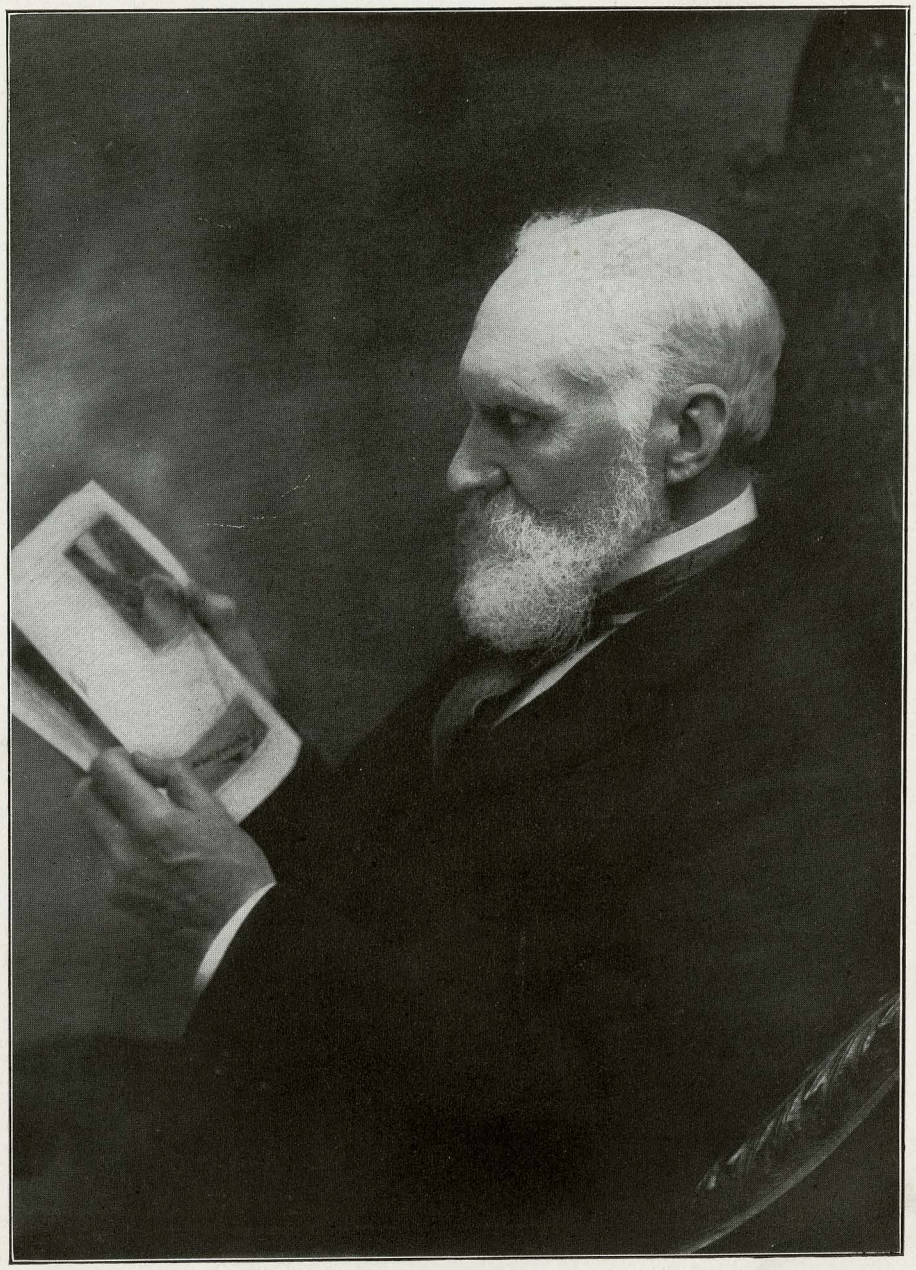

Kelvin New York May 6, 1902

In Memoriam

The Right Honorable

William Thomson, Lord Kelvin

P.C., O.M., G.C.V.O.

LL.D. (Camb.), D.C.L. (Oxon.), L.L.D. (Dubl.. Edin., Glasg., Princeton, Toronto)

Born June 26, 1824; Died December 17, 1907

Interred in Westminster Abbey December 23, 1907

PUBLISHED BY
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
NEW YORK
1908

The "Memoir of Lord Kelvin" and the account of the "Memorial Exercises in Honor of Lord Kelvin" in the following pages are reprinted from the January and February, 1908, issues of the Proceedings of the American Institute of Electrical Engineers

Memoir of Lord Kelvin

William Thomson, first Lord Kelvin, the noted scientist, President of the Institution of Electrical Engineers, died at Glasgow, Scotland, December 17, 1907, at the ripe age of eighty-three years. Born in Belfast, Ireland, June 25, 1824, William Thomson began life without a title, or any heritage, save that of brains. In 1832, his father, James Thomson, professor of mathematics in an institute in Belfast, removed the scene of his activities to his alma mater at Glasgow, which thenceforward remained the home of his distinguished son. William received his education in part from his father and in part from the College of Glasgow. In 1845 he was graduated from St. Peter's College, Cambridge, where he won notable honors, being first Smith's prizeman of his year, as well as second wrangler. While at Cambridge, Thomson was devoted to athletics, and rowed in the winning boat in a race with Oxford.

At the age of twenty-two, a year after he was graduated, Thomson became professor of natural history in the University of Glasgow, after several months spent in the laboratory of Regnault in Paris. Despite repeated offers of similar posts elsewhere, he remained loyal to the great city on the Clyde. In 1896, half a century after his appointment, he received a wonderful tribute of admiration and affection, in which the university and civil authorities of Glasgow, leading scientific societies of America and Europe, and distinguished individuals, including the Prince and Princess of Wales, united by personal presence, formal addresses, letters, telegrams, and cable messages, they made his jubilee celebration an event practically without a parallel in the history of science. He was elected Chancellor of the university in 1904.

One of Professor Thomson's first great achievements was in overcoming the retardation affecting electric signals sent through a submarine cable, which threatened to blur them beyond recognition. Faraday had previously furnished a partial key to the evil, but Thomson invented the instrument which made it possible to transmit signals with reasonably satisfactory clearness and speed. In a controversy disputing the correctness of his statement of the laws involved, Professor Thomson disposed of the argument so effectively that he was retained as consulting engineer, officiating in that capacity both for the cable of 1858 and for that of 1866. He was also electrical engineer for the French Atlantic cable in 1869, the Brazilian and River Plata cable in 1873, the

West Indian cables in 1875, and the Mackay-Bennett Atlantic cable in 1879.

As a further contribution to the success of these enterprises, Professor Thomson invented a method of testing the conductivity of a submarine wire while being laid, so that any defect might be promptly discovered and remedied. He also invented instruments for receiving messages. A mirror was so mounted on a tiny magnet that the feeble electric impulses traversing a cable caused it to sway, and a beam of light was deflected to the right and left, on a blank white surface in a dark room. The magnet being suspended by a silk fibre, its movements were virtually unimpeded by friction. This was supplemented by one which would leave a permanent trace on a strip of paper; it was called " the siphon recorder." It was employed to receive some of the greetings sent to its inventor in 1896. He was knighted in 1866, as one who had done more than any other scientific man to develop submarine telegraphy. Subsequently he devised a sending key for use with a cable, and perfected apparatus for taking deep-sea soundings, thus greatly facilitating the exploration of cable routes. Two of Sir William Thomson's valuable inventions are his improvements on the construction of the compass, and his provision for overcoming the influence of a ship's magnetism on that instrument. The compass card was lightened, and a large number of fine needles substituted for the few coarse ones formerly attached to it. To attain the other object, small globes of iron the sizes and distance of which were carefully computed, were placed near and on opposite sides of the compass.

For measuring charges of static electricity, Sir William originated the quadrant electrometer, and made useful additions to other types of apparatus. One of the most important of his non-electrical inventions is a machine for predicting the level of the tides in any part of the world. His wide experience, deep insight, and sound judgment made him an authority on electrical science. When American capitalists proposed to " harness Niagara," the Glasgow professor of natural philosophy (who was elevated to the peerage in 1892), was made chairman of the board of experts convened to study the possibilities of the plan. He made a trip to Niagara Falls in 1897 and displayed great enthusiasm over the achievement.

He visited the plant of the Niagara Falls Power Company on August 16, 1897, on which date his signature appears on the visitors' register with this comment:

" Very much pleased to see the great success here achieved, as a result of courageous undertaking and originality of invention, and skilful design and construction. K."

Lord Kelvin always evinced the warmest interest in the work of other electrical inventors. At the reception in his honor given by the

American Institute of Electrical Engineers and Columbia University, at New York in 1902, he publicly and cordially praised Mr. Edison who sat beside him, for perfecting the incandescent lamp. A few months later, at a reception by George Westinghouse in London, Lord Kelvin evinced much delight with the so-called " current rectifier," an invention of Cooper Hewitt, which was there exhibited. On that occasion he commended the introduction into England of certain American business methods, of which he regarded his host a fine exponent. The first commercial messages transmitted in Great Britain, by means of Marconi's invention, were dispatched in 1898, from Glum Bay, Isle of Wight, by Lord Kelvin; one to Sir George Stokes, in Cambridge, a second to his own assistant in Glasgow, and a third to Lord Rayleigh and Sir William Preece, in London.

Lord Kelvin, moreover, was one of the first men who admitted the credibility of the theory regarding the composite nature of the atom, as being a collection of tiny, negatively electrified particles; although he had once fancied that an atom might have a construction and an internal motion like that of a ring of smoke ejected from a locomotive smokestack.

As early as 1848 Professor Thomson published an article on an absolute thermometric scale, and in 1854 he modified his proposition. Two long articles from his pen in the " Encyclopædia Britannica " having been republished under the title " On Heat and Electricity." His work in connection with Professor Tait, " A Treatise on Natural Philosophy," contains material of the highest value.

While consistently conservative, Lord Kelvin took a deep and lively interest in the recent investigations regarding radium and radio-activity. He would not assent to the theory that one element could be evolved from another, nor to the theory lately advanced, that the heat of the sun or the earth is due to radium, rather than to gravitation.

Lord Kelvin's development of the relation which exists between heat and mechanical power enabled him to reconcile the diverse doctrines advocated by Joule and Carnot, and he coöperated with Joule in experiments which aided in dispelling the uncertainty relating to thermal effects in fluids, which results were communicated to the Royal Society in 1862.

Lord Kelvin's other published writings are: " Electrostatics and Magnetism (1 vol.); " Mathematical and Physical Papers " (3 vols.); " Popular Lectures and Addresses " (3 vols.); and " Baltimore Lectures," delivered at Johns Hopkins University, in 1884.

Lord Kelvin visited Montreal in 1884, and Toronto in 1897 to attend meetings of the British Association for the Advancement of Science, these meetings being ordinarily held on the other side of the Atlantic. That he was made a peer by Queen Victoria at the opening of the year

1892, was a delight to his scientific friends, who felt not only that the honor was deserved but also that it was a public though tardy recognition of the value of science. The title, Lord Kelvin, was suggested by the name of a stream, the Kelvin, that empties into the Clyde at Glasgow. The buildings of the University of Glasgow border on this stream.

He became the recipient of all honors that his fellow beings could bestow, was beloved by all with whom he came in contact, and was of benefit to many who never knew his name. Inheriting a fine intellect and a passion for the investigation of natural phenomena, he acquired a mastery of mathematics that served him as a precious instrument of research and promoted precision of thought. His conservative and sound judgment, coupled with an ever increasing wealth of experience, made his opinion concerning engineering undertakings invaluable. Oftentimes in scientific problems the suspense of this judgment, until all facts had been considered, ultimately lead to extremely interesting and fundamentally important cosmological conclusions. A free use of his analytical mind invariably gave a maximum of conclusions from a minimum of data. A highly developed power of imagination, balanced by a keen sense of the practicable, was evidenced in his great resourcefulness of invention. Withal, perhaps the most important element of greatness was his simple, sympathetic, loyal and generous nature. He was never governed by such sordid motives as jealousy, envy, hatred, and malice. His continuance to the end, of participation in the activities of scientific and engineering organizations, long after their power to confer distinction upon him had ceased, deserves emulation.

Quite recently he had been appointed President of the International Electrotechnical Commission, the duties of which are expected to supersede the functions heretofore delegated to International electrical congresses.

The honors and decorations otherwise bestowed upon this great man are legion: He received degrees from the leading universities of Great Britain and America. In 1893 he was elected an Honorary Member of the American Institute of Electrical Engineers. He was a foreign Associate of the Academy of Sciences of Paris, and an Honorary Member of other French scientific organizations. He was a Grand Officer of the Legion of Honor in France; a Knight of the Grand Cross of the Royal Victorian Order; a Knight of the Order of Merit of France, and a Commander of the Order of Leopold of Belgium. He was also a member of the Order of the First Class of the Sacred Treasure of Japan, and of the Order of Merit established by Edward VII in 1902. He had been president of the Royal Society of Edinburg, the British Association for the Advancement of Science, and three times president of the Institution of Electrical Engineers. As president of the Royal

Society of London he attained an honor that has, since Newton's day, been regarded as the highest to which a British scientist could aspire.

In death, as in life, Great Britain graciously bestows upon Lord Kelvin her highest honor; for he is to rest with Newton, Herschel, Darwin, and the other illustrious dead, in the nave of the venerable Westminster Abbey.

R. W. P.

American Institute of Electrical Engineers.

Resolutions in honor of Lord Kelvin, adopted by the Board of Directors January 10, 1908, and approved at the Memorial Meeting, New York, Jan. 12, 1908.

Whereas: With the death of the Right Honorable William Thomson, Lord Kelvin, Honorary Member of the American Institute of Electrical Engineers, there has passed away the greatest exponent of contemporary science; a man whose contributions to the advancement of knowledge and whose inventions for ameliorating the conditions of mankind give him place in history as one of the greatest benefactors of the human race; and

Whereas: His modest, kindly, and unassuming ways; his charming personality; his interest in the welfare of his fellow men; and his sympathetic nature, won for him the regard and affection of all with whom he came in contact; and

Whereas: His clear and comprehensive mind; his vast reach of thought; his ability in scientific research; his highly developed inventive faculties; and his achievements in the electrical arts and sciences; marked him as the first and greatest electrical engineer;

Be it Resolved: That the American Institute of Electrical Engineers gives expression to its sense of the irreparable loss which the engineering profession has sustained in the death of this great and good man, and it reverently offers Lady Kelvin its deep sympathy in her bereavement; and

Be it Further Resolved: That these Resolutions be forwarded to Lady Kelvin, that they may be entered in full in the Proceedings of the Institute, and that the National Flag be flown at half mast on the Engineers' Building upon the day of interment at Westminster Abbey, and during the Memorial Exercises in New York City, January 12, 1908

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.
HENRY G. STOTT,
President.

By order of the Board of Directors.
RALPH W. POPE,
Secretary.

Memorial Exercises in Honor of Lord Kelvin

Engineers' Building, New York, January 12, 1908

AT a special meeting of the Board of Directors held December 30, 1907, a committee was appointed to arrange for suitable memorial exercises in honor of Lord Kelvin, composed of the following members: Percy H. Thomas, chairman; John W. Lieb, Jr., T. C. Martin and Samuel Sheldon. President Stott also appointed the following committee on resolutions: John W. Lieb, Jr., chairman; Bion J. Arnold, Charles F. Scott, Charles P. Steinmetz, Samuel Sheldon, and Schuyler S. Wheeler. The date of the meeting was fixed for Sunday, January 12, 1908, and the following program of exercises arranged:

Program

MUSIC

(By the Kronold Sextette.)

Prayer.
Rev. Wm. T. Manning, D.D.

Introductory Remarks.
President Stott.

Reading of Memorial Resolutions by Secretary.
Adoption by Rising Vote.

Address.
Rev. William T. Manning, D.D.

Lord Kelvin as an Electrical Engineer.
Professor Elihu Thomson.

MUSIC

Lord Kelvin as a Scientist.
Professor E. L. Nichols.

Lord Kelvin's Work in Submarine Telegraphy
G. G. Ward, Esq.

Lord Kelvin in Naval Engineering.
Rear Admiral Geo. W. Melville, U.S.N.

Lord Kelvin and the American Institute of Electrical Engineers.
T. C. Martin, Esq.

Benediction.
Rev. Wm. T. Manning, D. D.

MUSIC

After a prayer by Dr. Manning, President Stott made the following introductory remarks:

Henry G. Stott

We have assembled here this afternoon to honor the memory of Lord Kelvin, and to offer our tribute of praise to his enduring work for mankind.

Your committee in considering the most fitting manner to set forth our appreciation of his career, were at once confronted by the question "Whom can we find capable of describing his vast work in mathematics, physics, science, electrical engineering, submarine telegraphy, and navigation, and last but not least, his lovable character as a Christian man." The answer was, no one.

It therefore was apparent, that our only resource was to invite several gentlemen, each of whom was notable for his preeminence in one of the many fields covered by Lord Kelvin's work.

Perhaps no greater tribute could be paid to his memory by the gentlemen whose names appear in the program, than to state that each one accepted our invitation to speak without a moment's hesitation, some coming from a distance at great personal inconvenience.

I will not trespass on the ground to be covered by these gentlemen, but I wish to quote a sentence from the words of that great German scientist, Helmholtz, which seems to summarize most admirably the characteristics of Lord Kelvin's work;

"His peculiar merit consists in his methods of treating problems of mathematical physics. He has striven with great consistency to purify the mathematical theory from hypothetical assumptions which were not a pure expression of the facts. In this way he has done very much to destroy the old unnatural separation between experimental and mathematical physics, and to reduce the latter to a precise and pure expression of the laws of the phenomena. He is an eminent mathematician, but the gift to translate real facts into mathematical equations and vice versa, is far more rare than that to find a solution of a given mathematical problem, and in this direction Sir. William Thomson is most eminent and original."

To the speaker, Lord Kelvin's charming personality was one of his most striking characteristics, and his own words in replying to a toast at his jubilee in 1896 in which he said "To live among friends is the primary essential of happiness" gives the keynote of his life, and surely no man was ever more blessed in his friends than he.

The dominant impression gained from personal contact with him was, that the most wonderful thing about this great man was his humility, a humility which made him the immediate friend of every child, which drew the confidence of the backward student as he took him by the arm to one side, so that he might explain a difficult point to him without embarrassment.

His words in reply to an address by one of the great scientific bodies, congratulating him upon his wonderful mastery of physics are a fitting lesson in real humility to us all.

"I have lived long, and have learned enough to realize that I know nothing."

During his life he was the recipient of every honor that man could confer upon him, and now a grateful sorrowing nation lays him to rest amongst its honored dead in Westminster Abbey.

The resolutions adopted by the Board of Directors were then read by the secretary, and approved by a rising vote. (These resolutions appear on page 8.) The secretary read the following communications:

[TELEGRAM]

WASHINGTON, D. C., Jan. 11, 1908.

I am very sorry that illness in my family prevents me from being present at the memorial meeting in honor of Lord Kelvin, for I should have liked to have said a few words of appreciation concerning Lord Kelvin's connection with the early history of the telephone, and his personal kindness to me when as a young and unknown man, I brought the telephone to his attention at the Centennial Exhibition in 1876.

It was really Lord Kelvin who made the telephone known to the world. In spite of my efforts, the general public were skeptical concerning the reality of electrical utterance, but when Sir William Thomson spoke, the world believed. Before he delivered his memorable address at the British Association for the Advancement of Science in 1876, the telephone was looked upon as a scientific toy, of no commercial value, even by persons who had themselves heard the articulation of the instrument, but Sir William Thomson's address banished skepticism and the telephone entered upon its career of practical usefulness. ALEXANDER GRAHAM BELL.

[LETTER]

111 BROADWAY, NEW YORK,

My Dear Sir: Jan. 10, 1908.

I thank you sincerely for your cordial invitation to be present at the Memorial meeting to be held under the auspices of the American Institute of Electrical Engineers in honor of the late Lord Kelvin, and especially for the opportunity afforded me to give public expression to those sentiments of admiration and esteem for him which were inspired by many years of acquaintanceship and friendship.

No words of mine are needed to enhance public appreciation of Lord Kelvin's great and enduring services to science and engineering, and particularly to electrical engineering. He combined in a rare degree, the ability to pursue the loftiest abstractions of pure science, and the practical engineering which promotes the progress and happiness of the human race. Seldom, if ever before, have the scientific mind and the knowledge of the practical engineer been so harmoniously united and so mutually complementary as in the genius of Lord Kelvin.

I was particularly impressed by his constant mental activity in devising improvements on his many useful inventions, the ardor with which he studied the inventions and the improvements of others, and the extraordinary inventive fertility of his mind, even when well advanced in years.

Whenever I had the pleasure of calling upon him in his London home, he was always desirous of discussing some detail with me, and during these discussions I had ample opportunity to note his great familiarity with mechanical subjects. He took a very great interest in discussing the advances made in electrical apparatus, prime-movers of all kinds, and the many novel uses of electricity, and in hearing of the new industries constantly being developed to meet the ever-increasing wants of humanity.

But, as one who was honored with his friendship for many years, I would not willingly forego the pleasure of speaking of the man himself, as well as of the scientist. His character, as all know, was blameless; his personality, most lovable. Years of association with him only heightened the esteem and admiration which he awakened at our first meeting. His modesty, the simplicity of his manners, his warmth of heart, the openness of his mind to receive new impressions, even at an age when great minds might be expected to become less observant and less easily impressed by new facts, the unerring quickness of his perceptions and the accuracy of his judgment, his friendliness to America and Americans and his interest, as I have already said, in the progress of science and engineering on this side of the Atlantic, excited in turn the admiration of all who met and knew him.

To have known him and Lady Kelvin, whose devotion and helpfulness added so much to his comfort and efficiency during his later years, and to have been admitted to their ever-widening circle of friends, will always remain for me a source of the purest pleasure.

Very sincerely yours,

GEO. WESTINGHOUSE.

To H. G. Stott, President, A. I. E. E.

A telegram from Mr. Edison stated that he was confined to his bed by illness, otherwise he would have been present in testimony of his sympathy in the loss of his esteemed friend, Lord Kelvin.

THE PRESIDENT: I will now ask the Rev. William T. Manning, D.D., Assistant Rector of Trinity Parish, to speak of Lord Kelvin as a Christian.

WILLIAM T. MANNING

We are here to pay our tribute to one who was not only the greatest scientist of his own age, but whose name takes its place, as you all know, among those of the few very greatest masters and leaders of scientific thought in any age—one whose place is beside Sir Isaac Newton, not only in Westminster Abbey where his body now lies, but in the just appreciation of his fellowmen. But there is one thing that we can say today about Lord Kelvin, even greater than that he was the world's greatest living scientist, and that is, that in a measure and to a degree in which the meaning of these words is seldom realized, he was a true Christian. For the life of this truly great man was one of singular beauty; his were the simplicity, the sincerity, the humility, the single-heartedness, the cheerfulness, the kindliness, the perfect devotion to truth, the firm, clear faith in God, which are the marks of a true Christian; in life and

also in faith, in character and also in clear, reasoned, deliberate conviction, he was a true example of a Christian man.

It is not surprising that Lord Kelvin should have been a Christian and a churchman; certainly not to us in these days, when the idea that there is some necessary conflict between religion and science belongs already to the past, when the faults, as I know you will allow me to call them, on both sides of that unhappy controversy are already largely forgotten, when we are all coming to realize that truth is One, whatever its source, and that any apparent conflict between the truth of God revealed in nature, and the truth of God revealed in Christ, is of our own making, and results solely from the insufficiency of our knowledge, on the one hand, or on the other. But though it is not surprising, it is an encouragement and an inspiration to hear a man like Lord Kelvin say, as he did say again and again all through his life in one form or another, in many forms, that the facts of science demand the recognition of a purposive power in this universe and that—I quote now from what he is reported to have said in his lecture on Present Day Rationalism—" With the utmost freedom of thought we are bound to reach the conclusion that science is not antagonistic to religion, but that it is a help to religion ".

It is a strength to us to know that with all the power of his great mind, with all the sincerity of his noble and simple nature he believed, definitely and avowedly, in a personal and living and loving God; that with all his knowledge of the law and order, that reign in this universe, he believed in a God who hears and answers prayer; that with all his utter and absolute devotion to truth, he found strength and comfort all his life long in the worship of the church; he believed and recited with singular earnestness and reality the Christian creed. He held as another great scientist, George John Romanes, came to hold after years of earnest and patient thinking, that it is reasonable to be a Christian.

It is surely most fitting that as we think of him here to-day we should honor him, not only for his great services to truth in the realm of science, but also for his great witness to truth in the sphere of religion, for the fact that with all the humility of a true scientist, with all the reverence of a true seeker after truth, with all the earnestness and simplicity of a true man, he lived and died in the faith of that One who came into this world to show us the truth, whose word to us is, " Ye shall know the truth, and the truth shall make you free ".

As one of Lord Kelvin's lifelong friends said just the other day in Scotland, " There is something very magnificent about the thought of a mind like his entering into the vastness of eternity, seeing at their sources the great rivers of truth which he has been so long, patiently investigating. He will be able to comprehend so much more than others; he has gone into the other life with powers developed, with heart and mind prepared, carrying with him the purity and simplicity of soul which will make him at once the companion of the holiest and the best among all who have gone before ".

And so to-day we pay our tribute to William Thomson, Lord Kelvin, great among the greatest as man of science, but greater still in his life and in his faith as a sincere and humble Christian.

THE PRESIDENT: In looking for some one to speak of Lord Kelvin's work in electrical engineering, we had no difficulty in selecting a gentleman who has become known as the Dean of the electrical engineering fraternity. We will now ask Professor Elihu Thomson to speak of Lord Kelvin as an electrical engineer.

ELIHU THOMSON

Along the semi-arid eastern coast of Spain there is to be seen even to-day, a very ancient form of chain pump for irrigation, kept in motion by animal power and bringing up from the well

the life-giving water which confers luxuriance upon the surrounding thirsty land, otherwise barren and desolate. A wooden wheel supports a long belt of cord or rope, which wet and in the sunshine, is bleached, and seems to possess a silvery lustre. It carries at intervals along its length earthen vessels, successively brought, full and dripping, from the well below into the full sunlight, suggesting to the poetic fancy, burnished gold. Now and then it may be that a maiden from a habitation near by, brings a quaint two-handle urn or pitcher to this fountain of life, just as was done in the eastern countries three thousand years ago. Only after seeing all this did I fully understand the beautiful figurative allusion to the close of life in the twelfth chapter of Ecclesiastes:

" Or ever the silver cord be loosed, or the golden bowl be broken; or the pitcher be broken at the fountain, or the wheel be broken at the cistern ".

" Then shall the dust return to the earth as it was; and the spirit shall return unto God who gave it ".

A great fountain of science has ceased to flow, the silver cord is loosed, the wheel is at rest.

In the recent death of Lord Kelvin the world has lost one of the greatest intellects, a most distinguished student of science, whose attitude was, in spite of his eminence, always that of great modesty. We knew him as the unequalled mathematician and physicist, who was also an electrical engineer of the highest type.

Withal his disposition was of the most kindly, his personality most lovable. Even to the end of his long and active life of more than four score years, his mind was clear; he did not pause in interest; his powers of dealing with abstruse problems did not flag. To those who have had the privilege of personal contact with him, he was full of inspiration, keenly alive to the value of all advances, giving freely of his great store of knowledge. His love for science was only matched by his mastery of its means and methods.

Others will speak of his lifelong mathematical and physical work, his contributions to navigation, and his pioneer electrical engineering in connection with submarine cables. His cable work was indeed, electrical engineering of a high type. It will be my part to draw attention to those other phases of his work which link him closely with the later developments in the electrical field. I cannot at the outset forbear to say that in Lord Kelvin were united a deep devotion to science, as such, the so-called pure science, and to the applications of science in industry, or engineering. Let his life and work be ever a standing rebuke to those who, few though they now be, forgetting the very dependence of pure research upon the growth of civilization, as a consequence of advance in applied science and material resources, affect to find superior or exceptional merit only in scientific results which are not of practical use. To the man of true genius such as Lord Kelvin was, the passion for accomplishing things is no more sordid when employed on engineering problems, than in pure research, and the two are mutually dependent.

If we consider the work he did in design and working of cables, studies of capacity and self-induction and the delicate instruments to be used therewith, prototypes of later forms, can we not discover in the great man who has passed from among us the father of modern electrical engineering? History shows that this early work was full of trials, disappointments, and difficulties, all arising from mechanical causes, inexperience of men in the making and handling of the cable and the machinery for its manipulation—overcome at last by a perseverance noble in itself. It is too often the case, that with new enterprises not only the thing itself, but a favorable environment must be created. Neither men, nor tools, nor materials, nor methods exist, or are to be had for the asking. The pioneer has often per-

force to cut his cloak to the cloth, and not the cloth to the cloak. James Watt had to be satisfied with engine cylinders which did not vary more than a quarter of an inch in bore from one end to the other, and, so it is said, with a piston packing of old felt hats. So it was when iron wire, cast iron or highly hysteretic stove-pipe sheet, the latter laboriously fashioned without the modern punch press, for dynamo armatures, had to bring what content they could to pioneers who knew better, but then could only wish. But this is a digression, and it is only made as an assistance to the perspective in appreciating disadvantages, looking back from the present age of highly developed materials, methods, skill and special tools. It was characteristic of Lord Kelvin's inventive engineering that his conceptions were complete, and when fully worked out gave excellent results in practice. Later work could only affect minor details, and even these he often provided for. He seemed mentally to pursue a problem to the end, and with the result that nothing more could be added later.

Dr. Nichols may deal with his early interest in the establishment of proper units and standards of electrical measurement, and his connection with the Electrical Standards Committee of the British Association for the Advancement of Science in 1861 and later, which took upon itself the task of establishment of the c. g. s. system.

It is not surprising that practically throughout his life he gave much attention to the revising of electric measuring instruments and methods of measurement. His absolute electrometer of 1855, followed by the quadrant electrometer, his graded galvanometers of the early period of electric lighting and power, his electrostatic voltmeters, and his later Kelvin balances attest his interest, activity and success. Some of these are lasting monuments to his science and skill; valuable alike to the physicist and electrical engineer.

His visit to the Centennial Exibition of 1876 was rendered notable from the fact that he was one of the first to listen to the speaking telephone of Bell, there, I believe, originally shown privately, and was the most distinguished witness of the reality of its powers.

It may be of interest to engineers to recall the fact that in the early eighties Lord Kelvin, then Sir Wm. Thomson, made notable inventions in dynamo machines and took out patents thereon, one of which at least, dated Dec. 26, 1881, was used, together with improvements made by the well-known pioneer engineer, Ferranti, in the Ferranti-Thomson alternating-current machine. It had a disc armature composed of a zigzag tape-winding without iron. This machine existed about 1884 in sizes up to 400 kw. capacity, an unusual output for the time. It was constructed to give 2000 amperes at 200 volts and light about 5000 incandescent lamps. The introduction of higher voltages and transformers, necessitated remodelling, which removed the characteristic zigzag winding from the subsequent great Ferranti generators of the Deptford plant.

From the early Atlantic cable success, it followed that in any large cable enterprise subsequent thereto Lord Kelvin should be consulted. Similarly his great and well-merited reputation brought like responsibilities in other directions. Upon the first se ious proposal to utilize the power of Niagara in electrical work he was made one of the International Commission, composed of a number of the most eminent scientists and engineers, which in 1891 was charged with the duty of deciding upon the methods to be followed, and which finally shaped the work of the Niagara Construction Company. The wisdom of the decisions then made, has been amply demonstrated in later years. There was at first some question as to whether direct currents or alternating currents should be generated and transmitted. The disposition of the water wheels, the governing of the same, the type of dynamo construction to be employed, generator voltage, ratios of transformation, frequency, number of phases, and other matters of more or less importance required definite selection.

It must be remembered that the original Niagara plant was created, not copied from existing practice, and therefore was a pioneer enterprise in all substantial respects. Nothing here said, can detract from the great courage and merit of the able engineers who were entrusted with the actual construction and installation of the plant. A few words may be said as to the attitude taken by Lord Kelvin concerning the utilization of Niagara power to the detriment of the sublime spectacle of the falls itself. If I interpret him rightly he said in effect that, in his view, there was just as much, or more sublimity, romance or poetry, as exists in a mad rush of waters over a precipice; in the establishment of a great community making valuable and beautiful products by electric power to enrich the whole world and add to its resources; in the supersedure of oxygen-consuming lamps by beautiful electric lights in all the surrounding territory; in the prevention of the smoke nuisance on railways and in cities miles away, with the incidental saving of fuel for the use of future generations. If this expresses his attitude, it is one in which I can heartily concur. Niagara in daylight and in full flow is indeed a sublime spectacle to be preserved, it seems to me, unchanged, provided the sacrifice is not too great, for it has some of the elements of a great conflagration, and moreover it runs on unseen, through fog and night, even the long dark nights of our winter season.

In bringing to a close this necessarily brief and inadequate statement of the connection of Lord Kelvin with electrical engineering proper, it may be of interest to recall some incidents of a more personal nature. It will be remembered by those who attended the Electrical Congress held in Philadelphia in 1884 on the occasion of the Electrical Exibition there, that the opening address was made by him. It was not a large body, but composing it were many who are still with us. It was my good fortune to again meet Lord Kelvin in London in 1889, when as a youthful president of this Institute, then indeed itself youthful, barely out of its swaddling clothes, I endeavored to fitly represent it in a speech at the gathering and banquet of notables and engineers of Great Britain and the visiting American body, in the Guildhall; a combined audience of about 600. I interpreted as a compliment to our young Institute, through myself as its official head, an invitation to visit Sir William Thomson at Glasgow. But my plans had been made, and time was limited, so that to my lasting regret I was unable to accept. But I now cherish as a memory of him, one meeting of a few hours in 1897 which came about quite unexpectedly. Lord Kelvin, who was accompanied by his devoted wife, Lady Kelvin, visited this country in that year, and incidentally made a tour of inspection of the shops of the General Electric Company at Schenectady. During this visit, those who were with him had an opportunity of discovering his striking ability to seize upon the essential points of a structure, to remark his incisive questions, his quickness and clearness of apprehension, and his untiring interest and appreciation, during some strenuous hours. It was a genuine surprise to us who were with him, that in spite of his burden of 73 years his mind had retained its alertness and vigor.

On the trip about the shops he carried a note-book and made frequent memoranda. Some years after this, Mr. E. W. Rice, well-known to you, visited Lord Kelvin at Glasgow, when at once the note-book was produced, the items of information gone over, and Mr. Rice was questioned as to later developments which were carefully noted, in order to bring the matters up to date. In the afternoon of the same day I had the

satisfaction of finding that I was to be a fellow traveler on the train to Boston, which arrived there in the evening. It is a trip which I have made very many times, and it has generally seemed long and tedious, but not at all so on that occasion. It seemed to me too short. Our talk ranged from details of construction of coils of measuring instruments, to the age of the earth, and the nature of ether and matter. Even at the end of the usually tiresome journey, late in the evening, his interest did not abate, for even at the late hour he insisted on visiting the then recently constructed Boston subway before going to his hotel. Lady Kelvin gently protested that he must be too tired, but accompanied him to the subway. To one of his nature, nothing that interested him could produce fatigue. The great charm about him was his simplicity of manner and entirely honest attitude as to truth. When he did not know, he had no hesitation in frankly saying so, and seeking for information. Later on, it fell to my lot to speak some words of appreciation at the meeting held in his honor at Columbia University in 1902, on the occasion of his last visit here.

He has been the recipient of numerous high honors. He was one of our very small list of honorary members, and I am conscious that nothing which I may say could add to the esteem, I might almost say, veneration, in which he has been held by all who have known him or known of him. Yet I am thankful to have had this opportunity to express appreciation of him in connection with certain phases of his long and wondrously active career.

THE PRESIDENT: We will now ask Professor E. L. Nichols, Professor of Physics of Cornell University, and also President of the American Society for the Advancement of Science, to speak of Lord Kelvin as a scientist.

EDWARD L. NICHOLS

It is often said and truly, that we are unable to estimate the value of our contemporaries, or to assign to them their proper position in the roll of fame. Those who are most widely and favorably known in their own time, are frequently supplanted in the judgment of later generations by others who receive but little or no recognition during their lives. Occasionally, however, there appears a man of genius, the value of whose attainments can scarcely be questioned, and the permanency of whose position seems assured. Kelvin was one of these.

It was said of Helmholtz[1] that he was one of the greatest physicists, one of the most accomplished physiologists and one of the most accomplished mathematicians of the century. Just as truly we may say of Kelvin that he was one of the greatest physicists, one of the most skilful mathematicians and one of the most fertile and ingenious of the inventors of his time.

Lord Kelvin was born in Belfast, Ireland, on June 26, 1824. His father, James Thomson, was a North-of-Ireland man of the sturdy Scot-Irish stock. He had been educated at Glasgow. He was a school teacher in Belfast, and it was in that city that his two sons, James Thomson and William Thomson, first saw the light.

From 1832 James Thomson, Sr., was professor of mathematics at Glasgow, and there the two boys had their education in an environment fitted early to familiarize them with mathematical and scientific subjects, and to develop whatever latent powers they might possess. William was precocious, and at an age when boys, at least in our day, are thinking of entering college he was graduated from the University of Glasgow and went to Cambridge for further studies. There he distinguished himself in mathematics and in 1841 when he was seventeen years old published the first of a series of papers in the Cambridge Mathematical Journal. At Cambridge he was a pupil of George Gabriel Stokes, or more properly a companion, for he speaks of learning solar and stellar chemistry from him while they wandered together among the colleges.[2] Just what passed between these two young fellows on that subject, nearly twenty years before the appearance of the work of Kirchhoff and Bunsen it would indeed be interesting to know. From Cambridge where his powers as a mathematical physicist were rapidly developed, Thomson went to Paris and worked for some months in the laboratory of Regnault, one of the accomplished experimental physicists of that time.

1. Clifford, "Seeing and Thinking." p. 18.

In 1846 William Thomson became professor of physics at the University of Glasgow, which position he held almost to the end of his very long and active life. His brother James was subsequently appointed professor of applied mathematics and engineering in the same institution. The two, who were very like each other in character and in intellectual endowment, were frequently engaged upon similar problems. In 1851, William Thomson was elected to the Royal Society; in 1866, he was knighted and became Sir William Thomson; in 1892, he was raised to the peerage and took the title of Lord Kelvin.

Kelvin was a man of wide interests in science, not a student of electricity merely, nor of mechanics, nor of heat, nor of sound and light, but of all of these, with many fruitful excursions into the fields of astronomy and geophysics on the one hand and of navigation engineering on the other. Owing perhaps to his early training in mathematics, and to the school in which he was brought up, his tendency was always to work from theory to experiment; seeking by the latter to verify the conclusions of his analysis. A man who naturally does this, however much experimental work he may perform, is to be classed as a theoretical physicist in contradistinction to those whose interests are primarily in phenomena, and who use theory to explain and elucidate what they observe.

2. Kelvin, Nature 67, p. 337.

The period from 1841, when young William Thomson wrote his first papers, to 1907, when at the age of 83 he was still an active contributor to scientific literature, has been incomparably the most fertile epoch in the history of science and industry. Consider the material world of 1841:

The railway had only just begun to displace the stage coach; there were a few ocean-going steamships, but most travelers crossed the ocean in sailing vessels; John Stephenson's attempt to introduce street railways in New York had been made and abandoned; there were as yet no street cars, even with horses as the motive power in any city. The conception of electric transmission of intelligence had been in men's minds for nearly a century, and a practical telegraph line had been constructed by Wilhelm Weber, and Gauss, the astronomer, in Göttingen. This line connected the observatory with the physical laboratory and had been in successful operation for five years. Railways, however, which were coming in, made the telegraph a public necessity, and in England in 1840, Wheatstone and Cooke were installing their so-called A B C system. In this country Morse was busy with the same problem, but it was not until 1844 that the line from Baltimore to Washington was erected, and telegraphy became a practical thing in America. In a few of the largest cities only, had gas come into use for street lighting; petroleum had not supplanted whale oil and candles, for household illumination. The arc lamp had long before been invented by Davy, but electric lighting as a public utility had yet forty years to wait. A generation of electricians and inventors (Gramme and Siemens, Jablokoff and Swan, Edison, Weston, Brush, and a host of others) were yet to spend years of ceaseless toil in the development of that art, and of the other great electrical industries that the dynamo and motor have made possible. The airship was a dream of the visionary; the telephone not even yet a dream. Thirty-six years

later, the latter was to burst in a night on an unprepared and unexpecting world—essentially complete and ready for service. The airship was much longer to remain a dream, and only in these later days after much cost in human lives and endeavor, does it seem to be nearing realization. These and a thousand other things, skyscrapers and elevators, trolley roads above and below ground, stock-tickers and typewriters, submarine boats and steam turbines, motor boats and motor cars, wireless telegraphs and all that render life to-day at once more luxurious, more strenuous, and more complicated, were dreams or less than dreams in the year of 1841.

It is even more difficult to realize the conditions of science at that time, than to appreciate the changes that have taken place in the industrial world. Nineteen years were yet to elapse before the publication of Darwin's "Origin of Species." Pasteur was not yet. Brewster was still fighting his losing battle against the undulatory theory of light. In electricity, Coulomb and Oersted and Ohm, Arago and Ampere had paved the way to a new order of things, but the labors of Faraday in England, and of Joseph Henry in this country were but just begun. Heat was still regarded as a subtle fluid, and nine years were still to elapse before the appearance of Helmholtz's paper on the "Conservation of Energy." An era of extraordinary activity, however, was about to begin, during which science was to revolutionize the industrial methods of the world, and to be herself revolutionized.

In both revolutions Kelvin was to have an important part. Science to him was the endeavor to give precise mathematical expression to relations perceived, and thus to bring to light relations hidden and obscure. He sought likewise to comprehend definitely the mechanism involved in physical processes. Where the mechanism was not capable of being directly observed, he strove to imagine one. With him, computation was a passion, observation of secondary interest. He was always calculating, and few men I suppose have ever applied mathematics to a greater variety of subjects. The heat of the sun, the age of the earth, the size of atoms, the density of the luminiferous ether, the power of a cubic mile of sunshine, the mechanical energy of the solar system, the annual loss of heat by radiation from the earth, the retardation due to tides; these and innumerable other problems engaged him. Even his popular addresses, where all higher mathematics was excluded, teem with numerical data. He was no compiler of statistics. He gave out the results of his own computation in illustration of his subject. In such cases he was wont to express himself in the homely British measures—capillary forces in tons to the square inch and the like—but at the same time he was an enthusiastic supporter of the metric system, and was chiefly instrumental in the establishment and adoption of the c. g. s. system of units. To a Philadelphia audience in 1884 he said:

"You in this country are subjected to the British system in weights and measures; you use the foot, inch and yard. I am obliged to use that system, but I apologize to you for doing so, because it is inconvenient. I look upon our English system, as a wickedly brain-destroying piece of bondage under which we suffer. The reason why we continue to use it, is the imaginary difficulty of making the change and nothing else; but I do not think in America that any such difficulty should stand in the way of adopting so splendidly useful a reform."

Kelvin was a most prolific writer, and his productiveness lasted from his student days at Cambridge in 1841, until the year of his death in 1907. He contributed over 300 papers to some 30 different journals and transactions. The list of titles is a catalogue of nearly everything about which the world of physics was thinking, during the long period of his scientific activity. Often it was but a passing, though always a significant and suggestive thought which

he presented, but certain great subjects were to him themes of lifelong interest, and to these he continually returned with new contributions to our knowledge. With the doctrine of energy, in the development of which he was long a co-worker with Joule, and the science of thermo-dynamics which has grown out of that doctrine; with the mathematical theories of heat and electricity; with the theory of wave motion and especially of water waves, and with nineteenth century speculation concerning the constitution of matter, his name will ever be associated. His work in any one of these fields of investigation would have placed him in the first rank, and insured him a lasting reputation. Taken altogether, they justify the universal acclamation of him as the foremost man of science of his time.

In 1854 Cyrus Field appeared in England with a proposal for a transatlantic cable. The great expense involved, rendered the question of great importance whether transmission was practicable to such distances, and, if possible, the conditions under which success was to be expected. There was no previous experience upon which to base opinions, and most of the electricians of that time were as ill-equipped to consider the question from the theoretical point of view, as were most of the practical men forty years later, when suddenly confronted with the change from direct to alternating current systems for light and power. Kelvin, however, had already considered from the mathematical standpoint, the conditions existing in a circuit containing capacity and inductance. Three years before, his analysis was sufficiently advanced to enable him to forecast the existence of the phenomenon of the oscillatory discharge, and to state the law of retardation. He was almost the only man in England capable of giving a definite answer to many of the questions involved in long-distance transmission of signals through cables.

The history of his connection with the transatlantic service is well known. We know that the breaking down of the first cable in 1858 was due to failure to heed his warning, and that the ultimate success of the scheme was very largely the result of his mathematical skill and rare mechanical insight. It was in recognition of these practical services as well as of his eminence as a man of science, that he was knighted in 1866.

Of his career as an electrical engineer, and of his contributions to the art of navigation it is not my province to speak. Permit me, however, to note the very unusual circumstance that although a considerable portion of his time was for many years given to technical work, his output as an engineer was but a by-product. He was not thereby diverted from the consideration of the most abstruse and difficult phases of pure science, but continued to contribute with unabated ardor and success to our knowledge of physical theory, to the very end of his long life. Only last summer at the meeting of the British Association, he was able to take an animated and interested part in the discussions of the mathematical and physical section, and although he had a few years ago resigned his professorship at Glasgow, he may be said to have died in harness, since his last illness a few days ago was brought on by cold, due to his experimenting in the unheated hallways of his country house in Scotland.

Kelvin was keenly appreciative of the scientific and technical work of America. Of his visit in 1876 he spoke in the following glowing terms on September 7 of that year:[1]

"I came home, indeed, vividly impressed with much that I had seen both in the great exhibition in Philadelphia and out of it; showing the truest scientific spirit and devotion, the originality, the inventiveness, the patient persevering thoroughness of work, the appre ciativeness, and the generous open-mindedness and sympathy, from which

1. Kelvin: Address to the Mathematical and Physical Section of the British Association, 1876.

the great things of science come. I wish I could speak to you of the veteran Henry, generous rival of Faraday in electromagnetic discovery; of Peirce, the founder of high mathematics in America; of Bache, and of the splendid heritage he has left to America and to the world in the United States Coast Survey; of the great school of astronomers which followed—Gould, Newton, Newcomb, Watson, Young, Alvan Clark, Rutherford, Draper (father and son); of Commander Belknap and his great exploration of the Pacific depths by pianoforte wire with imperfect apparatus supplied from Glasgow, out of which he forced a success in his own way; of Captain Sigsbee, who followed with like fervor and resolution, and made further improvements in the apparatus by which he has done marvels of easy, quick, and sure deep sea sounding in his little surveying ship Blake.

"In the United States telegraphic department I saw and heard Elisha Gray's splendidly worked out electric telephone actually sounding four messages simultaneously on the Morse code, and clearly capable of doing yet four times as many with very moderate improvements of detail; and I saw Edison's automatic telegraph delivering 1015 words in 57 seconds—this done by the long neglected electrochemical method of Bain, long ago condemned in England to the helot work of recording from a relay, and then turned adrift as needlessly delicate for that. In the Canadian Department I heard 'To be or not to be—there's the rub', through an electric telegraph wire; but scorning monosyllables, the electric articulation rose to higher flights, and gave me passages taken at random from the New York newspapers. All this my own ears heard, spoken to me with unmistakable distinctness by the thin circular disc armature of just such another little electromagnet as this which I hold in my hand. The words were shouted with a clear and loud voice by my colleague-judge, Professor Watson, at the far end of the telegraph wire, holding his mouth close to a stretched membrane, such as you see before you here, carrying a little piece of soft iron, which was thus made to perform in the neighborhood of an eletromagnet in circuit with the line, motions proportional to the sonorific motions of the air. This, the greatest by far of all the marvels of the electric telegraph, is due to a young countryman of our own, Mr. Graham Bell of Edinburgh and Montreal and Boston, now becoming a naturalized citizen of the United States. Who can but admire the hardihood of invention which devised such very slight means to realize the mathematical conception, that if electricity is to convey all the delicacies of quality which distinguish articulate speech, the strength of its current must vary continuously and as nearly as may be in simple proportion to the velocity of a particle of air engaged in constituting the sound"?

In 1884 Kelvin attended the British Association meeting in Montreal, and tarried to deliver before a distinguished and appreciative audience in Baltimore the extraordinary course of lectures on molecular dynamics which twenty years later he published in book form. In 1897 the Toronto meeting of the Association brought him across the water once more, and it was here that he read his striking paper on the "Fuel Supply and Air Supply of the World"; the suggestion being that free oxygen is the result of plant action, and that cessation of life is more likely to come from depletion of the air, than from lack of fuel. Upon his last visit to the United States in 1902 he showed a spirit unconquered by old age, an enthusiasm for all things scientific, and an interest in things technical, as vivid and trenchant as that which had characterized his younger days. Seeing a gang of 24 small direct-current generators operated in series for high-tension experiments in the laboratory at Cornell, I remember that he advocated the direct current for long-distance transmission in preference to alternating current—a suggestion which then met with little favor at least in this country, but which is now being worked out on a practical scale in Switzerland.

Kelvin was so familiar a figure to engineers and physicists in this country that I need not attempt to describe him. Many of you will remember the spare wiry form, almost frail as to physique, but full of life and imbued with an almost boyish eagerness. To my mind his most striking characteristic was an unostentatious simplicity; the simplicity which one remembers in men such as Heinrich Hertz, and in Lorentz, and which happily we find so frequently in great men, that it may fairly be termed the typical simplicity of genius. With this simplicity was combined a certain practicality; the practicality of his race. I do not know; but I suspect that Kelvin would have regarded Niagara fully harnessed to the service of man, a more beautiful and inspiring sight than the original unchained Niagara of the wilderness. I well remember that years ago when the esthetically inclined, protested against the unsightliness of overhead wires he remarked that the time would come when the network of wires across the sky would be regarded a fit subject for the rhapsodies of the poets.

Combined again with these personal attributes was the supreme quality of kindliness; and to this I am able to bear direct personal testimony. In the winter of 1879 I was in Scotland, and ventured somewhat timorously to visit Kelvin's laboratory at the University of Glasgow; an unknown student on my way home from Germany with no claim upon him, and no recommendation save a certain enthusiasm for physics and a keen interest in the work which he was doing. I shall never forget the warm friendliness of my reception, nor the trouble he took to show me everything in the laboratory and workshops, nor the cordial hospitality of his household and that of his brother, James Thomson, the professor of engineering.

Such was Lord Kelvin, physicist, mathematician, electrician, inventor, man of genius. He has passed from earth, and his fellow countrymen have paid him their highest tributes—a resting place in Westminster Abbey. May not we, his cousins across the sea, gathered in commemoration of him, and of his services to mankind say, fittingly, of him what he himself said, in his tribute to his fellow physicist and friend, Sir George Stokes:

"*The world is poorer through his death and we who knew him feel the sorrow of bereavement*".[1]

THE PRESIDENT: There is another part of Lord Kelvin's work, which appealed very largely to the popular imagination and benefited mankind in general very greatly, and that is his work in connection with submarine telegraphy.

I will now ask Mr. G. G. Ward, honorary secretary and treasurer for the U. S. A. of the Institution of Electrical Engineers of Great Britain, to address you on the subject, "Lord Kelvin's work in submarine telegraphy".

GEORGE G. WARD

Fifty years ago the world was waiting with profound interest, the outcome of that gigantic enterprise which eventually culminated in the completion of the short-lived but all important first transatlantic cable of 1858. Two ships were required to carry and lay the cable, viz.: the U. S. frigate "Niagara" and H.M.S. "Agamemnon." Lord Kelvin, then Professor Thomson, was the electrical engineer in charge, on board the Agamemnon, and now, just as the jubilee of that historic and epoch-making event approaches, we pay homage to his memory as the man whose contributions to the success of submarine telegraphy cannot be over-rated; the man who, we may truthfully say without the slightest exaggeration, first made long-distance ocean telegraphy possible.

As early as 1855 he outlined the laws of the speed of signals through ocean

1. Lord Kelvin: "The Scientific Work of Sir George Stokes": Nature, 67, p. 337.

cables, and their connection with other natural forces. In 1856 he knew, what no one else seemed to suspect, that two or more insulated wires of any great length under one sheathing, would suffer so much from mutual induction as to be unworkable, and he warned engineers of the danger of constructing such a cable.

He pointed out the great importance of using copper for the conductor of the cable, free from all traces of impurity, on account of the extremely deleterious effect such impurities had on its conductivity, Many scientists at the time were opposed to this theory, but his insistence on its correctness led to the appointment of a special commission under Dr. Matthiessen for the purpose of making a thorough experimental investigation of the question. The work of that commission is quoted to-day as a basis of comparison, and at that date revolutionized the manufacture of copper for electrical conductors.

Other scientific men of prominence had formed the opinion that the opposition of the cable to the passage of a current on account of its great length, and high resistance copper, could always be overcome by increasing the battery employed.

Professor Thomson knew, however, that to increase the voltage was to attack the subject from the wrong side, as was demonstrated in the cable of 1858, which, stimulated by powerful batteries and induction coils, expired in its effort to articulate. In 1865 his theory of the practicability of using but a minute power, one that could be generated in the bowl of a clay pipe or even in a lady's thimble, was fully demonstrated. He saw the need of a delicate and extremely sensitive apparatus which would respond to such a feeble current, and invented for the purpose that beautiful instrument, the mirror galvanometer. The mirror galvanometer was employed on the 1866 cable, and not only increased its efficiency, but probably has done more to reduce electrical measurement to an exact science, than any other instrument ever invented.

In 1869 he made a still further advance by inventing the siphon recorder, which writes every signal passing through a cable. This instrument was introduced on long submarine lines in 1869, and the speaker had the honor of being one of the first to work it. It was then in a crude experimental form.

His marine galvanometer, specially designed for ships, made it possible to accurately test cables while being laid or repaired. The motion of the vessel had no effect upon it.

His was the wonderful mind that devised the means of making the submarine cable complete its purpose of linking the hemispheres together.

At the jubilee of his professorship of natural philosophy at the University of Glasgow in 1896, his own inventions were used to convey him congratulations from every quarter of the globe.

He acted as electrical engineer during the manufacture and laying of the cables of 1865-1866 and at the end of the latter expedition, received the honor of knighthood, and in 1892 he was made a peer.

His early investigations were carried out at a time when no exact standards of measurement existed, and while the world owes him much for the direct results of his work for submarine telegraphy, the placing of these measurements on a permanent and scientific basis is equally important. Remembering all these difficulties, his mathematical work inspires one with profound admiration and respect, feelings which are doubly intensified when one thinks of the marvelous ingenuity and versatility, which provided all manner of simple and efficient expedients to overcome the many difficulties that arose in his experimental labors.

He devised many standard instruments for making precise electrical measurements. These have been used in all branches of electrical work. His quadrant electrometer is largely used in submarine cable work, and is a fine example of that care and forethought which provided so fully for all the requirements of a given problem. He taught telegraph engineers the principles of their business.

Lord Kelvin was a profound thinker and a busy worker in many diversified subjects, but his interest in cable telegraphy never flagged. With his death, the cable world has lost one of the pioneers, and the greatest master-mind of the art, whose work will remain as a prominent and lasting testimony to the exactness and thoroughness with which he carried out everything he undertook. Submarine telegraphy owes so much to the labors and genius of Lord Kelvin, that no history of the ocean cable could be written, that would not be largely a history of his investigations, researches, discoveries and inventions.

We who have worked submarine cables with his mirror galvanometer and with his siphon recorder, have tested them with his astatic galvanometer, and with his electrometer, have calculated their speeds by his formulas, have located their faults by his methods and instruments, have sent our repair ships guided by his compass, have taken our soundings in new waters by his sounding wire—how can we, who have worked with him all these years, think of any part of our branch of applied electricity without at the same time recalling William Thomson, Lord Kelvin. His figure looms so large with us that we deplore his death as an irreparable loss. Those who knew him and had the privilege of his friendship, and there are many such here to-day, will dwell with deep and genuine regret on the sorrowful thought that his modesty and his winning personality have passed into memory and will be seen no more.

After a life devoted with unsurpassed success to physical science and its practical applications, the mind that thought, has fled to Him who bestowed it; the body that wrought rests among kings in that sacred pile where Britain lays and guards her illustrious dead, but his name and fame will endure world-wide never to be forgotten while the sciences flourish. ———

THE PRESIDENT: The last speaker has touched upon some of Lord Kelvin's work of which the average layman has heard but little, and I will now ask Rear Admiral George W. Melville, U.S.N., to speak on the subject, " Lord Kelvin in naval engineering ".

GEORGE W. MELVILLE

William Thomson, Sir William Thomson, Lord Kelvin, I was going to say of Great Britain, but I must say of the whole world, for he belongs to us, as the engineers and physicists of America, as well as of Great Britain.

He was the product of the land of the thistle and heather, that storied land of Scott and Burns. Sterile with rocks and snows; but rich, so rich in song and story, of men of great deeds, and sterling worth; that land which in the last hundred years has produced more great men in every high station in life, for her population, than any other land under the sun. And he was one of these. I had the honor and privilege of knowing him personally, dined and supped with him, and had the great delight of listening to his learned discourse, this of itself a great privilege, and a bright milestone in my varied life.

Yet he was as simple in his manner as a child, and as patient as a Hindoo god in listening to the various pigmies who presented their varied opinions to his great and well-trained mind. His greatness was well exhibited in his patient well-bred manner.

I count it a privilege and a high honor to have been asked to represent " those who go down to the sea in ships " in paying a tribute for them to the memory of the great man, whose beneficent genius included them among the multitudes, whose lives are safer, broader and more enlightened because he lived and worked.

We all know how difficult it is to judge of relative magnitudes when we are close to them, and I think, in spite of the veneration in which we all held Lord Kelvin, something of the kind is

true of his reputation. He has been so close to us all in his wonderful ability to make practical application of abstruse mathematical reasoning, that we can hardly, as yet, give him his rightful place in the Pantheon of scientific immortals. I am sure, however, that we all believe his place will be among the highest.

My own training and habits of thought are such, that (like many others here probably) his mathematical genius in solving problems of extreme difficulty arouses deep admiration, even wonder, but without the appreciation which can come only from a kindred mind, of which there are very few indeed. But that is only one aspect of his genius. More wonderful still to me is the fact that, this mighty intellect, which was not daunted by the problem of forecasting the life of the world, could also turn itself to practical problems of the most concrete kind, and give us solutions which, when they have not remained unchanged, are still the essential feature of the latest form of the apparatus.

Is it going too far to say that the success of the trans-oceanic cables is due to Lord Kelvin. He was the engineer of the first ones which were successful, and while his mathematical skill foretold the conditions as they were proved to be, his practical talent as a physicist and mechanician developed the mirror galvanometer and the siphon recorder, without which the feeble energy transmitted could not have been utilized. What must be the feelings of a man who, for forty years, could reflect that the whole course of government, business life and the daily information of the " man on the street " had been absolutely revolutionized by his work. In ancient times an ambassador was in a very real sense the representative of his sovereign, and on his skill alone, often depended the issue of war and peace. But the work of this quiet scientist has made him little more than a messenger boy in a gilded coat. We all know how the battle of New Orleans in 1815 was fought two weeks after the treaty of peace had been signed; but the result of the treaty of Portsmouth was known in a few minutes in Tokio and St. Petersburg.

This almost instantaneous transmission of intelligence has linked the nations of the earth until they are far closer than provinces of the same country were a century ago. It has brought nearer to fruition Bobby Burns's prophesy that " Man to man, the world o'er, shall brothers be for a' that". We have had it exemplified within the last few months when Europe was shipping us gold within a day of its need being determined here.

Lord Kelvin's practical application of keen mathematical analysis gave us an improved mariner's compass to meet the conditions brought about, when iron and steel supplanted wood in shipbuilding, and at first seemed to threaten the usefulness and reliability of that best friend of the mariner. The details have now been worked out, so that the adjustments can be made by men of ordinary ability, thus again illustrating his wonderful capacity for the practical utilization of abstract theories.

Still another of his contributions to improvement in maritime affairs is the sounding machine for determining ocean depths. Before this, it was a difficult, uncertain and laborious task to attempt to ascertain great depths, some of which, as you doubtless know, are more than five miles. We have in this apparatus simple but ingenious applications of science all through. It can readily be imagined that the wire, in passing through such great depths, may be diverted by submarine currents, so the actual determination of the depth is by the registration in a protected tube, which is carried clear to the bottom.

I have referred to the intensely scientific side of Lord Kelvin's genius as though it were somewhat surprising, and, unfortunately, we all know that it is far from common to find it in combination with the genius for abstract reasoning, such as he possessed. We may remember, however, that the great

Newton was master of the mint for many years, where he did splendid work in the reformation of the coinage. I think perhaps the condition is a survival of that kind of education which considered the utilities as beneath notice, and that mental training, as such, was the great end. Even in our era, when the engineer is such a mighty factor, we shall occasionally hear some college president, trained in the old school, who wants education to be somewhat procrustean, and to compel all students to go through a dreary grind of dead languages on the alleged ground that it broadens them. Such men call their favorite studies " the humanities ", yet what have they really done for humanity, compared to the work of such men as Lord Kelvin?

Perhaps in our day we do not need to regard seriously these efforts to galvanize a decadent worship, but it is well to emphasize the lesson of Lord Kelvin's life in its devotion to the practical and the useful, and to pay our tribute to his memory for having made our world better and happier, and all our lives broader and more fruitful.

In conclusion I am pleased to say that Great Britain knew her duty toward this mighty mind. They have laid him to rest in their glorious Pantheon, Westminster Abbey, where for a thousand years all that is great, high, holy, or worthy of a nation's gratitude is gathered for their last long sleep.

I believe it was Britain's greatest admiral who said before the battle of Trafalgar, " Here is for the peerage or Westminster Abbey ". The great soul that is laid to rest with the best of Britain's heroes had no such thoughts in his mind. He won his peerage and rest in Westminster, not by destroying his fellowman, but by that higher, holier duty as he saw it by making the world better for man to live in. And the whole world is better because he had lived.

THE PRESIDENT: I will now call on Mr. T. C. Martin, editor of the *Electrical World*, and past-president of the Institute, to speak of " Lord Kelvin and the American Institute of Electrical Engineers ".

THOMAS COMMERFORD MARTIN

Although Sir William Thomson first landed on the shores of this continent in 1866, it was not until ten years later that he first came in contact with American electrical engineering, when in 1876, at the ever famous Philadelphia Centennial Exposition, he heard through the telephone and to use his own language, got inspiration from meeting its inventor, Alexander Graham Bell, our past-president. At that time our fellow members, Elihu Thomson, C. F. Brush, Edward Weston, and Thomas Alva Edison, were still low on the horizon, but they were well aloft in the firmament when this great European comrade came back in 1884. In the meantime, the phonograph had been added to the telephone; and it was perhaps logical and typical that the two greatest talking devices of all the ages should have been born in America.

But what pleased Sir William best in 1884, aside from the foundation in that year of our own Institute, was the marvelous development of electric lighting. Not only were the brilliant arcs of Brush and Thomson resplendent on the highways, " insistent sisters of the day ", to use Shelley's phrase, but he found, in his own phrase, " Edison's great invention perfected ", and that which he had regarded dubiously, the " subdivision of the electric light ", applied successfully for interior illumination in New York and other great cities. To the conquest of transmitted and recorded speech, America had added electric light for street and home, with lamps that like stars differed from each other only in their glory. And again the great-hearted representative of English science rejoiced, and again he filled up several more of those little green note-books with the answers to his ceaseless questions.

That year, 1884, the American Insti-

tute of Electrical Engineers struggled into existence, and he who was thrice president of our kindred society in Great Britain, gave those of us who worked anxiously for its foundation, the warmest support and sympathy. Even to-day, we are inclined to suppose, in spite of all our American chauvinism and national pride, that in things technical and scientific, leadership or supremacy belongs in Europe. What ever of truth or fallacy lurks in this idea, it was at least gratifying to us, to have Sir William predict a splendid outflowering of the electrical arts in America, with an Institute that would in a few years excel in membership any sister society throughout the world. His belief in our success did much to make us successful, did much to help us in developing along right lines, did much to help create this unequalled home and center of engineering.

In 1896, I was delegated by the Institute as your past-president, to represent it at the jubilee of Lord Kelvin at Glasgow University, when we could reciprocate some of his courtesies to us. Never shall I forget the stately and lively exercises of that glorious June morning, when in the big chapel above the tiny brook from which he took his title, that simple, good, gray old man, pioneer, inventor, physicist and thinker beyond any other contemporary of our race, received the plaudits of a notable assemblage and the addresses of every great university and every learned society throughout the world. The pile of engrossed resolutions rose ever higher on the platform, hiding the dignitaries, and as I sat with Hopkinson and Ayrton and Perry and Mascart we wondered whether the scrolls we carried might not presently tip the pile over to the intense delight of the cheering, surging mob of students up in the galleries. That night at the grand banquet to which the royal felicitations were sent, we heard this man so honored, avow with tears and almost with the note of tragedy in his voice, that his life had been a failure—that striving as he had for fifty years, he knew no more of electricity and magnetism, and was no nearer solving the deep problems of nature than when he began toiling up the ladder of knowledge.

Only as an evidence of his kindly disposition and unwearied interest in American development, I mention the fact that the same week, instead of resting after such memorable exercises, he made the long, weary trip from Glasgow to London to preside at a lecture I delivered before the Royal Institution on the utilization of Niagara, a project which he always encouraged, saying that the great cataract would never be beautiful, until it had ceased to be such an awful and unlovely example of waste.

In 1902 Lord Kelvin came back to this country, and in April with the cooperation of other societies, we gave him and Lady Kelvin a reception at Columbia University, attended by over 2000 members and friends. Whether there was a premonition or not, that it was his last visit to America I do not know, but it is the fact, that the throng of friends and acquaintances who crowded around to say personal good-bye, simply swamped the spacious platform and carried the guests of the evening off their feet. We had an electric coupé in waiting, and as they rode away I told Lord Kelvin jokingly that it was his chariot of fire. Many an idle word has the aspect of prophecy. Equally interesting as a souvenir of that last trip, was the last public function, the dinner given in his honor by Anthony Brady on behalf of the New York Edison Company at Delmonico's, when he spoke of the wonderful growth of the lighting system in this city since 1884, and said that old as he was, he always got new inspiration when he came to this country. Before he left for the other shore forever, he heard and was enthusiastic over the Cahill telharmonium, invented by one of our members, wherein the sound theories of his old friend Helmholtz were justified by electrical inventions, and where dynamos take the place of organ pipe and violin string, and give us literally the music of the spheres.

One of the conceptions we associate with Lord Kelvin is that of a universe where the driving power, the energy, is always the same, but where in regard to such a solar system as ours there is a constant slowing down, an inevitable tendency to degeneration, and at last cessation and death. True in all probability of the physical world and mortal man, but as for the spiritual world in which he had so profound a faith, the converse is equally true, and the heirs of all the ages, the generation that follows us will be lifted to loftier insight, to finer ideals, to broader principles, to higher peaks of philosophic vision, to a keener perception of divinity itself, because Kelvin lived. No man felt more intimately and reverently than he, the fellow member to whom we now pay this last tribute, the sentiment of Tennyson's beautiful lines:

"Our little systems have their day,
They have their day and cease to be,
They are but broken lights of thee,
And thou, O Lord, art more than they!"

———

Benediction was pronounced by Dr. Manning and the meeting adjourned.

Societies Officially Represented

Organizations	*Representatives*
American Association for the Advancement of Science	Edward L. Nichols, retiring president.
American Electrochemical Society	E. F. Roeber, chariman, executive committee. Joseph W. Richards, secretary.
American Institute of Mining Engineers	A. R. Ledoux, past-president
American Philosophical Society	Andrew Carnegie. Michael I. Pupin.
American Physical Society	Ernest Fox Nichols.
American Mathematical Society	J. Howard Van Amringe.
American Society of Civil Engineers	Charles Macdonald.
American Society of Mechanical Engineers.	Rear Admiral George W. Melville, U.S.N past-president and Hon. Member.
American Street and Interurban Railway Association	B. V. Swenson, secretary.
Association of Edison Illuminating Companies	W. W. Freeman, president. John W. Lieb, Jr., past-president.
Franklin Institute	Edwin J. Houston. T. Commerford Martin, corresponding member.
Institution of Electrical Engineers (Great Britain)	George G. Ward, honorary secretary and treasurer for U. S. A.
Illuminating Engineering Society	Clayton H. Sharp. Arthur H. Elliott.
National Electric Light Association	Dudley Farrand, president. W. W. Freeman, secretary.
New York Electrical Society	Albert F. Ganz, president. George H. Guy, secretary.

The audience numbered 355 in which the American Institute of Electrical Engineers, the American Institute of Mining Engineers, and the American Society of Mechanical Engineers were largely represented by their officers and members, accompanied by many ladies.

THE UNIVERSITY,
GLASGOW.

July 28. 1892.

Dear Mr Pope,

I beg that you will express my best thanks to the Council of the American Institute of Electrical Engineers, for

the honour they have
done me in electing
me to be an Honorary
Member. I must thank
Yourself also for your
kind letter of the
15th and for the

Volume of Transactions
of the Institute for
the Year 1891. which
you advise, and which
I have duly received.

Yours very truly,
Kelvin

To Lord Kelvin.

Peace and the grace of God abide with thee,
Fallen with weight of over-ripened days!
Thou canst not hear how men forbear to praise
For grief the world has lost thy majesty.
How shall we more exalt thy fame's degree,
Or to thy memory enduring raise
More lofty tribute than thy Learning lays
Upon thy tomb? What words of eulogy
Are needed more to save thy cherished name
From unremembered annals of the dead?
But with the great of every land we bow
In sorrow, while with loftiest acclaim
Thou to thine everlasting rest art laid
With crown of noble works upon thy brow.

Wilbur Morris Stine,
Associate A. I. E. E.