Possible Structure of the Electron and the Up Quark

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Abstract
Any particle consists of some combination of down quarks and (or) antidown quarks because their electric charges imply so.

Keywords: Electron, quark, interaction, bond, proton.

Introduction

Robert A. Millikan [1] conducted the renowned oil drop experiment [2] in 1909, demonstrating that the electric charge of an oil drop is always a multiple of $-1.6*10^{-19}$ C, which is the charge of a single electron.

Let us assume similarly that any particle consists of some combination of down quarks and (or) antidown quarks because their electric charges imply so.

For instance, the electron is composed of three down quarks, as its electric charge equals the sum of the electric charges of three down quarks::

$$q_e = -e = -1.6 * 10^{-19}\, C = 3 * \frac{1}{3}(-1.6 * 10^{-19}\, C) = 3 * \frac{1}{3}(-e) = 3q_d$$

The up quark is composed of two antidown quarks, as its electric charge is equivalent to the sum of the electric charges of two antidown quarks::

$$q_u = 2 * \frac{1}{3}(1.6 * 10^{-19}\, C) = 2 * \frac{1}{3} e = 2q_{\bar{d}}$$

In this paper I will assume that down, strange, and bottom quarks [3], [4] are all just down quarks, and difference in masses is due to difference in their respective environments. Just like down and up quark hold one mass in a free proton and neutron and smaller masses when they are in a nucleus [5].

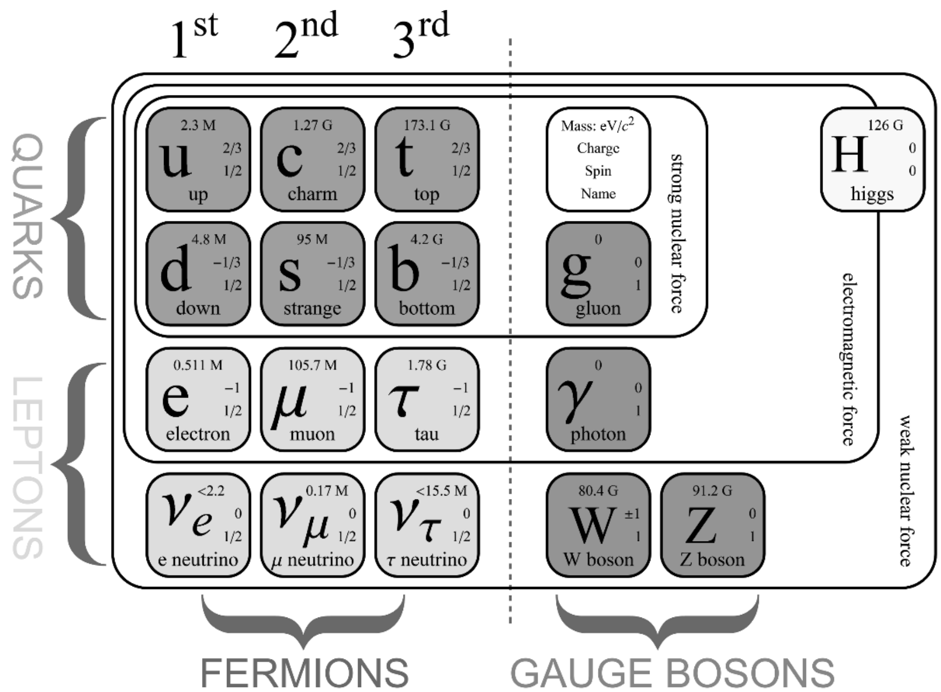


Figure 1

The Standard Model of particle physics [3]

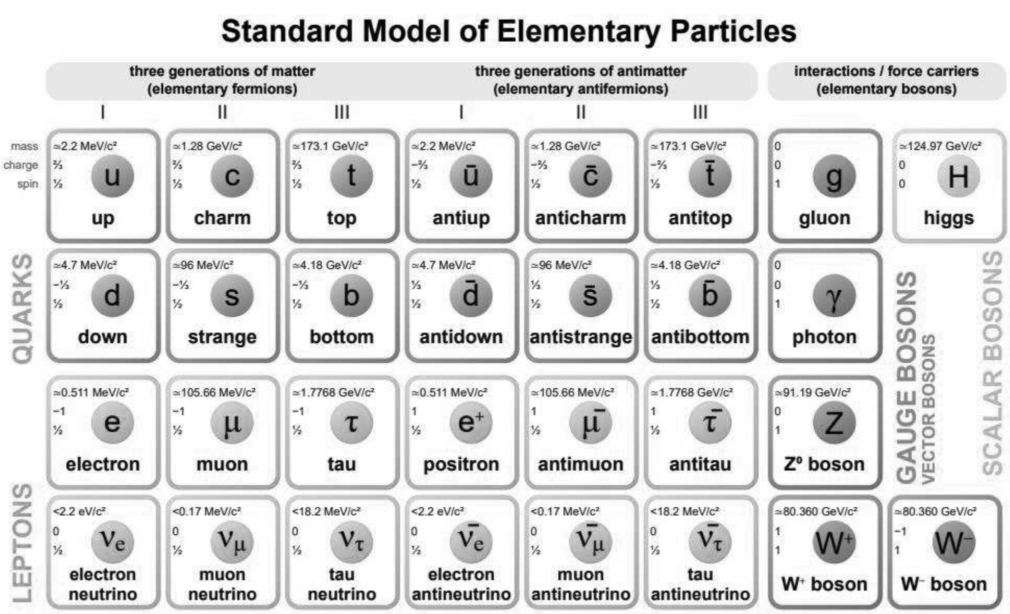
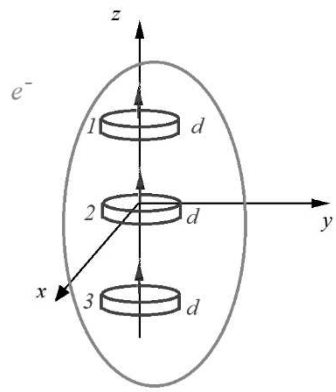


Figure 2

Standard Model of Elementary Particles [4]

Possible structure of the electron



I assumed that each down quark within the electron is identical (this does not have to be the case), and that they are aligned in a form of maximal magnetic attraction. This also does not have to be the case, there are other possible stabile balance configurations, not just in the form of a maximal magnetic attraction.

For the sake of simplicity, I will calculate the relation between quarks 1 and 2, disregarding (significant but not essential) influence of a third one on our objectives.

Figure 3

Sketch of the electron which consists out of 3 down quarks.

The objectives of these calculations are to demonstrate the possibility of a stabile particle and to provide rough sketch of reality, not to give exact version of it.

Quarks 1 and 2 in Figure 3 are oriented in a position of maximal magnetic attraction and because they are all electronegative, electric force is repulsive in any point, therefore resultant force that holds them (and electron) together is:

$$Fr = Fe - Fm$$

Fr – resultant force

Fe – electric (repulsive force)

Fm – magnetic (attractive force)

Magnitude of electric force between two small electric charges at distance z, if we disregard shape and size of the quarks 1 and 2 [6]:

$$F_e = k\frac{q_1 q_2}{z^2}$$

$k = 8.99 * 10^9 \frac{Nm^2}{C^2}$ - Coulomb's constant

In our case magnitude is:

$$q_1 = q_2 = \frac{1}{3}\ e\ = \frac{1}{3}\ 1.6 * 10^{-19}C$$

So

$$F_e = 8.99 * 10^9 \ \frac{Nm^2}{C^2} \frac{\frac{1}{3}\ 1.6 * 10^{-19}C * \frac{1}{3}\ 1.6 * 10^{-19}C}{z^2}$$

$$\boldsymbol{F_e = \ 2.557 * 10^{-29} \frac{1}{z^2}}\ Nm^2$$

Magnitude of magnetic force between two small magnetic dipoles at distance z [7], [8]:

$$F_m = \frac{3\mu_0 m_1 m_2}{2\pi z^4}$$

Where:

$\mu_0 = 4\pi * 10^{-7}$ T·m/A - permeability of space

z-distance between 1 and 2 quarks

$m_q = \frac{e_q \hbar}{2m_q}$, [9], [10]

$$magnitude\ of\ magnetic\ moment\ of\ any\ quark = \frac{its\ electric\ charge * reduced\ Plank's\ constant}{2 * mass\ of\ the\ quark}$$

For mass of the d quark in the electron I will approximate 1/3 of the electrons mass.

$m_d = \frac{1}{3} 9.1 * 10^{-31} kg \approx 3 * 10^{-31} kg$ [11]

Therefore, magnetic moment for down quark is:

$$m_{1,2} = \frac{1}{3}\frac{e\hbar}{2m_d} = \frac{1}{3}\frac{1.6 * 10^{-19}C * 1.05 * 10^{-34}Js}{2 * 3 * 10^{-31}kg} = 9.33 * 10^{-24}\frac{J}{T}$$

Therefore, magnetic part of the force is:

$$F_m = \frac{3 * 4\pi 10^{-7}\ \frac{Tm}{A} 9.33 * 10^{-24}\frac{J}{T} 9.33 * 10^{-24}\frac{J}{T}}{2\pi}\frac{1}{z^4}$$

$$\boldsymbol{F_m = 5.22 * 10^{-53}\frac{1}{z^4}}\ Nm^4$$

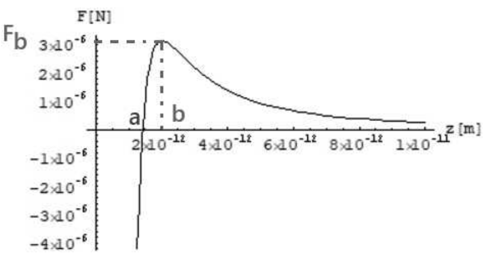
Therefore, magnitude of the force is:

$$Fr = Fe - Fm$$

$$\boldsymbol{Fr} = \mathbf{2.557} * \mathbf{10^{-29}} \frac{\mathbf{1}}{\boldsymbol{z^2}}\ Nm^2 - \mathbf{5.22} * \mathbf{10^{-53}} \frac{\mathbf{1}}{\boldsymbol{z^4}}\ Nm^4$$

Let us plot the graph to see function Fr(z)

```
Plot[ 2.557*10^-29 *1/z^2 - 5.22*10^-53 *1/z^4 , {z, 10^-12, 10^-11}, AxesLabel → {z [m], F[N]}, AxesOrigin → {0, 0}]
```




```
In[6]:= NSolve[2.557*10^-29 *1/z^2 - 5.22*10^-53 *1/z^4 == 0, z]
Out[6]= {{z → -1.42879 × 10^-12}, {z → 1.42879 × 10^-12}} a
In[8]:= ∂z (2.557*10^-29 *1/z^2 - 5.22*10^-53 *1/z^4)
Out[8]= 2.088 × 10^-52/z^5 - 5.114 × 10^-29/z^3
In[9]:=
NSolve[2.088*10^-52/z^5 - 5.114*10^-29/z^3 == 0, z]
Out[9]= {{z → -2.02062 × 10^-12}, {z → 2.02062 × 10^-12}} b
In[11]:=
Fmax = 2.557*10^-29 *1/(2.02062*10^-12)^2 - 5.22*10^-53 *1/(2.02062*10^-12)^4
Out[11]= Fmax = 3.13135 × 10^-6   Fb
```

Figure 4

Prt Scr picture of calculations in Wolfram Mathematica 5

As seen in calculations:

We have zero value for the $z = 1.43 * 10^{-12}m$ (point a)

Maximum value (maximum repulsion) for $z = 2.02 * 10^{-12}m$ (point b)

Maximum (repulsive force) at that point $Fmax = 3.13 * 10^{-6}N$

In distances greater than $z = 1.43 * 10^{-12}m$ resultant force is repulsive i.e. electric force is dominant. At these assumptions (if we disregard shape and size of the quarks 1 and 2) and at distances smaller than $z = 1.43 * 10^{-12}m$ force is attractive I.E. magnetic part of the force is dominant.

Therefore, our particle is possible, if distances between neighboring down quarks are smaller than $z = 1.43 * 10^{-12}m$.

The end

Sequel

As seen in the calculation stabile particle is possible for ranges smaller than $z = 1.43 * 10^{-12}m$ because in these regions magnetic attractive force is stronger than electric repulsive force.

The problem with this calculation is that there is no stabile balance point, and that attractive force becomes very strong for small distances. If we put $z = 10^{-30}m$ our force will be

$$Fr = 2.557x * \frac{1}{(10^{-30}m)^2} Nm^2 - 5.22 * 10^{-53} \frac{1}{(10^{-30}m)^4} Nm^4 = -5.22 * 10^{67}N$$

Which is much.

So, the question is why our particle does not collapse into itself under such strong force?

A possible answer for this conundrum could be in the nature of the down quark itself and in connection with that, better utilization of existing equations for close distances. In other words, we cannot "disregard shape and size of the quarks" for small distances. Whatever down quark might be it will have a finite dimension. In its own finite dimensions, it could have surface bonded electric charges and magnetic property bond to its core.

More likely; things that we perceive as electric charges are (all, mostly or at least partially) bond with the surface. And things that we perceive as magnetic properties are associated more to the object core. I have a personal opinion on what a down and antidown quark is, but I will not burden this work with that, let me just say that key to understanding the internal structure of the down quark and antidown quark is in direction of "reference frames" and relativity.

For the reason of the instructive demonstrative calculation let us assume that down quark is in a shape of a flattened cylinder[1] with height of $0.5 * 10^{-20}m$ and with a base radius of $1.25 * 10^{-20}\,m$. So, surface area of this cylinder is:

$$A = 2 * (1.25 * 10^{-20}\,m)^2 * 3.14 + 2 * 1.25 * 10^{-20}\,m * 3.14 * 0.5 * 10^{-20}m$$

$$A = 1.37375 * 10^{-39}m^2$$

[1] Down quark is in a shape of a cylinder probably as much as a cow is in the shape of a sphere.

Surface of one base is $B = (1.25 * 10^{-20}\, m)^2 * 3.14 = 4.90625 * 10^{-40} m^2$

So, magnitude of the electric charge of one base of one down quark is $q'_d = \frac{B}{A} * \frac{1}{3} e$

$q'_d = \frac{4.90625*10^{-40} m^2}{1.37375*10^{-39} m^2} * \frac{1}{3} 1.6 * 10^{-19} C \approx 1.9 * 10^{-20} C$

In order to balance strong magnetic attractive force two down quarks will have to move very close, in regions where distance between surfaces is much smaller than height of one individual quark, in that case electric repulsive part of the force will dominantly be between adjacent surfaces. Let us remind ourselves about the starting assumption that electric charge is surface bond and magnetic part of the force is associated with center of the down quark.

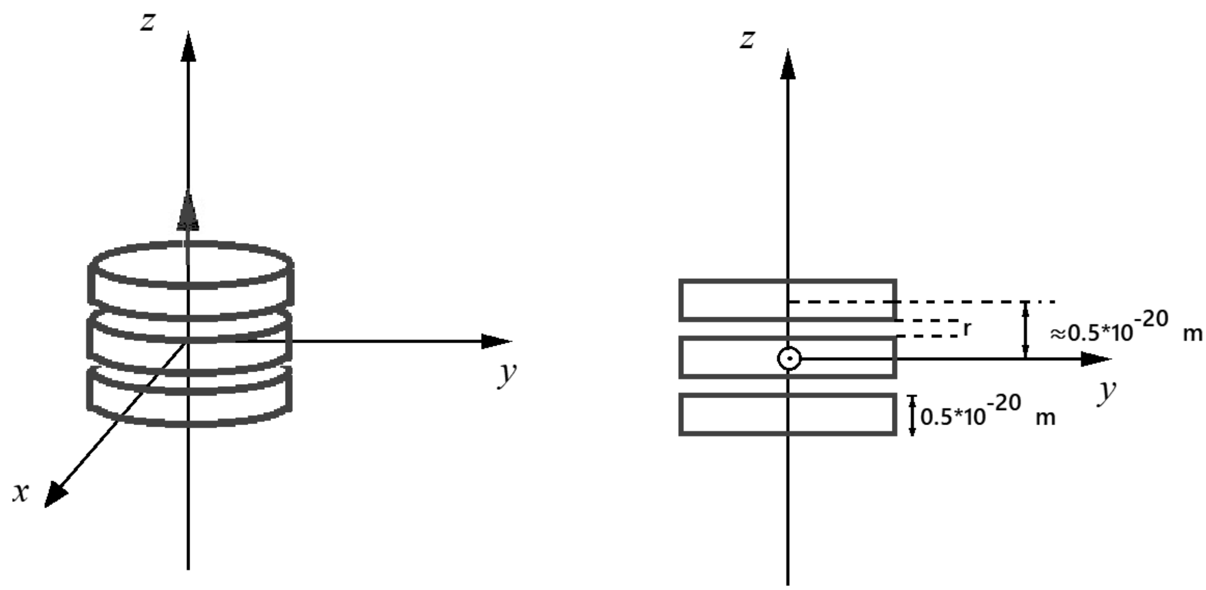


Figure 5

Depiction of the electron as the assembly of three down quarks that are very close to each other.

Now, let us define and examine the function of the resultant force for close ranges F'_r.

$$F'_r = F'_e - F_m$$

See figure 5

$F'_e = k\frac{q'_d q'_d}{r^2} \approx k\frac{q'_d q'_d}{(z-0.5*10^{-20} m)^2} = 8.99 * 10^9 \frac{Nm^2}{C^2}\ \frac{1.9*10^{-20} C*1.9*10^{-20} C}{(z-0.5*10^{-20} m)^2} = \frac{3.25*10^{-30} Nm^2}{(z-0.5*10^{-20} m)^2}$ and

F_m is unchanged, $F_m = 5.22 * 10^{-53} \frac{1}{z^4}\ Nm^4$

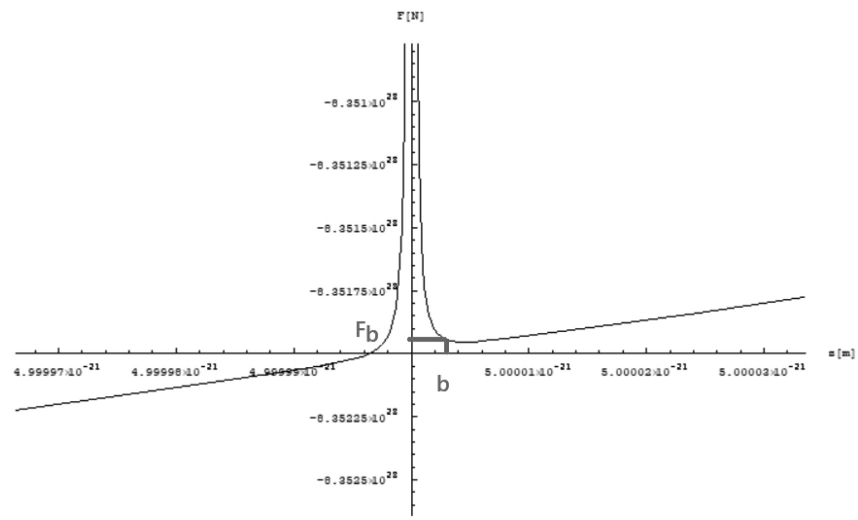
Therefore, for distances r much smaller than a quark height, depiction of interaction is better with

$$F'_r = F'_e - F_m$$

$$F_r' = \frac{3.25 * 10^{-30} Nm^2}{(z - 0.5 * 10^{-20} m)^2} - 5.22 * 10^{-53} \frac{1}{z^4}\ Nm^4$$

Let us plot the graph to see the function $F_r'(z)$

```
In[4]:= Plot[ 3.25*10^-30 *1 / (z - 0.5*10^-20) ^2 - 5.22 *10^-53 *1 / z^4 , {z, 4.9999*10^-21, 5.0001*10^-21}, AxesLabel → {z [m], F[N]}]
```




```
NSolve[ 3.25*10^-30 *1 / (z - 0.5*10^-20) ^2 - 5.22 *10^-53 *1 / z^4 == 0, z]

{{z → -4.007684930432444961533950128235160062800694557507077049314804105307846828113109854694677574920383456931851382533925721191024516305677732866375314 × 10^-12},
 {z → 4.007684920432444961533950645554891863566953644490410949066418090314715030996636305147239055227403941123017471512742478667006663037029900484861218 × 10^-12},
 {z → 5.000000006238015070677032786645779793496460605941469395490002283568987852629481614074136182362631228043617632329845937458600046466097631873278213 × 10^-21},
 {z → 4.999999993761984412003235412587961119520205494306916619503129513547485696917956905618843333446202682977565610194171915810047785915416464020859357 × 10^-21}}
```

z → $\boxed{5.0000000062380 * 10\text{\^{}}-21}$ a

```
∂z ( 3.25 *10^-30 *1 / (z - 0.5*10^-20) ^2 - 5.22*10^-53 *1 / z^4)
```

$$-\frac{6.5 \times 10^{-30}}{(-5. \times 10^{-21} + z)^3} + \frac{2.088 \times 10^{-52}}{z^5}$$

$$\text{Solve}\left[-\frac{6.499999999999999\grave{}*\wedge\!-30}{(-5.\grave{}*\wedge\!-21 + z)^3} + \frac{2.0879999999999998\grave{}*\wedge\!-52}{z^5} == 0,\ z\right]$$

{{z → -5.66772×10^{-12}}, {z → $5. \times 10^{-21} - 3.98298 \times 10^{-27}\,i$}, {z → $5. \times 10^{-21} + 3.98298 \times 10^{-27}\,i$}, {z → $5. \times 10^{-21}$}, {z → 5.66772×10^{-12}}}

```
z → 5.00000459915762`*^-21
```

z → $\boxed{5.0000045991576 * 10\text{\^{}}-21}$ b

```
Fmax == 3.25*10^-30 *1 / (z - 0.5*10^-20) ^2 - 5.22*10^-53 *1 / z^4

Fmax == 3.25*10^-30 *1 / (5.0000045991576*10^-21 - 0.5*10^-20) ^2 - 5.22*10^-53 *1 / (5.0000045991576*10^-21) ^4

Fmax == -8.35195 × 10^28
```

Fmax == $\boxed{-8.35195 * 10\text{\^{}}28}$ Fb

Figure 6

Prt Scr picture of calculations in Wolfram Mathematica 5

In figure 6 we have a graph with ranges at which we can see the minimum of a function i.e. place of stabile balance point b ($z = 5.0000045991576 * 10^{-21}m$) and associated maximum attractive force at that point Fb ($F_r'(z) = -8.35195 * 10^{28}N$).

Zero of a function exists at this range, but it is not visible in this graph. For z in point a ($z = 5.0000000062380 * 10^{-21}m$), $F_r'(z) = 0$

And let us define and plot equation (in approximate region) which is better representation of the reality:

$$\boldsymbol{Fr} = \begin{cases} \frac{3.25*10^{-30}Nm^2}{(z-0.5*10^{-20}m)^2} - 5.22 * 10^{-53}\frac{1}{z^4}\,Nm^4, & 5 * 10^{-21}m < z \le 5.00001 * 10^{-21}\mathrm{m} \\ 2.557 * 10^{-29}\frac{1}{z^2}\,Nm^2 - 5.22 * 10^{-53}\frac{1}{z^4}\,Nm^4, & 5.00001 * 10^{-21}m < z < +\infty \end{cases}$$

Figure 7 Equation 1

```
Show[Plot[ 3.25*10^-30 *1/ (z - 0.5*10^-20)^2 - 5.22*10^-53 *1/z^4, {z, 4.99999*10^-21, 5.00001*10^-21}, AxesLabel → {z [m], F[N]}],
 Plot[ 2.557*10^-29 *1/z^2 - 1.34*10^-53 *1/z^4 , {z, 5.00001*10^-21, 10^-19}, AxesLabel → {z [m], F[N]}]]
```

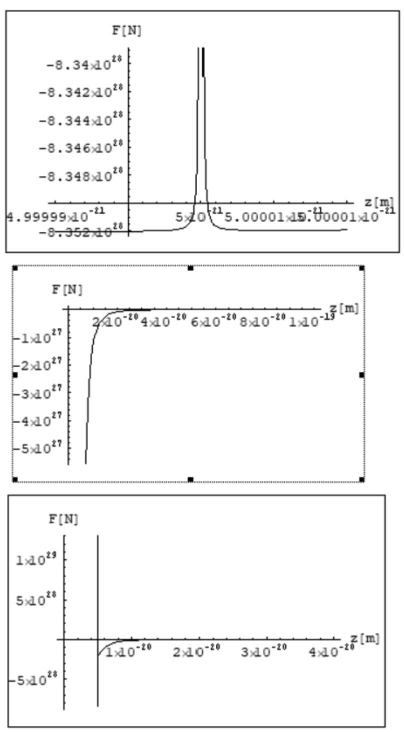


Figure 8

Prt Scr picture of calculations in Wolfram Mathematica 5

The third graph represents the combination of first two.

Our newly defined approximative function Fr have two real zeros, first at:

$$z = 5.0000000062380 * 10^{-21} m$$

And second at:

$$z = 1.43 * 10^{-12} m$$

Minimum value (maximum bond force) of:

$$Fr(z) = -8.35195 * 10^{28} N$$

At point (stabile balance point):

$$z = 5.0000045991576 * 10^{-21} m$$

And bond energy (approximation for two down quarks) of:

$$W = 834.155\, J + 1.39199 * 10^{8} J \approx 1.4 * 10^{8} J$$

In[5]:= $-\int_{5.0000000062380*10^{-21}}^{5.00001*10^{-21}} (3.25*10^{-30} *1/(z-0.5*10^{-20})^2 - 5.22*10^{-53} *1/z^4)\, dz$

Out[5]= 834.155

834.1549861344034`

In[6]:= $-\int_{5.00001*10^{-21}}^{1.42879*10^{-12}} (2.557*10^{-29} *1/z^2 - 5.22*10^{-53} *1/z^4)\, dz$

Out[6]= 1.39199×10^{8}

1.3919916480334085`*^8

Figure 9

Prt Scr picture of calculations in Wolfram Mathematica 5, calculation for bond energy

Some comments

1) Here we have:

Fr(5.00001*10^-21)= -8.3519299*10^28 N

Fr(5.00002*10^-21)= -2.1439657*10^28 N

Good result for the approximative calculations. In reality it will be continuous function even with "down quark as a cylinder" approximation.

2) Calculations and the results for the Up quark that consists of two antidown quarks are identical to this one, with some differences in mass, size etc. It also has an attractive magnetic force and repulsive electric force.

3) We can compare mass [3] and size [12] of the down quark in the neutron to have some idea about size of the down quark in the electron:

$$\frac{10^{-18}m}{8.90 * 10^{-30}kg} = \frac{D}{3 * 10^{-31}kg}$$

$D \approx 3.37 * 10^{-20}m$ Estimated diameter of a down quark within one electron

The end

[1] Robert A. Millikan; R. Nave; Georgia State University;
http://hyperphysics.phy-astr.gsu.edu/hbase/Nuclear/millikan.html
[2] The Millikan Oil Drop Experiment; Ryan McAllister; University of Alaska Fairbanks;
http://ffden-2.phys.uaf.edu/212_fall2003.web.dir/Ryan_McAllister/Slide3.htm
[3] Standard Model; Physik-Institut; Universität Zürich;
https://www.physik.uzh.ch/groups/serra/StandardModel.html
[4] Standard Model of Elementary Particles; Cush;
https://commons.wikimedia.org/wiki/File:Standard_Model_of_Elementary_Particles_Anti.svg
https://commons.wikimedia.org/wiki/User:Cush
[5] Nuclear Binding Energy, R. Nave; Georgia State University;
http://hyperphysics.phy-astr.gsu.edu/hbase/NucEne/nucbin.html
[6] Halliday, David; Resnick, Robert; Walker, Jearl (2013). Fundamentals of Physics. John Wiley & Sons. pp. 609, 611. ISBN 9781118230718.
[7] Kar W. Yung, Peter B. Landecker, Daniel D. Villani, "An Analytic Solution for the Force Between Two Magnetic Dipoles", *Physical Separation in Science and Engineering*, vol. 9, Article ID 079537, 14 pages, 1998.
https://doi.org/10.1155/1998/79537
[8] Magnetic force; https://player.slideplayer.com/39/10911280/#
[9] Perkins, Donald H. (1982). Introduction to High Energy Physics. Reading, Massachusetts: Addison Wesley. pp. 201–202. ISBN 978-0-201-05757-7.
[10] Electric and Magnetic Dipole Moments; Themis Bowcock;
http://www.ep.ph.bham.ac.uk/general/seminars/slides/Themis-Bowcock-2018.pdf
[11] Electron mass, NIST; https://physics.nist.gov/cgi-bin/cuu/Value?me
[12] Nuclear Decay; M.I. Ojovan, W.E. Lee, in; An Introduction to Nuclear Waste Immobilisation;
ISBN 978-0-08-099392-8; https://doi.org/10.1016/C2012-0-03562-4
"…the size of quarks is ~10^−18 m"
https://www.sciencedirect.com/topics/chemistry/up-quark#:~:text=While%20the%20size%20of%20protons,composed%20of%20smaller%20particles%20–%20preons.