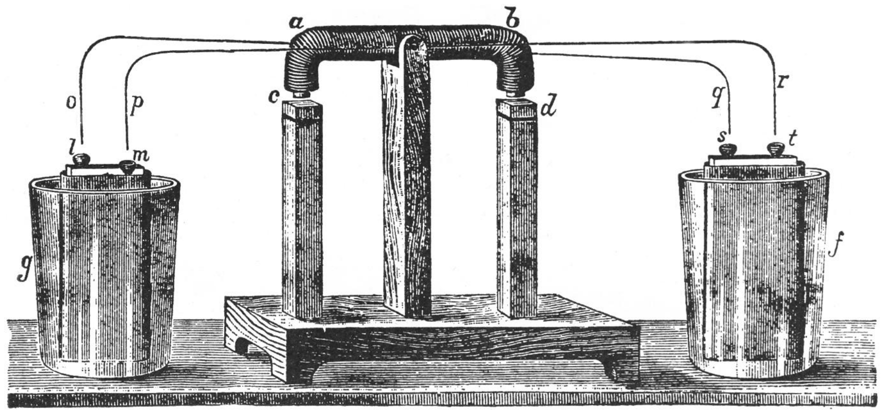
CLASSICS OF SCIENCE: An Ancestor of the Electric Motor

Physics

The mechanical toy here described by the first secretary of the Smithsonian Institution utilizes the principle of the electric motor. It will be easy for you, after duplicating it, to design a toy motor with a spinning motion instead of a reciprocating one for the magnet, for you have seen such machines and know their utility. In Joseph Henry's day there was no possibility of electricity being produced on a scale great enough to do useful work, and so he carried his discovery no further than to note the curious fact that mechanical motion can be obtained from nagnetism.



[Electro-magnetic Engine.]

Prof. Henry's Original Diagram

SCIENTIFIC WRITINGS OF JOSEPH HENRY: On a reciprocating motion produced by magnetic attraction and repulsion. (Silliman's American Journal of Science, July, 1831, *vol. XX, pp.* 340-343).

To the Editor:

SIR:—I have lately succeeded in producing motion in a little machine by a power which, I believe, has never before been applied in mechanics—by magnetic attraction and repulsion.

Not much importance, however, is attached to the invention, since the article, in its present state, can only be considered 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 practical 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 name are presented to each other.

In order to understand how this principle can be applied to produce a reciprocating motion, let us suppose a bar magnet to be supported horizontally on an axis passing through the center of gravity, in precisely the same manner as a dipping needle is poised; and suppose two other magnets to be placed perpendicularly, one under each pole of the horizontal magnet, and a little below it, with their north poles uppermost; then it is evident that the south pole of the horizontal magnet will be attracted by the north pole of one of the perpendicular magnets, and its north pole repelled by the north pole of the other: in this state it will remain at rest, but if, by any means, we reverse the polarity of the horizontal magnet, its position will be changed and the extremity, which was before attracted, will now be repelled; if the polarity be again reversed, the position will again be changed, and so on indefinitely: to produce, therefore, a continued vibration it is only necessary to introduce into this arrangement some means by which the polarity of the horizontal magnet can be instantaneously changed, and that too by a cause which shall be put in operation by the motion of the magnet itself; how this can be effected will not be difficult to conceive when I mention that instead of a permanent steel magnet in the movable part of the apparatus a soft iron galvanic magnet is used. (Professor Henry's "method of constructing the galvanic magnet on an improved plan" is reprinted below.)

The change of polarity is produced simply by soldering to the extremities of the wires which surround the galvanic magnet, two small galvanic batteries in such a manner that the vibrations of the magnet itself may immerse these alternately into vessels of diluted acid; care being taken that the batteries are so attached that the current of galvanism from each shall pass around the magnet in an opposite direction.

Instead of soldering the batteries to the ends of the wires, and thus causing them at each vibration to be lifted from the acid by the power of the machine, they may be permanently fixed in the vessels, and the galvanic communication formed by the amalgamated ends of the wires dipping into cups of mercury.

The whole will be more readily understood by a reference to the annexed drawing: *a b* is the horizontal magnet, about 7 inches long, and movable on an axis at the center: its two extremities when placed in a horizontal line, are about 1 inch from the north poles of the upright magnets *c* and *d*. *g* and *f* are two large tumblers containing diluted acid, in each of which is immersed a plate of zinc surrounded with copper. *l, m, s, t,* and 4 brass thimbles soldered to the zinc and copper of the batteries and filled with mercury.

The galvanic magnet *ab* is wound with 3 strands of copper bell-wire, each about 25 feet long; the similar ends of these are twisted together so as to form two stiff wires, which project beyond the extremity *b,* and dip into the thimbles *s, t*.

To the wires *q, r,* two other wires are soldered so as to project in an opposite direction, and dip into the thimbles *l, m*. The wires of the galvanic magnet have thus, at it were, four projecting ends; and by inspecting the figure it will be seen that the extremity *p,* which dips into the cup *m* attached to the copper of the battery in *g* corresponds to the extremity *r* connecting with the zinc in *f*.

When the batteries are in action, if the end *b* is *(Turn to next page)*

An Ancestor of the Electric Motor—*Continued*

depresesd until *q, r* dips into the cups *s, t, ab* instantly becomes a powerful magnet, having its north pole at *b;* this, of course, is repelled by the north pole *d,* while at the same time it is attracted by *c,* the position is consequently changed, and *o, p* comes in contact with the mercury in *l, m;* as soon as the communication is formed, the poles are reversed, and the position again changed. If the tumblers be filled with strong diluted acid, the motion is at first very rapid and powerful, but it soon almost entirely ceases. By partially filling the tumblers with weak acid and occasionally adding a small quantity of fresh acid, a uniform motion, at the rate of 75 vibrations in a minute, has been kept up for more than an hour: with a large battery and very weak acid, the motion might be continued for an indefinite length of time.

The motion here described is entirely distinct from that produced by the electro-magnetic combination of wires and magnets; it results directly from the mechanical action of ordinary magnetism: galvanism being only introduced for the purpose of changing the poles.

My friend, Prof. Green, of Philadelphia, to whom I first exhibited this machine in motion, recommended the substitution of galvanic magnets for the two perpendicular steel ones. If an article of this kind was to be constructed on a large scale, this would undoubtedly be the better plan, as magnets of that kind can be made of any required power; but for a small apparatus, intended merely to exhibit the motion, the plan here described is, perhaps, the most convenient.

Constructing Galvanic Magnet

A round piece of iron, about ¼ of an inch in diameter, was bent into the usual form of a horse-shoe, and instead of loosely coiling around it a few feet of wire, as is usually described, it was tightly wound with 35 feet of wire, covered with silk, so as to form about 400 turns; a pair of small galvanic plates, which could be dipped into a tumbler of diluted acid, was soldered to the ends of the wire and the whole mounted on a stand. With these small plates, the horse-shoe became much more powerfully magnetic than another of the same size, and wound in the usual manner by the application of a battery composed of 28 plates of copper and zinc, each 8 inches square. Another convenient form of this apparatus was contrived by winding a straight bar of iron 9 inches long with 35 feet of wire, and supporting it horizontally on a small cup of copper containing a cylinder of zinc—when this cup, which served the double purpose of a stand and the galvanic element, was filled with dilute acid, the bar became a portable electro-magnet. These articles were exhibited to the Institute in March, 1829.

The idea afterwards occurred to me, that a sufficient quantity of galvanism was furnished by the two small plates, to develope, by means of the coil, a much greater magnetic power in a larger piece of iron. To test this, a cylindrical bar of iron, ½ an inch in diameter, and about 10 inches long, was bent into the form of a horse-shoe, and wound with 30 feet of wire; with a pair of plates containing only 2½ square inches of zinc, it lifted 14 lbs. avoirdupois. At the same time, a very material improvement in the formation of the coil suggested itself to me, on reading a more detailed account of Prof. Schweigger's galvanometer, and which was also tested with complete success upon the same horse-shoe; it consisted in using several strands of wire, each covered with silk, instead of one:—agreeably to this construction, a second wire, of the same length as the first, was wound over it, and the ends soldered to the zinc and copper in such a manner that the galvanic current might circulate in the same direction in both, or in other words, that the two wires might act as one; the effect by this addition was doubled, as the horse-shoe, with the same plates before used, now supported 28 lbs.

With a pair of plates 4 inches by 6 inches, it lifted 39 lbs., or more than 50 times its own weight.

These experiments conclusively proved that a great development of magnetism could be effected by a very small galvanic element, and also that the power of the coil was materially increased by multiplying the number of wires, without increasing the length of each.

The multiplication of the wires, increases the power in two ways; first, by conducting a greater quantity of galvanism, and secondly, by giving it a more proper direction, for since the action of a galvanic current is directly at right angles to the axis of a magnetic needle, by using several shorter wires, we can wind one on each inch of the length of the bar to be magnetized, so that the magnetism of each inch will be developed, by a separate wire; in this way the action of each particular coil becomes very nearly at right angles to the axis of the bar, and consequently, the effect is the greatest possible. This principle is of much greater importance when large bars are used. The advantage of a greater conducting power from using several wires might in a less degree be obtained by substituting for them one large wire of equal sectional area, but in this case the obliquity of the spiral would be much greater and consequently the magnetic action less; besides this, the effect appears to depend in some degree on the number of turns which is much increased by using a number of small wires.

Joseph Henry was born December 17, 1797, in Albany, N. Y., and died in Washington, D. C., May 13, 1878. His instincts were decidedly scientific, and he studied chemistry, anatomy and physiology with the idea of becoming a physician. At the age of 27 he began to publish researches in chemistry and mechanics, and the next year he was appointed assistant engineer to survey a route for a state road from the Hudson River to Lake Erie. This experience inclined him to become a civil engineer. But in 1826 he was elected professor of mathematics and natural philosophy at Albany Institute, and from that time he devoted himself to research on "electricity and galvanism," or static and dynamic electric phenomena. His discoveries supplement those of Faraday in the history of the development of our knowledge of electricity. His interests were still broad in the field of science, however, for in 1844 he was studying cohesion in solids and liquids with soap bubbles and ice, and the next year he was measuring the difference in radiation from sun-spots and the general surface of the sun. In 1835 the Congress of the United States had been startled to discover that it was the trustee of a considerable fortune left by James Smithson, a disgruntled English chemist, to found in the promising New World "an institution for the increase and diffusion of knowledge." In 1846 the Smithsonian Institution was organized, and Joseph Henry was elected its first Secretary and director. As part of the work of the Institution he initiated weather forecasts based on telegraphic news of meteorological conditions throughout the country. He was also actively interested in the American lighthouse system. He was elected president of the National Academy of Sciences annually from 1868 until his death ten years later.