Real atomic effect of the reducing of the vacuum in the hydrogen atom by the heavy proton (nuclear matter)

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Abstract

The computer program, when it will be executed, then gives a possibility of computation and gaining of real effect of the reducing of vacuum by matter based on uncertainty relations, i.e. the effect, appearing in the electron-positron vacuum near heavy nuclear matter, is provided, as a potential solution of the vacuum energy calculation problem.

Introduction

At the previous we considered the two approaches to the vacuum energy problem in the light of *the reducing of vacuum by matter atomic effect* or as an alternative the limitation of vacuum effect. We reached that in the two articles: (1) 'A statement of the Cosmological constant problem and an effect of the reducing of vacuum by matter based on uncertainty relations' and (2) 'A further specification of the Cosmological constant problem by account the two fermions in the Standard model and an effect of the reducing of vacuum by matter based on uncertainty relations'. However in these articles there has been calculated so-called inoculating simple model-based effect which is not the real atomic effect. Due to the complexity of the real situation with calculating of this effect we have considered and managed with the simple model. As we remember, this model follows from the 2D geometrical scheme of the effect that is in the first mentioned article here. With aid of this inoculating model we can compute the maximal scale for the effect, on which it must terminate for the every left set parameters. In everything else this model does not have power and describes nature incorrectly. Thus, in the current article we will represent the computer program, which allows one to compute real atomic effect of the reducing of the vacuum in the hydrogen atom by heavy proton, i.e. the nuclear matter. The investigated vacuum in this work will be the electron-positron (e^-e^+) vacuum. We will describe the effect by natural, and not artificial, method.

1. The details of the work

According to [1], consider the general case of the relativistic wave packet – temporally developed at arbitrary time Gaussian wave packet at time moment $t=0$. It has the view

$$\psi = \frac{1}{\left(\pi d^2\right)^{3/4}} e^{-r^2/2d^2} \omega^1\left(0\right), \tag{1.1}$$

where $\omega^1\left(0\right)$ is the constant spinor at time 0, d is the width of the wave packet and

$$r = \sqrt{x^2 + y^2 + z^2} \,. \tag{1.2}$$

This wave-function takes in one single time moment and depends only on the Cartesian coordinates $\mathbf{r} = (x, y, z)$. In [1] the result of developing of (1.1) at arbitrary time is gained:

$$\psi(\mathbf{r},t) = \begin{pmatrix} c_1(\mathbf{r},t) \\ 0 \\ c_3(\mathbf{r},t) \\ c_4(\mathbf{r},t) \end{pmatrix}, \tag{1.3}$$

where

$$c_1(\mathbf{r},t) = \frac{1}{\pi^{3/4}}\left(\frac{d}{\hbar}\right)^{3/2} \int_{\mathbb{R}^3} e^{i\mathbf{p}\cdot\mathbf{r}/\hbar} e^{-p^2 d^2/2\hbar^2} \left(\cos\left(\frac{\sqrt{p^2c^2 + m_0^2c^4}}{\hbar} t \right) - i \frac{m_0 c^2}{\sqrt{p^2c^2 + m_0^2c^4}} \times \right. \tag{1.4}$$

$$\left. \times \sin\left(\frac{\sqrt{p^2c^2 + m_0^2c^4}}{\hbar} t \right) \right) \frac{d^3 p}{(2\pi\hbar)^{3/2}} \,,$$

$$c_3(\mathbf{r},t) = -\frac{i}{\pi^{3/4}}\left(\frac{d}{\hbar}\right)^{3/2} \int_{\mathbb{R}^3} e^{i\mathbf{p}\cdot\mathbf{r}/\hbar} e^{-p^2 d^2/2\hbar^2} \frac{p_z c}{\sqrt{p^2c^2 + m_0^2c^4}} \sin\left(\frac{\sqrt{p^2c^2 + m_0^2c^4}}{\hbar} t \right) \frac{d^3 p}{(2\pi\hbar)^{3/2}} \,, \tag{1.5}$$

$$c_4(\mathbf{r},t) = \frac{1}{\pi^{3/4}}\left(\frac{d}{\hbar}\right)^{3/2} \int_{\mathbb{R}^3} e^{i\mathbf{p}\cdot\mathbf{r}/\hbar} e^{-p^2 d^2/2\hbar^2} \frac{(p_y - ip_x)c}{\sqrt{p^2c^2 + m_0^2c^4}} \sin\left(\frac{\sqrt{p^2c^2 + m_0^2c^4}}{\hbar} t \right) \frac{d^3 p}{(2\pi\hbar)^{3/2}} \,, \tag{1.6}$$

where

$$\mathbf{p} = (p_x, p_y, p_z), \tag{1.7}$$

$$p = \sqrt{p_x^2 + p_y^2 + p_z^2} \,, \tag{1.8}$$

$$d^3 p = dp_x dp_y dp_z \,. \tag{1.9}$$

These integrals can be calculated only by use of numerical methods. Take in this wave-function the time instant $t = 2\text{s}$.

We have prepared the initial conditions for the Dirac equation, which must use to determine the considering effect. This effect will gain for the hydrogen atom, therefore the Dirac equation must be written using the Coulomb potential [2a]. It has the view

$$i\hbar \frac{\partial \psi}{\partial t} = -i\hbar c \vec{\alpha} \cdot \nabla \psi + m_0 c^2 \beta \psi + eA_{0I}(r,t,l)\psi \,, \tag{1.10}$$

where

$$A_{0I}(r,t,l) = -\frac{1}{4\pi\varepsilon_0}\frac{e}{r}S(t,l) \quad (1.11)$$

and

$$S(t,l) = \theta(t-2)\theta\left(-\left(t-2-\Delta t(l)\right)\right), \quad (1.12)$$

where $\theta(x)$ is the Heaviside-theta function, and for the lifetime of the virtual pair $\Delta t(l)$, which depends on the scale l one must take the formula (4.6) from the previous article (2). The formula (1.12) is written down at account of the considering time instant $t=2$ for the initial conditions (1.3). The wave-function in the equation (1.10) is the bispinor

$$\psi = \begin{pmatrix} \psi_1(\mathbf{r},t) \\ \psi_2(\mathbf{r},t) \\ \psi_3(\mathbf{r},t) \\ \psi_4(\mathbf{r},t) \end{pmatrix}. \quad (1.13)$$

$\vec{\alpha}$ and β are usual Dirac matrices, that can be found from [2b]. Now let's describe what natural method is. These conditions mean that at this time instant the free motion of the electron and positron which does not relate to the task terminates and the Coulomb potential turns on. Therefore the initial conditions are suitable for the Dirac equation at the time (in SI units) 2 seconds because the modified Coulomb potential (1.11) now has the time dependence (also it has the scale dependence). This potential activates exactly at this time. At the moment of the activation, which is the moment of the creation of the pair and each virtual particle, the particles move freely, actually, we have done in this model that they moved freely all the time before the turning on of the potential, and at the moment. Then the free motion of the electron and the positron at the end of it becomes the motion in the Coulomb electrostatic field, which terminates at being up of the lifetime of the pair. For this time period the particles, as it proposes, make the forward motion and the backward motion and then they annihilate. After the annihilation, as this simplified model assumes, the particles do not vanish, and they continue to move in the potential, but we do not consider that time in our task. This is done to simplify the task, and this approach remains right solution.

Natural approach presumes using of the Dirac equation and description of the virtual particle moving in the potential field in the hydrogen atom by this equation. This is real and not artificial situation that governs in the real world. In this method we assumed that the shape of the wave packet does not change and not depend of what, where this wave packet is (we think the shape of the wave packet is spherical, for simplicity), therefore the Coulomb potential must be usual and depend only on radius-vector r of the central proton in the atom. And, thus, our task gains the solution only in that case, if we are in usual spherical polar coordinates of the central body – proton in the hydrogen atom. These coordinates (r,θ,φ) set a location of point in any wave packet of the virtual particle, wherever it was.

The motion of the virtual particles in our approach is constantly direct, but it occurs at the time period for the forward motion and for the backward motion, i.e. for the full lifetime of the pair. By this way the full motion of each particle realizes, i.e. the natural, according the quantum field theory, moving of the particles turns out straightened. This peculiarity of the model solves the task rightly and greatly simplifies it. In such approach the all generality (movings and orientations) is conserved.

Let's take the numerical solution of (1.10) with the initial conditions (1.3) and compose the probability density, as it must look

$$\rho(\mathbf{r},t)=\psi_1\psi_1^*+\psi_2\psi_2^*+\psi_3\psi_3^*+\psi_4\psi_4^*. \tag{1.14}$$

Then, write the following algebraic equation

$$\int_0^{\varphi_{1,k}(l)}\int_0^{\theta_{1,k}(l)}\int_{r_{a;k}(l)}^{r_{a;k}(l)+l-\Delta l_k(l,t)}\rho(\mathbf{r},t)r^2\sin(\theta)drd\theta d\varphi=0.9973, \tag{1.15}$$

where $\mathbf{r}=(r,\theta,\varphi)$. As one can easily see, (1.15) is the probability integral, adapted for the task, and it is the 3σ rule – the probability of finding of the virtual particle at k-th radius from the central body for the scale l and at the time instant t is 99.73%, as we have chosen. At that the virtual particle does not recombine to make an atom, on the contrary, it exists in the atom, what the integral limits are explained with. The integral limits are justified for the initial free motion and have the views

$$r_{a;k}(l)=r_k+\frac{1}{2}l, \tag{1.16}$$

$$\theta_{1,k}(l)=\varphi_{1,k}(l)=2\arctan\left(\frac{1}{2}\frac{l}{r_{a;k}(l)}\right), \tag{1.17}$$

where $r_{a;k}(l)$ is the same that in (5.23) in (2) but without the limitation vacuum effect and the dispersion. The formulae (1.17) can be derived from the Figure 1 at the condition of absence of the effect. The algebraic equation (1.15) must be solved relatively of the effective reducing of the scale $\Delta l_k(l,t)$, which is the dynamics considering. Thus, the task of determination of the effect has now the gaining resolution, and the rest formulae of the applying of the limitation of vacuum effect do not change, as they are in (2), considering the dynamics.

2. The data needed for the computation

In the computation we have the following values for the physical fundamental constants in SI units: $c=299792458\,\mathrm{m/s}$, $\hbar=6.6260755\cdot10^{-34}\cdot1/2\pi\,\mathrm{J\cdot s}$, $\varepsilon_0=8.854187817\cdot10^{-12}\,\mathrm{F/m}$. In the program we have taken from (2): the electron mass, the Planck length, the radius of the hydrogen atom, the minimal radius of the effect and the task, the minimal scale, the inoculating maximal scale. Also we use the elementary charge or the value of electron's charge (without sign) in SI units: $e=1.6021773349\cdot10^{-19}\,\mathrm{C}$.

The units of angles: $\Theta=\pi/20$, $\Phi=2\pi/20$.

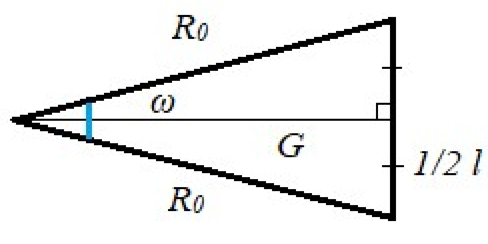

fig. 1

The numbers of the segments on the all axes in the spherical polar coordinate system: on the radius axis we have taken $aMAX = 20$, on the polar angle we have taken $bMAX = 20$ and on the azimuthal angle we have taken $gMAX = 20$. The minimal value of the radius of the atom to avoid the singularity at the solving of the Dirac equation, because there it stands in the denominator: $\rho_0 = 10^{-20}\,\mathrm{m}$; it is chosen in such a way that $\rho_0 = r(\min) \to 0$. The minimal value of the polar angle to avoid the singularity at the solving of the Dirac equation with the same reason: $Angl\theta_0 = \pi/10^{15}$; it is chosen in the same way, like the minimal value of the radius: it must go to zero. The maximal scale must be computed by the given below computer program; this computation is the cyclic computation with the beginning inoculating maximal value of the scale. As the initial maximal scale is the inoculating value of scale as the initial number of the segments on the scale axis is the inoculating number of the segments. The maximal inoculating number of the segments on the scale axis: $NMAX_0 = 50$. Why this number is so small will be said below. Knowing the inoculating value of scale and the inoculating number of the segments, we can calculate the initial length of the segment. The maximal number of segments on the time axis: $MMAX = 100$.

The small numerical constant ε that has dimensionality of time: $\varepsilon = T\left(l_{\min} + NMAX_F \cdot l_P\right) - \left(2MMAX - 1\right)\delta$. The duration of one single time interval: $\delta\left(l_{\max}\right) = 1.60995 \cdot 10^{-24}\,\mathrm{s}$. The fractions of presence in number relation of each atom in the full number of atoms are given in the program, they also are in (2) and they use at the final stage of the computation. The diameter of the virtual particle's wave packet is the corresponding scale l. The segment of the radius of the virtual particle's wave packet defines by the formula $\rho(l) = \left(1/\left(20 \cdot 2\right)\right)\left(l + 0.3 \cdot l\right)$.

The minimal segment on the scale axis must be the Planck length because, according the all theory that has been built in the previous articles, the space has divided into the segments of this length but if it really represents step on the scale axis, the number of such segments will be too large to compute any program on computer. Therefore we must use an extrapolation in the way that we should take not the Planck length minimal segment of scale, and the segment of much more length, than the Planck length; one such segment and the corresponding number of these segments to fill the full inoculating scale range, and another shorter segment with more number of these segments, and yet one that will be less, and if it is needed, yet some ones of the segments to compute the all data in every such approximate case. And then we must predict on which values of the data will go out and to continue graphically every value which the program gives on these expected values, when the length is the Planck length. Below we provide the computer program written in the Wolfram language®, that allows to gain the final result of the entire this work, summed up into the three articles – the e^-e^+ vacuum energy in the hydrogen atom for the entire Universe with the reducing of the vacuum effect; where the all atoms in the Universe are hydrogen atoms.

In[∘]:= $Tm1 = AbsoluteTime[];$
абсолютное значение

In[∘]:=
$m0 = 9.11 \times 10^{-31};$

$c = 299\,792\,458;$

$\hbar = 6.6260755 \times 10^{-34} \frac{1}{2\pi};$

$lP = 3.99984 \times 10^{-13};$

$\epsilon_0 = 8.854187817 \times 10^{-12};$

$r_{min} = 10^{-11};$

$r_{max} = 2.5 \times 10^{-11};$

$lmax_0 = 2.00008 \times 10^{-11};$

$\Delta L_0 = 1.99992 \times 10^{-11};$

$NMAX_0 = 50;$

$MMAX = 100;$

$Na = 7.39 \times 10^{79};$

$lmin = 10^{20} \times 1.616255 \times 10^{-35};$

In[∘]:=
$\Delta_1 = 0.739;$

$\Delta_2 = 0.24;$

$\Delta_3 = 0.0104;$

$\Delta_4 = 0.0046;$

$\Delta_5 = 0.0013;$

$\Delta_6 = 0.0011;$

$\Delta_7 = 0.00096;$

$\Delta_8 = 0.00065;$

$\Delta_9 = 0.00058;$

$\Delta_{10} = 0.00044;$

$dd := \frac{\Delta L_0}{50}$

$\delta := 1.60995 \times 10^{-24}$

In[∘]:= $\delta 2 := 1.54803 \times 10^{-24}$

In[∘]:= $$\delta = \frac{1}{2\,MMAX} \times \frac{lmin + \Delta L_0}{c} \times \frac{1}{\sqrt{3 + 16 \times \frac{m0^2\, c^2}{\hbar^2}\, (lmin + \Delta L_0)^2}}$$

Out[∘]=
1.60995×10^{-24}

In[∘]:= $n0 := 0$

In[∘]:= $$MMAXN0 = \frac{1}{\delta} \times \frac{lmin}{c} \times \frac{1}{\sqrt{3 + 16 \times \frac{m0^2\, c^2}{\hbar^2}\, lmin^2}}$$

Out[∘]=
1.93329

In[∘]:= $m00 = Floor[MMAXN0]$
округление вниз

Out[∘]=
1

In[∘]:= $\Delta t[l\_] := \frac{1}{c} \times \frac{1}{\sqrt{3 + 16 \times \frac{m0^2 c^2}{\hbar^2} l^2}}$

In[∘]:= $T[l\_] := \frac{1}{2} \Delta t[l]$

In[∘]:= $d[l\_] := \frac{1}{l}$

In[∘]:= $\rho[l\_] := \frac{1}{2 \times 20} \left(\frac{1}{d[l]} + 0.3 \times \frac{1}{d[l]}\right)$

$ra_{0,0}[l\_] = r_{min};$

In[∘]:= MID1[px_, py_, pz_, t_, l_] :=

$$\text{Exp}\left[-\frac{(px^2 + py^2 + pz^2)\, d[l]^2}{2 \hbar^2}\right] \left(\text{Cos}\left[\frac{\sqrt{(px^2 + py^2 + pz^2)\, c^2 + m0^2 c^4}}{\hbar} t\right] - \right.$$

показательная функция, косинус

$$\left. i \times \frac{m0\, c^2}{\sqrt{(px^2 + py^2 + pz^2)\, c^2 + m0^2 c^4}} \text{Sin}\left[\frac{\sqrt{(px^2 + py^2 + pz^2)\, c^2 + m0^2 c^4}}{\hbar} t\right]\right)$$

синус

In[∘]:= $\text{MID2}[px\_, py\_, pz\_, t\_, l\_] := \text{Exp}\left[-\frac{(px^2 + py^2 + pz^2)\, d[l]^2}{2 \hbar^2}\right]$

показательная функция

$$\frac{pz\, c}{\sqrt{(px^2 + py^2 + pz^2)\, c^2 + m0^2 c^4}} \text{Sin}\left[\frac{\sqrt{(px^2 + py^2 + pz^2)\, c^2 + m0^2 c^4}}{\hbar} t\right]$$

синус

In[∘]:= $\text{MID3}[px\_, py\_, pz\_, t\_, l\_] := \text{Exp}\left[-\frac{(px^2 + py^2 + pz^2)\, d[l]^2}{2 \hbar^2}\right]$

показательная функция

$$\frac{(py - i\, px)\, c}{\sqrt{(px^2 + py^2 + pz^2)\, c^2 + m0^2 c^4}} \text{Sin}\left[\frac{\sqrt{(px^2 + py^2 + pz^2)\, c^2 + m0^2 c^4}}{\hbar} t\right]$$

синус

S[t_, Q_] := HeavisideTheta[t - 2] HeavisideTheta[- (t - 2 - Δt[lmin + Q lP])]

тета-функция Хевисайда, тета-функция Хевисайда

$\text{A0I}[r\_, t\_, Q\_] := -\frac{1}{4 \pi \epsilon_0} \times \frac{e}{r} S[t, Q]$

$\text{Block}\left[\left\{F = 0,\ VU = 3.6 \times 10^{80},\ VA = 1.4625 \times 10^{-32} \times \frac{4}{3} \pi,\right.\right.$

программный блок

$e = 1.6021773349 \times 10^{-19},\ n0 = 0,\ \Theta = \frac{\pi}{20},$

$\Phi = \frac{2 \pi}{20},\ aMAX = 20,$

bMAX = 20,

```
gMAX = 20, ρ0 = 10^-20,
Angl⊖0 = π/10^15}, Do[If[i == 0, j0 = 1;, Null];
                  [⋯ [условный оператор  [пустой

  If[i ≥ 1 && i ≤ 10, ji = 928 i;, Null], {i, 0, 10}];
  [условный оператор                [пустой
 Tm10 = AbsoluteTime[];
       [абсолютное значение времени
 Table[r2_{0,x1,F} = rmin;, {x1, 0, NMAXF}];
 [таблица значений
 Table[ra_{0,x1,F} = rmin;, {x1, 0, NMAXF}];
 [таблица значений
 For[s1 = 0, ra_{s1,n0,F} ≤ rmax, s1++,
 [цикл ДЛЯ
  If[s1 == 0, Print["s1=", 0, " ", "ra_{s1,n0,F}=", N[rmin]], Null];
  [условный ⋯ [печатать                            [численно⋯ [пустой
  Do[l_x1 = lmin + x1 lP;
  [оператор цикла
   r2_{s1+1,x1,F} = r2_{s1,x1,F} + l_x1;
   ra_{s1+1,x1,F} = r2_{s1+1,x1,F};
   r2_{s1,x1,F} =.;
   l_x1 =., {x1, 0, NMAXF}];
  If[s1 > 0 && (s1 == j0 || s1 == j1 || s1 == j2 || s1 == j3 ||
  [условный оператор
      s1 == j4 || s1 == j5 || s1 == j6 || s1 == j7 || s1 == j8 || s1 == j9 || s1 == j10),
   Print["s1=", s1, " ", "ra_{s1,n0,F}=", ra_{s1,n0,F}], Null]];
   [печатать                                         [пустой
 Tm20 = AbsoluteTime[];
       [абсолютное значение времени
 Print["Δt10=", Tm20 - Tm10, " ", "F=", F];
 [печатать
 p1 = s1 - 1;
 Tm30 = AbsoluteTime[];
       [абсолютное значение времени
 Table[ra_{k5,F} = Interpolation[Table[{{lmin + x11 lP}, ra_{k5,x11,F}}, {x11, 0, NMAXF}],
 [таблица значе⋯ [интерполировать  [таблица значений
     InterpolationOrder → 5];, {k5, 1, p1}];
     [порядок интерполяции
 Print["ra_{k5,F}[l]"];
 [печатать
 Tm40 = AbsoluteTime[];
       [абсолютное значение времени
 Print["Δt20=", Tm40 - Tm30, " ", "F=", F];
 [печатать
 t = 2;
 Table[N1_{y,F}[l_] = π / ArcTan[1 / (2 Sqrt[ra_{y,F}[l]^2 - 1/4 l^2])];
 [таблица значений

  If[(y == j0 || y == j1 || y == j2 || y == j3 || y == j4 || y == j5 || y == j6 ||
  [условный оператор
     y == j7 || y == j8 || y == j9 || y == j10), Print["y=", y], Null];, {y, 0, p1}];
                                                 [печатать          [пустой
```

```
Table[R0k,F[l_] = rak,F[l] + 1/2 l;
таблица значений

 If[(k == j0 || k == j1 || k == j2 || k == j3 || k == j4 || k == j5 || k == j6 ||
 условный оператор
    k == j7 || k == j8 || k == j9 || k == j10), Print["k=", k], Null];, {k, 0, p1}];
                                                печатать          пустой

Tm50 = AbsoluteTime[];
       абсолютное значение времени

Do[lf1 = lmin + lP f1;
оператор цикла

 Do[ra1,f1 = a1 ρ[lf1];
 оператор цикла

  Do[θb1 = b1 Θ;
  оператор цикла

   Do[ϕg1 = g1 Φ;
   оператор цикла

    If[a1 == 0 && b1 == 0 && g1 == 0 && f1 == 0,
    условный оператор
     Print["a1=b1=g1=", a1, " ", "f1=", f1], Null];
     печатать                               пустой
    If[a1 == 0 && b1 == 0 && g1 == 0 && f1 == 0, tt0 = AbsoluteTime[];, Null];
    условный оператор                                  абсолютное значен···  пустой
    If[a1 == 0 && b1 == 0 && f1 == 0 && g1 == gMAX, ttgMAX = AbsoluteTime[];
    условный оператор                                        абсолютное значение времени
     Tg1 = ttgMAX - tt0;
     Print["The execution time of the all Cycles Do,(s)=",
     печатать                                 циклы  оператор цикла
      Tg1 (bMAX + 1) (aMAX + 1) (NMAXF + 1), " ",
      "The execution time of the a1 Cycle Do,(s)=", Tg1 (bMAX + 1) (aMAX + 1),
                                          оператор цикла
      " ", "The execution time of the Θ Cycle Do,(s)=", Tg1 (bMAX + 1)], Null];
                                          оператор цикла                  пустой
    If[a1 == aMAX && b1 == bMAX && g1 == gMAX && f1 == NMAXF, Print["a1=", a1, " ", "b1=",
    условный оператор                                         печатать
      b1, " ", "g1=", g1, " ", "f1=", f1, " ", "This module is finished!"], Null];
                                                                            пустой
```

$$c11_{a1,b1,g1,f1,F} = \frac{1}{\pi^{3/4}} \left(\frac{d[l_{f1}]}{\hbar}\right)^{3/2} \text{NIntegrate}\Big[$$

квадратурное интегрирование

$$e^{\frac{i}{\hbar}(px\, r_{a1,f1} \operatorname{Sin}[\theta_{b1}] \operatorname{Cos}[\phi_{g1}] + py\, r_{a1,f1} \operatorname{Sin}[\theta_{b1}] \operatorname{Sin}[\phi_{g1}] + pz\, r_{a1,f1} \operatorname{Cos}[\theta_{b1}])}\, \text{MID1}[px, py, pz, t, l_{f1}] \times$$

$$\frac{1}{(2\pi\hbar)^{3/2}}, \{px, -\infty, \infty\}, \{py, -\infty, \infty\}, \{pz, -\infty, \infty\}, \text{AccuracyGoal} \to 10\Big];$$

требуемая абсол. точность

```
    ϕg1 =., {g1, 0, gMAX}];
   θb1 =., {b1, 0, bMAX}];
  ra1,f1 =., {a1, 0, aMAX}];
 lf1 =.;, {f1, 0, NMAXF}];
```

```
Tm60 = AbsoluteTime[];
       абсолютное значение времени
Print["Δt30=", Tm60 - Tm50, " ", "F=", F];
печатать
Print["The execution time of the all modules, setting the initial conditions
печатать
   for the Dirac equation,(s)=", 3 Tg1 (bMAX + 1) (aMAX + 1) (NMAXF + 1)];
Tm70 = AbsoluteTime[];
       абсолютное значение времени
c1F = Interpolation[
      интерполировать
  Flatten[Table[{{aa1, bb1 Θ, gg1 Φ, lmin + f11 lP}, c11aa1,bb1,gg1,f11,F}, {aa1, 0, aMAX},
  уплостить таблица значений
    {bb1, 0, bMAX}, {gg1, 0, gMAX}, {f11, 0, NMAXF}], 3], InterpolationOrder → 5];
                                                        порядок интерполяции
Print["c1F[r/ρ[l],θ,ϕ,l]"];
печатать

Tm80 = AbsoluteTime[];
       абсолютное значение времени
Print["Δt40=", Tm80 - Tm70, " ", "F=", F];
печатать
Print["Time Δt of setting the all interpolation functions for the all
печатать
   initial conditions for the Dirac equation,(s)=", 3 (Tm80 - Tm70)];
Print["The execution time of the setting of the initial conditions for the
печатать
   Dirac equation,(s)=", 3 Tg1 (bMAX + 1) (aMAX + 1) (NMAXF + 1) + 3 (Tm80 - Tm70)];
Tm90 = AbsoluteTime[];
       абсолютное значение времени
Do[lf2 = lmin + lP f2;
оператор цикла
 Do[ra2,f2 = a2 ρ[lf2];
 оператор цикла
  Do[θb2 = b2 Θ;
  оператор цикла
   Do[ϕg2 = g2 Φ;
   оператор цикла
    If[a2 == 0 && b2 == 0 && g2 == 0 && f2 == 0, Print["a2=b2=g2=", a2, " ",
    условный оператор                            печатать
      "f2=", f2, " ", "The execution time of the all Cycles Do,(s)=",
                                                 циклы    оператор цикла
      Tg1 (bMAX + 1) (aMAX + 1) (NMAXF + 1)], Null];
                                              пустой
    If[a2 == aMAX && b2 == bMAX && g2 == gMAX && f2 == NMAXF, Print["a2=", a2, " ", "b2=",
    условный оператор                                        печатать
      b2, " ", "g2=", g2, " ", "f2=", f2, " ", "This module is finished!"], Null];
                                                                            пустой
    c33a2,b2,g2,f2,F = -i 1/π^(3/4) (d[lf2]/ħ)^(3/2) NIntegrate[
                                                     квадратурное интегрирование
```

```
e^(i/ℏ (px r[a2,f2] Sin[θ[b2]] Cos[ϕ[g2]] + py r[a2,f2] Sin[θ[b2]] Sin[ϕ[g2]] + pz r[a2,f2] Cos[θ[b2]])) MID2[px, py, pz, t, l[f2]] ×
   1/(2 π ℏ)^(3/2), {px, -∞, ∞}, {py, -∞, ∞}, {pz, -∞, ∞}, AccuracyGoal → 10];
                                                          требуемая абсол. точность

      ϕ[g2] =., {g2, 0, gMAX}];
     θ[b2] =., {b2, 0, bMAX}];
    r[a2,f2] =., {a2, 0, aMAX}];
   l[f2] =.;, {f2, 0, NMAX[F]}];
Tm[100] = AbsoluteTime[];
          абсолютное значение времени
Print["Δt50=", Tm[100] - Tm[90], " ", "F=", F];
печатать
Tm[110] = AbsoluteTime[];
          абсолютное значение времени
c3[F] = Interpolation[
        интерполировать
  Flatten[Table[{{aa2, bb2 Θ, gg2 Φ, lmin + f22 lP}, c33[aa2,bb2,gg2,f22,F]}, {aa2, 0, aMAX},
  уплостить таблица значений
    {bb2, 0, bMAX}, {gg2, 0, gMAX}, {f22, 0, NMAX[F]}], 3], InterpolationOrder → 5];
                                                            порядок интерполяции
Print["c3F[r/ρ[l],θ,ϕ,l]"];
печатать

Tm[120] = AbsoluteTime[];
          абсолютное значение времени
Print["Δt60=", Tm[120] - Tm[110], " ", "F=", F];
печатать
Tm[130] = AbsoluteTime[];
          абсолютное значение времени
Do[l[f3] = lmin + lP f3;
оператор цикла
 Do[r[a3,f3] = a3 ρ[l[f3]];
 оператор цикла
  Do[θ[b3] = b3 Θ;
  оператор цикла
   Do[ϕ[g3] = g3 Φ;
   оператор цикла
    If[a3 == 0 && b3 == 0 && g3 == 0 && f3 == 0, Print["a3=b3=g3=", a3, " ",
    условный оператор                            печатать
      "f3=", f3, " ", "The execution time of the all Cycles Do,(s)=",
                                                    циклы     оператор цикла
      Tg1 (bMAX + 1) (aMAX + 1) (NMAX[F] + 1)], Null];
                                                пустой
    If[a3 == aMAX && b3 == bMAX && g3 == gMAX && f3 == NMAX[F], Print["a3=", a3, " ", "b3=",
    условный оператор                                             печатать
      b3, " ", "g3=", g3, " ", "f3=", f3, " ", "This module is finished!"], Null];
                                                                            пустой
```

```
c44_{a3,b3,g3,f3,F} = 1/π^{3/4} (d[l_{f3}]/ℏ)^{3/2} NIntegrate[
                                                     квадратурное интегрирование
    e^{i/ℏ (px r_{a3,f3} Sin[θ_{b3}] Cos[ϕ_{g3}] + py r_{a3,f3} Sin[θ_{b3}] Sin[ϕ_{g3}] + pz r_{a3,f3} Cos[θ_{b3}])} MID3[px, py, pz, t, l_{f3}] ×
    1/(2 π ℏ)^{3/2}, {px, -∞, ∞}, {py, -∞, ∞}, {pz, -∞, ∞}, AccuracyGoal → 10];
                                                              требуемая абсол. точность

   ϕ_{g3} =., {g3, 0, gMAX}];
  θ_{b3} =., {b3, 0, bMAX}];
 r_{a3,f3} =., {a3, 0, aMAX}];
l_{f3} =.;, {f3, 0, NMAX_F}];
Tm_{140} = AbsoluteTime[];
           абсолютное значение времени
Print["Δt_{70}=", Tm_{140} - Tm_{130}, " ", "F=", F];
печатать
Tm_{150} = AbsoluteTime[];
           абсолютное значение времени
c4_F = Interpolation[
       интерполировать
  Flatten[Table[{{aa3, bb3 Θ, gg3 Φ, lmin + f33 lP}, c44_{aa3,bb3,gg3,f33,F}}, {aa3, 0, aMAX},
  уплостить таблица значений
    {bb3, 0, bMAX}, {gg3, 0, gMAX}, {f33, 0, NMAX_F}], 3], InterpolationOrder → 5];
                                                         порядок интерполяции
Print["c4_F[r/ρ[l],θ,ϕ,l]"];
печатать

Tm_{160} = AbsoluteTime[];
           абсолютное значение времени
Print["Δt_{80}=", Tm_{160} - Tm_{150}, " ", "F=", F];
печатать
t =.;
Tm_{170} = AbsoluteTime[];
           абсолютное значение времени
Do[ttΨD_0 = AbsoluteTime[];
оператор ⋯ абсолютное значение времени
 l_Q = lmin + Q lP;
 ΨD_{Q,F} = NDSolve[{i ℏ ∂_t ψ1_{Q,F}[r, θ, ϕ, t] ==
              численно решить ДУ
    -i ℏ c ((Sin[θ] Cos[ϕ] ∂_r ψ4_{Q,F}[r, θ, ϕ, t] + Cos[θ] Cos[ϕ] 1/r ∂_θ ψ4_{Q,F}[r, θ, ϕ, t] -
             синус   косинус                          косинус  косинус
        Sin[ϕ]/(r Sin[θ]) ∂_ϕ ψ4_{Q,F}[r, θ, ϕ, t]) - i × (Sin[θ] Sin[ϕ] ∂_r ψ4_{Q,F}[r, θ, ϕ, t] +
                                                          синус  синус
        Cos[θ] Sin[ϕ] 1/r ∂_θ ψ4_{Q,F}[r, θ, ϕ, t] + Cos[ϕ]/(r Sin[θ]) ∂_ϕ ψ4_{Q,F}[r, θ, ϕ, t]) +
        косинус синус
```

$$\left(\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\,\partial_r\psi3_{Q,F}[r,\theta,\phi,t]-\underset{\text{синус}}{\mathrm{Sin}[\theta]}\,\frac{1}{r}\,\partial_\theta\psi3_{Q,F}[r,\theta,\phi,t]\right)\Bigg)+$$

$$m0\,c^2\,\psi1_{Q,F}[r,\theta,\phi,t]+e\,\psi1_{Q,F}[r,\theta,\phi,t]\,A0I[r,t,Q],\ \mathbb{i}\,\hbar\,\partial_t\psi2_{Q,F}[r,\theta,\phi,t]==$$

$$-\mathbb{i}\,\hbar\,c\,\Bigg(\Bigg(\underset{\text{синус}}{\mathrm{Sin}[\theta]}\,\underset{\text{косинус}}{\mathrm{Cos}[\phi]}\,\partial_r\psi3_{Q,F}[r,\theta,\phi,t]+\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\,\underset{\text{косинус}}{\mathrm{Cos}[\phi]}\,\frac{1}{r}\,\partial_\theta\psi3_{Q,F}[r,\theta,\phi,t]-$$

$$\frac{\mathrm{Sin}[\phi]}{r\,\mathrm{Sin}[\theta]}\,\partial_\phi\psi3_{Q,F}[r,\theta,\phi,t]\Bigg)+\mathbb{i}\times\Bigg(\underset{\text{синус}}{\mathrm{Sin}[\theta]}\,\underset{\text{синус}}{\mathrm{Sin}[\phi]}\,\partial_r\psi3_{Q,F}[r,\theta,\phi,t]+$$

$$\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\,\underset{\text{синус}}{\mathrm{Sin}[\phi]}\,\frac{1}{r}\,\partial_\theta\psi3_{Q,F}[r,\theta,\phi,t]+\frac{\mathrm{Cos}[\phi]}{r\,\mathrm{Sin}[\theta]}\,\partial_\phi\psi3_{Q,F}[r,\theta,\phi,t]\Bigg)-$$

$$\left(\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\,\partial_r\psi4_{Q,F}[r,\theta,\phi,t]-\underset{\text{синус}}{\mathrm{Sin}[\theta]}\,\frac{1}{r}\,\partial_\theta\psi4_{Q,F}[r,\theta,\phi,t]\right)\Bigg)+$$

$$m0\,c^2\,\psi2_{Q,F}[r,\theta,\phi,t]+e\,\psi2_{Q,F}[r,\theta,\phi,t]\,A0I[r,t,Q],\ \mathbb{i}\,\hbar\,\partial_t\psi3_{Q,F}[r,\theta,\phi,t]==$$

$$-\mathbb{i}\,\hbar\,c\,\Bigg(\Bigg(\underset{\text{синус}}{\mathrm{Sin}[\theta]}\,\underset{\text{косинус}}{\mathrm{Cos}[\phi]}\,\partial_r\psi2_{Q,F}[r,\theta,\phi,t]+\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\,\underset{\text{косинус}}{\mathrm{Cos}[\phi]}\,\frac{1}{r}\,\partial_\theta\psi2_{Q,F}[r,\theta,\phi,t]-$$

$$\frac{\mathrm{Sin}[\phi]}{r\,\mathrm{Sin}[\theta]}\,\partial_\phi\psi2_{Q,F}[r,\theta,\phi,t]\Bigg)-\mathbb{i}\times\Bigg(\underset{\text{синус}}{\mathrm{Sin}[\theta]}\,\underset{\text{синус}}{\mathrm{Sin}[\phi]}\,\partial_r\psi2_{Q,F}[r,\theta,\phi,t]+$$

$$\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\,\underset{\text{синус}}{\mathrm{Sin}[\phi]}\,\frac{1}{r}\,\partial_\theta\psi2_{Q,F}[r,\theta,\phi,t]+\frac{\mathrm{Cos}[\phi]}{r\,\mathrm{Sin}[\theta]}\,\partial_\phi\psi2_{Q,F}[r,\theta,\phi,t]\Bigg)+$$

$$\left(\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\,\partial_r\psi1_{Q,F}[r,\theta,\phi,t]-\underset{\text{синус}}{\mathrm{Sin}[\theta]}\,\frac{1}{r}\,\partial_\theta\psi1_{Q,F}[r,\theta,\phi,t]\right)\Bigg)-$$

$$m0\,c^2\,\psi3_{Q,F}[r,\theta,\phi,t]+e\,\psi3_{Q,F}[r,\theta,\phi,t]\,A0I[r,t,Q],\ \mathbb{i}\,\hbar\,\partial_t\psi4_{Q,F}[r,\theta,\phi,t]==$$

$$-\mathbb{i}\,\hbar\,c\,\Bigg(\Bigg(\underset{\text{синус}}{\mathrm{Sin}[\theta]}\,\underset{\text{косинус}}{\mathrm{Cos}[\phi]}\,\partial_r\psi1_{Q,F}[r,\theta,\phi,t]+\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\,\underset{\text{косинус}}{\mathrm{Cos}[\phi]}\,\frac{1}{r}\,\partial_\theta\psi1_{Q,F}[r,\theta,\phi,t]-$$

$$\frac{\mathrm{Sin}[\phi]}{r\,\mathrm{Sin}[\theta]}\,\partial_\phi\psi1_{Q,F}[r,\theta,\phi,t]\Bigg)+\mathbb{i}\times\Bigg(\underset{\text{синус}}{\mathrm{Sin}[\theta]}\,\underset{\text{синус}}{\mathrm{Sin}[\phi]}\,\partial_r\psi1_{Q,F}[r,\theta,\phi,t]+$$

$$\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\,\underset{\text{синус}}{\mathrm{Sin}[\phi]}\,\frac{1}{r}\,\partial_\theta\psi1_{Q,F}[r,\theta,\phi,t]+\frac{\mathrm{Cos}[\phi]}{r\,\mathrm{Sin}[\theta]}\,\partial_\phi\psi1_{Q,F}[r,\theta,\phi,t]\Bigg)-$$

$$\left(\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\,\partial_r\psi2_{Q,F}[r,\theta,\phi,t]-\underset{\text{синус}}{\mathrm{Sin}[\theta]}\,\frac{1}{r}\,\partial_\theta\psi2_{Q,F}[r,\theta,\phi,t]\right)\Bigg)-$$

$$m0\,c^2\,\psi4_{Q,F}[r,\theta,\phi,t]+e\,\psi4_{Q,F}[r,\theta,\phi,t]\,A0I[r,t,Q],$$

$$\psi1_{Q,F}[r,\theta,\phi,2]==c1_F\left[\frac{r}{\rho[1_Q]},\theta,\phi,1_Q\right],\ \psi2_{Q,F}[r,\theta,\phi,2]==0,$$

$$\psi3_{Q,F}[r,\theta,\phi,2]==c3_F\left[\frac{r}{\rho[1_Q]},\theta,\phi,1_Q\right],\ \psi4_{Q,F}[r,\theta,\phi,2]==c4_F\left[\frac{r}{\rho[1_Q]},\theta,\phi,1_Q\right]\Big\},$$

$$\{\psi1_{Q,F}[r,\theta,\phi,t],\ \psi2_{Q,F}[r,\theta,\phi,t],\ \psi3_{Q,F}[r,\theta,\phi,t],\ \psi4_{Q,F}[r,\theta,\phi,t]\},$$

```
    {r, ρ0, 20 ρ[lQ]}, {θ, Anglθ0, π}, {ϕ, 0, 2 π}, {t, 2, 2 + Δt[lQ]}];
  ttΨD1 = AbsoluteTime[];
          абсолютное значение времени
  TΨD = ttΨD1 - ttΨD0;
  If[Q == 0, Print["Time of the solving the all Dirac equations,(s)=", TΨD (NMAXF + 1)],
  условный··· печатать
   Null];, {Q, 0, NMAXF}];
   пустой
Tm180 = AbsoluteTime[];
        абсолютное значение времени
Print["Δt90=", Tm180 - Tm170, " ", "F=", F];
печатать
Print["The execution time of the setting of the initial conditions
печатать
    for the Dirac equation and the solving of this equation(s)=",
  3 Tg1 (bMAX + 1) (aMAX + 1) (NMAXF + 1) + 3 (Tm80 - Tm70) + TΨD (NMAXF + 1)];
Tm190 = AbsoluteTime[];
        абсолютное значение времени
Do[Print[10 i];
··· печатать
  fi = 10 i;, {i, 1, 5}];
Table[ttTΨ0 = AbsoluteTime[];
таблица значе··· абсолютное значение времени
  Ψ1Q,F[r_, θ_, ϕ_, t_] := Evaluate[ψ1Q,F[r, θ, ϕ, t] /. ΨDQ,F];
                           вычислить
  If[Q == 0, Print["Q=", Q],
  условный··· печатать
   If[Q == f1 || Q == f2 || Q == f3 || Q == f4 || Q == f5, Print["Q=", Q], Null]];
   условный оператор                                      печатать          пустой
  ttTΨ1 = AbsoluteTime[];
          абсолютное значение времени
  TTΨ = ttTΨ1 - ttTΨ0;, {Q, 0, NMAXF}];
Print[
печатать
  "Time needed for the setting of the solutions of the Dirac equation,(s)=", 4 TTΨ];
Print["The execution time of the setting of the initial conditions
печатать
    for the Dirac equation, the solving of this equation and
    the setting of the solutions of the Dirac equation,(s)=",
  3 Tg1 (bMAX + 1) (aMAX + 1) (NMAXF + 1) + 3 (Tm80 - Tm70) + TΨD (NMAXF + 1) + 4 TTΨ];
Table[Ψ2Q,F[r_, θ_, ϕ_, t_] := Evaluate[ψ2Q,F[r, θ, ϕ, t] /. ΨDQ,F], {Q, 0, NMAXF}];
таблица значений              вычислить
Table[Ψ3Q,F[r_, θ_, ϕ_, t_] := Evaluate[ψ3Q,F[r, θ, ϕ, t] /. ΨDQ,F], {Q, 0, NMAXF}];
таблица значений              вычислить
Table[Ψ4Q,F[r_, θ_, ϕ_, t_] := Evaluate[ψ4Q,F[r, θ, ϕ, t] /. ΨDQ,F], {Q, 0, NMAXF}];
таблица значений              вычислить
Tm200 = AbsoluteTime[];
        абсолютное значение времени
Print["Δt100=", Tm200 - Tm190, " ", "F=", F];
печатать
Tm210 = AbsoluteTime[];
        абсолютное значение времени
```

```
Table[ρ1Q,F[r_, θ_, ϕ_, t_] := Ψ1Q,F[r, θ, ϕ, t] Conjugate[Ψ1Q,F[r, θ, ϕ, t]] +
таблица значений                              комплексное сопряжение
    Ψ2Q,F[r, θ, ϕ, t] Conjugate[Ψ2Q,F[r, θ, ϕ, t]] + Ψ3Q,F[r, θ, ϕ, t] Conjugate[
                      комплексное сопряжение                          комплексное сопряжение
      Ψ3Q,F[r, θ, ϕ, t]] + Ψ4Q,F[r, θ, ϕ, t] Conjugate[Ψ4Q,F[r, θ, ϕ, t]], {Q, 0, NMAXF}];
                                            комплексное сопряжение
Print["ρ1Q,F[r,θ,ϕ,t]"];
печатать
Tm220 = AbsoluteTime[];
        абсолютное значение времени
Print["Δt110=", Tm220 - Tm210, " ", "F=", F];
печатать
Tm230 = AbsoluteTime[];
        абсолютное значение времени
Do[lQ2 = lmin + Q2 lP;
оператор цикла
  TMAXQ2 = 2 + Δt[lQ2];
  Do[t11 = 2 + (TMAXQ2 - 2)/(2 MMAX) ll;
  оператор цикла
   Do[If[i == 0 && ll == 0 && Q2 == 0, Print["i=", i];
   ⌊⋯ условный оператор              печатать
      ttIρ0 = AbsoluteTime[];, Null];
              абсолютное значен⋯   пустой
    If[i == p1 && ll == 0 && Q2 == 0, ttIρ1 = AbsoluteTime[];
    условный оператор                 абсолютное значение времени
      TIρ = ttIρ1 - ttIρ0;
      Print["Time for execution of the ll Cycle Do,(s)=",
      печатать                               оператор цикла
        (2 MMAX + 1) TIρ, " ", "Time for execution of the Q2 Cycle Do,(s)=",
                                                                 оператор цикла
        (2 MMAX + 1) (NMAXF + 1) TIρ], Null];
                                       пустой
    AEi,ll,Q2,F = Δli,ll,Q2,F /. NSolve[Integrate[Integrate[ρ1Q2,F[r, θ, ϕ, t11] r^2 Sin[θ],
                                 числе⋯ интегриро⋯ интегрировать                 синус
          {r, rai[lQ2], rai[lQ2] + lQ2 - Δli,ll,Q2,F}], {θ, 0, 2 ArcTan[1/2 × lQ2/(R0i,F[lQ2])]},
                                                              арктангенс
         {ϕ, 0, 2 ArcTan[1/2 × lQ2/(R0i,F[lQ2])]}] == 0.9973, Δli,ll,Q2,F, Reals];, {i, 0, p1}];
                  арктангенс                                          множество действительных чисел
   t11 =., {ll, 0, 2 MMAX}];
  TMAXQ2 =.;
  lQ2 =., {Q2, 0, NMAXF}];
Tm240 = AbsoluteTime[];
        абсолютное значение времени
Print["Δt120=", Tm240 - Tm230, " ", "F=", F];
печатать
Print["Note! The execution time of the setting of the initial conditions for
печатать
```

```
печатать
    the Dirac equation, the solving of this equation, the setting of the
    solutions of the Dirac equation, the setting of the probability density
    and the solving of the algebraic equations relatively the effect,(s)=",
  3 Tg1 (bMAX + 1) (aMAX + 1) (NMAX_F + 1) + 3 (Tm_80 - Tm_70) + TΨD (NMAX_F + 1) +
   4 TTΨ + Tm_220 - Tm_210 + (2 MMAX + 1) (NMAX_F + 1) TIρ];
Tm_250 = AbsoluteTime[];
         абсолютное значение времени
Table[AAE_i2,F = Interpolation[Flatten[Table[{{lmin + QQ2 lP, ll1}, AE_i2,ll1,QQ2,F},
таблица значений интерполировать уплостить таблица значений
      {ll1, 0, 2 MMAX}, {QQ2, 0, NMAX_F}], 1], InterpolationOrder → 5];, {i2, 0, p1}];
                                               порядок интерполяции
Print["AAE_iv,F[l,llv]"];
печатать
Tm_260 = AbsoluteTime[];
         абсолютное значение времени
Print["Δt_130=", Tm_260 - Tm_250, " ", "F=", F];
печатать
Print["Note! The execution time of the setting of the initial conditions for the
печатать
    Dirac equation, the solving of this equation, the setting of the solutions of
    the Dirac equation, setting the probability density, the solving the algebraic
    equations relatively the effect and advance setting of the effect,(s)=",
  3 Tg1 (bMAX + 1) (aMAX + 1) (NMAX_F + 1) + 3 (Tm_80 - Tm_70) + TΨD (NMAX_F + 1) +
   4 TTΨ + Tm_220 - Tm_210 + (2 MMAX + 1) (NMAX_F + 1) TIρ + Tm_260 - Tm_250];
Tm_270 = AbsoluteTime[];
         абсолютное значение времени
Table[Δl_iv,F[l_, llv_] = AAE_iv,F[l, llv];
таблица значений
  If[(iv == j_0 || iv == j_1 || iv == j_2 || iv == j_3 || iv == j_4 || iv == j_5 || iv == j_6 || iv == j_7 ||
  условный оператор
     iv == j_8 || iv == j_9 || iv == j_10), Print["iv=", iv], Null];, {iv, 0, p1}];
                                            печатать         пустой
Print["Δl_iv,F[l, 2 (t - 2) MMAX / Δt[l] ]"];
печатать

Tm_280 = AbsoluteTime[];
         абсолютное значение времени
Print["Δt_140=", Tm_280 - Tm_270, " ", "F=", F];
печатать
Print["Note! The execution time of the setting of the initial conditions for
печатать
    the Dirac equation, the solving of this equation, the setting of the
    solutions of the Dirac equation, setting the probability density,
    the solving the algebraic equations relatively the effect, advance
    setting of the effect and the setting of the expected effect,(s)=",
  3 Tg1 (bMAX + 1) (aMAX + 1) (NMAX_F + 1) + 3 (Tm_80 - Tm_70) + TΨD (NMAX_F + 1) + 4 TTΨ +
   Tm_220 - Tm_210 + (2 MMAX + 1) (NMAX_F + 1) TIρ + Tm_260 - Tm_250 + Tm_280 - Tm_270];
lmax_F =.;
Tm_290 = AbsoluteTime[];
         абсолютное значение времени
lmax_F+1 =
```

```
 l /. Flatten[NMaximize[l, Reduce[rmin ≥ 1/2 Abs[l - Δl0,F[l, 2 MMAX]], l, Reals], l]][[2]];
     уплостить численная ма⋯ привести       абсолютное значение               множество действительн

Tm300 = AbsoluteTime[];
        абсолютное значение времени
Print["Δt150=", Tm300 - Tm290, " ", "F=", F];
печатать
Print["Note! The execution time of the setting of the initial conditions for the
печатать
   Dirac equation, the solving of this equation, the setting of the solutions of
   the Dirac equation, setting the probability density, the solving the algebraic
   equations relatively the effect, advance setting of the effect, the setting of
   the expected effect and the finding of the maximal scale for the task,(s)=",
 3 Tg1 (bMAX + 1) (aMAX + 1) (NMAXF + 1) + 3 (Tm80 - Tm70) + TΨD (NMAXF + 1) + 4 TTΨ +
  Tm220 - Tm210 + (2 MMAX + 1) (NMAXF + 1) TIρ + Tm260 - Tm250 + Tm280 - Tm270 + Tm300 - Tm290];
NMAXF+1 = (lmaxF+1 - lmin)/lP;
Print["ΔtGeneralTime0=", Tm300 - Tm10, " ", "F=", F];]
печатать

Block[{VU = 3.6 × 10^80, VA = 1.4625 × 10^-32 × 4/3 π,
программный блок

 e = 1.6021773349 × 10^-19, n0 = 0, Θ = π/20,
Φ = 2 π/20, aMAX = 20,
bMAX = 20,
gMAX = 20, ρ0 = 10^-20,
Angl00 = π/10^15}, Do[If[i == 0, j0 = 1;, Null];
                    ⋯  условный оператор  пустой

 If[i ≥ 1 && i ≤ 10, ji = 928 i;, Null], {i, 0, 10}];
 условный оператор                 пустой
For[F = 1, IntegerPart[NMAXF - NMAXF-1] > 0 || IntegerPart[NMAXF - NMAXF-1] < 0,
цикл ДЛЯ  целая часть                          целая часть

 F++, Tm11 = AbsoluteTime[];
             абсолютное значение времени
 Table[r20,x1,F-1 =.;
 таблица значений
  r20,x1,F = rmin;, {x1, 0, NMAXF}];
 Table[ra0,x1,F-1 =.;
 таблица значений
  ra0,x1,F = rmin;, {x1, 0, NMAXF}];
 For[s1 = 0, ras1,n0,F ≤ rmax, s1++,
 цикл ДЛЯ
  If[s1 == 0, Print["s1=", 0, " ", "ras1,n0,F=", N[rmin]], Null];
  условный ⋯ печатать                      численно⋯ пустой
  Do[lx1 = lmin + x1 lP;
  оператор цикла
   r2s1+1,x1,F-1 =.;
   r2s1+1,x1,F = r2s1,x1,F + lx1;
```

```
  ra_{s1+1,x1,F-1} =.;
  ra_{s1+1,x1,F} = r2_{s1+1,x1,F};
  r2_{s1,x1,F} =.;
  l_{x1} =., {x1, 0, NMAX_F}];
 If[s1 > 0 && (s1 == j_0 || s1 == j_1 || s1 == j_2 || s1 == j_3 ||
 условный оператор
     s1 == j_4 || s1 == j_5 || s1 == j_6 || s1 == j_7 || s1 == j_8 || s1 == j_9 || s1 == j_10),
  Print["s1=", s1, " ", "ra_{s1,n0,F}=", ra_{s1,n0,F}], Null]];
  печатать                                          пустой
Tm_21 = AbsoluteTime[];
        абсолютное значение времени
Print["Δt_11=", Tm_21 - Tm_11, " ", "F=", F];
печатать
p1 = s1 - 1;
Tm_31 = AbsoluteTime[];
        абсолютное значение времени
Table[ra_{k5,F-1} =.;, {k5, 1, p1}];
таблица значений
Table[ra_{k5,F} = Interpolation[Table[{{lmin + x11 lP}, ra_{k5,x11,F}}, {x11, 0, NMAX_F}],
таблица значе··· интерполировать таблица значений
     InterpolationOrder → 5];, {k5, 0, p1}];
     порядок интерполяции
Print["ra_{k5,F}[l]"];
печатать
Tm_41 = AbsoluteTime[];
        абсолютное значение времени
Print["Δt_21=", Tm_41 - Tm_31, " ", "F=", F];
печатать
t = 2;
Table[N1_{y0,F-1}[l_] =.;
таблица значений
 If[(y0 == j_0 || y0 == j_1 || y0 == j_2 || y0 == j_3 || y0 == j_4 || y0 == j_5 || y0 == j_6 || y0 == j_7 || y0 ==
 условный оператор
     j_8 || y0 == j_9 || y0 == j_10), Print["y0=", y0, " ", "F=", F], Null];, {y0, 0, p1}];
                                      печатать                            пустой
```

$$\text{Table}\left[N1_{y0,F}[l\_] = \frac{\pi}{\text{ArcTan}\left[\frac{1}{2\sqrt{ra_{y0,F}[l]^2 - \frac{1}{4}\,l^2}}\right]};\right.$$

таблица значений

```
 If[(y0 == j_0 || y0 == j_1 || y0 == j_2 || y0 == j_3 || y0 == j_4 || y0 == j_5 || y0 == j_6 || y0 == j_7 || y0 ==
 условный оператор
     j_8 || y0 == j_9 || y0 == j_10), Print["y0=", y0, " ", "F=", F], Null];, {y0, 0, p1}];
                                      печатать                            пустой
Table[R0_{k0,F-1}[l_] =.;
таблица значений
 If[(k0 == j_0 || k0 == j_1 || k0 == j_2 || k0 == j_3 || k0 == j_4 || k0 == j_5 || k0 == j_6 || k0 == j_7 || k0 ==
 условный оператор
     j_8 || k0 == j_9 || k0 == j_10), Print["k0=", k0, " ", "F=", F], Null];, {k0, 0, p1}];
                                      печатать                            пустой
```

$$\text{Table}\left[R0_{k0,F}[l\_] = ra_{k0,F}[l] + \frac{1}{2}\,l;\right.$$

таблица значений

```
If[(k0 == j0 || k0 == j1 || k0 == j2 || k0 == j3 || k0 == j4 || k0 == j5 || k0 == j6 || k0 == j7 || k0 ==
условный оператор
    j8 || k0 == j9 || k0 == j10), Print["k0=", k0, " ", "F=", F], Null];, {k0, 0, p1}];
                                  печатать                             пустой

Tm51 = AbsoluteTime[];
       абсолютное значение времени
Do[lf1 = lmin + lP f1;
оператор цикла

 Do[ra1,f1 = a1 ρ[lf1];
 оператор цикла

  Do[θb1 = b1 Θ;
  оператор цикла

   Do[ϕg1 = g1 Φ;
   оператор цикла

    If[a1 == 0 && b1 == 0 && g1 == 0 && f1 == 0,
    условный оператор
     Print["a1=b1=g1=", a1, " ", "f1=", f1, " ", "F=", F], Null];
     печатать                                            пустой
    If[a1 == 0 && b1 == 0 && g1 == 0 && f1 == 0, tt0,F = AbsoluteTime[];, Null];
    условный оператор                               абсолютное значен···  пустой
    If[a1 == 0 && b1 == 0 && f1 == 0 && g1 == gMAX, ttgMAX,F = AbsoluteTime[];
    условный оператор                                   абсолютное значение времени
     Tg1FF = ttgMAX,F - tt0,F;
     Print["The execution time of the all Cycles Do, (s) =", Tg1FF (bMAX + 1)
     печатать                            циклы   оператор цикла
       (aMAX + 1) (NMAXF + 1), " ", "The execution time of the a1 Cycle Do, (s) =",
                                                                   оператор цикла
      Tg1FF (bMAX + 1) (aMAX + 1), " ", "The execution time of the Θ Cycle Do, (s) =",
                                                                      оператор цикла
      Tg1FF (bMAX + 1), " ", "F=", F], Null];
                                       пустой
    If[a1 == aMAX && b1 == bMAX && g1 == gMAX && f1 == NMAXF,
    условный оператор
     Print["a1=", a1, " ", "b1=", b1, " ", "g1=", g1, " ", "f1=",
     печатать
      f1, " ", "This module is finished!", " ", "F=", F], Null];
                                                        пустой
    c11a1,b1,g1,f1,F-1 =.;
```

$$c11_{a1,b1,g1,f1,F} = \frac{1}{\pi^{3/4}}\left(\frac{d[l_{f1}]}{\hbar}\right)^{3/2} \text{NIntegrate}\Big[$$

квадратурное интегрирование

$$e^{\frac{i}{\hbar}(px\, r_{a1,f1}\, \text{Sin}[\theta_{b1}]\, \text{Cos}[\phi_{g1}] + py\, r_{a1,f1}\, \text{Sin}[\theta_{b1}]\, \text{Sin}[\phi_{g1}] + pz\, r_{a1,f1}\, \text{Cos}[\theta_{b1}])}\, \text{MID1}[px, py, pz, t, l_{f1}] \times \frac{1}{(2\pi\hbar)^{3/2}}, \{px, -\infty, \infty\}, \{py, -\infty, \infty\}, \{pz, -\infty, \infty\}, \text{AccuracyGoal} \to 10\Big];$$

требуемая абсол. точность

```
   ϕg1 =., {g1, 0, gMAX}];
  θb1 =., {b1, 0, bMAX}];
 ra1,f1 =., {a1, 0, aMAX}];
```

```
 l_f1 =.;, {f1, 0, NMAX_F}];
Tm61 = AbsoluteTime[];
        абсолютное значение времени
Print["Δt31=", Tm61 - Tm51, " ", "F=", F];
печатать
Print[
печатать
 "The execution time of the all modules, setting the initial conditions for the
   Dirac equation,(s)=", 3 Tg1F_F (bMAX + 1) (aMAX + 1) (NMAX_F + 1), " ", "F=", F];
Tm71 = AbsoluteTime[];
        абсолютное значение времени
c1_F-1 =.;
c1_F = Interpolation[
        интерполировать
  Flatten[Table[{{aa1, bb1 Θ, gg1 Φ, lmin + f11 lP}, c11_aa1,bb1,gg1,f11,F}, {aa1, 0, aMAX},
  уплостить таблица значений
    {bb1, 0, bMAX}, {gg1, 0, gMAX}, {f11, 0, NMAX_F}], 3], InterpolationOrder → 5];
                                                        порядок интерполяции
Print["c1_F[r/ρ[l],θ,ϕ,l]"];
печатать

Tm81 = AbsoluteTime[];
        абсолютное значение времени
Print["Δt41=", Tm81 - Tm71, " ", "F=", F];
печатать
Print["Time Δt of setting the all interpolation functions for the all initial
печатать
   conditions for the Dirac equation,(s)=", 3 (Tm81 - Tm71), " ", "F=", F];
Print["The execution time of the setting of the initial
печатать
   conditions for the Dirac equation,(s)=",
 3 Tg1F_F (bMAX + 1) (aMAX + 1) (NMAX_F + 1) + 3 (Tm81 - Tm71), " ", "F=", F];
Tm91 = AbsoluteTime[];
        абсолютное значение времени
Do[l_f2 = lmin + lP f2;
оператор цикла

 Do[r_a2,f2 = a2 ρ[l_f2];
 оператор цикла

  Do[θ_b2 = b2 Θ;
  оператор цикла

   Do[ϕ_g2 = g2 Φ;
   оператор цикла

    If[a2 == 0 && b2 == 0 && g2 == 0 && f2 == 0, Print["a2=b2=g2=", a2, " ",
    условный оператор                              печатать
      "f2=", f2, " ", "The execution time of the all Cycles Do,(s)=",
                                                     циклы   оператор цикла
      Tg1F_F (bMAX + 1) (aMAX + 1) (NMAX_F + 1), " ", "F=", F], Null];
                                                               пустой
    If[a2 == aMAX && b2 == bMAX && g2 == gMAX && f2 == NMAX_F,
    условный оператор
     Print["a2=", a2, " ", "b2=", b2, " ", "g2=", g2, " ", "f2=",
     печатать
```

```
печатать
    f2, " ", "This module is finished!", " ", "F=", F], Null];
                                                  пустой
  c33a2,b2,g2,f2,F-1 =.;
  c33a2,b2,g2,f2,F = -ⅈ 1/π^(3/4) (d[lf2]/ℏ)^(3/2) NIntegrate[
                                                   квадратурное интегрирование
    ⅇ^(ⅈ/ℏ (px ra2,f2 Sin[θb2] Cos[ϕg2] + py ra2,f2 Sin[θb2] Sin[ϕg2] + pz ra2,f2 Cos[θb2])) MID2[px, py, pz, t, lf2] ×
    1/(2 π ℏ)^(3/2), {px, -∞, ∞}, {py, -∞, ∞}, {pz, -∞, ∞}, AccuracyGoal → 10];
                                                           требуемая абсол. точность
  ϕg2 =., {g2, 0, gMAX}];
  θb2 =., {b2, 0, bMAX}];
  ra2,f2 =., {a2, 0, aMAX}];
  lf2 =.;, {f2, 0, NMAXF}];
Tm101 = AbsoluteTime[];
      абсолютное значение времени
Print["Δt51=", Tm101 - Tm91, " ", "F=", F];
печатать
Tm111 = AbsoluteTime[];
      абсолютное значение времени
c3F-1 =.;
c3F = Interpolation[
    интерполировать
  Flatten[Table[{{aa2, bb2 Θ, gg2 Φ, lmin + f22 lP}, c33aa2,bb2,gg2,f22,F}, {aa2, 0, aMAX},
  уплостить таблица значений
    {bb2, 0, bMAX}, {gg2, 0, gMAX}, {f22, 0, NMAXF}], 3], InterpolationOrder → 5];
                                                       порядок интерполяции
Print["c3F[r/ρ[l],θ,ϕ,l]"];
печатать
Tm121 = AbsoluteTime[];
      абсолютное значение времени
Print["Δt61=", Tm121 - Tm111, " ", "F=", F];
печатать
Tm131 = AbsoluteTime[];
      абсолютное значение времени
Do[lf3 = lmin + lP f3;
оператор цикла
 Do[ra3,f3 = a3 ρ[lf3];
 оператор цикла
  Do[θb3 = b3 Θ;
  оператор цикла
   Do[ϕg3 = g3 Φ;
   оператор цикла
    If[a3 == 0 && b3 == 0 && g3 == 0 && f3 == 0, Print["a3=b3=g3=", a3, " ",
    условный оператор                         печатать
      "f3=", f3, " ", "The execution time of the all Cycles Do,(s)=",
                                                  циклы  оператор цикла
```

```
циклы    оператор цикла
    Tg1F_F (bMAX + 1) (aMAX + 1) (NMAX_F + 1), " ", "F=", F], Null];
                                                        пустой
   If[a3 == aMAX && b3 == bMAX && g3 == gMAX && f3 == NMAX_F,
   условный оператор
    Print["a3=", a3, " ", "b3=", b3, " ", "g3=", g3, " ", "f3=",
    печатать
     f3, " ", "This module is finished!", " ", "F=", F], Null];
                                                        пустой
   c44_{a3,b3,g3,f3,F-1} =.;
```

$$c44_{a3,b3,g3,f3,F} = \frac{1}{\pi^{3/4}} \left(\frac{d[l_{f3}]}{\hbar}\right)^{3/2} \text{NIntegrate}\Big[$$

квадратурное интегрирование

$$e^{\frac{i}{\hbar}(px\, r_{a3,f3} \text{Sin}[\theta_{b3}] \text{Cos}[\phi_{g3}] + py\, r_{a3,f3} \text{Sin}[\theta_{b3}] \text{Sin}[\phi_{g3}] + pz\, r_{a3,f3} \text{Cos}[\theta_{b3}])} \text{MID3}[px, py, pz, t, l_{f3}] \times \frac{1}{(2\pi\hbar)^{3/2}}, \{px, -\infty, \infty\}, \{py, -\infty, \infty\}, \{pz, -\infty, \infty\}, \text{AccuracyGoal} \to 10\Big];$$

требуемая абсол. точность

```
   ϕ_g3 =., {g3, 0, gMAX}];
  θ_b3 =., {b3, 0, bMAX}];
 r_{a3,f3} =., {a3, 0, aMAX}];
l_f3 =.;, {f3, 0, NMAX_F}];
Tm_141 = AbsoluteTime[];
        абсолютное значение времени
Print["Δt_71=", Tm_141 - Tm_131, " ", "F=", F];
печатать
Tm_151 = AbsoluteTime[];
        абсолютное значение времени
c4_{F-1} =.;
c4_F = Interpolation[
      интерполировать
  Flatten[Table[{{aa3, bb3 Θ, gg3 Φ, lmin + f33 lP}, c44_{aa3,bb3,gg3,f33,F}}, {aa3, 0, aMAX},
  уплостить таблица значений
    {bb3, 0, bMAX}, {gg3, 0, gMAX}, {f33, 0, NMAX_F}], 3], InterpolationOrder → 5];
                                                  порядок интерполяции
```

$$\text{Print}\Big[\text{"c4}_F\Big[\frac{r}{\rho[l]}, \theta, \phi, l]\text{"}\Big];$$

печатать

```
Tm_161 = AbsoluteTime[];
        абсолютное значение времени
Print["Δt_81=", Tm_161 - Tm_151, " ", "F=", F];
печатать
t =.;
Tm_171 = AbsoluteTime[];
        абсолютное значение времени
Do[ttΨDF_{0,F} = AbsoluteTime[];
оператор цикла  абсолютное значение времени
 l_Q = lmin + Q lP;
 ΨD_{Q,F-1} =.;
 ΨD_{Q,F} = NDSolve[{i ℏ ∂_t ψ1_{Q,F}[r, θ, ϕ, t] ==
           численно решить ДУ
```

$$-i\hbar c\left(\left(\underset{\text{синус}}{\mathrm{Sin}[\theta]}\ \underset{\text{косинус}}{\mathrm{Cos}[\phi]}\ \partial_r\psi4_{Q,F}[r,\theta,\phi,t]+\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\ \underset{\text{косинус}}{\mathrm{Cos}[\phi]}\ \frac{1}{r}\ \partial_\theta\psi4_{Q,F}[r,\theta,\phi,t]-\right.\right.$$

$$\left.\frac{\mathrm{Sin}[\phi]}{r\,\mathrm{Sin}[\theta]}\ \partial_\phi\psi4_{Q,F}[r,\theta,\phi,t]\right)-i\times\left(\underset{\text{синус}}{\mathrm{Sin}[\theta]}\ \underset{\text{синус}}{\mathrm{Sin}[\phi]}\ \partial_r\psi4_{Q,F}[r,\theta,\phi,t]+\right.$$

$$\left.\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\ \underset{\text{синус}}{\mathrm{Sin}[\phi]}\ \frac{1}{r}\ \partial_\theta\psi4_{Q,F}[r,\theta,\phi,t]+\frac{\mathrm{Cos}[\phi]}{r\,\mathrm{Sin}[\theta]}\ \partial_\phi\psi4_{Q,F}[r,\theta,\phi,t]\right)+$$

$$\left.\left(\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\ \partial_r\psi3_{Q,F}[r,\theta,\phi,t]-\underset{\text{синус}}{\mathrm{Sin}[\theta]}\ \frac{1}{r}\ \partial_\theta\psi3_{Q,F}[r,\theta,\phi,t]\right)\right)+$$

$$\mathrm{m0}\ c^2\ \psi1_{Q,F}[r,\theta,\phi,t]+e\ \psi1_{Q,F}[r,\theta,\phi,t]\ \mathrm{A0I}[r,t,Q],\ i\hbar\ \partial_t\psi2_{Q,F}[r,\theta,\phi,t]==$$

$$-i\hbar c\left(\left(\underset{\text{синус}}{\mathrm{Sin}[\theta]}\ \underset{\text{косинус}}{\mathrm{Cos}[\phi]}\ \partial_r\psi3_{Q,F}[r,\theta,\phi,t]+\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\ \underset{\text{косинус}}{\mathrm{Cos}[\phi]}\ \frac{1}{r}\ \partial_\theta\psi3_{Q,F}[r,\theta,\phi,t]-\right.\right.$$

$$\left.\frac{\mathrm{Sin}[\phi]}{r\,\mathrm{Sin}[\theta]}\ \partial_\phi\psi3_{Q,F}[r,\theta,\phi,t]\right)+i\times\left(\underset{\text{синус}}{\mathrm{Sin}[\theta]}\ \underset{\text{синус}}{\mathrm{Sin}[\phi]}\ \partial_r\psi3_{Q,F}[r,\theta,\phi,t]+\right.$$

$$\left.\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\ \underset{\text{синус}}{\mathrm{Sin}[\phi]}\ \frac{1}{r}\ \partial_\theta\psi3_{Q,F}[r,\theta,\phi,t]+\frac{\mathrm{Cos}[\phi]}{r\,\mathrm{Sin}[\theta]}\ \partial_\phi\psi3_{Q,F}[r,\theta,\phi,t]\right)-$$

$$\left.\left(\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\ \partial_r\psi4_{Q,F}[r,\theta,\phi,t]-\underset{\text{синус}}{\mathrm{Sin}[\theta]}\ \frac{1}{r}\ \partial_\theta\psi4_{Q,F}[r,\theta,\phi,t]\right)\right)+$$

$$\mathrm{m0}\ c^2\ \psi2_{Q,F}[r,\theta,\phi,t]+e\ \psi2_{Q,F}[r,\theta,\phi,t]\ \mathrm{A0I}[r,t,Q],\ i\hbar\ \partial_t\psi3_{Q,F}[r,\theta,\phi,t]==$$

$$-i\hbar c\left(\left(\underset{\text{синус}}{\mathrm{Sin}[\theta]}\ \underset{\text{косинус}}{\mathrm{Cos}[\phi]}\ \partial_r\psi2_{Q,F}[r,\theta,\phi,t]+\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\ \underset{\text{косинус}}{\mathrm{Cos}[\phi]}\ \frac{1}{r}\ \partial_\theta\psi2_{Q,F}[r,\theta,\phi,t]-\right.\right.$$

$$\left.\frac{\mathrm{Sin}[\phi]}{r\,\mathrm{Sin}[\theta]}\ \partial_\phi\psi2_{Q,F}[r,\theta,\phi,t]\right)-i\times\left(\underset{\text{синус}}{\mathrm{Sin}[\theta]}\ \underset{\text{синус}}{\mathrm{Sin}[\phi]}\ \partial_r\psi2_{Q,F}[r,\theta,\phi,t]+\right.$$

$$\left.\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\ \underset{\text{синус}}{\mathrm{Sin}[\phi]}\ \frac{1}{r}\ \partial_\theta\psi2_{Q,F}[r,\theta,\phi,t]+\frac{\mathrm{Cos}[\phi]}{r\,\mathrm{Sin}[\theta]}\ \partial_\phi\psi2_{Q,F}[r,\theta,\phi,t]\right)+$$

$$\left.\left(\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\ \partial_r\psi1_{Q,F}[r,\theta,\phi,t]-\underset{\text{синус}}{\mathrm{Sin}[\theta]}\ \frac{1}{r}\ \partial_\theta\psi1_{Q,F}[r,\theta,\phi,t]\right)\right)-$$

$$\mathrm{m0}\ c^2\ \psi3_{Q,F}[r,\theta,\phi,t]+e\ \psi3_{Q,F}[r,\theta,\phi,t]\ \mathrm{A0I}[r,t,Q],\ i\hbar\ \partial_t\psi4_{Q,F}[r,\theta,\phi,t]==$$

$$-i\hbar c\left(\left(\underset{\text{синус}}{\mathrm{Sin}[\theta]}\ \underset{\text{косинус}}{\mathrm{Cos}[\phi]}\ \partial_r\psi1_{Q,F}[r,\theta,\phi,t]+\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\ \underset{\text{косинус}}{\mathrm{Cos}[\phi]}\ \frac{1}{r}\ \partial_\theta\psi1_{Q,F}[r,\theta,\phi,t]-\right.\right.$$

$$\left.\frac{\mathrm{Sin}[\phi]}{r\,\mathrm{Sin}[\theta]}\ \partial_\phi\psi1_{Q,F}[r,\theta,\phi,t]\right)+i\times\left(\underset{\text{синус}}{\mathrm{Sin}[\theta]}\ \underset{\text{синус}}{\mathrm{Sin}[\phi]}\ \partial_r\psi1_{Q,F}[r,\theta,\phi,t]+\right.$$

$$\left.\underset{\text{косинус}}{\mathrm{Cos}[\theta]}\ \underset{\text{синус}}{\mathrm{Sin}[\phi]}\ \frac{1}{r}\ \partial_\theta\psi1_{Q,F}[r,\theta,\phi,t]+\frac{\mathrm{Cos}[\phi]}{r\,\mathrm{Sin}[\theta]}\ \partial_\phi\psi1_{Q,F}[r,\theta,\phi,t]\right)-$$

```
      (Cos[θ] ∂r ψ2Q,F[r, θ, ϕ, t] - Sin[θ] (1/r) ∂θ ψ2Q,F[r, θ, ϕ, t])) -
       косинус                        синус
     m0 c^2 ψ4Q,F[r, θ, ϕ, t] + e ψ4Q,F[r, θ, ϕ, t] A0I[r, t, Q],
    ψ1Q,F[r, θ, ϕ, 2] == c1F[r/ρ[1Q], θ, ϕ, 1Q], ψ2Q,F[r, θ, ϕ, 2] == 0,
    ψ3Q,F[r, θ, ϕ, 2] == c3F[r/ρ[1Q], θ, ϕ, 1Q], ψ4Q,F[r, θ, ϕ, 2] == c4F[r/ρ[1Q], θ, ϕ, 1Q]},
   {ψ1Q,F[r, θ, ϕ, t], ψ2Q,F[r, θ, ϕ, t], ψ3Q,F[r, θ, ϕ, t], ψ4Q,F[r, θ, ϕ, t]},
   {r, ρ0, 20 ρ[1Q]}, {θ, Angl θ0, π}, {ϕ, 0, 2 π}, {t, 2, 2 + Δt[1Q]}];
  ttΨDF1,F = AbsoluteTime[];
             абсолютное значение времени
  TΨDFF = ttΨDF1,F - ttΨDF0,F;
  If[Q == 0, Print["Time of the solving the all Dirac equations,(s)=",
  условный… печатать
    TΨDFF (NMAXF + 1), " ", "F=", F], Null];, {Q, 0, NMAXF}];
                                      пустой
Tm181 = AbsoluteTime[];
        абсолютное значение времени
Print["Δt91=", Tm181 - Tm171, " ", "F=", F];
печатать
Print["The execution time of the setting of the initial conditions for the Dirac
печатать
   equation and the solving of this equation(s)=", 3 Tg1FF (bMAX + 1)
   (aMAX + 1) (NMAXF + 1) + 3 (Tm81 - Tm71) + TΨDFF (NMAXF + 1), " ", "F=", F];
Tm191 = AbsoluteTime[];
        абсолютное значение времени
Table[ttTΨFd0,F = AbsoluteTime[];
таблица значений  абсолютное значение времени
  Ψ1Q,F-1[r_, θ_, ϕ_, t_] =.;
  If[Q == 0, Print["Q=", Q, " ", "F=", F],
  условный… печатать
   If[Q == f1 || Q == f2 || Q == f3 || Q == f4 || Q == f5, Print["Q=", Q, " ", "F=", F], Null]];
   условный оператор                                  печатать                     пустой
  ttTΨFd1,F = AbsoluteTime[];
              абсолютное значение времени
  TTΨFdF = ttTΨFd1,F - ttTΨFd0,F;, {Q, 0, NMAXF-1}];
Print["Time needed for the unsetting of the F-1
печатать
   solutions of the Dirac equation,(s)=", 4 TTΨFdF, " ", "F=", F];
Print["The execution time of the setting of the initial conditions for the
печатать
   Dirac equation, the solving of this equation and the unsetting of the F-1
   solutions of the Dirac equation,(s)=", 3 Tg1FF (bMAX + 1) (aMAX + 1) (NMAXF + 1) +
  3 (Tm81 - Tm71) + TΨDFF (NMAXF + 1) + 4 TTΨFdF, " ", "F=", F];
Table[Ψ2Q,F-1[r_, θ_, ϕ_, t_] =.;, {Q, 0, NMAXF-1}];
таблица значений
Table[Ψ3Q,F-1[r_, θ_, ϕ_, t_] =.;, {Q, 0, NMAXF-1}];
таблица значений
Table[Ψ4Q,F-1[r_, θ_, ϕ_, t_] =.;, {Q, 0, NMAXF-1}];
таблица значений
```

```
таблица значений
Tm_{201} = AbsoluteTime[];
           абсолютное значение времени
Print["Δt_{101}=", Tm_{201} - Tm_{191}, " ", "F=", F];
печатать
Tm_{211} = AbsoluteTime[];
           абсолютное значение времени
Table[ttTΨF_{0,F} = AbsoluteTime[];
таблица значений  абсолютное значение времени
 Ψ1_{Q,F}[r_, θ_, ϕ_, t_] := Evaluate[ψ1_{Q,F}[r, θ, ϕ, t] /. ΨD_{Q,F}];
                            вычислить
 If[Q == 0, Print["Q=", Q, " ", "F=", F],
 условный··· печатать
  If[Q == f_1 || Q == f_2 || Q == f_3 || Q == f_4 || Q == f_5, Print["Q=", Q, " ", "F=", F], Null]];
  условный оператор                                          печатать                     пустой
 ttTΨF_{1,F} = AbsoluteTime[];
               абсолютное значение времени
 TTΨF_F = ttTΨF_{1,F} - ttTΨF_{0,F};, {Q, 0, NMAX_F}];
Print["Time needed for the setting of the solutions of the Dirac equation,(s)=",
печатать
 4 TTΨF_F, " ", "F=", F];
Print["The execution time of the setting of the initial conditions for the
печатать
   Dirac equation, the solving of this equation and the unsetting of the
   F-1 solutions of the Dirac equation with the setting of the solutions
   of the Dirac equation,(s)=", 3 Tg1F_F (bMAX + 1) (aMAX + 1) (NMAX_F + 1) +
  3 (Tm_{81} - Tm_{71}) + TΨDF_F (NMAX_F + 1) + 4 TTΨFd_F + 4 TTΨF_F, " ", "F=", F];
Table[Ψ2_{Q,F}[r_, θ_, ϕ_, t_] := Evaluate[ψ2_{Q,F}[r, θ, ϕ, t] /. ΨD_{Q,F}], {Q, 0, NMAX_F}];
таблица значений                  вычислить
Table[Ψ3_{Q,F}[r_, θ_, ϕ_, t_] := Evaluate[ψ3_{Q,F}[r, θ, ϕ, t] /. ΨD_{Q,F}], {Q, 0, NMAX_F}];
таблица значений                  вычислить
Table[Ψ4_{Q,F}[r_, θ_, ϕ_, t_] := Evaluate[ψ4_{Q,F}[r, θ, ϕ, t] /. ΨD_{Q,F}], {Q, 0, NMAX_F}];
таблица значений                  вычислить
Tm_{221} = AbsoluteTime[];
           абсолютное значение времени
Print["Δt_{111}=", Tm_{221} - Tm_{211}, " ", "F=", F];
печатать
Tm_{231} = AbsoluteTime[];
           абсолютное значение времени
Table[ρ1_{Q,F-1} =.;, {Q, 0, NMAX_{F-1}}, {v, 0, p1}];
таблица значений
Table[ρ1_{Q,F}[r_, θ_, ϕ_, t_] := Ψ1_{Q,F}[r, θ, ϕ, t] Conjugate[Ψ1_{Q,F}[r, θ, ϕ, t]] +
таблица значений                                        комплексное сопряжение
   Ψ2_{Q,F}[r, θ, ϕ, t] Conjugate[Ψ2_{Q,F}[r, θ, ϕ, t]] + Ψ3_{Q,F}[r, θ, ϕ, t] Conjugate[
                        комплексное сопряжение                                 комплексное сопряжение
     Ψ3_{Q,F}[r, θ, ϕ, t]] + Ψ4_{Q,F}[r, θ, ϕ, t] Conjugate[Ψ4_{Q,F}[r, θ, ϕ, t]], {Q, 0, NMAX_F}];
                                                  комплексное сопряжение
Print["ρ1_{Q,F}[r,θ,ϕ,t]"];
печатать
Tm_{241} = AbsoluteTime[];
           абсолютное значение времени
Print["Δt_{121}=", Tm_{241} - Tm_{231}, " ", "F=", F];
печатать
```

```
Tm251 = AbsoluteTime[];
        абсолютное значение времени
Do[lQ2 = lmin + Q2 lP;
оператор цикла
 TMAXQ2 = 2 + Δt[lQ2];
               TMAXQ2 - 2
 Do[t11 = 2 + ────────── 11;
 оператор цикла  2 MMAX

  Do[If[i == 0 && 11 == 0 && Q2 == 0, Print["i=", i];
  … условный оператор         печатать

    ttIρF0,F = AbsoluteTime[];, Null];
               абсолютное значен… пустой
   If[i == p1 && 11 == 0 && Q2 == 0, ttIρF1,F = AbsoluteTime[];
   условный оператор                 абсолютное значение времени
    TIρFF = ttIρF1,F - ttIρF0,F;
    Print["Time for execution of the 11 Cycle Do, (s) =",
    печатать                        оператор цикла
     (2 MMAX + 1) TIρFF, " ", "Time for execution of the Q2 Cycle Do, (s) =",
                                                       оператор цикла
     (2 MMAX + 1) (NMAXF + 1) TIρFF, " ", "F=", F], Null];
                                                   пустой
   AEi,11,Q2,F-1 =.;
   AEi,11,Q2,F = Δli,11,Q2,F /. NSolve[Integrate[Integrate[ρ1Q2,F[r, θ, ϕ, t11] r^2 Sin[θ],
                                 численн… интегриро… интегрировать          синус
      {r, rai[lQ2], rai[lQ2] + lQ2 - Δli,11,Q2,F}], {θ, 0, 2 ArcTan[1/2 × lQ2/(Rθi,F[lQ2])]},
                                                        арктангенс
     {ϕ, 0, 2 ArcTan[1/2 × lQ2/(Rθi,F[lQ2])]}] == 0.9973, Δli,11,Q2,F, Reals];, {i, 0, p1}];
              арктангенс                                   множество действительных чисел

  t11 =., {11, 0, 2 MMAX}];
 TMAXQ2 =.;
 lQ2 =., {Q2, 0, NMAXF}];
Tm261 = AbsoluteTime[];
        абсолютное значение времени
Print["Δt131=", Tm261 - Tm251, " ", "F=", F];
печатать
Print["Note! The execution time of the setting of the initial conditions for the
печатать
   Dirac equation, the solving of this equation, the unsetting of the
   F-1 solutions of the Dirac equations, the setting of the solutions
   of the Dirac equation, the unsetting of the F-1 probability density
   with the setting of the probability density and the unsetting of the
   F-1 solutions of the algebraic equations relatively the effect with
   the solving of the algebraic equations relatively the effect, (s) =",
 3 Tg1FF (bMAX + 1) (aMAX + 1) (NMAXF + 1) + 3 (Tm81 - Tm71) + TΨDFF (NMAXF + 1) +
  4 TΨFdF + 4 TΨFF + Tm241 - Tm231 + (2 MMAX + 1) (NMAXF + 1) TIρFF, " ", "F=", F];
Tm271 = AbsoluteTime[];
        абсолютное значение времени
```

```
Table[AAE_{i2,F-1} =.;, {i2, 0, p1}];
Table[AAE_{i2,F} = Interpolation[Flatten[Table[{{lmin + QQ2 lP, ll1}, AE_{i2,ll1,QQ2,F}},
      {ll1, 0, 2 MMAX}, {QQ2, 0, NMAX_F}], 1], InterpolationOrder → 5];, {i2, 0, p1}];
Print["AAE_{iv,F}[l,llv]"];
Tm_281 = AbsoluteTime[];
Print["Δt_141=", Tm_281 - Tm_271, " ", "F=", F];
Print["Note! The execution time of the setting of the initial conditions for the
   Dirac equation, the solving of this equation, the unsetting of the F-1
   solutions of the Dirac equations, the setting of the solutions of the Dirac
   equation, the unsetting of the F-1 probability density with the setting
   of the probability density, the unsetting of the F-1 solutions of the
   algebraic equations relatively the effect with the solving the algebraic
   equations relatively the effect and the advance unsetting of the F-1
   effect function with the advance setting of the effect function,(s)=",
  3 Tg1F_F (bMAX + 1) (aMAX + 1) (NMAX_F + 1) + 3 (Tm_81 - Tm_71) + TΨDF_F (NMAX_F + 1) + 4 TTΨFd_F +
   4 TTΨF_F + Tm_241 - Tm_231 + (2 MMAX + 1) (NMAX_F + 1) TIρF_F + Tm_281 - Tm_271, " ", "F=", F];
Tm_291 = AbsoluteTime[];
Table[Δl_{iv,F-1}[l_, llv_] =.;
 If[(iv == j_0 || iv == j_1 || iv == j_2 || iv == j_3 || iv == j_4 || iv == j_5 || iv == j_6 || iv == j_7 || iv ==
     j_8 || iv == j_9 || iv == j_10), Print["iv=", iv, " ", "F=", F], Null];, {iv, 0, p1}];
Table[Δl_{iv,F}[l_, llv_] = AAE_{iv,F}[l, llv];
 If[(iv == j_0 || iv == j_1 || iv == j_2 || iv == j_3 || iv == j_4 || iv == j_5 || iv == j_6 || iv == j_7 || iv ==
     j_8 || iv == j_9 || iv == j_10), Print["iv=", iv, " ", "F=", F], Null];, {iv, 0, p1}];
Print["Δl_{iv,F}[l, 2 (t - 2) MMAX / Δt[l] ]"];

Tm_301 = AbsoluteTime[];
Print["Δt_151=", Tm_301 - Tm_291, " ", "F=", F];
Print["Note! The execution time of the setting of the initial conditions for the
   Dirac equation, the solving of this equation, the unsetting of the F-1
   solutions of the Dirac equations, the setting of the solutions of the
   Dirac equation, the unsetting of the F-1 probability density with the
   setting of the probability density, the unsetting of the F-1 solutions
   of the algebraic equations relatively the effect with the solving the
   algebraic equations relatively the effect, the advance unsetting of the
```

```
      F-1 effect function with the advance setting of the effect function
      and the unsetting of the F-1 expected effect function with the setting
      of the expected effect,(s)=", 3 Tg1F_F (bMAX + 1) (aMAX + 1) (NMAX_F + 1) +
    3 (Tm_81 - Tm_71) + TΨDF_F (NMAX_F + 1) + 4 TTΨFd_F + 4 TTΨF_F + Tm_241 - Tm_231 +
    (2 MMAX + 1) (NMAX_F + 1) TIρF_F + Tm_281 - Tm_271 + Tm_301 - Tm_291, " ", "F=", F];
  lmax_F =.;
  Tm_311 = AbsoluteTime[];
          абсолютное значение времени
  lmax_F+1 =
   l /. Flatten[NMaximize[l, Reduce[r_min ≥ 1/2 Abs[l - Δl_0,F[l, 2 MMAX]], l, Reals], l]][[2]];
        уплостить  численная ма···  привести         абсолютное значение          множество действитель
  Tm_321 = AbsoluteTime[];
          абсолютное значение времени
  Print["Δt_161=", Tm_321 - Tm_311, " ", "F=", F];
  печатать
  Print["Note! The execution time of the setting of the initial conditions for the
  печатать
      Dirac equation, the solving of this equation, the unsetting of the F-1
      solutions of the Dirac equations, the setting of the solutions of the
      Dirac equation, the unsetting of the F-1 probability density with the
      setting of the probability density, the unsetting of the F-1 solutions
      of the algebraic equations relatively the effect with the solving the
      algebraic equations relatively the effect, the advance unsetting of the
      F-1 effect function with the advance setting of the effect function, the
      unsetting of the F-1 expected effect function with the setting of the
      expected effect and the finding of the maximal scale for the task,(s)=",
   3 Tg1F_F (bMAX + 1) (aMAX + 1) (NMAX_F + 1) + 3 (Tm_81 - Tm_71) + TΨDF_F (NMAX_F + 1) +
    4 TTΨFd_F + 4 TTΨF_F + Tm_241 - Tm_231 + (2 MMAX + 1) (NMAX_F + 1) TIρF_F +
    Tm_281 - Tm_271 + Tm_301 - Tm_291 + Tm_321 - Tm_311, " ", "F=", F];
  NMAX_F+1 = (lmax_F+1 - lmin)/lP;
  NMAX_F-2 =.;
  Print["Δt_GeneralTime1=", Tm_321 - Tm_11, " ", "F=", F];]]
  печатать

ϵ = T[lmin + NMAX_F lP] - (2 MMAX - 1) δ;
```

```
Table[r1_{0,u,w,F-1} =.;
таблица значений
  r1_{0,u,w,F} = r_min;, {u, 0, NMAX_F}, {w, 0, 2 MMAX}];
Table[r_{0,u,w,F-1} =.;
таблица значений
  r_{0,u,w,F} = r_min;, {u, 0, NMAX_F}, {w, 0, 2 MMAX}];
For[a = 0, r_{a,n0,m00,F-1} ≤ r_max, a++,
цикл ДЛЯ
  If[a == 0, Print["a=", 0, " ", "r_{a,n0,m00,F-1}=", N[r_min]], Null];
  условный… печатать                                 численно… пустой
  Do[l_n = lmin + n d;
  оператор цикла
   Do[t_m = m δ;
   оператор цикла
    r1_{a+1,n,m,F-1} =
     l_n + r1_{a,n,m,F-1} - 1/2 Δl_{a,F-1}[l_n, (2 MMAX (-2 + t_m))/(Δt[l_n])] - 1/2 Δl_{a+1,F-1}[l_n, (2 MMAX (-2 + t_m))/(Δt[l_n])];
    r_{a+1,n,m,F-1} = r1_{a+1,n,m,F-1};
    r1_{a,n,m,F-1} =.;
    t_m =., {m, 0, 2 MMAX}];
   l_n =., {n, 0, NMAX_F}];
  If[a > 0 && (a == j_0 || a == j_1 || a == j_2 || a == j_3 ||
  условный оператор
      a == j_4 || a == j_5 || a == j_6 || a == j_7 || a == j_8 || a == j_9 || a == j_10),
   Print["a=", a, " ", "r_{a,n0,m00,F-1}=", r_{a,n0,m00,F-1}], Null]] // Timing
   печатать                                              пустой     затраченное время
```

In[∘]:= s = a - 1

Out[∘]=

9280

In[∘]:= $r_{9280,n0,m00}$

Out[∘]=

2.49984×10^{-11}

```
Table[R_{k1} = Interpolation[
таблица зн… интерполировать
    Flatten[Table[{{lmin + n1 d, m1 δ}, r_{k1,n1,m1,F-1}}, {n1, 0, NMAX_F}, {m1, 0, 2 MMAX}], 1],
    уплостить таблица значений
    InterpolationOrder → 5];, {k1, 0, s}];
    порядок интерполяции

R_{k1}[l, t]
```

```
Do[l_a1 = lmin + a1 d;
оператор цикла
 If[a1 == 0 || a1 == 1, Print["a1=", a1, " ", "l_a1=", l_a1], If[a1 == f_1 || a1 == f_2 ||
 условный оператор      печатать                              условный оператор
   a1 == f_3 || a1 == f_4 || a1 == f_5, Print["a1=", a1, " ", "l_a1=", l_a1], Null], Null];
                                        печатать                                пустой  пустой
 Do[t_b1 = b1 δ;
 оператор цикла
  If[(b1 == 0 || b1 == 1 || b1 == 2 MMAX) && (a1 == 0 || a1 == 1 || a1 == f_1 || a1 == f_2 ||
  условный оператор
    a1 == f_3 || a1 == f_4 || a1 == f_5), Print["b1=", b1, " ", "t_b1=", t_b1], Null];
                                          печатать                              пустой
```

$$IdJ1_{a1,b1,F-1} = \left(\frac{1}{2}\left(\frac{\pi}{\text{ArcTan}\left[\frac{l_{a1}-\Delta l_{0,F-1}\left[l_{a1},\frac{2\,MMAX\,(-2+t_{b1})}{\Delta t[l_{a1}]}\right]}{2\sqrt{r_{min}^2-\frac{1}{4}\left(l_{a1}-\Delta l_{0,F-1}\left[l_{a1},\frac{2\,MMAX\,(-2+t_{b1})}{\Delta t[l_{a1}]}\right]\right)^2}}\right]}\right)^2 - \frac{\pi}{\text{ArcTan}\left[\frac{l_{a1}-\Delta l_{0,F-1}\left[l_{a1},\frac{2\,MMAX\,(-2+t_{b1})}{\Delta t[l_{a1}]}\right]}{2\sqrt{r_{min}^2-\frac{1}{4}\left(l_{a1}-\Delta l_{0,F-1}\left[l_{a1},\frac{2\,MMAX\,(-2+t_{b1})}{\Delta t[l_{a1}]}\right]\right)^2}}\right]} + 2\right)$$

$$\sqrt{\frac{\hbar^2 c^2}{16}\times\frac{3}{\left(l_{a1}-\Delta l_{0,F-1}\left[l_{a1},\frac{2\,MMAX\,(-2+t_{b1})}{\Delta t[l_{a1}]}\right]\right)^2} + m0^2 c^4} +$$

$$\sum_{k2=1}^{s}\left(\left(\frac{1}{2}\left(\frac{\pi}{\text{ArcTan}\left[\frac{l_{a1}-\Delta l_{k2,F-1}\left[l_{a1},\frac{2\,MMAX\,(-2+t_{b1})}{\Delta t[l_{a1}]}\right]}{2\sqrt{(R_{k2}[l_{a1},t_{b1}])^2-\frac{1}{4}\left(l_{a1}-\Delta l_{k2,F-1}\left[l_{a1},\frac{2\,MMAX\,(-2+t_{b1})}{\Delta t[l_{a1}]}\right]\right)^2}}\right]}\right)^2 - \frac{\pi}{\text{ArcTan}\left[\frac{l_{a1}-\Delta l_{k2,F-1}\left[l_{a1},\frac{2\,MMAX\,(-2+t_{b1})}{\Delta t[l_{a1}]}\right]}{2\sqrt{(R_{k2}[l_{a1},t_{b1}])^2-\frac{1}{4}\left(l_{a1}-\Delta l_{k2,F-1}\left[l_{a1},\frac{2\,MMAX\,(-2+t_{b1})}{\Delta t[l_{a1}]}\right]\right)^2}}\right]} + 2\right)\right.$$

$$\left.\sqrt{\frac{\hbar^2 c^2}{16}\times\frac{3}{\left(l_{a1}-\Delta l_{k2,F-1}\left[l_{a1},\frac{2\,MMAX\,(-2+t_{b1})}{\Delta t[l_{a1}]}\right]\right)^2} + m0^2 c^4}\right);$$

```
  t_b1 =., {b1, 0, 2 MMAX}];
 l_a1 =., {a1, 0, NMAX_F}]
```

```
IdJ11_{F-1} = Interpolation[Flatten[Table[{{lmin + a11 d, b11 δ}, IdJ1_{a11,b11,F-1}},
              интерполировать  уплостить  таблица значений
      {a11, 0, NMAX_F}, {b11, 0, 2 MMAX}], 1], InterpolationOrder → 5];
                                               порядок интерполяции

IdJ11_{F-1}[l, t]

In[•]:= t := 4 δ

Plot[IdJ11_{F-1}[l, t], {l, lmin, lmax_F}, PlotRange → {-10, 10}]
график функции                              отображаемый диапазон граф

t =.

Do[l_{a2} = lmin + a2 d;
оператор цикла

 If[a2 == 0 || a2 == 1, Print["a2=", a2, " ", "l_{a2}=", l_{a2}], If[a2 == f_1 || a2 == f_2 ||
 условный оператор      печатать                                условный оператор
    a2 == f_3 || a2 == f_4 || a2 == f_5, Print["a2=", a2, " ", "l_{a2}=", l_{a2}], Null]];
                                          печатать                           пустой

 Do[τ_{b2} = b2 δ;
 оператор цикла

  If[(a2 == 0 || a2 == 1) && (b2 == 0 || b2 == 1 || b2 == 2 MMAX), Print["b2=", b2,
  условный оператор                                                печатать
    " ", "τ_{b2}=", τ_{b2}], If[(a2 == f_1 || a2 == f_2 || a2 == f_3 || a2 == f_4 || a2 == f_5) &&
                             условный оператор
     (b2 == 0 || b2 == 1 || b2 == 2 MMAX), Print["b2=", b2, " ", "τ_{b2}=", τ_{b2}], Null]];
                                           печатать                               пустой

  J1_{a2,b2,F-1} = 1/(T[l_{a2}] - τ_{b2}) 1/T[l_{a2}] NIntegrate[IdJ11_{F-1}[l_{a2}, t], {t, τ_{b2}, T[l_{a2}]}];
                                                      квадратурное интегрирование

  τ_{b2} =., {b2, 0, 2 MMAX}];
 l_{a2} =., {a2, 0, NMAX_F}]

J11_{F-1} = Interpolation[Flatten[Table[{{lmin + a22 d, b22 δ}, J1_{a22,b22,F-1}},
            интерполировать  уплостить  таблица значений
      {a22, 0, NMAX_F}, {b22, 0, 2 MMAX}], 1], InterpolationOrder → 5];
                                               порядок интерполяции

J11_{F-1}[l, τ]

Do[If[(a == f_1 || a == f_2 || a == f_3 || a == f_4 || a == f_5), Print["a=", a], Null];
 ⋯ условный оператор                                               печатать     пустой
 l_a = lmin + a lP;
 Int1_{a,F-1} = NIntegrate[J11_{F-1}[l_a, τ], {τ, 0, T[l_a] - ϵ}];
                квадратурное интегрирование
 l_a =., {a, 0, NMAX_F}]

F1_{F-1} =
  Interpolation[Table[{lmin + a3 d, Int1_{a3,F-1}}, {a3, 0, NMAX_F}], InterpolationOrder → 5];
  интерполировать  таблица значений                                  порядок интерполяции

I1_{F-1} = NIntegrate[F1_{F-1}[l], {l, lmin, lmax_F}]
           квадратурное интегрирование
```

```
N[1/lP Na I1F-1]
```
численное приближение

In[∘]:=
```
t := 4 δ

Plot[IdJ11F-1[l, t], {l, lmin, 10^-12}, PlotRange → {-10, 10}]
```
график функции | отображаемый диапазон граф

```
FindRoot[IdJ11F-1[l, t] == 0, {l, 4 × 10^-13}]
```
найти корень

```
FindRoot[IdJ11F-1[l, t] == 0, {l, 8 × 10^-13}]
```
найти корень

```
t =.

Plot[F1F-1[l], {l, lmin, lmaxF}, PlotRange → {-1.5, 1.5}]
```
график функции | отображаемый диапазон графика

```
Plot[F1F-1[l], {l, lmin, 2 × 10^-12}, PlotRange → {-1.5, 1.5}]
```
график функции | отображаемый диапазон графика

```
N[1/lP Δ1 Na I1F-1]
```
численное приближение

In[∘]:=
```
Tm2 = AbsoluteTime[];
```
абсолютное значение

In[∘]:=
```
ComputationTime = Tm2 - Tm1
```

Conclusion

The given program is made to compute correctly, as it is in the real world, the new physical effect numerically and to compute numerically the real application of it to the computation of the vacuum energy in the framework of the considering mathematical model. This model is built on the basis of the qualitative result of the perturbative approach in the quantum field theory, which gives the understanding of virtual particles and their motion. Only these ideas we have used in this model, and we have considered the quantitative description of them in our manner but not as they appear in the QFT. The approach to calculation of the effect itself also demanded the mathematical model, from which it must be extracted. This model, as we considered, is natural that adds importance to it.

The provided computer program is the good chance to gain the influence of the new natural physical effect on the vacuum energy of the entire Universe in the atoms of matter, when atoms of the Universe approximately consider with the hydrogen atoms, as it usually does in the Cosmology, e.g. by the classical specialist on the general theory of relativity A. S. Eddington. The up-to-date on the time of writing of this paper state is that this program is not possible to execute. We hope that in the future suitable shell of the Wolfram Mathematica® that uses the Wolfram language® will be released.

References

1. W. Greiner Relativistic Quantum Mechanics – Wave Equations (Springer, 2000), pp. 191 – 196.
2. A. S. Davydov The quantum mechanics: manual. 3rd Russian edition, SPb.: BHV-Petersburg, 2011. pp. 298, 265.