Electricity and Magnetism

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Introduction

After getting to know the essential characteristics of the classical elements, it is possible to investigate other phenomena with more clarity. As brought out in a previous article (*The Elements in the Past, Present and Future*), the elements or states of matter are usually imagined as different degrees of solid, where little balls are kept packed together for a solid, dispersed more in a liquid, and completely dispersed in a gas. This "projection" or "carryover" of the solid state on to the other states of matter is an archetypal example of what *not* to do in a real scientific pursuit: impose properties not yet perceived onto things that are perceived differently. This carryover was also described in the study of electricity, where electricity was treated as a solid (electr*on*), liquid (electric-*current*), gas (electron-*gas*) and fire (electric-*plasma*). First of all, the states of matter are themselves seen as different aggregations of "solids", and secondly, the states of matter are further imposed on to the invisible "electrons", leading to a state of hopeless confusion for the imagination. This goes to show that great care has to be taken with the forming of images, and many a time, an image may be tantalizingly simple and completely off-track. Not only that, we have an inherent bias towards images, which is something suited to our visual sense, so that there is a definite "carryover" of the visible properties onto that which is not visible to start with and is sensed mainly using other sense organs.

In order to tackle a specific subject in the physical sciences, it is hence very important to stay true to the phenomena by staying with the sense organ that primarily detects the phenomena, and not allowing the other senses to directly interfere in the observation and confuse matters. For example, one might look at something that appears to be a big rock. One may judge that something heavy is present, and upon touching it with the hand, find out that the so-called rock was made of paper. Here the concept of "weight" was carried over into the visual image, and found to be unsuitable. Similarly, one may see nothing in front, but upon moving forward bump into a clean glass door or window. Here, the image showed nothing present, and we "carried over" this "nothing" into our judgment, leading to another mistake. Hence, in combining what is being perceived by the different senses, monumental errors of judgment are possible, and Goethe's maxim is applicable: *the senses do not deceive; the judgment deceives*.

Separating Electricity and Magnetism

Such deceptions are particularly more prevalent when the phenomena under investigation do not directly yield to the visual sense, such as the processes of electricity and magnetism. When little pieces of paper get attracted to a comb, or when an iron bar snaps towards a magnet, we clearly see something happening but the judgment stands confused because there are no ropes or other agents through which an attraction is normally affected. At this point we may fall into the "carryover" trap of asserting that: "There are ropes that pull, but they are merely invisible". But when it is observed that one magnet can, under certain circumstances, also push away another magnet, then the "rope idea" falls apart: it is hard to see how one can push with a rope. That is how reality corrects our mistaken attempts at creating facile concepts to juggle with, and the history of the study of electricity and magnetism bears witness to an immense number of such “rope ideas”.

But if we are able to withhold judgment and simply observe what is being perceived, what is it that is actually observed? As far as visual perception goes, it is possible only to observe a separation or coming-together of objects. It is not possible to tell right off the bat whether the attraction is due to electricity or magnetism. However, when it comes to the perception of touch, our fingers (or even the tongue) feel a distinct “zap” when electricity is involved; and in case of magnetism, only a push or a pull is perceived. This already tells us that even though both processes are invisible to begin with, their behaviour is distinct. Let us proceed to tease out these properties further.

Consider a “zap” usually felt in winter upon touching a metal door knob. It is clear that once we have been “zapped”, we can touch the knob safely again. Also, it is possible many times to catch a visible glimpse (or audible zap) of the spark, which is seen as a jagged line. On the contrary, if an iron bar that gets stuck to a magnet is repeatedly separated from it, it gets stuck, again, and again, and again. It is never done! In this way, electricity appears to be far more fleeting, and disappears on physical contact, while magnetism is far more stubborn, and stays on in spite of contact.

When we observed the zap, which hopped from surface to surface, a jagged line of electric spark became visible, but in case of a magnet, it is hard to make anything visible. In fact, there is only one sure fire way of actually visualizing magnetism, and that is the way done by Faraday and his peers: using iron filings. Sprinkling iron filings around a magnet and observing their accumulation gives an approximate idea of where the pushes and pulls are concentrated. Pointed regions are prone to getting an electric shock, as is seen in the case of lightning, while magnets show no such preference. There are many spherical magnets commercially available today with which one can play and verify this.

The *generation* of electricity and magnetism provides an additional clue regarding their nature. Electricity tends to be generated either by rubbing surfaces together, or, in a continuous fashion, by using dissimilar plates in an acidic or alkaline solution. (Note the use of the word *tends*, with which we try to be cautious about premature generalizations while always allowing for exceptions). In other words, it is generated on a *plane surface*. Even in the case of a capacitor, which typically consists of two parallel plates, the electricity is “held” on the two surfaces facing one another, after being connected with a battery. In case of magnetism, however, the generation process involves magnetizing the *whole volume*. Whether one patiently strokes all the sides of a bar of iron in one direction with a magnet, or sets a needle within the poles of a large magnet, the focus is on introducing the magnetism into the entire volume of the material.

While this is how electricity and magnetism are generated, their *actions* show another tendency. As already brought out, electricity “zaps” in a jagged *line.* This linear behaviour is more apparent when we observe electricity being transferred through wires. Magnetism, on the other hand, attracts plane surfaces to each other or pushes them apart. Its planar property becomes even more apparent when we consider the fact that magnetism always acts in a double-sided way, or in conventional terms, is always a dipole (or bipolar). People have tried for centuries to pull apart magnetic poles and create magnetic “monopoles”, but have failed. This is not surprising, since one cannot separate the two parts of a surface, without creating another surface! Every surface has a front and a back, and peeling it away will not make any difference. Magnetism behaves the same way: break a magnet into two, and you have two new magnets. Magnetism therefore, acts as a *plane*.

Putting these properties together, we have the following tentative summary:

Electricity:	Generated in a *plane*,	acts in a *line*.
Magnetism:	Generated in a *volume*,	acts in a *plane*.

What we see here, expressed in the sense of spatial ideas, is that there is a *dimensional difference* between the behaviour of electricity and magnetism. For the time being, we have only expressed this as a difference in spatial dimension, but we need not stop with that. The next question is, even though we have asked in what spatial way these phenomena occur, what about the second aspect of the senses: the tactile aspect? What exactly is the tactile difference between electricity and magnetism?

When we make contact with a large amount of electricity, our sensation of touch is disturbed, and we can sense either pin-pricks or, in extreme cases, a numbing and a corresponding tensing up of the muscles. Long experience has taught humanity that breaking contact with a live wire is not easy: "The amount of internal current a person can withstand and still be able to control the muscles of the arm and hand can be less than 10 milliamperes (milliamps or mA). Currents above 10 mA can paralyze or "freeze" muscles. When this "freezing" happens, a person is no longer able to release a tool, wire, or other object. In fact, the electrified object may be held even more tightly, resulting in longer exposure to the shocking current." (from a *Student Manual on Electrical Safety*[1]). Contact with large magnetic strength, as in an MRI, tends to disturb overall balance: dizziness and vertigo are common side effects, and some cases even report that it appears as if the "bed is spinning"[2]. Occasionally, flashes of light are seen as well.[3]

Such extreme cases help clarify the essential nature of these processes. In case of electricity, the "zap" that causes us to tense releases the tension from the surrounding region. In other words, the inner nature of electricity, as far as our bodily perceptions go, is to *create a tension*. The "zap" is a release of the tension, while the accumulation of electricity in any spatial region tends to increase the tension. We use the phrases "walking into a highly charged atmosphere" and "being hit by a bolt from the blue" to describe these processes even when they do not have anything to do with physics, shedding further light on the visceral nature of electricity. It is out of a similar feel for phenomena that the early researchers called this aspect of electricity "electric tension" – a word that still survives today in "high tension wires". It is only later that the more abstract expressions of voltage, potential etc. began to be used.

On the other hand, when dealing with magnetism in the simple sense of playing with magnets, its perception appears far less intense when compared to electricity, but more "bulky", as the weight of the magnet seems artificially increased or decreased in the direction of the other magnet. (Note: this bulkiness or ponderousness of magnetism is well known, and since it does not "zap" back like electricity, it has been used in memory devices like hard disks). The direct observation is both of a push and a pull, or a pressing out and a sucking in. In other words, magnets tend to *create pressures and suctions*. The extreme case offers further support for this, as the symptoms of dealing with a high magnetic field is very similar to running headlong into a solid brick wall: dizziness, vertigo, and "seeing stars". Hence we can add to our little table in this way:

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[1] http://www.elcosh.org/document/1624/888/d000543/section2.html
[2] https://www.frontiersin.org/articles/10.3389/fneur.2015.00201/full
[3] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4409466/ (see "phosphenes")

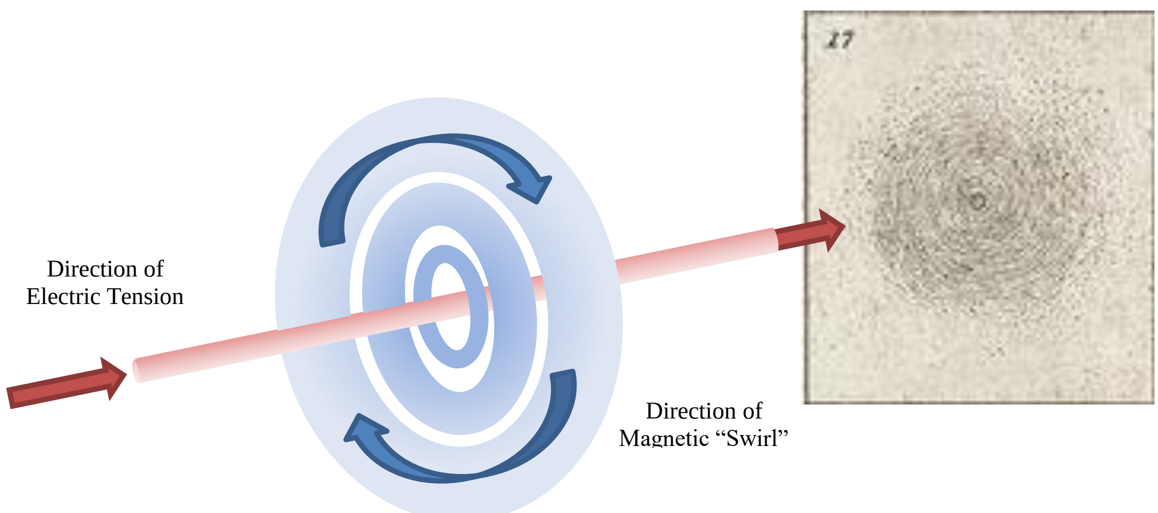
Electricity:	Generated in a *plane*,	acts in a *line*,	through *tension/release*
Magnetism:	Generated in a *volume*,	acts in a *plane*,	through *pressure/suction*

Ernst Lehrs, in his book *Man or Matter*[4], offers a remarkable description of electricity and magnetism from a slightly different point of view, and illuminates the ponderous nature of magnetism and the superficial nature of electricity. His description is a must read to round out a good many phenomena that are not brought out here. An article by Rudolf Cantz[5] on the electrical cable is equally important.

Electricity-Magnetism Interactions

Now that we have separated out some distinct properties of electricity and magnetism, it is time to pay attention to their relationships. The discovery that an electro-*dynamic* condition, such as a discharge of tension through air or through a metal wire, leads to the generation of a magnetic field (a spatial region where magnetism is active) around the line of action, opened up the first relationship between electricity and magnetism, which were earlier thought to be separate. The converse was also established by Faraday, where a magneto-*dynamic* condition (such as moving a magnet) sets up electric tensions and their corresponding discharges in conductive wires. So it is through their *dynamism* or movement that electricity and magnetism relate to each other.

The spatial dimensionality of electric action is related to that of magnetism in a very specific way as well. Around every high tension wire (or even low tension wire for that matter) there is an induced magnetism with a very peculiar nature: it forms loops at right angles to the direction of the wire! Following Faraday once again, this can be confirmed by sprinkling iron filings around the wire.



Here we are not going to concern ourselves about the precise directions of the arrows (towards right or towards left, curling clockwise or counterclockwise) and instead focus on the overall behaviour of the two intertwined processes. For one thing, there is a dimensional difference that is complementary: when electric tension acts in a particular direction, the magnetic disturbance in the surrounding space spreads in

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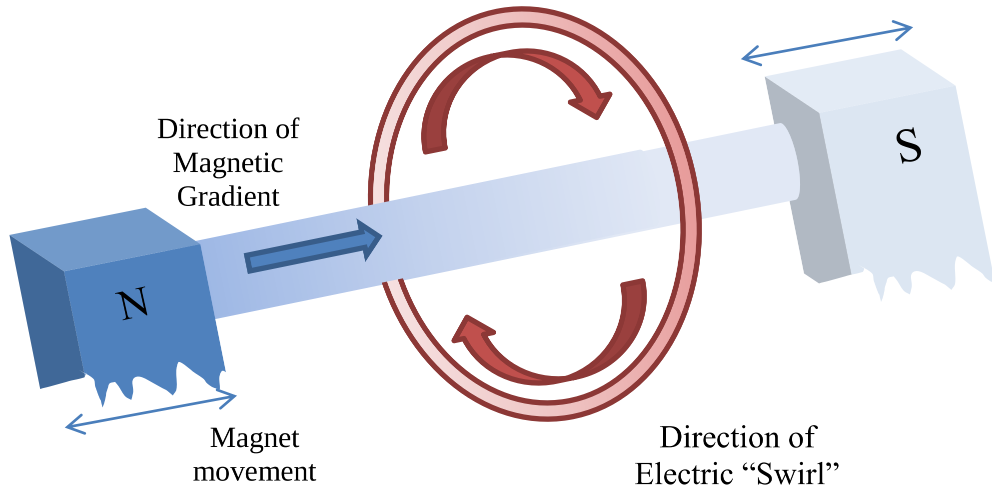
4 Ernst Lehrs, Chapter XIII "Radiant Matter", *Man or Matter*, Rudolf Steiner Press 1985.
5 Rudolf Cantz, "Das Anschlusskabel", *Elemente der Naturwissenschaft*, Vol 14, pg. 31, 1971.

the *other two directions*. The magnetic field generated also has no poles: only a circular direction. We cannot identify concentrations that we can call a north or a south pole. On the other hand, let us say a horse-shoe magnet is used to set up a magnetic region between the magnetic poles, and a circular hoop of wire is introduced in the region. When either the magnet or the loop is moved, there is an immediate electric discharge being conducted by the wire. Once again, this “induced” electricity has no poles! There is no positive and negative, as we have for a battery, for this loop of wire. Rather, it is a circuit:



So one can see how this process of induction works:

Bipolar electricity *induces* circular magnetism

Bipolar magnetism *induces* circular electricity

The bipolar and the circular forms of electricity and magnetism hence *complement* one another in occupying the surrounding space. It is very easy to get confused between the two forms, and unless the differences are kept very clear, errors crop up immediately. One error which has persisted for over a century is that of Ampere, who asserted that *all* magnetism is a secondary effect of electricity, and tried to make models of currents circulating inside a magnet. Today in modern science we are in the confusing position of saying that the fundamental “particle of electricity” – the so-called electron – has a magnetic “moment” due to a “spin”. While it is hard to understand how an electrical “particle” can be magnetic at the same time, the discussion shown just above clarifies that all such attempts are trying to grapple with the simultaneous occurrence of electricity and magnetism, and end up glomming them together. Teasing them apart helps us notice their distinctions better.

In order to get a more “visceral” sense of the relationship of electricity and magnetism, imagine first an eraser, made of elastic rubber. When the eraser is stretched along one axis, say lengthwise, the width and height shrink inwards. And when we let go of the stretched eraser, so that it can “snap” back to its original shape, the other two dimensions come back to their original larger size. Hence, we can see that the tension that is applied in one direction is compensated immediately in the other two dimensions. Similarly, squeezing the eraser in the center also tends to stretch it out lengthwise, with a subsequent snap back to its original position. We cannot have one without the other.

An eraser like this is what we regularly call a three-dimensional solid object, where we can grasp it as a totality in three dimensions. However, electricity appears to be a one-dimensional property that is complemented by a two-dimensional behaviour of magnetism, *with each retaining its distinct nature*. This dimensional distinction of electricity and magnetism as compared to solid matter has not always been properly appreciated, and it is indeed hard to digest at first. For example, we are used to seeing the tension and a lumbering bulkiness as properties of the *same* three-dimensional object. However, with electricity and magnetism, we have processes which seem to have either tension *or* bulkiness, but not both!

This "coming apart" of what one usually calls solid impenetrable dependable *substance* is the hallmark of dealing with electro-magnetic phenomena. And it is a bit unnerving to have to handle this reality, as we are not used to thinking in terms of a "one-dimensional world" or a "two dimensional world", since we are closely wedded to the solid three-dimensional one. Nevertheless, these facts are indicated directly by the phenomena themselves. Once again, if these essential facts are not recognized, and we are too attached to our solid little balls, then we end up instead with half-real-half-imaginary concepts such as tiny invisible "spinning" balls with *zero* radius (!) and a "very small" mass: the electron. This, of course, rivals the Cheshire Cat and its smile.

Further study along the same lines will be continued, showing how this "coming apart" proceeds with radioactivity.