Get a Straight Answer

Please note!

Listed below are questions submitted by e-mail to the author of "The Great Magnet, the Earth." Some of them (marked ***) came in response to an earlier site "The Exploration of the Earth's Magnetosphere" and are also found there in the question-and-answer section. Only some of the questions that arrive are listed, **either** because they keep coming up again and again--on the reversal of the Earth's magnetic field, for instance--**or** because the answers add extra details, which might interest other users.

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If you have a relevant question of your own, you can send it to
earthmag("at" symbol)phy6.org
Before you do, though, please read the instructions

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1. What is "Magnetic Flux" and what are "Flux Lines"?

I am retired from IBM. I love to read about space and astrophysics. When reading about the magnetic force, flux lines are mentioned. My question is: what are these flux lines made of. Does the magnetic force field have an exchange particle? Or are magnetic flux lines absent of any particles? This area never seems to be covered in any articles that I have read.

Reply

Dear Paul

"Flux lines" is another name for magnetic field lines, originally named "magnetic lines of force" by Michael Faraday, who introduced them.

What is "flux"? You may be aware that the mathematical description of **magnetic fields** is very similar to that of **a fluid like water,** which cannot be compressed. Where magnetic fields have **"field lines"**, flowing water has **"streamlines"** (we talk about the interior flow, ignore the surface) and both field lines and flux lines are closed loops.

In describing "fluid motion" the "flux" through an area--or the one carried by a bundle of streamlines--is the amount of water crossing it per second, or crossing each second any cross section of the bundle. Magnetic flux of a bundle of lines is similarly the cross sectional area of a bundle of field lines, TIMES the average field intensity on it. Mathematically, both are similar. Flux is important in designing transformers, etc. Some engineers call the flux through a cross section "the number of magnetic field lines" through it, but it's the same thing. You can see from that how the word "flux line" arose.

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2. Is the surface of the Earth expanding?

I am a university student taking business, I often have a few interests during a week of abstract ideas. I am currently in two geology courses as electives, and that is how I stumbled across your homepage, while looking for information on the movement/change reversal of our magnetic poles.

Part of our geology course was obviously the expanding and contracting of the continental plates. On average, using your knowledge, does the surface of the earth increase or decrease within terms of expanding from plate movement, and if so (I'm going to try to phrase this intelligently) does the atmosphere end up spreading itself thinner and therefore covering the new surface of the earth?

Reply

Dear David

It is difficult to reconstruct what went on millions of years ago. However, one can be pretty sure that **at the present time** (1) The crustal plates of the Earth **are** moving and (2) The Earth IS **not** expanding or shrinking.

Point (1) was confirmed by accurate distance measurements based on signals from radio stars, the VLBI experiment (Very Large Baseline Interferometer), and more recently by the satellite-based Global Positioning System (GPS) which (as you might know) is capable of greater accuracy than the public is allowed to use. Point (2) is derived by comparing the observed rotation period of the Earth, measured by telescopes, with very accurate clocks. Even a tiny expansion or contraction would slow down or speed up the Earth's rotation. The Earth's rotation is observed to slow down, but from all I know this is explained by loss rotational energy to ocean tides, which transfer angular momentum to the Moon.

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3. Will a compass work inside a car?

Dear Dr. Stern,

I was recently told that a compass will not work inside of a metal building. Is that true? Doesn't the field still propagate through the concrete floor, even though surrounded by a metal roof and walls? Also, I'm told that compasses that are available in automobiles must be specifically calibrated to compensate for their metal enclosure.

Reply

Dear Gordon

It is true that iron channels magnetic fields. Magnetic field lines of the Earth crowd into any iron oriented north-south, and since they are denser inside the iron, in the surrounding space they are more spread out, that is, the magnetic intensity there is weaker. Iron walls (if sufficiently thick) can therefore shield out magnetic fields, as described in http://www.phy6.org/earthmag/magmeter.htm , "About Electronic Magnetometers and about Smoking" (last section there).

However, I don't think a reinforced concrete building has enough iron to make much of a difference. Cars may be somewhat different, and their structural iron may be the reason why a car compass is usually mounted high on the windshield, next to the rear-view mirror. The accuracy demanded of car compasses is in any case so small--they only need enough to tell a right road from a wrong one-- that small deviations may be tolerated.

It is not so with ships and airplanes, whose navigation demands precision. Thanks to today's global positioning system, and before that, to gyrocompasses and radio beacons, this may be a moot point, but at least up to WW II the magnetic correction to a magnetic compass on a ship was quite important. The compass was placed on a pedestal called the binnacle, under an ellipsoidal cover of brass (brass has no magnetic influence) with spheres and bars of soft iron attached on the side, their positions calibrated to cancel the ship's effect. The binnacle stood in the open, since the enclosed bridge was surrounded by iron, but an electric repeater provided a helmsman inside the bridge with the compass heading.

I hope this tells you all you wanted to know.

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4. Pole Shifts? What Pole Shifts?

Given current knowledge on the subject of a pole shifts, where would the exact pivot point be and nearest large city in such an event. How does Antarctic ice buildup effect this process? What is the likelihood of such an event in our lifetime? Best guess?

Reply

Dear Gary

I am not sure what you mean. The poles of the Earth wobble in a small circle, a fraction of a mile-- due, I believe, to the attraction of the Moon on the equatorial bulge (I may be wrong here, have not checked). However, that is apparently not what you have in mind.

Before 1965, there existed a theory of "polar wandering" by which the poles wandered all over the Earth's surface--or to be more accurate, the crust of the Earth slid around the interior which, containing most of the angular momentum, rotated more or less without change. That theory was motivated by the magnetic record in lavas: when lava from a volcano hardens, it records the direction of the Earth's magnetism at that time. Geologists, examining ancient lavas, found that at times north and south were interchanged, and for India, it was 90 degrees from either direction.

From the magnetization of the sea floor we now know better (see http://istp.gsfc.nasa.gov/earthmag/reversal.htm). Those observations led to "plate tectonics," suggesting that pieces of the crust indeed move slowly, but not at all in unison--different plates move differently. India has moved from south of the equator to where it is now (and the collision continues, raising the Himalaya mountains). We also understand that in the past the Earth's magnetic poles exchanged polarity now and then, typically half a million years apart (on the Sun this happens every 11 years or so).

The poles thus don's shift. Land masses may shift--one half of San Francisco is sliding past the other half, for instance, with the San Andreas fault in between. But the rate is only about one inch per year.

5. What was it that Ned Benton did?

Dear Dr. Stern,

I was reading a section 'Gauss and Global Magnetic Field ' from http://istp.gsfc.nasa.gov/earthmag/gauss.htm and encountered your reference late Ned Benton. Excuse my ignorance - who was Ned Benton. Could you give me reference of his work saying that the Earth's magnetic field may not reach zero but at some stage the polarity of the geomagnetic field may flip as observed from paleomagnetic studies.

Reply

Dear Nalin

Ned (Edward) Benton was a researcher of geomagnetism, who studied the slow changes of the core's magnetic field. He died in the mid-1980s, of cancer and still quite young.

The Earth's field slowly changes, all the time. As explained in the section on Gauss, the field can be resolved into terms that depend on distance R like 1 over the 3rd, 4th, 5th etc. power of R: the dipole goes like $1/R^3$ and increasing powers are associated with parts of increasing complexity.

The complex parts--e.g. those that go like $1/R^7$ are very small at the surface of the Earth, but clearly they grow much faster than the dipole as you move inwards: at a distance of half the radius of the Earth, for instance, the dipole field is 8 times stronger, but the $1/R^7$ Actually, of course, you can only do so up to the boundary of the core: after that you are in a region of electric currents, and the description introduced by Gauss must be replaced with a different one, which does not grow so fast.

The Earth's dipole field is declining at a rate that suggests it will cross zero before the year 4000. Benton (and his colleague Coerte Voorhies) however knew that a certain theorem, developed by Raymond Hide, required the total unsigned flux leaving the surface of the core (counting negatives as if they had a positive sign, too) to stay the same all the time (assuming the electric conductivity is very high).

This does not allow the field to simply decay. What seems to be happening instead that magnetic flux (intensity time area, weighed over an area in a certain way) of the main north-south field is indeed weakening, but more complex parts of the field meanwhile increase. These component decay more rapidly with distance from the Earth's core, so they contribute relatively little, and the overall result is that as the field grows more complex, it also gets weaker. During reversals you will see a weaker magnetic field and perhaps 4 or more magnetic poles, but the field never vanishes.

You can now see why I was reluctant to go into details! They can be much more complicated. But that is what physics usually involves.

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6. Four questions about Magnetic Reversals ***

Later note: These messages date back some years. More details on the subject were since then added on these web files, especially in the article **"A Millennium of Geomagnetism"**

Question #6-A

I need to know as much as possible about the reversal of the magnetic field:

- how it was noticed
- who discovered the reversal
- how long ago did it reverse
- how many times did it reverse
- more information about the radiation from the sun if the magnetic field reverses.

Reply

ABOUT GEOMAGNETIC REVERSALS: This is a huge subject and I cannot do quick justice to it: look up in the index volume of the Britannica under: Geomagnetism, Plate tectonics, Reversals of the Earth's magnetic field.

HOW IT WAS NOTICED: When lava pours from a volcano, it solidifies to a black rock called basalt. Basalt is slightly magnetic, and it takes on the direction of the surrounding magnetic field at the time it solidifies. Scientists examined lavas for their magnetism early in this century (I believe) to see how consistent the direction of ancient magnetic fields was with the direction we observe now (would compasses point in the same direction?). The directions generally agreed, but there existed reversals of directions which suggested that there were times in the past when the poles were roughly interchanged.

No one knew what to make of it. Some suggested "polar wandering", that the whole surface of the Earth slid around the interior like a loose shell.

WHO DISCOVERED: I don't remember. Check a book by Allan Cox, a collection of historic articles.

But a big change happened in 1963. People noted that while rocks on

Earth were magnetized in a disordered way, the sea bottom was magnetized in long strips. Larry Morley (whose article was regarded so speculative that journals would not publish it) and then Matthews and Vine (who managed to publish) suggested that molten rock was spreading out like a conveyer belt from volcanic cracks in the middle of the ocean floor, e.g. the one in the middle of the Atlantic (Azores islands sit on it). Or rather like 2 belts, one moving towards Europe, one towards America, carrying on them the continental plates, so that Europe and America gradually drift apart. As each belt comes out of the crack, its lava solidifies to basalt, causing it to become magnetized, and when the field reverses, its magnetization reverses too. So the bottom of the ocean records the field like the tape of a tape recorder, containing perhaps 50 million years of record.

HOW LONG AGO: about 700,000 years, according to the "tape recorder"

HOW MANY TIMES: Many, about half a million years apart on the average.

RADIATION FROM THE SUN: Sunlight of course is undisturbed. High-energy protons from the Sun are usually diverted by the magnetic field. During the reversal the field probably does not disappear, but becomes complex and weaker, and protons can more easily reach the atmosphere, as they do now within 1000 miles or so of the magnetic pole. On the ground it makes no difference because the thick atmosphere shields us very well, and none of the protons penetrates far into it.

Question #6-B

Reversal of magnetosphere

We have been studying the magnetosphere and the Van Allen radiation belts in a high school physical science class. It has been brought to our attention that the magnetic poles of the earth reverse on an average of about every 500,000 years. The last change was about 700,000 years ago, so it would appear that we are long overdue.

What are the implications of this? How significant would the fluctuation of the magnetic field during such a change be on our protection from solar wind?

Ricky

Reply

Dear Ricky

Only yesterday a similar question was submitted, so as a shortcut a copy of it *[next item below]* and its answer are attached below.

Some people worry that during magnetic reversals the Earth would receive a higher dosage of high-energy ions and electrons ("radiation" in common terms), which might affect us and any living creatures on Earth. This is not so. Even today, the magnetic shield is not effective near the magnetic poles, yet the radiation received there on the ground is only slightly higher than anywhere else. The reason is that our main shield against such particles is not the magnetic field of the Earth but the atmosphere, equivalent to some 10 feet of concrete.

In any case, during reversal the magnetic field does not go away, it only gets weaker and develops several more magnetic poles, at unpredictable locations.

Question #6-C

Could you tell me when the earth's magnetic poles will change, and what will happen when it does? Will it happen fast (seconds) or slowly? Thank you!
Sarah

Reply

Dear Sarah

No one knows when the next field reversal will occur: in the past, they have occurred on the average about once in 500,000 years. The change, whenever it occurs, will be gradual and the field will not drop to zero in between--doing so would mean that the magnetic energy of the Earth was somehow converted or dissipated, and all processes we know for this tend to run on scales of thousands of year, if not more.

Right now the main (dipole) field is getting weaker at a rate of about 7% per century, and if you draw a straight line through the points you find it reversing between 1000 and 2000 years from now. It might happen, though the trend may also change before then. But as explained elsewhere, even if a reversal occurs, the field does not disappear during the time of polarity change, it just gets more complex and weaker.

The polar field of the Sun seems to reverse every 11 years or so, taking about a year or more. But the Sun's magnetism is different, it has foci right on the surface, in sunspots.

Question #6-D

Earth's magnetic field weakening--leading to a pole shift?

I am just a tax paying citizen, interested in astronomy all of my life. I am very interested in the physics of our Earth which I believe is related to astronomy as it is our home and a part of this solar system.

My question is: Is the Earth"s magnetic field weakening, heading to zero point? With this, is the base pulse frequency of the Earth speeding up causing the magnetic fields to fluctuate so that it interferes with the pilots navigational equipment, so that the navigational charts have to be redrawn periodically and the air strips renumbered? Are the magnetic poles fluctuating? My experience is that they are. I have a quality, liquid filled compass secured to my desk. It has been very still now for the past month but the six weeks or so prior to that, there were consistent fluctuations in its direction, up to as much as 2 1/2 degrees, always to the west.

My understanding is: I have seen photographs of the sun taken from satellites, showing the sun going through major activity. Repolarizing itself? Causing the earth to repolarize itself? Going through a natural cycle as it has many times in the past with pole shifts? On a scale from 1 to 10, with 1 being the weakest and 10 the strongest, 2,000 years ago it was a 10, today it is a 1. Is it heading for a zero point when a pole shift will occur? The closer it gets to the zero point, the more fluctuations will occur?

Are the change in the magnetic frequencies causing at times a confusion in migratory animals? Causing cells to mutate, changing the DNA pattern within the cell? Causing certain strains of bacteria such as staph infections to become resistant to our antibiotics and causing new viruses to appear that we have never seen before, being able to survive in a new magnetic frequency?

I believe these are very fascinating times in which we live. The science of all of this intrigues me to no end. I have some taped interviews of scientists and geologists relating to this subject and I read all that I can get my hands on, on the subject also. Your straightforward comments and answers will be most welcomed to help me to understand more, what is taking place. Thank you so very much.

Michael

Reply

Dear Michael

Questions on reversals regularly arrive at this desk, and some others are listed above. By the way, the source of the magnetic field is not any polarization (at the Sun or Earth) but electric currents, flowing below the visible surface of the Earth or Sun. In the present collection "The Great Magnet, the Earth you will find a great deal of material on the magnetic fields of Earth and Sun and the way they probably arise.

Now to your questions.

Is the Earth's field getting weaker? Yes and no. That field is often viewed as being a two-pole ("dipole") structure similar to that of a small bar-magnet at the center of the Earth, inclined by about 11 degrees to the rotation axis of the Earth, so that the magnetic poles are not the same as the geographic ones. But the actual situation is more complicated, and magnetic charts note the fact by mapping deviations between magnetic north and the direction to the magnetic pole, which fit no simple pattern.

Why? Because the magnetic field is actually more complicated, and it contains additional fields, of more complex nature. All this originates in the Earth's core, about half the radius of the Earth. If we could go to the surface of the core, all the complicated parts would be much bigger. But they weaken more rapidly with distance, so at the surface of the Earth they are already quite weak, while the "dipole" part stands out more (in addition of actually BEING the biggest chunk of the field).

Are you still with me?

The magnetic field of the Earth changes all the time, and yes, magnetic charts have to be redrawn from time to time (this was first found in 1641, by an Englishman named Gellibrand). And yes, in the century and a half since the first careful mapping of the Earth's field, the dipole has become weaker by about 8% (the rate may have speeded up in 1970). If you draw a straight line through the points, you will find that perhaps 1200 years from now, the line goes through zero.

Extending straight lines too far beyond the present, however, is risky business, as noted by no less a scientific authority than Mark Twain. In "Life on the Mississippi" Twain noted that the Mississippi river was getting progressively shorter (mainly by floods--and by people--creating shortcuts through bends in the river) and he wrote:

> "Now, if I wanted to be one of those scientific people, and "let on" to prove what had occured in the remote past by what had occured in a given time in the recent past, or what will occur in the far future by what has occured in late years, what an opportunity is here! ... Please observe:
>
> In the space of one hundred and seventy six years the lower Mississippi has shortened itself two hundred and forty-two miles. That is an average over a mile and a third per year. Therefore, any calm person, who is not blind or idiotic, can see that in the lower Oolitic Silurian Period, just a million years ago next November, the lower Mississippi was upward of one million three hundred thousand miles long, and stuck out over the Gulf of Mexico like a fishing rod. And by the same token any person can see that seven hundred and forty years from now the lower Mississippi will be only a mile and three quarters long, and Cairo and New Orleans will have joined their streets together, and will be plodding comfortably along under a single mayor... **There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment in fact**."

It is not impossible that the magnetic field will go through zero 1200 years from now, but (judging by the past record of reversals) not likely. In any case, the field is not going away: a "flux preservation theorem" suggests this is not happening (at least not on the relatively fast time scale of observed variations of the field; see **here**). In agreement with that theorem, one finds that while the dipole field is getting weaker, the complicated parts are getting stronger. That's why I wrote "yes and no." During a reversal the two-pole (dipole) component of the field (which now dominates it) may go through zero, but the complex parts of the field will be relatively high, and because of them, while the overall field will be weaker, it won't vanish.

I don't know about migrating animals (they may have magnetic organs, sort of built-in compasses), but there seem to exist no magnetic effects on DNA, resistance to antibiotics and so on; those changes seem more related to chemistry.

Finally, be cautious with compass readings in your house. Houses do contain electric currents and machinery, and these may affect the readings of a magnetic compass. On NASA's satellites the magnetic sensor usually sits at the end of a long boom, to keep it away from interfering electric currents in the satellite's circuits.

Keep up your interest in science!
David

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7. Can Magnetism propel Spaceships? ***

Dear Mr. Stern:

I am an Industrial Technology teacher at a middle school and one of my students is dreaming of a space propulsion system based on magnetic repulsion of the earth's magnetic field. Could you possibly squeeze in a moment for us and provide some information on the strength of this field and how it has been measured and maybe a relative comparison? Tyson, my student, is really excited about the Internet and will be enthralled to have an answer from a NASA scientist. Perhaps you could steer him to other references as I certainly will explain to him how busy a schedule you must have. Thank you.

Reply

I am afraid it won't work. First of all, the magnetic field is very weak. Compared to fields in electric machinery, where appreciable forces are exerted, it is a few thousand times weaker.

But there is a more fundamental reason. Magnetic poles always come in pairs, equal and opposite: if a field attracts an N pole, it repels the attached S pole. Similarly, if we generate the field by a current in a loop of wire --say, shaped like a rectangle--for each side in which the current flows in one direction, there exists a side where it flows in the opposite direction, and the magnetic field exerts opposite forces of equal strength on the two sides.

From the preceding one would guess that magnetic forces always cancel, and no net force is exerted. So how come magnets are attracted to each other, or pins to a magnet (same thing, really, since each pin in the magnetic field turns into a small magnet)?

The answer is that the forces on the N and S poles (or on the opposing currents) are not exactly equal, if one pole, or one wire, is closer to the source of the field than the other. This can be put into a mathematical formulation and the bottom line is that a suitably oriented magnet may be attracted by a magnetic field, moving towards the greatest strength of that field. But the force is proportional to the rate at which the field changes with distance, which in the case of the Earth, is very small.

The idea of magnetism as anti-gravity has come up before. Your student may look up "Gulliver's Travels" by Swift, where in the third voyage, in a spoof on science and learned societies, Gulliver arrives at an island floating in the air, held there by the repulsion of a large magnet. Swift even gives an explanation, except it's all gibberish gobbledygook, as befits a book of satire

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8. Reversal of the Sun's Magnetic Poles ***

Dear Mr. Stern:

I have a question about the sun that I was hoping you might be able to answer for me. A friend of mine recently returned from a new-age conference where it was presented that the magnetic poles of the sun were about to reverse, and cause a number of changes.

The idea of the sun having magnetic poles seemed counter to what I remember learning about the sun, and your web page seems to dispel the idea that the sun has actual poles. My guess is that the presenter was taking a dose of creative license with the 11 year cycle of sunspot activity.

Is it true then, that:

1.) There are no magnetic poles on the sun.
2.) Is the change in sunspots related at all to a reverse of polarity of magnetic fields?

Thank you.
If you can provide reference to a college-level text as a reference, it would be appreciated.

Reply

Actually, your friend was right: the Sun does have polar fields, and they do seem to reverse their polarity each sunspot cycle.

The Sun's most concentrated magnetic fields are of course in sunspots, but people have long suspected there might also exist polar fields, because during a total eclipse of the Sun one often sees streamers coming out from the polar regions, looking very much like the pattern of iron filings near the poles of a magnet.

But there was no good way of measuring such diffuse magnetic fields: the field of sunspots affects the light emitted from them ("Zeeman splitting") but the effect elsewhere is very weak. Then in the 1950s (if memory serves me) the Babcocks pushed the technique to its limits and found the polar field. This revealed the reversal of the polar magnetic field and suggested this field was somehow coupled to that of sunspots (which also reverse each cycle--they come in pairs, and the leading spot, in the direction of the Sun's rotation, has north or south polarity, in alternate cycles), a sort of a cumulative effect of the distant field of many spots. Theories exist by Horace Babcock and Robert Leighton, though they are somewhat qualitative.

The fact the magnetic field lines at the poles stick straight out means they do not hinder the escape of the solar wind in any way, and indeed the Ulysses spacecraft which recently passed above the Sun's poles confirmed (as was predicted) that the solar wind there is faster. There seems to exist no great effect of the reversal on Earth, though one might expect a bit more magnetic storminess when the polarity is opposite to that of the Earth.

For more on the Sun, see:

- http://seds.lpl.arizona.edu/nineplanets/nineplanets/sol.html
- Kenneth Philips, "A Guide to the Sun", Cambridge U. books, 1992 (paperback '95).

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9. Measuring Earth's Magnetic Field ***

I am doing a sixth year studies project on magnetism in and was delighted to find the question and reply page with topics similar to what I had thought of studying.

I was wondering if there was a practical method for measuring the strength and direction of the Earth's magnetic field at different geographical locations. Any help or inspiration would be greatly appreciated.

Reply

Is your "sixth year" in school or 6th year in college? It is not easy to tailor an answer to fit either level!

In any case, the electronic gizmos nowadays used in space are too complicated for a quick discussion, so let me instead describe earlier, simpler methods.

The direction of the magnetic field is of course given by the compass needle: but that is just the horizontal part of the force, Actually the magnetic force also points i n t o the Earth (or out of it, in the southern hemisphere).

To find the angle at which the force points down ("dip angle") people used a needle similar to a compass needle, but on a horizontal axis, allowing it to swing in the various directions to which the hands of a wall clock might point.

That is a bit harder to arrange than a compass needle: if one end of such a needle points at an angle downwards, how is one to know whether the magnetic force is responsible, and not, say, that the needle is not quite balanced on its pivot, but that one end is slightly heavier and therefore points downwards? To avoid this problem one starts with an unmagnetized needle, balances it very carefully, and only then magnetizes it. When in 1831 the expedition of John Ross searched for the north magnetic pole, it carried along a dip needle, and when it pointed straight down (while the regular magnetic needle showed no preference for any direction), that was it .

Measuring the strength of the field is harder. Take a thin long bar magnet and hang it by a thin thread, then wait until it points north-south. After it does, push one tip slightly left or right and let go: it will swing back to north-south, but will overshoot to the other side, then turn back to the right direction, swinging back and forth like a pendulum, gradually quieting down to point steadily. The average length of each swing depends on two things: the strength of the bar magnet and the strength of the magnetic force. With a stopwatch, measure 20 swings or so and figure out how long each swing takes.

Then put a small compass needle on a table, and put the small magnet nearby, in such a position that it tries to line up the compass to point east-west.The small magnet and the Earth's magnetic force obviously compete fordetermining which way the needle points, and by looking at the actual angle of the needle, and its distance from the small magnet, we again get an observation that depends on how strong are (1) the small magnet and (2) the magnetic attraction of the Earth. Using these two observations and some calculation, the physicist can find both these unknown quantities.

This method was proposed by Carl Friedrich Gauss in Germany around 1835. It obviously won't work on an orbiting satellite--but how measurements are made there is another story altogether.

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10. The Strength of the Earth's Magnetic Field ***

Could you please send me any information regarding the current field strength of the Earth's electromagnetic field? My data is current as of 1975 which is by far outdated. My reading from that time were 30,000 gammas at the equator. If possible could you please send information on the current decay of the earth's magnetic field.

Any information would be greatly appreciated.

Reply

I am not sure at what type of information you need, or to what use you put it. The most complete information on the Earth's internal magnetic field is in form of a set of coefficients, to be plugged into a mathematical representation--the so-called spherical harmonic expansion. The coefficients generally used are the so-called IGRF set (International Geomagnetic Reference Field) chosen by a committee every 5-10 years and based on the "best available" observations. You can find them on the world-wide web at

http://fdd.gsfc.nasa.gov/IGRF.html

Some of these models also include the annual change of the field (but not in the above files). You might like to search the web using (say) the Altavista or Yahoo search engine, on the term IGRF.

If you just want maps of the field, for instance those describing, the variation of its strength over the globe, try

http://swdcdb.kugi.kyoto-u.ac.jp/igrf/index-j.html

The text seems to be in Japanese, for on my computer it does not give anything readable, but the maps are in English. Clicking on the first will show you that the magnetic intensity around the equator varies quite a bit. but 30,000 gamma (or nanotesla, same thing) is a reasonable value.

The field has been weakening since Carl Friedrich Gauss measured it around 1836, by about 5% per century, recently accelerating to 7%/century. The total energy of the field however is nearly constant, as shown by the late Ned Benton. This means that the field is not really weakening, only reshuffling its energy, reducing the "main dipole" (=north-south bar-magnet pattern, declining as noted by about 7% per century) and reinforcing the more complicated parts.

These tend to contribute a weaker field, because the magnetism originates in the Earth's core, about half an Earth-radius down: all magnetic fields at the surface are weaker than those in the core, because of the distance, but the more complicated fields decrease faster.

Whether the main dipole will reverse in about 1300 years is anyone's guess. Geological evidence suggests it has happened in the past, but odds are against it, because the mean frequency of such reversals in the past seems to be about once in 500,000 years.

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11. Magnetic Shielding ***

My question is about induced magnetism and magnetic shielding.

I understand that we can screen out magnetic fields from a region by wrapping a piece of soft iron around the region. However, I also understand that soft iron can easily receive induced magnetism when placed near a permanent magnet.

So now my question is that: How is it possible to shield a region that near a permanent magnet by using a piece of soft iron? Won't this piece of soft iron eventually get induced magnetization and have the ability to attract any magnetic material that is nearby.?

Ong

Reply

Magnetic shielding is not my specialty and you might get a better answer from an engineer familiar with magnetic design, but I will try.

Soft iron--especially the kind used in shielding (mumetal, etc.) does not take permanent magnetization. Steel does, but even there, the magnetic intensity must be high enough for that to occur.

In shielding (e.g. a video tube) you wrap a sheet of soft iron around the shielded object, and the magnetic field lines which would have closed through the interior are diverted and close through the shield instead. Therefore any magnetic field that existed in the interior is greatly weakened. The field inside the iron sheet is stronger, but that is no problem--in fact, that is what we wanted to do, take the magnetic field from the inside volume and put it elsewhere (you can't just get rid of it, for all magnetic field lines have to close somewhere).

I hope this answers your question

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12. Building an electromagnet **

My name is Jon and I am a 6th grader. I have an invention using magnetism to prevent cars from being stolen and to keep them from bumping into each other. I tried making an electromagnet with a 9Volt battery, but it wasn't very strong. Can you tell me how to make a stronger magnet? Can I use a larger battery or real electricity? Thank you,

Reply

Dear Jon

I don't know what your invention is, what the magnet is supposed to do. If you want it to close an electric circuit, you are essentially building a device known as a relay. You can probably get old relays from a radio repair shop, or any place which has junked electric devices (cars have relays, too). Or ask your science teacher for help.

Building electromagnets without calculating and measuring is not simple: you must match the size of the wire and its length to the source of current (manufacturers of relays do so, of course). In particular be cautious about using house current (you call it "real electricity", but anything you use is real electricity). A small battery is limited in what it can do--usually, not much. House current is backed by big power stations, which can pour a LOT of "juice" into whatever you attach. If your wire is short and thick, it will try to draw a big electric current: a battery will be unable to provide it, but the power station can and will, enough electricity to perhaps melt a wire and cause a fire, or at least blow the fuses or trip the circuit breakers which are meant to protect houses against just this.

Also, house current is backed by a relatively high "electric pressure" (voltage) and can cause a nasty shock. Finally, even if you got the magnet working on this, it would hum and jitter, because houses have an "alternating current", which goes down to zero and up again more than 100 times each second. If you ever heard an electric device humming (old fluorescent lights sometimes do), that is the reason.

So my advice--stick to batteries, get a relay (you can also disassemble it and use just its magnet, if that's what you want), and most important, read and learn. You are just at the very beginning of an interesting adventure.

David Stern

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13. Effect of magnetic reversals on animal migrations ***

I teach 9th grade Earth Science and my class would appreciate the answer to the following question. What is the effect of the magnetic reversals of the poles on the migratory paths of sea turtles and certain birds and fish?

Thank you..... Janet

Reply

Dear Janet

I have no idea how to answer your question. How could one find out? The last reversal was 700,000 years ago!

I heard that some bacteria, suspended in water, find the "down" direction using magnetic materials embedded in their bodies. When they are moved to the opposite hemisphere, they tend to orient themselves in the opposite direction. That's as far as I know

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14. Which is the "True" North Magnetic Pole? ***

Hi!

I'm a teacher from Sweden. I'm also studying science and I have a question that I would like to ask you, about magnetism. I found your e-mail at http://www.phy6.org/Education/ The Earth's geographic north pole is near the magnetic north pole. But if the Earth's magnetic north pole is up north, why does a compass point up north? Then the magnetic north pole has to be a magnetic south pole, because south and north attract each other. So, my question is: Why isn't the Earth's magnetic north pole a "true" magnetic north pole?

Reply

Dear Asa

Your question has come up before and it is not really about science, but about language. The needle of the compass--or of any bar magnet-- has two ends, the N end tends to point to the north magnetic pole of Earth and the S end tends to point to the south magnetic pole.

So, if the source of the Earth's magnetism were a very powerful bar magnet somewhere deep inside, where would its N pole be and where its S pole? The answer, of course, is--the S pole would be at the northern end and the N pole at the southern end. How confusing!

Teachers and students have struggled with this ambiguity since times immemorial. One popular solution has been to call the N pole of a bar magnet, not its "north pole" but its "north-seeking pole", and the other end its "south-seeking pole," marking them N and S for short. You might try doing so with your students, too.

Sincerely

David

15. Magnetic Intensity at Singapore

I would like to know the value of the horizontal component of the earth's magnetic field. I am living near Singapore (at the equator). By the way does it vary a lot from place to place?

Reply

The horizontal intensity at Singapore is about 0.4 gauss, among the highest along the equator. The lowest is about 0.27 gauss in southern Venezuela.

One reason for the variation is that if we represent the Earth's magnetism by a bar magnet of small size but strong intensity ("dipole"), the best description is obtained by placing that magnet NOT at the center of Earth but some distance away from it, more or less in the direction of Singapore. As a result, over South America the field is relatively weak, and if you ever heard about the "Brazilian Anomaly" (or "South Atlantic Anomaly") where trapped particles of the radiation belt are most likely to hit the upper atmosphere--the weakness of the field there is the reason.

Of course, this is just approximate. The field near Earth has other sources of uneven structure. As one moves upwards, into space, these become smaller and smaller and the field appears smoother.

David

16. Inner core rotation

Hello,

Do you think it's possible to determine whether or not the earth's inner core is rotating faster than the rest of the earth by investigating the magnetic field? It seems like the strength of the magnetic field would be greater than we expect if the inner core is rotating faster, but perhaps it cannot be so easily calculated because we haven't accurately measured the amount of current that flows through the iron core.

Thanks, Sarah, Caltech undergrad

Reply

Dear Sarah

What you suggest has been proposed before, and there is even an echo back to Halley (although the inner core as we know it was only discovered in 1936, by Inge Lehmann). Evidence exists for the separate rotation of the entire core, from the gradual shift of the pattern of magnetization observed at the surface of the Earth. Acording to Halley--and some more recent evidence--it displays, in addition to its irregular variation, an average westward drift. To save rewriting, I clip below a section from a review submitted by me to Rev. Geophys.:

"In 1634 Henry Gellibrand showed [Malin and Bullard, 1981] that the magnetic declination observed near London had undergone a systematic shift. Subsequent observations confirmed such variations and also showed them to be world-wide and without any clear-cut pattern. If the Earth was permanently magnetized (and in the 1600s no other magnetization was known), how could its magnetism vary?

The only solution left, proposed ingeniously by Edmond Halley [Bullard, 1956; Evans, 1988; Chapman, 1941, 1943; Bauer 1896 (1990), 1913 (1990), Clark, 2000] was that the interior of the Earth consisted of concentric spherical shells, each magnetized differently, and that some rotated differently from others. Halley was so proud of his theory that when at age 80 he had his portrait painted, he appeared in it next to a model of his spherical shells. He thought he could locate 4 distinct magnetic poles, belonging to two different layers. The modern theory of the Earth's field actually suggests that the solid inner core of the Earth might rotate at a slightly different rate [Buffett and Glatzmaier, 2000] but this is a completely different process and permanent magnetism is not involved."

The reference: Buffett, Bruce A. and Gary A. Glatzmaier, Gravitational braking of inner core rotation in geodynamo simulations, Geophys. Res. Lett., 27 (19) 3125-8, 1 October 2000.

17. How does the Earth's field vary with location?

hello-

I am doing a project on the Earth's Magnetic Field. My question is: How does Earth's magnetic field vary with latitude, with longitude, with its distance from Earth and in time? How do people who rely on compasses account for those differences? if you couldn't give me some information on this topic, i would be very grateful. Thank you for your time and consideration

Sincerly, -Ava-

Reply

Dear Ava

Some of your questions are answered in "The Great Magnet, the Earth" We have magnetic charts, based on ground surveys and on satellites, and the direction of magnetic north is plotted there. You might even find such charts on the internet. The extension of the field into space near Earth follows the formulas of Gauss (see again on the web site). Far away the field of electric currents in space becomes predominant and for those regions we have models of average fields based on satellite data. On the surface, actually, the field varies more in intensity than in direction--25-42,000 nT on the equator, up to 60,000 nT at the magnetic poles.

That's it in a nutshell. You'll have to search by yourself for more.

After all, it is YOUR project.

18. The Effect of Magnetism on Water

Dave, I am studying magnets and was reading your site and came across the following:

"Short electromagnetic waves carry enough energy to eject electrons from matter, in particular ultra-violet light and x-rays. A near-vacuum is necessary for any such procedure to be effective, because in ordinary air free electrons collide with molecules, lose their energy and are recaptured. In most of space however matter is so rarefied and encounters are so few that free electrons persist for a long time."

and

"When one or more electrons are torn off an atom, the remaining atom becomes positively charged and is known as a positive ion. Positive ions carry most of the energy and electrical current in the magnetosphere, and are the main component of both the inner and the outer radiation belts. Fast ions are also produced by the Sun as a continuous outflow in all directions, known as the solar wind, which initiates and powers magnetic storms and similar phenomena.

The simplest atom is the one of hydrogen, with just one electron. Tearing off that electron gives the simplest ion, the proton. The proton has a close relative, the neutron--nearly the same mass, but no electric charge--and together these two form the basic building blocks from which the nuclei of all atoms are constructed.

Most of the fast ions in the magnetosphere and in the solar wind are protons. In the ionosphere one would expect to see ions of oxygen or nitrogen, the main atmospheric gases, and in fact most ions there are O+, oxygen atoms which have lost one electron (out of eight). Some O+ ions end up in the radiation belt, greatly energized by magnetic storms."

Which leads to my question. . .

What effect would a magnet have on H_2O, e.g. if you put a magnet in a glass of water, what happens to the water molecule, does it lose any electrons? What about any minerals that might be in the water? Thanks in advance.

Reply

Dear Gerald

If you put a magnet in a glass of water ... it will get wet, for sure. Electomagnetic effects are a bit more elusive, because magnetism affects only (1) magnets or (2) electric currents. Electric charge by itself responds to electric fields (voltage differences), which is something else. Let me stick here to magnetic forces.

Each proton is a tiny magnet, as is an electron, so a magnet will exert a small force on them. It will be like that of the Earth's field on a compass needle, namely it will try to turn them around to some preferred direction, but will not attract them anywhere.

Very little energy is involved. However, if your magnetic field oscillates (as does the one of a radio wave, say), the proton will try to swing back and forth rapidly, and if the frequency of the wave resonates with the natural frequency at which the tiny protonic magnet oscillates, the proton can absorb energy (and scatter it away, too). That is the basis of Magnetic Resonance Imaging (MRI) in medicine, and of the proton precession magnetometewr (and the more recent Overhauser magnetometer) used by scientists. I wrote a bit about it in
http://www.phy6.org/stargaze/Lprecess.htm

Somehow this does not look like what you had in mind!

If you pass an electric current through water in the presence of a magnetic field, its flow will be pushed aside. That force--it's a force on an electric current, the water is just incidental--can be used to pump water, but it is an inefficient method, because an electric current in water wastes energy and promotes corrosion. However, in "fast breeder" nuclear reactors, such as "Superphenix" in France, liquid sodium is used as coolant, and is pumped by "electromagnetic pumps" based on this principle. In such a reactor ("fast" refers to the type of neutrons used, not to the reactor) heat is generated by fission in a rather small volume, maybe a meter (3 ft) across, and since the heating rate is very high, it must be removed quickly. Liquid sodium is a good coolant, since it conducts heat very well, and it conducts electricity well, with small wastage. Unfortunately it is also tricky to handle and will burn when exposed to air. In 1990 Superphenix was shut down because of leaks of its coolant, and it has only operated intermittedly since then. See:
http://ccnr.org/news/news_briefs_12.html

Author and Curator: ***Dr. David P. Stern***
Mail to Dr.Stern: **earthmag**("at" symbol)**phy6.org**

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