The History of Electricity and Electronics

This month, we begin a new series, "The History of Electricity and Electronics." We will start with Joseph Henry, the father of American electronics.

by Chuck Ander

Joseph Henry, for whom the unit of inductance (the henry — what else?) is named, was the first person to construct a practical electromagnet. In fact, there is a mining community on Lake Champlain named port Henry where Henry's invention is used to separate iron ore.

Besides constructing the first practical electromagnet (capable of lifting more than a ton-and-a-half!), Henry built the first working telegraph. Although Samuel F.B. Morse (of Morse Code fame) was awarded the patent, Joseph Henry laid the theoretical groundwork and built the first working model. The electric motor was another first for Henry. Although Michael Faraday and Peter Barlow produced electric rotating devices, it is generally acknowledged that Joseph Henry produced the first electric motor which comprised the basics that could be developed into a workable machine.

Joseph Henry was the first to discover electromagnetic induction — that electricity can be produced by a changing magnetic field. However, his failure to publish his results led to Faraday being given credit for similar work — just a year later.

Joseph Henry was the first person to demonstrate the transmission of radio waves. Little was understood about the phenomenon at the time, but Henry rightly assumed that the transmission was "wave-like." And this was over fifty years before similar revelations by Hertz and Marconi!

Joseph Henry

The Early Years

Joseph Henry was born in Albany, New York on December 17, 1799. At the age of seven, his mother sent him to live with his grandmother on the family farm just outside of Galway. His mother certainly had her hands full, caring for her ailing husband and trying to make ends meet. Young Joseph was a dreamer, and more often than not, had his nose buried in a book. His strict grandmother, was not aware that he could read, and Joseph kept this knowledge from her, painfully aware that she would insist that he read only the Bible, to the exclusion of everything else. Indeed, many who knew young Joseph Henry, shared the opinion of his grandmother that he was "not quite richt i' the haid."

Joseph knew that he was not stupid or dull, but he just couldn't seem to find his niche in life. It certainly wasn't working in the general store — as he did in the years he lived on his grandmother's farm. And he definitely did not have a knack for watch repair, for which he was an apprentice when, at the age of thirteen, he moved back to Albany to live with his mother. (Sadly, his father died while he was living in Galway.)

One day in the watch shop, a prominent actor, John Bernard came in to inquire as to whether his watch was ready. Mr. Bernard must have been impressed with young Joseph, for he invited him to the theatre. To Joseph Henry, this sounded like the most exciting thing possible! He did not have to wait long to take Mr. Bernard up on his invitation. His boss shortly announced he was closing the store to move west — Joseph Henry was a free man!

His employment at the theatre was exciting and rewarding and, for the first time in his life, he seemed to have natural ability in something! But even this, after a while, seemed not enough. "Was it enough," he asked himself, "to do something one enjoyed and found exciting?" Apparently, the answer was no. Then something happened that would change the course of Joseph Henry's life forever.

Joseph is "Called"

While home sick one day, he came across a book entitled, *Lectures on Experimental Philosophy, Astronomy and Chemistry, intended chiefly for the use of students and young persons*, by G. Gregory, D.D., Vicar of West-Ham, published in London in 1808. Thumbing through it, Joseph paused at a paragraph: "You throw a stone, or shoot an arrow upward into the air; why does it not go forward in the line or direction that you give it? Why does it stop at a certain distance, and then return to you? What force is it that pulls it down to the earth again? On the contrary, why does flame or smoke always mount upwards, though no force is used to send them in that direction?"

Joseph sat down by the window and began to read. Only when dusk made it too dark to see did he put the book down again.

His mind was working feverishly. Yet he could see clearly and sharply, as he rarely did in his everyday pursuits. A new door had been opened to Joseph. He had never read anything like it before. Of course, it was all true — the laws of the universe that were forever the same, explaining the unexplainable. In a sudden burst of self-awareness, Joseph saw with absolute clarity that he must find some way to spend his life dealing with the kind of truth that lay in his lap. What mattered was the existence of the changeless physical laws — and he must become one of the people who explored and explained and learned how to use them.

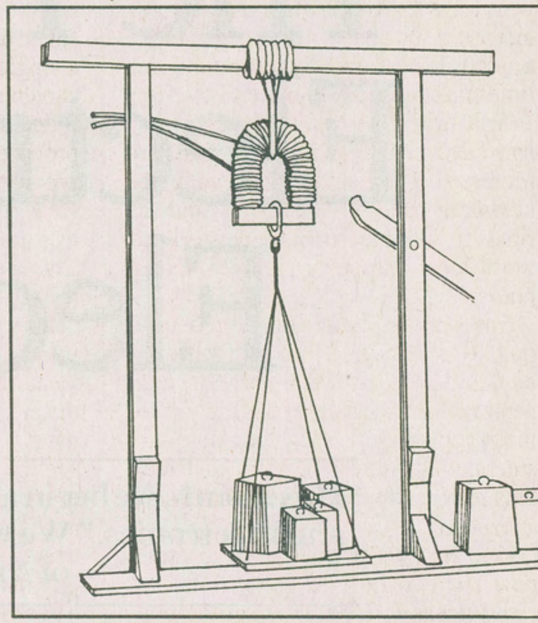
He knew he was "called" to this wonderful new pursuit. No wonder he was labelled as "unteachable" by his school teacher. He had just not been able to endure the drill-and-rote method of teaching which was the only way his teacher could imagine an eight-year-old managing to learn something. What his mind had needed was a chance to leap ahead, and a teacher to free it. Stupid? Dull-witted? "I'm not!" Joseph thought, clutching his new book. "I'm not! I've only been in the wrong place — and I'm not any longer!"

Years later, Joseph Henry, the scientist came across the volume in his library. He then inscribed on its flyleaf:

> *This book, by no means a profound work, has under Providence exerted a remarkable influence upon my mind. It accidentally fell into my hands when I was about sixteen years old, and was the first book I ever read with attention. It opened to me a new world of thought and enjoyment; fixed my attention upon the study of nature, and caused me to resolve at the time of reading it that I would immediately devote myself to the acquisition of knowledge.*

School Days

So at age sixteen, Joseph Henry knew the path he wanted to take in life. His first requirement was education. He hesitatingly approached Dr. T. Romeyn Beck, the Director of the Albany Academy, enquiring about attending that institution. Although unqualified, his youthful enthusiasm so impressed Dr. Beck, he agreed to take him on as a special student. Joseph, studying night



Henry's Electromagnets Could Lift Over One Ton!

and day, completed the equivalent of a four-year high-school course in seven months. When Joseph's small fund of money began to run out, Dr. Beck found him a teaching job to help him with expenses. For three years Joseph taught in a one-room school near Albany, earning fifteen dollars a month. Every evening he studied at the Academy, taking advanced classes in mathematics and "natural philosophy," as chemistry and physics were then called. He swallowed knowledge as though he were starving for it, and his teachers continued to be awed at his brilliance and retentive powers.

In 1824, Dr. Beck invited Joseph Henry to join the Albany Institute of Science and Art. This Institute was a society of teachers and amateur scientists that met weekly for scientific lectures and demonstrations. The meetings were open to the public for a small admission fee. Joseph had often attended as a non-member. Such lectures were not merely a diversion; in those days they were an accepted form of education. In fact, an ex-bookbinder's apprentice named Michael Faraday, had gotten most of his education in this way. Joseph did well as a member and his lectures were well received. As well, his training in the theatre gave him an excellent stage presence — which of course, helped with his presentations.

A frequent attendee at these lectures was Harriet Alexander, Joseph's fifteen-year-old cousin. They began to see a good deal of each other around this time and eventually, they were married.

In a few short years, Joseph Henry had advanced to the post of assistant professor of mathematics, with the honourary title of "professor" and the right to conduct experiments in his third-floor classroom after school hours.

For Joseph, mathematics broadened quickly into the new, almost totally unexplored field of electricity. He concentrated on it, sharing all his excitement and much brilliant thinking with students who may or may not have realized how lucky they were to have such a teacher.

One day he demonstrated a totally new innovation — a new kind of electromagnet. First showing the conventional style of electromagnet, he demonstrated that it could lift a maximum of seven pounds. This magnet was horseshoe shaped, was insulated with shellac and was wrapped around with several turns of plain wire.

"Now, your attention please," Joseph said in a commanding voice. He then held up another horseshoe-shaped magnet, a bulky one wrapped with many turns of a shiny pink material. "I have made some changes," he pointed out. "Instead of insulating the horseshoe with shellac, I've insulated the wire by wrapping it heavily with silk. Now look!"

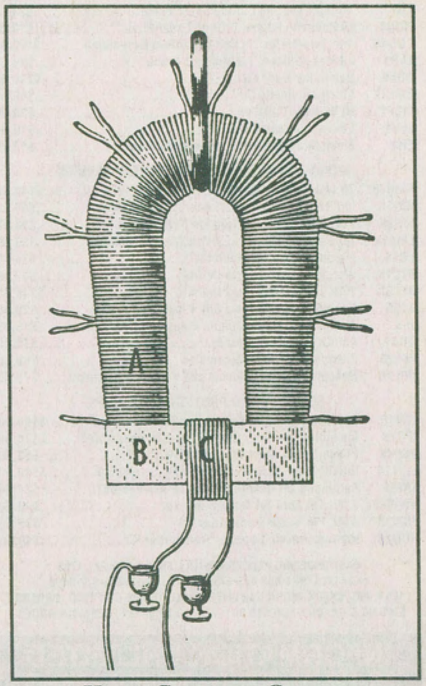
This new magnet lifted all the weights on hand — over four hundred times its own weight! Eventually, he was able to produce an electromagnet capable of lifting 3,600 pounds. Joseph Henry had invented the powerful electromagnet as we know it today.

In building the first powerful electromagnet, Henry drew on the work of William Sturgeon (1785-1850), who was a self-taught scientist and experimenter in Woolwich, England. He built, in 1824, the first lifting magnet, capable of holding nine pounds. Henry first found that he could lift more weight by simply adding to the number of turns or wire. To do this, he insulated the wire instead of the magnet. But adding turns worked only to a point. Then he had to add pairs of plates to his battery to keep up the current. More wire increased the resistance of the circuit, requiring more cells. But by using multiple coils connected in parallel, he found he could get a superior result with a single battery of large plate area (one capable of delivering high current). Since the amount of magnetic flux was proportional to the current, this provided the maximum lift power. This Henry called the "quantity" magnet. He also produced the "intensity" magnet. This was formed of a single coil consisting of many turns and had to be connected to multiple battery cells in series. This arrangement was necessary when the magnet had to work at some distance from the batteries. This arrangement produced a relatively high voltage, needed to overcome the resistance of the wire from the battery to the magnet. Thus Henry's "quantity" and "intensity" magnets both anticipated the fact that the maximum magnetic force was obtained when the resistance of the magnet and that of the battery were matched.

Henry reported his results in 1831 in a paper in the American Journal of Science: *On the Application of the Principle of the Galvanic Multiplier to Electro-Magnetic Apparatus, and also to Development of Great Magnetic Power in Soft Iron with a Small Galvanic Element.*

It was not until 1837 that Henry became acquainted with Ohm's law, which would explain the relationships accounting for the operation of his "quantity" and "intensity" electromagnets. But his projections of the possibilities of these arrangements and their extension to his experiments and discoveries of the early 1830s were to establish Henry as a first-rank American scientist, and a pioneer in electrodynamics.

The concept of sending signals magnetically (the telegraph) was first suggested by Ampère. Although many experimenters tried to build a practical telegraph, the main problem was sending signals over long distances. Joseph Henry solved the problem by using an "intensity" battery, using many pairs of plates in series for the power source at the sending end, and an "intensity" magnet of many turns of small wire at the receiving end. In effect he was matching resistance for the highest efficiency of transmission. To detect the signals he used a magnet with a clapper to strike a bell. This same concept led him to develop an electromagnetic relay for multiplying a signal.



Henry Generates Current Magnetically–The First Generator

Although Henry knew that he had assembled all the elements of a successful telegraph system, he did not make an invention of them. He was content that science had accomplished its purpose, and he left to others the extension of the scientific principles to an utilitarian end. Samuel F.B. Morse (1791-1872) developed the practical telegraph (along with the Morse Code) within a decade of Henry's work.

As soon as Oerstead had announced his discovery that electric current is accompanied by magnetism, and that the magnetism encircled the current, Faraday succeeded in assembling the first electromagnetic motor.

Faraday was followed by Peter Barlow (1776-1862), a physicist at Woolwich Academy, England, who developed an "Electromagnetic Wheel."

Contrasted to these novel but impractical devices, the electric motor constructed by Henry is credited as being the first which comprised the basics that could be developed into a workable machine. Henry described his motor in an article in the American Journal of Science entitled, *On a Reciprocating Motion Produced by Magnetic Attraction and Repulsion*:

> I have recently succeeded in producing motion in a little machine by a power, which, I believe has never before been applied in mechanics — by means of magnetic attraction and repulsion.
>
> Not much importance, however, is attached to the invention, because the article, in its state can only be considered as a philosophical toy, although 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. But without reference to its utility, and only viewed as a new effect produced by one of the most mysterious agents of nature, you will not, perhaps, think the following account of it unworthy of a place in the Journal of Science.
>
> It is well known that an attractive or repulsive force is exerted between two magnets, according as poles of different names or poles of the same, are presented to each other
>
> In order to understand how this principle can be applied to produce a reciprocating motion ...

Then Henry went on to describe the operation of his electromagnetic motor.

By 1938 Thomas Davenport of Brandon, Vermont had received U.S. Patent No. 132 on his rotary electric motor. Practical motorization, as time would show, had only to wait for the development of the dynamo.

One of the great problems of the day was that of producing electricity from magnetism. Since an electric current always produces magnetism, people reasoned that the inverse was also true. Also, since a steady current produces steady magnetism, most experiments involved wrapping wire around a magnet and looking for evidence of current produced. Henry perceived that the answer lay in a changing magnetic field. In the crucial experiment that demonstrated his hypothesis, Henry used one of his lifting magnets which he equipped with an armature wound at its central portion with 30 feet of insulated wire. The armature was placed across the poles of the magnet and the terminals of the armature winding were connected to the terminals of a galvanometer about 40 feet from the magnet.

"When this arrangement was completed," Henry reported, "I stationed myself near the galvanometer and directed an assistant to attach the galvanic battery to the magnet. At this instant the north end of the galvanometer needle was deflected 30 degrees to the west, indicating a current of electricity from the coil surrounding the armature. The effect, however appeared only as a single impulse...

"This experiment," Henry concluded, "illustrates most strikingly the reciprocal action of the two principles of electricity and magnetism, if indeed, it does not establish their absolute identity."

Henry had singled out the key element leading to an understanding of the dynamic relationship of electricity and magnetism. He had made one of the world's momentous discoveries — the electromagnetic induction of electricity by magnetism in motion. Unfortunately, his failure to publish his results led to Faraday being given credit for discovering electromagnetic induction. Joseph Henry further went on to discover the principle of self-induction. He also produced an electrical transformer capable of stepping up or down voltage and current.

Joseph Henry is the first to have demonstrated the propagation of radio waves. He showed that the induction from a single spark from the discharge of a Leyden jar (primitive glass capacitor) was penetrating enough to magnetize steel needles 30 feet away in a cellar, with two floors and ceilings intervening.

To account for the action Henry made the remarkable projection that the electricity, leaping through the space was *undulatory, or wave-like*, in nature, and was made possible by an intervening plenum, or *ether-like medium*, which transmitted the waves.

He ended his report ... *"It would appear that transfer of a single spark is sufficient to disturb perceptibly the electricity of space throughout a cube of 400,000 feet of space, and that the spark is oscillatory. It may be inferred further that the diffusion of motion in this case is comparable with that of the spark of a flint and steel in the case of light."*

Joseph Henry's career in research came to an end when he accepted the position as the first director and secretary of the newly created Smithsonian Institute. For the rest of his life, he was devoted to the responsibilities of this position. Similarly, when the American Civil War erupted, Henry pledged the entire resources of the Smithsonian Institute in an effort to protect the Union. He was a close friend of Abraham Lincoln and used his scientific knowledge to greatly aid the Northern forces on more than one occasion.

Joseph Henry was one of those scientific pioneers in the vanguard of the age of electricity. The electronic wonders of the modern world, dependent on the discoveries of so many would not have been possible without the contributions of this pioneer. The importance of Joseph Henry's discoveries in the field of electricity were to become clear only with future developments. Marconi, many years later, was to give Joseph credit for being the first to transmit and receive signals of spark frequency at a time when no one could assess the importance of the discovery. In 1893 the standard unit of inductance — the henry — was named for him. Thus Joseph joined farad, volt, ohm and the other immortals of electronics, whose names are now household words in the English language.

The development of the modern dynamo, or generator, was dependent on the discovery shared by Henry and Faraday — the principle of induction. Faraday had taken this principle one step further than Henry — in order to have continuous current, it was necessary to have continuous motion — and built the first dynamo, a copper disk rotating between the poles of a horseshoe magnet. The first dynamos produced only direct current; they lost much power in operation and were costly. But the right person, Nikola Tesla, came along with the right questions, "Is this the best way? Is this the only way?" Tesla developed a dynamo that

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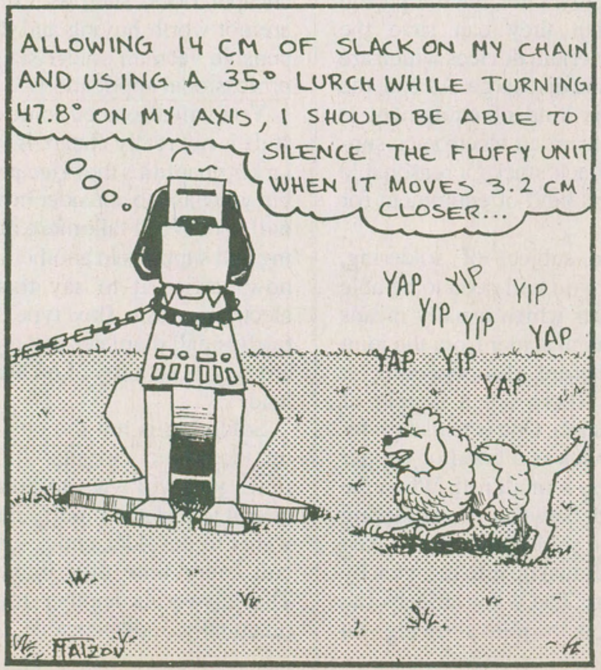
Bots by Ron Matzov



Henry, *Cont'd. from page 15*

produced alternating current, which was able to travel much greater distances without weakening. Also, it is much less costly. Alternating current was first demonstrated at the Chicago Wold's Fair in 1893.

But Joseph Henry did not live to see the demonstration at the Chicago World's Fair or the wonderful electric age which he helped to produce. He had been unwell for some months and at noon on May 13, 1878, at the age of 78, Joseph Henry woke from a deep sleep to see his family and friends gathered around his bed. He did not recognize them. Slowly he turned his head for a last look out the window at the world he loved, and asked, "What direction is the wind...?" ❐