LORD KELVIN

By Silvanus P. Thompson.

On the 17th of December, 1907, aged eighty-three years, died the Right Honourable Sir William Thomson, Baron Kelvin of Largs.

Adequately to set forth the life and work of a man who so early won and who for so long maintained a foremost place in the ranks of science were a task that is frankly impossible. The greatness of a man of such commanding abilities and such profound influence cannot rightly be gauged by his contemporaries, however intimately they may have known him.

But if we may not attempt the impossible, we may at least essay the task of setting down in simple fashion some account of his life and achievements.

William Thomson was born on June 26, 1824, in Belfast, being the second son and fourth child of James and Margaret Thomson James Thomson (or Thompson, as he spelled his name up to the age of twenty-four), who was at that time Professor of Mathematics in the Royal Academical Institution of Belfast, was the son of a small farmer at Ballynahinch, in County Down, Ireland, where his ancestors had settled about the year 1641, when they migrated from the lowlands of Scotland.

In 1830, when William was six years old, his mother died. His father would never send his boys to school, but taught them himself. In 1832, when William was eight years old, Professor Thomson was offered the Chair of Mathematics at Glasgow, and he with his family of six children accordingly removed from Belfast. After his removal to Glasgow he still kept the education of his sons in his own hands, and so it happened that in 1834 William Thomson, when in his eleventh year, matriculated as a student in the University without ever having been at school. He early made his mark by his progress in Mathematics and Physical Science, and in 1840 produced an essay " On the Figure of the Earth," which won him the University Medal. He also read Greek plays with Lushington, Latin with William Ramsay, Logic, and Moral Philosophy. To the end of his life he was in the habit of bringing out quotations from the classic authors. His fifth year as a student at Glasgow, 1839-40, was notable for the impulse toward Physics which he received from the lectures of Professor J. P. Nichol and from those of David Thomson (a relation of Faraday), who temporarily took the classes in Natural Philosophy during the illness of Professor Meikleham. In this year William Thomson had systematically studied the "Mécanique Analytique" of Lagrange and the "Mécanique Celeste" of Laplace, both mathematical works of a high order, and had made the acquaintance—a notable event in his career—of that remarkable book, Fourier's "Théorie analytique de la Chaleur." On May 1st he borrowed it from the College Library. In a fortnight he had read it completely through. The effect of reading Fourier dominated his whole career thenceforward. He took the book with him for further study during a three months' visit to Germany. During his last year (1840-41) at Glasgow he communicated to the Cambridge Mathematical Journal, under the signature "P. Q. R.," an original paper, "On Fourier's Expansions of Functions in Trigonometrical Series," which was a defence of Fourier's deductions against some strictures of Professor Kelland. He left Glasgow University after six years of study, without even taking his degree, and on April 6th, 1841, entered as a student at St. Peter's College, Cambridge, where he speedily made his mark. As an undergraduate of seventeen he was handling methods of difficult integration readily and with mastery, as his paper, entitled "The Uniform Motion of Heat in Homogeneous Solid Bodies, and its Connection with the Mathematical Theory of Electricity," clearly showed.

Of Thomson's Cambridge career so much has been written that it need only be very briefly touched on here. He went up for his Tripos in 1845, and came out Second Wrangler. He rowed in the University races of 1844, and won the Colquhoun silver sculls; he helped to found the Cambridge University Musical Society, and himself played the French horn in the orchestra. On leaving Cambridge Thomson went to Paris and worked in the laboratory of Regnault at the Collège de France. He was here four months, and it was here he made the acquaintance of Biot, Liouville, Pouillet, Sturm and Foucault, of whom he spoke in terms of admiration. Returning to Cambridge he was made College Lecturer in Mathematics, and elected to a Fellowship worth about £200 a year. Thomson was now twenty-one years old, but had already established for himself a growing reputation for his mastery of mathematical physics. He had published about a dozen original papers, and had gained experience in three Universities. In 1846 the Chair of Natural Philosophy at Glasgow became vacant by the death of Professor Meikleham, and Thomson, at the age of twenty-two, was chosen to fill it. His father, Professor James Thomson—he died in 1849—still held the Chair of Mathematics, Professor Thomas Thomson held that of Chemistry, while Professor Allen Thomson occupied the Chair of Anatomy. William Thomson was the youngest of the five Professor Thomsons then holding office in Glasgow. He chose for the subject of his inaugural dissertation: "De Motu Caloris per Terræ Corpus."

This Professorship he continued to hold till he resigned it in 1899, after continuous service of fifty-three years.

In the lecture theatre his manifest enthusiasm won for him the love and respect of all students, even those who were hopelessly unable to follow his frequent flights into the more abstruse realms of mathematical physics.

Over the earnest students of natural philosophy he exercised an influence little short of inspiration, an influence which extended gradually far beyond the bounds of his own University.

The next few years were times of strenuous work, fruitful in results. By the end of 1850, when he was twenty-six years of age, he had published no fewer than fifty original papers, mostly highly mathematical in character, and several of them in French. Amongst these researches there is a remarkable group which originated from his attendance in 1847 at the meeting of the British Association. But a more important event of that meeting was the commencement of his friendship with Joule, a Manchester brewer, and Honorary Secretary of the Manchester Literary and Philosophical Society, who had for several years been pursuing his researches on the relations between heat, electricity, and mechanical work.

Joule's paper, which he presented on this occasion, on the mechanical equivalent of Heat, would not have been discussed at all but for the intelligent remarks and observations of a certain young man, William Thomson, who had two years previously passed the University of Cambridge with the highest honour. Thomson, though, at first, scarcely grasping the significance of the subject, threw himself heart and soul into the new and strange doctrines that heat and work were mutually convertible, and for the next six or eight years, partly in co-operation with Joule, partly independently, he set his unique powers of mind to unravel those mutual relations.

Thomson's mind was essentially metrical. He must measure, he must weigh, in order that he might go on to calculate.

"I often say," he once remarked, "that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be. . . ."

Even before his first meeting with Joule, in June, 1847, he communicated to the Cambridge Philosophical Society a paper "On an Absolute Thermometric Scale founded on Carnot's Theory of the Motive Power of Heat, and Calculated from Regnault's Observations." In this paper he set himself to answer the question: Is there any principle on which an absolute thermometric scale can be founded? He arrived at the answer that such a scale is obtained in terms of Carnot's theory, each degree being determined by the performance of equal quantities of work in letting one unit of heat be transformed in being let down through that difference of temperature. This indicates as the absolute zero of temperature the point which would be marked as—273° on the air-thermometer scale. In 1849 he elaborated this matter in a further paper on "Carnot's Theory," and tabulated the values of "Carnot's function" from 1°C to 231°C. Joule, writing to Thomson in December, 1848, suggested that probably the values of "Carnot's function" would turn out to be the reciprocal of the absolute temperatures as measured on a perfect gas thermometer, a conclusion independently enunciated by Clausius in February, 1850. Independently of Joule, Mayer and Helmholtz had been considering the same problems from a more general standpoint. Helmholtz's famous publication of 1847, "Die Erhaltung der Kraft"--"On the Conservation of Force" (meaning what we now term Energy) was chiefly concerned with the proposition, based on the denial of the possibility of perpetual motion, that in all the transformations of energy the sum total of the energies in the universe remains constant.

In the years 1851 to 1854, Thomson formulated with scientific precision, in a long communication to the Royal Society of Edinburgh, the two great laws of thermodynamics—(1) the law of equivalence discovered by Joule, and (2) the law of transformation which he generously attributed to Carnot and Clausius. Thomson never was grudging of the fame of independent discoverers. "Questions of personal priority," he wrote, "however interesting they may be to the persons concerned, sink into insignificance in the prospect of any gain of deeper insight into the secrets of nature."

Thomson never made any use of the conception of entropy introduced by Clausius. In 1855 he introduced the wider conception of "available energy" which is the foundation of the later developments of thermodynamics.

In 1852, at the age of twenty-eight, William Thomson married Margaret Crum, and resigned his Cambridge Fellowship. The happiness of his life was, however, shadowed by his wife's precarious health, necessitating residence abroad at various times. In the summer of 1855 they stayed at Kreutznach, from which place Thomson wrote to Helmholtz inviting him to come to England in September to attend the British Association meeting at Glasgow. He assured Helmholtz that his presence would be one of the most interesting events of the gathering, so that he hoped to see him on this ground, but also looked forward with the greatest pleasure to the opportunity of making his acquaintance, as he had desired this ever since the "Conservation of Force" had come into his hands. Accordingly, on July 29, Helmholtz left Königsberg for Kreutznach to make the acquaintance of

Thomson before his journey to England. On August 6th he wrote to Frau Helmholtz that Thomson had made a deep impression on him.

"I expected to find the man, who is one of the first mathematical physicists of Europe, somewhat older than myself, and was not a little astonished when a very juvenile and exceedingly fair youth, who looked quite girlish, came forward. He had taken a room for me close by, and made me fetch my things from the hotel and put up there. He is at Kreutznach for his wife's health. She appeared for a short time in the evening, and is a charming and intellectual lady, but is in very bad health. He far exceeds all the great men of science with whom I have made personal acquaintance, in intelligence, and lucidity, and mobility of thought, so that I felt quite wooden beside him sometimes."

Faraday and Riess had observed that in certain cases the gases produced by the discharge of sparks through water consisted of mixed oxygen and hydrogen, and Helmholtz had conjectured that in such cases the spark was oscillatory. Thomson determined to test mathematically what was the motion of electricity at any instant after making contact in a circuit under given conditions. He founded his solution on the equation of energy, ingeniously building up the differential equation and then finding the integral. The result was very remarkable. He discovered that a critical relation occurred if the capacity in the circuit was equal to four times the coefficient of self-induction divided by the square of the resistance. If the capacity was less than this the discharge was oscillatory, passing through a series of alternate maxima and minima before dying out. If the capacity was greater than this the discharge was non-oscillatory, the charge dying out without reversing. This beautiful bit of mathematical analysis, which passed almost unnoticed at the time, laid the foundation of the theory of electric oscillations subsequently studied by Oberbeck, Schiller, Hertz, and Lodge, and forms the basis of wireless telegraphy. Feddersen in 1859 succeeded in photographing these oscillatory sparks. and sent photographs to Thomson, who with great delight gave an account of them to the Glasgow Philosophical Society.

At the Edinburgh Meeting of the British Association in 1854 Thomson read a paper "On the Mechanical Antecedents of Motion, Heat, and Light." Starting with some now familiar, but then novel, generalities about energy, potential and kinetic, and about the idea of stores of energy, the author touched on the source of the sun's heat and the energy of the solar system, and then reverted to his favourite argument from Fourier, according to which, if traced backwards, there must have been a beginning to which there was no antecedent.

The Proceedings of the Royal Society of Great Britain for 1854 contain the investigation of cables under the title, "On the Theory of the Electric Telegraph." Faraday had predicted that there would be retardation of signals in cables owing to the coating of gutta-percha acting like the glass of a Leyden jar. Forming the required differential equation, and applying Fourier's integration of it, Thomson drew the conclusion that the time required for the current, at the distant end, to reach a stated fraction of its steady value would be proportional both to the resistance and to the capacity; and as both of these are proportional to the length of the cable, the retardation would be proportional to the square of the length. This is the famous law of squares about which so much dispute arose. This was followed by a further research, "On Peristaltic Induction of Electric Currents," communicated to the British Association in 1855, and afterward in more complete mathematical form to the Royal Society.

The story of the Atlantic cable, of the failure of 1857, of the brief success of 1858, has so often been told that it need not be emphasised here. Thomson, after the failure of the first attempt, was called upon to assist more actively.

Of the part he played in preparation for the cables of 1865 and 1866, suffice it to say that throughout the preparations, the preliminary trials, the interrupted voyage of 1865, when 1,000 miles were lost, the successful voyage of 1866, when the new cable was laid and the lost one recovered from the ocean and completed, Thomson was the ruling spirit whose advice was eagerly sought and followed. On his return he was knighted. He had in the meantime made further improvements in conjunction with Cromwell Varley. In 1867 he patented the siphon recorder, and in conjunction with Fleeming Jenkin, the curb-transmitter. He was consulted on practically every submarine cable project from that time forth. He established a partnership with Varley and Jenkin, as consulting engineers, which proved a highly profitable professional connection.

When, in 1861, Sir Charles Bright and Mr. Latimer Clark proposed the names of ohm, volt, and farad for the practical units based on the centimetre-gramme-second absolute system, Sir William Thomson gave a cordial support; and on his initiative was formed the famous Committee of Electrical Standards of the British Association, which year by year has done so much to carry to perfection the standards and the methods of electrical measurement.

He was largely responsible for the international adoption of the system of units by his advocacy of them at the famous Paris Congress of 1881, in which Helmholtz, Mascart and Werner von Siemens took such prominent part, and of which Eric Gerard was sectional secretary. He was an uncompromising advocate of the metric system, and lost no opportunity of denouncing the "absurd, ridiculous, time-wasting, brain-destroying British system of weights and measures."

Faraday and Fourier had been the heroes of Thomson's youthful enthusiasm; and, while the older mathematicians shook their heads at Faraday's heretical notion of curved lines of force, Thomson had, in 1849 and 1850, developed a new theory with all the elegance of a mathematical disciple of Poisson and Laplace, discussing solenoidal and lamellar distributions by aid of the hydrodynamic equation of continuity. To Thomson we owe the terms "permeability" and "susceptibility," so familiar in the consideration of the magnetic properties of iron and steel. He also coined many other terms which have come into use, including "thermo-dynamics" and "kinetic energy."

In the winter of 1860-61 Thomson met with a severe accident, which left him with a slight limp for the rest of his life.

It was about this period that he engaged with his friend Professor P. G. Tait of Edinburgh in the production of a text-book of Natural Philosophy for the use of their students. Their idea was to cover the whole range of physics, but as the work grew under their hands, it never reached beyond the first of the projected four volumes, and covered only Dynamics, including Elasticity and allied topics.

The first part of Thomson and Tait's "Treatise on Natural Philosophy" was published in 1867, the second part only in 1874. But, fragmentary as the treatise was, it set the teaching of dynamics on a new basis, and wrought a revolution in the text-books of natural philosophy.

Thomson's contributions to the theory of elasticity are no less important than those he made to other branches of physics. He wrote the articles on Elasticity and Heat for the Encyclopædia Britannica of 1878. In 1867 he communicated to the Royal Society of Edinburgh his famous paper "On Vortex Atoms." Helmholtz had published a mathematical paper on the hydrodynamic equations of vortex motion, proving that closed vortices could not be produced in a liquid perfectly devoid of internal friction. Thomson seized on this idea. If no such vortex could be artificially produced, then if such existed it could not be destroyed. But being in motion and having the inertia of rotation, it would have elastic and other properties. He showed that vortex-rings (like smoke-rings in air) in a perfect medium are stable, and that in many respects they possess the qualities essential to the properties of material atoms — permanence, elasticity, and power to act on one another through the medium at a distance. The different kinds of atoms known to the chemist as elements were to be regarded as vortices of different degrees of complexity. Though he seemed at the end of his life to doubt whether the vortex-atom hypothesis was adequate to explain all the properties of matter, and was not satisfied with the proof of the permanence of vortex motions, the conception remains to all time a witness to his extraordinary powers of mind.

In 1870 Lady Thomson, whose health had been failing for several years, died. In the same year the University of Glasgow was removed from the old College to its present site on Gilmore Hill, overlooking the Kelvin burn.

For many years Thomson's sailing yacht, the *Lalla Rookh*, was conspicuous, and he was an accomplished navigator. His experiences in cable-laying had taught him much, and in return he was now to teach science in navigation. First he reformed the mariners' compass, lightening the moving parts to avoid protracted oscillations, and shortening the needles to facilitate the correction of the quadrantal and other errors arising from the magnetism of the ship's hull. At first the Admiralty would have none of it. Even the Astronomer Royal condemned it. "So much for the Astronomer Royal's opinion," he ejaculated. But the compass won its way, first with the Mercantile Marine, and then was universally adopted in the Navy. The compass, as well as his galvanometers and siphon recorders, and other instruments were constructed by the optical firm of James White of Glasgow. In this business Thomson became a partner, and later the principal owner and director. He was an exceedingly able judge of good workmanship, and a keen man of business.

Dissatisfied with the clumsy appliances used in sounding, when the ship had to be stopped before the sounding line could be let down, he devised the now well-known apparatus for taking flying soundings by using a line of steel piano wire. He was vastly interested in the question of the tides, not merely as a sailor, but because of the interest attending their mathematical treatment in connection with the problems of the rotation of spheroids, the harmonic analysis of their complicated periods by Fourier's methods, and their relation to hydrodynamic problems generally. He invented a tide-predicting machine, which will predict for any given port the rise and fall of the tides, which it gives in the form of a continuous curve recorded on paper; the entire curves for a whole year being inscribed by the machine automatically in about four hours. Further than this, adopting a beautiful mechanical integrator, the device of his ingenious brother, Professor James Thomson, he invented a harmonic analyser—the first of its kind—capable not only of solving differential equations of any order, but of analysing any given periodic curve, such as the tidal records, and exhibiting the values of the coefficients of the various terms of the Fourier series. Wave problems always had a fascination for him, and the work of the mathematicians Poisson and Cauchy on the propagation of wave-motion were familiar studies. In 1871 Helmholtz went with Sir William Thomson on the yacht *Lalla Rookh* to the races at Inveraray, and on some longer excursions to the Hebrides. Together they studied the theory of waves, "which he loved," says Helmholtz, "to treat as a race between us."

Almost the last publications of Lord Kelvin were a series of papers on "Deep Sea Ship Waves," communicated between 1904 and 1907 to the Royal Society of Edinburgh.

In 1874, on June 17th, Sir William Thomson married Miss Frances Anna Blandy, of Madeira, whom he had met on cable-laying expeditions. Lady Kelvin, who survives him, became the centre of his home in Glasgow and the inseparable companion of all his later travels.

Throughout the seventies and eighties Sir William Thomson's scientific activities were continued with untiring zeal.

In 1876 he visited America, bringing back with him a pair of Graham Bell's earliest experimental telephones.

Amongst the matters that cannot be omitted in any notice of his life was Lord Kelvin's controversy with the geologists. He had from three independent lines of argument inferred that the age of the earth could not be infinite, and that the time demanded by the geologists and biologists for the development of life must be finite. He himself estimated it at about a hundred million of years at the most. In vain did the naturalists, headed by Huxley, protest. He stuck to his propositions with unrelaxing tenacity but unwavering courtesy. "Gentler knight there never broke a lance," was Huxley's dictum of his opponent. His position was never really shaken, though the later researches of Perry, and the discovery by Strutt of the degree to which the constituent rocks of the earth contain radioactive matter, the disgregration of which generates internal heat, may so far modify the estimate as to increase somewhat the figure which he assigned.

In 1871 he was President of the British Association at its meeting in Edinburgh. In his Presidential Address, which ranged luminously over the many branches of science within the scope of the Association, he hazarded the suggestion that the germs of life might have been brought to the earth by some meteorite.

With the advent of electric lighting about the year 1880 Thomson's attention was naturally attracted to this branch of the practical applications of science. He never had any prejudice against the utilisation of science for practical ends.

"There cannot," he wrote, "be a greater mistake than that of looking superciliously upon practical applications of science. The life and soul of science is its practical application; and just as the great advances in mathematics have been made through the desire of discovering the solution of problems which were of a highly practical kind in mathematical science, so in physical science many of the greatest advances that have been made from the beginning of the world to the present time have been made in the earnest desire to turn the knowledge of the properties of matter to some purpose useful to mankind."

And so he scorned not to devise his well-known instruments and appliances for commercial use.

Lord Kelvin's patented inventions were very numerous. Without counting in those since 1900, taken mostly in the name of Kelvin and James White, they number 56. Of these 11 relate to telegraphy, 11 relate to compasses and navigation apparatus, 6 relate to dynamo machines or electric lamps, 25 to electric measuring instruments, 1 to the electrolytic production of alkali, and 2 to valves for fluids. He was an independent inventor of the zigzag method of winding alternators, which the public knew under the name of Ferranti's machine, which was manufactured under royalties payable to him. He was interested even in devising such details as fuses and the suspension pulleys with differential gearing by which incandescent lamps can be raised or lowered.

In his Presidential Address to the Mathematical and Physical Section of the British Association at York in 1881 he spoke of the electrical transmission and storage of energy, and of the possibility of utilising the powers of Niagara. He also read two papers, in one of which he showed mathematically that in a shunt dynamo best economy of working was attained when the resistance of the outer circuit was a geometric mean between the resistances of the armature and of the shunt. In the other he laid down the famous law of the economy of copper lines for the transmission of power.

Helmholtz, visiting him again in 1884, found him absorbed in regulators and measuring apparatus for electric lighting and electric railways.

At the same time he was revolving over the speculations which later in the same year he was to pour out in such marvellous abundance in his famous twenty lectures in Baltimore, "On Molecular Dynamics and the Wave Theory of Light." These lectures, delivered to twenty-one hearers, mostly accomplished teachers and professors, were reported verbatim at the time, and reprinted by him with many revisions and additions in 1904. Of this extraordinary work, done at the age of sixty, it is difficult to speak. Day after day he led the twenty-one "coefficients" who sat at his feet, through the mazes of the solid-elastic theory and the spring-shell molecule, newly invented in order to give a conception how the molecules of matter are related to the ether through which light-waves are propagated. Part of the extreme interest of the course arose from the circumstance that he had neither written out the lectures beforehand, nor had even prepared a consistent programme. Admitted to the very laboratory of his thoughts, his hearers became eyewitnesses of his methods, his amazing intuitive grasp, his headlong leaps, his mathematical agility, his perpetual recurrence to physical interpretations, his vivid use of mechanical analogies and his incessant resort to models, actual or imaginary, by which his meaning could be conveyed. His audience began to see that here was a man who thought things out for himself from first principles, making discoveries even while lecturing, and enjoying the surprises that some of the things he was newly discovering for himself had already been discovered by others. All his life he had been endeavouring to discover a rational mechanical explanation for the most recondite phenomena--the mysteries of magnetism, the marvels of electricity, the difficulties of crystallography, the contradictory properties of ether, the anomalies of optics. While Thomson had been seeking to explain electricity and magnetism and light dynamically, or as mechanical properties, if not of matter, at least of ether, Maxwell (the most eminent of his many disciples) had boldly propounded the electromagnetic theory of light, and had drawn all the younger men after him in acceptance of the generalisation that the waves of light were essentially electromagnetic displacements in the ether. Thomson had never accepted Maxwell's theory. It is true that in 1888 he gave a nominal adhesion, and in the preface which, in 1893, he wrote to Hertz's "Electric Waves," he himself uses the phrase "the electromagnetic theory of light, or the undulatory theory of magnetic disturbance." But later he withdrew his adhesion, preferring to think of things in his own way. Thomson's Baltimore lectures, abounding as they do in brilliant and ingenious points, and ranging from the most recondite problems of optics to speculations on crystal rigidity, the tactics of molecules and the size of atoms, leave one with the sense of their being a sort of protest of a man persuaded against his own instincts, and struggling to find new expression of his thoughts so as to retain his old ways of regarding the ultimate dynamics of physical nature. The lectures were revised and extended by him, but were published as a volume only in 1904.

One characteristic of all Lord Kelvin's teaching was his peculiar fondness for illustrating obscure notions by models. Possibly he derived this habit from Faraday; but he pushed its use far beyond anything prior. He was never satisfied until he could make a mechanical model to illustrate his ideas.

This use of models is indeed to be found in the work of every follower of Faraday. Maxwell designed physical models as we have seen. FitzGerald conceived a remarkable model of the æther. Andrew Gray has liberally employed them. The work of Sir Oliver Lodge teems with models of all sorts. It has become characteristic of the tone and temper of British physicists, of none more than of Lord Kelvin. Where Poisson or Laplace saw a mathematical formula, Kelvin with true physical imagination discerned a reality which could be roughly simulated in the concrete. And throughout all his mathematics his grip of the physical reality never left him. According to the standard that Kelvin set before him, it is not sufficient to apply pure analysis to obtain a solution that can be computed. Every equation, "every line of the mathematical process must have a physical meaning, every step in the process must be associated with some intuition, the whole argument must be capable of being conducted in concrete physical terms." In other words, Lord Kelvin, being a highly accomplished mathematician, used his mathematical equipment with supreme ability as a tool: he remained its master and did not become its slave.

New Year's Day, 1892, brought the announcement that a peerage of the United Kingdom had been conferred by Queen Victoria upon Sir William Thomson. The title assumed was that of Baron Kelvin of Largs. The name Kelvin was derived from the Kelvin river, which flows past the buildings of the Glasgow University, while the territorial addition "of Largs" referred to his country mansion Netherhall, near the town of Largs, in Ayrshire, which he built in 1875, and where he died.

In June, 1896, Glasgow University celebrated with a three days' festival the Jubilee of Lord Kelvin's professorship. It was attended by a large concourse of British and foreign savants, who brought addresses and congratulations from every university and academy of science in the civilised world. He resigned his chair in October, 1899, being then in his seventy-sixth year. But though he ceased to reside in Glasgow, and retired to his country house at Largs, he continued to take the most active interest in the progress of science and in the operations of his instrument factory in Glasgow. In his retirement much of his scientific thought centered around a subject which had been in his mind in 1846 and had often recurred: the possibility of formulating all the laws of matter and ether in a single comprehensive theory based on dynamics. This involved the conception of an ether which could not only transmit light by transverse vibrations like an elastic solid, but which must possess such a constitution as to explain the propagation of magnetic and electrostatic forces, and possibly also the existence of gravity. The vortex theory of matter had become untenable, and the problems of the molecular constitution of matter, with its related problems of crystalline structure and of double refraction forced new difficulties into view. The discoveries of Crookes followed by those of Hertz and of Rœntgen started fresh trains of thought, and still the comprehensive theory seemed as far off as ever. At his jubilee he characterised as failure the result of his most strenuous efforts during fifty-five years. But he toiled on, seizing eagerly upon the notion of electrons or electrions, as he called them—to explain the recondite facts of molecular equilibrium and of the pyro-electric properties of crystals, and in the added chapters of his Baltimore Lectures he announced that he had found--with the aid of electrions—a dynamical explanation of every one of the difficulties of twenty years before. His effort to find a dynamical theory in terms of matter and energy, or (by means of the vortex theory) in terms of matter and ether only, had ended in finding it necessary to bring in electricity as a *tertium quid.* He regarded the discovery of radium as bearing vitally on the subject, and himself worked experimentally at the investigation of the properties of radio-active bodies. His persistence was unceasing and his activity of mind surprising.

Honours fell thickly on Lord Kelvin in his later life. He was President of the Royal Society from 1890 to 1894. He had been made a Fellow of the Royal Society in 1851, and in 1883 had been awarded the Copley medal. His peerage was conferred in 1892. He was one of the original members of the Order of Merit founded by King Edward VII. in 1902, was a Grand Officer of the Legion of Honour, and held the Prussian Order Pour le Mérite. In 1902 he was named a Privy Councillor. In 1904 he was elected Chancellor of the University in which he had filled the Chair of Natural Philosophy for fifty-three years. He was a member of every foreign Academy, and held honorary degrees from almost every University. In 1899 he was elected an Honorary Member of the Institution of Electrical Engineers, of which he had been twice President. He was elected for a third time to the Presidency in the year of his death.

In 1906 he was elected First President of the International Electrotechnical Commission, in the success of which he took a deep interest, as clearly shown in his last letter to the Central Office, dated November 8th, 1907, when he said : " I am much pleased with what you tell me regarding the general progress of the International Electrotechnical Commission, in its work, which is surely destined to bear good fruit throughout the world."

His profound studies had led him again and again to contemplate a beginning to the order of things, and he more than once publicly professed a profound and entirely unaffected belief in Creative Design.

Kindly-hearted, lovable, modest to a degree almost unbelievable, he carried through life the most intense love of truth and of insatiable desire for the advancement of natural knowledge. Accurate and minute measurement was for him as honourable a mode of advancing knowledge as the most brilliant or recondite speculation. At both ends of the scale his pre-eminence in the quest for truth was unchallenged. If he could himself at the end of his long career describe his own efforts as "failure," it was because of the immensely high ideal which he set before him. "I know," he said on the day of his jubilee, "no more of electric and magnetic force, or of the relation between ether, electricity, and ponderable matter, or of chemical affinity, than I knew and tried to teach to my students in my first session." Yet which of us has not learned much of these things because of his work?

After taking part in the British Association meeting of 1907 at Leicester, where he entered with surprising activity into the discussions of radioactivity and kindred questions, he went to Aix-les-Bains for change. He had barely reached home at Largs in September when Lady Kelvin was struck down with a paralytic seizure. Lord Kelvin's misery at her helpless condition was intense. He had himself suffered for fifteen years from recurrent attacks of facial neuralgia, and in 1906 underwent a severe operation. Under these afflictions he had visibly aged, and the illness of Lady Kelvin found him little able physically to sustain the anguish of the stroke. He wandered distractedly about the corridors of his house unable at last to concentrate his mind on work in hand. A chill seized him, and after about a fortnight of prostration he sank slowly and quietly away on December 17.

He was buried in Westminster Abbey, with national honours, on December 23, 1907, his grave being next to that of Newton.