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The Faraday Effect Explained

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ABSTRACT: *The Faraday Effect of 1845 is re-explained; the rotation of linearly Polarized Electric Field (E_{PF}) in the transparent isotropic material in the direction of the Supplied Magnetic Field (B_S), is suggested to resulted from the produced Magneto-Optic Force (F_{MO}), established by the interaction of both the Polarized Electric Field (E_{PF}) and the Supplied Magnetic Field (B_S), a formula is establish to derive the magnitude of the Polarized Electric Field (E_{PF}), based on the inverse square of the wavelength, another formula derived the Magneto-Optic Force (F_{MO}); an Effective Magnetization of the Flint-glass (M_{EF}) is derived from the Theoretical Magnetization of the Flint-glass (M_{TF}), giving the Effective percentage of the Magnetization of the Flint-glass (M_{EF}), this enable a general formula for the Effective Magnetization of Diamagnetic Materials and the Magneto-Optic Force (F_{MO}); from which both the Effective Magnetization of Water (M_{EW}) and the Effective Magnetization of the Oil of turpentine (M_{EOT}) are derived; as the F_{MO} rotate the Polarized Electric Field (E_{PF}) the angular momentum turned it into an angle (ϕ), while it rotates along the magnetic line of force inside the transparent material; thus from the F_{MO} a formula for the angle of rotation for Flint-glass, Water and the Oil of turpentine are derived, giving the precise angle when the Supplied Magnetic Field (B_S) is known, as it derived the supplied magnetic field when angle is known; and since this interaction produced a different kind of force; the proper knowledge of which will help in the better understanding of the physical world.*

Keywords: *Faraday Effect; Polarized, Electric Field; Magnetization; Magneto-Optic Force; Magnetic Susceptibility; Diamagnetic*

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I. Introduction

The Faraday Effect was discovered by Michael Faraday in 1845, when scientists started unearth secrets behind electricity and magnetic phenomena [1] while the nature of light was not yet known, the action of magnetism on linear (vertical) polarized light [2], was discovered after great efforts by Faraday searching for evidence of electric force affecting polarized light, or what is now known as electro-optic effects shown in Fig.1 [3], in which Faraday passed linear polarized light through diamagnetic material, tracing the magnetic lines of force of the Supplied Magnetic Field (B_S) as shown in Fig.2; when the eye-piece is turned to the right or left, the flame image disappear, and by switching the Supplied Magnetic Field (B_S) on, with its pole nearest to the eye-piece set as the northern pole (N), and the further pole as southern pole (S), the light rotates and become visible as long as the Supplied Magnetic Field (B_S) is on, the rotation of the ray is right-handed as seen from the eye-piece and shown in Fig.2-A, and left-hand as shown in Fig.2-B [1], this phenomenon of the angular velocity of the medium was interpreted by Maxwell as a rotation of very small portions of the medium, each rotating on its own axis, upon which he based his molecular vortices hypothesis [2], he suggested the existence of innumerable vortices of revolving matter, in magnetic field, with the vortices having axes coinciding with the direction of the magnetic force at every point of the field; and though to explain the forces acting between magnets, electric currents, and matter, which is capable of causing magnetic induction [4], but the Faraday Effect differs from natural optical activity in that the sense of the rotation depends only on the direction of the magnetic field and not on the direction in which light passes through the medium [5], making it more complicated than can be perceived, this effect occurs in most optically transparent dielectric materials (including liquids) under the influence of magnetic fields and the relation between the angle of rotation of the polarization and the magnetic field in a transparent material thought to be expressed by [3]

$$\phi = \nu \, \mathrm{B_S} \, d \qquad (A)$$

Where, ϕ is the angle of rotation (in radians), $\mathrm{B_S}$ is the Supplied Magnetic Field in the direction of propagation in Tesla, d is the length of the path (of diamagnetic material) shown in Fig.1 in meters where both the light and the Supplied Magnetic Field ($\boldsymbol{B_S}$) interacted, the constant ν is called the Verdet constant after the French physicist Verdet who established all the quantitative laws given in Eq. (B&C) [5], the Verdet constant for the material, is an empirical proportionality constant in units of radians per Tesla per meter, it varies with wavelength and temperature and is tabulated for various materials, the Verdet constant is a material property and gives a quantitative measure of the Faraday rotation ability of the material [6].

The linear polarized light that is seen to rotate in the Faraday Effect is thought as consisting of the superposition of a right- and a left- circularly polarized beam [3], it is explained by imaging linearly polarized light as the coherent superposition of two opposite polarized components σ+ and σ− [7], while the rotation due to a magnetic field was expressed in terms of the ratio of the charge of an electron to its mass (*e/m*), according to the theory of Lorentz, an electron moving in its orbit around an atomic nucleus will change its frequency of revolution which in turn leads to a rotation of the plane of polarized light through the affected object [8], this lead to the first empirical formula given by Eq. (A), which was first derived by Henri Bequerel (of radioactivity fame) in 1897 and bears his name [6], then Larmor derived it theoretically in 1900 [8], the Verdet constant v was found to relate to wavelength by $\frac{1}{\lambda^2}$, based on the simple electron theory and the concept of the Larmor's precession, Bequerel derived the following formula connecting the Faraday rotation with the refractive dispersion [5]

$$\nu = \frac{e}{2mc^2} . \lambda \frac{dn}{d\lambda} \qquad (B)$$

Where, λ is the wavelength of light in vacuum. This relation cannot obviously be expected to hold good in most cases as the Larmor’s theorern is known to fail in the case of molecules; the modified form is [5]

$$\nu = \gamma \frac{e}{2mc^2} \lambda \frac{dn}{d\lambda} \qquad (C)$$

Where, γ is a constant factor, the Becquerel formula was found to fit the experimental data much better, the Becquerel formula was soon followed by two formulae derived by Drude, the first obtained on the hypothesis of “molecular currents” and the second on the concept of Hall effect [5], while George Fitzgerald connected Faraday effect with Zeeman effect in 1898 [6], to find logical justification, Arnold Sommerfeld in 1949 assumed electrons in a dielectric medium behave according to the classical mechanics under the combined effect of an external electromagnetic wave and a constant applied magnetic field [6]

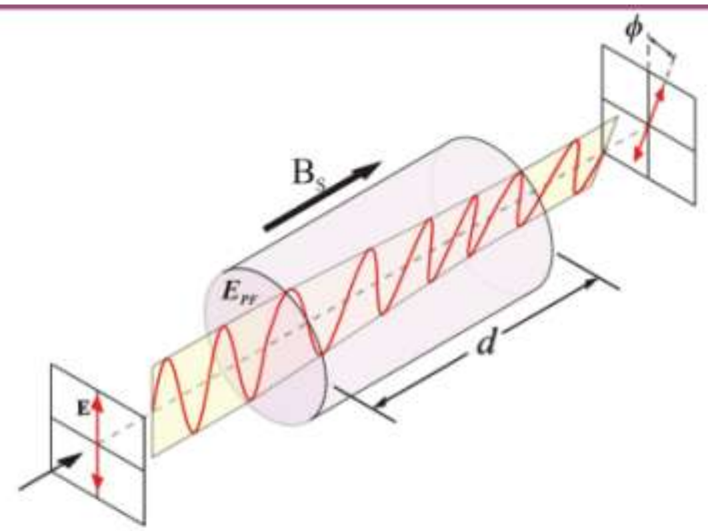

Fig. 1. The Faraday Effect [1], the rotation of the Polarized Electric Field (E_{PF}) of electromagnetic radiation in diamagnetic material with distance d, by angle (ϕ) due to Supplied Magnetic Field (B_s) [3]. The rotation in the diamagnetic material, produced the rotational Magneto-Optic Force ($\boldsymbol{F}_{MO}$), caused by an interaction of both E_{PF} and B_s.

Although the Faraday Effect was discovered 172 years ago, textbooks of the underlying physics are not very detailed and sometimes wrong [6]; the above summary of the assumed solution of the phenomenon is completely different from what the Faraday Effect stand for, the effect is a rotation of the Polarized Electric Field (E_{PF}) around the magnetic line of force inside the diamagnetic material as shown in Fig.2-A&B, therefore a force is established by this interaction, Faraday described the force causing the effect, as “*tend to prove that all* *natural forces are tied together, and have one common origin*" [1], but the justification given to derive the angle, completely ignored this rotational force within the phenomenon, rather it related the magnetic field given by Eq. (A) differently, and derived it in term of the ratio of the charge of an electron to its mass (*e/m*), taken the whole effect out of context into different unrelated field of electron's gyration in orbit around the nucleus [8], such an electron doesn't have any relation with the Polarized Electric Field (E_{PF}), and any formula derived from it doesn't reflects the nature of Faraday Effect, therefore a suggestion is made based on the interaction of both the Polarized Electric Field (E_{PF}) and the Supplied Magnetic Field (B_S), resulted in the Magneto-Optic Force (F_{MO}), this force rotates the Polarized Electric Field (E_{PF}), a formula derived the magnitude of the Polarized Electric Field (E_{PF}), based on the inverse square of its wavelength, and another formula for the Magneto-Optic Force (F_{MO}), the F_{MO} is an angular frequency rotation**,** it's the force rotating the related angle, these formulas shows the relationship between the angle and the wavelength and the Supplied Magnetic Field (B_S). The solution of this phenomenon will help in revealing how the microscopic physical world is such well organized.

II. The Magnitude Of The Polarized Wave

Since the phenomenon exhibited by electro-helices with the iron cores, is directly connected with the magnetic form of force [1], and the power of the rotation of the ray of light increased with the intensity of the magnetic lines of force, and appears to be directly proportionate to the intensity of the magnetic force [1], and the rotation axes coincided with the direction of the magnetic force [4, 1], and since the polarized field consists of the Polarized Electric Field of the radiation [9], therefore the phenomenon couldn't be properly investigated without the proper knowledge of the magnitude of the Polarized Electric Field (E_{PF}) created the phenomenon, then to derive the formula which cause the rotation of the Polarized Electric Field (E_{PF}) [5], therefore we suggested a different version based on the main fact, that is the interaction between the *Polarized Electric Field (E_{PF})* of the radiation and the *magnetic line of force*; and since the force between two charges is given by

$$\boldsymbol{F} = \frac{q^2}{\pi\, r^2 \varepsilon_0} = q\boldsymbol{E} = 9.24109990835734404 \times 10^{-28} \tag{1}$$

Where, q is the charge in an electron in Coulomb's, ε is the permittivity of free space in $C^2.N^{-1}.m^{-2}$, and the electric force $\boldsymbol{F}$ is in Newton; but an Electric Field at a distance of one meter from this charge is expressed by

$$\boldsymbol{E_R} = \frac{\boldsymbol{F}}{q} = \frac{q^2}{\pi\, q\, 1^2 \varepsilon_0} = \frac{q}{\pi\, 1^2 \varepsilon_0} = 5.767838388 \times 10^{-9} \tag{2}$$

Where, $\boldsymbol{E_R}$ is designated as a Reference Electric Field at a distance of one meter from an electron or proton, and since in micro- and nano-applications, a typical magnitude of an electric field is in the order of 10^6 V.m^{-1}, its achieved by applying a voltage of the order of 1 volt between conductors spaced 1 μm apart [10], therefore this is similar to our case, hence from Eq. (2), the electric field from charged particles decreased or increased from the reference point $\boldsymbol{E_R}$ of one meter distance given in Eq. (2) by the inversely square law, and given by

$$E_X = \frac{E_R}{r^{\pm n}} = \frac{5.767838388 \times 10^{-9}}{r^{\pm n}} \tag{3}$$

Where, $r^{\pm n}$ is a known radial distance from the charge, and E_x is the unknown electric field; but since the wavelength of an electromagnetic radiation is four times the radial distance ($\lambda = 4\, r_m$) [11, 12], hence ($\frac{\lambda}{4} = r_m$), substituting r with λ/4 in Eq. (3), thus the magnitude of the polarized wave, or electric field in any Electromagnetic Radiation (EM-R), is given by

$$E_{PF} = \frac{4^2 E_R}{\lambda^2} = \frac{4^2(5.767838388 \times 10^{-9})}{\lambda^2} \tag{4}$$

Where, E_{PF} is the Polarized Electric Field, or the Electric Field in Electromagnetic Radiation ($\boldsymbol{E_{EM}}$).

III. The Magneto-Optic Force (F_{MO})

The Faraday Effect is greatly connected with the magnetic force [1], the rotation axis coincided with the direction of the magnetic force [4, 1], and the rotational power of the phenomenon increased with the intensity of the magnetic lines of force [1], and in his experiments, Faraday discovered that, the phenomenon occurred only when the polarized rays of light are parallel to the lines of force, if they are perpendicular to the ray, they have no action upon it, duly he stated that "*the character of the force impressed upon the diamagnetic* *is that of rotation*" [1], as shown in Table.1, Faraday gave the strength of rotation compared to the water, but the magnetic susceptibility of each material in the Table.1, is also compared with that of water and give the same increase derived by Faraday, therefore the introduction of these diamagnetic materials only strengthen the Supplied Magnetic Field (B_S), not as a dimensional factor perceived by Verdet [5], Faraday experiments showed the importance of the magnetic lines of force and how the field been increased by these diamagnetic materials; contrary to the link to Lorentz [8], in which the change in frequency by an electron is thought to be related to the rotation of the plane of polarized light, in addition to the empirical formula derived for the Verdet constant by Becquerel, which was crafted to suit the formula [8], by substituting the parameters of the diamagnetic material with the Verdet, contrary to Faraday results, which showed that, the diamagnetic material only increase the rotation of the polarized light, and doesn't necessarily by the dimensional structure as given by Eq. (A) [1], and since the polarized field consist of the electric field of the electromagnetic radiation [9] as given by Eq. (2&4), while as shown in Fig.2-A&B, the axis of the Polarized Electric Field (E_{PF}) is rotating around the axis of the magnetic line of force; and recall Faraday's conclusion that "*the character of the force impressed upon the diamagnetic is that of rotation*" [1], and since Faraday also carried out his effect using electric current passed round a ray of polarized light in a plane perpendicular to the ray, and it causes the ray to revolve on its axis, as long as it is under the influence of the current, in the same direction as that in which the current is passing [1], and although Faraday first thought magnetic and electric forces appear to exert no power on the ordinary or on the depolarized ray of light [1], but he counter that statement by saying**, "***we can hardly doubt but that they have some special influence, which probably will soon be made apparent by experiment* [1], therefore, we are suggesting the Magneto-Optic Force (F_{MO}) as the force produced by the Faraday Effect, and resulted from the interaction of both the Polarized Electric Field (E_{PF}) and the Supplied Magnetic Field (B_S); and since the Magneto-Optic Force (F_{MO}) is a rotational force, therefore, it's an angular velocity, and given by

$$\boldsymbol{F_{MO}} = \omega = \frac{E_{PF} B_S \boldsymbol{\varepsilon_O}}{2\pi^3 \mu_0} \quad (5)$$

Where, μ_0 is the permeability of free space, B_S is the Supplied Magnetic Field and $\boldsymbol{F_{MO}}$ is the Magneto-Optic Force; thus ssubstituting E_{FP} in Eq. (5) with the right hand side of Eq. (4), therefore the Magneto-Optic Force (F_{MO}) is given by

$$\boldsymbol{F_{MO}} = \omega = \frac{(4^2) E_R B_S \boldsymbol{\varepsilon_O}}{2\pi^3 \mu_0 \lambda^2} \quad (6)$$

IV. The Relative Magnetization Of The Diamagnetic Materials

Since Faraday used different types of diamagnetic materials such as silicate borate of lead glass, water, glass and a great number of other substances, acting on polarized ray of light to obtained the phenomenon, which only exhibited with diamagnetic materials [1], and since the usage of diamagnetic materials with lower magnetic field caused individual magnetic zones "*magnetic domains*" within the materials to become more or less aligned, resulting in a net non-zero field, such as the case with earth's geomagnetic field [13], and the widespread knowledge of diamagnetic materials, is centered in that, it response to an applied magnetic field by acquiring a small induced magnetization, opposite to the direction of the applied field [14], although this will be discussed later, but as stated by Faraday, the magnetic lines only act upon a polarized ray of light when they are parallel to the ray, they have no action if they are perpendicular to the ray, and they give the diamagnetic the power of rotating the ray [1]; and since certain magnetic materials (e.g., magnetic garnets) are transparent enough to transmit a good fraction of the light while producing a fairly large Faraday rotation, and these materials can be magnetized in a given direction and sustain their magnetization when the external field is removed, meaning the Faraday effect in these media can temporarily be persists in the absence of the Supplied Magnetic Field (B_S) [15]; and since magnetic susceptibility is a dimensionless proportionality constant that indicates the degree of magnetization of a material in response to Supplied Magnetic Field (B_S) [16]; therefore the subjection of the diamagnetic material to the Supplied Magnetic Field (B_S), lead to the magnetization of the material, this is given by [16]

$$M = \chi_v H \quad (7)$$

Where, H is the magnetic field strength, also measured in amperes per meter, χ_v is the magnetic susceptibility a dimensionless quantity, M is the magnetization of the material (the magnetic dipole moment per unit volume) and measured in amperes per meter, while the relation between magnetic field and magnetic field strength, is given by

$$B = \mu H \quad (8)$$

And permeability in Eq. (7), is given by

$$\mu = \mu_0(1 + \chi_v) \quad (9)$$

Substituting the permeability in Eq. (8) with equivalent in Eq. (9), we get

$$H = \frac{B_S}{\mu_0(1 + \chi_v)} \quad (10)$$

Substituting H in Eq. (10) with equivalent in Eq. (7), thus the magnetization is given by

$$M = B_S\left(\frac{\chi_v}{\mu_0(1 + \chi_v)}\right) \quad (11)$$

Material	Oil of turpentine	Heavy glass	Flint-glass	Rock-salt	Water	Alcohol
Rotational speed(compared to water =1)	11.8	6.0	2.8 **25.34×10^{-6} [17]**	2.2 19.91×10^{-6}	1.0 [16]	-0.91
magnetic susceptibility water is χ_v	106.79 x10^{-6} (103x10^{-6} [18])		**−11.28×10^{-6}**	-10x10-6	-9.05 x 10^{-6}	-183.5·10^{-5} cm^3/mol [19]
χ_v / χ_v water	11.8 11.38		2.8	1.10	1.0	-0.002
Theoretical Magnetization (M)	84.974213841806650593360088760667		M=20.166037029979008138542117972246		7.2019084022291985652086589027001	
Effective (Practical) magnetization	25.723396879408328397381481820796		6.1046634096869900408495763935089		2.1801619543615232326868660643061	

Table.1. The six diamagnetic materials in the first row, the rotational speed of the polarized wave for each of the materials compared to water are given in the second row as measured by Faraday [1]; the third row give the magnetic susceptibility of each material, (as camphor can be produced synthetically from oil of turpentine with magnetic susceptibility of 103x10^{-6} [18], hence oil of turpentine obtained by multiplied water x 11.8), the fourth row compared the value of each magnetic susceptibility to water (giving Faraday speed in row one), the fifth gives theoretical magnetization of each material, while the sixth gives the effective (practical) magnetization.

Faraday, stated clearly that, "*the rotation appears to be in proportion to the extent of the diamagnetic through which the ray and the magnetic lines pass*," and "*the greater the extent of the diamagnetic in the line of the ray, whether in one, two, or three pieces, the greater was the rotation of the ray*" he continued stating that "*as far as I could judge by these first experiments, the amount of rotation was exactly proportionate to the extent of diamagnetic through which the ray passed*" and that "*no addition or diminution of the heavy glass on the side of the course of the ray made any difference in the effect of that part through which the ray passed*" [1]; the rotation is also found to be proportional to the thickness of the material traversed and the magnetization intensity [5], which clearly related to specific characteristics within the material; and since as stated above magnetic susceptibility is a dimensionless proportionality constant that indicates the degree of magnetization of a material in response to a Supplied Magnetic Field (B_S) [16]; thus the factor of diamagnetic material is not due to its length as perceived by the Verdet suggestion [5], because by bringing a large piece of iron near to the glass on the other side of the ray, it caused the power of the diamagnetic to fall, because some magnetic lines moved around the iron [1], or the length of Oil of turpentine supposed to extend to 11.8 times that of water as given in Table.1, hence an important factor been neutralized; that is the magnetic susceptibility given in Table.1, which showed the relationship between these materials with speed given by Faraday [1], and since magnetization started with orientation of "*magnetic domains*" within the materials [13], hence the length of a material is related to oriented numbers of domains; while an increase in their length or thickness is merely an increase in the related domains and the degrees of magnetization by the Supplied Magnetic Field (B_S) [9], these observations clearly showed the effect of diamagnetic materials as being magnetized, while if a strong magnetic field (B_S) is Supplied, this will reverse the internal magnetic domains of the diamagnetic material [14], leading to the establishment of a repulsive force by the diamagnetic material as a reaction to the Supplied Magnetic Field (B_S) [20], as discovered by Faraday himself [21]; such strong force obtained by P. Kapitza using liquid oxygen to eject glass rod from Dewar vacuum flask, using 30 Tesla (300,000 gauss) [21], the existence of this force could have been detected or realized and mentioned by Faraday while testing his Effect, hence such force was not detected by Faraday, as it will reverse the diamagnetic field, changing the direction of the rotation, while Faraday defined the rotation with the direction of the Supplied magnetic lines of force, that "*if a magnetic line of force be going from a north pole, or coming from a south pole, along the path of a polarized ray coming to the observer, it will rotate that ray to the right hand; or, that if such a line of force be coming from a north pole, or going from a south pole, it will rotate such a ray to the left-hand*" [1], both directions are shown in Fig.2A&B; while in regard to the magnetization of the diamagnetic material by the Supplied Magnetic Field (B_S), Faraday was confused about what takes place, as he stated "*if the magnetic forces had made these bodies magnets, we could, by light, have examined a transparent magnet, but it does not make them magnets*;" while he suggested that it could be *a new phenomenon* saying, "*or other such matter, and must be a new magnetic condition; and as the condition is a state of tension (manifested by its instantaneous return to the normal state when the magnetic induction is removed), so the force which the matter in this state possesses and its mode of action, must be to us a new magnetic force or mode of action of matter*;" [1], as will be seen this is something new, and since the imposition of magnetic field (B_I) first resulted in the alignment of the magnetic domains to the field direction [13], and the center of rotating wave is suggested to coincides with the magnetic line of force as shown in Fig.2-A&B, while the greater the extent of the diamagnetic in the line of the ray, the greater was the rotation of the ray [1], therefore, the Supplied Magnetic Field (B_S) is less than the threshold of diamagnetic effect that reverse its field, hence it oriented some percentage of domains of the diamagnetic materials within the magnetic lines of force of the Supplied Magnetic Field (B_S), but Faraday also stated that, "*other bodies, such as the oil of turpentine, sugar, tartaric acid, tartrates, &c, possess the same, but the effect of the magnetic force is* ***to add to, or subtract from****, their specific force*" [1], this means materials such as the oil of turpentine which posses higher magnetic susceptibility as given in Table.1, with similarity to camphor with magnetic susceptibility of $103\text{x}10^{-6}$ [18], its derived by multiplied water x 11.8, with its magnetic force increased by an internal factor, hence this factor is the magnetization with its level is proportional to how much percentage the domains numbers are well oriented, because even air and gases have the power to affect light, but in a degree so small that as yet it has not been made sensible, its similar to the increase in the rotation by the water upon the light in Faraday electrical experiment, when an iron put into the helix [1], but Faraday himself clearly stated the possibility of magnetization without been detected, when he stated that *"it is impossible, I think, to observe and see the action of magnetic forces, rising in intensity, upon a piece of heavy glass or a tube of water, without also perceiving that the latter acquire properties which are not only new to the substance, but are also in subjection to very definite and precise laws, and are equivalent in proportion to the magnetic forces producing them"* [1] although he clearly hinted to the existence of small percentage of magnetization; and since as stated by Faraday "*the direction of the rotation is, in every case, independent of the nature or state of the substance, and dependent upon the direction of the magnetic line of force, according to the law*," [1], therefore, its suggested that, domains of the diamagnetic materials are initially orientated by the Supplied Magnetic Field (B_S), and as they differ as given in Table.1, some could be magnetized to higher magnitudes, giving faster rotational force of the polarized wave, these are distinguished by their higher magnetic susceptibility, such as Oil of turpentine, which will be magnetized more and give more force, thus great rotation [1], therefore, the role of diamagnetic materials is to instantly oriented the domains and increase the magnetization to higher percentage of magnitude, then back to zero when the Supplied Magnetic Field (B_S) is removed; therefore using Eq. (11), the magnetization for Flint-glass is given by

$$M_{TF} = B_S\left(\frac{\chi_v}{\mu_0(1+\chi_v)}\right) = 20.166037029979008138542117972246\ B_S \qquad (12)$$

Where, M_{TF} is the theoretical Magnetization of the Flint-glass; but using the angles and magnetic fields in Table.2, as a given reference for results obtained using Flint-glass as diamagnetic material [7], this result will be used as a reference to get the effective magnitude of magnetization, as derived through empirical process, representing the magnitude that when used in Eq. (22), will derive the values given in our Table.2, and Table.2 by GmbH [7], and when subtracted from amount given by Eq. (12), the remains is the Effective Magnetization (M_{EF}) = 6.104663409686990040849576393509; hence, from this we can get the percentage of the Effective Magnetization of the Flint-glass (M_{EF}) from the Theoretical Magnetization of the Flint-glass (M_{TF}) given by Eq. (12), therefore, this percentage raised the magnitude of the Supplied Magnetic Field (B_S) to value at which it interacted with the polarized wave to produce the Magneto-Optic Force (F_{MO}), the percentage is given by

$$\Gamma_{\text{FG}} = \frac{6.104663409686990040849576393509}{20.166037029979008138542117972246}\times 100 = 30.272003371865992739664843701281\% \qquad (13)$$

Where, the capital gamma Γ_{FG} is the percentage of the Effective Magnetization of the Flint-glass (M_{EF}) during the Faraday Effect, as percentage of magnetization given by Eq. (11), and increase from the Supplied Magnetic Field (B_S), as given in Table.1.

ϕ	Supplied Magnetic Field (B_S) In T	*Derived Angle* (ϕ) *Using* water As Diamagnetic	*Derived Angle* (ϕ) *Using* Oil of turpentine As Diamagnetic
2	0.026	**1.477**	72.8%
3	0.052	**2.955**	98.5%
4	0.078	**4.432**	110.8%
6	0.107	**6.080**	101.3%
8	0.136	**7.728**	96.6%
9	0.159	**9.035**	100.4%
10	0.182	**10.342**	103.4%
11	0.202	**11.478**	104.3%
12	0.221	**12.558**	104.6%
13	0.240	**13.637**	104.9%

Table. 2. Angles (ϕ) in the first column resulted when Supplied Magnetic Field ($\boldsymbol{B_S}$) given in second column, using Flint-glass and wavelength λ=450nm and Verdet constant [7]. If Eq. (22) is used with these Supplied Magnetic Field (B_S), the same wavelength give Polarized Electric Field (E_{PF}) of 1.4506350465665411623915729640137x10^5 V.m^{-1}, and resulted with angles given in the third column; the forth column compared percentage of new angles (ϕ_1) to angles (ϕ) in 1st column, showing great similarity.

Inserting the percentage given by Eq. (13) in the magnetization given by Eq. (11), therefore, the M_{EF} is given by

$$M_{EF} = B_S\left(\frac{\chi_v}{\mu_0(1+\chi_v)}\right) \times \frac{30.272003371865992739664843701281}{100} \qquad (14)$$

Where, M_{EF} is the Effective Magnetization for Flint-glass; hence when Eq. (14) is resolved, thus the increase in the magnetized of the Supplied Magnetic Field (B_S) for any Flint-glass is given by

$$M_{EF} = B_S\left(\frac{\chi_v}{\mu_0(1+\chi_v)}\right)\Gamma_{\mathrm{FG}} = 6.104663409686990040849576393509 \qquad (15)$$

Therefore based on Eq. (13), the B_S in Eq. (6) will be replaced by M_{FE}, the formula is given by

$$\boldsymbol{F_{MO}} = \omega = \frac{(4^2)E_R M_{EF}\boldsymbol{\varepsilon_O}}{2\pi^3\mu_0\,\lambda^2} \qquad (16)$$

Replacing M_{EF} in Eq. (16) with the right hand of Eq. (14), the following is obtained

$$\boldsymbol{F_{MO}} = \omega = \frac{(4^2)E_R\, B_S\, \boldsymbol{\varepsilon_O}}{2\pi^3\mu_0\,\lambda^2}\left(\frac{30.272003371865992739664843701281\chi_v}{100\mu_0(1+\chi_v)}\right) \qquad (17)$$

Changing from radians to degree, the following formula is used

$$Dig = \frac{180Radi}{\pi} \qquad (18)$$

Transforming the force given by Eq. (17) into angle by inserting Eq. (18) in Eq. (17), and replacing M_{EF} with value given on the right hand side of Eq. (15), the angle is given by

$$\phi_{FG} = \frac{180(4^2)\,E_R\,B_S\,\boldsymbol{\varepsilon_O}}{2\pi^3\mu_0\,\lambda^2}\,(6.104663409686990040849576393509) \qquad (19)$$

Substituting the Reference Electric Field (E_R) in Eq. (19) with numerical value given in Eq. (4), the following is obtained

$$\phi_{FG} = \frac{180(4^2)B_S\boldsymbol{\varepsilon_O}\,(5.767838388\times10^{-9})}{2\pi^3\mu_0\lambda^2}(6.104663409686990040849576393509)(20)$$

Solving the numeric in Eq. (20), the angle is given by

$$\phi_{FG} = \frac{(1.1506367791129514214974814308888 \times 10^{-11})}{\lambda^2} B_S \qquad (21)$$

For wavelength of 450nm, using Flint-glass as diamagnetic, the angle is given by

$$\phi_{FG} = 56.821569338911181308517601525371 B_S \qquad (22)$$

Table.2, give the equivalent angles to the given reference angles when the wavelength λ=450 nm, and the Supplied Magnetic Field (B_S) is as in the second column [7], the derived electric field of the polarized wave is= $1.4506350465665411623915729640137\times 10^5$ V.m^{-1}, from Table.2, the results obtained using Eq. (22) is nearly the same.

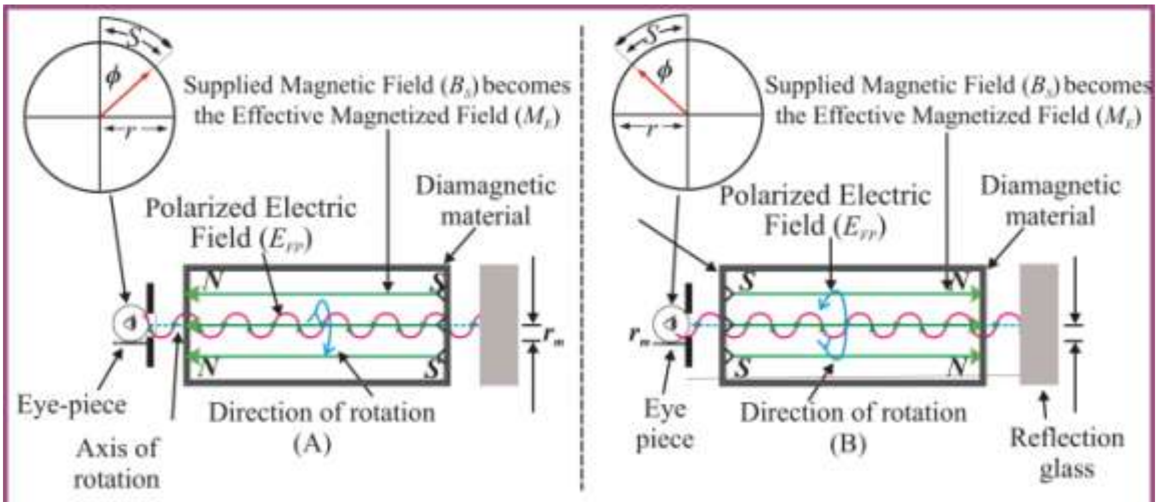

Fig.2. The Polarized Electric Field (E_{FP}) interacted with the Effective Magnetized Field (M_E), producing the Magneto-Optic Force ($\boldsymbol{F_{MO}}$), it rotates around the Magnetic Line of Force (MLF), the rotation is clockwise in A and counterclockwise in B.

Faraday discovered that, the great rotation of the polarized wave is directly proportional to the length of fluid, or the diamagnetic material, thus by adding iron tubes to a short tube of water, by increasing the development of magnetic forces, the helix and core, as a whole, produce increased action on the water; but on adding more irons and the disposal of the forces through it, their action is removed in part from the water and the rotation is lessened [1]; while using very powerful electro-magnetic, Faraday measured and compared the force of rotation from the eye-piece of several materials with water as 1, and as given in Table.1, the numbers he obtained were: Oil of turpentine 11.8, Heavy glass 6.0, Flint-glass 2.8, Rock-salt 2.2, Water 1.0, Alcohol -0.91, and Ether less than alcohol **[**1], since Faraday data is found to related to the magnetic susceptibility shown in Table.1**,** therefore from Eq. (17) and related to Faraday's relation between the Flint Glass and water given in Table.1, therefore, a general formula for the percentage of the General Effective Magnetization (M_{EG}), is given by

$$\frac{M_{EF}}{M_{TF}} = \frac{M_{EX}}{M_{TK}} \qquad (23)$$

Where, M_{EF} is the Effective Magnetization of the Flint-glass (M_{EF}), M_{TF} is the Theoretical Magnetization of the Flint-glass (M_{EF}), M_{TK} is the Theoretical Magnetization of the Known Material (M_{EK}), and M_{EX} is the unknown Effective Magnetization of the Known Material (M_{EX}). Therefore, from Eq. (23), the general formula for the Effective Magnetization of the Known Material (M_{EX}), is given by

$$M_{EX} = M_{TK}\left(\frac{M_{EF}}{M_{TF}}\right) \qquad (24)$$

To get the Effective Magnetization of Water (M_{EW}), using Eq. (24), the Theoretical Magnetization of Water (M_{EW}) = 7.2019084022291985652086589027001, will be inserted in Eq. (24), the following is obtained

$$M_{EX} = 7.2019084022291985652086589027001 \times \left(\frac{6.1046634096869900408495763935O9}{20.166037029979008138542117972246}\right) \quad (25)$$

This gives the Effective Magnetization of Water (M_{EW}), which is M_{EW}=2.1801619543615232326868660643061, therefore replacing this in Eq. (15), the Effective Magnetization for Water (M_{EW}), is given by

$$M_{EW} = B_S\left(\frac{\chi_v}{\mu_0(1+\chi_v)}\right) \times \Gamma_{\mathrm{W}} = 2.1801619543615232326868660643061 \quad (26)$$

Substituting the right hand of Eq. (26) with the right hand side of Eq. (19), therefore the Magneto-Optic Force (F_{MO}) when using water is given by

$$F_{MO} = \frac{(4^2)E_R\, B_S\, \boldsymbol{\varepsilon_O}}{2\pi^3\mu_0\, \lambda^2}(2.1801619543615232326868660643061) \quad (27)$$

The angle is given by

$$\phi_W = \frac{180(4^2)B_S E_R \boldsymbol{\varepsilon_O}}{2\pi^3\mu_0\lambda^2}\ (2.1801619543615232326868660643061) \quad (28)$$

Hence, the angle is given by

$$\phi_W = \frac{(4.1092757466865235559206070781821 \times 10^{-12})B_S}{\lambda^2} \quad (29)$$

For wavelength of 450 nm, the angle using water as diamagnetic material and as in Table.2, is given by

$$\phi_W = 20.292719736723573115657318904603\ B_S \quad (30)$$

Angle ϕ	Supplied Magnetic Field (B_S) *Using* water	Supplied Magnetic Field (B_S) *Using* Flint-glass	Supplied Magnetic Field (B_S) *Using* Oil of turpentine
2	0.099	**0.035**	0.008
3	0.148	**0.053**	0.013
4	0.197	**0.070**	0.017
6	0.296	**0.106**	0.025
8	0.394	**0.141**	0.033
9	0.443	**0.158**	0.038
10	0.493	**0.176**	0.042
11	0.542	**0.194**	0.046
12	0.591	**0.211**	0.050
13	0.641	**0.229**	0.054

Table. 3. Variation of the Supplied Magnetic Field (B_S) with angles (ϕ) and diamagnetic material for wavelength λ=450 nm, having Polarized Electric Field (E_{PF}) of 1.4506350465665411623915729640137× 10^5 V.m^{-1}; B_S in second column using water in Eq. (30); B_S in the third column are using Flint-glass in Eq. (22) and B_S in fourth column using Oil of turpentine in Eq. (35).

Since the theoretical Magnetization of Oil of turpentine (M_{TOT}) is = 84.974213841806650593360088760667, therefore using Eqs. (24&25), the Effective Magnetization of Oil of turpentine (M_{EOT}), is M_{EO}= 25.723396879408328397381481820796, thus substituting this in Eq. (26), the Effective Magnetization of Oil of turpentine (M_{EO}),is given by

$$M_{ET} = B_S\left(\frac{\chi_v}{\mu_0(1+\chi_v)}\right) \times \Gamma_{\mathrm{T}} = 25.723396879408328397381481820796 \quad (31)$$

Substituting the right hand of Eq. (31) with the right hand side of Eq. (19), therefore the Magneto-Optic Force ($\boldsymbol{F_{MO}}$) for Oil of turpentine is given by

$$\boldsymbol{F_{MOT}} = \frac{(4^2)E_R\ B_S\ \boldsymbol{\varepsilon_O}}{2\pi^3 \mu_0\ \lambda^2}(25.7233968794083283973814818 20796) \qquad (32)$$

The angle is given by

$$\phi_G = \frac{180(4^2)B_S E_R \boldsymbol{\varepsilon_O}}{2\pi^3 \mu_0 \lambda^2}(25.723396879408328397381481820796) \qquad (33)$$

Therefore from Eq. (33), the angle for Oil of turpentine is given by

$$\phi_{OT} = \frac{4.848471495774762874444008152 7873 \times 10^{-11} B_S}{\lambda^2} \qquad (34)$$

For wavelength of 450nm, the resulted angles using Oil of turpentine as diamagnetic material is given by

$$\phi_{OT} = 239.43069114937100614538311865616\ B_S \qquad (35)$$

V. Results And Discussion

- The essence of the Faraday Effect is based on the rotation of the Polarized Electric Field (E_{PF}) of the electromagnetic wave.
- To get the angular momentum which turns this electric field, first its magnitude should be derived the formula give the magnitude of the field as an inverse square of the wavelength.
- This formula can also derive an electric field in any electromagnetic wave.
- The Magneto-Optic Force ($\boldsymbol{F_{MO}}$) is suggested as an angular force, which is produced by the interaction of both the Polarized Electric Field (E_{PF}) and the Supplied Magnetic Field (B_S).
- The Magneto-Optic Force ($\boldsymbol{F_{MO}}$) is a rotational force, therefore, it's an angular velocity, containing the angle by which the $\boldsymbol{F_{MO}}$ rotate.
- The Magneto-Optic Force ($\boldsymbol{F_{MO}}$) is proportional to the magnetization of the diamagnetic material.
- The diamagnetic material is magnetized, but to a lower level, after the orientation of the magnetic domain in the direction of the Supplied Magnetic Field (B_S).
- Each diamagnetic material is magnetized according to its magnetic susceptibility.
- The few percentage from the total magnetization, is what cause many to think the diamagnetic doesn't magnetized, simply because only 30.272% of the water, Flint-glass, and Oil of turpentine is used from the susceptibility to magnetized these diamagnetic materials, and this is the reason why scientists rejected the magnetization factor.
- As I couldn't get the magnetic susceptibility of oil of turpentine, and camphor with magnetic susceptibility of $103x10^{-6}$ which can be produced synthetically from oil of turpentine [18], its equivalent to multiplying water x 11.8 as from Faraday speed estimate in Table.1 [1].
- The angle by which the Polarized Electric Field (E_{PF}) rotates is proportional to the Supplied Magnetic Field (B_S), and inversely to the square of the wavelength.
- The value of angles for Flint-glass derived by Eq. (22) and given in Table.2, column three is derived with the percentage to what has been derived using Eq. (A) and the Verdet, the difference is not big, except for the first angle 2.
- Failure to get some basic data hindered the precise result of the paper, particularly the results for oil of turpentine.
- If light can be rotated by magnetic field as shown in Faraday Effect, hence why light from a star such as that of May 29, 1919 [22], can't be displaced by the sun's magnetic field?

VI. Conclusion

The Faraday Effect is explained in a pattern emphasized by Faraday, after he finished his experiment in 1845, the effected resulted from the rotation of the Polarized Electric Field (E_{PF}) around the magnetic line of force inside the diamagnetic material, the force is suggested to represents the Magneto-Optic Force ($\boldsymbol{F_{MO}}$), resulted from the interaction of both the linearly Polarized Electric Field (E_{PF}) and the Supplied Magnetic Field (B_S), within the transparent diamagnetic material, the magnitude of the electric field is derived and it is inverse square of its wavelength, while the magnetization of the diamagnetic material is suggested to represents 30.272% of the susceptibility, thus reducing the total magnetization by 69.728%; the model gives formula for the rotated angle and the magnitude of the Supplied Magnetic Field (B_S) required to produced specific angle.

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