THE EFFECT OF GRAVITATION ON THE INVERSE FARADAY EFFECT AND FARADAY EFFECT: MULTIPLE FIELD INTERACTIONS IN ECE THEORY.

by

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ABSTRACT

The effect of gravitation on the inverse Faraday effect and Faraday effect is considered as an example of multiple field interactions in Einstein Cartan Evans (ECE) field theory. The interactions of fundamental fields are considered on classical, semi-classical and fully quantized levels. For example, the fully quantized interaction between electron, photon and graviton is considered. In its classical limit, the interaction of photon and graviton is shown to produce the light deflection due to gravitation.

Keywords: Einstein Cartan Evans (ECE) field theory, inverse Faraday effect, Faraday effect, gravitation, multiple field interaction in ECE theory.

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1. INTRODUCTION

Recently, a generally covariant unified field theory has been developed {1-12} from standard Cartan geometry {13, 14}. It is known as Einstein Cartan Evans (ECE) field theory and has several fundamental advantages (www.aias.us) over the standard model. One major advantage is the ability of ECE theory to describe multiple field interactions on classical, semi-classical and quantum levels. In this paper an example of a multiple field interaction is given - that between the fermion matter field (exemplified by an electron), the electromagnetic field, and the gravitational field. In Section 2 this three field interaction is developed on the classical level and exemplified by the effect of gravitation on the inverse Faraday effect (IFE) and Faraday effect (FE). In Section 3, the difference is emphasized between the motion of an electron in a static magnetic field and an electromagnetic field. In Section 4 the self consistency of the classical method is checked by comparing a direct integration method with a Hamilton Jacobi method. In Section 5 the calculation is extended to the quantum level by considering the interaction between an electron and photon using ECE wave equations. In Section 5 the electron photon graviton interaction is considered on the quantum level, and in Section 6 the light deflection due to gravitation is obtained straightforwardly on the classical level.

2. CLASSICAL LIMIT : THE EFFECT OF GRAVITATION ON IFE AND FE.

In the first approximation the effect of gravitation on the IFE and FE can be developed from previous work on the ECE theory of IFE and FE by using the rule {1-12}:

$$m \rightarrow \frac{\hbar}{c}\left(kT\right)^{1/2} \qquad -(1)$$

where m is the electron mass, $\hbar$ is the reduced Planck constant, c is the speed of light, k is the Einstein constant and T is the scalar canonical energy momentum density. This rule originates in the correspondence principle applied to the ECE wave equation {1-12}:

$$\left(\Box + kT \right) q^a_\mu \qquad -(2)$$

where q^a_μ is the tetrad wave-function and also the fundamental field. In general this is a unified field, so T and q^a_μ contain information about the interaction of any or all of the fundamental fields of physics: gravitational, electromagnetic, weak, strong and matter fields. If the fermion field is considered for example, it becomes free of the influence of any other fundamental field when:

$$kT = \left(\frac{mc}{\hbar} \right)^2 \qquad -(3)$$

from which follows Eq. (1). When the fermion (e.g. electron) is free of any other field its mass is m. In the presence of gravitation for example its mass changes according to Eq. (1) and in general its mass changes in the presence of any other field, including the electromagnetic field. The fermion (electron) is no longer free because it is influenced by a gravitational field. To consider the effect of gravitation on the IFE and FE requires a three field interaction: the effect of gravitation on a fermion interacting with the electromagnetic field. The gravitational influence may be developed in a series of approximations. In the first approximation it may be assumed that the electromagnetic field is not affected by the gravitational field, and in this approximation Eq. (1) is used with the minimal prescription {1-12, 15}. In a better approximation, developed in later sections of this paper, the fermion and electromagnetic fields are both affected by the gravitational field. On the fully quantum level this requires the simultaneous solution of three ECE wave equations.

In the classical minimal prescription of ECE field theory, the complex valued four potential may be defined by:

$$A_\mu := A^{(0)}_\mu + A^{(1)}_\mu + A^{(2)}_\mu + A^{(3)}_\mu \qquad -(4)$$

where:

$$a = (0), (1), (2), (3) \quad -(4)$$

are polarization indices. The time-like index is (0), the three space-like indices by (1), (2) and (3). Here (1) and its complex conjugate (2) are transverse and (3) is longitudinal. The potential in ECE theory is manifestly covariant, so that all four indices are physical. It is also possible to consider individual components of A_μ in the minimal prescription. An example is the transverse plane wave:

$$\underline{A}^{(1)} = \frac{A^{(0)}}{\sqrt{2}} (\underline{i} - i\underline{j}) e^{i\phi_0} \quad -(5)$$

where

$$\phi_0 = \omega t - \kappa Z \quad -(6)$$

is the electromagnetic phase. Here ω is the angular frequency at instant t and κ the wave-number at point Z. In general the four-potential is:

$$A^\mu = \left(\frac{\phi}{c}, \underline{A} \right) \quad -(7)$$

where ϕ is the scalar potential and $\underline{A}$ the vector potential. In the first approximation defined already, ϕ and $\underline{A}$ are not changed, but m is changed wherever it occurs using Eq. (1). In previous work {1-12} it has been shown from direct integration of the classical Einstein equation with minimal prescription that the relevant kinematics of the IFE and FE for the free classical electron (the classical limit of the Dirac electron) are as follows. The angular momentum is:

$$\underline{J} = \gamma \underline{r_0} \times \underline{p} + e \underline{r_0} \times \underline{A} + e \int \underline{A}\, dt \times \underline{v_0} + \frac{e^2}{\gamma m} \int \underline{A}\, dt \times \underline{A} \quad -(8)$$

where $\underline{r_o}$ and $\underline{v_o}$ are respectively the initial position and velocity of the electron, e is the magnitude of the charge on the electron, m is the mass of the electron, $\underline{A}$ is the electromagnetic vector potential, and:

$$\gamma = \left(1 - \frac{u^2}{c^2}\right)^{-1/2} \quad -(9)$$

where u is the constant speed of one frame moving with respect to another in a Lorentz boost {13, 15, 16}. For a plane wave such as Eq. (5) an analytical solution may be obtained for the magnitude of the angular momentum:

$$J = \left(r_o + \frac{eA}{\gamma m \omega}\right)\left(\gamma m v_o + eA\right). \quad -(10)$$

The kinetic energy of the electron is {1-12}:

$$T = \frac{\left(\gamma m v_o + eA\right)^2 c^2}{mc^2(1+\gamma) + e\phi} \quad -(11)$$

and its angular velocity is:

$$\Omega = \frac{\left(\gamma m v_o + eA\right) c^2}{\left(r_o + \frac{eA}{\gamma m \omega}\right)\left(mc^2(1+\gamma) + e\phi\right)} \quad -(12)$$

from which the angular velocity of the electromagnetic field can be expressed in terms of Ω as:

$$\omega = \frac{eA\Omega}{\gamma m (x - \Omega r_o)} \quad -(13)$$

where the factor x is:

$$x = \frac{(\gamma m v_0 + eA)c^2}{mc^2(1+\gamma) + e\phi} \, . \qquad -(14)$$

Therefore all these kinematic equations are affected by gravitation according to Eq. (1), i.e. the electron mass is changed by gravitation wherever it occurs, and in consequence the kinematic quantities are all affected by gravitation. This shows that both the IFE and FE are effected by gravitation.

In a better approximation the effect of gravitation on the minimal prescription itself is considered. Therefore A^{μ} as well as p^{μ} is changed by the presence of the gravitational field. Therefore gravitation changes $\underline{A}$ and ϕ as follows:

$$\underline{A} \rightarrow \left(\frac{\hbar}{mc} (kT)^{1/2} \right) \underline{A} , \qquad -(15)$$

$$\phi \rightarrow \left(\frac{\hbar}{mc} (kT)^{1/2} \right) \phi \, . \qquad -(16)$$

In ECE theory the relation between the electromagnetic potential and the electromagnetic field is also changed by gravitation because the latter implies the existence of a non-zero homogeneous current. In the standard notation of differential geometry {13}, the homogeneous current is defined by:

$$j^a := \frac{A^{(0)}}{\mu_0} \left(R^a{}_b \wedge q^b - \omega^a{}_b \wedge T^b \right) \qquad -(17)$$

where μ_0 is the vacuum magnetic permeability (S.I. units), $R^a{}_b$ is the curvature form, omega is the spin connection and T^b is the torsion form {1-12}. Therefore various levels of approximation may be used to describe field interactions in ECE theory. The whole of physics can be defined as the interaction of fields. ECE allows this to be considered in a generally covariant manner as demanded by the basics of relativity. The latter is by far the most precise theory in physics, so the ECE methods are well founded in experiment.

3. THE MOTION OF THE CLASSICAL ELECTRON IN A STATIC MAGNETIC FIELD AND A RADIATED ELECTROMAGNETIC FIELD.

Before proceeding to higher levels of approximation in multiple field interactions the differences between the motion of an electron in a static magnetic field and in a radiated electromagnetic field are emphasized here on the classical level. This is to emphasize that a classical magnetic field has important differences from the radiated electromagnetic spin field of ECE theory. The latter is an observable of IFE and FE and is one of the indications that electrodynamics is a generally covariant sector of unified field theory. The standard model description of a static magnetic field must be developed in ECE theory {1-12} to include the spin connection, but the standard model description is given here for the sake of illustrating the differences in electron motion. From the minimal prescription the angular momentum of the electron in the static magnetic field is:

$$\underline{J} = \underline{r} \times \underline{p} = e\underline{r} \times \underline{A} \qquad (18)$$

where, in the standard model, the static magnetic flux density is:

$$\underline{B} = \underline{\nabla} \times \underline{A}, \quad \underline{A} = \frac{1}{2}\underline{B} \times \underline{r}. \qquad (19)$$

Therefore the electron's angular momentum magnitude is:

$$J = erA = er^2 B \qquad (20)$$

and its kinetic energy is:

$$T = \frac{e^2 A^2}{2m}. \qquad (21)$$

Its angular velocity is:

$$\Omega = \frac{2T}{J} = \frac{eA}{rm} = \frac{e}{m}B. \quad -(22)$$

Therefore its angular momentum magnitude can be written as:

$$J = e\Phi \quad -(23)$$

where:

$$\Phi = r^2 B \quad -(24)$$

is the magnetic flux in weber. The magnetic flux density is $\underline{B}$ (in tesla or weber per square meter). The quantum of flux is therefore:

$$\Phi = \frac{\hbar}{e}. \quad -(25)$$

The magnetic dipole moment induced by a static magnetic field in the standard model is therefore

$$\underline{m} = \frac{e}{2m}\underline{J} = \left(\frac{e^2 r^2}{2m}\right)\underline{B} \quad -(26)$$

where

$$\chi := \frac{e^2 r^2}{2m} \quad -(27)$$

is the static magnetic susceptibility.

It is seen from a comparison with Section 2 that these quantities are different from the corresponding ones for an electron in an electromagnetic field. Using the Hamilton Jacobi method for example {1-12} the angular momentum of an electron in a circularly polarized electromagnetic field may be expressed as:

$$\underline{J}^{(3)} = \frac{e^2 c^2}{\omega^2} \left(\frac{B^{(0)}}{(m^2\omega^2 + e^2 B^{(0)2})^{1/2}} \right) \underline{B}^{(3)} \quad -(28)$$

where $\underline{B}^{(3)}$ is the ECE spin field {1-12}. The latter originates in the spinning of space-time itself and is a radiated field. The static magnetic field is not a radiated field. The angular velocity of the electron in the electromagnetic field from the Hamilton Jacobi method is {1-12} is:

$$\Omega = \left(\omega^2 + \left(\frac{eB^{(0)}}{m} \right)^2 \right)^{1/2} . \quad -(29)$$

From Eq. (8), the angular momentum of the electron in a radiated plane wave is:

$$\underline{J}^{(3)} = -\frac{ie^2}{\gamma m} \int \underline{A}^{(1)} dt \times \underline{A}^{(2)} \quad -(30)$$

where:

$$\underline{A}^{(1)} = \underline{A}^{(2)*} \quad -(31)$$

in which * denotes complex conjugate. So:

$$\underline{J}^{(3)} = \frac{e^2 A^{(0)2}}{\gamma m \omega} \underline{e}^{(3)} . \quad -(32)$$

Using the fundamental optical relation { 17 }:

$$A^{(0)} = \frac{c}{\omega} B^{(0)} \quad -(33)$$

and:

$$\underline{B}^{(3)} = B^{(0)} \underline{e}^{(3)} = B^{(0)} \underline{k} \quad -(34)$$

it is found that the angular momentum from the direct integration method {1-12} is:

$$\underline{J}^{(3)} = \frac{e^2 c^2}{\gamma m \omega^3} B^{(0)} \underline{B}^{(3)} \quad -(35)$$

In the non-relativistic limit:

$$\gamma \rightarrow 1, \quad m\omega \gg eB^{(0)} \quad -(36)$$

and Eq. (35) becomes Eq. (28) of the Hamilton Jacobi method. A fuller comparison of the Hamilton Jacobi method and the direct integration method of describing the relativistic motion of an electron in an electromagnetic field is given in the next section. From Eq. (35) the angular momentum magnitude is

$$J = \frac{e^2 c^2}{\gamma m \omega^3} B^{(0)2} = \frac{\mu_0 e^2 c}{\gamma m \omega} \left(\frac{I}{\omega^2} \right) \quad -(37)$$

where { 17 }:

$$I = \frac{c}{\mu_0} B^{(0)2} \quad -(38)$$

is the power density in watts per square meter of the electromagnetic field. The induced magnetic dipole moment due to the $\underline{B}^{(3)}$ spin field is:

$$\underline{m}^{(3)} = \left(\frac{e^3 c^2}{2\gamma m^2 \omega^3} \right) B^{(0)} \underline{B}^{(3)} \quad -(39)$$

where

$$\beta := \frac{e^3 c^2}{2\gamma m^2 \omega^3} \quad -(40)$$

is the magnetic hyper-magnetizability of one electron. It is seen that the $\underline{B}^{(3)}$ field interacts through this property while the static magnetic field interacts through the one electron static susceptibility.