Zero-Point Energy and its Effects

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ABSTRACT

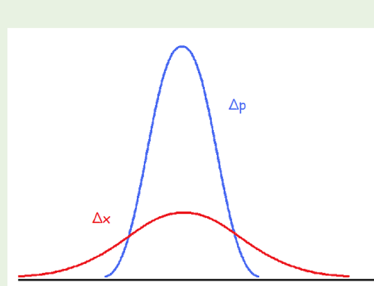
Zero-point energy (ZPE) is energy associated with the vacuum, or where temperature is near absolute zero. Individuals such as Dirac, lamb, Casimir, and even Einstein will make significant progress in proofing the existence of ZPE. In this poster, we would discuss the various contribution of these individuals. We will look at Heisenberg's uncertainty principle and how ZPE is a direct implication of this principle. We will touch on some aspect of quantum field theory, the Casimir effect, dynamic Casimir effects, and experiments attempting to use Casimir effect in nanotechnology.

Introduction

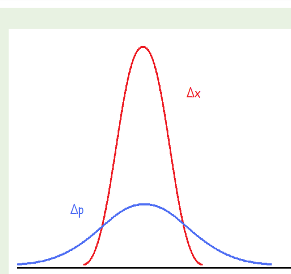
When we think of the vacuum, we generally associate it with a void or empty region that has no energy or matter. However, is it really empty? In quantum field theory, the world around us can be thought of as a wave of (matter or energy) field and wave of force field. The places we find matter and the behavior of certain forces, such as strong nuclear force, is simply a pick of the wave's amplitude. Thus, in a vacuum, the matter wave still exists but it could be thought of as being at the trough. This means somewhere in between the peak and trough is a state where matter can exit and seamlessly not, even in the vacuum.

Heisenberg's Uncertainty Principle

- States that some pair of properties, including position and momentum, are intricately connected.



- You can not get accurate information on both pairs at the same time.



- The uncertainty principle can be used to relate the time and energy of a quantum system.

$$\Delta E \, \Delta t \geq h$$

- For this reason, you could never truly know both quantities simultaneously in a quantum system. More specifically, when E increases, t gets smaller and vice versa.
- Zero point energy is an implication from the concept above.

Dirac's Sea of Negative Electron

- In 1930 the British physicist postulated the idea that space contain infinitely many electrons with energy from negative infinity to 0.
- Every now and then, one of these electrons gains enough energy to cross zero. This is when we can interact with it.
- If one of these electrons is removed from the sea, Dirac postulated that the void left would mimic the absent electron but will have a different charge.
- If an electron with different charge but same mass came across this void, it falls into the void and annihilates, releasing a certain amount of energy.
- Dirac had just predicted the existence of the antimatter particle.

Einstein Contributions

Einstein laid much of the ground work for the experiment that would describe the effects of ZPE. Dirac's work was essentially based on Einstein theory of relativity, which is why it is sometimes referred to as relativistic quantum mechanics. This gives the foundation for which it describes the energy of a massless particle, such as a photon that requires that the last equation, when M is set to zero, becomes the momentum of the particle multiplied by the speed of light.. Quantum mechanics comes into play when you equate this to Plank's Constant multiplied by the speed of the particles.

$$E= mc^2 \longrightarrow E= \frac{mc^2}{\sqrt{1-(v/c)^2}} \longrightarrow p= \frac{mv}{\sqrt{1-(v/c)^2}}$$

$$\boxed{E= \sqrt{(pc)^2+(mc^2)^2}} \qquad \boxed{E= pc = hv}$$

Lamb Shift

In 1947, Willis lamb measured an effect that showed, in a vacuum, an electron in an hydrogen atom gets affected by energy fluctuation . This was particularly noticeable as the electron was able to jump orbit.

The Casimir Effect

Background

In 1948, a Dutch physicists, by the name Hendrik Casimir, formulated a theory which states that if two identical conducting plates (not charged) are placed in a vacuum and separated by a distance, then they would begin to attract each other.

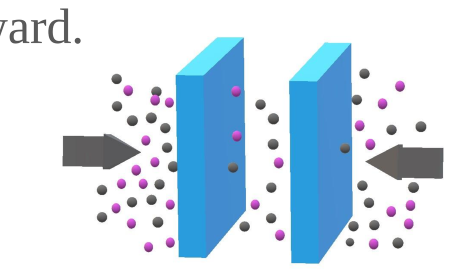
- The Casimir Effect is both relativistic and quantum by nature, as it both relies on the plank constant and the speed of light for constants, similar as to how G is to gravity.
- The magnitude of the force is inversely proportional to the area of the plates and the distance between them.

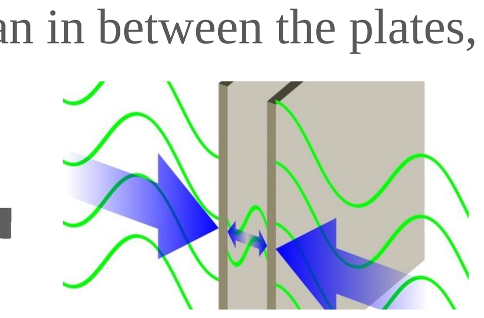
$$P(z)= \frac{f(z)}{s} = \frac{\pi^2}{240}\frac{hc}{z^4}$$

But why?

Lets take a photon for example: it exhibits both the properties of a mass and wave, and can simply be taught to be a quantized packet of energy .

- We can, with good precision, measure the energy and time of the emergence of this photon.
- As such, every now and then, the photon can have some energy.
- This means that particles in the vacuum can simply pop into existence.
- Every time a particle pops in. it brings its counterpart (antimatter particle) so that, when both particles collide, they annihilate and pop out of existence.
- With plates in the vacuum, these photons (virtual photons) begin to collide with the surface area of the plate outside and inside before they pop out of existence.
- Collision with the surface area is more frequent outside the plates than inside.
- This results in more momentum outside the plate than in between the plates, causing the plates to move inward.





Conclusion

In conclusion, zero point energy is one of the many fascinating topics in quantum physics. However, it is also one that has provided the breeding ground for pseudo science that says free energy can be harnessed; this is simply not the case. Regardless, there are still potential applications for it, as the attractive force mechanics is similar to that of Vander der Wal forces and could be used in nanotechnology someday.

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