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Charged Particle Attraction and Repulsion Explained: A Detailed Mechanism Based on Particle Wave-Functions

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Abstract

The phenomenon of electrical attraction and repulsion between charged particles is well known, and described mathematically by Coulomb's Law, yet until now there has been no explanation for ***why*** this occurs. There has been no mechanistic explanation that reveals what causes the charged particles to accelerate, either towards or away from each other. This paper gives a detailed explanation of the phenomena of electrical attraction and repulsion based on my previous work that determined the exact wave-function solutions for both the Electron and the Positron. It is revealed that the effects are caused by wave interactions between the particles' wave-functions that result in Electromagnetic reflections of parts of these wave-functions, causing a change in the particles' momenta.

Keywords: electrostatic, charge, electron, positron, coulomb, force, attraction, repulsion, wave, function, electric, magnetic, field, static, radiation, pressure, RMS, Shell, Theorem, 3D, computer, model, graphical, space, volume, area, reflection, quantum

1. Introduction

In earlier work [Traill. D. A, 2018, 2005] it was found that the wave functions of the Electron and Positron each comprise a three-dimensional spiral wave that is rotating, such that there is a flow of wave phase either outwards or inwards as it rotates. This direction of the phase flow is what determines if the particle is negatively or positively charged. These spiral wave structures can be further broken down into the sum of inwardly and outwardly traveling spherical spiral waves. It has been shown that the sum of the energies of the Electric and Magnetic fields in these particle wave-functions, integrated over a small volume of space (with the particle at the center) yields that particle's rest mass energy equivalent [Traill. D. A, 2020].

In stable particles such as the electron or positron, there is an energy balance between the inward and outward waves (i.e. the magnitude of the energy of the inflowing waves equals that of the outflowing waves) resulting in no net energy loss/gain for the particle as a whole. The frequencies, amplitudes and speeds of the waves are set such that the energies of the inward and outward waves are identical and each can become the other at the moment they reflect and become Doppler shifted at the nodes of the wave function's structure. This is a guaranteed feature of the wave functions, as they are mathematical solutions to both the Classical and Schrödinger wave equations; thus, they represent temporally stable wave structures. For example, a higher frequency outward wave contains the same energy as the inward wave because its amplitude is lower – two effects and resulting wave energies balance out exactly.

For an Electron, there exists (at any chosen point in space) a phase flow of the wave-function's waves, outward with respect to the Electron's centre. This phase flow causes the attraction/repulsion when it combines with a similar phase flow of other charged particles. The attraction/repulsion is classically associated with the electric field (Coulomb's Law) when it interacts with other charged particle's wave-function. As one moves further from the Electron's centre the amplitude of the waves decreases, so too does the electric field and its associated Coulomb force due to these waves (i.e. lower wave amplitude = lower momentum in waves = lower force on other charged particles). The processes occurring that cause this attraction/repulsion can be analysed in detail based on considerations of the particles' wave-functions and their interactions within the same region of space.

When the wave-function of the electron interacts with that of other charged particles (for example another identical electron), the inward and outward waves of each Electron's wave-function overlap in space. When this

happens, at the interface between the two electrons (at exactly equal distances between each electron's centre) the two outward wave components will form a standing wave and the two inward wave components will form a standing wave – each of these resulting standing waves will have no phase flow in space as an equal amount and frequency of each Electromagnetic wave is coming from each side of the interface location in space. Thus, the node of the standing wave at this interface location will not be moving.

As the overall wave-function of the electron has an outward phase flow, the nodes of the standing wave will be moving outward. The outward wave of the electron normally forms the inward wave when it reflects off a moving node (causing the wave number change between the outward and inward waves), but at this midway point between the two Electrons' centers the node is not moving, so the outward wave will be reflected and Doppler shifted to form an inward wave of higher frequency than usual (Doppler shifted). Similarly, looking at the space between the two Electrons, the nodes from the electron's centre out to the midway point between the two Electrons become progressively slower the further away from the Electron center one gets, until at the midway point between Electrons the node stops completely. Thus, the interface between two electrons provides a frequency conversion, or momentum change of the inward/outward waves in the region between the two Electrons. These frequency/momentum changes will propagate through each node of the Electron's wave function, right back to the electron's centre, thus causing the whole electron to move – this way, the electron has been accelerated.

2. Aim

The aim of this paper and the modelling results it presents is to demonstrate that the known attractive or repulsive force that exists between charged particles can be accurately modelled and explained theoretically using Classical Physics when the wave structure of charged particles (such as the electron and positron) is taken into consideration.

3. Method

The interaction between the dynamic, three-dimensional, Electromagnetic wave structures of two or more such charged particles can account for the observed attraction/repulsion through an incident radiation pressure at the node interfaces in the space occupied by the particle's wave structures.

When Electromagnetic waves reflect perfectly, they impart a radiation pressure equal to twice the incident radiation pressure. So, by identifying all the points in space where such reflection is occurring, over the region containing the two (or more) charged particle wave functions that are interacting, it is possible to calculate an overall radiation pressure that is acting on the particle. When this is done (for example between two Electrons, two Positrons, or an Electron and a Positron) the total force acting on each particle can be determined. Then, by using Newton's 2nd Law (F=ma), the acceleration of each particle can be determined. For two Electrons or two Positrons, the wave reflections occur predominantly in the space between the two particles – thus, causing an outward force that repels each particle from the other. For an Electron and a Positron, the regions that reflect are predominantly outside of the two-particle system – thus, the pressure is from the outside causing an inward, attractive force between the two particles. The following two figures are plots of the magnitude of the x-axis component of the reflected Electromagnetic energy for two different modelled particle configurations: (1) Two Electrons, (2) An Electron and a Positron.

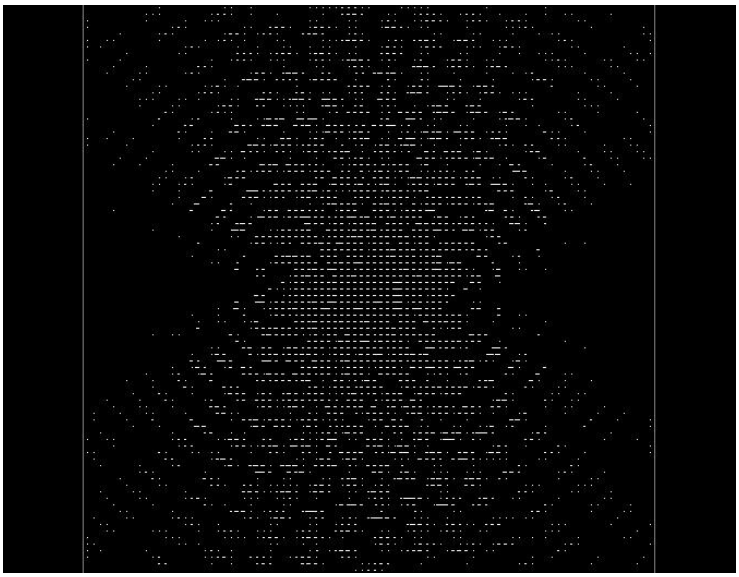

Figure 1. Wave reflections between two Electrons

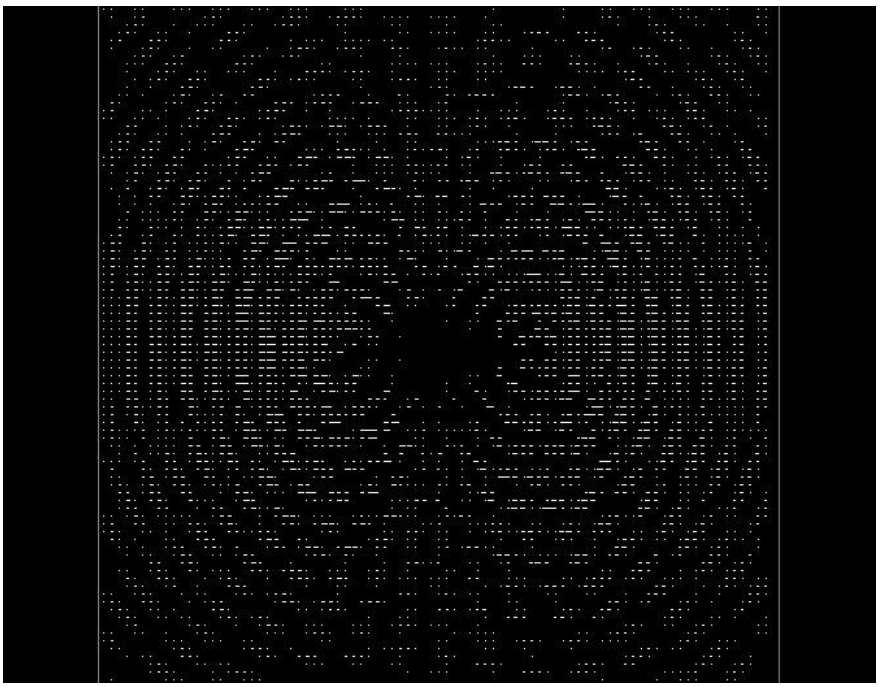

Figure 2. Wave reflections between an Electron and a Positron

The amount of power coupling between the two particles (electrons) depends on the amount of reflection of the waves from each particle on the other. This amount depends on the minimum power of the two interacting waves along the axis connecting the two particle centres (the x-axis in this model), as the waves can only reflect when equal but opposite Electromagnetic wave components meet at the reflection point.

The power values of each Electromagnetic wave are calculated from the Poynting Vector (vector cross product) of the instantaneous Electric and Magnetic field values of the minimum power of the two interacting waves at each point. As these values are instantaneous, the RMS of these values must be taken to get the actual, effective value [Wonseok Shin et al, 2011]:

Electric energy density: $u_e = \frac{\varepsilon_0 \cdot \varepsilon_{RMS}^2}{2}$

RMS in 1 dimension (along the line connecting the two particle centres):

$$\varepsilon_{RMS} = \frac{E}{\sqrt{2}}$$

$$\therefore\ u_e = \frac{\varepsilon_0 \cdot \varepsilon_{RMS}^2}{2} = \frac{\varepsilon_0 \cdot E^2}{4}$$

However, the electron wave-function varies sinusoidally in all of its three dimensions, so the RMS must be taken over all three dimensions:

$$\varepsilon_{RMS} = \frac{E}{\sqrt{2}\sqrt{2}\sqrt{2}}$$

$$\therefore\ u_e = \frac{\varepsilon_0 \cdot \varepsilon_{RMS}^2}{2} = \frac{\varepsilon_0 \cdot E^2}{16}$$

There is an additional factor that determines the amount of power coupling between the two particles - the relative orientations of the polarizations of the two waves and how much they align and thus, reflect off each other. As the interface area between the two electrons is a circle, the amount of coupling between the two Electromagnetic waves will vary sinusoidally (around this circle) with the angle difference between the polarizations of the two waves.

However, this effect is taken care of in the maths as the dot product of the two Electromagnetic waves is used to determine the amount of reflection during the calculation of the total reflected power between the two particles' wave-functions. See **Appendix A** for an extract of the code used to determine the acceleration between the two electrons.

The Power value obtained is then converted into a pressure by dividing by the speed of light. To work out the actual force between the two particles we need to simplify the calculation by conceptually reducing each particle to a point particle at its wave-function centre, with an effective area of interaction of one grid point in the model. The force between them is due to wave reflections at the mid-way point between them - where waves from each side are equal.

In a similar way to the Shell Theorem for gravity, where the force between two bodies due to the mass of one spherical body can be treated as all coming from a single point at that spherical body's centre of mass, the attractive/repulsive force between charged particles can be treated similarly, but centered around the charged particle's center of charge.

If we start from the situation where both particles are together at the same point, then there is a single grid point of area interacting between them. As the particles move apart, the volume of the sphere from each particle's centre to the mid-way point between them represents all of the contributing grid points to the total force attributed to the single central point.

So, in order to keep the area of interaction between the particles as one single point (one grid point of area, in the model's calculation) we must divide by the rate of increase in the volume (V) of the sphere over the distance from the mid-way point (R) to the particle's center. This quantity is given by dV/dR.

As the volume of a sphere is:

$$\mathrm{V} = \frac{4}{3}\pi R^3, \qquad \frac{dV}{dR} = 4\pi R^2$$

Then expressing this differential in terms of the separation distance (r) between the particles, as r = 2R, we have:

$$4\pi R^2 = 4\pi\left(\frac{r}{2}\right)^2 = \pi r^2$$

Where r is the number of modelled grid points between the two particle centres.

Once this has been done, the actual force between the two particles can be determined by multiplying this pressure by the area of a single grid point.

So, the total Electromagnetic power (P) imparted on each particle is:

$$P = \frac{1}{\pi r^2} \sum \left(P_A \frac{1}{16} \right) dA$$

Where P_A is the instantaneous Electromagnetic power at each area element within the modelled region.

Thus, the Instantaneous Pressure [Wikipedia, Radiation pressure, 2020] is:

$$\mathrm{I} = \frac{\mathrm{P}}{\mathrm{c}}$$

Where c is the speed of light.

The acceleration of the particle is thus:

$$A = \frac{F}{m}$$

When the model is run (configured for two Electrons repelling), and the results are recorded for a range of different modelled data points in the 3D space, a graph can be obtained comparing the calculated Electron Acceleration compared to the known Electron acceleration (determined using Coulomb's Law). I have done this for x, y, and z-axis data points ranging from 100 to 270 data points along each axis. Due to memory constraints on the computer, I cannot model a region of space with more than 270 points along each axis, but as you can see from the following graph, as the number of modelled points increases (and thus, the accuracy of the calculation), the percentage match between the model and the known acceleration approaches 100%.

4. Results

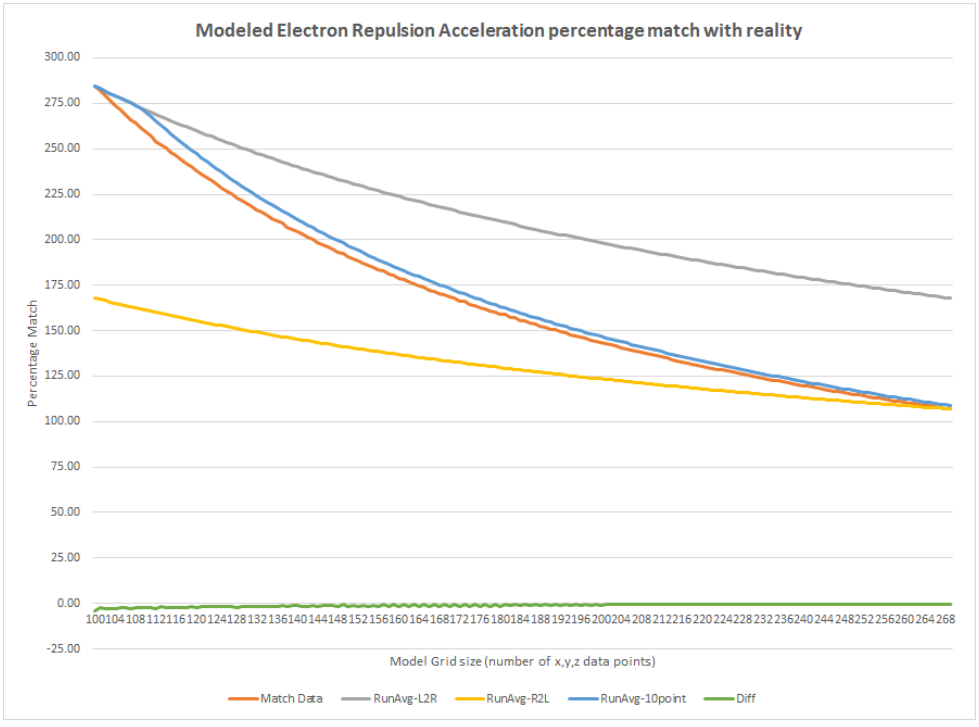

Figure 3. Percentage match between the model and reality over number of modelled grid points. Modelled space was 6.0E-11 metres cubed. The separation of the two electrons was 6.0E-11 metres

As you can see, the accuracy of the model's calculations increases as the number of modelled points increases (as one would expect) and the curve asymptotes to a 100% match with the expected electron acceleration (given by Coulomb's Law).

There are 4 curves plotted in Figure (3). They are as follows:

(1) **Match Data**: The actual percentage match value for a given model configuration.

(2) **RunAvg-L2R**: A continuous running average value, starting with the first data point (on the Left-Hand side of the graph and moving to the Right).

(3) **RunAvg-R2L**: A continuous running average value, starting with the last data point (on the Right-Hand side of the graph and moving to the Left).

(4) **RunAvg-10point**: A 10-point windowed running average value of the match data.

(5) **Diff**: The amount of difference between successive data points.

Also, a plot can be made of the modelled acceleration between the two electrons over a range of particle separations (from 1% to 100% of the actual modelled width; which in this case is 5.8E-11 meters):

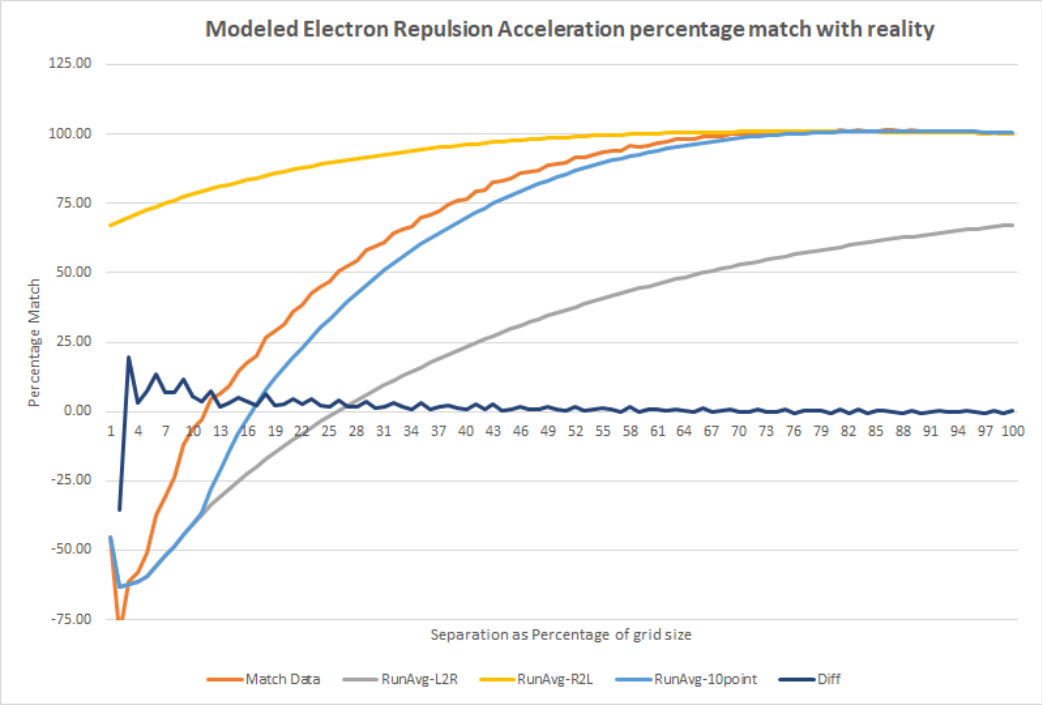

Figure 4. Percentage match between the model and reality over separation distance as a percentage of the modelled space. Modelled space was 5.8E-11 metres cubed

As you can see from the plot, at very short ranges, the normally repulsive force between the electrons becomes attractive. This effect is a known effect. See reference [Puthoff. H. E et al, 2004] for discussion on this in regards to Casimir forces, but my finding may also be contributing to the observed charge clumping at high charge densities.

Then at about 10% of the distance (5.8E-12 metres), the force between the two electrons becomes repulsive, and reaches about 100% of the expected classical value from about 72% of the modelled distance onwards. This distance equates to about 4.176E-11 metres between electron centres.

5. Conclusion

Modelling electrons and positrons as spherical standing waves according to the wave-function equations determined earlier [Traill. D. A, 2018] and the electrostatic interactions (Coulomb forces) between such charged particles as being due to the radiation pressure between such standing waves (due to the interactions between the waves that comprise the wave-functions) is able to predict, quite accurately, the known amount of

attractive/repulsive force between such particles in the real world. Only simple, known Classical Physics principles have been employed here in the model and the explanation for the Coulomb forces.

With all of these model calculations there is a balance between the size of the actual physical space being modelled and the number of modelled data grid points within that space. To get more accurate calculations we would need a larger number of data points per wavelength of the electron wave-function's waves, but to get a greater proportion of the electron's energy being included in the calculations, we would need a greater physical size of the space being modelled.

These two requirements work in opposite directions, and due to memory constraints and computation time, the maximum number of data points along each size of the modelled cube of space that is able to be achieved with the current computer model is 270. Doubling the number of points down each side results in 8 times as many points in space, and each data point in the model's code holds many different data variables for each of the possible fields being calculated when the model runs, which has the effect of multiplying the memory requirements by a lot more than a factor of 8.

The two graphs I have presented here are about as good a balance between these competing requirements that I can achieve with my current modelling capability. I'm sure that someone with a supercomputer could do a much better job of this modelling, but unfortunately, I do not have one nor have access to one.

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Appendix A: The Code Used to Determine the Acceleration From the Two Particle's Wave-Functions

```
PowerCount_neg:=0;
  PowerSum_neg:=0;
  PowerCount_pos:=0;
  PowerSum_pos:=0;

  p1_p2_diff:=abs(particle2_x - particle1_x);

  for xpos:=0 to GridWidth-1 do begin {scan grid's x coords}
   for ypos:=0 to GridHeight-1 do begin {scan grid's y coords}
    for zpos:=0 to GridDepth-1 do begin {scan grid's z coords}
     Power_x1:=particle1_Power[xpos, ypos, zpos].x;
     Power_x2:=particle2_Power[xpos, ypos, zpos].x;

     vect:=particle1_E[xpos,ypos,zpos];
     vect2:=particle2_E[xpos,ypos,zpos];
     vect.x:=0;
     vect2.x:=0;
     vect:=Normalize(vect);
     vect2:=Normalize(vect2);
     dot_v1v2:=abs(VectorDot(vect,vect2));

     // The Force imparted upon reflection is double the incident radiation pressure
     reflected_power:=2*dot_v1v2*min(abs(Power_x1),abs(Power_x2));

     ReflectedPowerAtPoint:=0;

     if ((Power_x1 > 0) and (Power_x2 < 0)) then begin
      if (xpos > particle1_x) and (xpos < particle2_x) then begin
       ReflectedPowerAtPoint:=ReflectedPowerAtPoint - reflected_power;
      end
      else begin
       ReflectedPowerAtPoint:=ReflectedPowerAtPoint + reflected_power;
      end;
     end
     else if ((Power_x1 < 0) and (Power_x2 > 0)) then begin
      if (xpos > particle1_x) and (xpos < particle2_x) then begin
       ReflectedPowerAtPoint:=ReflectedPowerAtPoint - reflected_power;
      end
      else begin
       ReflectedPowerAtPoint:=ReflectedPowerAtPoint + reflected_power;
      end;
     end;

     if ReflectedPowerAtPoint < 0 then begin
      Inc(PowerCount_neg);
      PowerSum_neg:=PowerSum_neg + ReflectedPowerAtPoint;
```

```
47        end
48        else begin
49          Inc(PowerCount_pos);
50          PowerSum_pos:=PowerSum_pos + ReflectedPowerAtPoint;
51        end;
52
53      end; // for zpos
54    end; // for ypos
55  end; // for xpos
56
57  // Total Pressure = The sum of both the Positive & Negative Power
58  // divided by speed of light
59  Pressure:=(PowerSum_neg + PowerSum_pos)/SpeedOfLight;
60
61  // The actual pressure at a single, central grid point is 1/πr^2,
62  // where r is the number of grid points between the two particle centres.
63  Pressure:=Pressure/(Pi*sqr(GridWidth*p1_p2_diff*dx/ActualWidth));
64
65  // Total force is pressure * the area of 1 point
66  Force:= Pressure*PointArea;
67
68  Accel:=Force/ElectronMass; // F = m*a
69
70  ExpectedAccel := sqr(ElectronCharge)/sqr(ActualWidth*(p1_p2_diff/GridWidth));
71  ExpectedAccel := ExpectedAccel * Ek/ElectronMass;
72
73  AccelPercentageMatch := 100*Accel/ExpectedAccel;
```