Pioneers

3. André Marie Ampère (1775-1836), father of electrodynamics.

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Execution by guillotine is a grisly death. For an 18-year old to have his dear father die in that way is a profound psychological shock. Ampère's father died on the guillotine during the French Revolution on 22nd November 1793. Grief stricken, the man whose name we now remember on every plug, socket and fuse became a recluse for almost a year.

Though his life continued to be marred by tragedy and unhappiness, Ampère grew to become a respected mathematician and chemist, and an electrical physicist of world renown. Maxwell dubbed him the Newton of electricity.

Even if Ampère had died in the early months of 1820 he would still be honoured for his contributions to mathematics and chemistry. In France, for example, Avogadro's law is known as the Avogadro-Ampère law, Ampère having arrived at it just three years later. He was also narrowly beaten to the recognition of chlorine (1810) and iodine (1813) as elements, this time by Humphrey Davy. However it was his monumental work on electrodynamics from 1820 to 1827 which earned him a place in history. It was he who founded the subject and he who crafted the beauty of its structure.

André Marie Ampère was born in Lyons on 22nd January 1775. His father was a well-to-do merchant who moved his family out of the city soon after his son was born. Ampère grew up in a village. His home was his school. His education, provided and supervised by his father, seems to have consisted mainly of studying a large variety of books. In this way he discovered and developed interests in science, metaphysics, mathematics and poetry, even teaching himself Latin in order to read the mathematical works of Euler and Bernoulli.

Besides science and mathematics (and Latin!) Ampère also received a thorough grounding in the Roman Catholic faith. As with Oersted, his Christianity helped determine his view of nature. Throughout his life the teachings of Christianity and those of the 18th century philosophers, though not always mutually supportive, had great influence on him.

After the tragedy of his father's grotesque death, a year passed before Ampère began to rejoin the world, partly through a study of botany and by writing poetry. By the time he was 22 he had met the girl he was to marry, but had no skilled trade and only a small inheritance. Financial worries were never to be far away.

The couple married in 1799 and settled in Lyons, with Ampère earning a modest living by teaching mathematics. His first published paper, on the theory of games of chance, earned him a step up the academic ladder to the post of professor of physics and chemistry at Bourg, near Lyons, and more money.

Tragedy however struck again. After less than four years of very happy marriage his wife died. Plunged into grief and despair, Ampère left Lyons, with all its memories, for Paris.

There he made an unfortunate second marriage and was swindled by his new father-in-law. After a divorce he set up a new home in Paris with his mother and an aunt, where his two children, a son by his first wife and a daughter by his second, were raised. And there he conducted his immortal work.

Paris was now his home. He obtained a position at the renowned École Polytechnique, became a member of the Institut Imperial (1814), and in 1819 began teaching at the University of Paris. His contemporaries included Arago, Biot, Savart, Laplace and Poisson. It is said that he was the epitome of the absent-minded professor – even forgetting a dinner date with the Emperor Napoleon, so the story goes.

For the first time, an experiment on magnetism had been performed without a magnet...

For much of his life Ampère seems never to have been far from unhappiness, a stunning contrast to the public service he rendered. Late in life, it is said, he confessed that only a few years had brought him real happiness. He died alone in Marseilles on 10th June 1836, aged 61.

Oersted's epic discovery that an electric current produces magnetic effects was published on 21st July 1820 and it created a sensation. For many years there had been speculation that electricity and magnetism were somehow connected, yet Charles Coulomb some 30 years before had apparently proved beyond doubt that they were not. Oersted's news was conveyed by François Arago to an astonished meeting of the French Académie des Sciences on 4th September.

In the days and weeks that followed, Paris witnessed the spectacular birth of a new branch of science as Ampère dissected Oersted's discoveries and extended them. Others joined in, notably Arago, Jean Biot and Félix Savart in Paris, Johann Schweigger in Germany, and Davy in London.

But it was Ampère who became the major contributor to the new science of *electrodynamics*, the name which he gave to the newly-discovered phenomena. "It expresses their true character, that of being produced by electricity in motion", he wrote. The older type of electricity he named *electrostatics* – "phenomena produced by the unequal distribution of electricity at rest in the bodies in which they are observed" (1822).

As well as giving us these new words, Ampère carefully defined the terms electric current and electric tension (voltage), phrases which had until then been used very loosely. Ohm's Law, however, was still a few years away (1826-27).

After verifying Oersted's work Ampère expressed it as a law: if an observer had a current flowing from his feet to his head then a needle placed in front of him would have its north-seeking pole deflected to his left. Later this was re-expressed as the right-hand screw rule.

With electricity and magnetism now known to be related the question arose as to which of the two was the fundamental phenomenon.

To Ampère, electrical 'fluids' seemed more likely than magnetic 'fluids' as the fundamental cause, and so he formed an hypothesis that electric currents were the cause of magnetism. If that were true, then when an electric current caused a magnetic compass needle to move it could only be the

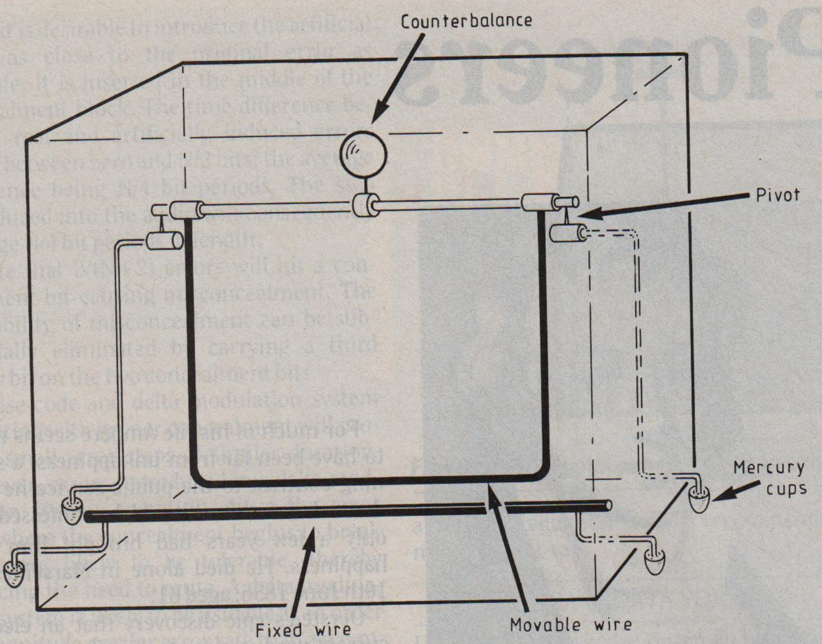

Fig 1: Ampère's experiment to show the magnetic effects of one (direct) electric current on another. The movable wire, hanging on pivots, would swing towards or away from the fixed wire when currents flowed. Connections to the wires were via cups of mercury.

result of electricity acting upon electricity. Therefore, he reasoned, two electric currents should interact via their magnetic effects. In a very clever experiment, suggested by Laplace, two parallel wires each carrying a current were shown to attract one another magnetically when the currents were in the same direction and repel when the currents were in opposite directions (Fig.1).

For the first time an experiment on magnetism had been performed without a magnet.

Ampère proved that these attractions and repulsions were not due to electrostatic phenomena. He described them as *voltaic* so as to emphasise the point. The name of Volta, the Italian inventor of the electric battery, was passing into electrical terminology.

Ampère also gave us the word *galvanometer*, an instrument he described as *"similar to a compass needle, which, in fact, differs from it only in the use that is made of it."*

He simply placed the conductor horizontally above or below the magnetic compass needle. The direction of movement of the needle indicated the direction of flow of the current through the conductor and the angle indicated the magnitude. He named the instrument after Galvani, the Italian usually credited with the discovery of the electric current. It was left to someone else to name its unit of measurement after Ampère himself.

With a little of what now might be called lateral thinking Ampère suggested another use for the galvanometer.

"By employing as many conducting wires and magnetized needles as there are letters, by fixing each letter on a different magnet ... we may form a sort of telegraph, by which we can write all the matters we may wish to transmit."

He also suggested a way of using a keyboard at the transmitter to make transmission easier.

Ampère's telegraph was never built and it is doubtful that his suggestion contributed to the electrical telegraphs which appeared a decade and a half later. But the galvanometer certainly did. When telegraphs did appear, codes were used to minimize the number of wires and needles needed.

Meanwhile in Germany, Schweigger had made a more sensitive galvanometer using a coil of wire of about 100 turns with a compass needle pivoted within it. Announced on 13th September 1820, it was this *multiplier* that became important in the early telegraphs.

Ampère also used coils of wire which he named *solenoids*. He and others showed that such coils could imitate all the effects of a magnet. These solenoids were developed into powerful electromagnets, notably by William Sturgeon in England and especially by Joseph Henry in America. By 1831 Henry had constructed a giant which could lift a ton.

Ampère now made a great conceptual leap.

A bar magnet itself could be explained, he suggested, by assuming the presence of circular electrical currents within it, running concentric to its axis. Such concentric currents might, he speculated, originate from contact between the molecules of the material. It was now only a short step for him to explain the Earth's magnetism as being caused by electric currents running from east to west.

However, Ampère's friend Augustin Fresnel, of wave theory of light fame, pointed out a serious flaw. Iron was not a very good electrical conductor and any such currents would produce a very noticeable heating effect in bar magnets. If Ampère was right, bar magnets should be warm, perhaps hot. And they are not.

Fresnel himself suggested a way out of the dilemma. Since nothing was known of the internal properties of molecules, why not assume circular currents within the molecules themselves? Ampère did. And he used this electrodynamic molecule in developing his mathematical theory of electrodynamics. The magnetism of a bar magnet was simply the sum of the magnetic effects of the molecular currents. Further, in materials such as iron, nickel and cobalt, the randomly-oriented molecular currents, which summed to give a zero effect, could be realigned by the action of other currents so as to produce a permanent magnet. In other non-magnetizable materials this realignment did not take place.

This theory was later considerably advanced by Wilhelm Weber and became the basis of his theory of electromagnetism. It is still basic to our understanding of magnetism.

Ampère pushed his electrodynamic molecule even further, suggesting that it was not only the source of electromagnetism but also of chemical combinations. He was suggesting a whole new theory of matter, but it had relatively few adherents.

It is of interest to note a comment of nearly a century and a half later. R.P. Feynmann, a renowned physicist discussing modern quantum electrodynamics in 1965 wrote: "In this one theory we have the basic rules of all ordinary phenomena except for gravitation and nuclear processes. For example, out of quantum electrodynamics come all known electrical, mechanical, and chemical laws."

Though he could not have foreseen quantum electrodynamics Ampère would have found the theory to his liking.

Ampère was without doubt the leading light of the period, performing many beautiful experiments and consolidating electrodynamics into a mathematical subject. In 1827 he published a synthesis of his work which became famous and is still the foundation of the mathematical theory of electrodynamics.

Later, his interests returned to a subject he had long held dear; the classification of the sciences. His last major publication was his own classification published in 1834, which he is said to have regarded as the capstone of his career. Today it is largely forgotten. The capstones that history awarded him are his work on electrodynamics and the naming after him of the unit of electric current. And, of course, the words he coined: electrodynamics, electrostatics, galvanometer, voltaic and solenoid.

Though his epitaph is "Happy, at last", a tribute by his son is more fitting: "He was never content with probabilities but always sought Truth."

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Next in this series of pioneers of electrical communication: Charles Wheatstone, developer of the electric telegraph.