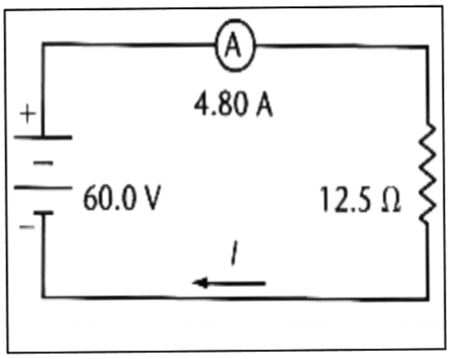
Stories of Science: Electrons; the corpuscles of J.J. Thomson's achievement.

The story about how current changed direction.

Benjamin Franklin was fascinated by charges; who isn't? Franklin knew that rubbing two carefully selected materials together could produce a somewhat attractive force between them and, if brought close enough together this force would discharge into a spark between the objects. There were no batteries at this time and Franklin did not have the fundamental understanding of how this came about and had to surmise that a transfer of a kind of 'electric fluid' was responsible for creating this force. Franklin imagined that there must be a plentiful supply of this fluid on one object and a deficit on the other, which directed its movement. He termed objects with 'plenty' of the fluid 'positive', and those with a deficit as 'negative'. Pioneering these new ideas, Franklin initiated 150 years of the understanding of what is now referred to as the 'conventional' current.

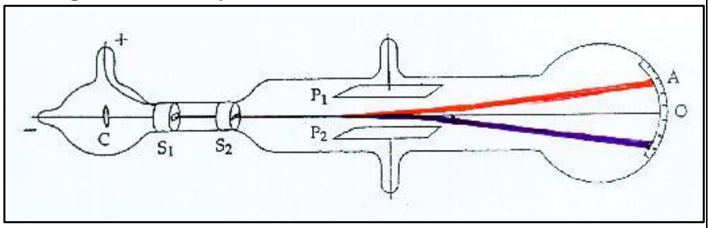


Cathode Ray Tubes

A cathode ray tube (See also 'Crookes' tubes'.) is a vessel of significantly low-pressure gas containing two electrodes, one positive and one negative, across which a large potential difference is applied. Following an electrical discharge from the electrodes, glowing streams of light can be observed between them. These streams of light were referred to as cathode rays, noting that they left the cathode (negative electrode) and travelled towards the anode. At the time, many German physicists suggested that the nature of these cathode rays was an occurrence in the ether and thought that this weightless substance pervaded all space.

Joseph John Thomson

Born in Manchester, 1856, J. J. Thomson was destined for a career in engineering. But, after the death of his father, fate found him a place at Trinity College, Cambridge. Despite being a young graduate in Mathematics, Thomson was controversially elected to replace Lord Rayleigh as Cavendish chair just four years after he began working under him in the department of physics. Thomson began to experiment with discharging electricity through gases at low pressure using cathode ray tubes.



The race against Hertz?

The 'occurrence in the ether' nature of cathode rays was supported by Heinrich Hertz' demonstration that these beams could penetrate thin foils, and this behaviour was akin to light through glass. Hertz also determined through experimentation that electric fields could not deflect this 'ether', conluding that it was not of a charged property. Thomson discovered that at too high a pressure, the as charged gas ions would neutralise the electric field that Hertz had been using to try to deflect the rays. Thomson reduced the pressure of the gas in the vessel and showed that the beams were in fact deflected by an electric field. A scale placed at the bulbous end of the vessel allowed for measurements of the deflection; the red, upper line in the diagram (above) denotes the path taken by the cathode rays when P1 is a positive charged plate. Thomson proved that negative charges were being fired from the cathode. Furthermore, applying Faraday's earlier experiments, Thomson showed that a magnetic field, applied perpendicular to both the electric field and the cathode rays, could also deflect the beam. This observation further supported the theory that negative charges were flowing along the beam.

The discovery of the electron and the plum pudding model

Thomson's claim to this discovery is based on two contributing factors: Firstly, his ability to distinguish this newly observed particle as having fundamentally different properties to known matter. Thomson measured the charge-mass ratio of this particle to be 1000 times smaller than the smallest known particle, hydrogen, using his measurements of deflection due to a measured force. Secondly, Thomson defined his newly termed particle, the 'corpuscle', as being a universal constituent of matter. He achieved this by showing that his measurements were independent of the gas used, and the metal forming the electrons. Thomson's corpuscles, electrons, were fundamental. This new understanding of fundamental matter led Thomson to suggest a plum pudding model for the atom, trying to consolidate the known properties of negative electrons, and neutral atoms. Thomson's student, Ernest Rutherford, explored further.

Comprehension and Reflection Questions

1. Describe the thought process that caused Franklin to describe current as the flow of positive charge.

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2. Explain why we still use the idea of conventional current today despite Thomson's discovery.

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3. Suggest why physicists thought cathode rays were probably waves, rather than particles.

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4. Suggest why Thomson's success relied on work by Faraday.

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5. Produce a balanced argument for the following claim, referring to evidence given in Thomson's story: 'Scientific discoveries result as a culmination of expertise and experiments.

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Extension Activities	Further Reading
Ideas for things to do next: Find out how Milikan's experiment was able to confirm the size of a fundamental charge. Research the link between Thomson and Rutherford and consider how successful discoveries in science are often a product of probing earlier work. Find out about the role of Cathode Ray Tubes in discoveries by other scientists such as Roentgen.	Ideas for things to read next: Nobel Lecture, December 11, 1906 https://web.lemoyne.edu/giunta/ea/THOMSONann.HTML for how the charge-mass ratio was determined.