THE

Electrical Engineer.

VOL. XIII. JANUARY 13, 1892. No. 193.

AMERICA'S PART IN THE DISCOVERY OF MAGNETO-ELECTRICITY—A STUDY OF THE WORK OF FARADAY AND HENRY.—I.

BY

Mary A. Henry

THE phenomena of self-induction and of mutual induction are closely connected, and indeed must be treated together as one whole in the modern theories of electricity and magnetism. After the discovery of self-induction by Henry, it seems to me but a step to the discovery of magneto-induction. This step was more-

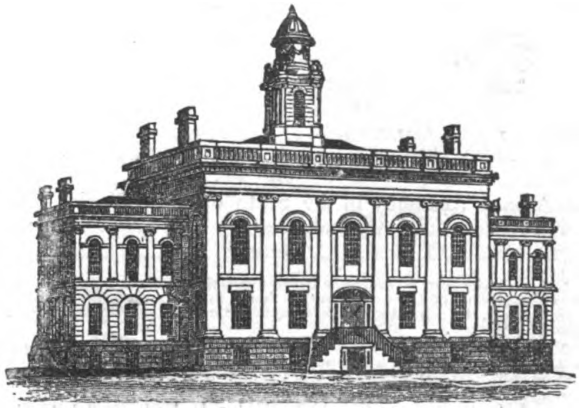
MICHAEL FARADAY.

JOSEPH HENRY.

over made easy by the construction by Henry of electromagnets with great numbers of coils of wire. With a suitable galvanometer, also constructed with many turns of wire, there was sufficient residual magnetism in Henry's large electromagnets to give deflections of the galvanometer when the armature of the magnet was moved on or off the poles of the electromagnet, even when the latter was not excited by a battery.

From a careful survey of the evidence presented, I believe that *Henry was the first to perceive the fluctuations of the galvanometer due to magneto-induction*, and that he had a conception of the relations of magnetism and electricity before Faraday published his first paper on the subject of magneto-induction. Henry has himself stated that he had perceived the phenomena of magneto-induction, and had been intending to study them further; but was prevented from pursuing the subject by unavoidable interruptions, and the desire to construct more powerful apparatus to continue his investigations. When we reflect that he had to insulate his wires with calico cloth, and to wind all his own electromagnets; that he was pursuing his investigations in Albany—then little more than a frontier town—while Faraday was at the Royal Institution, in the intellectual centre of the world, we feel that too much cannot be claimed for our countryman.—JOHN TROWBRIDGE.

IN the year 1774, a question of no small significance was presented as a subject for prize essays by the Academy of Bavaria. The subject was one which even at that early day had excited deep interest in the scientific world; it was no less than "the identity of the two great mysterious forces, electricity and magnetism." The essays received in the competition were so numerous as to make 13 large folio volumes of matter, but the report of the Academy nevertheless was to the effect that "although electricity and magnetism are by some experimenters proved to be the same in some respects, in other respects they are dissimilar, so much so that they must of necessity be as yet considered as distinct." In this indeterminate state the matter rested for 56 years, until 1819, when, by the deflection of a needle Oersted became immortal. While the Danish philosopher was one day lecturing to his class in the University of Copenhagen, an experiment occurred to him and he tried it then and there for the first time. It was a simple matter; nothing more than the passing of a galvanic current through a wire parallel to and above a magnetic needle. Oersted found that under these conditions, the needle, swinging upon its pivot, turned eastward, and at length came to rest at right-angles to the wire, its north pole pointing east. When the wire was held below the needle, the north pole turned westward, and settled pointing west. What had happened here? What was there in this mere swaying of a bit of steel through an inch of distance to bring fame to a philosopher like Oersted? The little needle was not a common needle, a mere unresponsive fragment of steel. Endowed with the mysterious principle of magnetism, it had as one might say, a soul, and as human soul answers to human soul, it was quick to respond to another magnetic soul. Had an ordinary magnet been brought to bear upon it, in obedience to the magnetic instinct, it would have excited no surprise, had it responded to its influence. What then, we ask again, had happened in the experiment of Oersted? The little needle was behaving exactly as if the wire traversed by the electric current possessed magnetic prop-



THE ALBANY ACADEMY, AS IT APPEARED IN 1826–32. FROM A CONTEMPORANEOUS WOOD-CUT.

erties. Was this, in truth, the case? Had electricity produced magnetism in or about the wire? Or was electricity itself magnetism? Oersted published four quarto

pages on the subject;[1] the fame of his experiment spread with almost unexampled rapidity throughout the civilized world; it was repeated everywhere, and Schweigger seized upon the little needle to make of it the gavanometer,[2] so indispensable in the laboratory of the electrician from that day until this.

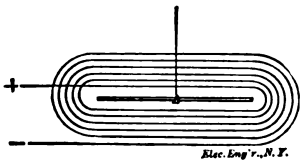
Very brilliant were the scientific men in the old world of that day, and about the year 1820 not a few of them were deeply interested in the question of the "identity of electricity and magnetism."

In the same year we find Arago and Sir Humphry Davy passing currents of electricity through wires and noting carefully the attractive power produced. Ampère caused two wires, each traversed by a current, to attract and repel each other, as if they indeed had been two magnets. Arago reached a result of no small importance; it was this: He placed a common steel sewing needle within a glass tube; around the exterior of the tube he wound a helical wire, through which the electric current was made to pass.

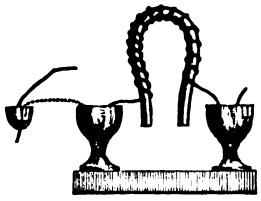
MAGNETIZATION OF STEEL NEEDLE BY ARAGO, 1820.

The needle under these circumstances was found to become strongly magnetic.[3] Nature here asserted, in most unmistakable terms, that electricity could produce magnetism. Five years later we find Sturgeon bending a bar of soft iron into a horseshoe and by an obvious adaptation of Arago's method rendering it so strongly magnetic by means of a current of electricity, as to be capable of sustaining a weight of nine pounds.[4]

There is not the shadow of a doubt, after the year 1825, that electricity can produce magnetism; but the reverse, Can magnetism produce electricity? With ever-deepening interest as year after year goes by, the scientific world asks this question, but with all the most eminent men of Europe at work upon it, nature vouchsafes no reply, and so we come down to the last days of August, 1831, and to two men, one in the old world, the other in the new, at work upon the problem, each unconscious of the other, an ocean between them. One of these men is Michael Faraday, professor of chemistry in the Royal Institution of Great Britain; the other is Joseph Henry, professor in



SCHWEIGGER'S GALVANOMETER, 1820.



STURGEON'S ELECTROMAGNET, 1826.

the Albany Academy in the State of New York. These two were destined to find the key to the problem; the answer to the question which had baffled the world of science for half a century.

We say the last days of August, 1831, because at that date, the work of the two men nearly touch in point of time; but the actual discovery of magneto-electricity, the reader will see, if with kind patience he will follow our story, had been made by the one, that is, Henry, at least a year earlier, namely, in August, 1830, while it was not fully accomplished by the other until some thirteen months later, namely, the 24th of September, 1831; for this we shall find to be the date at which Faraday first fully recognized the phenomenon, and the principle by which it is controlled.

To understand properly the work of these two men, in reference to the discovery of magneto-electricity, it is necessary to know something of the circumstances in which they were placed. When Sir Humphry Davy was asked, which he considered his greatest discovery, he answered, "Michael Faraday." Entering the Royal Institution in an humble capacity in 1813, the flower of his genius growing and expanding under the fostering care of Sir Humphry, Faraday had attained a high position, and an enviable scientific reputation, in the great London institution. Director of the laboratory, he was surrounded by every possible

FARADAY'S LABORATORY IN THE ROYAL INSTITUTION.

facility for the prosecution of his investigations; and what was perhaps even more important, had unlimited time at his command in London, the great centre of scientific light. He was now forty years of age. Henry was nine years younger. When Faraday first entered the Royal Institution as an assistant, Henry was but thirteen. Counting the years of his age with those of the century, he had entered upon a course of original investigation as early as 1827, but amid such arduous duties as an instructor in the Albany Academy, that of all the twelve sisters of the year, he could only claim the month of August, the vacation time of the institution, as really his own. During four years he had been able to secure hardly more than as many months for regular scientific research. Could we look into his laboratory at this time, we would find, instead of the well-filled cabinets of the Royal Institution, only a few rude instruments made at great expense of time and labor by his own hands. Even the material for these rude tools was often difficult to obtain. Experiments, for instance sometimes stopped merely for the want of a scrap of zinc. We say "could we look into his laboratory," but we would seek in vain for a room which could properly be so called. Each series of experiments was necessarily carried on in the large hall of the Academy, which was available for Henry's use at no other time than during the summer vacation. Invariably all investigations came to a stop with the first of September, the beginning of the autumn session of the Academy, and were rarely resumed

1. A verbatim copy of Professor Oersted's original communication, in Latin, and a translation of the same may be found in *Journal of the Soc. of Tel. Engrs.*, v, 459, 464; together with a biographical sketch of Oersted by C. L. Madsden. [EDITOR.

2. Schweigger's first galvanometer was a very simple affair, consisting of a small compass box, around which was coiled several turns of copper wire in a direction parallel to the meridian line of the dial. See *Schweigger's Journal für Chemie and Physik*, xxxi, 1-17. [EDITOR.

3. Arago's experiments were published in *Annales de Chemie et de Physique*, xv, 93. Immediately afterwards, but before any account of Arago's experiments had reached him, Davy had also magnetized needles by the voltaic current, and by discharges of frictional electricity. He had also discovered the attractive effect of the conductor upon iron filings. His letter to Wollaston, recounting these experiments, is in *Philosophical Transactions*, 1821. It bears date Nov. 12, 1820. [EDITOR.

4. *Transactions Society of Arts*, 1825, xliii, 38-52. The accompanying illustration is a fac-simile of that annexed to Sturgeon's paper.

until the month of August came again.[5] The invaluable stimulus of scientific intercourse and appreciation too, was wanting. Very different was the dull commercial town of Albany, from London, the intellectual metropolis of the world. A wide expanse of waters, not yet crossed by the swift ocean steamer, lay between Henry and all the culture of the old world, and in provincial America, little could be found to make good its place. Moreover, it must not be forgotten that Henry was the first who had undertaken a series of electrial experiments in America since the time of the immortal philosopher who first drew lightning from the clouds; "the mantle of Franklin"—said Sir David Brewster—"has fallen upon his young shoulders." Excepting Dr. Hare of Philadelphia, who was making notable improvements in galvanic apparatus, almost alone in the electric field, he stood to face the army of the old world.

Recalling the wide difference in condition surrounding the two, it is of no small interest now to see to what eminence each had at this time attained, the one during his eighteen years of culture and unimpeded work; the other in his few months of intermittent study, snatched at long intervals from the crowded days of four years of arduous professional labor. Constantly pursuing similar investigations, making many identical discoveries, Faraday and Henry seem like two competitors in a closely contested race, upon whose course we have suddenly come in these August days of 1831, and with curious eyes we scan the field to see how they are running. Bence Jones says:

"If Faraday's life had ended at this time, when he finished his higher education, it might have well been called a noble success, but when we turn to the eight volumes of manuscripts of his *Experimental Researches* which he bequeathed to the Institution, we find that *his great work was just going to begin.*"[6]

Henry had begun his course with a series of original discoveries which might well weigh in the balance with anything Faraday had as yet accomplished, while in the particular field in which lay the "*great work*" of Faraday, which he was now "*just going to begin*" he had not only entered, but was already far ahead. The mysterious phenomena of the induction of electric currents, the reciprocal production of the magnetic and electric forces, were to him already old stories, intimately familiar, singularly well comprehended by him at this early date. He is in truth but amplifying the results which Faraday has just begun to seek, in these waning days of the summer of 1831. The younger man, as it were, had struck almost immediately into this particular path, and is now almost lost to sight in it, while the elder has only just come to the spot where his entering footsteps began.

Let us dwell for a moment upon the importance of the answer to the great question we have been considering, the value to the world of the discovery made by these two men.

It is not too much to say that it constitutes a veritable epoch in electrical science; upon it depend many of the most important applications of electricity to the uses of man, and new applications are developing day by day. Tyndall, the successor of Faraday in the Royal Institution, does not attempt to restrain his enthusiasm in the contemplation of it:

"I cannot help thinking" (he says) "when I dwell upon it that this discovery of magneto-electricity is the greatest experimental result ever obtained. It is the Mont Blanc of Faraday's own achievements. He always worked at great elevations, but higher than this he never attained."[7]

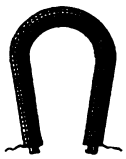
Edward N. Dickerson, the eminent advocate, said of Henry:

"The towering heights that were scaled by the daring spirit of Faraday from the East, were at the same time surmounted from the West by our own countryman; both were climbing from opposite sides at the same time, and neither was conscious of the other's efforts till both stood face to face upon the summit."[8]

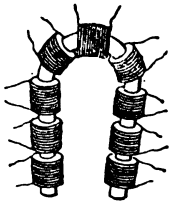
But the standard of the West had been floating many months upon these towering heights before the standard of the East was planted. It was Henry's foot, not Faraday's, which first touched the untrodden peak.

It was curious, that with such a host of the most brilliant minds of Europe at work upon the problem, the discovery which solved it was so long delayed. But there was a fact, which, it would seem almost with malicious or mischievous intent, successfully eluded all research. This fact was the necessary condition of *motion or change* for the production of the effect, and consequently the transitory nature of the phenomenon. If a magnet is thrust into the opening of a hollow helix of wire, electricity is manifested in the wire, but only for a brief instant, when the magnet is inserted and when it is withdrawn.

There is a fairy tale of a farmer's wife, whose heavy labors were lightened by a friendly gnome, who was never seen because he could never be caught at the moment he was at work. In all these years magnetism had been pro-



HENRY'S INTENSITY MAGNET.



HENRY'S QUANTITY MAGNET.

ducing electricity under the very hands of these wise philosophers, but had never been detected in the act. *It was not caught at the moment it was at work.*

Let us see in what way Faraday and Henry, these two favored children of nature, ask of her the all-important question, so as to win at last a reply. Courtesy to the elder man and to the inhabitant of another country, would seem to suggest that we first go over the sea to Faraday; but this may not be, for we must look among Henry's own instruments for the stepping-stone to the great discovery, made by Henry's own hands to be a stepping-stone not only for himself but for Faraday.

Young Henry had before this time, as one of his friends has said, "made the lightning his familiar, his demon, his servitor; had lured it into his lecture-room from out of its cloud home in the thunder-storm, and tamed it so that he could bridle it, mount, ride it and spur it at will."[9]

He had taken the soft iron horseshoe of Sturgeon, with its spiral of loose uninsulated wire, an infant lifting but a few pounds at an inordinate expense of battery power, and had transformed it into a giant capable of sustaining fifty times its own weight, under the stimulus of a battery of a single pair of plates of copper and zinc, scarce a hand's breadth in area. He had made two magnets; his "intensity" magnet with a long single wire, and his "quantity" magnet with many short wires; the latter the stronger in actual physical force, but the

5. The Albany Academy, in which Joseph Henry occupied the chair of Mathematics and Natural Philosophy from 1826 to 1832, is an institution which for three quarters of a century has been held in deservedly high esteem, not alone in the community in which it is situated, but throughout the United States. Among the oldest foundations of its kind in the country, "its venerable walls seem imbued with that subtle spirit of the past, that favors study, and that nothing but time can give." The Academy building, beautifully situated on the public square near the head of State street at the right of the Capitol, is a dignified and admirable architectural example of the classical or "colonial" type. In the words of the late Dr. Meads in his oration at the semi-centennial anniversary of the Academy in 1863:—"Time has not rendered it in any degree unfitted for its purposes, nor unworthy of its position among the public buildings of Albany. It seems to have had a power to charm down and repress even the proverbial destructiveness of youth, and it stands to-day, after the lapse of half a century, unmarred by any spoiling hand, in all its original freshness and beauty."

The room in which Henry prosecuted his memorable experiments in electricity and magnetism, during the vacations of the Academy, has remained almost unchanged since his day. It is a lofty, well lighted and spacious hall of admirable proportions, and chaste and classical decoration, and is in no respect unworthy of the interesting associations that cluster about its venerable walls. [EDITOR.

6. *Life and Letters of Faraday*, i, 384.

7. *Faraday as a Discoverer.*

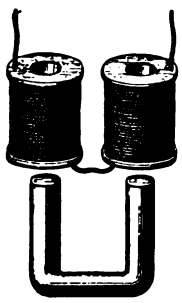
8. *Joseph Henry and the Magnetic Telegraph*, p. 11.

9. S. S. Cox, Memorial Speech in the House of Representatives Jan. 16, 1879.

former endowed with the subtle capacity which enabled it to respond to the electric influence at long distances; the magnet, in fact, which made the electric telegraph a commercial possibility instead of a philosopher's plaything. He had discovered and made plain the law governing the relation between the electric flow and the electric resistances in battery and magnet, and by this discovery had married, as it were, his magnets to their respective batteries; the "intensity" magnet of a long single wire to the "intensity" battery of many pairs of plates; the "quantity" magnet of many short wires to the "quantity" battery of a single large pair of plates; and had sent forth these children of his brain, through the pages of *Silliman's Journal*, to take their places as willing servitors in all the physical laboratories of the world; all this in the early days of this very year, in January, 1831.[10]

Prof. William B. Taylor says:

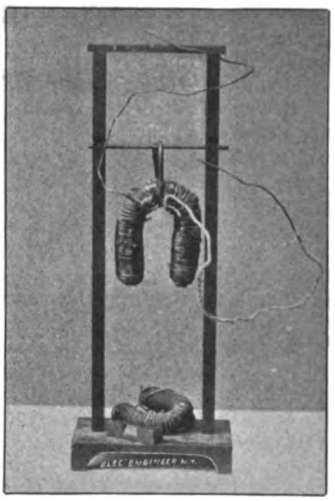
"The importance of this discovery can hardly be over-estimated. The magnetic 'spool' of fine wire, of a length—tens and even hundreds of times as great as that ever before employed for this purpose was in itself a gift to science which really forms an epoch in the history of electro-magnetism. It is not too much to say that almost every advancement which has been made in the fruitful branch of physics since the time of Sturgeon's happy improvement; from the earliest researches of Faraday downward has been directly indebted to Henry's magnets. By means of the Henry 'spool' the magnet almost at a bound was developed from a feeble childhood to a vigorous manhood. And so rapidly and generally was the new form introduced abroad among experimenters, few of whom had ever seen the papers of Henry, that probably very few indeed have been aware to whom they were really indebted for this familiar and powerful instrumentality. But the historic fact remains that prior to Henry's experiments, in 1829, no one on either hemisphere had ever thought of winding the limbs of an electromagnet on the principle of the 'bobbin,' and not till after the publication of Henry's method in January, 1831, was it ever employed by any European physicist."



THE PRINCIPLES OF THE SPOOL OR BOBBIN, AS APPLIED BY HENRY TO THE ELECTRO-MAGNET.

"But in addition to this large gift to science, Henry has the pre-eminent claim to popular gratitude of having practically worked out the differing functions of two entirely different kinds of electromagnet; the one surrounded with numerous coils of no great length, designated by him the 'quantity,' the other surrounded with a continuous coil of very great length designated by him the 'intensity' magnet. The latter and feebler system (requiring for its action a battery of numerous elements) was shown to have the singular capability, never before suspected or imagined, of subtle excitation from a distant source. *Here for the first time is experimentally established the important principle that there must be a proportion between the aggregate internal resistance of the battery and the whole external resistance of the conjunctive wire or conducting circuit.* This was a very important, though unconscious, experimental confirmation of the mathematical theory of Ohm, embodied in his formula expressing the relation between electric flow and electric resistance, which, although propounded two or three years previously, failed for a long time to attract any attention from the scientific world."

"Never should it be forgotten that he who exalted the 'quantity' magnet of Sturgeon from a power of twenty pounds to a power of twenty hundred pounds, *was the absolute* CREATOR *of the 'intensity' magnet; and that the principles involved in this creation constitute the indispensable basis of every form of magnetic telegraph since invented.*"[12]



INTENSITY MAGNET MADE BY HENRY IN 1829; NOW IN THE CABINET OF THE COLLEGE OF NEW JERSEY.

It detracts nothing from Henry's independent and original discovery of the law of relation between the "electric flow" and the "electric resistance," that Ohm, in far-distant Munich, had a theoretical dream of such a law, which, with a sagacity little short of marvellous, he reduced to a concrete mathematical formula. Consider for a moment the distinction between the man who propounds a theory and the man who makes a veritable discovery; for precisely in these two attitudes stand Ohm and Henry in relation to this fundamental electric law. A theory may, it is true, be of inestimable value; but however ingenious, however founded upon intimate knowledge of the subject, it at the most can only suggest *what may be;* can only point out an intelligent mode of asking Nature a question. The theory may, or may not, prove to be true. A discovery, on the contrary, tells us *what is;* it tells us that a certain fact or a certain relation in nature actually exists. Of the theory of Ohm, now at the tongue's end of every schoolboy, but for a long time ridiculed, or at least unnoticed by the scientific world, Henry, in far-distant America, knew absolutely nothing. Five years later, in a letter written from Princeton, dated December 17, 1833, we find him asking Dr. Bache: "Can you give me any information about the theory of Ohm? Where is it to be found?" In another letter of about the same period: "Who is Ohm? What is his theory?" It was not until 1836, during his visit to London, that he sees at last Ohm's theory, and finds that, after all, it is in substance nothing more nor less than his own discovery, interpreted in the language of mathematical prophecy.

10. Silliman's *Amer. Jour. Science*, Jan. 1831, xix, 404-5.

11. "It is evident"—says Mr. Fahie—"that it was not until after the interview with Henry [on April 11, 1837] that Wheatstone recognized the applicability of Ohm's laws to telegraphic circuits, the study of which would likewise have enabled him to ascertain the best proportions between the length, thickness, etc., of the coils, as compared with the other resistances in the circuit, and to determine the number and size of the elements of the battery necessary to produce the maximum effect." [*History of Electric Telegraphy*, p. 515.] Yet Wheatstone—characteristically, it must be said—has not hesitated to claim Henry's discovery for himself. In a statement written by him in 1841, to be presented to the arbitrators in a disagreement which had arisen between himself and Mr. Fothergill Cooke, he says:—"These methods of completing the secondary circuits have lost nearly all their importance, and are scarcely worth contending about, *since my discovery, that electromagnets may be so constructed as to produce the required effects by means of the direct current even in very long circuits.* [*The Electric Telegraph; Was it Invented by Professor Wheatstone*, ii, 96.] In a subsequent portion of the same document he nevertheless says of himself:—"Wherever I have borrowed an idea from Ohm, Gauss, Steinheil, or any other person, I have, and shall always be ready to acknowledge it." Yet Henry's paper in *Silliman's Journal*, had then been published for some years, and Henry himself had explained to Wheatstone in King's College, on April 11, 1837, the construction and use of his "intensity" magnet. In later years, however, Wheatstone became somewhat more guarded in his assertions, for we find him writing to Cooke in 1856, in reference to the same matter:—"With this law and its applications, no persons *in England* who had before, occupied themselves with experiments relating to electric telegraphs, had been acquainted." The words which we have italicized are significant, and are only capable of construction as an acknowledgment—though not a particularly graceful one—of the priority of Henry. [EDITOR.

12. *Memorial of Joseph Henry*, pp. 226, 227.

ASBESTOS PORCELAIN.

IN a recent communication to the Académie des Sciences, M. F. Garros called attention to a new form of porcelain brought out by him. He takes asbestos fibre and reduces it to a fine powder. If pure, it exhibits an exceedingly white apparence, but if traces of iron oxide are present there is a slightly yellow tint. In the latter case the oxide is removed by sulphuric or hydrochloric acid. The powder is then made into a paste, moulded into shape, dried slowly, and baked (1200° C.) from 17 to 18 hours. If placed in a very high-temperature furnace, a remarkably transparent species of porcelain is obtained. This "asbestos porcelain" has already been used for filtration and sterilization purposes, experiments showing that it is a more rapid and effective filterer than ordinary porcelain, and that the pores are less liable to become clogged up.