Electricity: Crash Course History of Science #27

Crash Course: History of Science
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Like thermodynamics, the history of electrical physics has its roots in pre-industrial questions that converged in the nineteenth century.

These questions became a research paradigm, driven by a whole crew of researchers… And they led to a power system that reshaped the world. Time to get tingly! [Intro Music Plays] The study of electricity goes all the way back to antiquity.

Like, for a long time, people knew that lightning is the powerful release of energy caused when two clouds are in love and make a baby cloud. But that's hard to study. Much easier to study, however, was static electricity, or the electrical charge produced by stationary friction: it waits for you to pet your cat, and then shocks you!

But for centuries, natural philosophers didn't really have any good ideas about how to more deeply understand this phenomenon. For one, they had no concept of current, or electricity as a flow of electrical charge. Current can happen either by the movement of negatively charged subatomic particles called electrons through wires, or by the movement of charged molecules called ions.

And these people didn't know either of those things existed. Secondly, the relationship between electricity and magnetism, which are intimately linked, was a mystery. And, third, a lot of experimentation into these phenomenon basically amounted to weird parlor tricks that had no obvious uses.

English natural philosopher Francis Hauksbee, for example, found out in the early 1700s that spinning a glass globe produced electricity—thus creating one of the first electrical generators. Then, in 1729, two amateur scholars named Stephen Gray and Granville Wheler discovered that electricity could be communicated over long distances by contact. This was an important first step toward researching currents.

But mostly it was an excuse to conduct totally ethical scientific demonstrations… like suspending a young boy from the ceiling, charging him up, and then watching him attract objects with different body parts. And we can't forget statesman, encyclopedist, and infamous know-it-all Ben Franklin. He witnessed one of these flying-boy demonstrations in Boston, then went home to Philadelphia and waited for a thunderstorm.

As the story goes, in 1752, he flew his kite in a storm and succeeded in "drawing off" electrical fire. Inspired by this incident, he developed the lightning rod. But no real epistemic knowledge.

One of the first modern electrical physicists was Italian physician Luigi Galvani. In the late 1700s, his assistant accidentally caused a frog's leg to twitch with a spark from a nearby electrostatic generator. Inspired by this chance observation, he conducted many freaky experiments with frogs.

After much frog-shocking, he theorized the existence of animal electricity, or the electrical basis of nerve impulses. That inspired one young woman who was remarkably well informed about contemporary science: in 1818, Mary Shelley published what would become a very famous book about a man zapped to life by a Galvani-esque Doctor Frankenstein. Galvani also inspired his colleague, Italian physicist and chemist Alessandro Volta, to push his work on nerves further.

And Volta became a rockstar of electrical physics when he created the first practical method of generating electricity—the first battery, known as the voltaic pile So Thought Bubble, let's make some sparks fly! Volta's battery evolved from humble origins. The first iterations were made of two different metals separated by a brine-soaked cloth or piece of cardboard.

But Volta kept improving the pile. In 1800, he stacked pairs of copper and zinc discs, again separated by briny cloth or cardboard. When he connected the top and bottom of the pile, it generated a steady electric current that could be carried by a wire.

Volta had created the first stable source of electrical current! This type of two-metal battery fulfilled the world's scant electrical needs throughout much of the First Industrial Revolution, until around 1870. But no one could really explain how it worked, in part because no one had brought electricity and magnetism together.

One of the first steps in this direction was taken in 1820 by Danish physicist and chemist Hans Christian Ørsted. While demonstrating to his students how to heat up a wire by running an electrical current through it, Ørsted noticed that his compass' needle kept jumping to a ninety-degree angle. Somehow, he realized, the electrical charge and the magnetic attraction of the compass were linked. Ørsted conducted further experiments and showed that electric currents actually produce neatly circular magnetic fields when they flow through wires.

This became known as Ørsted's law. Later in 1820, at the Academy of Science in Paris, physicist André-Marie Ampère watched as a friend reproduced Ørsted's electrically-messing-with-a-compass trick. Amazed, Ampère went to work figuring out the math behind this special relationship.

He showed that two parallel, electrified wires attract each other if the currents flow in the same direction, and repel if the currents flow in opposite directions. Thanks Thoughtbubble. Ampère also showed that the force between the currents was inversely proportional to the distance between them, and proportional to the intensity of the current flowing in each.

This became known as Ampère's law. You can watch a whole episode about that over at Crash

Course: Physics! And he even theorized that there must be some "electrodynamic molecule" that carried the currents of electricity and magnetism. This became the basis for the electron. Ampère's insights became the foundation of the quantitative science of electromagnetism, or "electrodynamics." In 1827, Germany physicist Georg Ohm —who'd been conducting research using Volta's battery—published his discovery that an electrical current between two points is directly proportional to the voltage, or potential difference, between them. This became known as Ohm's law. This can be expressed using the concept of resistance, or the difficulty of passing an electric current through that conductor, in a really simple equation: "I = V/R." Current, measured in amperes, is equal to voltage, measured in volts, divided by resistance, measured in ohms.

Yep: all three scientists became standard units. Congrats, scientists! They say, in Physics the greatest honor is when your name starts to be spelled with a lower case letter. With practical batteries and basic scientific laws, the stage was set for electricity to become an industry—enter motors and lights.

Born to a poor family in Newington Butts, London, Michael Faraday became obsessed with electricity and chemistry at a young age. Eventually, he became as important to the sciences of stuff as Darwin was to those of life. In 1821—a year after Ørsted characterized electromagnetism and Ampère began experimenting with the math behind it—Faraday got to work inventing electromagnetic motors. His motors worked due to "electromagnetic rotation," a motion made by the circular magnetic force around an electrified wire. In 1831, he had his big breakthrough—electromagnetic induction, meaning the generation of electricity in one wire via the changing magnetic field created by the

current in another wire. This became the basis of the electromagnetic technologies that we use today. So… thanks, Mike!

In the same year, Faraday also discovered magneto-electric induction, which is the generation of a steady, direct electrical current in a wire by attaching it to a copper disc, and then rotating the disc between the poles of a magnet. This was the first modern electrical generator! And he proved that the electricity created by magnetic induction, the electricity produced by a voltaic battery, and good ole static electricity were all the same phenomenon. Faraday's experiments led to the invention of modern electrical motors, generators, and transformers. He figured out how to make electricity do work on magnetism and vice versa.

And his young buddy, Scottish physicist James Clerk Maxwell, played the Ampère to his Volta, figuring out the math involved in induction. In 1855, Maxwell dropped "On Faraday's lines of force," showing Faraday's discoveries about electricity and magnetism in the forms of differential equations. Maxwell's long paper, "On Physical Lines of Force," introduced his full theory of electromagnetism in parts over 1861 and '62. Here, he theorized that electromagnetic waves travel at the speed of light, and that light must exist in the same medium as electrical and magnetic energy. By connecting light, electricity, and magnetism, Maxwell laid the groundwork for modern physics. And his work was a major influence on Einstein.

But the average person in the 1870s didn't know who Faraday and Maxwell were, much less that they had revolutionized energy and work. There was still no system for using electricity industrially. For that useful system, we have to hop across the Atlantic to the first home of corporate research and development in science—Menlo Park, New Jersey. Here, a mix of brilliant engineers, scarcely trained boys, and one pet bear (yes!) worked under the direction of a controversial inventor— who was or was decidedly not much of a scientist himself, depending on which historian you prefer.

His name was Thomas Edison. Edison, or the "Wizard of Menlo Park," or the "Napoleon of Science," started his career as a lowly telegraph operator at the age of sixteen. He worked his way up, improving telegraph systems, until he could open his own contract-based-lab-slash-workshop in 1876. Mostly, people remember Edison for his work on making practical incandescent light bulbs, but he should really be thought of as the person who first saw the potential for an entire electrical grid. This included the generation of power, its distribution to homes and businesses, and the invention of useful products that required electricity to work. In the late 1870s, people didn't understand or see the need for electricity. Customers had to be created. So what did Edison do? Befriended the richest guy in New York, who was also the richest guy in the world—J. P. Morgan.

With Morgan's money, Edison had the resources to work out the longest-lasting filament, or slender, heated-up-until-visibly-lighted bit, for his bulbs. This ended up being made of carbon, after thousands of experiments on different materials. But he also had the resources to show off his lights in Paris and London. And, most importantly, to electrify downtown Manhattan. Think about it for a second: the night before 1880 was dark. Yes, gas lamps existed, but they were weak, smelly, and dangerous.

Edison's electrification of the cultural and financial capital of an ascendant American empire was… blindingly amazing. People stayed up longer. More work got done. The feedback loop of just pushing off bedtime by a few hours was enormous—and this was before anyone had devised a good mass-scale electrical motor or vehicle.

It's true that Edison didn't invent the components of his electrical power system, only improved upon them, thanks to his team-based, finance-backed approach to science and technology. And it's true that he became embroiled in an intense public battle called the Current War, over the safety and efficiency of his direct current, or DC, versus his rival Westinghouse's much more practical alternating current, or AC. Aaaaand it's true that Edison promoted capital punishment in New York, using an electric chair powered by Westinghouse's AC. But—beginning with incandescent light—Edison and other inventors used the discoveries of the early electrical physicists to utterly transform the world. Next time—we'll follow Edison, tracing the effects of corporate research and mega-scale engineering through many fields during the Second Industrial Revolution. It's time to go big or go bigger!

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