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Empty Space, Aether and Vacuum

2.1 The Coordinate Space

The crisis of modern physics can be attributed to a wide spread mix-up between the abstract mathematical notions and the physical concepts of space. Therefore, we need to bring out a clear distinction between the two notions of space in vogue. The first notion is that of a mathematical or coordinate space and the second is that of physical space. Let us consider them one by one.

The cardinal idea responsible for the invention of coordinate systems by Descartes consists of the assumption that to each real number there corresponds a unique point on a straight line. The association of the set of points P on coordinate line X with the set of real numbers x, constitutes a coordinate system of the one-dimensional space, once the notion of certain unit length has been defined. The one-to-one correspondence of ordered pairs of numbers with the set of points in the plane X^1X^2 is the coordinate system of the two-dimensional space. The extension of this representation to points in a 3-dimensional space is obvious. With predefined notion of unit length, the essential feature of it is the concept of one-to-one correspondence of points in space with the ordered sets of real numbers. The predefined notion of unit length or scale for different coordinate axes constitutes the metric of space for quantifying the position measurements of the sets of points in this coordinate space. [1]

We define a space (or manifold) of N dimensions as any set of objects that can be placed in a one-to-one correspondence with the ordered sets of N numbers $x_1, x_2, ..., x_N$ such that $0 \leq x_k <$ infinity. Any particular one-to-one association of the points with the ordered sets of numbers ($x_1, x_2, ..., x_N$) is called a coordinate system and the numbers $x_1, x_2, ..., x_N$ are termed the coordinates of points in the coordinate system. In all coordinate spaces that are metricized, we associate the notion of unit length along all coordinate axes and a metric tensor g_{ij} with each coordinate system. All essential metric properties of a metricized space are completely determined by this tensor.

A necessary condition for the equality of mixed partial derivatives of a function u(x,y) is that u(x,y) be of class C^2; that is, the function together with its first two partial derivatives are continuous. But this restriction alone is not sufficient to insure the equality of mixed covariant derivatives. It can be shown that, if the order of covariant differentiation

is to be immaterial, our tensors must be defined over a particular metric manifold X for which a certain tensor of rank four, made up entirely of the g_{ij} components, vanishes. This tensor known as the Riemann - Christoffel tensor R_{ijkl} plays a basic role in many investigations of differential geometry, dynamics of rigid and deformable bodies, electrodynamics, and relativity.

2.2 The Physical Space

The notion of physical space implies the spatial extension of the universe wherein all material particles and all fields are embedded or contained. The true void between material points is in essence the physical space. Any region of space which is devoid of any material particle is known as empty space or free space. It is important to note here that the coordinate space, along with its scale or metric, is our 'human' creation intended to facilitate the quantification of relative positions of material particles and fields. The existence of physical space does not depend in any way on the existence or non-existence of coordinate systems and coordinate spaces. Of course, for the study and analysis of physical space and the material particles and fields embedded in it, we do need the structure of coordinate systems and coordinate spaces as a quantification tool. The most significant point to be highlighted here is that whereas the metric scaling property is only associated with coordinate spaces, the physical properties of permittivity, permeability and intrinsic impedance are only associated with the physical space. Even though the notion of material particles and 'fields' being embedded or contained in the physical space, is generally accepted yet, the detailed mechanism involved in this embedding is not known. Obviously, such a mechanism must involve the known physical properties of free space.

2.3 Notion of Aether, Vacuum or Quantum Vacuum

In 19th century Physics, the notion of an all-pervading medium called aether was considered a necessity for distinguishing the concept of physical space from that of the coordinate space. However, some self-contradicting properties had to be ascribed to this aether. It was supposed to be an extremely thin medium to enable resistance free motion of solid bodies through it. At the same time it was required to be an elastic solid to enable the transverse (light) wave propagation through it. This was essentially due to the fact that matter and aether medium were regarded as two separate, independent entities. Maxwell's development of the electromagnetic theory of light, the null result of Michelson-Morley experiment and Einstein's special theory of relativity, apparently

rendered the notion of aether superfluous. Electromagnetic field was granted an independent status, capable of independent existence just as matter. The relativity theories just brushed aside the very necessity of aether by declaring through its postulates that the coordinate space is de-facto the physical space.

Now, there is a growing realization in scientific circles that matter and electromagnetic field, both appear to have a common origin in empty space or vacuum. There is also a notion of vacuum energy and the phenomenon of creation, annihilation and transmutation of unstable elementary particles occurring in vacuum. As per the current viewpoint, empty space or vacuum no longer represents 'nothingness' but is supposed to be the seat of, or supporter of, all ultra-microscopic phenomenon of nature. This entity representing the old 'empty space' or vacuum has now been assigned a modern name of 'quantum vacuum'. This reincarnation of poor old aether certainly looks much more sophisticated and acceptable. The 'quantum vacuum' is thought of as - "a seething froth of real particle-virtual particle pairs going in and out of existence continuously and very rapidly". The quantum vacuum is considered to be a dynamic condition of equilibrium in which this reversible process is occurring everywhere extremely quickly. In reality however, all these notions of physical space, empty space, vacuum, aether and their modern reincarnation the quantum vacuum, all mean the same entity – call it by any name. Hence, the physical space continuum, referred by any other name like vacuum or quantum vacuum or aether will still have the same physical properties. We will however, prefer to call this entity 'Elastic Space Continuum'.

2.4 Physical Properties of Vacuum or Aether

Fundamental properties of this vacuum or empty space are represented by the following dimensional parameters.

Permittivity of free space $= \varepsilon_0 = 8.854 \text{ X } 10^{-12}$ Coulomb^2 /N. m^2

Permeability of free space $= \mu_0 = 1.257 \text{ X } 10^{-6}$ Weber / Amp. m

$= 1.257 \text{ X } 10^{-6}$ N / Amp^2

Speed of propagation of EM waves in vacuum = $c = 2.998 \text{ X } 10^8$ m/s

The intrinsic impedance of vacuum $= Z_0 = 377$ Ohms

These four parameters are dimensional constants and hence represent fundamental physical properties of vacuum. The speed c of propagation of electromagnetic disturbances is governed by the

permittivity ε_0 and permeability μ_0 constants associated with the empty space or vacuum. Since these four parameters are inter-related, only two of these are independent.

$$c = \sqrt{1/(\mu_0 \varepsilon_0)} \qquad \text{and} \qquad Z_0 = \sqrt{\mu_0 / \varepsilon_0}$$

It needs to be strongly emphasized here that the parameter c given above represents a fundamental physical property of vacuum or aether and not a property of photons or EM waves. Just as the speed of stress/strain waves in a material media depends entirely on the physical properties of that media, the speed of photons in a transparent material also depends on the relative permittivity and permeability of that media. Similarly Z_0 represents a fundamental physical property of vacuum or aether and not a property of the electro-magnetic (EM) field. Further it is interesting to note that μ_0 can be replaced with Z_0/c and $1/\varepsilon_0$ can be replaced with $c.Z_0$ in all relations involving μ_0 or ε_0. These parameters are quite routinely measured experimentally and are universally well known. Since the intrinsic impedance of vacuum, Z_0 is 377 Ohms, it does give the impression that perhaps the aether or vacuum is primarily the seat of electrical phenomenon of nature. However the propagation of transverse waves in a continuous media is essentially a feature of mechanical phenomenon. Hence, we need to reinterpret these physical properties in mechanical terms.

Mechanical Interpretation of Physical Properties of Vacuum. Now we have two different notions of vacuum or physical space; one with dimensional properties of ε_0, μ_0, c and Z_0 and the second with fundamental dimensional properties of elasticity and inertia to enable transverse wave propagation through it. In order to establish a correlation between these two notions of vacuum or the space continuum, we need to postulate the equivalence of their fundamental properties. Thus we assume that the parameter $1/\varepsilon_0$ (or $c.Z_0$) represents the elastic constant and μ_0 (or Z_0/c) represents the inertial constant of the physical space continuum or vacuum. Appropriate physical dimensions can be assigned to these parameters through dimensional analysis. The plausibility of this assumption is confirmed by the fact that square root of (elastic constant / inertial constant) represents the velocity of strain wave propagation in an elastic continuum and the square root of $((1/\varepsilon_0)/\mu_0)$ also represents the velocity of transverse electromagnetic wave propagation in vacuum. Further, since the light waves propagate as transverse waves, the fluid characteristics of aether or vacuum are totally ruled out. Ideally, this fact should get highlighted in a more appropriate name of physical space or

vacuum. That is, we might refer to the vacuum or empty space in such a way so as to highlight its elastic properties.

With this correlation between different notions of physical space or vacuum, it is formally established that the aether, vacuum, physical space, empty space and the quantum vacuum, all represent one and the same entity which is characterized by its elastic and inertial properties. To make this entity a little more representative of its elastic properties, which are so very necessary for supporting transverse electromagnetic wave propagation, we may assign a more appropriate name to this entity - 'The Elastic Space Continuum'.

2.5 Detection of Aether, Vacuum or Elastic Space Continuum

One crucial question that needs to be answered is:- how exactly do we detect the existence of aether or vacuum or the elastic space continuum? The detection and measurement of any physical entity actually involves the detection and measurement of some of its characteristic attributes. Such characteristic attributes of the Aether or the Elastic Space Continuum are ε_0, μ_0, c and Z_0, which are well known and have been measured quite precisely.

However, there is one special feature of this detection on which scientists had persistently focused their attention for a long long time. Since the aether or vacuum represent the physical space within which all material particles and fields of the universe are embedded, we should be able to define a special coordinate reference frame which is at rest in this physical space or aether. This special reference frame is termed as the absolute or universal reference frame. In principle we should be able to refer the motion of all material particles in the universe to this absolute reference frame and all such motion will then be termed as absolute motion. It has been argued that to detect the existence of aether, we should be able to detect this absolute reference frame.

The famous Michelson-Morley (MM) experiment[2] was one of many such attempts made to detect this absolute or universal reference frame, which however, did not succeed. Since the speed of propagation of light c is a physical property of aether or vacuum, it must be a universal constant in this absolute or universal reference frame. Obviously therefore, if an observer is in motion in the absolute reference frame, the speed of propagation of light must appear to be different from c to this observer. It was this change in the speed of propagation of light which was attempted to be measured in the MM experiment (MMX) through the expected variation in the interference fringes. The actual MM

experiment yielded null result which was wrongly interpreted as a proof of non-existence of the absolute or universal reference frame. However, it can be logically explained that the null result of MM experiment was due to the invalidity of an implicit assumption that frequency of emission of light photons is not influenced by the motion of source in the absolute reference frame.

Independent Status of Matter and Fields. Let us now examine the next pertinent question as to how exactly particles of matter could move through an elastic space continuum without any resistance. For this we need to view material particles as a sort of lumped up strain energy, or, a sort of localized strain wave packets. For the elastic space continuum, the equilibrium equations of elasticity can be shown to be identical to the vector wave equation. Particular solutions of these equilibrium equations as functions of space-time coordinates, satisfying appropriate boundary and stability conditions within a bounded region, can be shown to represent various strain wave fields and strain wave packets. The electromagnetic field as well as all other forms of energy and matter can be shown to exist in the the elastic space continuum as strain wave fields or strain wave packets. The energy density associated with these stress/strain waves in any particular region of the space continuum will be proportional to the square of the intensity of such waves. The matter particles essentially exist in this elastic space continuum as packets of standing strain wave oscillations whose total strain energy remains conserved in the absence of any interaction with other strain waves or packets. Hence matter and EM field do not have any independent existence separate from the physical space.

To view the motion of material particles in the elastic space continuum, we may consider a rough analogy of a boat moving on water or as a tornado moving in the atmosphere. Just as a moving boat is always accompanied by surface waves in its vicinity, a matter particle moving in the space continuum will always be accompanied by a localized strain wave field, something like De Broglie waves. Kinetic energy of a particle in motion in the elastic space continuum can be viewed as the strain energy stored in the accompanying strain wave field.

