Correct and New Bohr's Model Helium of the 21th Century

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Abstract

In the hydrogen atom, the Bohr-Sommerfeld model completely agrees with the experimental data including the fine structure. But it was impossible to express the three-body Helium atom by the Bohr model in 1920's due to lack of computers. **Here we show that Bohr's model-based methods can calculate the experimental value (-79.005 eV) of Helium ground state energy correctly.** The standard Helium model has the spin-up and spin-down electrons, so it seems to generate no magnetic fields. But to be precise, the magnetic fields are produced in almost all space because the two electrons stay apart from each other by the repulsive Coulomb force. If they move to cancel the magnetic fields out, the (electro)magnetic fields changes, and they radiate the electromagnetic waves. So the standard(QM) Helium model contains the self-contradiction.

Here we suppose the orbital planes of the two electrons are perpendicular to each other. By a computational method, we calculate the Coulomb force among the particles, and the number of de Broglie's waves contained in the short segment at short time intervals. **Our results demonstrate that two electrons of Helium are actually moving on the orbits of just one de Broglie's wavelength.** The two orbits are symmetrical, crossing perpendicularly, and wrapping the whole Helium atom beutifully, which can explain the strong stability and the closed shell property of Helium due to the de Broglie's wave nature.

The more detailed version is in the homepage (http://www7b.biglobe.ne.jp/~kcy05t/index.html), which includes also about **serious faults** of Photon, Bell inequality, and relativistic quantum field theory. See also this page!

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In 1913, Niels Bohr postulates the Bohr's model which agreed with the observed hydrogen spectrum [1]. Later, Sommerfeld developed his theory to explain the fine structure completely [2]. **His fine structure values accidentally coincided with the Dirac hydrogen model which uses the new idea of the spin-orbital interaction** [3]. In 1923 Louis de Broglie suggested that electrons might have wave aspect and its wavelength λ is equal to h/mv, where h is Plank's constant ($= 6.62606896 \times 10^{-34}$ Js) and m is the electron mass ($= 9.1093826 \times 10^{-31}$ kg). In 1927, Davisson and Germer experimentally confirmed de Broglie's hypothesis in the interference experiment [4]. Recently the results of the two-slit experiment of an electron showed its wavelike properties [5].

In the Bohr-Sommerfeld model which adds this de Broglie's theory to the traditional Maxwell's theory, when the orbital length is equal to a integer times the wavelength of the electron, its motion becomes stable, not radiating energy. On the other hand, the quantum mechanical standard model contains **self-contradiction** about the reason why the electrons don't fall into the nucleus, (which are explained in the latter part). Now in several phenomena, the Bohr's model is known to provide good accuracy [6–8]. The most important problems which killed the Bohr's model were the Helium problems and the anomalous Zeeman effect in 1920's.

The Helium atom has the two electrons and the +2e nucleus. The three-body calculation like the Helium was much more difficult than the two-body hydrogen atom. If the Helium structure has not been defined, the development of all the physics and chemistry would have stopped at that point. On the other hand, in 1928-1930, Hylleraas succeeded in getting the approximate value of the Helium ground state energy using the Schroedinger equation. Now the latest calculation value of the Helium ground state energy is about -79.015 eV [9]. But it is a little different from the experimental value -79.005147 eV (Nist Data), because the Helium of the Schroedinger equation can't calculate the effect of the nuclear movement correctly.

The hydrogen atom shows the normal Zeeman effect, and the Lithium tends to show the Paschen-Back effect. So the anomalous Zeeman effect was studied mainly using the multi-electron atoms such as the sodium and magnesium. The Bohr model doesn't have the electron spin. Now the spin is generally accepted, but the mysterious features of the spin have not yet been clarified. One electron is very light and small, so by equating the angular momentum of the spinning sphere of the electron to $\frac{1}{2}\hbar$, the sphere speed leads to more than

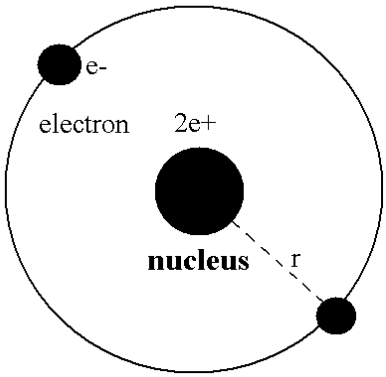

FIG. 1: One schematic model of Helium in which two electrons are moving on the opposite sides of the nucleus.

one hundred times the speed of light [10]. And the spinning electron doesn't return to its original forms by the 2π rotation. (By the 4π rotation, it returns.)

The quantum mechanics has many serious problems which are explained in detail in the latter part of this paper. So we try to go back to the Bohr model and solve those problems of the quantum mechanics. First we try the Helium model using the Bohr's theory based methods. In Fig. 1, the two electrons of the Helium are on the opposite sides of the nucleus and moving on the same circular orbit.

Equating the centrifugal force to the Coulomb force, we have

$$\frac{mv^2}{r} = \frac{2e^2}{4\pi\epsilon r^2} - \frac{e^2}{4\pi\epsilon(2r)^2} \tag{1}$$

where r is the circular orbital radius (meter), e is the electron charge ($= 1.60217653 \times 10^{-19}C$), and ϵ is the permittivity of vacuum ($= 8.854187817 \times 10^{-12}\frac{C^2}{Nm^2}$). The circular orbital length is supposed to be an integer times the wavelength of the electron, we have

$$2\pi r = \frac{h}{mv} \times n \tag{2}$$

The total energy E is the sum of the kinetic and the Coulomb potential energy of the two electrons, so

$$E = 2 \times \frac{mv^2}{2} - 2 \times \frac{2e^2}{4\pi\epsilon r} + \frac{e^2}{4\pi\epsilon(2r)} \tag{3}$$

Solving the above three Eqs. (1-3), the ground state energy (n=1) becomes -83.33 eV. This value is lower than the experimental value -79.005 eV. In this model, the two electrons are on the same one orbit of one de Broglie's wavelength, But if the two electrons can be in one

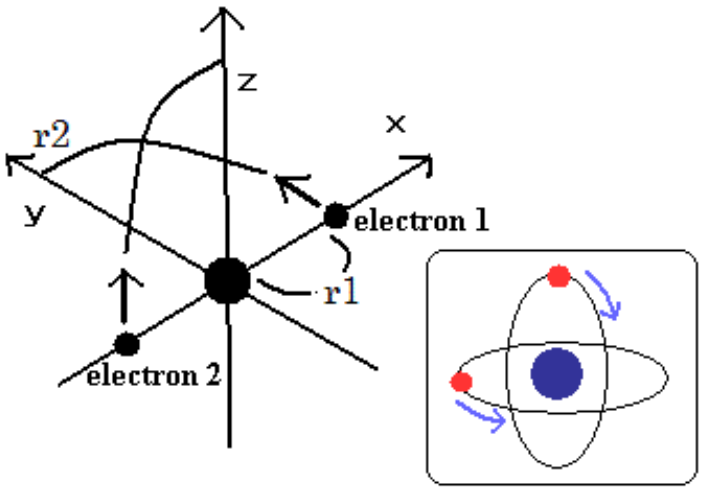

FIG. 2: Schematic model of Helium. Two same-shaped orbital planes are perpendicular to each other. This figure shows one quarter of the orbitals. Electron 1 starts at (r1, 0, 0), while electron 2 starts at (-r1, 0, 0). The two orbits are avoiding each other.

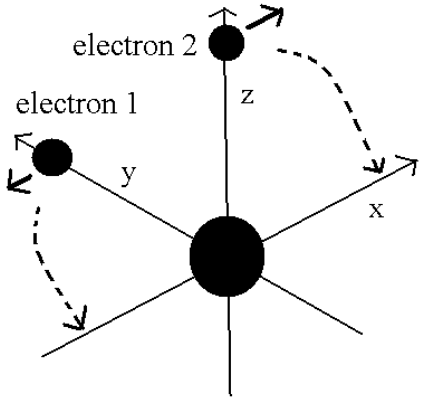

FIG. 3: Schematic model of Helium. Two electrons have moved one quarter of their orbitals. Electron 1 is crossing y axis perpendicularly, while electron 2 is crossing z axis.

small orbit, this means that the ground state electron of the Bohr hydrogen model can come closer to the nucleus than the original orbit.

And in Fig. 1 orbit, the two electrons are just at the opposite positions, so the wave phases of them may interfere with each other and vanish. To avoid such problems, we suppose another model as shown in Fig. 2 and 3. In this model, the electron 1 moves on the X-Y plane, the electron 2 moves on the X-Z plane. So only the x-direction is common.

As the two orbits are symmetrical and same-shaped, any points on the electron 1 orbit are at the same distance from the points on the both-side (± z) electron 2 orbit. The both-side (± z) electron 2 orbit have the opposite ± x-directions. On the electron 1 orbit, the x-direction de Bloglie's waves of the electron 2 interfere with themselves and vanish. So the wave of electron 1 would not be affected by the wave of electron 2. The same thing can be said on the electron 2 orbit.

Here we investigate how the electrons of the Helium are moving by calculating the Coulomb force among the two electrons and the nucleus at short time intervals. The computer program (class filename: MathMethod) written in the JAVA language (version 1.5.0) to compute the electron orbit of the Helium is shown in Supplementary Methods.

As shown in Fig. 2 and 3, the Helium nucleus is at the origin. The electron 1 initially at (r1, 0, 0) (Fig. 2) moves one quarter of its orbital to (0, r2, 0) (Fig. 3), while the electron 2 initially at (-r1, 0, 0) moves to (0, 0, r2). Meter and second are rather large units for measurement of atomic behavior, here we use new convenient units MM (1 MM $= 1 \times 10^{-14}$ meter), SS (1 $SS = 1 \times 10^{-25}$ second) and MM/SS (1 MM/SS $=1 \times 10^{-14}$ meter/1×10^{-25} second $= 1 \times 10^{11}$ meter/second).

In this program, we first input the initial x-coordinate r1 (in MM) of the electron 1, and the absolute value of the total energy E (in eV) of the Helium. From the inputted value, we calculate the initial velocity of the electron. And at intervals of 1 SS we compute the Coulomb force among the two electrons and the nucleus. When the electron 1 is at (xx, yy, 0), the electron 2 is at (-xx, 0, yy) (in MM). Change MM to meter as follows; x (m) = xx $\times 10^{-14}$. y (m) = yy $\times 10^{-14}$. So the x component of the acceleration (m/sec^2) of the electron 1 is

$$-\frac{2e^2x}{4\pi\epsilon(rm)(x^2+y^2)^{\frac{3}{2}}}+\frac{e^2\times(2x)}{4\pi\epsilon(rm)(4x^2+2y^2)^{\frac{3}{2}}} \tag{4}$$

where the first term is by the Coulomb force between the nucleus and the electron 1, and the second term is by the force between the two electrons. Considering the Helium nuclear mass, we use here the reduced mass ($rm = \frac{1}{2} \times \frac{2m_e m_{nuc}}{2m_e+m_{nuc}} = 9.10688561 \times 10^{-31}$ kg) except when the center of mass is at the origin. Here the two electrons has completely the same mass and charge. So we can assume one virtual particle of $2 \times m_e$ at the center of the two electrons. The center of the two electrons' charges agrees with this virtual particle's position, too. (Though its effective charge which influences the nucleus is changing with

time.) This means that only the force $F(t)$ between this virtual particle and the nucleus affect their motions. When we fix the motion of the nucleus, we can use the above reduced mass equation.

In the same way, the y component of the acceleration (m/sec^2) is

$$-\frac{2e^2y}{4\pi\epsilon(rm)(x^2+y^2)^{\frac{3}{2}}}+\frac{e^2\times y}{4\pi\epsilon(rm)(4x^2+2y^2)^{\frac{3}{2}}} \tag{5}$$

Change m/sec^2 to MM/SS^2 using the next relation

$$1m/sec^2 = 1\times 10^{14}MM/(1\times 10^{25}SS)^2 = 1\times 10^{-36}MM/SS^2 \tag{6}$$

Based on that calculation value we change the velocity vector and the position of the electrons. We suppose electron 1 moves only on the XY-plane, so the z component of the acceleration of the electron 1 is not considered. If we consider all components of the Coulomb force against the electrons, the electron's motion becomes as shown in Fig. 1. But in Fig. 1, the two electrons are packed in one orbit of one de Broglie's wavelength. We suppose de Broglie's waves are related to some limited spaces. Actually the two slit behavior of the electron is caused by this de Broglie's wave. So if the two electrons's orbits come close to each other to some extent, the wave fields becomes condensed and block it.

We also calculate de Broglie's wavelength of the electron from the velocity ($\lambda = h/mv$) at intervals of 1 SS. The number of that wave (λ in length) contained in that short movement section (the sum of them is WN) is

$$\frac{\sqrt{VX^2+VY^2}\times 10^{-14}}{\frac{h}{(rm)\sqrt{VX^2+VY^2}\times 10^{11}}} \tag{7}$$

where (VX, VY) are the velocity of the electron 1 (in MM/SS), the numerator is the movement distance (in meter) for 1 SS. the denominator is de Broglie's wavelength (in meter). Here, the estimated electron's orbit is divided into more than one hundred million short segments for the calculation. When the electron 1 has moved one quarter of its orbit and its x-coordinate is zero (Fig. 3), this program checked the y-component of the electron 1 velocity (last VY). When the last VY is zero, two electrons are periodically moving around the nucleus on the same orbitals as shown in Fig. 2 and 3. So, only when -0.000001 $<$ last VY $<$ 0.000001 (MM/SS) is satisfied, the program displays the following values on the screen, r1, VY, $preVY$ (VY $1SS$ ago), and (mid)WN (the total number of de Broglie's waves contained in one quarter of the orbit).

TABLE I: Results of r1 and WN (Number of de Broglie's waves) in which y component of electron 1 velocity in Fig. 3 is zero at various energy levels of Helium. WN × 4 is the total number of de Broglie's waves contained in one round of the orbital. This result shows the relativistic correction to the energy = -79.005147-(-79.0035) = -0.001647 eV

E (eV)	r1 (MM)	WN	WN × 4
-77.500	3134.0	0.25241336	1.00965344
-78.000	3114.0	0.25160304	1.00641216
-78.500	3094.0	0.25080048	1.00320192
-79.000	3074.5	0.25000555	1.00002220
-79.0030	3074.1	0.25000079	1.00000316
-79.0035	3074.0	0.25000000	1.00000000
-79.0040	3074.0	0.24999921	0.99999684
-79.010	3073.8	0.24998972	0.99995888
-79.500	3055.0	0.24921812	0.99687248
-80.000	3036.0	0.24843810	0.99375240
-80.500	3017.0	0.24766535	0.99066140

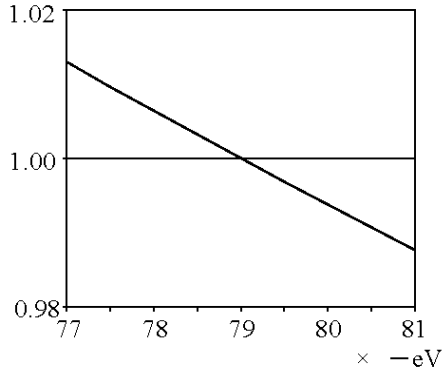

FIG. 4: Plots of the number of de Broglie's waves contained in one orbital at various energy levels of Helium

Table I shows the results in which the last VY is the closest to zero. Fig. 4 graphs the results in Table I. As shown in Table I and Fig. 4, when the total energy of the Helium (E) is -79.0035 eV, WN × 4 is just 1.00000000. The experimental value is -79.005147 eV. So the

relativistic correction to the energy caused by the electron's velocity is -0.001647 eV. This value is proper, because it is just between the Helium ion (-0.0028 eV) and the hydrogen atom (-0.000...). This results demonstrate that two electrons of the helium are actually moving around the nucleus on the orbits of just one de Broglie's wavelength as shown in Fig. 2 and 3.

The latest result of the variational methods using the Schroedinger equation is about -79.015 eV. This Bohr model-based new method is much simpler and shows more accurate result than the Shroedinger equation-based complicated methods. The fault of the Shroedinger equation is that it doesn't have the clear electron's orbit. So it is impossible to know when we should use the reduced mass in the Schroedinger equation. If we "by mistake" use the reduced mass instead of the electron mass in the condition such as Fig. 2(the center of mass is at the origin), the result becomes inaccurate. (For example, here we use the usual electron mass (not the reduced mass) in calculating the initial electron's velocity from the inputted values in the JAVA program, because this initial state is Fig.2.) This judgement is possible only in the Bohr model Helium which has the clear electron orbits.

Here we use the new unit ($1SS = 1 \times 10^{-25}$ second) and compute each value at the intervals of $1SS$. If we change this definition of $1SS$, the calculation results of the total energy (E) in which the orbital length is just one de Broglie's wavelength change as follows,

$$1SS = 1 \times 10^{-22} sec \rightarrow 1 \times 10^{-23} sec \rightarrow 1 \times 10^{-24} sec \rightarrow 1 \times 10^{-25} sec \tag{8}$$

The total energy results change as,

$$E = -79.00470eV \rightarrow -79.00370eV \rightarrow -79.00355eV \rightarrow -79.00350eV \tag{9}$$

This means that as the orbit becomes more smooth, the calculation values converge to -79.00350 eV.

The standard Helium model of the quantum mechanics(QM) has the spin-up and spin-down electrons. So it seems to generate no magnetic field. But to be precise, in all areas except in the part at just the same distance from the two electrons, magnetic fields are theoretically produced by the electrons even in the standard helium model. So as the electrons move to cancel the magnetic field out, they lose energy by emitting electromagnetic waves. Actually, the one-electron atom hydrogen has the magnetic moment, the two-electron atom Helium has no magnetic moment. So the standard QM Helium model has self-contradiction.

In this new Helium, the two symmetrical orbits crossing perpendicularly are wrapping the whole Helium atom completely. (The Bohr model hydrogen which has only one orbit, can not wrap the direction of the magnetic moment completely.) It is just consistent with the fact of the strong stability and the the closed shell property of Helium.

If we can describe the ground state of Helium atom by the Bohr-model based methods correctly (which means "more correctly" than the quantum-mechanical variational methods), the excited states and the atoms with more electrons can be explained by the Bohr-model based methods, too. For example, in the Lithium atom, the third electron is known to be in the 2S state, and we can get the approximate calculation value close to the experimental value using the 2S state function of the hydrogen atom wich energy levels are the same in both the Bohr model and the quantum-mechanical model.

In the standard model of the quantum mechanics, it is said that the electrons are stable as electron clouds, which are not actually moving. They say this is the reason why the electrons don't fall into the nucleus radiating energy in QM. But if so, how do we explain about the relativistic corrections to the energy (caused by the high electron's velocity) and the use of the reduced mass? If we use the reduced mass of an electron, the calculation results of the hydrogen energy levels becomes more accurate. Does this mean that the electron and the nucleus are actually moving around the center of mass? So the quantum-mechanical model contains self-contradiction also in this subject.

The fermions like electrons don't go back to their original configurations when they are rotated by an angle of 2π. (By the 4π rotation, they return.) This is called the "two-valued". It is very surprising that this two-valued property of the fermions was experimentally observed [11]. **But in this real world, does such a strange phenomenon actually happen?** In this experiment, they rotated the neutrons around the spin axis by using precession. The angular frequency of the precession is,

$$\omega = \frac{g\mu_n}{\hbar} H \tag{10}$$

This means that they "imagine" the rotation angle based on the spin g-factor(g), because we can't directly look at this precession. The fermion's spin angular momentum is $\frac{1}{2}\hbar$. If we change this angular momentum to $\hbar$, (spin) g-factor becomes half of the original value, which keeps the original (spin) magnetic moment(=g-factor $\times$ angular momentum) unchanged. We can experimentally measure only the (spin) magnetic moment, can't measure the (spin)

angular momentum and g-factor. If we use the precondition of the half (spin) g-factor, the interpretation of the above experimental result changes to the very natural one that the spinning neutrons returned to their original by the 2π rotation.

If the (spin) angular momentum becomes $\hbar$ (= the (spin) g-factor becomes half), this means that the atomic models change to the Bohr model in which the serious problem of the spinning speed faster than the speed of the light doesn't occur. Only the Stern Gerlach experiment can not determine the existence of the spin. Because also in the Bohr model, when the plane of the electron orbit contain the direction of the magnetic field, the electron's motion becomes unstable.

There are other problems in the quantum mechanics. For example, in the hydrogen solution of the Schrodinger equation, the probability density of the ground state electron near the point at infinity is **not** zero. It is very strange.

The hydrogen solution of the Bohr-Sommerfeld model completely coincides with that of the Dirac equation. Why does the Bohr-Sommerfeld model which has no electron spin coincide with the Dirac equation which includes the spin-orbital interaction? For example, the fine structure means the relativistic energy difference between 2S and 2P states in the Bohr-Sommerfeld model. (It is caused by the electron's velocity difference between these states). But in the standard (Dirac) hydrogen model with electron spin, the "interpretation" of this fine structure has been changed to the spin-orbital interaction (= the energy difference between $2P_{1/2}$ and $2P_{3/2}$). "Accidentally" this value coincided with that of the Bohr-Sommerfeld model. Furthermore, the Dirac hydorogen model includes "many accidental coincidences" of the relativity and spin-orbital interactions (For example, $2S_{1/2}$=$2P_{1/2}$, $3S_{1/2}$=$3P_{1/2}$, $3P_{3/2}$=$3D_{3/2}$ .....). It is much more unnatural than the Bohr Sommerfeld model.

How about the singlet and triplet states? In the triplet states ($S = S_1 + S_2 = 1/2 + 1/2 = 1$), we can't actually imagine the state in which the total Spin angular momentum S is perpendicular to the angular momentum L. In the singlet state ($S = 1/2 - 1/2 = 0$), the spin effect is said to vanish, but the two electrons of the different orbits are apart from each other. So around the electron 1, the magnetic moment by the electron 1 exist, and the spin-orbital interaction (by the electron 1 itself) can occur. (if we imagine this state concretely). The spin-orbital interaction means that the spin effect doesn't vanish. This is inconsistent with the fact $S = 0$.

How about the anomalous Zeeman effect? For multi-electron atoms, for example, the 3s electron of the sodium D line comes very close to the nucleus through the inner electrons. But the Lande-g-factor does not contain the influence of the inner electrons at all. The delicate spin and orbital precession is so stable to stand the influence of the inner electrons? The Lande g factor contain the unnatural precession around the total angular momentum J. This J is different from the total magnetic moment μ and the external magnetic field direction. So J has no relation to the direction of the force. Why does this unnatural precession occur?

The actual experimental spectrum results under the magnetic fields are much more complicated than the Lande's theory. And one-electron hydrogen atom is known to show the "normal" Zeeman effect. (Some textbooks say that even the hydrogen atom shows the "anomalous" Zeeman effect. But it is only "theoretical" thing. The experimental results clearly show the "normal" Zeeman effect in the hydrogen atom.)

It is quite natural to think that the anomalous Zeeman effect is caused by the inner electrons rather than the strange electron's spin. These electron spin and Lange g-factor are only "mathematical things". **They are not what actually happen.** The same thing can be said about the "virtual particles" in QFT which are used in calculating the Lamb shift and the electron g-factor.

By the result of the simple Dirac hydrogen model which doesn't use the renormalization theory, the energy levels of the $2S_{1/2}$ and $2P_{1/2}$ are completely the same. And the very small energy difference between them is called the Lamb shift (the vacuum polarization) which can be calculated only by the relativistic quantum field theory (QFT) using the renormalization theory. But the calculation of the simple Dirac hydrogen model uses the "nonrelativistic" Coulomb potential. So, **before** considering the QFT (vacuum polarization), the energy difference between $2S_{1/2}$ and $2P_{1/2}$ occur in the different inertial reference frames. This means that it is inconsistent with the fact that the Lamb shift is caused by the vacuum polarization. So the quantum field theory and the Lamb shift contain the self-contradiction. They need "other" interpretations.

If the Bohr model is correct, the problems of the collapse interpletations using the many world interpretaions and so on, would not occur. And of course, in the Bohr model, the

electron doesn't hit the nucleus, because the orbital angular momentum is not zero.

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In this program, we first input the initial x-coordinate r1 (in MM) of electron 1, and the absolute value of the total energy E (in eV) of Helium. From the inputted values, this program outputs the y component of electron 1 velocity in Fig. 3, and WN (the number of de Broglie's waves contained in one quarter of the orbital). Here $1SS = 1 \times 10^{-25}$ second. The calculation takes several minitues per one r1. (The fast and easy program ($1SS = 1 \times 10^{-22}$ sec) is in the homepage shown in the abstract. It may be better to try first that program in the homepage.)

```
import java.util.Scanner;
class MathMethod {
public static void main (String[ ] args) {

Scanner stdIn = new Scanner ( System.in ) ;          // input r1 and |E |
System.out.println ("r1 between nucleus and electron 1 (MM)? ");
double r = stdIn.nextDouble ();
System.out.println ("total energy |E |in the helium (eV) ? ");
double E = stdIn.nextDouble ();
double me = 9.1093826e-31 ; double nucle = 6.64465650e-27;
                                        //nucle =α particle
                                        //rm = reduced mass of an electron
double rm = (2*me*nucle) / (2*(2*me+nucle));
double pai = 3.141592653589793; double epsi = 8.85418781787346e-12;
double h = 6.62606896e-34; double ele = 1.60217653e-19;
                                    // calculation of initial VY from E and r1
double poten = - (2*ele*ele*2) / (4*pai*epsi*r) + (ele*ele) / (4*pai*epsi*2*r);
                                    // vya = total E-potential energy
double vya = - (E*1.60217646e-19) - poten*1.0e14;
if (vya >0) {
                                    // vyb=velocity from kinetic energy
double vyb = Math.sqrt(vya/me);
```

```
double VY = vyb*1.0e-11;                    // change m/sec to MM/SS
double prexx = r; double VX = 0.0; double WN = 0.0; double preyy=0.0;
double xx, yy, vk, preVY, preWN, midWN;
do {
xx = prexx + VX; yy = preyy + VY;          //electron 1 position after 1SS
preVY = VY; preWN = WN ;
vk = VX * VX + VY * VY;                 // calculation of WN from VX,VY
                                            // WN = WN + Eq(7)
WN = WN + (rm*vk*1.0e-3) / h;
                              // calculation of VX,VY from Coulomb force
double ra = Math.sqrt (prexx * prexx + preyy * preyy);
double rb = Math.sqrt (4.0 * prexx * prexx + 2.0 * preyy * preyy);
                                            // change MM to meter
ra = ra * 1.0e-14; rb = rb * 1.0e-14;
prexx = prexx * 1.0e-14; preyy = preyy * 1.0e-14;
double ac = (2 * ele * ele) / (4 * pai * epsi * rm);
                                            // VX = VX + Eq(4) * 10^-36
VX = VX + 1.0e-36 * ac * prexx * (-1.0 / (ra*ra*ra) + 1.0 / (rb*rb*rb));
                                            // VY = VY + Eq(5) * 10^-36
VY = VY + 1.0e-36 * ac * preyy * (-1.0 / (ra*ra*ra) + 0.5 / (rb*rb*rb));
prexx = xx; preyy = yy;
} while ( xx >0 );                 //repeat above until electron 1 arive at y axis
if (VY >-0.000001 && VY <0.000001) {                // last VY condition
System.out.print ("r1: " + r + "     ");
System.out.printf ("VX: % .10f      ", VX);
System.out.printf ("VY: % .10f      ", VY);
System.out.printf ("preVY: % .10f      ", preVY);
midWN = (preWN + WN) / 2; System.out.printf ("midWN: % .10f \n", midWN);
}
} } }
```