Magnetic Fields Stellarator

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Scientists have developed a highly sensitive sensor to detect tiny changes in strong magnetic fields. The sensor may find widespread use in medicine and other areas. [12]

Scientists at the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL) and Princeton University have proposed a groundbreaking solution to a mystery that has puzzled physicists for decades. At issue is how magnetic reconnection, a universal process that sets off solar flares, northern lights and cosmic gamma-ray bursts, occurs so much faster than theory says should be possible. [11]

New method of superstrong magnetic fields' generation proposed by Russian scientists in collaboration with foreign colleagues. [10]

By showing that a phenomenon dubbed the "inverse spin Hall effect" works in several organic semiconductors - including carbon-60 buckyballs - University of Utah physicists changed magnetic "spin current" into electric current. The efficiency of this new power conversion method isn't yet known, but it might find use in future electronic devices including batteries, solar cells and computers. [9]

Researchers from the Norwegian University of Science and Technology (NTNU) and the University of Cambridge in the UK have demonstrated that it is possible to directly generate an electric current in a magnetic material by rotating its magnetization. [8]

This paper explains the magnetic effect of the electric current from the observed effects of the accelerating electrons, causing naturally the experienced changes of the electric field potential along the electric wire. The accelerating electrons explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the wave particle duality and the electron's spin also, building the bridge between the Classical and Quantum Theories.

The changing acceleration of the electrons explains the created negative electric field of the magnetic induction, the changing relativistic mass and the Gravitational Force, giving a Unified Theory of the physical forces. Taking into account the Planck Distribution Law of the electromagnetic oscillators also, we can explain the electron/proton mass rate and the Weak and Strong Interactions.

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Preface

Surprisingly nobody found strange that by theory the electrons are moving with a constant velocity in the stationary electric current, although there is an accelerating force **F = q E**, imposed by the **E** electric field along the wire as a result of the **U** potential difference. The accelerated electrons are creating a charge density distribution and maintaining the potential change along the wire. This charge distribution also creates a radial electrostatic field around the wire decreasing along the wire. The moving external electrons in this electrostatic field are experiencing a changing electrostatic field causing exactly the magnetic effect, repelling when moving against the direction of the current and attracting when moving in the direction of the current. This way the **A** magnetic potential is based on the real charge distribution of the electrons caused by their acceleration, maintaining the **E** electric field and the **A** magnetic potential at the same time.

The mysterious property of the matter that the electric potential difference is self maintained by the accelerating electrons in the electric current gives a clear explanation to the basic sentence of the relativity that is the velocity of the light is the maximum velocity of the electromagnetic matter. If the charge could move faster than the electromagnetic field, this self maintaining electromagnetic property of the electric current would be failed.

More importantly the accelerating electrons can explain the magnetic induction also. The changing acceleration of the electrons will create a –**E** electric field by changing the charge distribution, increasing acceleration lowering the charge density and decreasing acceleration causing an increasing charge density.

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as a relativistic changing electromagnetic mass. If the mass is electromagnetic, then the gravitation is also electromagnetic effect. The same charges would attract each other if they are moving parallel by the magnetic effect.

Physicists confirm the precision of magnetic fields in the most advanced stellarator in the world

Physicist Sam Lazerson of the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL) has teamed with German scientists to confirm that the Wendelstein 7-X (W7-X) fusion energy device called a stellarator in Greifswald, Germany, produces high-quality magnetic fields that are consistent with their complex design.

The findings, published in the November 30 issue of Nature Communications , revealed an error field—or deviation from the designed configuration—of less than one part in 100,000. Such results could become a key step toward verifying the feasibility of stellarators as models for future fusion reactors.

W7-X, for which PPPL is the leading U.S. collaborator, is the largest and most sophisticated stellarator in the world. Built by the Max Planck Institute for Plasma Physics in Greifswald, it was completed in 2015 as the vanguard of the stellarator design. Other collaborators on the U.S. team include DOE's Oak Ridge and Los Alamos National Laboratories, along with Auburn University, the Massachusetts Institute of Technology, the University of Wisconsin-Madison and Xanthos Technologies.

Twisty magnetic fields

Stellarators confine the hot, charged gas, otherwise known as plasma, that fuels fusion reactions in twisty—or 3-D—magnetic fields, compared with the symmetrical—or 2D —fields that the more widely used tokamaks create. The twisty configuration enables stellarators to control the plasma with no need for the current that tokamaks must induce in the gas to complete the magnetic field. Stellarator plasmas thus run little risk of disrupting, as can happen in tokamaks, causing the internal current to abruptly halt and fusion reactions to shut down.

PPPL has played key roles in the W7-X project. The Laboratory designed and delivered five barn door-sized trim coils that fine-tune the stellarator's magnetic fields and made their measurement possible. "We've confirmed that the magnetic cage that we've built works as designed," said Lazerson, who led roughly half the experiments that validated the configuration of the field. "This reflects U.S. contributions to W7-X," he added, "and highlights PPPL's ability to conduct international collaborations." Support for this work comes from Euratom and the DOE Office of Science.

To measure the magnetic field, the scientists launched an electron beam along the field lines. They next obtained a cross-section of the entire magnetic surface by using a fluorescent rod to intersect and sweep through the lines, thereby inducing fluorescent light in the shape of the surface.

Remarkable fidelity

Results showed a remarkable fidelity to the design of the highly complex magnetic field. "To our knowledge," the authors write of the discrepancy of less than one part in 100,000, "this is an unprecedented accuracy, both in terms of the as-built engineering of a fusion device, as well as in the measurement of magnetic topology."

The W7-X is the most recent version of the stellarator concept, which Lyman Spitzer, a Princeton University astrophysicist and founder of PPPL, originated during the 1950s. Stellarators mostly gave way to tokamaks a decade later, since the doughnut-shaped facilities are simpler to design and build and generally confine plasma better. But recent advances in plasma theory and computational power have led to renewed interest in stellarators.

Such advances caused the authors to wonder if devices like the W7-X can provide an answer to the question of whether stellarators are the right concept for fusion energy. Years of plasma physics research will be needed to find out, they conclude, and "that task has just started." [13]

High-precision magnetic field sensing

Scientists have developed a highly sensitive sensor to detect tiny changes in strong magnetic fields. The sensor may find widespread use in medicine and other areas.

Researchers from the Institute for Biomedical Engineering, which is operated jointly by ETH Zurich and the University of Zurich, have succeeded in measuring tiny changes in strong magnetic fields with unprecedented precision. In their experiments, the scientists magnetised a water droplet inside a magnetic resonance imaging (MRI) scanner, a device that is used for medical imaging. The researchers were able to detect even the tiniest variations of the magnetic field strength within the droplet. These changes were up to a trillion times smaller than the seven tesla field strength of the MRI scanner used in the experiment.

"Until now, it was possible only to measure such small variations in weak magnetic fields," says Klaas Prüssmann, Professor of Bioimaging at ETH Zurich and the University of Zurich. An example of a weak magnetic field is that of the Earth, where the field strength is just a few dozen microtesla. For fields of this kind, highly sensitive measurement methods are already able to detect variations of about a trillionth of the field strength, says Prüssmann. "Now, we have a similarly sensitive method for strong fields of more than one tesla, such as those used, inter alia, in medical imaging."

Newly developed sensor

The scientists based the sensing technique on the principle of nuclear magnetic resonance, which also serves as the basis for magnetic resonance imaging and the spectroscopic methods that biologists use to elucidate the 3D structure of molecules.

However, to measure the variations, the scientists had to build a new high-precision sensor, part of which is a highly sensitive digital radio receiver. "This allowed us to reduce background noise to an extremely low level during the measurements," says Simon Gross. Gross wrote his doctoral thesis on this topic in Prüssmann's group and is lead author of the paper published in the journal Nature Communications.

Eliminating antenna interference

In the case of nuclear magnetic resonance, radio waves are used to excite atomic nuclei in a magnetic field. This causes the nuclei to emit weak radio waves of their own, which are measured using a radio antenna; their exact frequency indicates the strength of the magnetic field.

As the scientists emphasise, it was a challenge to construct the sensor in such a way that the radio antenna did not distort the measurements. The scientists have to position it in the immediate vicinity of the water droplet, but as it is made of copper it becomes magnetised in the strong magnetic field, causing a change in the magnetic field inside the droplet.

The researchers therefore came up with a trick: they cast the droplet and antenna in a specially prepared polymer; its magnetisability (magnetic susceptibility) exactly matched that of the copper antenna. In this way, the scientists were able to eliminate the detrimental influence of the antenna on the water sample.

Broad applications expected

This measurement technique for very small changes in magnetic fields allows the scientists to now look into the causes of such changes. They expect their technique to find use in various areas of science, some of them in the field of medicine, although the majority of these applications are still in their infancy.

"In an MRI scanner, the molecules in body tissue receive minimal magnetisation - in particular, the water molecules that are also present in blood," explains doctoral student Gross. "The new sensor is so sensitive that we can use it to measure mechanical processes in the body; for example, the contraction of the heart with the heartbeat."

The scientists carried out an experiment in which they positioned their sensor in front of the chest of a volunteer test subject inside an MRI scanner. They were able to detect periodic changes in the magnetic field, which pulsated in time with the heartbeat. The measurement curve is reminiscent of an electrocardiogram (ECG), but unlike the latter measures a mechanical process (the contraction of the heart) rather than electrical conduction. "We are in the process of analysing and refining our magnetometer measurement technique in collaboration with cardiologists and signal processing experts," says Prüssmann. "Ultimately, we hope that our sensor will be able to provide information on heart disease - and do so non-invasively and in real time."

Development of better contrast agents

The new measurement technique could also be used in the development of new contrast agents for magnetic resonance imaging: in MRI, the image contrast is based largely on how quickly a magnetised nuclear spin reverts to its equilibrium state. Experts call this process relaxation. Contrast agents influence the relaxation characteristics of nuclear spins even at low concentrations and are used to highlight certain structures in the body.

In strong magnetic fields, sensitivity issues had previously restricted scientists to measurement of just two of the three spatial nuclear spin components and their relaxation. They had to rely on an indirect measurement of relaxation in the important third dimension. For the first time, the new high-precision measurement technique allows the direct measurement of all three dimensions of nuclear spin in strong magnetic fields.

Direct measurement of all three nuclear spin components also paves the way for future developments in nuclear magnetic resonance (NMR) spectroscopy for applications in biological and chemical research. [12]

Researchers propose an explanation for the mysterious onset of a universal process

Scientists at the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL) and Princeton University have proposed a groundbreaking solution to a mystery that has puzzled physicists for decades. At issue is how magnetic reconnection, a universal process that sets off solar flares, northern lights and cosmic gamma-ray bursts, occurs so much faster than theory says should be possible. The answer could aid forecasts of space storms, explain several high-energy astrophysical phenomena, and improve plasma confinement in doughnut-shaped magnetic devices called tokamaks designed to obtain energy from nuclear fusion.

Magnetic reconnection takes place when the magnetic field lines embedded in a plasma—the hot, charged gas that makes up 99 percent of the visible universe—converge, break apart and explosively reconnect. This process takes place in thin sheets in which electric current is strongly concentrated.

According to conventional theory, these sheets can be highly elongated and severely constrain the velocity of the magnetic field lines that join and split apart, making fast reconnection impossible. However, observation shows that rapid reconnection does exist, directly contradicting theoretical predictions.

Detailed theory for rapid reconnection

Now, physicists at PPPL and Princeton University have presented a detailed theory for the mechanism that leads to fast reconnection. Their paper, published in the journal Physics of Plasmas in October, focuses on a phenomenon called "plasmoid instability" to explain the onset of the rapid reconnection process. Support for this research comes from the National Science Foundation and the DOE Office of Science.

Plasmoid instability, which breaks up plasma current sheets into small magnetic islands called plasmoids, has generated considerable interest in recent years as a possible mechanism for fast reconnection. However, correct identification of the properties of the instability has been elusive.

The Physics of Plasmas paper addresses this crucial issue. It presents "a quantitative theory for the development of the plasmoid instability in plasma current sheets that can evolve in time" said Luca Comisso, lead author of the study. Co-authors are Manasvi Lingam and Yi-Ming Huang of PPPL and Princeton, and Amitava Bhattacharjee, head of the Theory Department at PPPL and Princeton professor of astrophysical sciences.

Pierre de Fermat's principle

The paper describes how the plasmoid instability begins in a slow linear phase that goes through a period of quiescence before accelerating into an explosive phase that triggers a dramatic increase in the speed of magnetic reconnection. To determine the most important features of this instability, the researchers adapted a variant of the 17th century "principle of least time" originated by the mathematician Pierre de Fermat.

Use of this principle enabled the researchers to derive equations for the duration of the linear phase, and for computing the growth rate and number of plasmoids created. Hence, this least-time approach led to a quantitative formula for the onset time of fast magnetic reconnection and the physics behind it.

The paper also produced a surprise. The authors found that such relationships do not reflect traditional power laws, in which one quantity varies as a power of another. "It is common in all realms of science to seek the existence of power laws," the researchers wrote. "In contrast, we find that the scaling relations of the plasmoid instability are not true power laws - a result that has never been derived or predicted before." [11]

New method for generating superstrong magnetic fields

Researchers of MEPhI (Russia), the University of Rostock (Germany) and the University of Pisa (Italy) suggest a new method for generating extremely strong magnetic fields of several giga-Gauss in the lab. Currently available techniques produce fields of one order of magnitude less than the new method. In nature, such superstrong fields exist only in the space. Therefore, generation of such fields in laboratory conditions provides new opportunities for the modeling of astrophysical processes. The results will contribute to the new research field of laboratory astrophysics.

The Faraday effect has been known for a long time. It refers to the polarization plane of an electromagnetic wave propagating through a non-magnetic medium, which is rotating in the presence of a constant magnetic field. There is also an inverse process of the generation of a magnetic field during the propagation of a circularly polarized wave through a crystal or plasma. It was considered theoretically in the 1960s by Soviet theorist Lew Pitaevsky, a famous representative of Landau's school. The stronger the wave, the higher the magnetic field it can generate when propagating through a medium. However, a peculiarity of the effect is that it requires absorption for its very existence—it does not occur in entirely transparent media. In highly intense electromagnetic fields, electrons become ultrarelativistic, which considerably reduces their collisions, suppressing conventional absorption. The researchers demonstrate that at very high laser wave intensities, the absorption can be effectively provided by radiation friction instead of binary collisions. This specific friction leads to the generation of a superstrong magnetic field.

According to physicist Sergey Popruzhenko, it will be possible to check the calculations in the near future. Several new laser facilities of record power will be completed in the next several years. Three such lasers are now under construction within the European project Extreme Light Infrastructure (ELI) in the Czech Republic, Romania and Hungary. The Exawatt Center for Extreme Light Studies – XCELS is under the development at the Applied Physics Institute RAS at Nizhny Novgorod. These laser facilities will be capable of the intensities required for the generation of superstrong magnetic fields due to radiation friction and also for the observation of many other fundamental strong-field effects. [10]

Inverse spin Hall effect: A new way to get electricity from magnetism

By showing that a phenomenon dubbed the "inverse spin Hall effect" works in several organic semiconductors - including carbon-60 buckyballs - University of Utah physicists changed magnetic "spin current" into electric current. The efficiency of this new power conversion method isn't yet known, but it might find use in future electronic devices including batteries, solar cells and computers.

"This paper is the first to demonstrate the inverse spin Hall effect in a range of organic semiconductors with unprecedented sensitivity," although a 2013 study by other researchers demonstrated it with less sensitivity in one such material, says Christoph Boehme, a senior author of the study published April 18 in the journal Nature Materials.

"The inverse spin Hall effect is a remarkable phenomenon that turns so-called spin current into an electric current. The effect is so odd that nobody really knows what this will be used for eventually, but many technical applications are conceivable, including very odd new power-conversion schemes," says Boehme, a physics professor.

His fellow senior author, distinguished professor Z. Valy Vardeny, says that by using pulses of microwaves, the inverse spin Hall effect and organic semiconductors to convert spin current into electricity, this new electromotive force generates electrical current in a way different than existing sources.

Coal, gas, hydroelectric, wind and nuclear plants all use dynamos to convert mechanical force into magnetic-field changes and then electricity. Chemical reactions power modern batteries and solar cells convert light to electrical current. Converting spin current into electrical current is another method.

Scientists already are developing such devices, such as a thermoelectric generator, using traditional inorganic semiconductors. Vardeny says organic semiconductors are promising because they are cheap, easily processed and environmentally friendly. He notes that both organic solar cells and organic LED (light-emitting diode) TV displays were developed even though silicon solar cells and nonorganic LEDs were widely used.

A new way to get electricity from magnetism

Vardeny and Boehme stressed that the efficiency at which organic semiconductors convert spin current to electric current remains unknown, so it is too early to predict the extent to which it might one day be used for new power conversion techniques in batteries, solar cells, computers, phones and other consumer electronics.

"I want to invoke a degree of caution," Boehme says. "This is a power conversion effect that is new and mostly unstudied."

Boehme notes that the experiments in the new study converted more spin current to electrical current than in the 2013 study, but Vardeny cautioned the effect still "would have to be scaled up many times to produce voltages equivalent to household batteries."

The new study was funded by the National Science Foundation and the University of Utah-NSF Materials Research Science and Engineering Center. Study co-authors with Vardeny and Boehme were these University of Utah physicists: research assistant professors Dali Sun and Hans Malissa, postdoctoral researchers Kipp van Schooten and Chuang Zhang, and graduate students Marzieh Kavand and Matthew Groesbeck.

From spin current to electric current

Just as atomic nuclei and the electrons that orbit them carry electrical charges, they also have another inherent property: spin, which makes them behave like tiny bar magnets that can point north or south.

Electronic devices store and transmit information using the flow of electricity in the form of electrons, which are negatively charged subatomic particles. The zeroes and ones of computer binary code are represented by the absence or presence of electrons within silicon or other nonorganic semiconductors.

Spin electronics - spintronics - holds promise for faster, cheaper computers, better electronics and LEDs for displays, and smaller sensors to detect everything from radiation to magnetic fields.

The inverse spin Hall effect first was demonstrated in metals in 2008, and then in nonorganic semiconductors, Vardeny says. In 2013, researchers elsewhere showed it occurred in an organic semiconductor named PEDOT:PSS when it was exposed to continuous microwaves that were relatively weak to avoid frying the semiconductor. [9]

New electron spin secrets revealed: Discovery of a novel link between magnetism and electricity

The findings reveal a novel link between magnetism and electricity, and may have applications in electronics.

The electric current generation demonstrated by the researchers is called charge pumping. Charge pumping provides a source of very high frequency alternating electric currents, and its magnitude and external magnetic field dependency can be used to detect magnetic information.

The findings may, therefore, offer new and exciting ways of transferring and manipulating data in electronic devices based on spintronics, a technology that uses electron spin as the foundation for information storage and manipulation.

The research findings are published as an Advance Online Publication (AOP) on Nature Nanotechnology's website on 10 November 2014.

Spintronics has already been exploited in magnetic mass data storage since the discovery of the giant magnetoresistance (GMR) effect in 1988. For their contribution to physics, the discoverers of GMR were awarded the Nobel Prize in 2007.

The basis of spintronics is the storage of information in the magnetic configuration of ferromagnets and the read-out via spin-dependent transport mechanisms.

"Much of the progress in spintronics has resulted from exploiting the coupling between the electron spin and its orbital motion, but our understanding of these interactions is still immature. We need to know more so that we can fully explore and exploit these forces," says Arne Brataas, professor at NTNU and the corresponding author for the paper.

An electron has a spin, a seemingly internal rotation, in addition to an electric charge. The spin can be up or down, representing clockwise and counterclockwise rotations.

Pure spin currents are charge currents in opposite directions for the two spin components in the material.

It has been known for some time that rotating the magnetization in a magnetic material can generate pure spin currents in adjacent conductors.

However, pure spin currents cannot be conventionally detected by a voltmeter because of the cancellation of the associated charge flow in the same direction.

A secondary spin-charge conversion element is then necessary, such as another ferromagnet or a strong spin-orbit interaction, which causes a spin Hall effect.

Brataas and his collaborators have demonstrated that in a small class of ferromagnetic materials, the spin-charge conversion occurs in the materials themselves.

The spin currents created in the materials are thus directly converted to charge currents via the spin-orbit interaction.

In other words, the ferromagnets function intrinsically as generators of alternating currents driven by the rotating magnetization.

"The phenomenon is a result of a direct link between electricity and magnetism. It allows for the possibility of new nano-scale detection techniques of magnetic information and for the generation of very high-frequency alternating currents," Brataas says. [8]

Simple Experiment

Everybody can repeat my physics teacher's - Nándor Toth - middle school experiment, placing aluminum folios in form V upside down on the electric wire with static electric current, and seeing them open up measuring the electric potential created by the charge distribution, caused by the acceleration of the electrons.

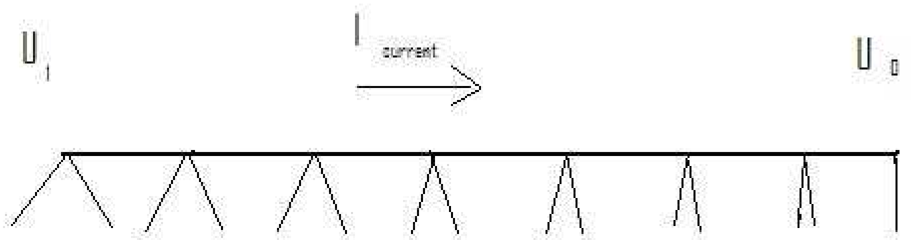

Figure 1.) Aluminium folios shows the charge distribution on the electric wire

He wanted to show us that the potential decreasing linearly along the wire and told us that in the beginning of the wire it is lowering harder, but after that the change is quite linear.

You will see that the folios will draw a parabolic curve showing the charge distribution along the wire, since the way of the accelerated electrons in the wire is proportional with the square of time. The free external charges are moving along the wire, will experience this charge distribution caused electrostatic force and repelled if moving against the direction of the electric current and attracted in the same direction – the magnetic effect of the electric current.

Uniformly accelerated electrons of the steady current

In the steady current **I= dq/dt**, the **q** electric charge crossing the electric wire at any place in the same time is constant. This does not require that the electrons should move with a constant v velocity and does not exclude the possibility that under the constant electric force created by the **E = - dU/dx** potential changes the electrons could accelerating.

If the electrons accelerating under the influence of the electric force, then they would arrive to the **$x = 1/2\ at^2$** in the wire. The **dx/dt = at**, means that every second the accelerating q charge will take a linearly growing length of the wire. For simplicity if a=2 then the electrons would found in the wire at x = 1, 4, 9, 16, 25 …, which means that the dx between them should be 3, 5, 7, 9 …, linearly increasing the volume containing the same q electric charge. It means that the density of the electric charge decreasing linearly and as the consequence of this the U field is decreasing linearly as expected: **-dU/dx = E = const**.

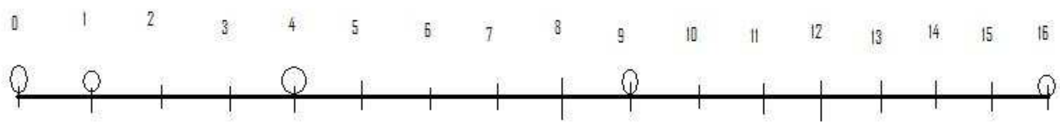

Figure 2.) The accelerating electrons created charge distribution on the electric wire

This picture remembers the Galileo's Slope of the accelerating ball, showed us by the same teacher in the middle school, some lectures before. I want to thank him for his enthusiastic and impressive lectures, giving me the associating idea between the Galileo's Slope and the accelerating charges of the electric current.

We can conclude that the electrons are accelerated by the electric **U** potential, and with this accelerated motion they are maintaining the linear potential decreasing of the **U** potential along they movement. Important to mention, that the linearly decreasing charge density measured in the referential frame of the moving electrons. Along the wire in its referential frame the charge density lowering parabolic, since the charges takes way proportional with the square of time.

The decreasing **U** potential is measurable, simply by measuring it at any place along the wire. One of the simple visualizations is the aluminum foils placed on the wire opening differently depending on the local charge density. The static electricity is changing by parabolic potential giving the equipotential lines for the external moving electrons in the surrounding of the wire.

Magnetic effect of the decreasing U electric potential

One **q** electric charge moving parallel along the wire outside of it with velocity v would experience a changing **U** electric potential along the wire. If it experiencing an emerging potential, it will repel the charge, in case of decreasing **U** potential it will move closer to the wire. This radial electric field will move the external electric charge on the parabolic curve, on the equipotential line of the accelerated charges of the electric current. This is exactly the magnetic effect of the electric current. A constant force, perpendicular to the direction of the movement of the matter will change its direction to a parabolic curve.

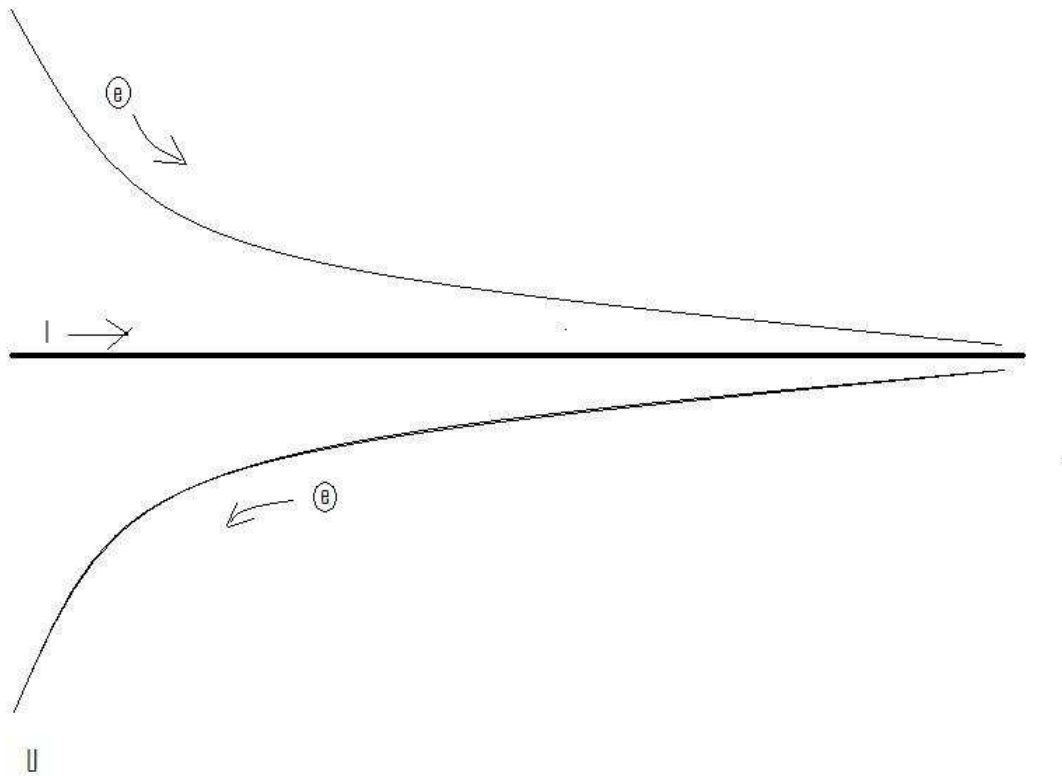

Figure 3.) Concentric parabolic equipotential surfaces around the electric wire causes the magnetic effect on the external moving charges

Considering that the magnetic effect is **F=q v x B**, where the **B** is concentric circle around the electric wire, it is an equipotential circle of the accelerating electrons caused charge distribution. Moving on this circle there is no electric and magnetic effect for the external charges, since **vxB=0**. Moving in the direction of the current the electric charges crosses the biggest potential change, while in any other direction – depending on the angle between the current and velocity of the external charge there is a modest electric potential difference, giving exactly the same force as the **v x B** magnetic force.

Getting the magnetic force from the **F = dp/dt** equation we will understand the magnetic field velocity dependency. Finding the appropriate trajectory of the moving charges we need simply get it from the equipotential lines on the equipotential surfaces, caused by the accelerating charges of the electric current. We can prove that the velocity dependent force causes to move the charges on the equipotential surfaces, since the force due to the potential difference according to the velocity angle – changing only the direction, but not the value of the charge's velocity.

The work done on the charge and the Hamilton Principle

One basic feature of magnetism is that, in the vicinity of a magnetic field, a moving charge will experience a force. Interestingly, the force on the charged particle is always perpendicular to the direction it is moving. Thus magnetic forces cause charged particles to change their direction of motion, but they do not change the speed of the particle. This property is used in high-energy particle accelerators to focus beams of particles which eventually collide with targets to produce new particles. Another way to understand this is to realize that if the force is perpendicular to the motion, then no work is done. Hence magnetic forces do no work on charged particles and cannot increase their kinetic energy. If a charged particle moves through a constant magnetic field, its speed stays the same, but its direction is constantly changing. [2]

In electrostatics, the work done to move a charge from any point on the equipotential surface to any other point on the equipotential surface is zero since they are at the same potential. Furthermore, equipotential surfaces are always perpendicular to the net electric field lines passing through it. [3]

Consequently the work done on the moving charges is zero in both cases, proving that they are equal forces, that is they are the same force.

The accelerating charges self-maintaining potential equivalent with the Hamilton Principle and the Euler-Lagrange equation. [4]

The Magnetic Vector Potential

Also the <u>**A**</u> magnetic vector potential gives the radial parabolic electric potential change of the charge distribution due to the acceleration of electric charges in the electric current.

Necessary to mention that the <u>**A**</u> magnetic vector potential is proportional with <u>a</u>, the acceleration of the charges in the electric current although this is not the only parameter.

The <u>**A**</u> magnetic vector potential is proportional with I**=dQ/dt** electric current, which is proportional with the strength of the charge distribution along the wire. Although it is proportional also with the U potential difference I=U/R, but the R resistivity depends also on the cross-sectional area, that is bigger area gives stronger I and <u>**A**</u>. [7] This means that the bigger potential differences with smaller cross-section can give the same **I** current and <u>**A**</u> vector potential, explaining the gauge transformation.

Since the magnetic field B is defined as the curl of <u>**A**</u>, and the curl of a gradient is identically zero, then any arbitrary function which can be expressed as the gradient of a scalar function may be added to A without changing the value of B obtained from it. That is, A' can be freely substituted for A where

$$\overrightarrow{A'} = \overrightarrow{A} + \overrightarrow{\nabla}\phi$$

Such transformations are called gauge transformations, and there have been a number of "gauges" that have been used to advantage is specific types of calculations in electromagnetic theory. [5]

Since the potential difference and the vector potential both are in the direction of the electric current, this gauge transformation could explain the self maintaining electric potential of the accelerating electrons in the electric current. Also this is the source of the special and general relativity.

The Constant Force of the Magnetic Vector Potential

Moving on the parabolic equipotential line gives the same result as the constant force of gravitation moves on a parabolic line with a constant velocity moving body.

Electromagnetic four-potential

The electromagnetic four-potential defined as:

SI units	**cgs units**
$A^\alpha = (\phi/c, \mathbf{A})$	$A^\alpha = (\phi, \mathbf{A})$

in which ϕ is the electric potential, and **A** is the magnetic vector potential. [6] This is appropriate with the four-dimensional space-time vector (T, **R**) and in stationary current gives that the potential difference is constant in the time dimension and vector potential (and its curl, the magnetic field) is constant in the space dimensions.

Magnetic induction

Increasing the electric current **I** causes increasing magnetic field **B** by increasing the acceleration of the electrons in the wire. Since l=at, if the acceleration of electrons is growing, than the charge density **dQ/dl** will decrease in time, creating a **–E** electric field. Since the resistance of the wire is constant, only increasing U electric potential could cause an increasing electric current **I=U/R=dQ/dt**. The charge density in the static current changes linear in the time coordinates. Changing its value in time will causing a static electric force, negative to the accelerating force change. This explains the relativistic changing mass of the charge in time also.

Necessary to mention that decreasing electric current will decrease the acceleration of the electrons, causing increased charge density and **E** positive field.

The electric field is a result of the geometric change of the **U** potential and the timely change of the **A** magnetic potential:

E = - dA/dt - dU/dr

$$\mathbf{B} = \nabla \times \mathbf{A}, \quad \mathbf{E} = -\nabla\phi - \frac{\partial \mathbf{A}}{\partial t},$$

The acceleration of the electric charges proportional with the A magnetic vector potential in the electric current and also their time dependence are proportional as well. Since the A vector potential is appears in the equation, the proportional **a** acceleration will satisfy the same equation.

Since increasing acceleration of charges in the increasing electric current the result of increasing potential difference, creating a decreasing potential difference, the electric and magnetic vector potential are changes by the next wave - function equations:

$$\frac{1}{c^2}\frac{\partial^2\varphi}{\partial t^2} - \nabla^2\varphi = \frac{\rho}{\varepsilon_0}$$

$$\nabla^2\mathbf{A} - \frac{1}{c^2}\frac{\partial^2\mathbf{A}}{\partial t^2} = -\mu_0\mathbf{J}$$

The simple experiment with periodical changing **U** potential and **I** electric current will move the aluminium folios with a moving wave along the wire.

The Lorentz gauge says exactly that the accelerating charges are self maintain their accelerator fields and the divergence (source) of the A vector potential is the timely change of the electric potential.

$$\nabla \cdot \vec{A} + \frac{1}{c^2}\frac{\partial\varphi}{\partial t} = 0.$$

Or

$$\vec{E} = -\nabla\varphi - \frac{\partial\vec{A}}{\partial t}.$$

The timely change of the A vector potential, which is the proportionally changing acceleration of the charges will produce the negative electric field.

Lorentz transformation of the Special Relativity

In the referential frame of the accelerating electrons the charge density lowering linearly because of the linearly growing way they takes every next time period. From the referential frame of the wire there is a parabolic charge density lowering.

The difference between these two referential frames, namely the referential frame of the wire and the referential frame of the moving electrons gives the relativistic effect. Important to say that the moving electrons presenting the time coordinate, since the electrons are taking linearly increasing way every next time period, and the wire presenting the geometric coordinate.

The Lorentz transformations are based on moving light sources of the Michelson - Morley experiment giving a practical method to transform time and geometric coordinates without explaining the source of this mystery.

The real mystery is that the accelerating charges are maintaining the accelerating force with their charge distribution locally. The resolution of this mystery that the charges are simply the results of the diffraction patterns, that is the charges and the electric field are two sides of the same thing. Otherwise the charges could exceed the velocity of the electromagnetic field.

The increasing mass of the electric charges the result of the increasing inductive electric force acting against the accelerating force. The decreasing mass of the decreasing acceleration is the result of the inductive electric force acting against the decreasing force. This is the relativistic mass change explanation, especially importantly explaining the mass reduction in case of velocity decrease.

Heisenberg Uncertainty Relation

In the atomic scale the Heisenberg uncertainty relation gives the same result, since the moving electron in the atom accelerating in the electric field of the proton, causing a charge distribution on delta x position difference and with a delta p momentum difference such a way that they product is about the half Planck reduced constant. For the proton this delta x much less in the nucleon, than in the orbit of the electron in the atom, the delta p is much higher because of the greater proton mass.

This means that the electron and proton are not point like particles, but has a real charge distribution.

Wave – Particle Duality

The accelerating electrons explains the wave – particle duality of the electrons and photons, since the elementary charges are distributed on delta x position with delta p impulse and creating a wave packet of the electron. The photon gives the electromagnetic particle of the mediating force of the electrons electromagnetic field with the same distribution of wavelengths.

Atomic model

The constantly accelerating electron in the Hydrogen atom is moving on the equipotential line of the proton and it's kinetic and potential energy will be constant. Its energy will change only when it is changing its way to another equipotential line with another value of potential energy or getting free with enough kinetic energy. This means that the Rutherford-Bohr atomic model is right and only the changing acceleration of the electric charge causes radiation, not the steady acceleration. The steady acceleration of the charges only creates a centric parabolic steady electric field around the charge, the magnetic field. This gives the magnetic moment of the atoms, summing up the proton and electron magnetic moments caused by their circular motions and spins.

Fermions' spin

The moving charges are accelerating, since only this way can self maintain the electric field causing their acceleration. The electric charge is not point like! This constant acceleration possible if there is a rotating movement changing the direction of the velocity. This way it can accelerate forever without increasing the absolute value of the velocity in the dimension of the time and not reaching the velocity of the light.

The Heisenberg uncertainty relation says that the minimum uncertainty is the value of the spin: **1/2 h = dx dp** or **1/2 h = dt dE**, that is the value of the basic energy status, consequently related to the m_o inertial mass of the fermions.

The photon's 1 spin value and the electric charges 1/2 spin gives us the idea, that the electric charge and the electromagnetic wave two sides of the same thing, 1/2 – (-1/2) = 1.

Fine structure constant

The Planck constant was first described as the proportionality constant between the energy ***E*** of a photon and the frequency ***ν*** of its associated electromagnetic wave. This relation between the energy and frequency is called the Planck relation or the Planck–Einstein equation:

$$E = h\nu \, .$$

Since the frequency ***ν*,** wavelength ***λ***, and speed of light ***c*** are related by ***λν* = *c***, the Planck relation can also be expressed as

$$E = \frac{hc}{\lambda}.$$

Since this is the source of the Planck constant, the e electric charge countable from the Fine structure constant. This also related to the Heisenberg uncertainty relation, saying that the mass of the proton should be bigger than the electron mass because of the difference between their wavelengths, since **E = mc²**.

The expression of the fine-structure constant becomes the abbreviated

$$\alpha = \frac{e^2}{\hbar c}$$

This is a dimensionless constant expression, 1/137 commonly appearing in physics literature.

This means that the electric charge is a result of the electromagnetic waves diffractions, consequently the proton – electron mass rate is the result of the equal intensity of the corresponding electromagnetic frequencies in the Planck distribution law.

Planck Distribution Law

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! The weak interaction transforms an electric charge in the diffraction pattern from one side to the other side, causing an electric dipole momentum change, which violates the CP and time reversal symmetry.

The Planck distribution law is temperature dependent and it should be true locally and globally. I think that Einstein's energy-matter equivalence means some kind of existence of electromagnetic oscillations enabled by the temperature, creating the different matter formulas, atoms, molecules, crystals, dark matter and energy.

One way dividing the proton to three parts is, dividing his oscillation by the three direction of the space. We can order 1/3 **e** charge to each coordinates and 2/3 **e** charge to one plane oscillation, because the charge is scalar. In this way the proton has two +2/3 **e** plane oscillation and one linear oscillation with -1/3 **e** charge. The colors of quarks are coming from the three directions of coordinates and the proton is colorless. [1]

Electromagnetic inertia and Gravitational attraction

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as an electromagnetic changing mass.

It looks clear that the growing acceleration results the relativistic growing mass - limited also with the velocity of the electromagnetic wave.

The negatively changing acceleration causes a positive electric field, working as a decreasing mass.

Since ***E = hν*** and ***E = mc²***, ***m = hν /c²*** that is the ***m*** depends only on the ***ν*** frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the m_o inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

If the mass is electromagnetic, then the gravitation is also electromagnetic effect caused by the magnetic effect between the same charges, they would attract each other if they are moving parallel by the magnetic effect.

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths. Also since the particles are diffraction patterns they have some closeness to each other – can be seen as the measured effect of the force of the gravitation, since the magnetic effect depends on this closeness. This way the mass and the magnetic attraction depend equally on the wavelength of the electromagnetic waves.

Conclusions

The generation and modulation of high-frequency currents are central wireless communication devices such as mobile phones, WLAN modules for personal computers, Bluetooth devices and future vehicle radars. [8]

Needless to say that the accelerating electrons of the steady stationary current are a simple demystification of the magnetic field, by creating a decreasing charge distribution along the wire, maintaining the decreasing U potential and creating the **A** vector potential experienced by the electrons moving by **v** velocity relative to the wire. This way it is easier to understand also the time dependent changes of the electric current and the electromagnetic waves as the resulting fields moving by c velocity.

There is a very important law of the nature behind the self maintaining **E** accelerating force by the accelerated electrons. The accelerated electrons created electromagnetic fields are so natural that they occur as electromagnetic waves traveling with velocity c. It shows that the electric charges are the result of the electromagnetic waves diffraction.

One of the most important conclusions is that the electric charges are moving in an accelerated way and even if their velocity is constant, they have an intrinsic acceleration anyway, the so called spin, since they need at least an intrinsic acceleration to make possible they movement .

The bridge between the classical and quantum theory is based on this intrinsic acceleration of the spin, explaining also the Heisenberg Uncertainty Principle. The particle – wave duality of the electric charges and the photon makes certain that they are both sides of the same thing. Basing the gravitational force on the magnetic force and the Planck Distribution Law of the electromagnetic waves caused diffraction gives us the basis to build a Unified Theory of the physical interactions.

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