Casimir attraction between electrons

By: Ray Fleming

Summary
In a previous paper the author showed that the Casimir force between protons is strong enough to account for the nuclear force. The purpose of this paper is to investigate if the Casimir force between two electrons computed by using a proximity force approximation is also strong enough to overcome Coulomb repulsion. The electrons are approximated as shells on the scale of the Compton wavelength, since their mass-energy has been shown to be consistent with a shell structure on that scale. It was determined that the Casimir force between two electrons is strong enough to overcome Coulomb repulsion such that there is a strong attraction between them. This is important as it gives us a mechanism to explain electron charge clustering.

PACS: 03.70.+k, 12.60.-i, 13.66.-a

Background
One of the many great mysteries of physics is why electrons tend to form clusters when due to electric repulsion alone they should expand to fill all available space. To understand the problem better we can consider a cold cathode arc lamp. With such a lamp the generation of arcs is dependent on many factors including arc length, electrode shape, fill gas, gas pressure, capacitance, impedances and last but not least voltage. There also appears to be a minimum amount of charge needed to form an arc, as the author's experiments with alternating current vacuum arc discharge lamps in a x-ray emitting configuration operating at 100 kilovolt potential showed the minimum current per pulse was in the 10-15 millijoule range. That works out to more than 100 billion (10^{11}) electrons per pulse.

To our naked eye and electronic detectors these electrons travel in a line rather than fill the available space. And, if you put a current transformer around the path and look at the current flow on an oscilloscope you find that they travel in a small packet rather than a continuous stream. The measured width of each packet is limited by the detection system with most common equipment. Consequently we find that electrons somehow form these large clusters even though they should be well distributed if electrostatic forces alone are considered. The same thing happens with static electric arcs we all experience and with lightning, not to mention truly unusual phenomena such as ball lightning.

There must be some force that keeps the electrons together. It has been hypothesized that there are positive charges, e.g. protons, mixed in to help bind the electrons together, but the proton mass is much larger than the electron, so it could not accelerate as fast as an electron arc even if it could accelerate the wrong direction. There is no mechanism for free positrons to be produced either and once again they would be have to accelerated in the opposite direction in an arc lamp to be of any help in holding the electrons together.

Perhaps there is some type of virtual electron-positron interaction. Perhaps so, but as it turns out not in the way one might first think.

Another possibility arose after the author determined that the Casimir force between protons is strong enough to overcome Coulomb repulsion and account for the nuclear force as presented in a paper titled "*The nuclear force computed as the Casimir effect between spheres*."[1] It was realized that a Casimir force between protons was possible after it was determined that a proton interacts with the vacuum as if it were a spherical shell, since the mass of a proton is due to the vacuum energy excluded by a spherical shell the size of the proton charge radius. This was described in a paper titled "*Proton and electron mass derived as the vacuum energy displaced by a Casimir cavity*."[2] As the title states the electron is also in the form of a spherical shell as far as vacuum fluctuations are concerned. This led to the idea that perhaps electrons are bound together in clusters due to Casimir forces.

Investigation

As in the previous paper the Casimir force between two electrons can be computed using a Proximity Force Approximation (PFA) equation for two spheres.[3] The energy equation for two spheres with a common radius *a* and minimum distance between them *L* is shown in Equation 1.

1)

$$E = -\frac{\hbar c \pi^2}{1440} \frac{\pi a^2}{L^2(2a + L)}$$

We can note that *a* is the radius of the electron, which is a constant. We can then use the value for the charge radius for the electron 1.592×10^{-12} meters (or 1.592 pm) as derived by the author in the mass derivation paper.[2] Note that the charge radius of an electron due to electron scattering has never been formally determined, but the diameter is known to be on the scale of the Compton wavelength. That said, the following result is similar to the result if the Compton wavelength is used as the electron diameter. To continue we can then note that *a* is similar in magnitude to *L*, such that we can treat it like a multiple of *L* and solve for the energy and the differentiate to determine the force. The force equation for the special case where a=L is shown in equation 2.

2)

$$F = -\frac{\hbar c \pi^3}{5760} \frac{1}{L^2}$$

That can be compared to the Coulomb repulsion computed by Equation 3.

3)

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2}$$

Computation

By repeatedly substituting for *a* in terms of *L* the Casimir force was calculated for minimum approach distances *L* between the two electron's spherical shells in 0.1pm increments from 0.1pm to 1 pm and 1pm increments from 1pm to 11pm. The Coulomb repulsion was also computed using the electron charge and the distance between the centers of the spheres based on the same distance *L*. Lastly the ratio of the Casimir force over the Coulomb force was determined. The results are in Figure 1.

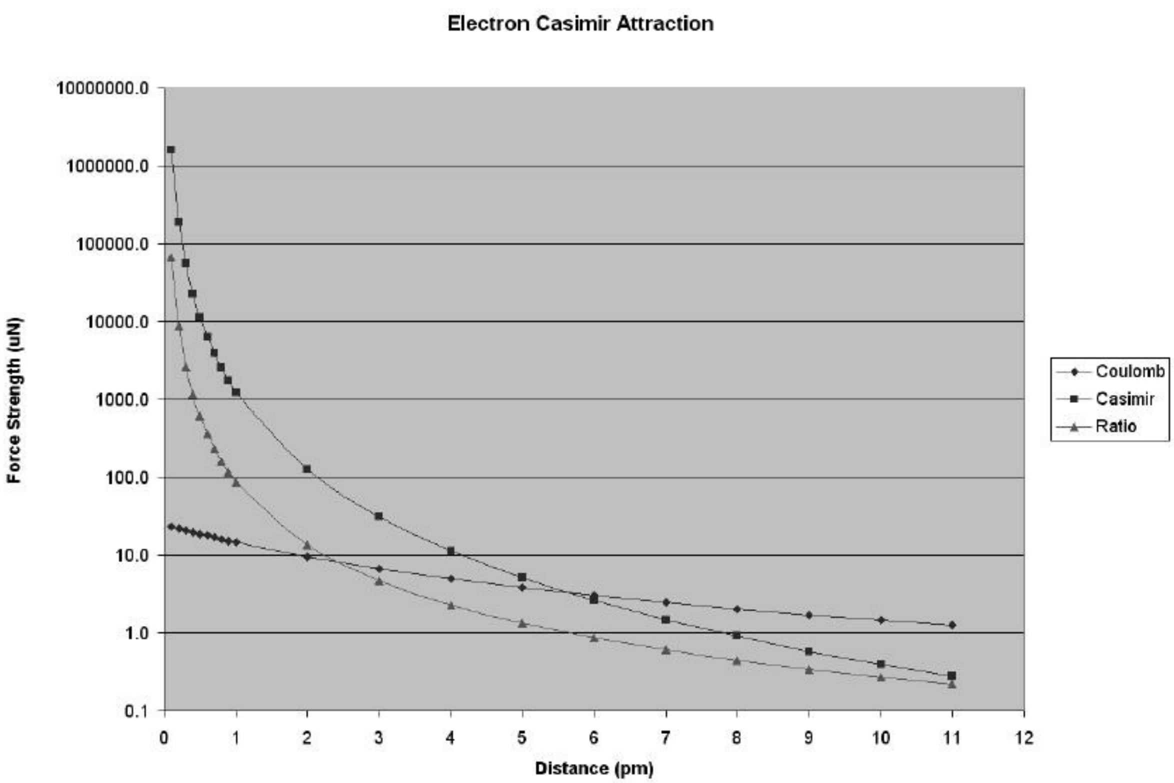

Figure 1 Chart comparing the Casimir attraction versus the Coulomb repulsion between two electrons. The data was plotted with a logarithmic Y scale given the rapid change in the Casimir force for distances less than 2pm. The ratio line crosses 1.0 between 5pm and 6pm indicating net attraction at closer distances.

At 6pm the attractive Casimir force is 2.6micronewtons (μN) while the Coulomb repulsion is 3.0μN. At 5.65pm the Casimir force has strengthened to 3.25μN overtaking the Coulomb repulsion. As the nucleons approach 1pm the Casimir force reaches 1237μN while the Coulomb repulsion is only 14.5μN, so the Casimir force is now 85 times stronger than Coulomb repulsion. The intensity of the Casimir force between electrons is sufficient to explain the electron clustering phenomena.

Discussion

As with the proton this computation shows that if the electron's surface were infinitely fine the force becomes exponentially stronger as the two electrons approach. There is no known force that is strong enough to oppose such a strong Casimir force, so something must cause the Casimir force to be reduced at closer distances. The simplest explanation would be if the structure of the electron were not infinitely fine. The proton has a charge radius of 0.8775fm (CODATA 2010), but the nuclear force diminishes over the 0. 5fm to 0.7fm distance range. It is expected that the Casimir force between electrons will similarly diminish over the 0.9pm to 1.2pm distance.

In another paper the author speculated about a semi-classical particle structure that would account for the electron properties including having large enough openings to limit the range of the Casimir force on this scale. [4]

Conclusion

While the Casimir effect is usually thought of as a very weak force, PFA computations show that it becomes relatively strong at distances less than 10pm between electrons. The magnitude of this force is sufficient to overcome Coulomb repulsion between electrons leading to a net attractive force between free electrons. This force provides an explanation for the electron clustering we observe in every day phenomena such as arc lamps and static electricity while also providing a mechanism to explain more unusual phenomena such as ball lightning.

Additional research needs to be conducted to determine the electron charge radius due to electron scattering, so that more precise calculations can be made. Experiments should also be conducted to confirm the Casimir force between electrons, which should also confirm the expected effective range and magnitude of the force.

[1] Fleming, R., The Nuclear Force computed as the Casimir effect between spheres (2014), http://vixra.org/pdf/1403.0006v1.pdf
[2] Fleming, R., Proton and electron mass derived as the vacuum energy displaced by a Casimir cavity (2012), http://vixra.org/pdf/1203.0033v1.pdf
[3] Bulgac, A., Magierski, P., Wirzba, A., " Scalar Casimir effect between Dirichlet spheres or a plate and a sphere," Phys. Rev. D 73, 025007 (2006). doi:10.1103/PhysRevD.73.025007
[4] Fleming, R., Investigation of the rhombic triacontahedron as a semi-classical particle model (2014), http://vixra.org/pdf/1403.0055v1.pdf