



Joseph Henry's Contributions to the Electromagnet and the Electric Motor

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At the beginning of his career as an investigator of electromagnetism, in the fall of 1827, Joseph Henry took up a simple idea, and soon found that it led him to some remarkable results. He was starting his second academic year as Professor of Mathematics and Natural Philosophy at the Albany Academy, a school for boys in Albany, New York, offering instruction extending from what we would now call elementary grades up to and overlapping with the college level.¹ Henry took his teaching responsibilities seriously, but he also had an ambition to make original scientific contributions.

His first paper on electromagnetism, presented on October 10, 1827, shows that at this early stage his research was guided by the didactic concerns of his science classes and the experimental demonstrations that he considered an essential element of effective teaching.²

Henry began by pointing out that the introduction of electromagnetism as a subject of instruction had been hampered because of the expense and awkwardness of the large batteries and delicate apparatus needed to show the effects. Recently, however, the English experimenter William Sturgeon had eliminated much of the difficulty by showing that the use of strong permanent magnets allowed many of the experiments to be done on a larger scale, and with a smaller battery, than was previously thought possible. But some electromagnetic experiments depend on the earth's magnetic field, or the interaction between two current-carrying wires. For these experiments permanent magnets could not be used, and the difficulties remained.

Here is where Henry made his first contribution. He had read that Johann S. C. Schweigger, professor of chemistry at the University of Halle, had invented what came to be called a "galvanic multiplier" for augmenting the deflecting action of an electric current on a compass needle. This effect (the first discovery linking electricity with magnetism) had been announced in 1820 by Hans C. Oersted. Oersted used in his experiments a single straight wire passing close to the compass; Schweigger, a few months later, showed that if the wire was formed into a vertical coil of several turns around the compass, the effect would be greatly increased.³ Henry, in turn, now described in his 1827 paper how Schweigger's coil idea could be applied to other standard electromagnetic demonstration devices to make them more sensitive or powerful. Henry's versions of these devices embodied no new discovery, but were simply more dramatic and effective as educational aids.



His next step was to apply the coil principle “to a developement [*sic*] of magnetism in soft iron, much more extensively, than to my knowledge had been previously effected by a small galvanic element.” He did this by winding an electromagnet with about 400 tight turns of a wire 35 feet long, “instead of loosely coiling around it a few feet of wire, as is usually described.”⁴ This is probably an indirect reference to the electromagnet described by Sturgeon, who is generally credited with its invention. Sturgeon used uninsulated [*sic*] wire (insulated wire for electrical use was not then commercially available); to prevent short-circuiting of the windings, he varnished the iron core and separated the turns of wire to keep them from touching. The illustration of his magnet, in fact, shows only 18 loose turns.⁵ Henry insulated the wire itself with silk thread and so could apply a large number of tight turns.

So far, he had not done anything really new, but just extended and combined known principles using simple techniques. He now saw, however, a new line of investigation opening before him: the determination of the principles for designing powerful, efficient electromagnets, which would develop the greatest possible lifting force with a given small battery. Systematically he explored different methods of winding, using various lengths of wire in various arrangements and trying increasingly large iron cores. From these experiments Henry discovered that if a cell of a single pair of electrodes is to be used with a given magnet, the magnet should be wound with several coils of wire in parallel; on the other hand, if a battery of many cells is to be used, the magnet winding should form a single long wire. Henry was the first person to understand this idea. It later became a fundamental basis for much of electrical technology, and, in particular, made Samuel F. B. Morse’s telegraph feasible.

Applying this principle (together with the valuable but less easily described practical skill in magnet-making he had acquired in the course of his experiments), Henry, with the assistance of a colleague, Philip Ten Eyck, went on to build a 21-pound “experimental magnet on a large scale.” With a modest battery, this “Albany magnet” supported 750 pounds, making it, Henry claimed, “probably, therefore, the most powerful magnet ever constructed.”⁶ Quickly he wrote a paper describing these experiments and his magnet-winding principle, and sent it off to Benjamin Silliman, Professor of Chemistry and Natural History at Yale College and editor of the *American Journal of Science*, a widely read and influential publication. Silliman readily accepted what he called Henry’s “highly important & interesting paper” and published it in the issue of January, 1831.⁷

In addition to the paper, Henry sent Silliman an offer to “superintend the construction for your lecture room of a Galvanic magnet on my pla[n] which will support 1000 or 1200 lbs.” Silliman agreed, and in a few months Henry built a magnet that exceeded his own projection. This “Yale magnet” embodied no principles not already explained in Henry’s paper, but it represented a big step beyond the Albany magnet in size and power. With a core weighing 59 pounds, it supported the unprecedented weight of 2,063 pounds. Silliman published Henry’s detailed description of this latest and most highly developed product of his magnet-building skills and in an editor’s note said of Henry, “He has the



honor of having constructed by far, the most powerful magnets that have ever been known, and his last ... is eight times more powerful than any magnet hitherto known in Europe.” [8](#)

Henry’s papers on his electromagnets attracted considerable attention. Before long requests started coming in for magnets like the one made for Silliman. He turned down most of these but did provide helpful practical information to his correspondents. Henry made an exception for Parker Cleaveland of Bowdoin College, furnishing him with a magnet similar to Silliman’s while incorporating some recent refinements of construction.[9](#) In the meantime, however, having worked out and published the fundamental principles of the design of these magnets, he was considering the next stages of his research: “At the conclusion of the series of experiments which I described in Silliman’s Journal, there were two applications of the electro-magnet in my mind: one the production of a machine to be moved by electro-magnetism, and the other the transmission of or calling into action power at a distance.” [10](#)

In the summer of 1831 Henry described the first of these applications in a short paper, “On a Reciprocating Motion Produced by Magnetic Attraction and Repulsion.”[11](#) It was a simple device whose moving part was a straight electromagnet rocking on a horizontal axis. Its polarity was reversed automatically by its motion as two pairs of wires projecting from its ends made connections alternately with two electrochemical cells. Two vertical permanent magnets alternately attracted and repelled the ends of the electromagnet, making it rock back and forth at 75 vibrations per minute.

Henry at this time considered his little machine merely a “philosophical toy,” but nevertheless believed it was important as the first demonstration of continuous motion produced by magnetic attraction and repulsion. Furthermore, “in the progress of discovery and invention, it is not impossible that the same principle, or some modification of it on a more extended scale, may hereafter be applied to some useful purpose.” Indeed, one authority has stated, “Henry’s apparatus was the first clear-cut instance of a motor capable of further mechanical development. It had the essentials of a modern DC motor: a magnet to provide the field, an electromagnet as armature, and a commutator to apply the mechanical forces at the right time.”[12](#) Other inventors did later develop motors of various designs based on similar reciprocating actions, but it is not clear whether these inventors knew of Henry’s device, or created theirs independently. In any case, reciprocating motors never became commercially successful; continuous rotary motion proved to be a more efficient and useful principle.

In 1831 the future development and importance of what we now call the electric motor could scarcely be foreseen. Henry at that time was striving to build a solid reputation as an original scientist while conscientiously discharging his teaching responsibilities at the Albany Academy. At the start of his career, a few years before, his research interests had been dominated by a desire to develop effective, compelling demonstration apparatus for his classes. His 1827 paper on extending the “galvanic multiplier”



principle, discussed above, exemplifies this motivation. Large equipment and dramatic experimental effects, he knew from experience, attract the attention and hold the interest of students. Certainly some of the original motivation for the construction of his powerful electromagnets can also be ascribed to this desire. But the process of developing those magnets led Henry to make a real discovery, and this, along with the magnets themselves, was beginning to make his name known in scientific circles.

His next project, the oscillating electromagnet, was not built on the grand scale of the large magnets. But it, like them, exemplifies Henry's continuing desire not only to make original discoveries, but also to embody them in the form of didactically useful devices. And, as with his original idea for developing the electromagnet, Henry could not leave his motor alone after he had conceived the principle, embodied it in a working model, and described it to the scientific community. Although he published no more papers about it, there is ample evidence that he continued to ponder and develop the idea after he had submitted his article to Silliman. A few months later, for example, he wrote to Parker Cleaveland that he had "lately improved the form of the little machine" there described, but he gave no details of any change in the design.¹³

In November 1832, a year after his letter to Cleaveland, Henry moved from Albany to the college at Princeton, New Jersey, where he continued conducting experimental researches whenever he could find time away from his teaching duties. In 1834, he lent the machine (apparently in its original configuration) to another colleague, Jacob Green of Philadelphia, who wanted to use it in a popular lecture. In their correspondence about this loan, both men called the device the "sheep's tail," presumably referring to the wagging motion of the projecting wires.¹⁴ The familiar use of such a nickname suggests that Green and Henry had discussed the machine at some length. In his letter to Green, Henry remarked that he was constructing a new version "on a somewhat different plan" using C-shaped magnets in place of straight ones. This promised to give "a moving force double of that in the other plan." He also said, "Many different forms of the instrument have suggested themselves to my mind." It is clear that the device had become more than a mere "philosophical toy" in Henry's imagination.

Concrete evidence of this continuing interest is a machine long preserved in the Princeton apparatus collection.¹⁵ In its general form it is similar to Henry's 1831 invention, but it differs in having, instead of the two vertical bar magnets under the rocking electromagnet, a single horizontal bar magnet. With this configuration, the ends of the electromagnet are acted on by two different magnetic poles, north and south; in the original device both were north poles. In consequence of this change, an ordinary electromagnet would not oscillate--both ends would be attracted or repelled at the same time. An apparently accurate replica of the Princeton device made for the Smithsonian suggests that Henry accordingly wound the electromagnet in opposite directions on its two ends--in effect, creating two electromagnets end to end, with like poles together at the middle. No written record of this development appears to survive; it is known to us only through the three-dimensional evidence of the demonstration device.



In 1833, not long after Henry invented his oscillating electromagnet, William Ritchie, a clergyman, educator, and experimentalist in England, contrived a way to make an electromagnet revolve continuously. He caused its polarity to reverse twice in each revolution by an arrangement of wires grazing across two semicircular troughs of mercury.¹⁶ It is unlikely that Ritchie had heard of Henry's invention; he probably devised his scheme independently. Nevertheless, when Henry heard of it, he suspected that Ritchie had "lately reinvented my machine," implying that he had neglected to give Henry due credit for the idea.

On several later occasions extending over twelve years Henry went to some lengths to see that his claim was acknowledged in published accounts on the subject, and in his notes and correspondence he repeatedly asserted his priority.¹⁷ In 1840, for example, he described to the American Philosophical Society yet another variant of his machine. Even in the brief official note of his talk, his pique is perceptible: "Prof. Henry described an apparatus for producing a reciprocating motion by the repulsion in the consecutive parts of a conductor, through which a galvanic current is passing, and made some remarks in reference to the electromagnetic engine invented by him in 1831, and subsequently described by Dr. Ritchie, of London."¹⁸

His touchiness in this matter is an example of a characteristic he displayed at other times in his career. The most notable instance was his [dispute with Samuel Morse](#) about his contributions to the electromagnetic telegraph. Like his remarks in that dispute, Henry's expressions of concern about the credit due him for his motor reveal his strongly held beliefs about the value of his contributions and the importance of scrupulous fairness in scholarly publications.

Ritchie's device, like Henry's, was a didactic instrument, with no practical application beyond its demonstration of electromagnetic principles. The first manufacturer of educational electromagnetic apparatus in the United States, Daniel Davis of Boston, seems to have ignored Henry's machine. In his catalogue of 1838, Davis did, however, include Ritchie's, as well as a similar device, "Page's Revolving Magnet."¹⁹ In the latter, Ritchie's awkward mercury commutator was replaced with a "pole-changer," identical with the present-day commutator. This device, which had previously been used by others in somewhat different applications, consisted of two wires, each connected to a pole of the battery, and making contact with a pair of insulated half-cylinders on the rotating shaft. Each half-cylinder was soldered to one end of the winding of the electromagnet, so the polarity reversed with every half revolution.²⁰ Davis attributed this improved version of Ritchie's instrument to Charles Grafton Page, an experimenter and prolific inventor of electromagnetic devices, many of which Davis offered for sale. But in his 1848 catalogue Davis changed its name to "Revolving Electro-Magnet," probably to acknowledge that Page did not deserve exclusive credit for it.²¹ Even so, Page later did claim credit for it.²²



It is clear that all along Henry believed that much of the honor belonged neither to Ritchie nor to Page, but to himself. Yet whatever Henry may have felt about the lack of recognition for his contribution to the Revolving Electro-Magnet, Davis's commercial version of it was just the kind of impressive demonstration device that he liked to put into action for his classes and lectures. And indeed an example survives at the Smithsonian among a collection of apparatus said to have once belonged to Henry. The date he acquired it is unknown. It agrees closely with Daniel Davis's illustration in his catalogues of 1842 and 1848, however, and may have been made by Davis about that time. It is impossible to be certain, however, because the device is not signed, and other makers copied Davis's handsome designs.

Here in one instrument, then, are embodied the contributions of several electrical investigators. With regard to Henry, Ritchie, and Page, perhaps it would do justice to all three to say that Henry was the first to show how polarity could be automatically reversed and Ritchie the first to produce rotary motion of an electromagnet, while Page introduced into Ritchie's device the simple and effective "pole-changer," which remains in use today.



Notes

1. For Henry's appointment, see Nathan Reingold, Stuart Pierson, and Arthur P. Molella, eds., *The Albany Years: December 1797-October 1832*, vol. 1 of *The Papers of Joseph Henry* (Washington, DC: Smithsonian Institution Press, 1972), 132-133. For the Albany Academy's curriculum and educational philosophy, see Reingold, Pierson, and Molella, eds., *The Albany Years: December 1797-October 1832*, 44-49 and Albert E. Moyer, *Joseph Henry: The Rise of an American Scientist* (Washington, Smithsonian Institution Press, 1997), 26, 50-51. [Return to [text.](#)]
2. Joseph Henry, "On Some Modifications of the Electro-Magnetic Apparatus," *Transactions of the Albany Institute*, vol. 1, 22-24; reprinted in *Scientific Writings of Joseph Henry*, vol. 1 (Washington: Smithsonian Institution, 1886), 3-7. See Reingold, Pierson, and Molella, eds., *The Albany Years: December 1797-October 1832*, 201, and Moyer, *Joseph Henry*, 59-60. For Henry's thoughts on the value of experimental demonstrations in scientific education, see his Albany Academy inaugural lecture, Reingold, Pierson, and Molella, eds., *The Albany Years: December 1797-October 1832*, 176-178, and Moyer, *Joseph Henry*, 46, 54, 56-57, 98. [Return to [text.](#)]
3. For Schweigger's work and publications, see Robert A. Chipman, "The Earliest Electromagnetic Instruments," *Contributions from the Museum of History and Technology*, Paper 38, Smithsonian Institution, United States National Museum Bulletin 240 (Washington, DC: Smithsonian Institution, 1966), 127-131. Henry could not have read Schweigger's original reports, which were in German; he refers to Jacob Green, *Electro-Magnetism, Being an Arrangement of the Principal Facts hitherto Discovered in that Science* (Philadelphia, PA: Dobson, 1827), 30. See Reingold, Pierson, and Molella, eds., *The Albany Years: December 1797-October 1832*, 322-323. [Return to [text.](#)]
4. Joseph Henry, "On the Application of the Principle of the Galvanic Multiplier to Electro-Magnetic Apparatus, and Also to the Development of Great Magnetic Power in Soft Iron, with a Small Galvanic Element," *American Journal of Science and Arts* 19 (January 1831): 401, reprinted in *Scientific Writings of Joseph Henry*, vol. 1, 38. [Return to [text.](#)]
5. For Sturgeon's electromagnet, see W. James King, "The Development of Electrical Technology in the 19th Century: 1. The Electrochemical Cell and the Electromagnet," *Contributions from the Museum of History and Technology*, Paper 28, United States National Museum Bulletin 228, (Washington: Smithsonian Institution, 1962), 258 and Fig. 41. [Return to [text.](#)]
6. Joseph Henry, "On the Application of the Principle of the Galvanic Multiplier..." *Scientific Writings*, vol. 1, 39-45. [Return to [text.](#)]
7. For Henry's correspondence with Silliman about this paper (see note 4 above), see Reingold, Pierson, and Molella, eds., *The Albany Years: December 1797-October 1832*, 301-303, 316-319. See also Moyer, *Joseph Henry*, 62-67. [Return to [text.](#)]
8. Joseph Henry, "An Account of a Large Electro-Magnet, Made for the Laboratory of Yale College," *American Journal of Science and Arts* 20 (April 1831): 201-203, reprinted in *Scientific Writings*, vol. 1, 50-53, and reproduced in facsimile in James E. Brittain, ed., *Turning Points in American Electrical History* (New York: IEEE Press, 1977), 27-29. For the correspondence about this magnet, see Reingold, Pierson, and Molella, eds., *The Albany Years: December 1797-October 1832*, 316-321, 330-334. The magnet itself is preserved in the Electricity Collection of the Smithsonian Institution's National Museum of American History; its catalogue number is 181,343. [Return to [text.](#)]



9. For requests to Henry for electromagnets and information on their construction and management, see Reingold, Pierson, and Molella, eds., *The Albany Years: December 1797-October 1832*, 320-321, 327-328, 345-346, 348-349, 380, 400-402, 416-417. For the construction of Cleaveland's magnet, see Reingold, Pierson, and Molella, eds., *The Albany Years: December 1797-October 1832*, 373, 375-378, 402-404, 413, 420-426, 432-433. The core of this magnet (the windings have been removed) is on display in the exhibition, "Edison: Lighting a Revolution," in the National Museum of American History; its catalogue number is 315,390. [Return to [text](#).]
10. "Statement of Prof. Henry, in relation to the History of the Electro-magnetic Telegraph," *Annual Report of the Board of Regents of the Smithsonian Institution for the Year 1857* (Washington: William A. Harris, Printer, 1858), 105. [Return to [text](#).]
11. *American Journal of Science and Arts* 20 (July 1831): 340-343; reprinted in *Scientific Writings of Joseph Henry*, vol. 1, 54-57; reproduced in facsimile in Brittain, ed., *Turning Points in American Electrical History*, 31-34. [Return to [text](#).]
12. King, "The Development of Electrical Technology," 260-261. For a detailed account and assessment of the earliest devices for producing motion by electromagnetism, including Henry's, see Brian Gee, "Electromagnetic Engines: Pre-Technology and Development Immediately Following Faraday's Discovery of Electromagnetic Rotations," *History of Technology*, vol. 13, 1991, 41-72. [Return to [text](#).]
13. Reingold, Pierson, and Molella, eds., *The Albany Years: December 1797-October 1832*, 376. [Return to [text](#).]
14. Nathan Reingold, Arthur P. Molella, and Michele L. Aldrich, eds., *The Princeton Years: November 1832-December 1853*, vol. 2 of *The Papers of Joseph Henry* (Washington, DC: Smithsonian Institution Press, 1975), 161-164. [Return to [text](#).]
15. This device is on display in the lobby of Jadwin Hall, Princeton University. See Malcolm MacLaren, *The Rise of the Electrical Industry During the Nineteenth Century* (Princeton, N.J.: Princeton University Press, 1943), 21-22 and Fig. 14. MacLaren dates the Princeton motor to 1837, but gives no evidence. For many years it was at the Smithsonian Institution, where it was given the number 180,928. [Return to [text](#).]
16. William Ritchie, "Experimental Researches in Electro-Magnetism and Magneto-Electricity," *Philosophical Transactions of the Royal Society of London*, vol. 123, 1833, 313-321. [Return to [text](#).]
17. Reingold, Molella, and Aldrich, eds., *The Princeton Years: November 1832-December 1853*, 162-163, 195, 446-448. [Return to [text](#).]
18. *Proceedings of the American Philosophical Society*, vol. 1, p. 301, reprinted in *Scientific Writings*, vol. 1, 189. For still another modification by Henry to his engine, see Moyer, *Joseph Henry*, 73. [Return to [text](#).]
19. Daniel Davis, Jr., *Davis's Descriptive Catalogue of Apparatus and Experiments: To Illustrate the Following Branches of Science, Namely, Galvanism, Electro-magnetism, Electro-dynamics, Magneto-electricity, Magnetism, Thermo-electricity* (Boston, MA: Press of Marden & Kimball, 1838), 27, 30. [Return to [text](#).]
20. Charles G. Page, "Experiments in Electro-Magnetism," *American Journal of Science and Arts* 33 (No. 1, January 1838): 118-120. [Return to [text](#).]



21. Daniel Davis, *Davis's Descriptive Catalogue of Apparatus and Experiments: To Illustrate the Following Branches of Science, Namely, Galvanism, Electro-magnetism, Electro-dynamics, Magneto-electricity, Magnetism, Thermo-electricity* (Boston, MA, 1848, 2nd edition), 211-213, fig. 146. [Return to [text.](#)]

22. Charles G. Page, *History of Induction: The American Claim to The Induction Coil and its Electrostatic Developments* (Washington, DC: Intelligencer Printing House, 1867), 121-122. [Return to [text.](#)]