

## Zero Point Energy

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### Abstract

Zero point Energy/ zero point fields are not the new issue in the arena of physics but we feel new. Here, I am not going to set up a model to calculate zero point energy in particular case but collect some ideas and give definition of zero point energy, based on earlier brief attempts and present two ways of getting zero point energy in nature and some calculated result of zero point energy in some special cases. These things provide some ideas about zero point energy and substantiate the entity of zero point fluctuations and zero point energy in vacuum even at absolute zero.

In general, zero point energy refers either to energy at absolute zero or to Zero energy (i.e. no energy). A B.Sc. third year student of Prithvi Narayan Campus heard the word “zero point energy” and asked me during his final year physics practical examination, when I was there as an external examiner. I replied him to meet me tomorrow at the Campus but I could not see him at that place and time. I thought to write a short note on the title ‘zero point energy’ and to be published for the benefit of the students.

The energy of a body or system in classical mechanics is defined only in relation to the motion or its given position. According to ‘ $E = (1/2)mv^2 + mgh$ ’ the body at motionless and at ground level has zero energy. It means the energy of a system is a relative term, which may be defined in terms of given state of the system.

In thermodynamics the energy of the system depends upon absolute temperature (T) of the system. The stationary system at absolute zero has zero energy in the ground of thermodynamics. But in quantum mechanics the energy of a system is always associated with the expectation value of Hamiltonian operator, which is given by formula,

$$E = \frac{1}{2}h\nu + \frac{h\nu}{e^{\frac{h\nu}{kT}} - 1}$$

Where h is Planck’s constant,  $\nu$  is the frequency and k is Boltzmann’s constant.

The lowest possible energy that a system has at ground state is first proposed by Albert Einstein and Otto Stern in 1913 was termed as zero point energy. There is significant amount of energy at ground state even at absolute zero of a quantum system as well as in vacuum of empty space. Actually, every oscillator or quantum system has a residual energy even at

absolute zero, such non zero-energy is,  $(\frac{1}{2})h\nu$ , which is the residual energy of the quantum system and later called zero point energy.

When we talk about vacuum, we usually think the empty region of space or field free space. Actually in Quantum / modern physical point of view, the vacuum is different and far from empty. When we remove all particles and all electromagnetic radiations from a region of space at absolute zero then, there will be an apparently empty region of space at absolute zero. In fact this region i.e.; “vacuum” will still be full of energies and particles pairs. All these particles and energies are referred to as the quantum vacuum. The “vacuum”, thus has zero point fluctuations as well as the zero point field and hence zero point energy. So that, it is referred to as the quantum vacuum zero point energy. This zero point field hypothesis was first put forward by Max Planck in 1911 and later developed by Max Planck and Walther Nernst during 1911 to 1916 A.D. Willis Lamb is the first scientist who carried out a famous experiment in 1947 to reveal the zero point field (ZPF) which he himself described as “a proof that the vacuum does not exist”. Right after Willis Lamb, Casimir evaluated the attractive force between parallel metallic plates separated by vacuum and suggested a model for charged particles on the basis of that result. Accordingly, the electron, a conducting sphere, is a charge and its coulomb self-energy is balanced by the quantum electromagnetic zero point energy, c where he considered it would be negative. But Boyer calculated the zero point energy and found that positive, thus Casimir’s model cannot account for the stability of charged particles.

When we go back to the past history about the source of the zero point energy/field (ZPF), we will get two

schools of thought. The first idea or consideration is that it is simply the component of the passive boundary conditions of the universe such as 3-k cosmic background radiation left over from the big bang. The second thought is that the zero point fluctuation spectrums is dynamically generated by the motion of the charged particles everywhere which are themselves undergoing ZPF-induced motion.

Many scientist, physicist and mathematicians calculated the zero point energy in different cases. Some of them are given below:

Case (I). Quantum electromagnetic zero point energy of a conducting spherical shell of radius,  $a$  is given

by the formula  $\Delta E (a) = \lim_{R \rightarrow \infty} E_I + E_{II} - E_{III}$ , It consists of three regions / two concentric spheres: the interior of small sphere (I), the concentric shell between the two spheres (II), and the interior of the large sphere when small sphere is absent (III) and the universe of radius  $R$ . Each of the regions has zero point energy defined by,  $E = \sum_k \frac{1}{2} \hbar \omega_k$ . By using Mellin Transform, the numerical value of zero point energy was found to be,  $\Delta E (a) = +0.9243$ .

Case (II). Zero-point energy in bag models was calculated by using the relation.<sup>5</sup>

$$E_{\text{interior}} = E_{\text{shell}} - E_{\text{exterior}} \text{ Where, } E_{\text{shell}} = \frac{0.04618}{a}$$

Here  $E_{\text{shell}}$  is cutoff ( $\delta$ ) independent term,  $a$  is radius of a spherical cavity imbedded in a perfect conductor.

$$E_{\text{exterior}} = \frac{1}{\pi a} \left( \frac{4}{3\delta^2} - \frac{1}{8} \right) + \frac{3}{128a}$$

Thus, the zero point energy of a single free vector field confined by a spherical cavity is

$$E_{\text{interior}} \cong -\frac{4}{3\pi \cdot a \delta^2} + \frac{1}{128a} \left( \frac{16}{\pi} + 3 \right)$$

The cutoff dependent term in this equation has the form predicted by Balian and Bloch.

In conclusion, zero point energy has been introduced in this article as the residual energy of

an oscillator even at absolute zero and in vacuum as well. As we have mentioned the ways of origin of electromagnetic zero point energy: one is the passive boundary condition of the universe and another is the dynamically generated by the motion of the charged particles which are true in real sense. Moreover, the calculated result of two cases; quantum electromagnetic zero point energy of a conducting spherical shell and zero point energy in bag models have been incorporated for the real hallucination. Thus, the subject matter exposed here is not my proclamation, but the findings of admired scientists. I have just introduced here in this manner.

### Acknowledgments

I wish to express heartfelt appreciation and thank to Mr. Kapil Adhikari, a research fellow in Texas University, USA, for providing the materials and journals, without his help this paper in this form were unattainable. I also wish to thank Prof. L N Jha, HOD, CDP, Kirtipur. Associate Prof. Dr. S K Lamichhane and Kul Pd Dahal, PN Campus, Pokhara for their constant stimulation and encouragement. Last but not least, thanks to the unnamed pupil who asked me the query in zero point energy in dark room of physics lab at PNC compelled me to prepare this article.

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