

William E. Ayrton (1847-1908) is known as a pioneer electrical engineer, inventor, physicist, remarkable teacher, and educational organizer. After his years as a student at the University of London, he studied electricity under William Thomson (later Lord Kelvin), then worked in the special testing and improvement division of the telegraph services of India and later of England. After a short time he was appointed to the chair of physics and telegraphy at the Imperial Engineering College of the University of Tokyo, where he set up a laboratory for teaching applied electricity, the first of its kind and a model for other laboratories elsewhere. Then began a most fruitful collaboration with his colleague, Professor John Perry, with whom he carried out a vast amount of original work: the first determinations of dielectric constants of gases, and the significance of the constant in defining the electrostatic unit of quantity; viscosity of dielectrics; theory of terrestrial magnetism; electrolytic polarization; etc.

He returned home and was appointed professor at the City and Guilds of the London Institute for the Advancement of Technical Education, where "his first class consisted of an old man and a boy of fourteen." John Perry joined him at the Institute, and by 1881 two colleges had arisen, Finsbury Technical College and the Central Technical College, later known as City and Guilds College, South Kensington, where Ayrton was the first professor of physics and electrical engineering, a chair that he held until his death.

Ayrton and Perry collaborated in creative work until 1891, inventing electrical devices for railways as well as numerous instruments for making electrical measurements: ammeter, power meter, voltmeters of several designs, clock meter, and motor meter which could have made them very wealthy if they had not abandoned their patents too soon. They also invented instruments used in other branches of physical science: transmission and absorption dynamometers, dispersion photometer, and so on. In addition, they carried on research in many branches of electrical and mechanical engineering. After 1881 Ayrton's collaborators were his pupils, past and present. (Special mention may be made of his universal shunt box, a joint invention with his assistant, Thomas Mather.) In collaboration with his second wife he carried on research for the British Navy (see Letter 7, Note 2.)

He was the first to suggest the economical and safe distribution of power "by means of high tension currents of relatively small quantity 'transformed down' at the distant end of the transmission system." He

was a consultant for the British government and for private firms and was in demand for expert testimony in patent cases (see Letters 3, 4, 6, and 7) in which he served only if he felt upon investigation that his client had a justifiable cause.

Professor Ayrton was elected a fellow of the Royal Society in 1881 and was awarded a royal medal in 1901. Among the offices that he held was the presidency of the Institution of Electrical Engineers (1892), a society whose growth profited greatly from his devotion to it.

He was a most inspiring teacher and may be credited with having trained an enormous number of electrical engineers. His life was apparently cut short by overwork. Professor Ayrton's published papers run to 151 in number, both independently and in collaboration, and his book, *Practical Electricity* (London: Cassell & Co., Ltd.) passed through eleven editions in his lifetime. His interests and capacities ranged widely beyond the field of science and included the drama, music, and philosophy.

William Ayrton was a devoted friend of Elihu Thomson and had a hand in the awarding to him of three great honors, the Faraday, Hughes, and Kelvin medals.

1

W. London

March 14, 1896

Dear Professor Thomson:

A new glow lamp manufacturing company in which I take an interest are contemplating engaging a Mr. Frie, or Frei, now at the Boston Lamp Factory to come to London to assist in the factory to be organized here.

If by chance you happen to know anything about him and you would do me the favor to let me have your opinion confidentially I should esteem it a favor.

Your stereoscopic Roentgen photography¹ has interested me much, as well as the success with which your form of the electric energy meter² proposed by Perry and myself in 1882 is now meeting.

The question of the gain or loss to an Electric Supply Company by the use of this form of meter is dealt with neatly by Mr. Ricks in his student's paper on meters on pp. 76-77 Journal of the Inst. of Elec. Engs., for March just published.

Sincerely yours,

W. E. Ayrtton

1. Very shortly after the discovery of "x rays" by Wilhelm Konrad Roentgen in 1895, Professor Thomson conceived the idea of producing stereoscopic roentgen pictures. Two separate pictures were made, the tube being held in two different positions some inches away from each other. When viewed in a stereoscopic device, the illusion of depth resulted. The technique was quickly adopted by the medical profession and became a standard method for examining the setting of bone fractures, thus enabling surgeons to make certain that the alignment was correct and no deformity would appear after healing. Professor Thomson demonstrated the successful application of his process by locating a bullet in a man's chest. (See: "Stereoscopic Roentgen Pictures," in *Electrical Engineer*, March 14, 1896, and in *Electrical World*, March 27, 1896. See also "Work in the First Decade of Roentgenology," a survey by Thomson in *American Journal of Roentgenology*, 28: 385-388, 1932.)

2. In the early days of electric lighting there were no simple instruments for measuring the amount of current consumed by a customer. Thomas Edison devised an electrolytic method of making such measurements: on every customer's premises there was a pair of cells, each with zinc electrodes. As the current flowed, zinc was lost by the positive electrode and deposited upon the negative, one cell serving as a check upon the other. The electrodes were collected each month and weighed at headquarters, and from such measurements the quantities of electricity involved could be calculated and each customer's bill determined. However, the slightest error by a member of the weighing staff might result in a fantastic bill. For example, one small storekeeper once found himself charged \$200 for a month's service, resulting from the failure of a staff member to remember that he had cut a piece of connecting wire from a plate, and he later compared the weight of this zinc plate (or electrode) with the weight in a previous month, when the wire had not been clipped. The Professor solved the problem of lack of suitable measuring devices as follows: in his invention the current consumed was made to flow through a very small electric motor requiring nearly zero power, but the flow was proportional to the power being consumed by the customer. The motor shaft activated a train of dials, which indicated total energy involved. By connecting the revolving part of the motor across the line (responding to voltage) and having the field coils operating on some of the customer's current (amperage), an invention resulted for measuring watts of electrical energy, the dials registering the number of kilowatt hours consumed. (Ayrton and Perry, in England, had indeed tried the motor principle but failed to construct a sufficiently delicate, and therefore accurate, instrument.) Thomson was at work for almost two years on this invention, solving such problems as designing a device to prevent the little motor from "running away," by using magnetically induced eddy currents in an aluminum plate attached to the shaft, thus acting as a finely proportioned brake, and the problem of the commutator, by using solid silver bars and brushes. At about this time (1889), a prize of ten thousand francs was announced in Paris for an instrument that would measure both alternating- and direct-current power. Thomson's meter shared the prize with one invented by Professor Aron, of Paris, and soon thereafter became the standard instrument everywhere. Thomson always felt that his watt-hour meter was one of his most important inventions. He continued to study the problem of electric measurements and in 1895 produced the "inclined coil" instrument, "for a long time about the only reliable alternating current instrument, a new form of ammeter, voltmeter and

wattmeter . . . still largely employed.” (See “Letter on the Paris Meter Prize,” *Electrical World*, February 9, 1895; letter to Rice, December 6, 1916; also letter to Paul Brockett, January 26, 1933, at the Library of the American Philosophical Society, Philadelphia.) A by-product of his competing for the wattmeter prize in Paris was the establishing of his *Compagnie Française Thomson-Houston*, and, shortly thereafter, the *Union Elektricitäts Gesellschaft* in Germany and the *British Thomson-Houston Company* in England.

2

On Board S.S. Lake Superior

August 3, 1897

Dear Professor Elihu Thomson:

I am hoping to meet you while I am in America to which country I have not been since I saw you in 1893.

In addition to the pleasure of renewing our acquaintance I am desirous of discussing with you the possibility of your firm taking up the American manufacture of the Evershed Ohmmeter and the Ayrton and Mather Electrostatic Voltmeters.

Shall you come to the meeting of the British Association at Toronto August 18th to 25th, or will you be at the meeting of the A.A., A.S. at Detroit, or, if you are going to neither, should I find you at Lynn about August 30th?

I am a little doubtful about going to Detroit with my daughter, but if that would be the only way of meeting you I will certainly do so.

Would it be troubling you too much to send me a telegram on Thursday morning the 5th inst. to “Canada Sugar Refinery Montreal” saying whether Detroit, Toronto or Lynn would be the most convenient place for you to meet me. Believe me,

Sincerely yours,

W. E. Ayrton

3

London

September 21, 1897

Dear Professor Elihu Thomson:

My daughter and I arrived safely on Saturday the 18th after having a delightful voyage—strong wind the whole way, but a favorable stern wind. She sends the enclosed letter to Mrs. Thomson, and, like myself, is full of happy remembrances of our stay at Swampscott.

From the papers that have been sent me since my return by the lawyers of the British Thomson-Houston Company it would appear that Messers Chamberlain and Hootcham are going to base their attack on the fact that your energy meters¹ are used “upon circuits of constant potential” and therefore that their use infringes claim one of the Specification viz, “First—An electricity meter for measuring currents consisting of an electro motor with constant field arranged substantially—the said electro motor being combined with an electric brake also moving in a constant or nearly constant field—”. Also they contend that your meter infringes claim three viz. “Thirdly—In electricity meters the use for the purpose of procuring a powerful and constant magnetic field of permanent magnets arranged as described with very large polar surfaces closely fronting each other so as to form a narrow slit in which the disc armature revolves, etc.”

Of course the words “disc armature” in this third claim of the Chamberlain and Hootcham patent specification really referred to the *wound* disc armature with commutator used in the original type of their meter, but, as a disc of copper was fastened directly into this armature, there is a probability that the counsel on their side with endeavour to interpret the disc armature as meaning the copper disc alone.

To impress on the Judge the difference between the two meters I propose to put one of yours and one of the Chamberlain and Hootcham meters in series—first on a circuit with *several* glow lamps in parallel run at a *low* voltage, next on a circuit with *fewer* lamps run at a *much higher* voltage, the circuits being so arranged that the lamps take the same current in each case, and, therefore, causing the Chamberlain and Hootcham meter to read the same in the two cases. Whereas, of course, your meter will read higher with the few bright lamps than with the larger number of dull ones.

They will reply to this that this is not an example of a circuit of constant potential—but we can answer to that that there is not such a thing in practice as a circuit for public supply at really constant potential, and show curves of variation of the pressure observed on various London circuits.

The letter which I wrote about the tests of your meter appears in the London papers this week.

Very sincerely yours,

W. E. Ayrton

1. See Letter 1, Note 2. Before the first appearance of the Thomson watt-hour meter, measurements were made by galvanometer and Wheatstone bridge, previously calibrated against a standard resistance and known voltage. Great patience and ingenuity were required for such an operation. Thomson once determined wattage by passing the output of a generator through a coil of known resistance immersed in a precisely known quantity of water contained in a homemade calorimeter, and noting the rise in temperature in a given number of minutes, followed by a calculation. Edgar F. Smith, in his *Electro-chemical Analysis* (Philadelphia, 1890, pp. 29-32), tells how currents were measured in his laboratory by means of the Bunsen voltameter, in which water was decomposed by the current, the disengaged gases collected in a eudiometer, and the volume corrected for temperature and pressure, then a calculation made, as shown on p. 31 of his book. He also describes the Kohlrausch amperemeter, in which “the current travels through an insulated wire surrounding a bar of soft iron. The latter, in its magnetized state, attracts the needle attached to a spiral. [The needle] moves over a graduated face, (in amperes), and its deflection gives at once the strength of the current in amperes.”

4

London

November 5th 1897

Dear Prof Thomson,

My daughter and I were so sorry to hear about Stuart,¹ but we hope that you may have already seen signs of improvement.

We have not yet had any consultation in London about the meter case as we have been waiting for the return of Mr. Parshall from your country. But he is just back and so we are now about to consider the line of attack and defence.

Your suggestion to have one of your meters constructed in which the ends of the permanent magnets instead of being flat so to say should look at the copper disc end on is I think a good one and I would suggest that it might be well to give the magnets the shape illustrated in some old book showing the "Barlow Wheel"² so that as far as that part of your meter is concerned it might have been constructed from that particular illustration.

It appears to me that it will be important to find some reference prior to Messers Chamberlain and Hootcham's patent of a piece of copper-disc or cylinder—being used *with a permanent magnet* for damping, in a fairly efficient way. The illustrations of Foucault's³ experiment with the the rotating disc show an electro magnet, but it ought not to be difficult to find one with a permanent magnet, or at any rate a satisfactory account of a permanent magnet being satisfactorily used in this connection.

Your remarks about length of magnet being necessary with wide air gap confirm the older construction of permanent magnets—But our enemies may say again that the old idea was to secure power only, for example the long limbed early Edison dynamo, they might say, was for the purpose of securing a powerful field.

You will be interested to hear that I was upholding America's rapid evolution last evening, at the Institution of Mechanical Engineers, against the attacks of my countrymen who considered that it showed want of knowledge of what was the best from an engineering point of view—to have to change the dynamos, etc. in a Central Station within 3 or 4 years after its erection. But I told them that what they complained of, viz. that your people threw away an old thing as soon as they obtained a better was what America ought to be proudest of. For we over here never throw away any machine, we go on muddling on with it long after its antiquated character has been demonstrated without possibility of doubt.

I am writing to Mr. Fish⁴ by this mail to say that I shall be glad to receive your Company's decision regarding the purchase of the American patents for the Ohmmeter and Generator, and the American patents for the Electrostatic Voltmeters.

I also am mentioning in my letter to him that the actual sale of Test-

ing Sets ("Ohmmeter and Magneto Generator") up to the end of October, and the orders in hand, fully justify the prediction I made (in my letter to him of September 6th.) of this year's probable sale: secondly that I find that there is a fourth patent in connection with Electrostatic Voltmeters which we have not hitherto applied for in the States. We are now, however doing this, and, as this patent specification covers part of the actual instrument fitted up in your factory at Lynn we think that it would be only equitable that we should include this fourth American Electrostatic Voltmeter patent with the other three—referred to in my letter—for the sum therein suggested.

With our very kindest regards to Mrs. Thomson and yourself,

Believe me sincerely yours,

W. E. Ayrton

1. Professor Thomson's firstborn son.

2. A "Barlow wheel" consists of (1) a copper disk, free to spin vertically, placed between (2) the poles of a horse-shoe magnet, the lowest edge of the disk being immersed in (3), a pool of mercury. The wheel rotates when a potential difference between the axle of the disk and the pool of mercury is maintained. Thus the Barlow's wheel is a primitive motor. (For an engraving, see *Philosophical Magazine*, vol. 59, 1822, pl. 4, fig. 4.)

3. Jean Bernard Léon Foucault (1819-1868) discovered the electrical currents that bear his name, i.e., the eddy currents which are induced in a copper disk when in motion in a strong magnetic field. Besides "Foucault currents," he is well known for the "Foucault pendulum," a heavy pendulum suspended on a long wire, by which in 1851 he demonstrated the diurnal motion of the earth, and for his invention of the gyroscope. For these the Royal Society presented him with its Copley Medal in 1855. He made improvements in the electric arc, and is also known for his contributions in the field of the measurement of the velocity of light, and in the design of the speculum of reflecting telescopes.

4. Frederick P. Fish, lawyer.

5

London

November 20th 1897

Dear Professor Thomson,

When staying at your house you showed me a copy of Silliman's Physics,¹ and on Page 528, if my notes are correct, we found that there was a reference to the form of magnet not only producing [one word, illegible—Eds.] but also *constancy*—The word "*constant*," if I remember rightly, occurred on the page 528 of the book. We also looked at pages 112, 113 and 220 of Davis Manual of Magnetism published in 1848 but the references there were not as important.

I was not aware at that time that Silliman's Physics was such a rare book or I would have copied the page out of your book.

There is no copy, I find, of Silliman's Physics in either the Libraries of the Royal Society, the Royal Institution, the Institution of Electrical Engineers, the South Kensington Museum, or the Institution of Civil Engineers, all good scientific libraries. In the Library of the British Museum there is a copy of the *Second Edition* of the book, but on Page 528 there is not the reference I expected to find. Probably yours is a later edition.

Would it be possible for you to spare our own copy of the book?—I would take the greatest care of it, and return it to you by registered post after the trial of the meter case.

Perhaps also you could tell me whether there is some mistake in the memorandum which I made in my note book.

Very sincerely yours,

W. E. Ayrtton

1. Silliman, *First Principles of Physics, or Natural Philosophy, Designed for the Use of Schools and Colleges*. (Philadelphia, 1859. Second edition, Philadelphia, 1861. The Silliman book of neither date has the word that William Ayrtton sought on page 528).

6

London

May 30th 1900

Dear Professor Thomson,

I write a line to offer you my most sincere congratulations on the result of the trial "Chamberlain and Hootcham versus the Bradford Corporation."

We, if I may say so—made our preparations well, we fought hard, and won a success all along the line like the one Lord Roberts¹ is now gaining in South Africa.

The judgment of Mr. Justice Farwell is very crushing to the opponents, and I can hardly imagine that in face of it they will think it worth while to appeal.²

In a letter which we received from Mrs. Thomson today she says that although there is no chance of her coming to Europe this summer, you on the contrary may. If you do, I need not tell you how delighted we shall be if you will come and stay at our house 41 Kensington Park Gardens.

Believe me sincerely yours,

W. E. Ayrton

When we were talking over the subject of transforming up at successive points along a line transmitting electric energy in 1897 I think you mentioned that you had taken out a patent³ for that idea. Could you kindly refer me to the date and number of that Specification?

1. Frederick Sleigh Roberts, Earl Roberts of Kandahar, Pretoria, and Waterford (1832-1914). After the defeat of the British by the Boers at Magersfontein, Stormberg, and Colenso, Lord Roberts was made commander in chief of British forces, and reached Cape Town in January, 1900. He reorganized the defeated army, advanced upon Bloemfontein, capital of the Orange Free State, and turned the tide of events. The sieges of Kimberley and Ladysmith were raised, and Cronje, the able Boer general, put to flight. Roberts took Bloemfontein in March, then advanced upon Pretoria, capital of the Transvaal, which he occupied on June 5, about a week after Ayrton's letter to Thomson was written.

2. See Letter 7.

3. See Letter 7.

W. London

June 14, 1900

Dear Prof. Ayrton:

Your letter of May 30, conveying congratulations on the meter victory¹ is received. I do not know, in fact, whether we are to be congratulated here, or whether those who have done the work so effectively before the court are not the most deserving of congratulation. I had followed the printed accounts of the testimony in the case, and those accounts convinced me that the matter was being well taken care of.

I have now within a day or two read the judgment of Justice Farwell, and can but admire the clearness with which he puts things, showing that he had attained a pretty thorough grasp of the case. His judgment leaves people free to make magnets as they see fit, in accordance with well recognized principles, which is all that we ever claimed to have done in making our meter magnets. It is, of course, a great satisfaction to us here to have the matter turn out in our favor, leaving the meter built upon the original plan set forth by Ayrton & Perry unhampered as hitherto.

I have made nondefinite arrangements to make a trip abroad this year, and if I make the trip at all it will probably be late in the season, though I begin to doubt the possibility of it; so do not count upon me in any way. I am exceedingly obliged for your kind invitation, and should enjoy being with you most heartily, if it were possible.

I am indebted to either you or Mrs. Ayrton for a copy of the paper on the Electric Arc,² which came a few days ago. I had seen the paper in the journals, but it is of course better to take it as a whole in the pamphlet form. I have no doubt that I shall have frequent occasion to refer to it, as it is a most valuable contribution to the literature of the electric arc, and it effectively solves some of the enigmas in relation to the behavior of the arc.

In regard to the matter which was referred to in your postscript, I have had a rather hurried search made for the patent papers in the case of the repeated or successive transformation along the line. There are so many patents that it may have been overlooked. I clearly remember, however, sending the description and data for the patent application to the Patent Department of our Company some considerable time before

our talk. I have not yet succeeded in getting on the track of the matter so as to be able to give you any details.

Yours very truly,

Elihu Thomson

1. See Letter 6.

2. Hertha Marks Ayrton (1854-1923), a pupil of Professor Ayrton (at the Central Technical College, in London) whom she later married, is known for her contributions to the literature of the electric arc, (*The Electric Arc*, 1902; see Letter 9, also the articles mentioned at the end of this note). In response to the request of the British Admiralty to deal with the problems of the electric search-light, the Ayrtons produced four reports, most of which resulted from Mrs. Ayrton's efforts. She is the inventor of the Ayrton antigas fan, used against poison gases in France in 1916. Mrs. Ayrton studied the problems of air pollution in gun emplacements and the transfer of fuel gases from one locality to another, thus eliminating the necessity of having many local factories.

Judging from the date, the article by Mrs. Ayrton, referred to in this letter, is probably: "The Light Emitted by the Continuous-Current Arc," *Electrician*, 45, 1900. Mrs. Ayrton also published, at about that time: "The Drop of Potential at the Carbons of the Electric Arc," *Brit. Asso. Rep.* (1898) and "The Hissing of the Electric Arc," *Inst. Elect. Eng.* (1899). She was awarded the Hughes Medal of the Royal Society in 1906.

8

W. London, England

September 23, 1901

Dear Professor Ayrton:

Prof. William L. Puffer, in charge of the Electrical Engineering work of the Massachusetts Institute of Technology, is traveling in the interest of the Institute, and visiting various foreign schools and institutions, in view of a contemplated very considerable extension of the facilities of the Institute in his department.

AYRTON-THOMSON

Thanking you in advance for any favors you may be able to grant him in the line of his quest, and trusting yourself and family are well, I am,

Very truly yours,

E. T.

P. S. Kindest regards to Mrs. Ayrton and Edith.

9

W. London

January 15, 1903

Dear Madam (Mrs. Hertha Ayrton):

Permit me to express my thanks for the favor of a copy of your work on "The Mechanism of the Electric Arc", which I shall read with deep interest.¹

Yours respectfully,

E. T.

1. See Letter 7, note 2.