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CREATION OF A VISUAL MODEL OF THE ATOMIC STRUCTURE AS A POSSIBLE ELEMENT OF A QUANTUM COMPUTER

Using only the laws of classical mechanics, a possible physical model of the structure of an atom as an element of a quantum computer — a cube is proposed. The stable motion of an electron in an atom is substantiated, which is provided not only by the motion in the main elliptical or circular orbit, but also by the additional motion of the electron around the main trajectory along the trajectory (helical line), the projection of which on the plane of the main orbit has the form of a cosine. It is shown why the trajectory of the electron is "smeared", and the electron does not fall on the nucleus and, in general, what keeps it in the sphere of influence of the nucleus.

Keywords: qubit, atomic structure model, electron trajectory, electromechanical self-balancing systems, self-oscillating systems, rotational motion.

I will immediately agree with a reader who is not satisfied such a decision, provided that he is able to bring weighty arguments in support of their dissatisfaction.

(D. Poya. Mathematical discovery. P. 89. M. 1976).

Introduction

Quantum computers and quantum computing have revived interest in the structure of the atom in a new way. At the beginning of this century (in 2000), a fundamental work on quantum computing was published [1]. However, quantum computers have not yet appeared in widespread use. Once again, mathematics, as a less costly science, has outstripped physics and engineering. A similar thing already happened with Boolean algebra, which found application only after physicists and engineers created logic gates, trigger, etc. Obviously, to create quantum logic gates, physics is not enough to represent the structure of the atom (of which

everything around us) in the form orbitals. A more detailed understanding of the atom is needed.

Here is a quote from [1]: "Building devices for processing quantum information is a daunting task for scientists and engineers of the third millennium ... Two possible obstacles are seen on the way to the practical solution of this problem: quantum noise and the fact that quantum mechanics may be wrong... From the theory of codes correcting errors, it follows that noise does not represent a fundamental problem... There is still no such clarity in solving the second problem, therefore, based on the facts known to date, we will assume that quantum mechanics gives a complete and correct description of the world" (Section 1.5.2).

It is known [1] that atoms and molecules can be used in the practical construction of devices for processing quantum information (Section 7.1).

In the literature on the structure of the atom, there are sometimes conflicting ideas about the structure of the atom [2, 3]. In general, quantum

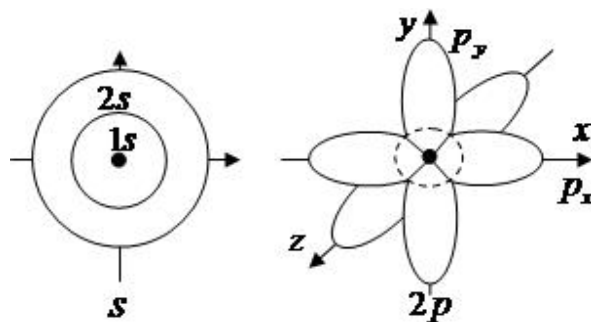


Fig.1. The approximate forms of the wave model of the atom

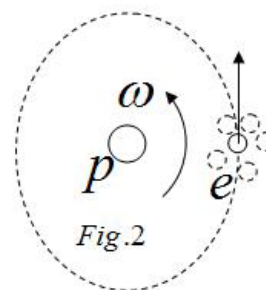


Fig.2. The motion of the center of gravity by inertia

science is difficult for specialists to perceive, especially in presenting models of the phenomena that occur there. A long time ago, even famous scientists such as A. Einstein, R. Feynman, N. Bohr wanted to describe the processes in quantum mechanics using the classical theory. But, they had to create a special quantum theory. And now, there are attempts to return to the classics. This article also applies to such an attempt.

The Rutherford-Bohr model of the atomic structure has been widely known for a long time. They intuitively presented the model of the atomic structure in a form similar to that of the planets, where the nucleus is located in the center of the model, and the electron revolves around the nucleus. At the same time, Niels Bohr expressed a number of well-known postulates without substantiating them [4, 5]. Later E. Schrodinger tried to give an analytical substantiation of atomic phenomena. He intuitively proposed the differential equations known under his name. However, with their help, it is not the trajectory of motion of an electron in an atom that is calculated, but only the probability of finding an electron-wave in one or another place in space around the nucleus, and today, with their help, only a few of the simplest problems have been solved: an oscillator and a hydrogen atom [6] ... Now there is a modern idea of the atomic structure model — in the form of orbitals.

Fig.1 shows the approximate (not exact) forms of the wave model of the atom, which have "regions of probability" of the existence of electrons: *s*- and *p*-orbitals (*d*-orbitals have a more complex shape), obtained by mathematical calculation. However,

even here the problem of determining the coordinates of the electron has not been solved. You can only calculate the probability of finding an electron in a certain volume of space [4, 5].

A common feature of the above-mentioned models, built on the basis of quantum theory, is the lack of certainty with the coordinates and trajectory of the electron motion.

But the recently proposed model, built on the basis of classical electrodynamics, namely, the laws of rotational motion in classical mechanics, also does not eliminate the indicated drawback [3]. There, a model is proposed in which the motion of an electron around a nucleus consists of two independent parts:

- a) a kind of quasi-Brownian movement under the influence of random vacuum waves;
- b) motion of the center of gravity by inertia, or rather the electron cloud around the nucleus, with a certain constant average orbital moment (see Fig. 2). The reason that hinders the achievement of the set task is the lack of certainty with the coordinates of the electron due to a kind of quasi-Brownian motion.

Statement (theorem). An electron moves not just along the main elliptical or circular orbit, but also along a trajectory around the main orbit, the projection of which onto the plane in which the ellipse, or circle, lies, has the form of a cosine wave. The cosine wave starts from the point of intersection of two mutually perpendicular straight lines: the line connecting the centers of mass of the nucleus and the electron and the line of direction of

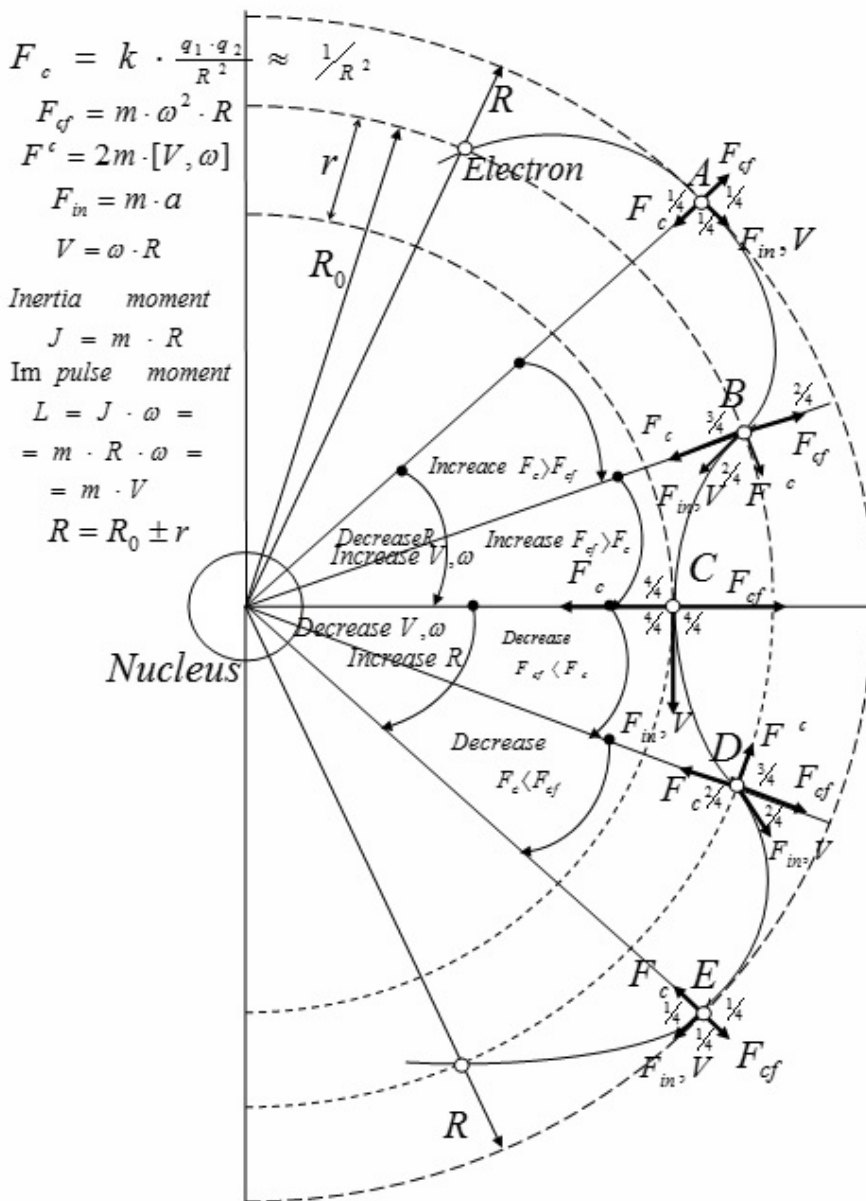


Fig. 3. The trajectory of an electron around a nucleus in an atom

the vector of the linear velocity of the electron. At the same time, under the influence of the torque of gravitational forces, the main elliptical (circular) orbit additionally rotates around its axis, creating as a whole an orbital in the form of a ball with a wall thickness equal to the amplitude of the cosine wave (see Fig. 3).

An analytical, qualitative (without cumbersome calculations) substantiation of the model of the trajectory of an electron around a nucleus in an atom within the framework of classical mechanics is proposed, which gives a more accurate visual representation of the trajectory of the electron and the structure of the atom. In this case, we will use only

the nature of the relationship between the quantities that are part of the well-known formulas on the theory of oscillations and rotational motion, the method of studying functions.

Starting Position

Let us assume that the electron appeared from outside in the sphere of influence of some nucleus. Depending on the linear velocity (and its direction) and the distance to the nucleus, it can: “go to ram the nucleus”, fly by or interact with the nucleus. We will consider the last option. The interaction of an electron with a nucleus actually begins at point A , at the intersection of the direction of the linear velocity and the line perpendicular to it connecting the centers of mass of the nucleus and the electron (see Fig. 3). We will consider the trajectory of an electron in a plane containing these intersecting straight lines (it can be proved that point A and the plane exist and are unique). Therefore, we can use the formulas for the rotation of the body around the axis [6, 7]. Here, basically, three forces will act on the electron: Newton’s inertial force $F_{in} = ma$, the force of the Coulomb attraction of oppositely polar charges $F_c = k \cdot (q_1 \cdot q_2 / R^2) \sim 1 / R^2$ and the centrifugal force $F_{cf} = m \cdot V^2 / R = m \cdot (\omega \cdot R) = m \cdot \omega^2 \cdot R$. Where m is the mass of the electron, a is its acceleration, q_1 and q_2 are the charges of the nucleus and the electron, $R = R_0 \pm r$, where R_0 is the radius of the main circle of the electron’s motion, V is the linear velocity of the electron, ω is its angular velocity. There are intentionally written different expressions for the centrifugal force formula in order to compare the degree of influence of the values when compared with a competitor. For a qualitative comparison of the ratio of the forces acting on the electron, we restrict ourselves only to the relative values of the forces and linear velocity in relation to the maximum, in the situation under consideration (see in Fig.3 fractions: 1/4, 2/4, 3/4, 4/4).

So, at point A (Fig. 3), the electron is acted upon: directed perpendicular to the radius $R = R_0 \pm r$, connecting the electron with the nucleus, the force $F_{in} = ma$ (let equal to 1/4 of the maximum value), directed along the radius R two equal in magnitude

(let equal to 1/4 of the maximum) and opposite in the direction of the Coulomb force F_c , and the centrifugal force F_{cf} . The nonzero linear velocity V existing before the interaction, let it be equal to 1/4 of the maximum value, and it coincides in direction with the vector F_{in} .

Under the influence of the Coulomb force F_c , the electron will try to approach the nucleus and “fall” onto it. Therefore, it will begin to turn towards the nucleus. Due to the motion of the electron to the center of rotation, there will appear: the normal component in the vector V , directed to the center, and the Coriolis force F^c , directed perpendicular to the radius R . The Coriolis force F^c will increase the tangential component of the vector V (equal to 2/4). And all together will cause an increase in the absolute value of the vector V . As a result of all this, the radius R will decrease and the Coulomb force $F_c \sim 1 / R^2$ will increase. At the same time, the growth of the tangential component of the force vectors F_{in} and the Coriolis force F^c (and the velocity V) will lead the electron away from the rectilinear approach. An increase in V and a decrease in R will inevitably lead to a sharp increase in ω , since they are related by the formula $V = \omega \cdot R$. With some delay at the start (since $F_{cf} \sim R$), the centrifugal force $F_{cf} = m \cdot R \omega^2$ will begin to show more of its action, since for some time the influence of the increase in ω^2 will exceed the influence of the decrease in R . All this taken together will restrain the “desire” the electron immediately “fall” on the nucleus, or rather, will take it to point B , away from the rectilinear approach.

As a result, the electron will be at point B . Here, the vector V will turn towards the nucleus, increase in magnitude, and will go tangentially to the line of future movement (cosine). The ratio of forces at point B is approximately as follows: $F_c = 3/4$, $F_{cf} = 2/4$, $F^c = 2/4$. Since the angular momentum $L = mR\omega = \text{const}$ and R decreases, it follows that ω will increase. But $F_{cf} = m \cdot \omega^2 \cdot R$, although the radius has decreased, but also ω^2 , because of which the rate of increase of F_{cf} will outstrip the growth of F_c , which does not depend on ω . As a result, you will have to deviate even more from the direct approach — and the electron will be at point C .

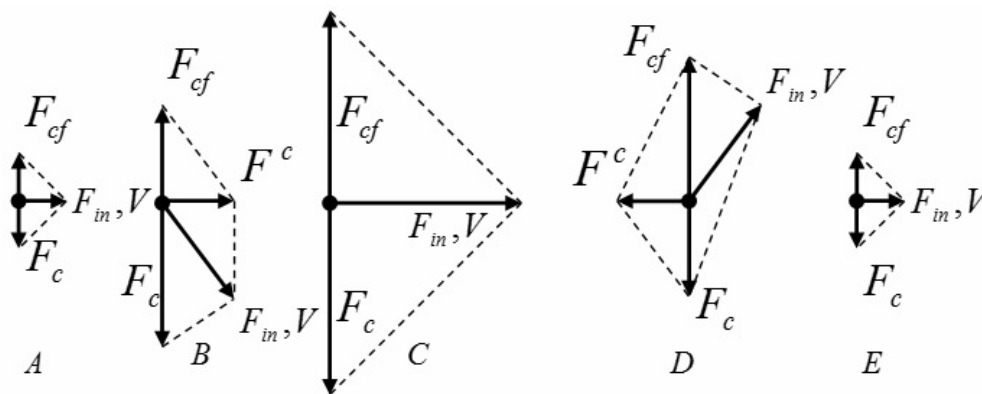


Fig. 4. Illustration of the imbalance in the system

At point C, according to the law of conservation of momentum $J_a \cdot \omega_a = J_c \cdot \omega_c$, where J and ω are the moment of inertia and angular velocity at points A and C. The forces acting on the electron reach their maximum values: $F_c = 4/4 = 1$, $F_{cf} = 4/4 = 1$, $F_{in} = 4/4 = 1$.

The electron will approach the nucleus at the shortest distance $R_0 - r$. But! The force of inertia F_{in} will force the electron to move in a direction perpendicular to the line of the shortest distance, taking into account, although the maximum values, but acting in opposite directions, the forces $F_c = F_{cf} = 1$. In this case, since the decrease in the force F_{cf} will be less than the force F_c , as a result of the competition of forces $F_{cf} > F_c$, the electron will begin to move away from the nucleus and end up at point D. The Coriolis force F^c will change its direction to the opposite, because the electron began to move away from the center.

At point D, the ratio of forces will become as follows: $F_c = 2/4$, $F_{cf} = 3/4$, $F^c = -2/4$. The vector of linear velocity V will turn away from approaching the nucleus in the opposite direction (tangential to the cosine) and decrease in magnitude to 2/4 of the maximum.

There was a tendency of the electron to leave the sphere of influence of the nucleus. But! With the forced (due to inertial forces) increase in the distance to the nucleus, the inevitable decrease in the value of the Coulomb force will lag behind the decrease in the centrifugal force, which depends on

the decrease in ω^2 . The Coulomb force, with a mutual decrease, will still win the competition in its favor — which will slow down the removal of the electron from the nucleus. Coriolis force will again exert its influence, this time, in decelerating the electron. The electron will be at point E.

At point E, the ratio of forces will turn out to be as follows, $F_c = 1/4$, $F_{cf} = 1/4$, $F_{in} = 1/4$, $F^c = 0$. The linear velocity vector V will rotate in the direction of rotation (perpendicular to the radial forces) and become minimal in magnitude ($V_e = V_a = 1/4$). At point E, the law of conservation of momentum is also fulfilled $L_e = L_a = mV_e = J_e \omega_e = J_a \omega_a$, where J and ω are the moment of inertia and angular velocity at points A and E. Moment of inertia $J_e = J_a = mR$.

But, we had the same at point A — the circle is closed!

Fig. 4 shows a qualitative illustration of the imbalance in the system (points B, C and D) and, roughly, the dynamics of changes in its kinetic energy (see the areas of three or four gons stretched at the ends of the force vectors).

Thus, we considered the motion of an electron, as it turned out, along a cosine wave. Then the same will be repeated and, obviously, an integer number of times. This can explain that the laws of number theory are fulfilled in the atomic world!

Additional explanation 1. Let us consider in more detail the process of establishing equilibri-

um in a dynamic system. Looking at Fig. 5, which shows the qualitative curves of the Coulomb force $F_c \sim 1/R^2$ and the centrifugal force $F_{cf} \sim \omega^2$, it can be seen that the "electron-nucleus" system has two equilibrium points: in the first and second quadrants.

This is natural for the complex roots of the differential equations of motion. Let's choose a clockwise rotation that corresponds to the first quadrant in Fig. 5. Zoom in about equilibrium points. Fig. 6 shows an illustration of the establishment of dynamic equilibrium of the system corresponding to points *A*, *B*, *C*, *D*, *E* in Fig. 3. The process of an increase and subsequent decrease in the Coulomb force F_c is shown on the left, and on the right — the same — the centrifugal force F_{cf} . Here, everything is also given in relative values: the values of the forces along the ordinate axis, and the values of both the radius R and the angular velocity ω are plotted along the abscissa axis. Namely, the dependence of the competing forces on the values of R and ω independent of each other ensures the possibility of establishing dynamic equilibrium in the system.

Additional explanation 2. Consider the formula $F_{cf} = m\omega^2 R$. At the beginning of rotation (from *A* to *B*) ω is small and, the decrease in F_{cf} , one might say, is carried out according to a linear law depending on R , let us assume $F_{cf} \sim 1/4R$ (see Fig. 7). Therefore, the growth of F_{cf} lags behind the growth of $F_c \sim 1/R^2$ (R decreases). But, then, when ω increased, then the growth of $F_{cf} \sim \omega^2$ (from *B* to *C*, according to the law $Y = X^2$) became larger. From *C* to *D* due to the conservation of the imhuls momentum $L = mR\omega^2$ with a decrease in ω , R inevitably increases. Due to a decrease in ω , $F_{cf} \sim m\omega^2$ decreases, but with an increase in R , slower than $F_c \sim 1/R^2$. From *D* to *E*, $E \cdot F_{cf} = m \omega^2 R$ and, if the decrease in ω and R coincides, it goes faster, one might say, according to the law $Y = X^3$ (see Fig. 5), in comparison with the decrease in $F_c \sim 1/R^2$ (see. Fig. 7, $Y = 1/X^2$).

We have made sure that the electron and the nucleus form a self-balancing electromechanical self-oscillating dynamic system, in which the electron is held in dynamic equilibrium in an orbit consisting of a main circle (ellipse) and an additional cosine wave around the main circle(ellipse).

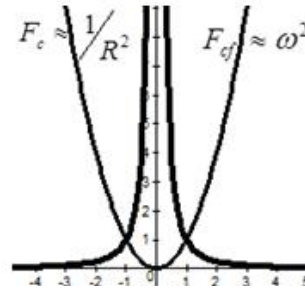


Fig. 5. Curves of the Coulomb and centrifugal force

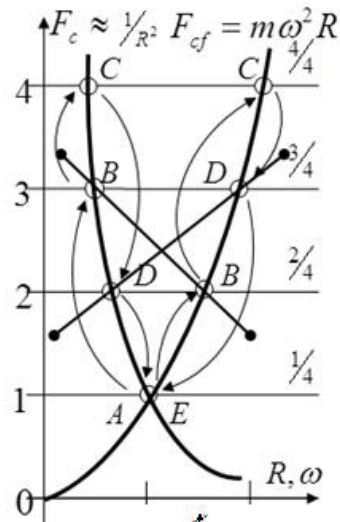


Fig. 6. The illustration of the establishment of dynamic equilibrium of the system

At the same time, this system has a choice of specific values of the quantities R_0 and r , provided that an integer number of cosine waves ($2\pi \cdot R_0 = \lambda_c n$) is placed on the main circular orbit, where λ_c is the wavelength of the cosine wave.

Otherwise, the rotating system will be unstable (remember Louis de Broglie waves).

It is also important that this representation does not see any uncertainties in determining the position (coordinates) (and velocities) of an electron in the considered "electron-nucleus" system. Point *A*, for example, is predetermined by the initial conditions and is located at the intersection of the direction of the linear velocity V (or tangent, if the

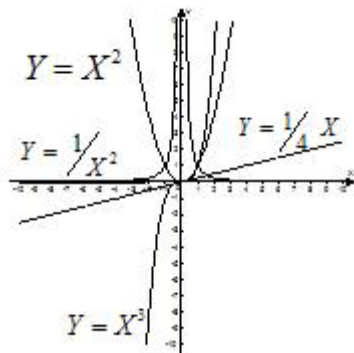


Fig. 7. Illustration of the beginning of rotation

trajectory was previously a curve) and the line perpendicular to it connecting the centers of mass of the nucleus and the electron. The plane in which the trajectory of the electron motion lies, the same is predetermined by the fact that the named two intersecting straight lines are located on it.

On the influence of the forces of electromagnetic interaction. It is clear that a cosine-changing electric field between the nucleus and the electron will cause the appearance of a changing magnetic field. The resulting Lorentz force, in accordance with the left-hand rule, will be directed to the center of curvature of the cosine. It seems that its action inhibits, dampens the desire of the electron to increase the amplitude of the cosine wave, due to the possible manifestation of resonance in a system with an integer number of cosine waves.

Above, the trajectory of the electron was considered taking into account the main, main forces of the first magnitude: F_{in} , F_c , F_{cp} , F^z and only in the two-dimensional plane, where the line connecting the centers of the electron with the nucleus lies. But, it is possible that if we go to three-dimensional space and take into account the influence of forces of the second degree of importance, for example, gyroscopic and gravitational, then the trajectory of the electron may become even more complicated.

For example, if an electron rotates around its own axis, which coincides with the direction of its motion, then when it moves along a cosine wave, the rotating force of the gyroscopic moment will act on the electron. As is known from the theory of gyroscopes, forcing a body rotating around its own axis by external forces to rotate in a perpendicular

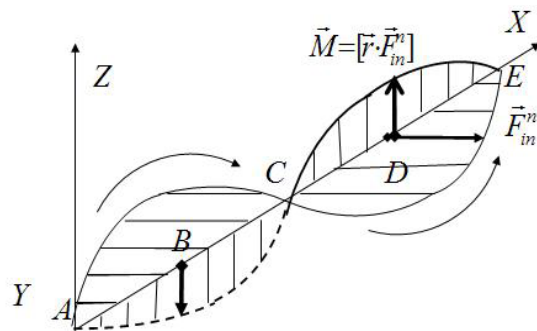


Fig. 8. The direction of the moment M

lar plane causes the precession of this axis. In this case, the external force causing precession is the normal component of the inertial force \vec{F}_{in}^n . Fig. 8 shows an illustration of the mutual development of the propagation processes in a three-dimensional space of the force \vec{F}_{in}^n and the moment $\vec{M} = [\vec{r} \cdot \vec{F}_{in}^n]$, with reference to the phases of development of the cosine $ABCDE$. It is known that the direction of the moment M is determined by the rule of the right screw (see arcs with arrows in Fig. 8). As a result of the manifestation of another moment (gyroscopic), the electron will move in a spiral, similar to the propagation of an electromagnetic wave.

On the influence of the forces of electromagnetic interaction

It is clear that a cosine-changing electric field between the nucleus and the electron will cause the appearance of a changing magnetic field. The resulting Lorentz force will be directed perpendicular to the velocity V , towards the nucleus. This requires a separate, more detailed study. In the meantime, we will only note that it seems that its action slows down, dampens the desire of the electron to increase the amplitude of the cosine wave, with the manifestation of parametric resonance in a system with an integer number of cosine waves.

It remains to consider the influence of gravitational forces on the trajectory of an electron around the nucleus. It is obvious that the dynamical system "electron-nucleus" is asymmetric. Therefore, the gravity force of the electron $F = mg$ will cause one more rotating (gravitational) moment

$M = F \cdot R_0$ in the system (Fig. 9). And therefore, like a gyroscope, the action of the gravity of an

electron, for example, in a horizontal plane, will inevitably cause the entire system to rotate in a vertical plane perpendicular to it, according to the same rule of the right screw. Specifically, in Fig. 9, the system, as a result of the action of gravity F , will rotate around the X -axis, instead of the expected rotation around the Y -axis. This figure reflects the moment the electron passes through point B in Fig. 2. As a result: the trajectory of the electron will have the shape of a ball (or ellipsoid) with a wall (crust) thickness equal to the amplitude of the considered above the cosine. Let us agree with the name of this figure accepted in textbooks — "Is orbital" and recall the well-known Bloch sphere and the work of Sommerfeld.

There are two kinds of vibrations in the atom. High frequency cosine waves, flat or three-dimensional. And low-frequency vibrations generated by the movement of an electron along an ellipsoid around the nucleus. They modulate high frequencies.

The above analysis of the forces acting on the electron confirms the statement (theorem) made at the beginning of the article.

The above procedure for the formation of the trajectory of an electron around the nucleus can be represented as follows (by the formula of nested rotations), similar to the rule of opening brackets in mathematics $T(\text{trajectory}) = (n \dots (3 (2 (1 \text{ rotation}) 1) 2) 3 \dots)n$. For example, in this case. The trajectory of an electron around the nucleus contains the following rotations. $T = (5 (4 (3 (2 (1 \text{ rotation of the electron around its own axis})_1 \text{ rotation of the electron along the main circle (ellipse) around the nucleus})_2 \text{ rotation of the electron along the cosine wave around the line of the circle (ellipse)})_3 \text{ rotation of the electron in a spiral around the circle line (ellipse)})_4 \text{ planetary rotation of the electron on the surface of the ball around the nucleus})_5$. Then the total rotation is equal to the "union" of all references, by expanding the nested parentheses, according to the precedence 1,2,3, etc.

By the way, if we agree that rectilinear motion is motion in a circle of infinite radius, then this formula can be used to sum up the motion of all bodies, including the planets.

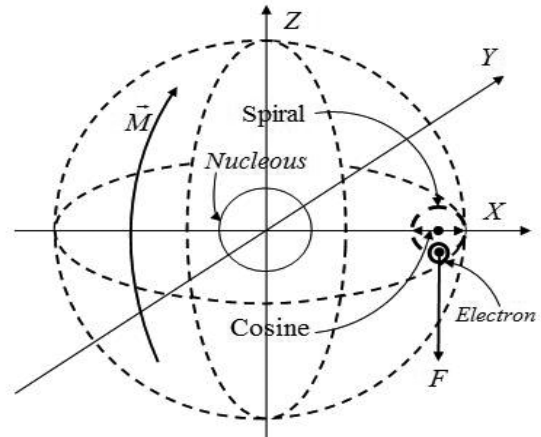


Fig. 9. The dynamical asymmetric system "electron-nucleus"

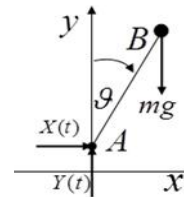


Fig.10. The inverted pendulum with a rigid weightless rod

Traditionally, the new is explained by reducing to the already known. The analogue of the system under consideration, in my opinion, is a well-studied object — a pendulum, but not an ordinary one. Fig. 10, borrowed from the book by J. Stoker [10], shows an inverted pendulum with a rigid weightless rod. The suspension point of the pendulum is not at the top (as usual), but at the bottom. A periodic vertical force $Y(t)$ is applied to the lower end of the rod with the appropriate amplitude and frequency. The movement of the pendulum occurs in a plane xy under the action of gravity mg , external force $Y(t)$ and the reaction of the connection $X(t)$ at point A of the rod. It is described by the equation

$$\ddot{\theta} + \left(-\frac{g}{l} + \frac{1}{l} \cdot p(t) \right) \theta = 0, \text{ where } l \text{ is the length } l \text{ of}$$

the rod, and $p(t)$ is the periodic function of time (Hill's equation). It turns out that if we take a function $p(t) = A \cos \omega t$ and at the same time choose

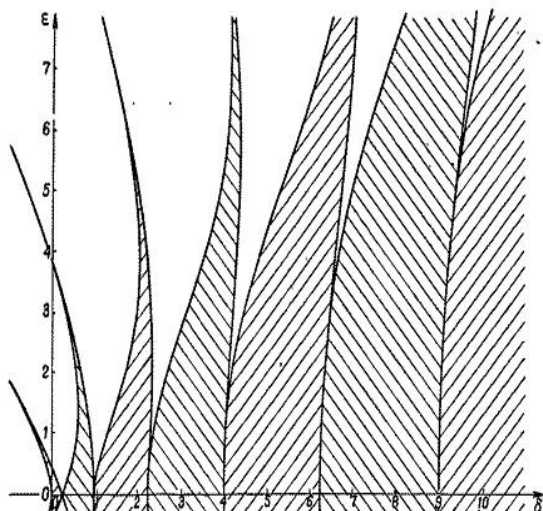


Fig. 11. The regions of stability instability of solutions of the Mathieu equation

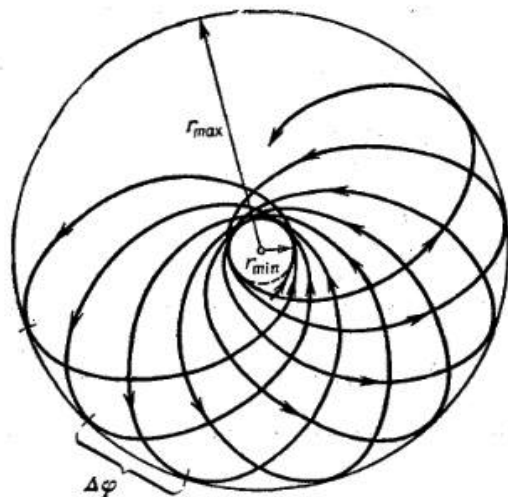


Fig. 12. The motion of body in an external field

the constants A and ω , then all solutions of the equation will be bounded [10]. In other words, an unstable inverted pendulum can be turned into a stable one. This particular form of Hill's equation is usually called the Mathieu equation, which has been studied in great detail. It is written in the liter

ature in this form $d^2\omega/dz^2 + (\delta + \varepsilon \cos z) \cdot \omega = 0$.

The stability domains of the Mathieu equation on

the plane $\varepsilon \cdot \omega$ meet each other at the points $\delta = n^2/4, \varepsilon = 0$, where n is an integer [10].

Fig. 11 shows the regions of stability (shaded) and instability of solutions of the Mathieu equation [10] (recall the well-known jumps of N. Bohr in the atom).

Comparing the results obtained in the article with those known before, the following should be said. Known solutions to the problem of interaction of two oppositely charged bodies in classical mechanics since the time of Newton and later (see, for example, [7] p.40 and further). Whence it follows that the orbit of the particle's motion is an ellipse, hyperbola, or parabola, depending on the initial conditions. What was said in the article does not contradict this, but supplements it. L. Landau reduced the problem of the motion of two interacting material bodies to the solution of the problem of the motion of one body in a given external potential field. And he considered the motion of one body in an external field, in which its potential energy depends only on the distance r to a certain fixed point [11]. If the area changes in r has two boundaries r_{min} and r_{max} , then the motion is finite and the trajectory entirely lies inside the ring bounded by the circles $r = r_{max}$ and $r = r_{min}$ (see Fig. 12).

However, in the general case, the trajectory of a finite motion is not closed. It passes the minimum and maximum distance countless times and fills the entire ring between the two boundary circles in an infinite time. But, there are only two types of central fields in which all trajectories of finite motions are closed. These are fields in which the potential energy of a particle is proportional to $1/r$ or r^2 . Fields in which the potential energy is inversely proportional to r are the most important case of central fields. These are fields, in which the potential in which the potential energy, is inversely proportional to r are the most important case of central fields. These are Newtonian gravitational fields and Coulomb electrostatic fields. L. Landau solved the Keplerian problem and obtained a formula for the trajectory of a particle also in the form of a conical section with a focus at the origin. It is a circle or an ellipse or a hyperbola or a parabola. This also does not

contradict what was proposed in the article, but complements it.

But, I believe that the problem statement is not precise enough here and therefore the well-known questions of "quantum" effects are "hanging in the air". Such as, "smearing" the trajectory, the fall of an electron on the nucleus, Planck's constant.

It is also known that L. Landau's solution to the problem of the motion of an electron in a hydrogen atom at a higher level of abstraction — by means of quantum mechanics [12, Chapter III]. But, as he himself said, the quote: "Most of the problems of quantum mechanics lead to too complex equations that cannot be solved in an exact way" [12, p. 121]. In addition, solutions to problems in quantum mechanics are usually hard to imagine physically. So then we get approximate solutions in the form of orbitals, in side which "with an amplitude of probability everything canbe".

The main part of what is proposed in the article is in good agreement with the already known from the literature and substantiates the known postulates. But part of what was proposed contradicts what is known. I believe that the coincidence of the cosine waves in the Mathieu equation, as well as with the results of the article by L. Landau [11, Fig. 12] are not accidental, but testifies to the manifestation of objective laws in nature, namely in the movement of an electron around a nucleus in an atom. So far, I have not found any errors in the above in my article. Since the ultimate criterion of truth is practice, I believe that there are objective grounds to present the article to the judgment of a wide range of readers.

If we agree with the above reasoning, then, without belittling the merits of the predecessors, we can make changes, clarifications, in our next ideas about the model of the atomic structure.

On Particle-wave Dualism

It is necessary to distinguish between object and process. An electron is an object that has mass (and potential energy). And, at the same time, he can be a "participant", a carrier of various processes (with their kinetic energy), including oscillatory or wave-like ones. And, depending on the circumstances

(the ratio of the scales, sizes of elements and the formulation of the problem), we have to reckon with the electron and/or, as an object and/or as a participant in the process. For example, it seems that de Broglie investigated precisely the process involving the electron.

On the Heisenberg uncertainty. Everyone has their own problems. It is necessary to distinguish between the problems of experimental physicists in the accuracy of measuring the position of the electron and the problems of theoretical physicists, more precisely, calculators, in the accuracy of calculating coordinates on computers. And the atom has its own problems. It doesn't have enough energy to hit the core, or fly past. Therefore, he is forced to go for "peaceful coexistence" with the nucleus until a third force appears from outside. For example, if you measure the dimensions in Fig. 3. with a ruler with a division of at least $2r$, then the cosine wave will be "visible" as a foggy ring with a thickness of $2r$ and the position of an electron inside this ring can only be spoken of using the theory of probability (in terms of amplitudes of probabilities, etc.).

About randomness and probability. It is clear that the moment of the meeting and the initial coordinates of the trajectory of the point of origin of interaction of the "electron-nucleus" system will always be random. But, after equilibration of the system, the refined coordinates of point A can be calculated and, further, the trajectory of the electron can be calculated without applying the theory of probability. Even in advance, substituting the initial conditions into the corresponding differential equations, using the theory of oscillatory systems. The choice of the direction of rotation from point A will also be random: clockwise or counterclockwise.

On the quantization and jumps of electrons in the atom. As it should be in self-oscillating systems, the role of the primary pendulum, the quantizer that sets the pace, is played by an electron oscillating along a cosine wave. And the jumps of electrons are a consequence of the requirement for stable operation of the system, provided that an integer number of cosine waves are placed on the base circle (ellipse) (see also Fig. 11).

About electron clouds and orbital. The above results of the scientific work done by the author: a qualitative substantiation of a new model of the trajectory of an electron in an atom (in fact, a new model of the structure of an atom), may prompt the discovery of a new direction in the study of the physics of the atom. In particular, in the deterministic calculus of the trajectories of motion, both of one electron and several. In this case, one can use, for example, such already known to us knowledge as Lissajous figures and Fourier series [9].

In this case, it is necessary to clearly distinguish between the deterministic process of the electron motion around the nucleus, predetermined by the initial conditions, and the random events of the beginning of the interaction of the electron with the atom, its place (coordinates) and time, as well as the random direction of rotation of the electron around the nucleus.

The presence of unstable states of the "electron-nucleus" system and the aforementioned random events are fundamental conditions for the creation of a quantum computer based on atoms. This is important when superposition of system states

The above sufficiently clear qualitative analysis of the motion of an electron around the nucleus is a necessary prerequisite for the subsequent quantitative analysis and, then, the synthesis of computing devices of a quantum computer.

Conclusion

1. The electron and the nucleus form a self-balancing electromechanical self-oscillating dynamical system in which the electron is held in dynamic equilibrium in an orbit consisting of a basic circle (ellipse) and an additional cosine wave around the basic circle.

2. There are two balancing processes in the system: small and large. The first is balancing during each period of the cosine by the action of competing forces, primarily the Coulomb and centrifugal forces. The second is the balancing of the system by the interaction of the forces of parametric resonance and electromagnetic forces that slow down

the action of the former. This eliminates the processes of both gradual approach of the electron to the nucleus and moving away from the nucleus.

3. It was the identification of the cosine wave in the model of the electron motion that provided the physical manifestation of the Planck constant (which was not in the previous models). The cosine wave quantizes the process in the "electron-nucleus" system in time (sec.) And in portions of energy (erg) and, as a result, we get an action (erg · s). Oscillations of an electron along a cosine wave sets the rate of motion in an atom, similar to the oscillations of a pendulum in an ordinary mechanical clock. The only difference is that in the atom the position of the pendulum at zero velocity is unstable, in comparison with the widely known pendulums. This is exactly what is taken into account in the Mathieu equation. In this case, the well-known Bohr jumps in the atom also become understandable (see Fig. 11).

4. *By a simple comparison of Fig.9 with the structure of the atom in the form of orbitals (Fig. 1, 1s) given in the textbooks, it is easy to convince yourself of a more detailed representation of the model of the structure of the atom.*

5. The above results clarify previous ideas and make them more understandable, visual (in the form of images) and more substantiated, and not in the form of postulates, as it was before. The validity of the results presented in the article is confirmed by their consistency with the previously stated in the relevant literature (see [10] p.186 and [11] p.46).

6. This concept does not see any uncertainties in determining the position of an electron in the considered system "electron-nucleus". Knowing, or setting, the initial conditions (coordinates and velocity of the electron at point A), it is possible, in principle, to determine the position of the electron in time and space relative to the nucleus at any time.

7. The results presented may be of interest to specialists in quantum computers and quantum computing; for physicists in research and development in atomic physics, or mechanics, as well as for students and schoolchildren.

REFERENCES

1. Nielsen M. A., Chuang I. L., 2000. Quantum Computation and Quantum Information, 1st ed., Cambridge University Press, Cambridge.
2. Milantiev V. P., 2017. Istoriyavozniknoveniyakvantovoyemekhanikiirazvitiyepredstavleniyobatoome [History of the emergence of quantum mechanics and the development of ideas about the atom], Book House LIBROKOM, Moscow, 247 p. (In Russian).
3. Shalyapin A. L., Stukalov V. I., 2006. Vvedeniye v klassicheskuyuelektrodinamikiuatomnuyufiziku [Introduction to classical electrodynamics and atomic physics], Publishing house of USTU, Yekaterinburg, 492 p. (In Russian).
4. Bader R., 2001. Atomy v molekulakh, Kvantovayateoriya [Atoms in Molecules, Quantum theory], Mir, Moscow, 532 p. (In Russian).
5. Davydov A. S. 2011. Kvantovayamekhanika [Quantum mechanics], St. Petersburg, 704 p. (In Russian).
6. Fedorchenko A. M., 1971. Theoretical physics, Mekhanika [Mechanics], Vysshayashkola, 272 p. (In Russian).
7. Kuznetsov S. I., 2006. Physical foundations of mechanics, TPU Publishing House, Tomsk, 118 p. (In Russian).
8. Sivukhin D. V., 2006. Obshchiy kurs fiziki [General course of physics], 5th ed. Fizmatlit, Moscow, 1 Mechanics. 560 p. (In Russian).
9. Aleshkevich V. A., Dedenko L. G., Karavaev V. A., 2001. Kolebaniyaivolny [Oscillations and waves], Publishing house of Moscow State University, Moscow, 143 p. (In Russian).
10. Stoker J., 1953. Nelineynyyekolebaniya v mekhanicheskikhielektricheskikh sistemakh [Nonlinear oscillations in mechanical and electrical systems], IL, Moscow, 264 p. (In Russian).
11. Landau L. D., Lifshits Ye. M., 1958. Teoreticheskayafizika [Theoretical physics], Fizmatgiz, Moscow, I Mekhanika [Mechanics], 208 p. (In Russian).
12. Landau L. D., Lifshits Ye. M., 1972. Kratkyy kurs teoreticheskoy fiziki, Nauka, Moscow, 2 Kvantovayamekhanika [Quantum mechanics], 367 p. (In Russian).

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ЛІТЕРАТУРА

1. Нильсен М., Чанг И. Квантовые вычисления и квантовая информация / пер. с англ. Мир, 2006. 824 с.
2. Милантьев В. П. История возникновения квантовой механики и развитие представлений об атоме. М. : Книжный дом «ЛИБРОКОМ», 2017. 247 с.
3. Шаляпин А. Л., Стукалов В. И. Введение в классическую электродинамику и атомную физику. Екатеринбург : Изд-во УГТУ, 2006. 492 с.
4. Бейдер Р. Атомы в молекулах. Квантовая теория. М. : Мир, 2001. 532 с.
5. Давыдов А. С. Квантовая механика. СПб., 2011. 704 с.
6. Федорченко А. М. Теоретическая физика. Механика. Высшая школа, 1971. 272 с.
7. Кузнецов С. И. Физические основы механики. Томск : Изд-во ТПУ, 2006. 118 с.
8. Сивухин Д. В. Общий курс физики. 5-е изд., стереотипное. М. : Физматлит, 2006. Т. 1. Механика. 560 с.
9. Алешкевич В. А., Деденко Л. Г., Караваев В. А. Колебания и волны. М. : Изд-во МГУ, 2001. 143 с.
10. Стокер Дж. Нелинейные колебания в механических и электрических системах. М. : ИЛ. 1953. 264 с.
11. Ландау Л. Д., Лифшиц Е. М. Теоретическая физика. М. : Физматгиз, 1958. Том I. Механика. 208 с.
12. Ландау Л. Д., Лифшиц Е. М. Краткий курс теоретической физики : в 3 кн. М. : Наука, 1972. Кн. 2. Квантовая механика. 367 с.

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СТВОРЕННЯ НАОЧНОЇ МОДЕЛІ БУДОВИ АТОМА ЯК МОЖЛИВОГО ЕЛЕМЕНТА КВАНТОВОГО КОМП'ЮТЕРА

Вступ. Одним із відповідних варіантів реалізації кубітів для квантового комп'ютера можуть бути атоми. Тому доводиться по-новому переглянути структуру атома з урахуванням нових застосувань. У літературі про будову атома наводяться часом суперечливі уявлення щодо траєкторії руху електрона навколо ядра. Останнім досягненням є уявлення моделей атомів у вигляді орбіталей. Але воно недостатньо визначено для застосування у створенні квантового комп'ютера.

Мета статті — створення наочного (образного) уявлення про можливу модель структури атома для реалізації кубіта квантового комп'ютера.

Методи. Засобами класичної механіки і методом якісного аналізу (без складних обчислень, шляхом дослідження функцій) пропонується аналітичне обґрунтування можливої моделі траєкторії руху електрона навколо ядра в атомі, яке дає більш точне наочне уявлення про траєкторію руху електрона і про будову атома. При цьому, був використаний характер взаємодії сил, що діють на електрон в кулонівському полі і закони обертового руху тіла навколо осі.

Результат. Показано, що стійкий рух електрона в атомі забезпечується не тільки рухом за основною еліптичною або круговою орбітою (що відомо з літератури), але й додатковим рухом електрона навколо основної траєкторії по спіралі, проекція якої на площину основної орбіти має вигляд косинусоїди (що не було відомо до цього). При обліку крім основних сил, які впливають на електрон (сил інерції, Кулона, відцентрових і Кориоліса), ще й додаткових сил (електромагнітної взаємодії, гіроскопічних і гравітаційних), структура атома має вигляд не просто орбіталей (кулі). У статті детально розкрито структуру всередині кулі: Траєкторія руху електрона має форму кулі (точніше еліпсоїда) з товщиною стінки (кірки), що дорівнює амплітуді розглянутої вище косинусоїди. При цьому, уздовж кола (еліпса) укладається ціле число косинусоїд.

Висновок. Доведено, що електрон і ядро це самоврівноважувальна електромеханічна автоколивальна динамічна система, в якій електрон утримується в динамічній рівновазі на орбіті, що складається з основного кола (еліпса) і додаткової косинусоїди, навколо основного кола. Основна частина запропонованого в статті матеріалу добре узгоджується з уже відомим з літератури і обґрунтовує відомі постулати. Але частина запропонованого суперечить відомому. Тому важливо представити новий підхід на суд широкого кола фахівців для з'ясування істини в досить складному для розуміння питанні.

Ключові слова: кубіт, модель будови атома, траєкторія руху електрона, електромеханічні самоуравнюючіся системи, автоколивальні системи, обертовий рух.