

DIAMAGNETISM, FERROMAGNETISM AND ELECTROSTATIC DIPOLES

It is helpful first to explain magnetic moments of electrons and atoms in terms of electrostatic dipoles. The forces producing the velocities of electrons in orbit also produce radial charge polarization in the electrons; the proximity of the nucleus r meters away, inhibits the magnitude of the dipole in the orbiting electron. This is analogous to the inhibition of transverse dipoles as in the nuclei and free electrons of parallel current carrying wires. That is, there is a transverse force between nucleus and electron that inhibits the tendency of the orbiting negative charge inside the electron to become more elliptical. The dipole length increases as r increases. So the dipole in the orbiting electron of mass, m , in the ground orbit of hydrogen is erv/c where $mvr = \hbar$. This dipole then is equal to the Bohr magneton, $\mu_B = e\hbar/2m$, times $1/c$. The Bohr magneton is the unit in which the magnetic interaction of atoms with applied magnetic forces from solenoids and bar magnets is usually expressed.

On the next page is a diagram representing an electron orbiting a nucleus and the electrostatic dipoles produced inside the electron by the forces causing the motion of the electron. The side diagrams show the elliptical movement of charge inside the electron.

Note the difference in the effect of an electric field on free electrons in a conductor which is a movement in the same direction as the field and the effect of an electric field on electrons bound in a circular orbit by a central charge. The direction of the electric field is tangent to the orbiting electron at some point and the combined effect of this tangential force and the radial force on the orbiting electron is to produce an elliptical extension of the circular orbit transverse to the tangential force.

The size of the dipoles associated with a wire carrying a current $i = nevA$ is r/c times the current. Why? Because this gives the necessary inverse r square force between infinitesimal wire segments that Ampere showed implied the observed inverse r force between parallel current carrying wires a few centimeters long.

But what causes the dipoles in the wires to increase with the separation of the wires?

The transverse electric fields of the dipoles causes the transverse ellipse in the other wire to revert to being more circular. This effect decreases with an increase in r , the separation distance between the wires.

The idea that an orbiting charged mass could move inside an electron at speeds necessarily greater than the speed of light is justified as follows. The apparent increase in mass of electrons ejected from radioactive nuclei for electrons of greater speed is attributed instead to a decrease in responsiveness of the electrons to the magnetic and electric fields through which they are made to pass. What causes this decreased responsiveness? The increased speed of the electron implying an increased force causes

an increased polarization of charge inside the electron but not as great an increase as the increase associated with the same increase in orbital speed starting at a lower initial speed.

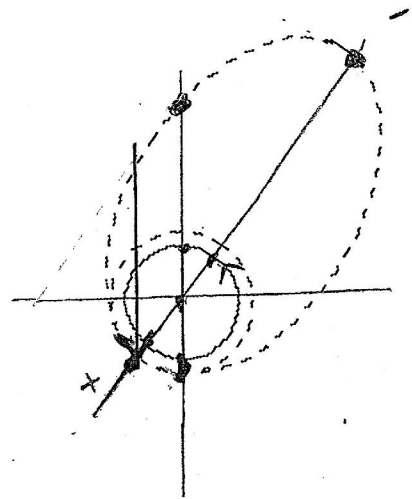
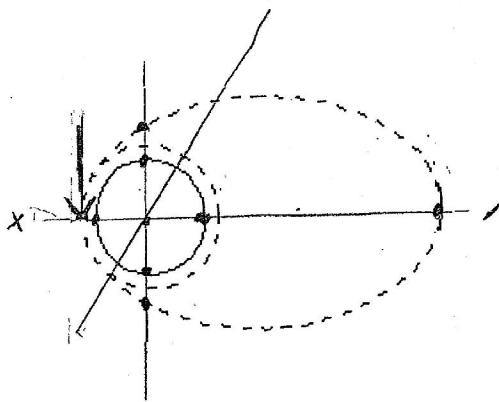
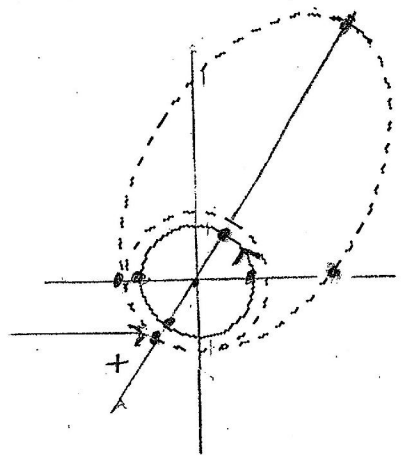
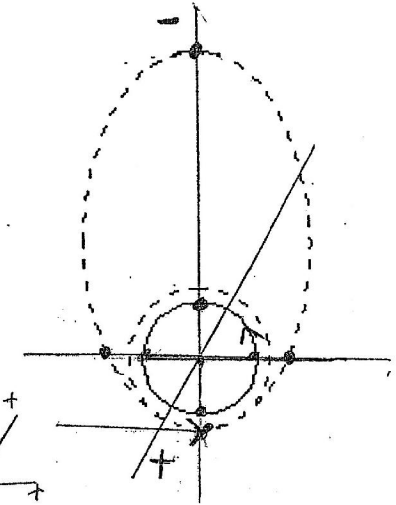
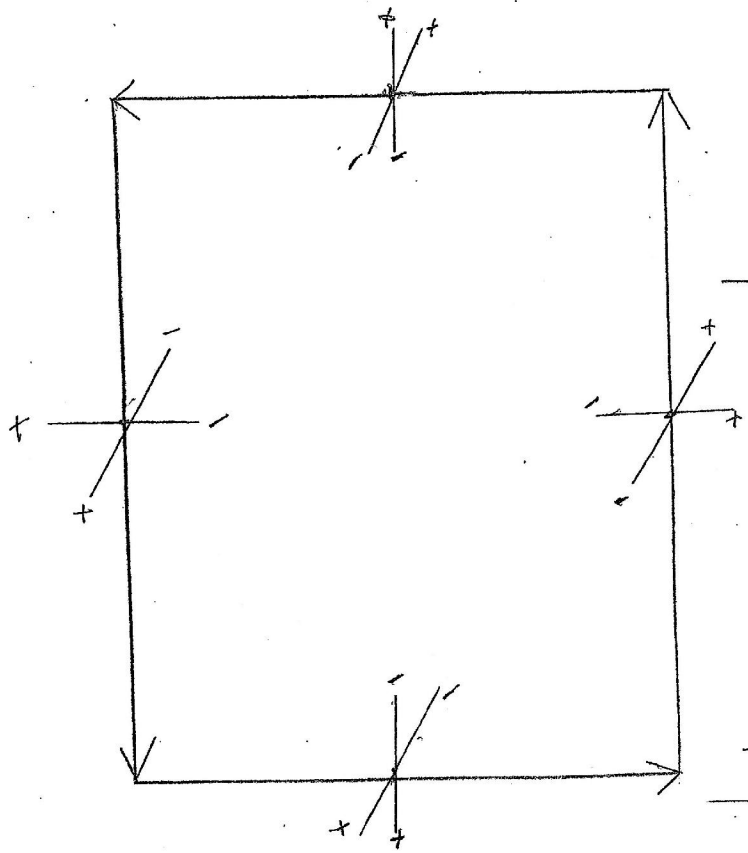
Thus mass, electron mass, does not increase to infinity as the speed of light is approached but rather charge polarization inside the electron that increases with electron velocity, increases less as the speed of light is approached. The forces that produce the ejected electron velocity also produce charge polarization inside the electron up to an elastic limit, the speed of light. At this limit the charged particle inside can escape the electron at a speed far in excess of the speed of light.

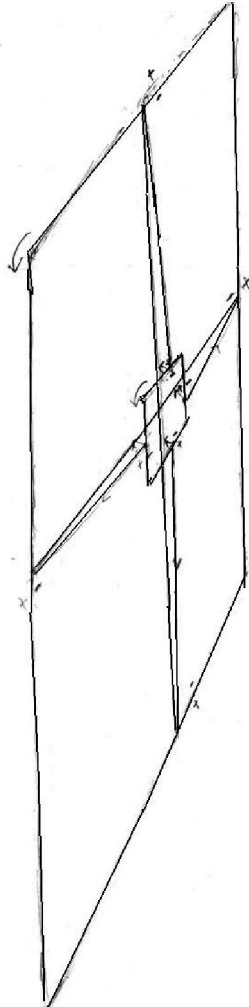
Thus, if the direction of the orbital electron in an atom is counter clockwise in the plane of the paper or computer screen as in this diagram, and the direction of orbiting charge inside the electron is counter clockwise in the same plane, the negative pole is always pointing toward the nucleus.

But when the orbiting charge inside the electron is moving counterclockwise in a horizontal plane into and out of the paper, the negative pole is half the time into the paper and half the time out of the paper.

For any other orientation of the electron orbit, the dipoles are the vector sum of these two orthogonal components.

If there are two electrons in this counterclockwise orbit diametrically opposite each other and the charge inside one electron is moving in a clockwise direction while the charge inside the other is moving in a counterclockwise directions the collinear dipoles in each are oriented so as to attract each other. The negative pole of one is facing the nucleus and the positive pole of the other is facing the nucleus.





Instead of an electron in orbit around a femto-meter diameter atomic nucleus, suppose the above diagram represents the flow of electrons in a few centimeter diameter one turn current carrying coil. Inside the one turn coil, we can imagine a very small one turn current carrying coil, say of one tenth the diameter of the large one, randomly oriented and not necessarily in the plane of the paper or exactly in the center.

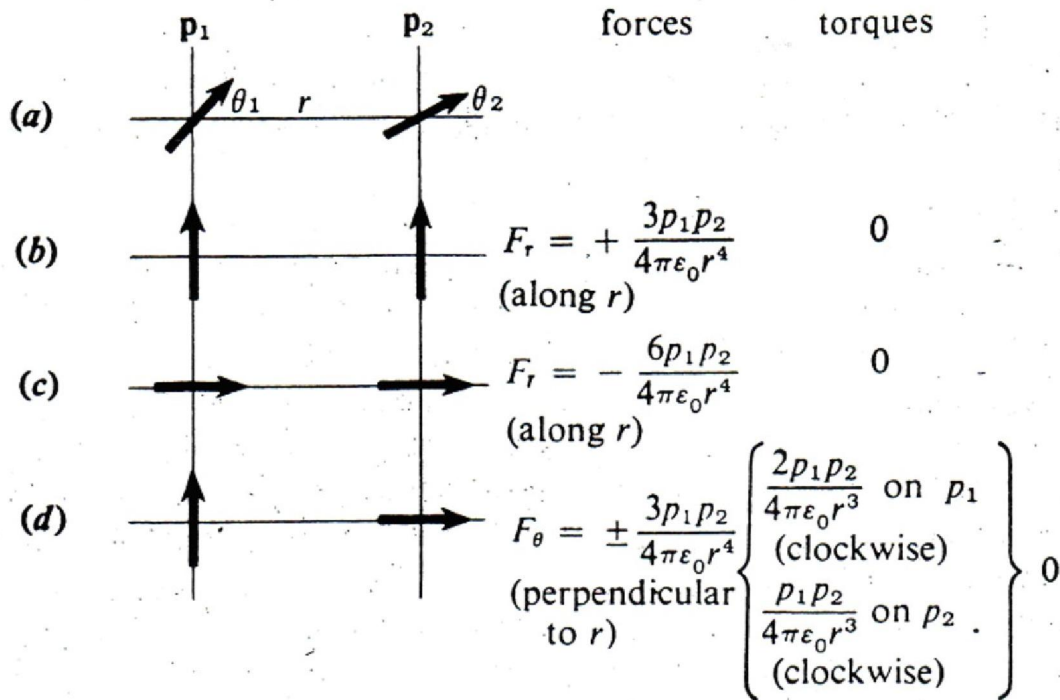
The forces and torques between the electrostatic dipoles in the smaller coil and those in the larger coil will cause the smaller coil to rotate so that the current in the smaller coil is always parallel to the current in the larger coil. But in these corresponding segments there are dipoles perpendicular to these radial dipoles and to the direction of current in the respective coils. These similarly oriented parallel dipoles repel each other but with a force that is half as strong as the attraction between the associated collinear radial dipoles.

Thus there is a net dipole dipole torque that aligns the two coils and a net dipole dipole attraction between corresponding segments of the two coils that acts on opposite sides of the smaller coil in opposite directions. But because the forces are almost equal and opposite at each side of the coil, they largely cancel. The remaining force is less than the forces that hold the coils together.

In this arrangement, dipoles transverse to the current in each segment of the smaller coil attract the similarly oriented transverse dipoles in the nearest segment of the larger coil. The transverse dipoles in the smaller coil are always oriented in the same way as the nearest transverse radial dipoles in the larger coil. Thus there is an attraction between these corresponding dipoles in corresponding segments of the two coils. And the attraction between corresponding dipoles is greater than the repulsion between more distant non corresponding dipoles as shown in the diagram,

[http://physics101.org/2 coils.pdf](http://physics101.org/2%20coils.pdf)

The following diagram from W.J.Duffin's, **Electricity and Magnetism**, shows the forces and torques between dipoles. One must imagine wavy arrows perpendicular to the dipole arrows to be collinear or parallel current carrying wire segments, ds , to see the forces between current carrying segments forming dipoles per unit length: $(r/c) \times (nAev)$ where $nAev$ is the current per unit segment ds :



Instead of the smaller coil being in the same plane as the larger coil, suppose it is in a parallel plane slightly displaced from the plane of the larger coil. Draw lines from a dipole in the smaller coil to the corresponding dipole in the larger. The same dipole dipole forces have component force vectors in the plane of the larger coil between corresponding segments of the coils produce an attraction of the smaller coil to the plane of the larger coil. The other oppositely directed dipole dipole forces cancel.

Consider a hollow many turn coil, a slightly smaller diameter coil inserted partially inside the larger coil. The smaller coil is pulled inside, if the currents in both coils are in the same direction. The dipoles in the turns of the outer coil are attractively oriented to those adjacent in the nearest parts of the turns in the inner many turn coil.

Ferromagnetic domains behave like the very small one turn coil. A ferromagnetic domain consists of many similarly oriented electron orbits in a specific random orientation, forming a larger randomly oriented orbiting charge. A ferromagnetic cylinder or armature inside a many turn coil or solenoid, behaves like a many turn coil inside a slightly larger many turn coil. The aligning torques and attractive forces can be

described as electrostatic dipole forces between corresponding segments of a very small one turn coil representative of a domain in a ferromagnetic cylinder and of the solenoid coil around the ferromagnetic cylinder..

The 1921 Stern Gerlach experiment with silver atoms showed that half of the atoms, all with a single outer electron around a Palladium core of 46 electrons, had orbital electrons which were “ferromagnetic” , That is they behaved like the small one turn current carrying coil which lines up with the larger one turn coil along the same axis or lines parallel to this axis and was then attracted to the larger turn coil or its ferromagnet equivalent..

Stern and Gerlach produced a gas, silver in its gaseous state, and the silver atoms, were thermodynamically forced from a high temperature region to a lower temperature region, and a small fraction of these through collimating slits and then through an inhomogeneous magnetic field. “Thermodynamically forced” means stronger and more frequent pushes from hotter atoms than colder atoms.

Roughly half of the silver atoms would move, in effect, toward a pole of one magnet and the other half would move away from the same pole. As a result the beam of neutral silver atoms would be divided into two beams and produce two lines instead of one on a photographic plate.

If there is a single orbital electron with counterclockwise moving charge inside the electron, the rapid movement of the electron in orbit makes the orbital electron similar to the small current carrying coil in our discussion. Thus the alignment and attraction to a larger coil or many turn coil or ferromagnet is to be expected.

However if the charge inside the single orbital electron is moving in a clockwise direction while the electron is moving in a counterclockwise orbit, the dipoles produced are opposite to those shown in the diagram, eg radial dipoles with the positive pole pointing to the center and nucleus.

The result then is that the orbital electron is repelled by the same larger single or many turn coil or a ferromagnet that attracted the first orbital electron. The result is the same if you reverse the direction of current in the many turn coil or turn the magnetized ferromagnetic cylinder so that the opposite side of the cylinder is facing the first orbital electron.

This is what happened to the other half of silver atoms in the Stern Gerlach experiment. Thus it seems that randomly oriented orbital planes are twisted by the strong magnetic field so that half are oriented to be attracted to one pole of an electromagnet equivalent to a large current carrying coil with clockwise moving current and half become oppositely oriented and are repelled by the same pole and attracted to the other pole.. The single electron in orbit moves so fast, it is at opposite sides at almost the same time and so acts like a macro current carrying coil with moving electrons at all points of the coil simultaneously.

(When there are two diametrically opposite orbital electrons in their least energy ground state, one electron has its negative pole pointing toward the nucleus while the other electron has its positive pole pointing toward the nucleus)

From these considerations, atoms, with an even number of electrons, should have no response to an applied magnetic field except a small repulsion due to induced currents. So diatomic molecules having an even number of electrons, eg, in an outer figure eight orbit, are non magnetic. The slight repulsion of such non magnetics as bismuth and antimony from a magnetic field of either orientation and the levitation of a frog because of the water in the frog, from a neodymium or other very strong magnet seem to be due to the induction of oppositely moving currents in electron orbitals as well as in free electrons as in usual conductors. That is the orbital planes are flipped so that the orbital direction in the dielectric is opposite to that in the ferromagnet. Thus non magnetics are also diamagnetic.

That is, the changing magnetic field of a magnetized ferromagnet as it is brought near diamagnetic material, seems to be to induce movements of electrons in atomic or molecular orbits in the diamagnetic material, so that the average electrostatic dipoles produced, are oppositely oriented to, and so repel, the equivalent electrostatic dipole of the ferromagnet. The mechanism is similar to the momentary, oppositely directed, current induced in a wire when a parallel current carrying wire is brought near it, the so-called 'Lenz effect'.

Let us consider now how the atoms in iron domains become similarly oriented and produce in effect the randomly oriented small coil that an applied magnetic field, a larger coil, can realign so as to produce the observed ferromagnetic effect.

Iron has two electrons in an outer 4s orbit; that is, the "4" is the value of the principal quantum number, n , and $n^2 = 16$ gives the radius of the orbit as a multiple of the innermost orbit radius of two electrons in orbit next to the iron nucleus.. The "s" indicates in this context that the orbit is elliptical. The next more inner or 3d orbit has $n^2 = 9$ and "d" indicates that the orbit is a broad circular orbit with quantum number, 3. Thus, there is the likelihood that the 6 electrons in the 3d orbit or orbits which may be in different planes, cross repeatedly, the orbital path of the 2 electrons in the 4s orbit of the same atom and also of an adjacent atom.

One possibility is that the paired electrons in the outermost 4s elliptical orbit cause one electron of the six in the circular 3d orbit to flip over and, the reaction force causes one of the 4s electrons to flip over. Thus the net dipole of each of these and its previously paired dipole will be in the same direction and not zero. That is, the electrons are moving in the same orbit in counterclockwise direction and the orbiting charge inside each electron are now both moving in the same counterclockwise direction. That is, the two electrons have dipoles which are both oriented with the negative pole facing the nuclear core.

This makes iron in a vapor state, 4 times more paramagnetic than silver. That is more responsive momentarily to the same applied magnetic field. But in a solid state, something else happens. These similarly oriented paramagnetic atoms coalesce to form a domain with similarly oriented dipoles. And when a strong external magnetic field is applied to this solid, these domains will be lined up with their magnetic moments parallel to this field. That is, the net electrostatic dipole of the ferromagnetic solid will line up with the net electrostatic dipole of the applied field.

This explanation of ferromagnetism, is consistent with standard wave mechanics: http://en.wikipedia.org/wiki/Exchange_interaction, in attributing the magnetism of the iron atoms to the 'exchange' interaction between 4s and 3d orbital electrons.

But since only electrostatic dipoles, and the actual electron positions and electron motions, albeit very rapidly changing, are involved, the proposed explanation involves no new axioms such as exchange forces, electron clouds and the uncertainty principle.

But you say, these Quantum Mechanics axioms and others are needed elsewhere. I would just point out that charge polarization inside nuclei and orbital electrons can explain in part why the electrons do not fall into the nucleus as they radiate away energy but instead have ground orbits due to repulsion at the ground orbit radial distances, involving polarized charges inside the electron and nucleus as well as to the net charges in both the electron and nucleus.

It is possible also that the lack of radiation from ground and meta-stable orbits is due to a dynamic alignment of adjacent atoms over time so that as an outer electron in one atom is moving up an outer electron in an adjacent leg of an adjacent atom is moving down. That is half of the time the orbital electrons are opposing each others motion and half of the time they are reinforcing each other motions. The net effect is zero and a canceling of each others radiation. During the transition between orbits the energy of the radiation produced is Planck's constant times the difference frequency. But the difference frequency and the energy produced is not measurably different than the average frequency and the energy produced by the average frequency.

The potential energy of the 4s electron due to the nucleus and other electrons and that of a 3d electron which being sometimes at equal distances from the nucleus are sometimes equal. Note the average energy of each electron can be approximated from spectral data making certain simplifying perturbation assumptions and it is equivalent to the average energy calculated for a specific orbit making similar simplifying assumptions. But the actual cause of magnetism can be explained more clearly in classical terms. The electrons in the same or overlapping orbits repel each other less if the electrostatic dipoles in the electrons are oriented so as to attract each other even if this means a slight decrease in the attraction of the electron to the nucleus or nuclear core. The least energy principle applied to atomic systems apparently requires this dynamic adjustment in the electron orbits in iron.

Lets consider the force the head on force between a larger iron bar magnet say a magnetic needle and an iron atom as a small bar magnet.

The Bohr magneton is defined as the dipole moment of a circular current produced by the ground orbit motion of an electron around a proton in the hydrogen atom. The actual current is, ev , where $e=1.602(10^{-19})$ coulombs and, v , is about 10^6 meters per second. If we divide this by $2\pi r$ where $r=.5(10^{-10})$ meters we get a velocity that is within the range of drift velocities of electrons in current carrying wires with currents typically from milliamps to tens of amps. Also another property of "current" is the number of electrons passing a point in the current path per second in addition to the property, the number of electrons at any point in the current path moving at speed v . Also, $ev/2\pi r$, as the defined current in this context, is justified because when multiplied times the area of one loop current carrying coil, πr^2 , the resulting dipole moment is that implied by observations of atoms in a magnetic field, their scattering and their atomic spectra.

The dipole moment of a current carrying loop of area πr^2 with a current I is $I\pi r^2$. Thus for a loop of the area of hydrogen electron orbit and an atomic current $ev/2\pi r = I$ we have a magnetic dipole moment $\mu_B = evr/2\pi = 9.27(10^{-24})$ in amps meters in the usual definition of current but $ev/2\pi r$ times $I\pi r^2$ in amps meters squared, in this special definition of current in the context of orbital electrons.

The length of the magnetic dipole moment associated with the orbiting electron is not specified but an approximate value is implied by the distance between atoms.

For example the total dipole magnetic moment of a 30 by 1 by .5 millimeter magnetic needle ($1.5(10^{-8})m^3$) is measured to be .00027 amps meters squared. The magnetic moment of an iron atom is 2.26 Bohr magnetons, or $2.1(10^{-23})$ amps meters squared. The total number, N , of pure iron atoms in the needle is determined as follows: the density of iron, 7900 kg/m^3 , times the volume $1.5(10^{-8})m^3 = 1.185(10^{-4}) \text{ kg} = 1.185(10^{-1})$ grams is the mass of the needle. A mole of iron is 55.847 grams and contains Avogadro's number, $6.02(10^{23})$ atoms so .1185 grams divided by 55.847 equals $x/6.02(10^{23})$ atoms where x is the number of atoms in the needle = $.00212$ times $6.02(10^{23}) = .01273(10^{23})$. Thus $N=1.27(10^{21})$. And if all of the dipoles were aligned, the total dipole moment of the needle would be $(1.27)(2.1)(10^{21-23})$ which is about ten times the measured dipole moment, indicating a 10% alignment of the atomic dipoles in the needle. The magnetic poles associated with the total magnetic moment of the needle, $L = 3\text{cm}$ long is $Lm = 2.7(10^{-3})$ amp meters meters so $m = 2.7/3$ times $10^{-3-2} \sim 10^{-5}$ amp meters or webers in pole strength.

We can think of a single iron atom as bar magnet of length, L , and magnetic poles - p and + p at opposite ends where pL is defined to be equal to $evr/2\pi \sim 10^{-19+6-10} \sim 10^{-23}$ amp meters squared. If we let $L=10^{-10}$ meters then $p = 10^{-13}$ amp meters or webers, as the unit of magnetic poles. Thus if we have a line of 10 of these dipole moments, 3Angstroms apart, the positive pole of $m_1 = +10^{-12}$ webers at one end, approximately 30 Angstroms from the opposite end, would attract the negative pole, $m_2 = 10^{-5}$ amp meters, of the magnetic needle dipole at a distance $a = 1\text{cm}$ in air with a force, $F = 10^{-7}$

$[10^{-12}][[-10^{-5}]/1^2 = -10^{-24}$ dynes. To obtain the net force we would have to add to this, the three other pairwise forces which gives a reduced net negative or attractive force. The total force then is written:

$$10^{-7} [10^{-12}][[10^{-5}] \{-1/1^2 + 1/(1+10^{-8})^2 + 1/(1+3)^2 - 1/(10^{-8}+3)^2\}$$

The actual force here is due to electrostatic dipoles, $erv/c \sim 10^{-19}$ Coulombs times 10^{-12} meters, inside the two 4s orbital electrons of the iron atoms. With each segment of the circular orbit there is associated an electrostatic dipole transverse to the segment in the plane of the orbit and another perpendicular to the plane of the orbit.

Orbital segments diametrically opposite each other both have the dipoles in the plane of the orbit with their negative pole pointing to the nuclear core or both have the positive pole pointing to the nuclear core. The associated dipoles perpendicular to the orbital plane both have their negative poles in front of the plane as in the first diagram at the beginning of this paper, or both have their positive poles behind the plane. Thus two such parallel orbits attract each other because their electrostatic dipoles perpendicular to the parallel planes of the orbits attract each other.

The 4s orbital is the outermost orbit of the iron atom of radius $16r_0 = 1.26$ Angstroms where, r_0 is the radius of the innermost iron electrons orbit. Thus the force between two parallel orbits of this type is the force between collinear dipoles transverse to corresponding parallel orbital current segments.

Sums of such 10^{-12} meter long electrostatic dipoles, instead of the assumed 10^{-10} meter long magnetic dipoles along the 3 cm length of the magnetic needle and about an Angstrom apart or several Angstroms apart, produce a net electrostatic dipole in the magnetic needle that acts on the sum of the two electrostatic dipoles in the single iron atom outer orbit. The placement of the two net electric poles on the length of the magnetic needle would be one hundredth of the distance apart of the magnetic poles and the strength of the electric poles would be greater than that of the magnetic poles..

So we see that electrostatic dipoles inside orbital electrons and atomic nuclei can help explain phenomena such as the magnetic dipole moment of electrons and atoms. We have already discussed how such dipoles explain magnetic phenomena on a larger scale. Let me summarize again some of these results.

The magnetic field of spinning, orbiting planets and stars can be associated with dipoles produced in their protons etc by the forces also causing the tangential spin and orbital motions. The radially and longitudinally oriented dipoles in each proton and nucleus about 10^{-18} meters, cause a ferromagnetic needle to line up longitudinally and to dip downward. I argue elsewhere that this magnetic field is equivalent to the gravitational field except, in the Earth's case, for a slight differences due to the slightly uneven distribution of iron. The orbital motion of the Earth also increases this elemental dipole when the orbital direction is in the same direction as the spin direction but decreases it when the two directions are opposite. This line of reasoning leads to an explanation of the bending of light by the Sun. The dipole nature of the Sun's gravity and the gravity of the planets leads to an explanation of the greater torque and precession of planets near the

Sun.

That Gravity is ultimately magnetic and so electrostatic is related to the views proposed by V.A. Bailey and also those of Thornhill and Scott. Bailey claimed that the Sun had a large net electric charge at the same time that authorities at Harvard vehemently denied it. The net charge was finally measured by NASA space probes as Bailey had contended. Thornhill and Scott claim that the power of the Sun and stars are provided wholly or in part by plasma currents or the solar wind comprised of positive Helium and Hydrogen ions moving away from the Sun and a smaller number of electrons moving toward the Sun but a net flow of positive charge toward the edge of the solar system implying for unexplained reasons a more negative potential in this region.

Other explanations of the solar wind are that electrons and positive ions are present in equal numbers and are pushed out of the Sun by heat and pressure factors at up to 450km/second but are not close enough to recombine. And that they continue by inertia past the Earth unless captured by oppositely charged particles or are deflected by other sources of magnetic and electric fields such as the spinning orbiting Earth etc, to the edge of the solar system etc.. It is helpful to consider the magnetic fields of the plasma streams as due to charge polarization inside the ions and electrons transverse to the direction of the streams. It is also helpful to recognize the electrical interaction between electrically neutral spinning orbital bodies in terms of electrical dipoles and plasmas.

The magnetic field of moving charges in the Sun is added to the magnetic field associated with the 24.7 day rotation of the Sun. The magnetic field due to electrostatic dipoles associated with the Sun's rotation and with the moving charges of plasma streams influence radiation emitted by Sunspots on the Sun's photosphere. Specifically the line of an observed frequency is split into many closely spaced lines showing that the field there is thousands of times stronger than that of the Earth. Also that the first spot in the direction of the Sun's spinning has the opposite polarity of that in a nearby spot that comes next into view. That is, the excitation from one orbit to another of the electrons emitting light is inhibited or stimulated by the surrounding magnetic field so called, depending on its orientation.

From the mass and number of atoms or ions in the Sun, we can estimate the Gravitational field of the Sun and so the equivalent magnetic or electrostatic dipole field of the Sun not due to the magnetic (gravitational) effect of solar currents. That is the electrostatic dipole field of the Sun is the Gravitational field of the Sun and the magnetic field of the Sun independent of the magnetic or electrostatic dipole field associated with the plasma stream of positive ions and electrons of the solar wind.

