporations employ research experts with the express understanding that they are free to pursue any project in pure or applied science that may be of interest to them, knowing full well that sooner or later the investigation under way will result in some practical applications of benefit to mankind.

An indication of how the spirit of inquiry has pervaded public and private institutions and also the industries is afforded by reference to the present (May, 1931) program offered by the American Physical Society at its Washington, D. C., meeting, in which appeared no less than one hundred sixty abstracts of researches either finished or under way. And this does not represent the work of the year. This society holds four other meetings, averaging about fifty papers each, making thus an output of some three hundred fifty papers for the school year of 1930-31.

Nor is this the end. The activity at the present time is quite in contrast to a prediction made in the late nineties by a distinguished physicist and electrical engineer when he said that all of the important discoveries had been made and it only remains for us to seek greater refinement in the measurements already made. Nothing could have been farther from the truth. No one man, or set of men, can predict what the future holds for us. Certainly one should confidently expect the contributions during the next thirty years to be quite as outstanding as those in the three decades just passed. You students entering upon your college courses have a golden opportunity. The spirit of inquiry may not lead to riches, but I dare say if pursued with devotion it will lead to happiness that riches cannot buy.

I should feel remiss if I did not call attention to the Century of Progress Exposition that is to be held in Chicago in 1933. As the name implies, this will be a fair setting forth the progress made in all lines of human endeavor during the past century. The Directors decided early that this Exposition should be given the scientific approach. To that end they appealed to the National Research Council for a policy. This body in turn appointed 40 chairmen, leaders in their divisions, to head 40 committees of ten members each, all committees to serve in an advisory capacity to the fair officials. Of these about 10 represent the pure sciences, and the rest the applied sciences. Each committee was instructed to plan a suitable exhibit based on the scientific approach. The committee on physics did its work in the fall of 1929 and early 1930.

Note: The following experiments were performed as the closing part of the lecture.

1 High frequency high potential generator, small set.
2 Simple discharge tube.
3 Positive ray tube (with fixed vacuum).
4 Electrodeless discharges—
  a) Neon bulb.
  b) Hydrogen bulb.
  c) Mercury vapor toroid.
  d) Combination of (a) and (c).
5 Mercury vapor tube (pith balls).