Role of air pressure in diamagnetism

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Abstract

In a gradient of magnetic field, magnetic dipoles of the air are attracted toward the region of intense field such that the air pressure is more in the regions of more intense field. The formed pressure gradient exerts a net force on a body placed in the air in this gradient of magnetic field toward the region of low pressure or the region having weaker field. This is like what takes place in sink-float separation.

1 Introduction

As we know all substances have diamagnetic property, ie are repelled from a region of intense magnetic field. To show this interesting and nearly strange behavior, many experiments have been performed by the physicists [1] some of which have gained spectacular state (like the levitation of different substances, eg a frog, above intense gradients of magnetic field [2]).

This fact that a substance is attracted toward the region of intense magnetic field is easily justified by this assumption that the molecules of the substance are in fact magnetic dipoles which are attracted toward the region of intense field in a gradient of magnetic field. But this fact that substances are repelled from the region of intense field in such a gradient is not justified with that ease. What is presented in all of the textbooks (eg see [3, 4, 5, 6, 7, 8, 9, 10, 11, 12]) to justify this phenomenon is using Lenz' law in atomic scale. Shortcomings of this justification have been investigated in this article, but before that, a reason for this phenomenon has been presented which is based on the existence and role of the gaseous medium (eg air) in which the experiment is performed. This reason seems very evident and esp is easily verifiable by performing easy experiments.

Therefore, in the case of experimental confirmation of it, this question will show itself that whether the current justification of this phenomenon is still valid or is not valid at all, or it is valid as a part of the reason for diamagnetism. Reply to this question will be possible after careful study of the theory presented here and performing the experiments proposed in it.

2 Diamagnetism and air pressure

In a gradient of magnetic field in the air a net force is exerted on each molecular magnetic dipole of air toward the region of more intense field because due to the torque exerted on the dipole it turns and its axis will coincide with the line of magnetic field in such a manner that the force exerted on the pole placed in the region of more intense field is toward the region of more intense field and is bigger than the force exerted on the other pole which is toward the region of weaker field. In this manner some net forces toward the region of more intense field will be exerted on the air molecules which pull them toward this region. These pulled dipoles (or molecules) are pressed against the body of the magnet or face, in a solenoid, the pressure of the dipoles pulled inward from the other end of the solenoid and in any case their pull will cease by reaction of the leaning surface and, in return, air molecules will be pressed, ie the air pressure will increase as we enter the region of more intense field. Such a pressure difference must be measurable by a proper pressure gauge.

The situation is quite similar to the gravity exerted on the water molecules which causes the water pressure to increase by going toward the region being pointed by the gravity exerted on the water molecules, ie the earth center. Therefore, as an upward force will be exerted on a body placed in a volume of water due to the difference in pressures at lower and upper parts of the body, in a gradient of magnetic field there exists a force on a body placed in this gradient toward the region of low pressure or the region of weak field due to the above-mentioned pressure difference. If this is the real cause of diamagnetism, it is expected that by performing the experiment in a gas, rather than air, lacking molecular magnetic dipoles (eg nitrogen) or in vacuum the mentioned pressure difference to disappear practically and in practice there exists no longer exertion of any net force on the body toward the region of weaker field. Result of the performance of such an experiment can test the validity of this theory.

Therefore, this article proposes that a paramagnetic fluid like oxygen (of air) when being attracted into a region of high magnetic field gradient will create a net force on any material immersed in it which tends to expel it from the field gradient. This expulsion in such fluids is a well-known phenomenon (being used for some techniques of magnetic separation), but what is important here is that this article shows that the existence of such a fluid is necessary for such an expulsion while the current theory of diamagnetism doesn't see existence of it necessary for considerable repulsion of the materials from the region of high magnetic field. The above-mentioned well-known industrial phenomenon is sink-float separation using ferrofluids. Since the process used in this phenomenon is exactly the same one stated here to justify diamagnetism we explain it here:

One way to separate a mixture of fragments of different materials having different dimensions is pouring them into a liquid and using Archimedes' law. According to this law, which is obtained easily, regardless of its volume each fragment having density ρ will have an acceleration equal to $g - (\rho'/\rho)g$ when being immersed in a liquid having density ρ' in which g is the gravity acceleration. Thus, when pouring fragments of different materials into the liquid all fragments having the same density will have the same acceleration when settling. This fact can be used in separation of different materials. But in practice this method is not so useful for separation of heavy (metallic) materials, because for them ρ is considerably bigger than ρ' even if the densest usable liquid is used, and then $g - (\rho'/\rho)g$ will not be sufficiently smaller than g. One solution to this problem is substituting a greater acceleration for the g in the second term of $g - (\rho'/\rho)g$ instead of trying to increase ρ'/ρ considerably. In other words suppose that there exists an additional constant force, other than the gravitational force, which is exerted on each molecule of the liquid in the same direction of the gravity, such that this force is not exerted also on the molecules of the bodies placed in the liquid. So, in the process of obtaining Archimedes' law for this new situation, we shall have $g-(\rho'/\rho)g'$ for the acceleration of the fragments having density ρ in which g' is the acceleration due to both the gravity and the above-mentioned additional force. It is clear that depending on the largeness of this additional force the acceleration $g - (\rho'/\rho)g'$ can be very smaller than g.

This procedure is an approximation to what takes place in sink-float separation. In this method instead of common liquids we use a ferrofluid that firstly its density is more than many other liquids (because of the presence of tiny ferromagnetic metallic particles in it) and secondly, and much more important than the previous one, when we set this ferrofuid on a solenoid in an intense gradient of magnetic field, separate from the gravity, it tends to pull strongly downwards the ferromagnetic tiny particles suspended in (and adherent to the molecules of) the liquid, while this force won't be exerted also on the bodies (or fragments) inside the liquid which are not paramagnetic or ferromagnetic and we want to separate them from each other. In simple words such a mechanism creates a considerable great pressure inside the liquid which can be observed by a simple pressure gauge.

Presently ferrofluids are produced industrially in which sufficiently tiny particles of ferromagnetic materials have been coated with sufficiently light materials in such a manner that the volume of the particle and its coat is so big that the weight of the particle and its coat equals the weight of the displaced liquid resulting in suspension of particles in the liquid. This suspension and the molecular attraction between the coats of these particles and the molecules of the liquid and that due to their much smallness these particles have thermal fluctuation give ferrofluids the specifications of real physical liquids. Smallness of the particles and strong attraction between their coats and the molecules of the liquid have so much importance in giving the ferrofluid a homogeneous state as a real liquid, because if the particles are tinier we can increase the number of them used in the carrier liquid in order that fill all spaces empty of these particles and so decrease the distances between these particles and the surrounding molecules to such extent that, considering strong attraction between the molecules and the coats of the particles, all of the molecules of the liquid will be in the domain of attraction of the coats of the particles. Therefore, the situation will be such that we will have a pile of molecules attached to each particle under the influence of the strong attraction between each molecule and the coat the particle, and there will be no molecule not attached in this manner to a particle. In this manner indeed we will have a new (real) liquid which each of its molecules is the above-mentioned complex consisting of a particle and a pile of molecules of the carrier liquid attached to it. It is clear that if the particles are tinier these new molecules (or in fact complexes) will also be smaller and so the whole fluid will be more similar to a real liquid.

3 Examination of the current theory

At first let's see what Lenz' law is in simple language. Suppose that in an inertial right-handed cartesian coordinate system of xyz a loop of narrow copper wire has been set in the xz plane such that its center is the center of coordinate system, O. Also suppose that the N pole of a magnet is moving toward O on the positive section of the y-axis. A force in the direction of $-\hat{\imath}$ will be exerted on an electron in the wire at the intersection of the loop and z-axis which makes it move in this same direction and electron will flow in the wire. Motion of the electron in the direction $-\hat{\imath}$ in the vicinity of the pole N, which we suppose it motionless for simplicity, will exert a force in the direction $-\hat{\jmath}$ on it. Since this force is normal to the loop plane and the loop is rigid, there will be no way for flowing of the electron in this direction and this force will be exerted on the whole loop in the direction of $-\hat{\jmath}$. Namely, by entrance of N into the loop, a force in the same direction of the motion of N will be exerted on the loop (and its reaction force is an opposite force being exerted on the pole N).

If, instead of the above situation, motion of N be at first in the direction of going away from the loop, the force exerted on the electron is in the direction of $\hat{\imath}$, and by flowing and motion of the electron in this direction in the vicinity of N a force in the direction of $\hat{\jmath}$ will be exerted on it which, because of the rigidity of the loop and that there is no way for flowing of the electron in this direction, this force will be exerted directly on the rigid body of the loop in the direction of $\hat{\jmath}$; ie when N moves away from the loop, there will be a force exerted on the loop in this same direction of moving away. It is obvious that if N is motionless relative to the loop, there won't be any force exerted on the loop.

What is considered at present for justifying diamagnetism is using this same Lenz' law in atomic scale. Namely, motion of the electron around the nucleus of atom is considered in a circuit similar to a circuit mentioned above, and it is said that according to the above analysis if N comes near to the loop, a force directed to getting away from N, ie in the direction of $-\hat{\jmath}$, will be exerted on the loop (or in fact on the atom). But, this justification has some weaknesses:

Firstly, the circuit of the motion of electron about the nucleus is not rigid to cause the force to be exerted on the whole atom in the direction of $-\hat{\jmath}$. In other words the force exerted on the electron in the direction of $-\hat{\jmath}$ in the above analysis in the atomic scale can make the electron flow in this same direction rather than being exerted on the rigid body of the loop in this direction repelling the body from N.

Secondly, as the above analysis shows, Lenz' law necessitates that when N is moving away from the loop, the loop is attracted to N, while in diamagnetism this is not the case that by making the magnetic pole away from the body the body is pulled toward the magnet.

Also, in Lenz' law, if N is motionless relative to the loop, no force is exerted on the loop, while in diamagnetism, always, even in a stationary state, there is a force, exerted on the body, toward the region of weaker field.

4 Secondary conclusion

If the theory, presented above, is correct, we must expect bodies to be diaelectric as they are diamagnetic, that is to say we must expect that in a gradient of electric field in a gaseous medium with molecules having electric dipole the gas pressure to be more in regions of more intense field, and then a net force toward the region of weaker field, arising from the pressure difference between the two ends of a body situated in this medium, to be exerted on this body.

5 Points

1. To perform the experiment of diamagnetism in vacuum we must notice that if the intense magnetic field exists before creating the vacuum, it will cause the air molecules to be attracted to the poles (causing increase in the air pressure there) and even after evacuation of the container of the air molecules these molecules to remain attracted (or attached) to the poles (just like when the tiny particles of a ferrofluid remain attracted (or attached) to a magnetic pole as a pile, and by elimination of the magnetic field this pile flows downward due to its weight). In other words, by evacuation of the container of air, the air pressure near the poles will not decrease sufficiently, and this can cause insufficient and unnoticeable decrease in diamagnetism when the air of the container is pumped out.

To avoid this situation, the air of the container is necessary to be evacuated first and afterwards the intense magnetic field is created and the phenomenon of diamagnetism is examined. (This matter itself suggests making an innovative instrument for separating oxygen from air. We know that oxygen has more paramagnetic property than other gases of air. In a closed container we switch a powerful electromagnet on, and then we open the evacuation valve, and afterwards we pump the air of the container out. So, practically only oxygen remains in the container, attached to the poles. Now, we first close the evacuation valve and then switch the magnet off and afterwards open another exit valve connected to another sucker device for sending the oxygen out and storing it in another container. We then close this recent valve. By opening a third valve for ventilation into the container and switching the electric magnet on and then closing this third valve and repeating the above process as many times as necessary we can properly store oxygen.)

2. If you intend to verify diamagnetism by observing the speed of objects getting away from intense magnetic regions rather than observing levitation of objects over these regions, notice that existence of air molecules is an obstacle against objects in their getting away from intense magnetic regions. So, by reducing the air pressure (through evacuation), although the paszani (or Archemidus) force, exerted on the objects, is also reduced, prevention of the air molecules against the movement is reduced too which this helps more acceleration of the objects. These two opposing factors may cancel each other or one overcome the other. To become sure that air resistance can not have practical effect on the experiment the container of the experiment must become evacuated of air as more as possible.

3. If the theory presented here is true, the phenomenon of diamagnetism is expected to be more apparent for objects having less densities. (This is also the case for Archemidos force.) So, it seems that if a small thin glass bulb is evacuated of air nearly completely, it will show this phenomenon better.

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