RADIO MAGIC

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The Road to Radio — Part 7

Introduction

We take a quantum leap back across the Atlantic from Albany, New York, to London, England — still in the early 1830s. As noted in Part 6 (see Nov-Dec 2025 *TCA*), Joseph Henry and Philip Ten Eyck knew of William Sturgeon's simple electromagnet design, as did Michael Faraday in London, along with his colleague and friend Gerard "Gerrit" Moll in Utrecht, The Netherlands. Moll likely learned about the various Henry-Ten Eyck electromagnet designs and experiments through Silliman's American Journal of Science and Arts or personal correspondence. Either way, he kept Faraday informed. Moll is a polymath genius: a mathematician, astronomer and physicist who speaks and publishes in four languages — Dutch, German, French and English. His multilingual fluency was not merely a scholarly show-off; it was a strategic tool Moll used to disseminate scientific knowledge across international borders and oceans.

The Geometry of Magnetic Influence

By the 1830s, experiments and mathematics showed that an electric current produced a magnetic "influence," “effect,” or “action” — as it was described at the time — around conductors. This influence takes the form of a circular geometry — clockwise or counterclockwise, depending on current polarity — oriented orthogonally (at 90 degrees) to the current. But it is static and does not physically rotate around the conductor.

Arrows in diagrams, even today, represent only spatial orientation, not physical motion. Around straight wires, the magnetic influence forms concentric circles **(Figure 1A)**.

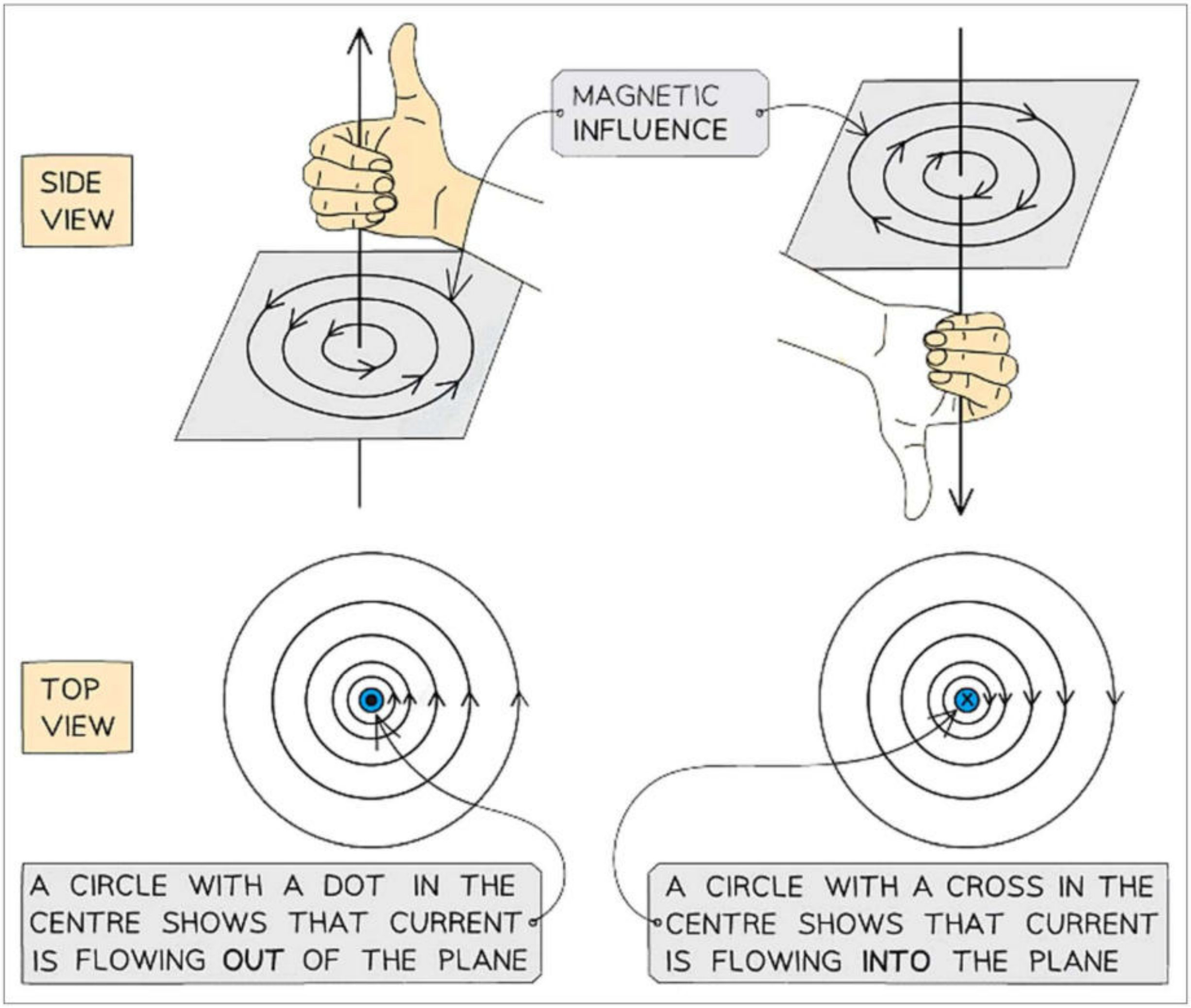


Figure 1A: Magnetic Influence Around a Straight Wire — The right-hand rule determines the orientation of the magnetic field around a conductor. Credit: https://edurev.in.

When current flows through coils or solenoids, it forms magnetic dipoles with closed loops extending between the north and south poles, effectively creating a temporary bar magnet — an electromagnet **(Figure 1B)**.

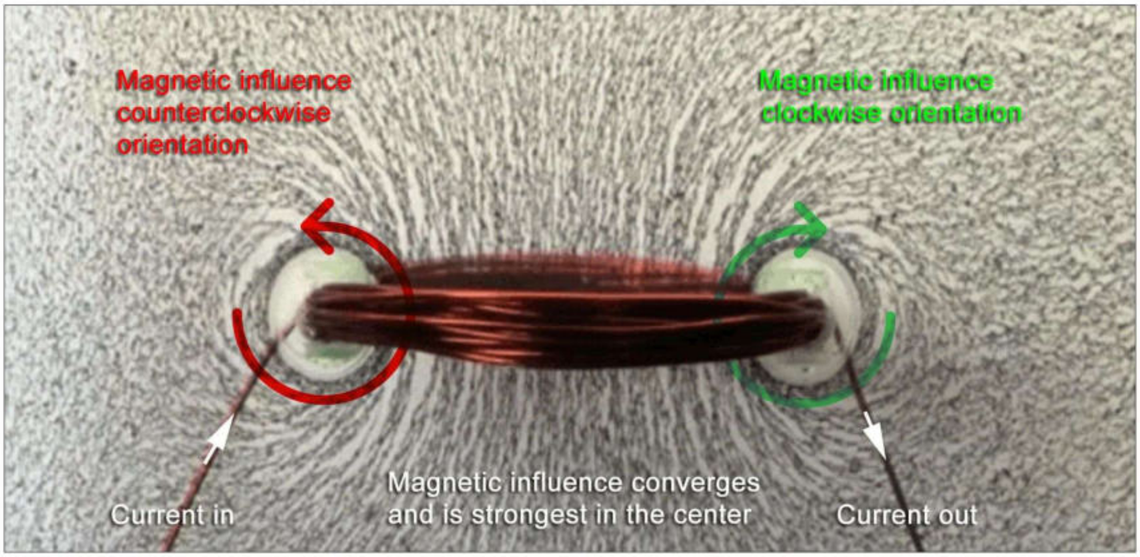


Figure 1B: Magnetic Influence Around a Coiled Wire — Cardstock and iron filings make the invisible force of electromagnetism visible. Credit: www.funscience.in.

Note 1: Faraday and his contemporaries used loose terms such as influence, effect, or action to describe the phenomena observed around current-carrying conductors. They reflected the observed reality of experiments: something was undeniably happening, but its true nature remained mysterious and unexplained.

The Discovery of Electromagnetic Induction

We have arrived — less jarringly this time — at 21 Albemarle Street, London, home of the Royal Institution. It is late summer 1831. Michael Faraday works alone, in secret, in his basement laboratory. He shares nothing of his intentions with anyone — not his wife, Sarah or even Moll. A tantalizing idea drives him, based on the wave theory of light: electricity and magnetic influence may also create waves, vibrations, or disturbances in the ether. Perhaps this could unlock the long-sought-after reciprocal effect, inducing a steady electric current from magnetism.

Throughout the 1820s, many attempts were made, but all failed to produce "magnetoelectricity." Faraday himself made two unsuccessful efforts. By 1830, the search for this reciprocity seemed to lead down a cul-de-sac. Faraday still thought otherwise.

Despite his demanding schedule as a full-time electrochemist and Chair of Chemistry, he found time to teach himself experimental physics. But his admitted Achilles' heel was complex mathematics. But his carefully dated, numbered note-taking and amazing observational skills more than compensated. He was the “Sherlock Holmes” of experimental physics and has no equal (and probably never will). He did not jump to conclusions; he did not believe what others said until he had confirmed it himself. He repeated his experiments, and those of others, many times over, testing every possible variation he could think of.

In doing so, Faraday deduced that a closed ring of soft iron would confine magnetic influence internally and shield it from external magnetic influence (interference) — unlike straight or horseshoe open-ended designs. This property is now known as “self-shielding.” His design is the prototype for all transformers. Okay, he has left for the day, but his laboratory journal is open on the bench. Only the most important of the 19 notes, recorded in their original point form of experiments and observations, are listed below **(Figures 2A to 2B)**.

<u>August 29, 1831</u>

1. Experiments on the production of Electricity from Magnetism, etc. etc.
2. Have had an iron ring made (soft iron), iron round and 7/8 inches thick and ring 6 inches in external diameter. Wound many coils of copper wire round one half, the coils being separated by twine and calico — there were 3 lengths of wire each about 24 feet long and they could be connected as one length or used as separate lengths. Each was insulated from the other. Will call this side of the ring A.
3. On the other side but separated by an interval was wound wire in two pieces together amounting to about 60 feet in length, the direction being as with the former coils; this side call B.
4. Made the coils on B side one coil and connected its extremities to a magnetic needle. Then connected the ends of one of the coils on A side with battery; immediately a sensible effect on needle. It oscillated and settled back in original position. On breaking connection of A side with battery again a disturbance of the needle.

5. Made all the coils on A side one coil and sent current from battery through the whole. Effect on needle much stronger than before.
6. This effect is transient, and does not persist during the continued passage of the current. It appears to arise only at the moment of establishing or interrupting the battery connection. The recurrence of the disturbance upon breaking the circuit suggests that the wire on side B is influenced not by a permanent state, but by a change occurring in the wire on side A.
7. The direction of the needle, when the battery is first connected, is such as would be produced if the wire on side B were itself connected to the battery and the current flowed in the same direction as in side A. But when the battery is disconnected, the motion is reversed, as though a contrary current were momentarily present.
8. From these observations, I am led to conclude that the wire on side B is affected by a species of electrical wave or transient influence, occasioned by the sudden establishment or cessation of the current in side A.
9. The phenomena do not appear to be due to the mere presence of magnetism. Rather, the influence seems to arise from the motion or change of the electric current itself.

Figure 2A: Faraday's Induction Ring — The nearly two-hundred-year-old Faraday proto-transformer was painstakingly hand-wound. Credit: Royal Institution of London.

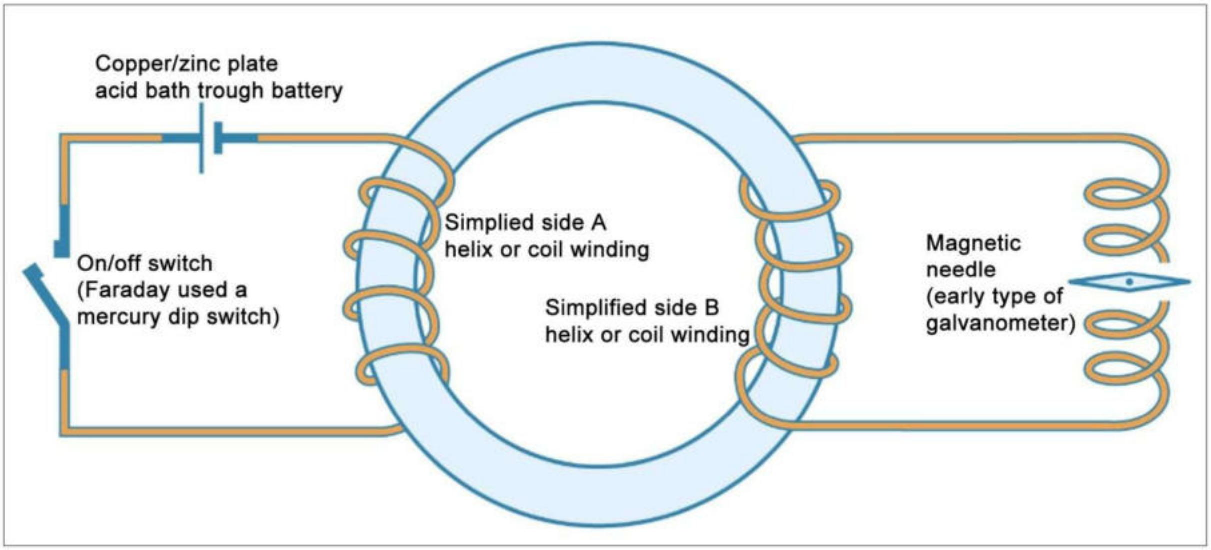


Figure 2B: Faraday's Induction Experiment (Using Electric Current) — Faraday called this method "voltaic-electric induction." Credit: www.britannica.com.

He had done it. But he was also puzzled because he expected sustained needle deflection — evidence of magnetic waves inducing a steady electric current. Instead, he observed only transient needle deflections when he connected and disconnected the circuit. He digs deeper. His next series of experiments reduces the problem to its simplest form (Occam's Razor). First, he removes the soft iron ring. The result? The magnetic influence is still detected, though needle deflections are weaker.

He suddenly realizes that the A side of his soft-iron ring is simply a small electromagnet — a temporary bar magnet. In one stroke of the Razor, he takes a bar magnet and moves it in and out of a coil of wire connected to a galvanometer. The induced electric current swings back and forth between positive and negative **(Figure 2C)**. But of what use is this "alternating current" in 1831? Not very. Mr. Faraday will leave it to others to solve that "problem."

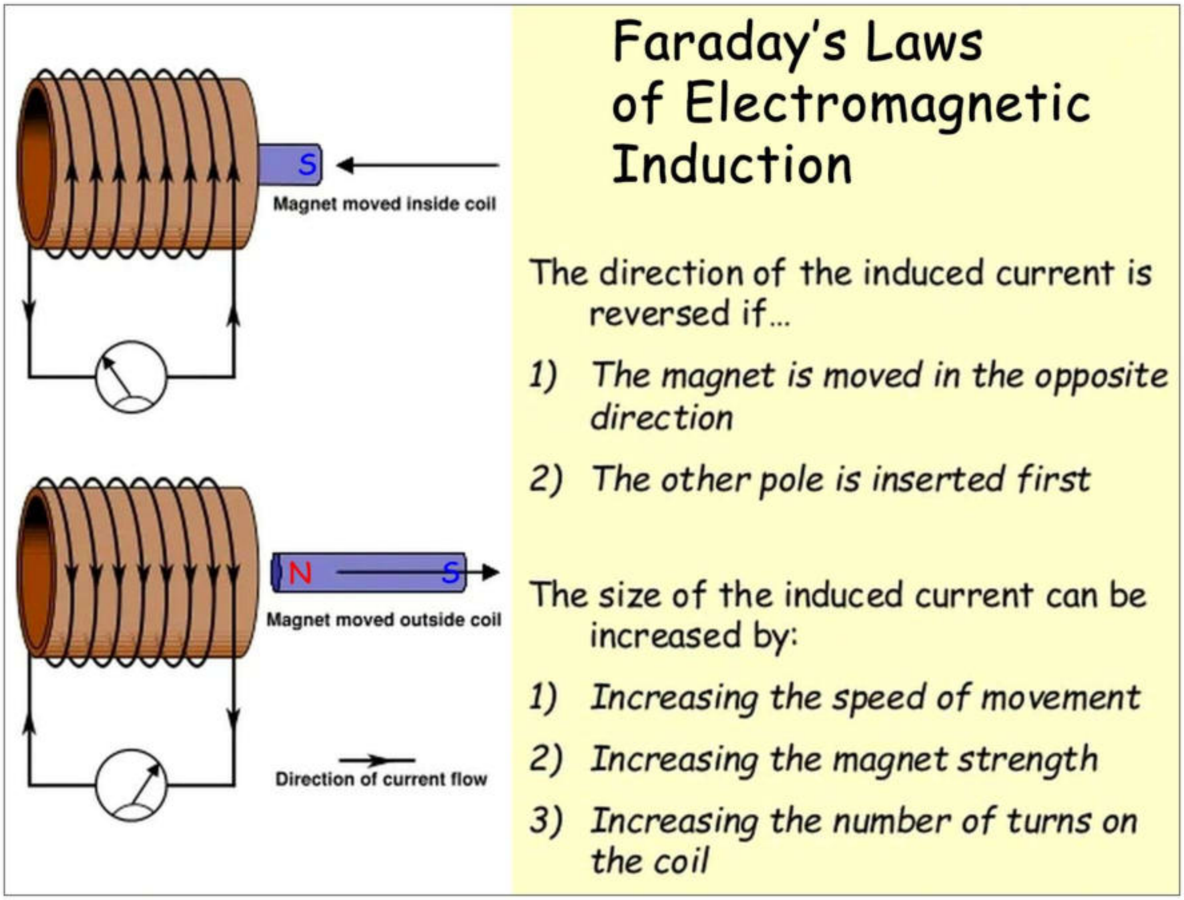


Figure 2C: Faraday's Induction Experiment (Using Magnetism) — Faraday called this method "magneto-electric induction." Credit: Katalin Molnar, 2014 (Slideserve.com).

Note 3: Faraday increasingly preferred the generic term "electricity" over galvanism and "voltaic" over galvanic. Standardized terminology and units of measurement in physics were still in flux. The "magnetic needle" referred to is an early form of galvanometer — essentially a modified compass with coils of wire wound around it. It could indicate the presence of electric current only through relative needle deflections, because no calibrated scale or units of measurement existed.

Announcement and Acclaim

He formally announced and demonstrated his discovery of electromagnetic induction during the Royal Institution's weekly meeting on Friday, November 25, 1831, before a very astonished membership. The worldwide academic community learned of it in early 1832 through the *Philosophical Transactions of the Royal Society of London* and the *Journal of the Royal Institution of Great Britain*.

In Faraday's concluding paragraphs, this sentence caught Joseph Henry's eye back in Albany: "As all the effects can be produced by ferruginous electro-magnets, there is no doubt that arrangements like the magnets of Professors Moll, Henry and Ten Eyke, and others, in which as many as two thousand pounds have been lifted, may be used for these experiments."

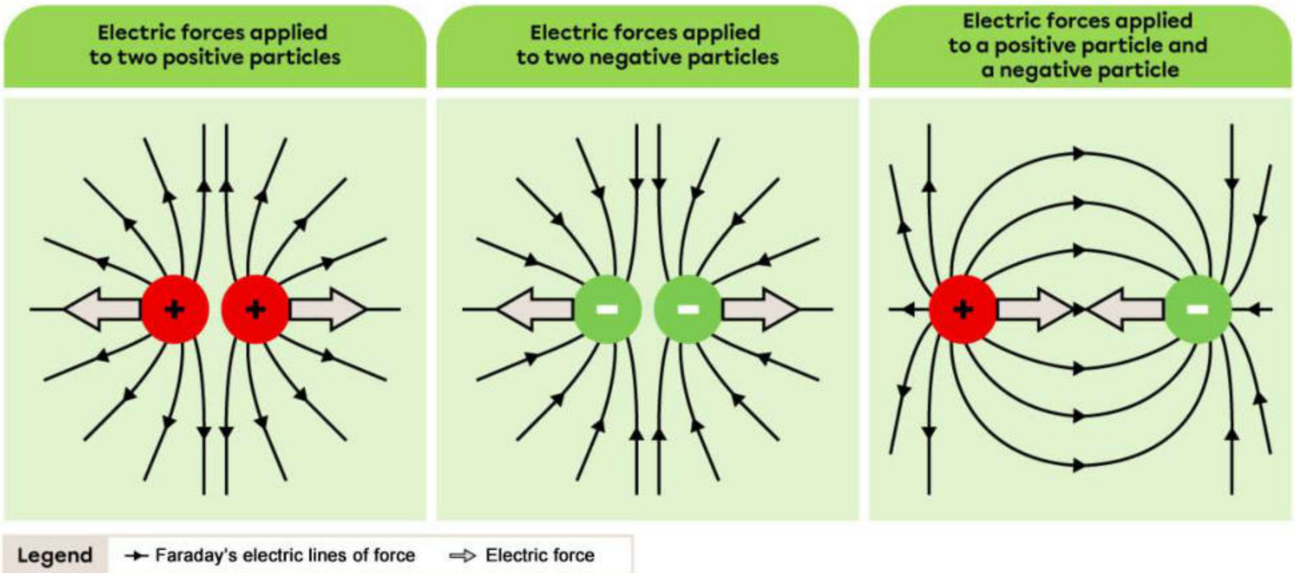
It was a real shock to him because Faraday clearly knew of his and Ten Eyck's work, while they knew nothing of his. But it also jolted Henry into realizing that Faraday's induction explained the sparks produced by his long-wire "intensity" electromagnet telegraph circuit whenever it was rapidly keyed on and off (Part 6 refers).

Faraday's Lines of Force

In *Experimental Researches in Electricity, Series 1* (1832), Faraday introduced his bold concept of "lines of force" along which electric and magnetic forces act. Faraday's lines of force radiated from positive electric charges and from magnetic poles, becoming denser where their influence was stronger, and diverging or converging as the case may be **(Figures 3A and 3B)**. In his view, this fully explained electromagnetic induction: changing magnetic lines of force could induce electric lines of force, and vice versa. However, he could only demonstrate this experimentally — not mathematically model it — nor could anyone else. As a result, the classically trained, hardcore calculus Newtonian physicists dismissed his "lines of force" as speculation, conjecture, metaphysics — even mysticism.

Note 4: Initially, Faraday omitted negative electric charges because they were much harder to conceptualize — electric lines of (negative) force radiating inward, seemingly from nowhere. However, as his theory matured, he unified both charges in one simple, stunning statement: "All lines of electric force begin at positive charges and end at negative charges, thus forming complete, continuous lines."

Figure 3A: Electric Lines of Force — Lines of electric force begin on positive charges and terminate on negative charges. Between like charges, they diverge because of repulsion, and between unlike charges, they converge because of attraction. Credit: www.alloprof.qc.ca.



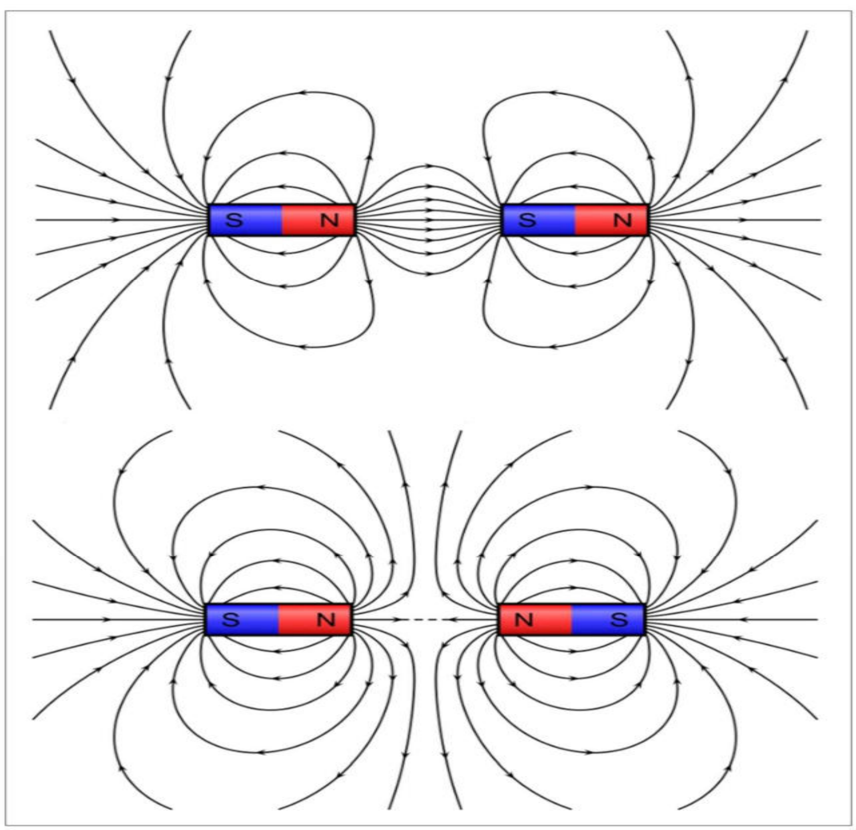
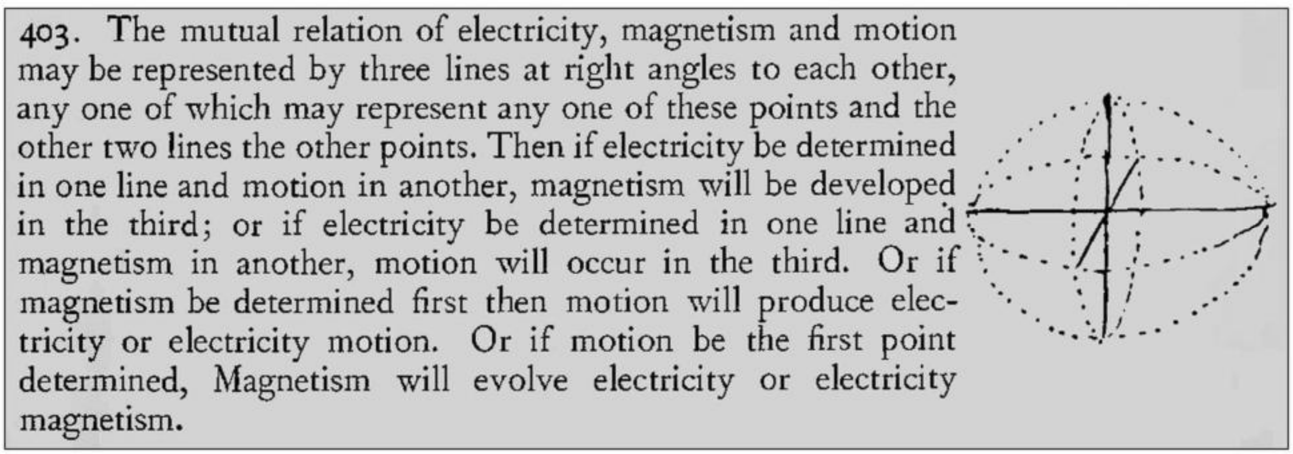


Figure 3B: Magnetic Lines of Force — Magnetic lines of force always form continuous closed loops — some closing directly from pole to pole, others extending far outward before eventually curving back to complete the circuit through the magnet. Credit: Conceptual Physics, https://tinyurl.com/4cxsmucd.

Faraday and André-Marie Ampère debated the nature of electromagnetism in private letters. While he could not doubt Ampère's elegant equations (admitting they were beyond his comprehension), he rejected their implied "(instantaneous) action at a distance," instead proposing that the physical effects of electric and magnetic forces propagate through the ether by a contiguous interaction. This interaction is not instantaneous and therefore imposes a speed limit on electromagnetism (he was unsure about the force of gravity).

Faraday also posited that electric and magnetic lines of force were not confined to linear attraction or repulsion. They could also form continuous curves in space (the ether), bend, interact, and transmit physical effects. This was sheer scientific heresy to the Newtonians **(Figure 4)**.



403. The mutual relation of electricity, magnetism and motion may be represented by three lines at right angles to each other, any one of which may represent any one of these points and the other two lines the other points. Then if electricity be determined in one line and motion in another, magnetism will be developed in the third; or if electricity be determined in one line and magnetism in another, motion will occur in the third. Or if magnetism be determined first then motion will produce electricity or electricity motion. Or if motion be the first point determined, Magnetism will evolve electricity or electricity magnetism.

Figure 4: Mutual Relation of Electricity, Magnetism and Motion — The genesis of Faraday's lines of force; journal entry 402, March 26, 1832. His geometric orthogonal force theory of electromagnetism was nothing short of mind-blowing. Credit: *Experimental Researches in Electricity, Series I*, Michael Faraday, 1832.

My Final

We will remain cloaked and parked in front of the Royal Institution building as we shimmer into the mid-1850s. As the years swirl around our Humvee's static time bubble, here are Mr. Faraday's major discoveries relevant to our road trip:

- **1836:** The Faraday cage — showing how conductive enclosures prevent external electric lines of force from penetrating and confine internal ones within (he lined a room with metal foil). We use many Faraday cage-like products (even woven fabrics) for data protection, electromagnetic pulse shielding, secure communications, forensic isolation, and health concerns.
- **1845**: The Faraday effect (now Faraday rotation) — demonstrating how magnetic lines of force can influence the polarization of light. In journal entry 19,954, dated September 13, 1845, he excitedly scribbled, "I have at last succeeded in illuminating a magnetic curve or line of force and in magnetizing a ray of light!" It was pure shock and awe. Newtonian physicists struggled to grasp its significance because they could not mathematically explain the unexplainable. To his contemporaries, Faraday seemed like a man from another planet — or another time.

His inquisitive genius and fearless, unstoppable drive have taken him deep and alone into *terra incognita*, where "Here be dragons!" He will need to find a dragon-slayer. — 73

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