ELECTRON SPIN ORBIT RESONANCE

by

M. W. Evans and H. Eckardt,

Civil List and AIAS

(www.webarchive.org.uk, , www.aias.us, www.atomicprecision.com, www.upitec.org,

www.et3m.net)

ABSTRACT

By rigorous inspection term by term of the interaction hamiltonian of the fermion equation of ECE theory a new type of fermion resonance is inferred and named electron spin orbit resonance (ESOR). The minimal prescription in the classical hamiltonian is sufficient to deduce the existence of ESOR

Keywords: ECE theory, interaction hamiltonian of the fermion equation, electron spin orbit resonance (ESOR).

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1. INTRODUCTION

In recent papers of this series {1 - 10} the fermion equation has been used to deduce a new particle theory and to link it with the theory of low energy nuclear reactors (LENR). This involved a careful and systematic inspection of the terms in the well known hamiltonian for the interaction of one electron with a field, notably an electromagnetic field. In this case the hamiltonian of the fermion equation is the same as the well known hamiltonian of the Dirac equation. It was found that terms had been overlooked, terms which can lead to new electron resonance spectroscopies of great potential utility. In section 2 one of these overlooked terms is evaluated in detail and developed into electron spin orbit resonance (ESOR). There are several other spectroscopies that can be developed in this way.

2. DEVELOPMENT OF ESOR AT THE SIMPLE ONE ELECTRON LEVEL

Consider the classical kinetic energy of an electron of mass m and linear momentum $\underline{p}$:

$$H = \frac{p^2}{2m} \quad -(1)$$

and use the minimal prescription {11} to describe the interaction of the electron with a vector potential $\underline{A}$. For the sake of initial argument we will use the standard physics, and later develop this theory into ECE physics. The interaction hamiltonian is defined as:

$$\begin{aligned} H &= \frac{1}{2m}\left(\underline{p} - e\underline{A}\right)\cdot\left(\underline{p} - e\underline{A}\right) \\ &= \frac{p^2}{2m} - \frac{e}{2m}\left(\underline{p}\cdot\underline{A} + \underline{A}\cdot\underline{p}\right) + \frac{e^2A^2}{2m} \quad -(2) \end{aligned}$$

For a uniform magnetic field the vector potential can always be defined as:

$$\underline{A} = \frac{1}{2}\underline{B} \times \underline{r} \quad -(3)$$

where $\underline{B}$ is the magnetic flux density in tesla. Now consider the following term of the hamiltonian:

$$H_1 = -\frac{e}{2m}\left(\underline{p}\cdot\underline{A} + \underline{A}\cdot\underline{p}\right) \quad -(4)$$
$$= -\frac{e}{4m}\left(\underline{p}\cdot\underline{B}\times\underline{r} + \underline{B}\times\underline{r}\cdot\underline{p}\right)$$

where the orbital angular momentum is:

$$\underline{p} \times (\underline{B} \times \underline{r}) = \underline{B}\cdot\underline{r}\times\underline{p} = \underline{L}\cdot\underline{B}. \quad -(5)$$

The well known hamiltonian emerges for the interaction of a magnetic dipole moment with the magnetic flux density:

$$H_1 = -\frac{e}{2m}\underline{L}\cdot\underline{B} = -\underline{m}_0\cdot\underline{B}. \quad -(6)$$

The magnetic dipole moment is defined by the product of the gyromagnetic ratio e / (2m) with the orbital angular momentum.

The classical hamiltonian responsible for eq. (6) is:

$$H_1 = -\frac{e}{2m}\left(\underline{p}\cdot\underline{A} + \underline{A}\cdot\underline{p}\right) \quad -(7)$$

which can be written in the SU(2) basis as:

$$H_1 = -\frac{e}{2m}\left(\underline{\sigma}\cdot\underline{p}\,\underline{\sigma}\cdot\underline{A} + \underline{\sigma}\cdot\underline{A}\,\underline{\sigma}\cdot\underline{p}\right). \quad -(8)$$

Using Pauli algebra {12}:

$$\underline{\sigma}\cdot\underline{p}\,\underline{\sigma}\cdot\underline{A} = \underline{p}\cdot\underline{A} + i\underline{\sigma}\cdot\underline{p}\times\underline{A} \quad -(9)$$
$$\underline{\sigma}\cdot\underline{A}\,\underline{\sigma}\cdot\underline{p} = \underline{A}\cdot\underline{p} + i\underline{\sigma}\cdot\underline{A}\times\underline{p} \quad -(10)$$

and the same result (6) is obtained because:

$$i\underline{\sigma}\cdot\left(\underline{p}\times\underline{A} + \underline{A}\times\underline{p}\right) = 0. \quad -(11)$$

However {12}:

$$\boldsymbol{\sigma}\cdot\mathbf{p} = \frac{1}{r^2}\,\boldsymbol{\sigma}\cdot\mathbf{r}\left(\mathbf{r}\cdot\mathbf{p} + i\boldsymbol{\sigma}\cdot\mathbf{L}\right) \quad -(12)$$

$$\boldsymbol{\sigma}\cdot\mathbf{A} = \frac{1}{r^2}\,\boldsymbol{\sigma}\cdot\mathbf{r}\left(\mathbf{r}\cdot\mathbf{A} + i\boldsymbol{\sigma}\cdot\mathbf{r}\times\mathbf{A}\right) \quad -(13)$$

in which:

$$\frac{1}{r^2}\,\boldsymbol{\sigma}\cdot\mathbf{r}\,\boldsymbol{\sigma}\cdot\mathbf{r} = 1. \quad -(14)$$

Therefore:

$$\boldsymbol{\sigma}\cdot\mathbf{p}\,\boldsymbol{\sigma}\cdot\mathbf{A} = \frac{1}{r^2}\Big(\mathbf{r}\cdot\mathbf{p}\,\mathbf{r}\cdot\mathbf{A} + i\boldsymbol{\sigma}\cdot\mathbf{L}\,\mathbf{r}\cdot\mathbf{A} + i\mathbf{r}\cdot\mathbf{p}\,\boldsymbol{\sigma}\cdot\mathbf{r}\times\mathbf{A} - \boldsymbol{\sigma}\cdot\mathbf{L}\,\boldsymbol{\sigma}\cdot\mathbf{r}\times\mathbf{A}\Big). \quad -(15)$$

From comparison of the real and imaginary parts of Eqs. (9) and (15):

$$\mathbf{p}\cdot\mathbf{A} = \frac{1}{r^2}\left(\mathbf{r}\cdot\mathbf{p}\,\mathbf{r}\cdot\mathbf{A} - \boldsymbol{\sigma}\cdot\mathbf{L}\,\boldsymbol{\sigma}\cdot\mathbf{r}\times\mathbf{A}\right). \quad -(16)$$

and

$$\boldsymbol{\sigma}\cdot\mathbf{p}\times\mathbf{A} = \boldsymbol{\sigma}\cdot\mathbf{L}\,\mathbf{r}\cdot\mathbf{A} + \mathbf{r}\cdot\mathbf{p}\,\boldsymbol{\sigma}\cdot\mathbf{r}\times\mathbf{A} \quad -(17)$$

in which:

$$\mathbf{r}\cdot\mathbf{A} = \frac{1}{2}\,\mathbf{r}\cdot\mathbf{B}\times\mathbf{r} = \frac{1}{2}\,\mathbf{B}\cdot\mathbf{r}\times\mathbf{r} = 0. \quad -(18)$$

Therefore we obtain the important identities:

$$\mathbf{p}\cdot\mathbf{A} = -\frac{1}{r^2}\,\boldsymbol{\sigma}\cdot\mathbf{L}\,\boldsymbol{\sigma}\cdot\mathbf{r}\times\mathbf{A}, \quad -(19)$$

$$\boldsymbol{\sigma}\cdot\mathbf{p}\times\mathbf{A} = \mathbf{r}\cdot\mathbf{p}\,\boldsymbol{\sigma}\cdot\mathbf{r}\times\mathbf{A}. \quad -(20)$$

The hamiltonian (7) can therefore be written as:

$$H_1 = -\frac{e}{m}\,\mathbf{p}\cdot\mathbf{A} = \frac{e}{mr^2}\,\boldsymbol{\sigma}\cdot\mathbf{L}\,\boldsymbol{\sigma}\cdot\mathbf{r}\times\mathbf{A} = -\mathbf{m}_B\cdot\mathbf{B}. \quad -(21)$$

Finally use Eqs. (3) and (21) to find that

$$H_1 = \frac{e}{2mr^2}\,\underline{\sigma}\cdot\underline{L}\;\underline{\sigma}\cdot\underline{r}\times(\underline{B}\times\underline{r})$$

$$= \frac{e}{2m}\,\underline{\sigma}\cdot\underline{L}\left(\underline{\sigma}\cdot\underline{B} - \frac{\underline{\sigma}\cdot\underline{r}}{r^2}\,\underline{B}\cdot\underline{r}\right) \quad -(22)$$

$$= -\,\underline{m}_D\cdot\underline{B}.$$

It can be seen that the well known hamiltonian responsible for the Zeeman effect has been developed into a hamiltonian that gives electron spin resonance of a new type, hitherto undiscovered. The resonance arises from the interaction of the Pauli matrix with the magnetic field. If the magnetic field is aligned in the Z axis resonance occurs between the two states of the Pauli matrix:

$$\sigma_Z = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \quad -(23)$$

and the ESOR frequency is:

$$\omega = \frac{eB}{m}\,\frac{\underline{\sigma}\cdot\underline{L}}{\hbar}. \quad -(24)$$

This compares with the usual ESR frequency

$$\omega = \frac{eB}{m} \quad -(25)$$

from the pure quantum hamiltonian:

$$H_2 = -\frac{e\hbar}{2m}\,\underline{\sigma}\cdot\underline{B}. \quad -(26)$$

The ESOR hamiltonian contains a novel spin orbit coupling, and when quantized:

$$\hat{H}_1\psi = \frac{e}{2m}\,\underline{\sigma}\cdot\underline{B}\;\hat{\underline{\sigma}}\cdot\hat{\underline{L}}\,\psi \quad \ldots\ldots \quad -(27)$$

The well known spin angular momentum operator {12} is defined as:

$$\hat{\underline{S}} = \frac{1}{2}\hbar\,\underline{\sigma} \quad -(28)$$

where:

$$\hat{L} \cdot \hat{S} \phi = \frac{1}{2}\left(\hat{J}^2 - \hat{L}^2 - \hat{S}^2\right)\phi \quad -(29)$$
$$= \frac{1}{2}\hbar^2\left(J(J+1) - L(L+1) - S(S+1)\right)\phi$$

so the energy levels of the ESOR hamiltonian operator are:

$$E = \frac{e}{2m}\hbar\left(J(J+1) - L(L+1) - S(S+1)\right)\underline{\sigma} \cdot \underline{B} \quad -(30)$$

giving the ESOR frequency

$$\omega = \frac{eB}{m}\left(J(J+1) - L(L+1) - S(S+1)\right). \quad -(31)$$

Here J is defined by the Clebsch Gordan series:

$$J = L + S, \; L + S - 1, \ldots, |L - S|. \quad -(32)$$

It is clear that Eq. (27) is new to electron resonance and that it is different from the usual ESR hamiltonian:

$$H_{ESR} = -\frac{e}{2m}\underline{L} \cdot \underline{B} + \lambda \underline{S} \cdot \underline{L} - \frac{e\hbar}{2m}\underline{\sigma} \cdot \underline{B} \quad -(33)$$
$$= -\gamma_{spin}\,\underline{\sigma} \cdot \underline{B}$$

the well known spin hamiltonian.

The ESOR hamiltonian can be used to develop a new nuclear resonance technique and new MRI technique, and can be developed in ECE physics. Note 249(2) accompanying this rapid communication give another new resonance technique based on the use of a rotating magnetic field.

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