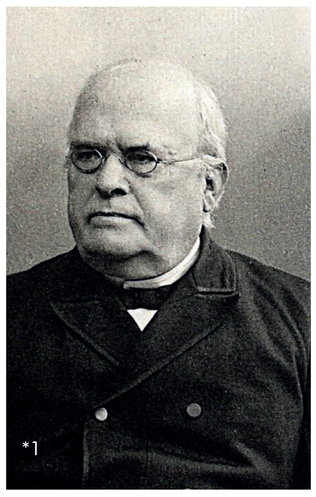
THE GAS DISCHARGE PHYSICS IN THE 19th CENTURY (PART II)

– by Julia Cipo, Holger Kersten –

Johann Wilhelm Hittorf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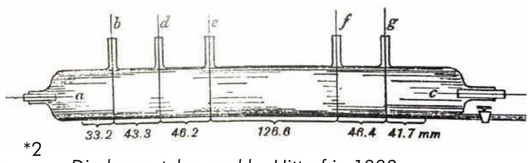
* March 17th, 1824 in Bonn, Germany
† November 28th, 1914 in Münster, Germany

Johann Wilhelm Hittorf was a german physicist, chemist and a student and assistant of Julius Plücker. He continued the work of Plücker and kept using the geissler tubes and the induction apparatus created by Heinrich Daniel Rühmkorff. As well as Faraday he used thinned gases, watching their glow discharges and the spectra of each element. He extended the geissler tube by adding potential probes with the purpose of studying the voltage flow. This way Hittorf could describe that "the glowing was a process, where a current transition between the gas particles and the ones in the cathode takes place". Then he studied the rays from the cathode to the anode, by calling them "the rays of the negative light" because of the current of negative charges. So 1869 Hittorf had discovered the cathode rays, even though Eugen Goldstein later named them this way. Hittorf also admitted the existence of "a positive light" referring to the ion conduction in electrolytes. His other work contained studying the properties of the cathode rays. So he discovered that the cathodic rays have a linear propagation direction and that they generate fluorescence appearances on the glass side, as well as they start to convolve helical around magnets.



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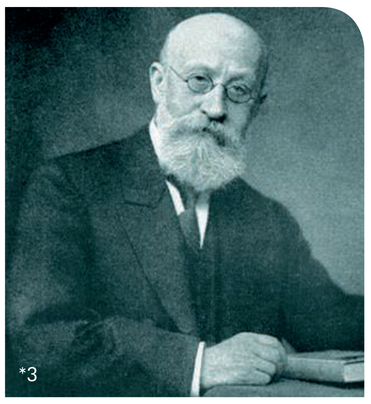
Discharge tube used by Hittorf in 1883

Gotthilf-Eugen Goldstein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* September 5th, 1850 in Gleiwitz, Poland
† December 25th, 1930 in Berlin, Germany

Gotthilf-Eugen Goldstein was a german physicist, known for his work on the electrical discharge phenomena and on the cathode rays. He also discovered the canal rays and was a student and friend of the physicist Hermann von Helmholtz, who encouraged him in this researches. After naming the "cathode rays" this way because of their source: the cathode, Goldstein focussed on studying the properties of them. So in 1876 he found out, that these rays were emitted perpendicular to the cathode surface. In 1886 he discovered the anode rays, which were generated by positively charged particles after the electrons were removed from the gas in the cathode ray tubes. The anode rays travel in the opposite direction to the cathode rays by covering the distance from the positive anode toward cathode. As they arrive the cathode, they pass through the channels in the cathode, so he called them "Canal rays" (germ. Kanalstrahlen). Right after the cathode they would cause discharge appearances, different from the fluorescence of the cathode rays. Since the "canal rays" had the opposite direction than the "cathode rays" Goldstein speculated, that these rays were carrying positive charged particles. About 15 years later the physicist Wilhelm Wien showed that these rays were an amount of positive ions from the gas. With his work Goldstein had open new ways for other physicists searching the atomic rays and the mass spectroscopy.


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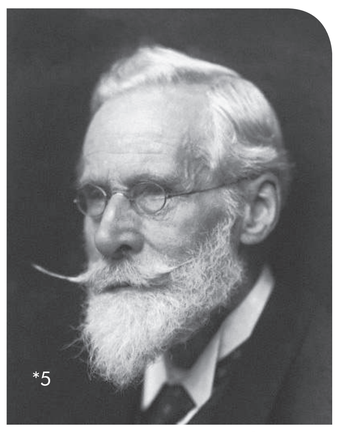
Canal rays observed in a discharge tube

Sir William Crookes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* June 17th, 1832 in London, England
† April 4th, 1919 in London, England

Sir William Crookes was an english physicist, chemist and member of the Royal Society. His extensive work on the cathode rays delivers new explanations for this phenomena. To achieve more exact results, he reduced the gas pressure in his glass tubes by reaching values of up to 10^{-8} atm, way lower than the pressure of about 10^{-3} atm in the geissler tubes. After he lowered the pressure he discovered a dark space next to the cathode, later called the "Crookes dark space" and fluorescence appearances on the glass wall after the anode. He speculated that his invisible matter of the cathode rays wouldn't collide with the gas molecules, but obtains its velocity and creates this way the dark space. The sight fluorescence was explained with a collision of the cathode rays with the glass atoms by exciting them. Crookes started designing tubes with new shapes for the glass vessels and for the anode. So he constructed the egg shaped tubes, the Y tubes, the tube with a maltese cross shaped anode and the mill tube, where he positioned a paddlewheel between the cathode and the anode. There he could see the rotation of the wheel because of the heating effect of the cathode rays. These tubes are nowadays called Crookes tubes. In 1879 he could prove with the maltese cross tube, that the cathode rays beam linear from the cathode to the anode, because of the sighted shadow on the glass wall after the anode. He predicted, that the cathode rays must be an amount of negative charged particles. By the later discovery of the electrons, his theory has been approved. After increasing the gas pressure he noticed a glowing discharge, which he explained with the existence of a "fourth state of matter".


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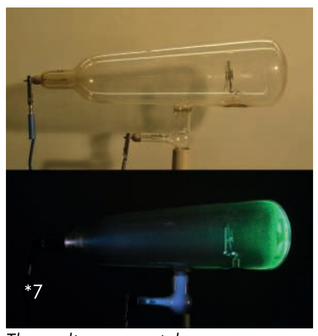
The Crookes´Y tube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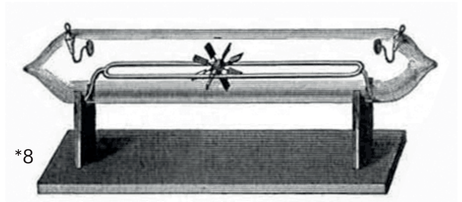
The maltese cross tube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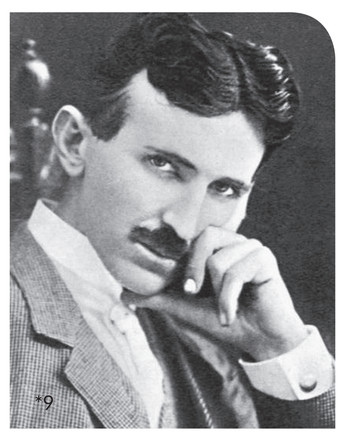
Crookes´paddlewheel tube in 1879

Nikola Tesla

* July 10th, 1856 in Smiljan, Croatia
† January 7th, 1943 in New York, USA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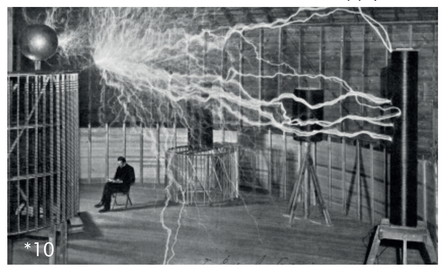
Nikola Tesla was a serbian-american inventor, electrical engineer and physicist. He was the first to invent an alternating current system, that replaced the weak direct current generators and motors. In the year 1891 he patented "Tesla coil", a high- frequency transformer, which could generate impressive large corona discharges around the high-voltage terminal. The purpose after this discovery was the wireless transmission of electrical energy. So he demonstrated a lot of experiments that confirmed his theory. During a lecture at the Columbia College he introduced his "Tesla coil" connected to two metal sheets, that were used as electrodes. With the coil he could apply high voltage and a high-frequency alternating current, which generated an oscillating electric field between the electrodes.The electric field ionized the gas inside of the geissler tubes he was holding in his hands and the gas inside of them started to glow. The principle of the "Tesla coil" was later applied for building the electrical inverter, which is now used for the supply of alternating current in cold cathode fluorescent lamps. Another use of the "Tesla coil" can can be found in the plasma balls or plasma globes, where the applied electric field causes the ionisation of the inert gas inside. The ionised gas propagates radially because of the electric field, that also propagates radially from the spherical electrode inside the globe to the outside electrode, represented by the environmental atmosphere.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Tesla in his laboratory in December 1899


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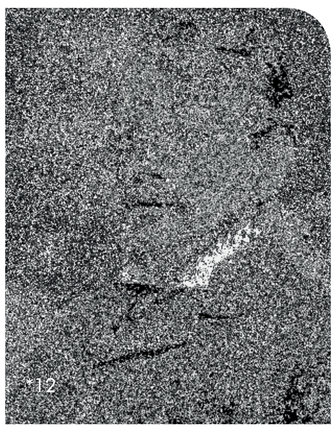
Plasma globe

Sir Joseph John Thomson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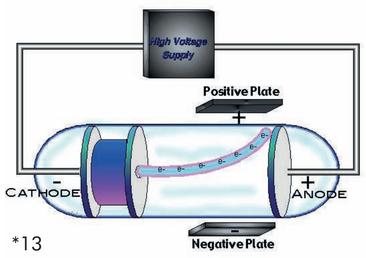
* December 18th, 1856 in Cheetham Hill, Manchester, England
† August 30th, 1940 in Cambridge, England

Sir Joseph John Thomson was an english physicist, president of the Royal Society, the teacher of Ernest Rutherford and winner of the Nobel Prize in physics in the year 1906. He succeeded in studying the nature of the cathode rays by conducting different experiments. Thomson was the first to recognize that all the cathode rays had the same origin. To prove this he used magnets, that caused a deflection of the cathode rays in the Crookes tubes. In 1897 he repeated the experiment with different anode materials and different gases, but the deflection remained the same. Then he placed additionally a metal cylinder on the end of the cathode ray tube. The cylinder had two small gaps leading to electromotors, that measured electric charges. After he applied a magnetic field across the tube, the ray had been deflected and so the electromotor did not record any electrical activity. He speculated that the rays and the negative charges were the same. Later Thomson observed the electrical deflection caused by an electric field between two additional metal plates. He got clear about the fact, that the cathode rays were charged particles or as he called them "corpuscles". To determine the mass-to-charge-ratio of these particles he equaled the magnetic deflection with the electrical one. He obtained that each of the particles had the same small mass, about ~ 1/2000 of the hydrogen atom. This way he had discovered the negative charged electrons.



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The deflection of cathode rays by a magnet

Karl Ferdinand Braun


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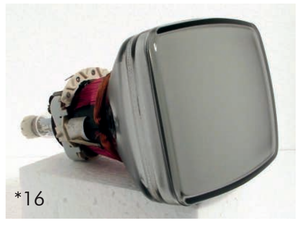
* June 6th, 1850 in Fulda, Germany
† April 20th, 1918 in New York, USA

Karl Ferdinand Braun was a german physicist, electrical engineer and winner of the Nobel Prize in physics in the year 1909. His famous and in the daily life usable invention was the "Braun tube" in the year 1897, a cathode ray tube (CRT) which can be found in the tube televisions. Braun used the Crookes Tubes, but implemented some modifications. He applied a filament/heater voltage on the cathode by creating a thermionic cathode instead of a cold one. Because of the thermionic emission the electrons could be accelerated in the direction of the anode. To guarantee a precise linear propagation direction of the electrons, Braun placed a negative charged toroidal Wehnelt-Cylinder right after the thermionic cathode. The geometry and the charge of this cylinder allowed a centrally focus of the electron beam, so that they pass the toroidal anode. After the anode Braun positioned parallel capacitors, connected to voltage generators. The cathode rays would be deflected precisely and at the end of the tube, they collide with a fluorescent matter, causing glow appearances on the screen. The "Braun tube" is used in the tube televisions, the oscilloscopes, the scanning electron microscopes and in more graphic measure techniques.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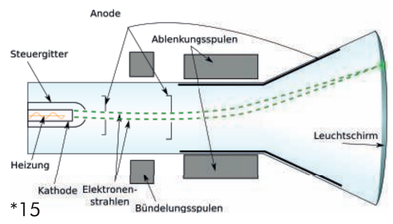
Prototype of a tube TV



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Braun discharge tube

Sources: 1- Zeitschrift für Physikalische Chemie (Journal of Physical Chemistry) Band 12, 1893, 2- "Gasentladungsforschung im 19. Jahrhundert", 2004 von Falk Müller, 3- Biografias y vidas- La Enciclopedia Biográfica en Linea, 4- Wikimedia, Work of K.Murray , 5- Portrait of Sir William Crookes by George Charles Beresford in 1906, 6- The Cathode Ray Tube site (crtsite.com) , 7- Emaze.com- Amazing Presentations, 8- "On radiant Matter" by William Crookes, Popular Science Monthly, London, November 1879 , 9- Focus Online, 10- Spiegel Online, 11- National Geographic Store, 12- Popular Science Monthly Volume 73, 1908 , 13- OpenStax CNX by the Rice University, U.S.A, 14- Nobelprize.org, 15- ph2.physik.uni-goettingen.de, 16- r-type.org