DOWNLOAD PDF DOMAIN THEORY OF MAGNETISM

Chapter 1 : Theories of magnetism, Webers Theory

The domain theory of magnetism explains what happens inside materials when magnetized. All large magnets are made up of smaller magnetic regions, or domains. The magnetic character of domains comes from the presence of even smaller units, called dipoles.

Ask your students to give examples of a few ferromagnetic materials. This should be quite easy. An interesting point of trivia to bring up in discussion is that oxygen, even in its gaseous state, is paramagnetic. This principle is exploited in the design of some oxygen concentration analyzer equipment, which measure oxygen content by measuring the amount of force generated by a tiny glass container filled with a solution to be sampled! Question 8 A mechanic visits you one day, carrying a large wrench. She says the wrench became magnetized after setting it near a large magnet. Now the wrench has become an annoyance, attracting all the other tools in her toolbox toward it. Can you think of a way to demagnetize the wrench for her? Hide answer An object may be de-magnetized by careful magnetization in the opposite direction. Incidentally, this is generally not how de-magnetization is done in industry, but it is valid. Students may want to test their hypotheses on magnetized paper clips, which are easy to work with and quite inexpensive. It will be interesting to see how many of your students actually researched modern de-magnetization techniques in preparation for answering this question. Question 9 Suppose we needed to shield a sensitive electronic instrument from external magnetic fields. How would you suggest we do such a thing? How can we keep stray magnetic fields away from this instrument? Discuss these terms as they apply to the subject of magnetic shielding. After discussing these concepts, ask your students to give examples of suitable enclosure materials. What metals would be especially good for shielding purposes? Where did they obtain their information about magnetic shielding? Question 10 Find a magnet and bring it with you to class for discussion. Identify as much information as you can about your magnet prior to discussion: Please be careful to keep any magnets away from cassette tapes, computer disks, credit cards with magnetic information strips or any other form of magnetic media! Be prepared to explain to your classmates how you were able to determine the polarity North and South of your magnet! The purpose of this question is to get students to kinesthetically interact with the subject matter. Another good learning experience with this question is how your students determined the polarity of their magnet.

Chapter 2 : Magnetism | Basic Electricity Worksheets

A magnetic domain is a region within a magnetic material in which the magnetization is in a uniform direction. This means that the individual magnetic moments of the atoms are aligned with one another and they point in the same direction.

Domain Theory A remarkable property of ferrimagnetic materials is not so much that they have a spontaneous magnetization, but rather that their magnetization can be influenced by the application of very low magnetic fields. What allows this to occur is the fact that the sample is actually composed of small regions called magnetic domains, within each of which the local magnetization is saturated but not necessarily parallel. The existence of domains is hinted at by the observation that some magnetic properties, and in particular, coercivity and remanence vary greatly with grain size. This is best illustrated in the figure below, which shows the variation of Hc with grain size. The magnetic behavior can be subdivided on the basis of grain size into four ranges SPM: For larger grain sizes, coercivity decreases as the grain subdivides into domains. For smaller grain sizes, coercivity again decreases, but this time due to the randomizing effects of thermal energy. Domains constitute a fundamental concept in magnetism. A ferro- or ferrimagnetic material may be generally defined as one that possesses a spontaneous magnetization, Ms, dependent on temperature, but only slightly dependent on applied field. The theory of ferromagnetism, based on electronic exchange forces, predicts the magnitude of Ms, but says nothing about the direction of Ms. Experimentally, it is observed that for a homogeneous specimen at constant temperature, the magnitude of Ms is uniform but the direction of Ms is in general not uniform from one region to another on a scale of microns to millimeters. Domains are formed for the following reason. Consider a large single crystal. Suppose it is uniformly magnetized, and hence a single domain. Surface charges will form on the ends due to the magnetization and are themselves a second source of a magnetic field the demagnetizing field. The energy associated with the surface charge distribution is called the magnetostatic energy. It is just the volume integral of the field over all space. The magnetostatic energy can be approximately halved if the magnetization splits into two domains magnetized in opposite directions. This subdivision into more and more domains can not continue indefinitely because the transition region between domains called a domain wall requires energy to be produced and maintained. Eventually an equilibrium number of domains will be reached for a given particle size. Domain walls are interfaces between regions in which the magnetization has different directions. Within the wall, the magnetization must change direction from that in one domain to that in the other domain. Domain walls have a finite width that is determined principally by exchange and magnetocrystalline energy. The change in magnetization within the wall can be gradual as in a or abrupt as in b. Therefore, the exchange energy is small in a but large in b. However, the spins within the wall are no longer aligned along an easy axis of magnetization. This produces an anisotropy energy, which is high in a but low in b. The exchange energy tends to make the wall as wide as possible whereas the anisotropy tends to make the wall as thin as possible. As a result of this competition between exchange and anisotropy energies,the domain wall has a finite width on the order of nm and surface energy. The interplay between long range and short range effects results in the domain states being grain-size dependent. In addition, the number of domains for a given grain size depends on the magnitudes of the exchange, magnetocrystalline, and saturation magnetization. As mentioned before, these constants are dependent on temperature as well as composition. Hence domain states in different magnetic minerals magnetite and hematite will have a different grain size dependence. The domain states will also vary with temperature for a single grain size. However, as a rule of thumb, the larger the grain size the more domains it contains. Single Domain SD As the grain size decreases, a critical size will be reached where the grain can no longer accommodate a wall. Below this critical size, the grain contains a single domain SD. An SD grain is uniformly magnetized to its saturation magnetization. SD grains are very important. To change the magnetization of a MD grain, all you need to do is translate the domain wall, a energetically easy process, which can be accomplished in relatively low fields. Thus MD grains are magnetically soft with low values of coercivities and remanence. However, the only way to change the magnetization of a SD grain is to rotate the magnetization, an energetically difficult process. Thus, SD grains are magnetically hard and have high coercivities and remanence. Here is an example of an SD and MD grain as characterized by hysteresis loops: The critical size for SD behavior depends on several factors including, the saturation magnetization and the shape of the grain. Most estimates of the SD-MD transition size are based on theoretical calculations. For magnetite, the best estimate for the transition size is about 80 nm. Here are some theoretical results: For hematite, the transition size from SD to MD is much larger 15 mm , primarily because the saturation magnetization is about times lower than for magnetite. For magnetite, this behavior occurs in the size range between 0. There has been much theoretical and experimentally work on PSD grains. Some current thinking is that small MD particles that contain just a few domains may actually have difficulty nucleating domains. In some cases MD grains exist in metastable SD states. The transformation of one domain state into another, such as addition or loss of domains, is call transdomain transformation. The importance of PSD behavior in magnetite, is that the grain size range for PSD behavior covers the range in sizes that most commonly occur in natural samples. Superparamagnetism SPM As particle size continues to decrease within the SD range, another critical threshold is reached, at which remanence and coercivity go to zero. When this happens, the grain becomes superparamagnetic. An SD particle of volume v has a uniform magnetization directed along the easy axis of magnetization. In an applied field, there will be a net statistical alignment of magnetic moments. This is analogous to paramagnetism, except now the magnetic moment is not that of a single atom, but to an SD particle containing atoms. Hence, the term superparamagnetism, which denotes a much higher susceptibility value than that for simple paramagnetism.

Chapter 3 : Magnetic domain - Wikipedia

If a magnetic field is applied to the crystal, the domains that align with the magentic field will grow as the expense of the domains that are pointing in other directions. Atomic Theory of Magnetism We are familiar with the model of the atom with a nucleus that contains the protons and neutrons and electron orbit the nucleus.

Lithium gas[edit] In , a team of MIT physicists demonstrated that a lithium gas cooled to less than one kelvin can exhibit ferromagnetism. This demonstration is the first time that ferromagnetism has been demonstrated in a gas. Tetragonal ruthenium[edit] In , a team of University of Minnesota physicists demonstrated that body-centered tetragonal ruthenium exhibits ferromagnetism at room temperature. Magnetism is now regarded as a purely quantum mechanical effect. Ferromagnetism arises due to two effects from quantum mechanics: This dipole moment comes from the more fundamental property of the electron that it has quantum mechanical spin. Due to its quantum nature, the spin of the electron can be in one of only two states; with the magnetic field either pointing "up" or "down" for any choice of up and down. The spin of the electrons in atoms is the main source of ferromagnetism, although there is also a contribution from the orbital angular momentum of the electron about the nucleus. When these magnetic dipoles in a piece of matter are aligned, point in the same direction their individually tiny magnetic fields add together to create a much larger macroscopic field. Only atoms with partially filled shells i. These unpaired dipoles often called simply "spins" even though they also generally include orbital angular momentum tend to align in parallel to an external magnetic field, an effect called paramagnetism. Ferromagnetism involves an additional phenomenon, however: Exchange interaction When two nearby atoms have unpaired electrons, whether the electron spins are parallel or antiparallel affects whether the electrons can share the same orbit as a result of the quantum mechanical effect called the exchange interaction. This in turn affects the electron location and the Coulomb electrostatic interaction and thus the energy difference between these states. The exchange interaction is related to the Pauli exclusion principle , which says that two electrons with the same spin cannot also be in the same spatial state orbital. This is a consequence of the spin-statistics theorem and that electrons are fermions. Therefore, under certain conditions, when the orbitals of the unpaired outer valence electrons from adjacent atoms overlap, the distributions of their electric charge in space are farther apart when the electrons have parallel spins than when they have opposite spins. This reduces the electrostatic energy of the electrons when their spins are parallel compared to their energy when the spins are anti-parallel, so the parallel-spin state is more stable. In simple terms, the electrons, which repel one another, can move "further apart" by aligning their spins, so the spins of these electrons tend to line up. This difference in energy is called the exchange energy. This energy difference can be orders of magnitude larger than the energy differences associated with the magnetic dipole-dipole interaction due to dipole orientation, [14] which tends to align the dipoles antiparallel. In certain doped semiconductor oxides RKKY interactions have been shown to bring about periodic longer-range magnetic interactions, a phenomenon of significance in the study of spintronic materials. For instance, in iron Fe the exchange force is about times stronger than the dipole interaction. Therefore, below the Curie temperature virtually all of the dipoles in a ferromagnetic material will be aligned. In addition to ferromagnetism, the exchange interaction is also responsible for the other types of spontaneous ordering of atomic magnetic moments occurring in magnetic solids, antiferromagnetism and ferrimagnetism. There are different exchange interaction mechanisms which create the magnetism in different ferromagnetic, ferrimagnetic, and antiferromagnetic substances. These mechanisms include direct exchange , RKKY exchange , double exchange , and superexchange. Magnetic anisotropy Although the exchange interaction keeps spins aligned, it does not align them in a particular direction. Without magnetic anisotropy , the spins in a magnet randomly change direction in response to thermal fluctuations and the magnet is superparamagnetic. There are several kinds of magnetic anisotropy, the most common of which is magnetocrystalline anisotropy. This is a dependence of the energy on the direction of magnetization relative to the crystallographic lattice. Another common source of anisotropy, inverse magnetostriction , is induced by internal strains. Single-domain magnets also can have a shape anisotropy due to the magnetostatic effects of the particle shape.

As the temperature of a magnet increases, the anisotropy tends to decrease, and there is often a blocking temperature at which a transition to superparamagnetism occurs. Kerr micrograph of metal surface showing magnetic domains, with red and green stripes denoting opposite magnetization directions. Magnetic domain The above would seem to suggest that every piece of ferromagnetic material should have a strong magnetic field, since all the spins are aligned, yet iron and other ferromagnets are often found in an "unmagnetized" state. The reason for this is that a bulk piece of ferromagnetic material is divided into tiny regions called magnetic domains [17] also known as Weiss domains. Within each domain, the spins are aligned, but if the bulk material is in its lowest energy configuration; i. Ferromagnetic materials spontaneously divide into magnetic domains because the exchange interaction is a short-range force, so over long distances of many atoms the tendency of the magnetic dipoles to reduce their energy by orienting in opposite directions wins out. If all the dipoles in a piece of ferromagnetic material are aligned parallel, it creates a large magnetic field extending into the space around it. This contains a lot of magnetostatic energy. The material can reduce this energy by splitting into many domains pointing in different directions, so the magnetic field is confined to small local fields in the material, reducing the volume of the field. Magnetized materials[edit] Moving domain walls in a grain of silicon steel caused by an increasing external magnetic field in the "downward" direction, observed in a Kerr microscope. White areas are domains with magnetization directed up, dark areas are domains with magnetization directed down. Thus, a piece of iron in its lowest energy state "unmagnetized" generally has little or no net magnetic field. However, the magnetic domains in a material are not fixed in place; they are simply regions where the spins of the electrons have aligned spontaneously due to their magnetic fields, and thus can be altered by an external magnetic field. If a strong enough external magnetic field is applied to the material, the domain walls will move by the process of the spins of the electrons in atoms near the wall in one domain turning under the influence of the external field to face in the same direction as the electrons in the other domain, thus reorienting the domains so more of the dipoles are aligned with the external field. The domains will remain aligned when the external field is removed, creating a magnetic field of their own extending into the space around the material, thus creating a "permanent" magnet. This is shown by the Barkhausen effect: This magnetization as a function of the external field is described by a hysteresis curve. Although this state of aligned domains found in a piece of magnetized ferromagnetic material is not a minimal-energy configuration, it is metastable , and can persist for long periods, as shown by samples of magnetite from the sea floor which have maintained their magnetization for millions of years. Heating and then cooling annealing a magnetized material, subjecting it to vibration by hammering it, or applying a rapidly oscillating magnetic field from a degaussing coil tends to release the domain walls from their pinned state, and the domain boundaries tend to move back to a lower energy configuration with less external magnetic field, thus demagnetizing the material. Commercial magnets are made of "hard" ferromagnetic or ferrimagnetic materials with very large magnetic anisotropy such as alnico and ferrites , which have a very strong tendency for the magnetization to be pointed along one axis of the crystal, the "easy axis". During manufacture the materials are subjected to various metallurgical processes in a powerful magnetic field, which aligns the crystal grains so their "easy" axes of magnetization all point in the same direction. Thus the magnetization, and the resulting magnetic field, is "built in" to the crystal structure of the material, making it very difficult to demagnetize. Curie temperature As the temperature increases, thermal motion, or entropy , competes with the ferromagnetic tendency for dipoles to align. When the temperature rises beyond a certain point, called the Curie temperature , there is a second-order phase transition and the system can no longer maintain a spontaneous magnetization, so its ability to be magnetized or attracted to a magnet disappears, although it still responds paramagnetically to an external field. Below that temperature, there is a spontaneous symmetry breaking and magnetic moments become aligned with their neighbors. The Curie temperature itself is a critical point , where the magnetic susceptibility is theoretically infinite and, although there is no net magnetization, domain-like spin correlations fluctuate at all length scales. The study of ferromagnetic phase transitions, especially via the simplified Ising spin model, had an important impact on the development of statistical physics. There, it was first clearly shown that mean field theory approaches failed to predict the correct behavior at the critical point which was found to fall under a universality class that includes many other systems, such as liquid-gas transitions , and had to be replaced by renormalization group theory.

Chapter 4 : EXPLORING: The domain theory of magnetism

Domain Theory. A remarkable property of ferrimagnetic materials is not so much that they have a spontaneous magnetization, but rather that their magnetization can be influenced by the application of very low magnetic fields.

The compass, an important device for navigation, has a suspended magnet which aligns parallel to the magnetic field produced by the Earth and as a result points to the North pole The compass was documented as early as The Ching Tsung Yao describes how iron can be magnetised by heating and quenching in water. It is known that the Vikings used Lodestone to navigate. By the end of the twelfth century, Europeans were using this simple compass to aid navigation. A steel needle stroked with such a "lodestone" became "magnetic" as well. In , William Gilbert also known as Gilberd of Colchester proposed an explanation in his work De Magnet for the operation of the compass and that The Earth itself was a giant magnet, with its magnetic poles some distance away from its geographic ones i. He made an experimental model of the earth by creating a Lodestone sphere. Properties of Magnets William Gilbert also experimented on bar magnets and found the following properties: A magnet will always have two poles which we call arbitrarily North and South. I the magnet is broken in two this will create two new magnets with North N and South S poles. If a bar magnet is broken in two, at the fracture new north and south poles are formed at the point of fracture. Properties of Magnets Like poles repel each other. If a N pole is brought close to the N pole of a second magnet a repulsive force will be felt. Similarly if a S pole is brought close to the S pole of another magnet, the two magnets will repel each other. Unlike poles attract and will stick together. Magnets attract iron rich materials and like poles and the repulsion between like poles can be reduced if a strip of iron is placed between them. The Domain Theory of Magnetism How can we explain these intriguing properties? The domain theory states that inside a magnet there are small regions in which the magnetic direction of all the atoms are aligned in the same directions. These regions are known as domains. Within a domain, the aligment of the magnetic direction is the same. In the next domain it may be in a completely different direction. On average over the many domains in the magnet there there is no preferential direction for the magnetic force. However, using an external magnetic field from another magnet say, the direction of the magnetic direction in each domain can be made to align with the magnetic field the net magnetic field can be increased. Why do Magnetic Domains Form? Consider a bar magnet which has been been magnetised such that the entire magnet forms a single magnetic domain. Surface charges will appear at either end of the crystal. Associated with the surface charges is a secondary magnetic field called the demagnetising field which acts to reduce the magnetic field. The energy of the surface charges is called the magnetostatic energy. Domain Formation in a Magnet The magnetostatic energy can be reduced if the crystal forms a second domain, magnetised in the opposite direction. In this way, the separation of positive and negative surface charges are reduced decreasing the spatial extent of the demagnetising field. Naturally, one might ask, if the magnetostatic energy is reduced by the formation of domains, can they carry on forming indefinitely? To which the answer is no. The reason being that energy is required to produce and maintain the region of transition from one domain to another, the domain wall. Equilibrium will be reached when the magnetostatic energy is equal to the energy required to maintain the domain walls. However, domains are much larger than the individual molecules within the magnet. There are only 4 ferromagnetic elements at room temperature. Of these, iron Fe , nickel Ni , and cobalt Co are shown above. The fourth is gadolinium Gd. The pictures below show the formation made visible with the use of magnetic colloidal suspensions which concentrate along the domain boundaries. The domain boundaries can be imaged by polarized light, and also with the use of electron diffraction. Observation of domain boundary movement under the influence of applied magnetic fields has aided in the development of theoretical treatments. It has been demonstrated that the formation of domains minimizes the magnetic contribution to the free energy. If a magnetic field is applied to the crystal, the domains that align with the magentic field will grow as the expense of the domains that are pointing in other directions. Atomic Theory of Magnetism We are familiar with the model of the atom with a nucleus that contains the protons and neutrons and electron orbit the nucleus. Within the atom, the electrons behave as if they are magnets. Electrons, protons and neutrons all have a magnetic dipole moments however the magnetic moment of an electron is the most significant. In fact it is conveniently assigned a unit called the Bohr magneton, which is equal to the magnetic dipole moment of an electron. The Magnetic Field Magnetic field strength is given the symbol H with the unit Tesla Magnetic flux density is given the symbol B and has the unit W m-2 To measure the magnetic field caused by a current the Biot Savart law is used The magnetic field is a vector field which means that it has a magnitude and direction for each point in space. The strength and direction of the magnetic field at any point is defined in terms of the force on a moving charged particle such as an electron. The force created the magnetic field comes from the Lorentz equation without the electric field. The magnetude and direction come from the Lorentz force equation. Since a magnetic monopole has never been found, it does not make sense to talk about a magnetic point charge. Instead, lines of magnetic field form closed loops along line of equal magnetic force. The strength of the magnetic field is determined by the number of field lines passing a unit area. The more field lines the stronger the magnetic field. A unit of magnetic field strength is known as the Gauss is defined as one magnetic field line per square centimetre. The direction of the field line could be determined by using a compass needle. Its direction creates a tangent line to the magnetic field at that point. By convention the arrow tip on magnetic field lines points towards the south magnetic pole and away from the north magnetic pole. The magnetic poles alway occur in pairs, no one has ever found a magnetic monopole, though there is research into their posible existance. The image shows the field lines produced by a bar magnet. Iron fillings are sprinked on a piece of paper and the bar-magnet is placed under the paper. The iron-fillings line up and show the intensity of the magnetic field.

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Chapter 5 : DOMAIN THEORY OF MAGNETISM - Microsoft in Education

Simple Domain Theory Of Magnetism Posted on February 16, by John Vagabond It's no coincidence that the three common magnetic materials, iron, nickel and cobalt are next to each other in the Periodic Table.

Magnets[change change source] Magnetism can be made by a permanent magnet , or by electricity in a wire. This is called an electromagnet. When magnets are put near magnetic objects, the magnet and the object are pulled toward each other. This is called magnetic attraction. Magnets can also repel push away other magnets. Most objects that are attracted to magnets have iron in them. Most other metals, such as aluminium , are not attracted to magnets. Magnetic fields[change change source] Magnets have an unseen area around them called a " magnetic field ". Magnetic objects inside this unseen field are attracted to the magnet. Magnetic things outside the magnetic field are not attracted to the magnet. This is why a magnet must be close to an object to attract it. The poles of two magnets repel or attract each other. Different poles attract each other. For example, if the south pole of one magnet is put near the south pole of another magnet, the magnets will repel each other. This will also happen with two north poles that are put near each other. If a north pole is put near a south pole, the magnets will attract each other until they stick to each other and can be hard to pull apart. Magnetic domains[change change source] Magnetism is caused by electrons the negative particles in atoms that are also electric charges spinning. The more a group of electrons spin in the same direction, the stronger the magnetic force. In a magnet, many electrons are spinning in the same direction. Uses of magnets[change change source] Magnets have many uses. Electromagnets and electromagnetism[change change source] Electromagnets are another kind of magnet. They only work when electricity is running through them. An electric current makes a magnetic field. If you wrap the wire into a coil, the electrons spin around the coil and make a stronger magnetic domain. Often, these magnets work by using a coil of wire that makes a magnetic field when there is a current in it. In addition to this coil of wire, a large piece of metal, usually iron, is placed inside the coil to increase the magnetic field made. Though most large electromagnets employ many solenoids to lift heavy objects, smaller solenoids are used in everyday electronics. For example, they are used to change voltage in a transformer. Electromagnets are used to make many things work like computers , televisions and radios and also doorbells.

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Chapter 6 : domains theory of magnetism? | Yahoo Answers

Ferromagnetism. The domain theory of magnetism. In some materials, of which iron, steel, and certain alloys are outstanding examples, the atomic magnets or dipoles do not act independently as in paramagnetic substances but small groups interact with one another so that their magnetic axes spontaneously line up together in a certain preferred direction.

Later, the quantum theory made it possible to understand the microscopic origin of the Weiss field. The exchange interaction between localized spins favored a parallel in ferromagnets or an anti-parallel in anti-ferromagnets state of neighboring magnetic moments How dividing a ferromagnetic material into magnetic domains reduces the magnetostatic energy Why domains form[edit] The reason a piece of magnetic material such as iron spontaneously divides into separate domains, rather than exist in a state with magnetization in the same direction throughout the material, is to minimize its internal energy. This requires a lot of magnetostatic energy stored in the field. To reduce this energy, the sample can split into two domains, with the magnetization in opposite directions in each domain diagram b right. The magnetic field lines pass in loops in opposite directions through each domain, reducing the field outside the material. To reduce the field energy further, each of these domains can split also, resulting in smaller parallel domains with magnetization in alternating directions, with smaller amounts of field outside the material. The domain structure of actual magnetic materials does not usually form by the process of large domains splitting into smaller ones as described here. When a sample is cooled below the Curie temperature, for example, the equilibrium domain configuration simply appears. But domains can split, and the description of domains splitting is often used to reveal the energy tradeoffs in domain formation. Size of domains[edit] As explained above, a domain which is too big is unstable, and will divide into smaller domains. But a small enough domain will be stable and will not split, and this determines the size of the domains created in a material. This size depends on the balance of several energies within the material. The exchange interaction which creates the magnetization is a force which tends to align nearby dipoles so they point in the same direction. Forcing adjacent dipoles to point in different directions requires energy. Therefore, a domain wall requires extra energy, called the domain wall energy , which is proportional to the area of the wall. Thus the net amount that the energy is reduced when a domain splits is equal to the difference between the magnetic field energy saved, and the additional energy required to create the domain wall. The field energy is proportional to the cube of the domain size, while the domain wall energy is proportional to the square of the domain size. So as the domains get smaller, the net energy saved by splitting decreases. The domains keep dividing into smaller domains until the energy cost of creating an additional domain wall is just equal to the field energy saved. Then the domains of this size are stable. Magnetic anisotropy[edit] Micrograph of surface of ferromagnetic material, showing the crystal grains, each divided into several domains parallel to its "easy" axis of magnetization, with the magnetization in alternating directions red and green areas. Animation showing how magnetostriction works. A changing external magnetic field causes the magnetic dipoles to rotate, changing the dimensions of the crystal lattice. An additional way for the material to further reduce its magnetostatic energy is to form domains with magnetization at right angles to the other domains diagram c, right , instead of just in opposing parallel directions. However, forming these domains incurs two additional energy costs. First, the crystal lattice of most magnetic materials has magnetic anisotropy , which means it has an "easy" direction of magnetization, parallel to one of the crystal axes. Changing the magnetization of the material to any other direction takes additional energy, called the " magnetocrystalline anisotropy energy ". Magnetostriction[edit] The other energy cost to creating domains with magnetization at an angle to the "easy" direction is caused by the phenomenon called magnetostriction. The change in magnetic field causes the magnetic dipole molecules to change shape slightly, making the crystal lattice longer in one dimension and shorter in other dimensions. However, since the magnetic domain is "squished in" with its boundaries held rigid by the surrounding material, it cannot actually change shape. So instead, changing the direction of the magnetization induces tiny mechanical stresses in the material, requiring more energy to create the domain. This is called " magnetoelastic anisotropy energy". To form these closure domains with "sideways" magnetization requires additional energy due to the aforementioned two factors. So flux closure domains will only form where the magnetostatic energy saved is greater than the sum of the "exchange energy" to create the domain wall, the magnetocrystalline anisotropy energy, and the magnetoelastic anisotropy energy. Therefore, most of the volume of the material is occupied by domains with magnetization either "up" or "down" along the "easy" direction, and the flux closure domains only form in small areas at the edges of the other domains where they are needed to provide a path for magnetic field lines to change direction diagram c, above. Grain structure[edit] The above describes magnetic domain structure in a perfect crystal lattice, such as would be found in a single crystal of iron. However most magnetic materials are polycrystalline , composed of microscopic crystalline grains. These grains are not the same as domains. Each grain is a little crystal, with the crystal lattices of separate grains oriented in random directions. In most materials, each grain is big enough to contain several domains. Each crystal has an "easy" axis of magnetization, and is divided into domains with the axis of magnetization parallel to this axis, in alternate directions. The magnetization of neighboring domains point in different directions, confining the field lines to microscopic loops between neighboring domains within the material, so the combined fields cancel at a distance. Therefore, a bulk piece of ferromagnetic material in its lowest energy state has little or no external magnetic field. The material is said to be "unmagnetized". However, the domains can also exist in other configurations in which their magnetization mostly points in the same direction, creating an external magnetic field. Although these are not minimum energy configurations, due to a phenomenon where the domain walls become "pinned" to defects in the crystal lattice they can be local minimums of the energy, and therefore can be very stable. Applying an external magnetic field to the material can make the domain walls move, causing the domains aligned with the field to grow, and the opposing domains to shrink. When the external field is removed, the domain walls remain pinned in their new orientation and the aligned domains produce a magnetic field. This is what happens when a piece of ferromagnetic material is "magnetized" and becomes a permanent magnet. Heating a magnet, subjecting it to vibration by hammering it, or applying a rapidly oscillating magnetic field from a degaussing coil , tends to pull the domain walls free from their pinned states, and they will return to a lower energy configuration with less external magnetic field, thus " demagnetizing " the material. Landau-Lifshitz energy equation[edit] Electromagnetic dynamic magnetic domain motion of grain oriented electrical silicon steel Moving domain walls in a grain of silicon steel caused by an increasing external magnetic field in the "downward" direction, observed in a Kerr microscope. White areas are domains with magnetization directed up, dark areas are domains with magnetization directed down. The contributions of the different internal energy factors described above is expressed by the free energy equation proposed by Lev Landau and Evgeny Lifshitz in , [4] which forms the basis of the modern theory of magnetic domains. The domain structure of a material is the one which minimizes the Gibbs free energy of the material. For a crystal of magnetic material, this is the Landau-Lifshitz free energy, E, which is the sum of these energy terms:

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Chapter 7 : Simple Domain Theory Of Magnetism | Physics and Chemistry for IG and A level

Domain theory also gives us an easy way to look at demagnetizing an existing magnet. â€¢ If you drop a magnet on the floor or strike it with a hammer, you are basically adding energy to the atoms of magnet.

This theory assumes that all magnetic substances are composed of tiny molecular magnets. Any unmagnetized material has the magnetic forces of its molecular magnets neutralized by adjacent molecular magnets, thereby eliminating any magnetic effect. A magnetized material will have most of its molecular magnets lined up so that the north pole of each molecule points in one direction, and the south pole faces the opposite direction. A material with its molecules thus aligned will then have one effective north pole, and one effective south pole. When a steel bar is stroked several times in the same direction by a magnet, the magnetic force from the north pole of the magnet causes the molecules to align themselves. Test Yourself Domain Theory A more modern theory of magnetism is based on the electron spin principle. From the study of atomic structure it is known that all matter is composed of vast quantities of atoms, each atom containing one or more orbital electrons. The electrons are considered to orbit in various shells and subshells depending upon their distance from the nucleus. The structure of the atom has previously been compared to the solar system, wherein the electrons orbiting the nucleus correspond to the planets orbiting the sun. Along with its orbital motion about the sun, each planet also revolves on its axis. It is believed that the electron also revolves on its axis as it orbits the nucleus of an atom. It has been experimentally proven that an electron has a magnetic field about it along with an electric field. The effectiveness of the magnetic field of an atom is determined by the number of electrons spinning in each direction. If an atom has equal numbers of electrons spinning in opposite directions, the magnetic fields surrounding the electrons cancel one another, and the atom is unmagnetized. However, if more electrons spin in one direction than another, the atom is magnetized. An atom with an atomic number of 26, such as iron, has 26 protons in the nucleus and 26 revolving electrons orbiting its nucleus. If 13 electrons are spinning in a clockwise direction and 13 electrons are spinning in a counterclockwise direction, the opposing magnetic fields will be neutralized. When more than 13 electrons spin in either direction, the atom is magnetized. An example of a magnetized atom of iron is shown in figure A pattern of this directional force can be obtained by performing an experiment with iron filings. A piece of glass is placed over a bar magnet and the iron filings are then sprinkled on the surface of the glass. The magnetizing force of the magnet will be felt through the glass and each iron filing becomes a temporary magnet. If the glass is now tapped gently, the iron particles will align themselves with the magnetic field surrounding the magnet just as the compass needle did previously. The filings form a definite pattern, which is a visible representation of the forces comprising the magnetic field. Examination of the arrangements of iron filings in figure will indicate that the magnetic field is very strong at the poles and weakens as the distance from the poles increases. It is also apparent that the magnetic field extends from one pole to the other, constituting a loop about the magnet. Refer to figure For what purpose would you sprinkle iron filings on the glass plate? What pattern would be formed if sawdust was sprinkled on the glass instead of iron filings?

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Like the domain theory, atomic theory can explain many of the things we know about magnets, including paramagnetism (the way magnetic materials line up with magnetic fields). Most of the electrons in an atom exist in pairs that spin in opposite directions, so the magnetic effect of one electron in a pair cancels out the effect of its partner.

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Domain Theory. A more modern theory of magnetism is based on the electron spin principle. From the study of atomic structure it is known that all matter is composed of vast quantities of atoms, each atom containing one or more orbital electrons.