Resolving the Mystery of the Fine Structure Constant

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Abstract: A quantized magnetic flux version of Planck's reduced constant is deduced from first principles. The magnetic flux quantum can explain the fine structure constant and the "anomalous" magnetic moment of an electron.

INTRODUCTION

The magnetic flux quantum Φ_0[1], [2], [3] is equivalent to,

(1) $$\Phi_0 = \frac{h}{2e},$$

where e is the unit of elementary charge and h is Planck's constant,

(2) $$h = 2\pi\hbar.$$

Planck's reduced constant ħ can also be defined from Bohr's radius r_B as,

(3) $$\hbar = \alpha m_e r_B c,$$

where α is the fine structure constant, m_e is the rest mass of an electron and c is the speed of light in a vacuum. Combining Eqs. (1) through (3) yields,

(4) $$2\pi\hbar^2 = 2e\Phi_0 \alpha m_e r_B c.$$

It is remarkable that the dimensions in Eq. (4) are balanced by the dimensionless quantity Đ,

(5) $$Đ = \frac{\alpha}{\pi} = \frac{\hbar^2}{e\Phi_0 m_e r_B c}.$$

AN ELECTRON'S ANOMALOUS MAGNETIC MOMENT

The g−factor for an electron's magnetic moment[4] is,

(6) $$g = 2 + \frac{\alpha}{\pi} = 2 + Đ,$$

suggesting that the fine structure constant and an electron's "anomalous" magnetic moment may be related to the the magnetic flux quantum Φ_0. Substituting the g−factor for an electron's magnetic moment $\boldsymbol{\mu_e}$ yields,

$$(7)\quad \boldsymbol{\mu}_e = \mathrm{g}\frac{-e}{2\mathrm{m}_e}\mathbf{L}_\mathrm{T} = (2+\text{Đ})\frac{-e}{2\mathrm{m}_e}\mathbf{L}_\mathrm{T} = \frac{\hbar^2}{-\Phi_0\mathrm{m}_e c}(\mathbf{L}_\mathrm{S}+\boldsymbol{v}),$$

where $\mathbf{L}_\mathrm{T}$ is an electron's total angular momentum, $\mathbf{L}_\mathrm{S}$ is the angular momentum of its spin and $\boldsymbol{v}$ is its tangential speed. A dimensionless correction factor is not needed with this classical definition since the electron's magnetic moment is related to the magnetic flux quantum Φ_0 and not to the electrostatic charge e. A special relativistic version of Eq. (7) can then be given as,

$$(8)\quad (\mathbf{L}_\mathrm{S}+\boldsymbol{v})\hbar^2 = \pm\Phi_0\boldsymbol{\mu}\gamma\mathrm{m}_0 c,$$

where γ is the Lorentz factor and m_0 is the rest mass of a particle[5]. The ± sign in Eq. (8) suggests that the rotational direction of a nuclear particle relative to an atomic barycenter may be opposite to the rotational direction of an electron.

WAVE–PARTICLE DUALITY

A particle's wavelength can be determined with de Broglie's matter wave relation[6],

$$(9)\quad \lambda = \frac{\mathbf{h}}{\boldsymbol{p}} = \frac{2\pi\hbar}{\mathrm{m}_0\boldsymbol{v}}.$$

where $\boldsymbol{p}$ is a particle's momentum. Substituting the mass in de Broglie's relation with the mass in Eq. (8) yields,

$$(10)\quad \lambda = \pm\frac{2\pi}{(\mathbf{L}_\mathrm{S}+\boldsymbol{v})}\frac{\Phi_0\boldsymbol{\mu}\gamma c}{\hbar\boldsymbol{v}}.$$

A particle's frequency f is therefore,

$$(11)\quad f = \frac{\boldsymbol{v}}{\lambda} = \pm\frac{(\mathbf{L}_\mathrm{S}+\boldsymbol{v})}{2\pi}\frac{\hbar\boldsymbol{v}^2}{\Phi_0\boldsymbol{\mu}\gamma c},$$

and a wave mechanical version of Eq. (8) can be given as,

$$(12)\quad (\mathbf{L}_\mathrm{S}+\boldsymbol{v})\hbar\boldsymbol{v}^2 = \pm\omega\Phi_0\boldsymbol{\mu}\gamma c,$$

where ω is a particle's angular frequency. Since $\omega = \boldsymbol{v}/\boldsymbol{r}$, an alternative system of natural units can be given as,

$$(13)\quad (\mathbf{L}_\mathrm{S}+\boldsymbol{v})\hbar\boldsymbol{r}\boldsymbol{v} = \pm\Phi_0\boldsymbol{\mu}\gamma c.$$

With this system, a particle's speed could be determined if you know its position, hypothetically negating Heisenberg's uncertainty principle!

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