Electron as Torus of Displacement Current and the Fine Structure Constant as a Parameter of the Torus

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The model of the electron in the form of a torus of Maxwell's displacement current is presented. Parameters of such free electron model are defined. It is shown, that the known Fine Structure Constant can be treated as parameter of this model.

Since the discovery of the electron by J.Thomson in 1897 discussions on its structure and size continue [1]. There is an opinion, that the electron is a ball with a diameter of 10^{-17}~10^{-18} m. The theoretical constant (so-called «classical radius of an electron») is introduced as

$$r_0 = \frac{e^2}{4\pi\varepsilon_0\mathcal{E}_0} = 2.81794 \cdot 10^{-15}\ \text{m} \qquad (1)$$

Attempts to measure the electron scattering cross-section by various methods have not been able to determine its size. In the modern quantum physics the question of the electron structure is not considered.

In the XIX century Maxwell introduced the so-called displacement current in order to find the solution in the form of an electromagnetic wave. In this paper the model of an electron in the form of a torus i.e. the charged ring of the Maxwell's displacement current is suggested.

Let R_e be the radius of a ring of a torus, and r_e is the radius of cross-section of the torus (one half of its thickness) (Fig.1).

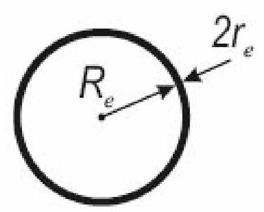

Fig.1. The displacement current torus

Let's define a "form-factors of the torus" as $\dfrac{1}{\alpha_0} = \ln\dfrac{8R_e}{r_e}$. Then formulae for the capacitance and the inductances of the torus (charge and current are concentrated at its surface) are expressed the in the form of [2]:

$$C_e = \pi\varepsilon_0 R_e \alpha_0 \qquad (2)$$

$$L_e = \pi\mu_0 R_e/\alpha_0 \qquad (3)$$

Let's break self-energy of the electron (rest energy) $\mathcal{E}_0 = 8.18724 \cdot 10^{-14}$ J into two identical parts: $\mathcal{E}_0 = m_e c^2/2 + m_e c^2/2$, where $c = \dfrac{1}{\sqrt{\varepsilon_0\mu_0}}$ is the light velocity.

One part is the energy of the electrical field around a single charge (e):

$$\mathcal{E}_{el} = \mathcal{E}_0/2 = C_e U_e^2/2 = e^2/2C_e \qquad (4)$$

where the potential U_e, capacitance C_e and the quantum of electron charge (e) are related by the ratio

$$U_e = e/C_e \qquad (5)$$

The second part of the electron self-energy is the energy of the magnetic field of the current ring

$$\mathcal{E}_{mag} = m_e c^2/2 = \mathcal{E}_0/2 = L_e I_e^2/2 \qquad (6)$$

This part can be treated also as the energy of motion of the distributed mass m_e along the circle of with the velocity of light. We see that it coincides with the classical dependence of the kinetic energy $\mathcal{E}_{kinetic} = mv^2/2$, where $v = c$.

Let's define the current ring I_e as a motion of the distributed charge (e) with the velocity of light along the circle of radius R_e

$$I_e = \frac{ec}{2\pi R_e} \qquad (7)$$

Considering (3) we gain

$$I_e = f_0/L_e \qquad (8)$$

where f_0 can be called the “electron current quantum”. Equating formulae for energies (4), (6) and considering (2), (3) we gain a formula for the form-factor of the torus:

$$\frac{1}{\alpha_0} = \frac{f_0}{e}\sqrt{\frac{\varepsilon_0}{\mu_0}} \qquad (9)$$

The self-energy of the electron is then expressed as

$$\mathcal{E}_0 = \frac{ef_0 c}{\pi R_e} \qquad (10)$$

Let's guess that the radius of the electron ring R_e is the radius defined by the formula of a Compton wave length of an electron (Compton's experiments, 1923)

$$2\pi R_e = \lambda_{kompton} = hc/\mathcal{E}_0 \qquad (11)$$

From (10) and (11) we gain

$$f_0 = h/2e \qquad (12)$$

We see that it coincides with the known “quantum of magnetic flux”

$$\Phi_0 = h/2e = 2.06785 * 10^{-15} \text{ Wb}$$

Let's find numerical values of the electron parameters:

- form-factor of the electron torus $\dfrac{1}{\alpha_0} = 34.259$;
- radius of the electron ring $R_e = \dfrac{ef_0 c}{\pi \mathcal{E}_0} = 3.8616 * 10^{-13}$ m;
- thickness of the ring cross-section $2r_e = 16R_e/\exp(1/\alpha_0) = 8.165 * 10^{-27}$ m;
- electron capacitance $C_e = e^2/\mathcal{E}_0 = 3.1358 * 10^{-25}$ F;

  (a sphere with the “classical radius” r_0 (1) has the same capacitance value, if the charge (e) is distributed on a surface of the sphere)
- electric potential on the surface of electron $U_e = e/C_e =$ 511 kV;
- inductance of the electron ring of $L_e = f_0^2/\mathcal{E}_0 = 5.2228 * 10^{-17}$ H;
- electric current of the ring $I_e = f_0/L_e = 39.593$ A.

Let's calculate a magnetic moment of the current ring by the known formula $p_m = I_e \cdot \pi R_e^2$ by using (7)

$$p_m = ecR_e/2 \qquad (13)$$

Considering (11) it is gained

$$p_\mathrm{m} = \frac{ehc^2}{4\pi\mathcal{E}_0} = \frac{e\hbar}{2m_e} \tag{14}$$

that corresponds to the known formula of the magnetic moment of the electron.

Let`s consider an equilibrium condition for the moving element of the charge (q) along the surface of the torus along a circle of large radius R_e. The current of the torus-ring can be regarded as a set of parallel linear currents along the surface of the torus. According to the Ampère law, attractive force acts between them, which compensates the Coulomb repulsive force from charges of the same polarity. From the electron model it is obtained that $R_\mathrm{e}/r_\mathrm{e} \approx 10^{14}$. Therefore, the influence of the charges and currents of the distant sections of the torus, as well as the curvature of the ring, can be neglected. Solutions for a linear charged wire with current are known. The electric field strength at a distance r_e from the center of the wire is $E = e/2\pi r_\mathrm{e}\varepsilon_0 2\pi R_\mathrm{e}$. The magnetic induction from the current $I = ec/2\pi R_\mathrm{e}$ is equal to $B = \mu_0 I/2\pi r_\mathrm{e}$. The force that repels the negligibly small charge (q) from the surface is $F_\mathrm{el} = qE = qe/2\pi r_\mathrm{e}\varepsilon_0 2\pi R_\mathrm{e}$, and the force that attracts this moving charge (q) to the center of the wire is $F_\mathrm{mag} = qcB = q\mu_0 cI/2\pi r_\mathrm{e} = qe/2\pi r_\mathrm{e}\varepsilon_0 2\pi R_\mathrm{e}$. We see that these forces are equal to each other and therefore the torus is a stable shape of the electron.

Dimensionless "Fine Structure Constant" was included into A.Zommerfeldom's atomic spectrum analysis in 1916 [3]. It is related to constants (e) and (h) by the ratio

$$\alpha = \frac{e^2}{2h}\sqrt{\frac{\mu_0}{\varepsilon_0}} \tag{15}$$

Considering (9) and (12) we gain relation of this Constant with «form-factors of the ring»

$$4\alpha = \alpha_0 \tag{16}$$

Conclusion:

1. The model of electron in a form of a torus (the charged ring of a displacement current of the Compton size) is suggested.
2. Interpretation of the formula $\mathcal{E}_0 = m_\mathrm{e}c^2$ as the sum of two identical parts (kinetic energy of motion on a circle of ring $\mathcal{E}_\mathrm{kinetic} = m_\mathrm{e}c^2/2$ and energy of a Coulomb field) is presented.
3. The known quantum of the magnetic flux Φ_0 is obtained from the given model.
4. Magnetic moment of the proposed structure corresponds to the known formula for p_m of the electron.
5. The model based on the torus shape of electron solves a problem of stability of the electron structure.
6. Interpretation of "Fine Structure Constant" through the “form-factors of the torus” of a free electron (the coefficient is equal to 4) is obtained.

References:

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