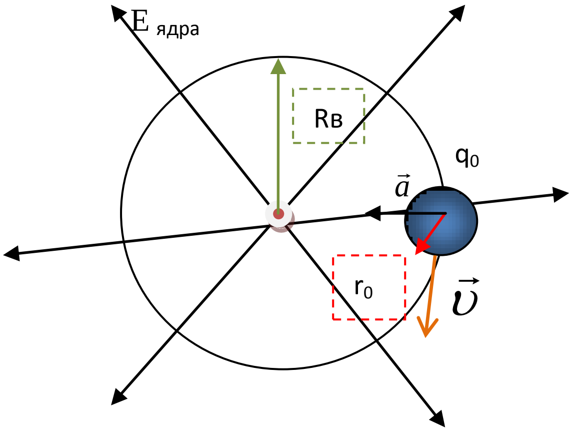
Self-inductance of electron



Let’s consider the hydrogen atom.

The electron moves around the atom along a circular orbit. Such movement demonstrates an alternating current. Coulomb force and the force generated by the electro magnetic field (emf) are operating on the electron. From a mechanical point of view, any body rotating along a circular orbit is under the influence of centripetal and centrifugal forces. At the same time, $F_{cf} = F_{coul}$

and $F_{cf} = F_{self}$

$$F_{coul} = q_0 \cdot \vec{E}, \qquad (1)$$

where q0 is the nuclear charge.

The electron’s charge is also q0. The interacting force between a proton and an electron - the Coulomb force - is determined by the following formula:

$$F_{coul} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_0{}^2}{R_B{}^2} \quad , \qquad (2)$$

where R_B is the Bohr orbit radius.

An electron in accelerated motion creates an alternating electric current:

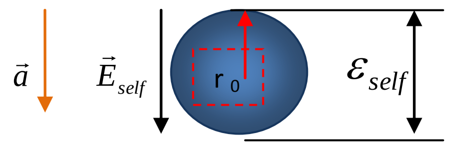
$$\dot{I} = \frac{q_0 \cdot a}{2 \cdot r_0} \qquad (3)$$

Alternating current always causes induction and self-induction. In this particular case, the relevant phenomenon is self-induction. Emf is always directed (according to Lenz's rule) in such a way as to inhibit whatever caused the current change. It is clear from the formula (3) that this cause is acceleration.

From electrodynamics, we know that the Emf of self-induction is:

$$\varepsilon_{self} = -L_0 \cdot \dot{I},$$

where L_0 is the proportionality coefficient (known in electrodynamics as self-inductance coefficient), which represents the electron’s properties. Electromotive force in this case plays the role of the centrifugal $F_{cf} = F_{self}$



$$\left|F_{coul}\right| = \left|F_{self}\right| \quad (4)$$

The field density is $E_{self} = \dfrac{\varepsilon_{self}}{2 \cdot r_0}$; therefore, the self-inductance force is F_{self}

$$\vec{F}_{self} = q_0 \cdot \vec{E}_{self} \quad (5)$$

We substitute the value of E_{self} into the expression for alternating current (3), and obtain:

$$F_{self} = q_0 \cdot \frac{\varepsilon_{self}}{2r_0} = \frac{q_0}{2r_0} \cdot (-L_0) \cdot \dot{I} = \frac{q_0}{2r_0}(-L_0)\frac{q_0 \cdot a}{2r_0} = -L_0 \frac{q_0{}^2 \cdot a}{4r_0{}^2} \quad (6)$$

Electron acceleration is $a = \dfrac{V^2}{R_B}$,

where R_B is Bohr radius and V is electron velocity in this Bohr orbit. We equate $\left|F_{coul}\right| = \left|F_{self}\right|$ and substitute the expression for acceleration into the formula and get:

$$\frac{q_0}{4\pi\varepsilon_0}^2 \cdot \frac{1}{R_B} = L_0 \frac{q_0{}^2}{4r_0{}^2} \cdot \frac{V^2}{R_B}, \quad (7)$$ hence

$$L_0 = \frac{r_0{}^2}{\pi\varepsilon_0 R_B V_B{}^2} \quad (8)$$

Indeed, since there is a certain dependence between the electron velocity in a Bohr orbit and the radius of this orbit, (see Hydrogen atom. Linear spectra. “The World of Physics” http://www.fizmir.org/bestsoft/9_3.htm),

$$V_{Bn}{}^2 = \frac{q^2}{4\pi\varepsilon_0 m_0 R_n}, \quad (9)$$

we can determine an expression for the product $R_B V_B^2$ which is in the formula (8) in the denominator.

$$V_n{}^2 R_B = \frac{q^2}{4\pi\varepsilon_0 m_0} \quad (10)$$

We substitute the expression (10) into the formula (8) and obtain for L_0:

$$\boxed{L_0 = \frac{r_0{}^2 4\pi\varepsilon_0 m_0}{\pi\varepsilon_0 q_0^2} = \frac{4r_0{}^2 m_0}{q_0^2}} \quad (11)$$

It is clear that the self-inductance coefficient of electron is proportional to the mass!

The last formula shows that the inertia (whose numerical expression heretofore was the mass m_0) is indeed the self-induction whose expression is coefficient L_0. The expression for the self-inductance coefficient of the electron includes only the numerical characteristics of the electron. Consequently, the self-inductance coefficient is also a characteristic of the electron and can be called the *inductance of the electron*.

Note that the formula (9) which connects the electron velocity and the radius of the Bohr orbit is valid for any Bohr orbit, and therefore, L_0 calculated by the formula (8) will be the same for any (n) orbit of electron motion.

Return to http://en.fphysics.com/