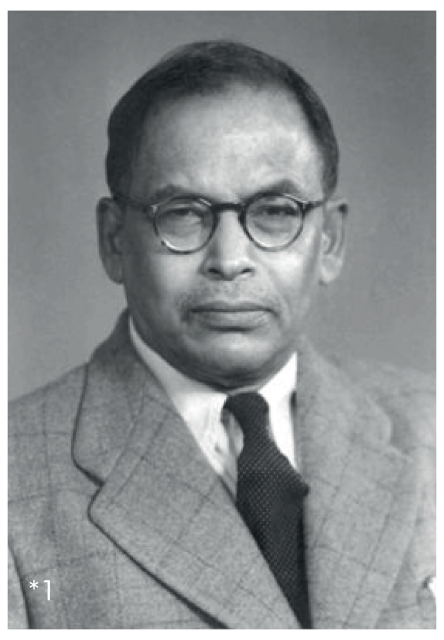
THE GAS DISCHARGE PHYSICS IN THE 20th CENTURY (PART II)

– by Julia Cipo, Holger Kersten –

Meghnad Saha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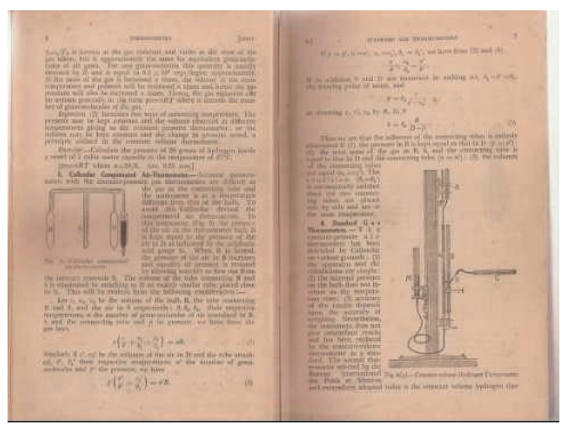
* 6th October, 1893 in Shaoratoli by Dhaka, British India (now Bangladesh)
† February 16th, 1965 in Delphi, India

Meghnad Saha was an Indian astrophysicist, politician, fellow of the Royal Society and a classmate of the famous physicist Satyendra Nath Bose. As described in 1931 in his book "Treatise on Heat", which was originally published under the title "A Text Book on Heat", he concentrated on the thermodynamics and on the connection of thermodynamics with radiation. But his greatest discovery "On Ionization in the Solar Chromosphere" was published in 1920 in the "Philosophical Magazine". There he presented "The Saha-Eggert Equation", a new formula which he developed based on the work of John Eggert. It shows the correlation between the temperature, the density and the ionisation energies of the charged particles in a plasma. This formula is used for determining the ionisation level of a gas. With it the occupation of diverse ionisation states can be calculated. By reference to his equation Saha could show the influence of the pressure on the degree of ionisation in the high-level chromosphere. The atoms of Calcium, Barium, Strontium and Scandium located in the chromosphere were almost totally ionised due to the low pressure in this region. Saha later became also interested in nuclear energy and helped building the first cyclotron in his country.


"A Text Book on Heat", 1931 *2

$$\frac{N_{el}\, N_i^{+}}{N_a} = 2\,\frac{Z_i(T)}{Za(T)}\,\frac{(2\pi m_{el} k_B)^{3/2}}{h^3} \cdot T^{3/2} \exp\left(-Ei/k_B T\right)$$

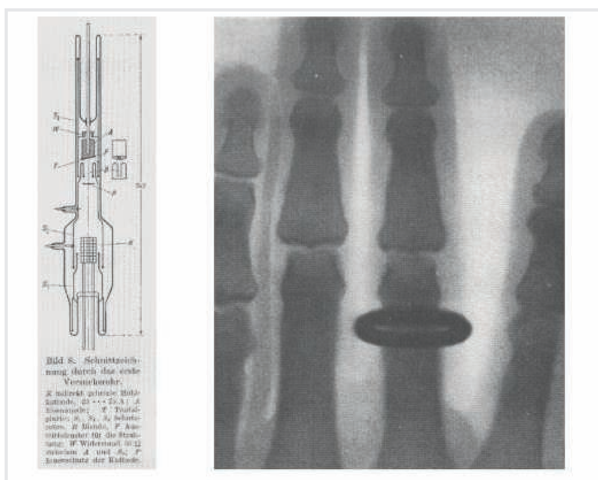
Saha-Eggert equation

Max Christoph Theodor Steenbeck


*3

* March 21st, 1904 in Kiel, Germany
† December 15th, 1981 in Berlin, Germany

Max Christoph Theodor Steenbeck was a german physicist, known for his researches in the gas discharge physics and a student of Hans Geiger. He later worked for the company "Siemens", where he constructed a device for the acceleration of the electrons called the "Betatron". After working for a long time with high-voltage rectifiers he invented in 1937 the x-ray flash tubes. These tubes consist of normal discharge tubes connected to a high-voltage charged capacitor. The discharge happens between the electrodes, where the high current flows from the cathode to the anode. The x-ray discharges here are not continuous, but they are portioned, which makes them very common in the veterinary for radiographing limbs. In his books "Elektrische Gasentladungen, ihre Physik und Technik" ("Electrical gas discharges, their physics and technique"), which he wrote in 1932/34 with his colleague Alfred von Engel and in the article "Der Plasmazustand der Gase" ("The plasma state of gases") from the year 1939 he describes the Minimum Principle. Through this principle he explained, that the states, created by current-controlled arc discharges require just a minimal voltage for their maintenance. In the late ´50s Steenbeck created in Jena, Germany the Institute for magnetohydrodynamics, where he developed some ideas of gaining energy by nuclear fusion processes of hydrogen.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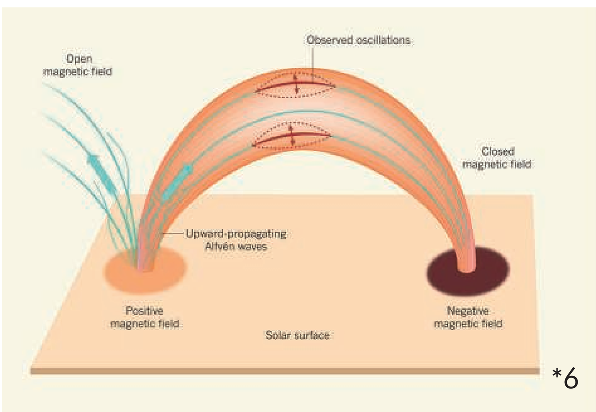
X-Ray flash tube and radiography of a hand

Hannes Olof Gösta Alfvén


*5

* May 30th, 1908 in Norrköping, Sweden
† April 2nd, 1995 in Djursholm, Sweden

Hannes Olof Gösta Alfvén was a swedish physicist, a colleague of Ernest Rutherford, professor and one of the most important persons in the plasma physics. He was a member of the Royal Swedish Academy, the European Physical Society and foreign member of the Yugoslav, U.S. and Soviet Academies of Sciences. "For fundamental work and discoveries in magneto-hydrodynamics with fruitful applications in different parts of plasma physics" he received the Nobel Prize in physics in the year 1970. In the year 1939 Alfvén published a paper presenting a theory about the formation of auroras and magnetic storms, which he extended in his famous book "Cosmical Electrodynamics" in 1950. There he describes how plasma flows around the magnetic dipole field of the Earth by generating electric currents. These currents play a tremendous role in the acceleration of auroral electrons by creating the glowing phenomena of auroras. In honour of his work the inner edge of the plasma sheet, which is in the source of the aurora, is called the "Alfvén layer". Alfvén also invented a more simpler calculation method for the spiral motion of charged particles in magnetic fields, calling it "the guiding-center approximation". For this he separated the motion of the particles into a gyration bias to the local magnetic field and a drift, called the center of the gyration. In the letter "Existence of electromagnetic-hydrodynamic waves" published in "Nature" in 1942 he presented his discovery of what is later known as the "Alfvén Waves". Alfvén investigated the sunspots and the derivation of their magnetic fields from electrical currents in the solar plasma. These electrical currents and magnetic fields lead to forces, that affect the motion of the plasma, while the plasma in return induces electric fields in a cyclic manner, causing a wave motion. This opened a new branch of the plasma physics, the so called "magnetohydrodynamics".



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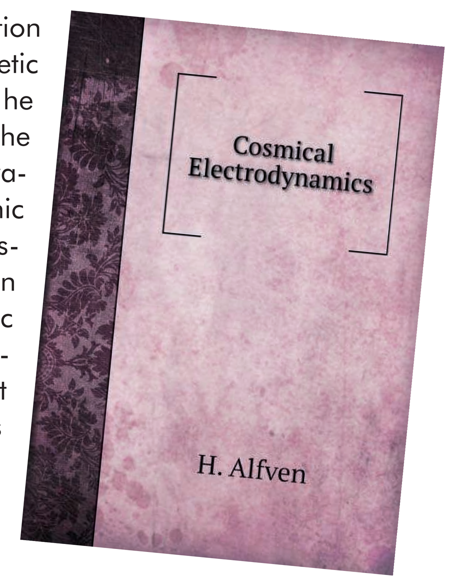
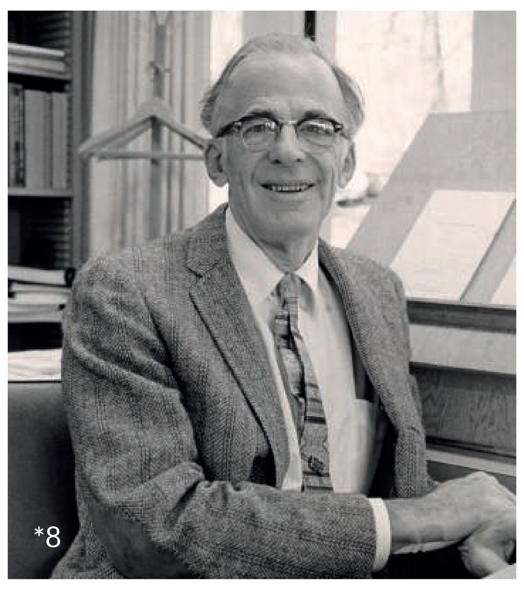
Alfvén waves in two coronal geometries



"Cosmical Electrodynamics", 1950 *7

Stellarator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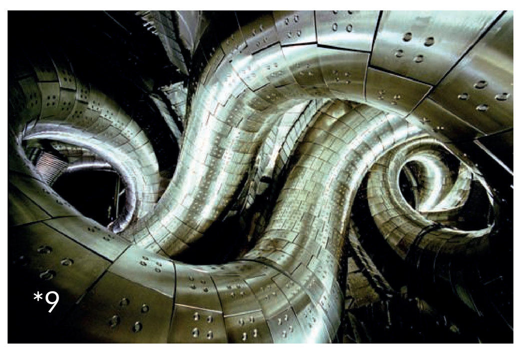
Lyman Spitzer (born on the 26th June 1914 in Toledo, Ohio, U.S.A; died on the 31st March 1997 in Princeton, New Jersey, U.S.A.) was an american theoretical physicist and astronomer, who made huge contributions in the thermonuclear fusion, plasma physics and space astronomy. Before the creation of NASA he had the idea of a space telescope for detecting a wide range of wavelengths and for acquiring better images of far space objects. This was the idea behind the later constructed Hubble Space Telescope. His work on the secret "Matterhorn Project", implemented in the laboratories of the Princeton University, had a fundamental meaning in the use of nuclear fusion as an energy source. His idea of enclosing plasma, so it can be heated to fusion temperatures made him develop the concept of Stellarators. The name of this device is accelerated to the latin word "stella" meaning star. So there was a comparison of the processes in a Stellarator with the nuclear fusion processes in the stars. The first model of a Stellarator was constructed in 1951 and had a twisted toroidal shape. To form this shape a lot of helical magnetic coils were used, which were responsible for the torsion of the magnetic field. The magnetic coils confined an amount of produced plasma. The energy of the free neutrons produced in the nuclear fusion reactor is being converted in thermal energy. The thermal energy will later be generated to electrical current in a thermal power station. A huge advantage of the stellarator is the stability of the plasma current. This is being studied in different stellarator facilities worldwide like the Large Helical Device in Japan and the Wendelstein 7-X in Greifswald, Germany.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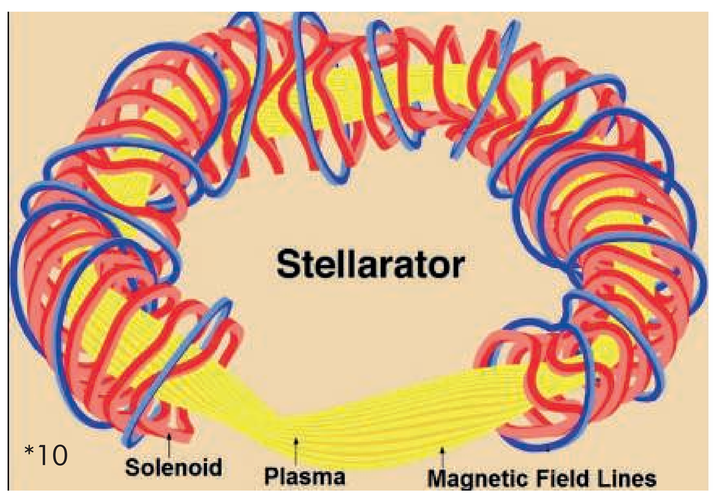
Large Helical Device, Japan



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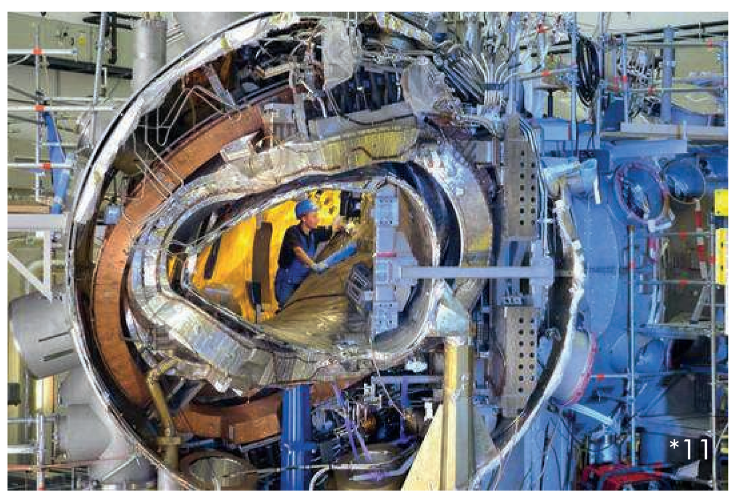
Stellarator Principle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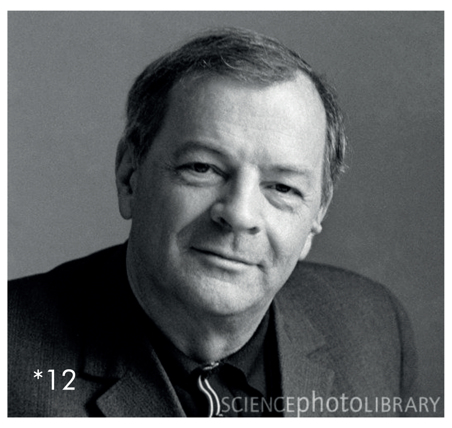
Wendelstein 7-X, Germany

Tokamak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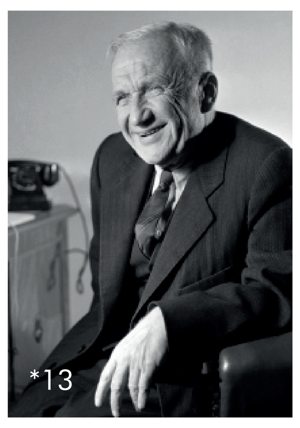
Artsimovich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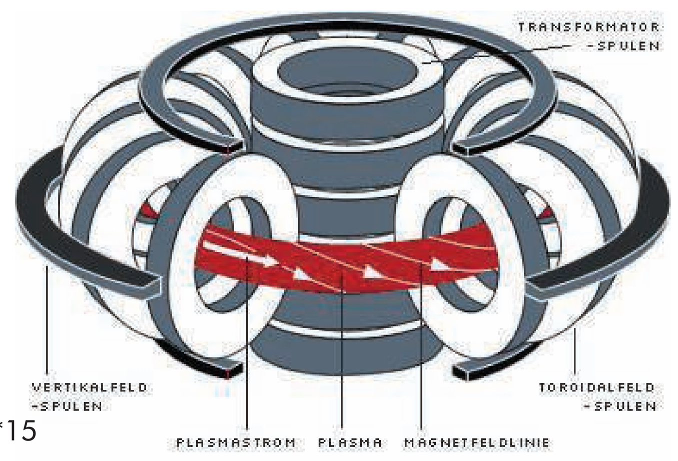
Tamm


*14

Sakharov

Lev Andreevich Artsimovich (born on the 25th February 1909 in Moscow, Russia; died on the 1st March 1973 in Moscow, Russia), Igor Tamm (born on the 8th July 1895 in Vladivostok, Russia; died on the 12th April 1971 in Moscow, Russia), Andrei Sakharov (born on the 21st May 1921 in Moscow, Russia; died on the 14th December 1989 in Moscow, Russia) were Soviet physicist, who worked on the Soviet atomic bomb project. Their futuristic discovery in the field of plasma physics and nuclear fusion was the Tokamak. The Tokamak is a toroidal nuclear fusion reactor consisting of different kinds of magnetic coils surrounding the plasma inside the ring. The name is a shortcut for 'toroidalnaja kamera w magnitnych katuschkach', meaning 'toroidal chamber in magnetic coils'. It is also in a nod to the plasma current, because the word "Tok" means "current" in russian. A frictionless function of a Tokamak requires a superposition of three magnetic fields: the first field is ring-shaped and is produced by the plane coils, the second one is produced by an electrical current in the plasma. By the combination of these fields, there result helical field lines. The third vertical field locates the current in the plasma. The principle of the Tokamak was developed and introduced in the year 1952 at the Kurchatov Institute in Moscow, while the first constructed Tokamak was introduced in 1962. Because of the plasma current being generated by electromagnetic induction, a Tokamak can not work in continuous, but in pulsed mode. Nowadays there are about 30 Tokamak facilities in use, whereby the ITER (International Thermonuclear Experimental Reactor) in Cadarche in Southern France and the JET (Joint European Torus) in Culham by Oxford in Great Britain are the largest ones.



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Tokamak Principle


*16

ITER, South France

Sources: 1- Ramakrishna Mission Calcutta Students Home, 2- Archive.org, 3- Das Bundesarchiv ("The Bundesarchive", digital pictures), 4- "Wissenschaft und Politik im Leben von Max Steenbeck", Bernd Helmbold -"Science and policy in the life of Max Steenbeck" by Bernd Helmbold, 5- Techmania Science Center, 6- Nature- international weekly journal of science, 7- Archive.org, 8- Princeton Weekly Bulletin, 9- The Japan Times, 10- Global Research for Safety, 11- Max-Planck-Institut für Plasmaphysik , 12- eduspb.com, 13- nobelprize.lebedev.ru, 14- Encyclopedia Britannica, 15- Max-Planck-Institut für Plasmaphysik, 16- Science AAAS (American Association for the Advancement of Science)