

Towards a Theory of Everything Part I

Introduction of Consciousness in Electromagnetic Theory, Special and General Theory of Relativity

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Abstract

Theory of everything must include consciousness. *In this Part I* of the series of three articles, we introduce the subjective experience (SE) and/or proto-experience (PE) aspect of consciousness in classical physics, where PEs are precursors of SEs. In our dual-aspect-dual-mode PE-SE framework, it was hypothesized that fundamental entities (strings or elementary particles: fermions and bosons) have two aspects: (i) material aspect such as mass, charge, spin, and space-time, and (ii) mental aspect, such as experiences. There are three competing hypotheses: (1) *superposition* based H_1 (SEs/PEs are superposed in the mental aspect of entities; when a specific stimulus is presented to the neural-network, the associated specific SE is selected by the matching and selection process and experienced by this network), (2) *superposition-then-integration* based H_2 (only PEs are superposed, which are *integrated* by *neural-Darwinism* leading to specific SEs) and (3) *integration* based H_3 (each entity has its own PE, which keeps on transforming appropriately as matter evolves from elementary particles to neural-networks; it is a dual-aspect panpsychism). We found that the followings, in classical physics, are invariant under the PE-SE transformation: electromagnetic strength tensor, electromagnetic stress-energy tensor, the electromagnetic theory (Maxwell's equations), Newtonian gravitational field, the entropic force, Special and General Theory of Relativity. Our analysis suggests that (i) SEs are embedded in space-time geometry for the structure of space-time (empty space or the vacuum without matter). (ii) For matter field, SEs can move with spatiotemporal coordinates of matter because it is in the mental aspect of matter as both mental and material aspects are always together in the dual-aspect-dual-mode *optimal* PE-SE framework. (iii) Our specific SE is the result of matching and selection processes and can change with space and time. For example, the experience *redness* has V4/V8/VO-red-green neural-network with redness-state as neural correlates. When a subject moves, the specific SE *redness* also moves with the subject's correlated neural-network. In addition, SEs can change with time as stimuli change. In other words, SEs in a subject change with space-time. We conclude that it is possible to introduce the SE/PE aspect of consciousness in classical physics. In Parts II and III, the SE aspect of consciousness will be introduced in orthodox quantum physics and modern quantum physics (such as loop quantum gravity and string theory), respectively. Thus, the introduction of the SE aspect of consciousness in physics leads us to unify consciousness with known four fundamental forces, which entails towards a theory of everything.

Key Words: Theory of everything, proto-experiences, subjective experiences, consciousness, superposition, elementary particles, electromagnetic theory, entropic force, special and general theory of relativity, fundamental forces

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1. Introduction

The phrase ‘theory of everything’ (TOE) is controversial (’t Hooft *et al.*, 2005): some argue that the unification of gravity and quantum theory leads to TOE, so the F-theory, M-theory or loop quantum gravity and quantum theory together might be close to TOE; some argue that TOE must also address anthropic system; and some argue that consciousness must also be included in TOE.

Abbreviations and symbols list

$g_{\mu\nu}$: metric tensor
 H_1 : *superposition* based hypothesis
 H_2 : *superposition-then-integration* based hypothesis
 H_3 : *integration* based hypothesis
 I : stimulus intensity
 Λ : the cosmological constant
 LGN : lateral geniculate nucleus
 LQG : loop quantum gravity
 Orch OR : orchestrated objective state-reduction
 PE(s) : proto-experience(s)
 $R_{\mu\nu}$: Ricci curvature tensor
 R : Ricci scalar curvature
 SE(s) : subjective experience(s)
 SQ : sub-quantum
 $T_{\mu\nu}$: the stress-energy tensor
 TOE : Theory of Everything
 SAS(s) : self-aware substructure(s)
 V1 : visual area 1; V4 : visual area 4
 V8 : visual area 8; VO : ventral-occipital cortex

According to (Tegmark, 1998), TOE is merely the ultimate ensemble theory that contains *self-aware substructures* (SASs), which can logically think and subjectively perceive time (not necessarily space!) and perceive themselves as existing in a physically *real* world. For the existence of SASs, the three necessary criteria are complexity, predictability, and stability.

In my view, the critical problem of observer dependent reality should be addressed, and the TOE must explain consciousness² (Chalmers, 1996).³ This

² (Vimal, 2009e) describes, “meanings (or aspects) attributed to the term consciousness, extracted from the literature and from recent online discussions. Forty such meanings were identified and categorized according to whether they were principally about function or about experience; some overlapped but others were apparently mutually exclusive – and this list is by no means exhaustive. Most can be regarded as expressions of authors’ views about the basis of consciousness, or opinions about the significance of aspects of its contents. The prospects for reaching any single, agreed definition of consciousness thus appear remote. However, much confusion could be avoided if authors were always to specify which aspects of consciousness they refer to when using ISSN 1303 5150

problem was qualitatively addressed in a dual-aspect-dual-mode framework (Vimal, 2008b; Vimal, 2010a), where classical and quantum concepts related to SEs and proto-experiences (PEs) were discussed and qualitatively and briefly introduced in string theory.⁴

Furthermore, Types A, B, and C materialism (Chalmers, 1995a; Chalmers, 2003; Levin, 2006; Levin, 2008; Loar, 1997; Papineau, 2006) imply that SEs are *identical with* or *emerge from* non-experiential matter. However, there is no shred of evidence that SEs can be created from non-experiential matter of classical physics; even the dominant Type-B materialism (Levin, 2006; Levin, 2008; Loar, 1997; Papineau, 2006) with *phenomenal concept strategy* requires the *pre-existence* of SEs to *pick them out demonstratively* (Vimal, 2009a). This monistic materialism has the problem of Levine’s explanatory gap (Levine, 1983): how can an experiential entity be *identical with* or *emerge from* non-experiential entities? On the other extreme, we have Cartesian substance dualism, which has ‘the mind-brain interaction problem’, ‘the mental causation problem’, and other problems as detailed in (Vimal, 2009h; Vimal, 2009j).⁵

the term. An example is outlined of how this can be done (using a ‘PE-SE’ framework), where PE is proto-experience and SE is subjective experience.

³According to Chalmers, “a complete theory will have two components: physical laws, telling us about the behavior of physical systems from the infinitesimal to the cosmological, and what we might call psychophysical laws, telling us how some of those systems are associated with conscious experience. These two components will constitute a true theory of everything” (Chalmers, 1995b).

⁴ “In general, PEs are precursors of SEs. In hypothesis H_1 , PEs are precursors of SEs in the sense that PEs are superposed SEs in unexpressed form in the mental aspect of every entity, from which a specific SE is selected via matching and selection process. In hypotheses H_2 and H_3 , PEs are precursors of SEs in the sense that SEs *somehow* arise/emerge from PEs” (Vimal, 2009h).

⁵ (Stapp, 2010) appears to address some of the problems of materialism: “The probing and observing *psyche* of the experimenter/observer is thereby shifted completely outside the physically described world. Yet von Neumann’s laws of *interaction* between the two realms remained intact. Hence the residents of these disparate domains become dynamically linked, producing an ontology akin to Descartes’ psycho-physical dualism. But the mental and physical aspects are not two independent Cartesian *substances*, each completely sufficient unto itself. [...] The quantum explanation of how our minds and brains can be both ontologically different, yet dynamically connected by the orthodox laws of physics, is a welcome revelation. It solves a problem that has plagued both science and philosophy for centuries—the imagined science-mandated need either to equate mind with brain, or to make the brain dynamically independent of the mind”. “This seems to imply that mind and matter are NOT two

The dual-aspect-dual-mode PE-SE framework addresses these problems in a complementary way, which is a ‘non-reductive physicalism’, where the physicalism is the materialism plus experiences. In addition, our framework is sympathetic to the view that SEs emerge from the recursive dual-aspect *information* based macroscopic world, such as a neural-net of brain. However, this view needs unpacking. For example, one could argue that *information* is a dual-aspect entity that has mental and physical aspects (Chalmers, 1995a; Chalmers, 2003). In addition, the terms ‘*identical with*’ and ‘*emerge from*’ need unpacking. This is done in the PE-SE framework (Vimal, 2008b; Vimal, 2010a), which entertains three hypotheses:⁶ *superposition* based **H₁**, *superposition-then-integration* based **H₂**, and *integration* based **H₃** where superposition is not required. They are detailed in (Vimal, 2008a; Vimal, 2008b; Vimal, 2009f; Vimal, 2009i; Vimal, 2009j; Vimal, 2010a) and concisely described below.

In (Vimal, 2009f), the terms ‘*identical with*’ and ‘*emerge from*’ in materialism related to SE *redness* are qualitatively unpacked in the dual-aspect-dual-mode PE-SE framework as follows (Vimal, 2008b; Vimal, 2010a): (i) there exist a *virtual reservoir* (such as elementary particles, external/internal stimuli, neural-nets, and so on: detailed in (Vimal, 2008b)) that *stores* all possible fundamental experiences (SEs/PEs) in superposed/latent form, (ii) the interaction of long wavelength light (stimulus) dependent feed-forward with

cognitive and attentional feedback signals in the red-green ‘V4/V8/VO’ color neural-network creates a specific neural-net state, (iii) this specific state is assigned to a specific SE, *redness*, from the *virtual reservoir* during *neural Darwinism* (co-evolution, co-development and sensorimotor co-tuning by the evolutionary process of adaptation and natural selection), (iv) this specific SE, *redness*, is embedded as a memory trace of neural-network-PE, and (v) when a specific *redness*-related stimulus (such as long wavelength light) is presented to the red-green ‘V4/V8/VO’ color neural-network, the associated specific SE, such as *redness*, is selected by the matching and selection process (Vimal, 2008a; Vimal, 2010a) and experienced by this network.⁷ We call the steps (i)-(v) **hypothesis H₁**. The generation of specificity involves premises (ii)-(v) (Vimal, 2008b; Vimal, 2010a). The matching process (Vimal, 2010a) can be further elaborated by dividing it into (i) classical matching for non-quantum pathways such as classical neural firing along axon-dendritic pathway, and (ii) quantum conjugate matching for quantum pathway such as involved in OR Orch framework (Hameroff and Penrose, 1998). The classical matching is for classical physics based theories and the quantum conjugate matching is for quantum physics based frameworks. The introduction of consciousness in *classical physics* is the main topic of current article, whereas that in *orthodox quantum physics* is the topic of Part II and that in *modern physics* (string theory and loop quantum gravity) is the topic of Part III of the current series of three articles.

According to (Vimal, 2008b), the term *virtual reservoir* in the dual-aspect-dual-mode PE-SE framework (Vimal, 2008a; Vimal, 2010a) is consistent with our fundamental assumption that all types of

independent substances because they are both dynamically and conceptually *entangled* according to Neumann’s laws of *interaction*, but at the same time, each is completely sufficient by itself. This framework seems to bridge dualism with materialism via orthodox quantum physical laws. In my view, this is CLOSE to ‘substance monism with property dualism’ or ‘dual-aspect’ view, which *a sort of* addresses mind-brain interaction problem and mental causation problem of materialism. However, the implications zombies (brains without SEs), controversial *ghosts* (minds without brain), and one-many/many-many relations are still mysteries and further elaboration is needed” (Vimal, 2009a).

⁶ There are two more hypotheses H₄ (intelligent mechanism, such as cosmic consciousness and universal mind, exists) and H₅ (*emergence* of SE and anti-SE in a dual-aspect ‘vacuum or Aether’ at the onset of universe), which are discussed in (Vimal, 2009i; Vimal, 2009j).

⁷ The color area ‘V8/V4/VO’ refers to visual area V8 of Tootell-group (Hadjikhani *et al.*, 1998; Tootell *et al.*, 2003), visual area V4 of Zeki-group (Bartels and Zeki, 2000), and VO of Wandell-group (Wandell, 1999); they are the same human color area (Tootell *et al.*, 2003). VO is ventral-occipital cortex.

fundamental experiences (SEs/PEs) are stored in *superimposed form* in the mental aspect of each elementary particle. Thus, the mental aspect of each elementary particle can be considered storage area as a *virtual reservoir* containing all types of fundamental experiences in *superimposed form*. Though apparently different, *virtual reservoir* can also be considered as a sort of “Penrose Platonic world” in Orch OR framework (Hameroff and Penrose, 1998), “societies of occasions of experience” or “space for the qualia of material” in Whitehead framework (Baer, 2007; Whitehead, 1978), “sub-quantum (SQ) space” in SQ-framework (Boyd and Klein, 2007), “cosmic consciousness space” in cosmic-consciousness-framework (Schäfer, 1997; Schäfer, 2006), and “*Purusha-Vishnu*”, *Paramatman*, or “primordial consciousness” space in RigVedic-Buddhist framework (Sarasvati, 1974-89; Wallace, 2007).

Alternatively, according to the principle of *emergence*, the physical property of salt (NaCl) *emerges* from the interaction/integration of its constituents Na⁺ and Cl⁻ ions because the property of salt is not present in its constituents (Vimal, 2008a). In analogy to this, a specific SE, such as *redness*, can *emerge* in a neural-net from the interaction/integration of its constituent neural-PEs in ‘V4/V8/VO’-color neural-net. For example, the reportable SE *redness* might have *emerged* in ‘V4/V8/VO’-color neural-net from the interaction/integration of two types of signals: (i) feed-forward long wavelength (say 650 nm) light dependent PE-carrying-neural-signal from retina to LGN to V1 to ‘V4/V8/VO’ color area (call it FF₆₅₀) and (ii) feedback fronto-parietal attention related re-entrant PE-carrying-neural-signal (call it FB), i.e., *redness* related to 650 nm light is SE $redness_{650} = (FF_{650})*(FB)$, in analogy to $NaCl = (Na^+)*(Cl^-)$.

As in **H₁**, we hypothesize that each string or elementary particle (fermion and boson) has two aspects: mental and physical. To

unpack further, we propose hypotheses **H₂** and **H₃**, where the principle of *emergence* related to non-reductionist dual-aspect view is needed, as follows: In **hypothesis H₂**, fundamental entities and inert matter are the *carriers* of superimposed fundamental PEs (not SEs). In **hypothesis H₃**, the mental aspect is a proto-experience (PE); this does not require superposition, whereas **H₁** and **H₂** do.

In hypothesis **H₃**, as the physical aspect (such as mass, charge, spin, and space-time) of an entity evolves, its mental aspect (its PE) also evolves, i.e., they co-evolve. In other words, it follows the principle of *integration* from elemental level to neural-net level. In every level of evolution, an entity has its own specific PE obtained from the integration/evolution of its constituent PEs of lower level, for example, neural-net PE, neural-PE, genetic-PE, ..., molecular-PE, atomic-PE, and elemental-PE. A specific SE emerges during interaction process as described above in **H₂**.

In hypothesis **H₁**, we hypothesized that all types of fundamental SEs/PEs are superimposed in fundamental entities (strings or elementary particles: fermions and bosons). This implies that inert matter is simply the *carrier* of superposed SEs/PEs because it contains all types of fundamental SEs/PEs and hence it is non-specific to SEs/PEs, and matter behaves as a non-experiential entity. In hypothesis **H₃**, the matter is not a *carrier*; rather matter has two aspects at every level of evolution. These two aspects are rigorously *integrated* as if they are the two sides of the same coin or as if the reality can be viewed in either of the two aspects, in analogy to matter that can be viewed as a wave or a particle depending on experimental measurements.

The hypothesis **H₁** has Type-2 explanatory gap: how it is possible that our SEs (such as happiness, sadness, painfulness, and similar SEs) were already present in primal entities, whereas there is no shred of evidence that such SEs were conceived at the onset of universe. This is

addressed in (Vimal, 2009b; Vimal, 2009i; Vimal, 2009j; Vimal, 2010a): (i) Since the superposition of SEs/PEs in elementary particles refers to *possibilities* (or *potentialities*) that *actualize* when neural-network is formed and since we know that these SEs are indeed real in our daily mind-dependent reality, it is justified that all types of SEs/PEs could be considered *possibilities* (or *potentialities*) at the onset of universe (more later). In addition, one could further argue that SEs might have been one of major motivations for the evolution to form neural-networks. (ii) Alternatively, in the hypothesis H_1 , the SEs that entail this gap are secondary SEs derived from primary fundamental irreducible PEs/SEs. However, one has to explain how they can be derived, i.e., there is the combination problem (Goff, 2009). If all SEs lead to Type-2 explanatory gap, then one could argue that they are derived from some superposed PEs and the hypothesis H_1 becomes equivalent to the hypothesis H_2 . (iii) In the hypothesis H_2 , PEs (not SEs) are in *superposed form* in inert matter to avoid combination problem and Type-2 explanatory gap. (iv) Fundamental SEs/PEs follow the principle of the *emergence* of SE and anti-SE in vacuum at the onset of universe, which is similar to the principle involved in the emergence of matter and anti-matter in vacuum (more later) (Vimal, 2009i; Vimal, 2009j). (v) SEs can be derived from a PE and three *gunas* (qualities) (Vimal, 2009b).

The hypotheses H_2 and H_3 have (I) the *combination problem*: “how low-level proto-experiential and other properties somehow together *constitute* our complex unified conscious experiences” (Chalmers, 1997; Seager, 1995), i.e., how a specific SE can *emerge* from the PEs of constituent elements in a related neural-net. This is addressed in (Vimal, 2009j) by using the principles of *integration* and *neural Darwinism* (co-evolution, co-development, and sensorimotor co-tuning), in analogy to that of matter. The hypothesis H_3 is a dual-aspect panpsychism, proto-experientialism or proto-panpsychism view (Type F view:

(Chalmers, 2003)). H_3 has the following problems in addition to the ‘combination problem’, (Seager, 1995; Vimal, 2008b): (II) The ‘*unconscious mentality problem*’ is “accepting the mentality of the elemental units of mind while denying that they are actually conscious experiences” (Seager, 1995). (III) The ‘*completeness problem*’ is that the inert system should also show sometime causal power of proto-experiences, which is not the case; this leads to incompleteness of physical picture of world. (IV) The ‘*no sign problem*’ is, “there is no evidence whatsoever of a nonphysical dimension to the elemental units of nature” (Seager, 1995) and there is no ‘sign’ of mentality in the basic features of the world. (V) The ‘*not-mental problem*’ is “if there was some feature of these units we chose to label as ‘mental’, what possible ground could one provide to justify this label” (Seager, 1995).

The hypothesis H_2 falls between H_1 and H_3 . H_2 follows the principle of superposition of PEs (not SEs) to escape from Type-2 explanatory gap of H_1 and to avoid the above problems (I)-(V) of H_3 . H_2 then follows the principle of *integration/emergence* (as in H_3) and is closer to the current trend in neuroscience than H_1 . However, it has the ‘combination problem’ (as in H_3), which is mysterious and hard to address. Further research is needed for a framework that is free from all the problems.

In all three hypotheses, SEs emerge/arise when the necessary ingredients of SEs (such as the formation of neural-networks, wakefulness, attention, re-entry, working memory, stimulus at or above threshold level, and neural-net-PEs) are satisfied (Vimal, 2009f).

The PE-SE framework (Vimal, 2008b; Vimal, 2010a) is extended to address (i) “the localization of consciousness within the physical matter of the brain consistent with contemporary theoretical physics, molecular and system biology, and neuroscience” via a two-factor approach (MacGregor and Vimal, 2008), (ii) Self (Bruzzo and Vimal, 2007), (iii) phenomenal time (Vimal and Davia,

2008), (iv) the necessary ingredients of consciousness awareness (Vimal, 2009f), (v) emotion (Vimal, 2008a), (vi) integration of classical, quantum, and subquantum concepts (Vimal, 2009i), (vii) integration of classical and quantum concepts for emergence hypothesis (Vimal, 2009j), (viii) an overview of the meanings attributed to the term 'consciousness' (Vimal, 2009e), (ix) optimal and general definition of consciousness (Vimal, 2009h), (x) linking Dynamic Systems theory and Fractal Catalytic Theory with Standard Representation Theory using PE-SE framework (Vimal, 2009d), (xi) the implication of dual-aspect framework (Vimal, 2009c), (xii) derivation of SEs from a PE and three *gunas* (qualities) in the dual-aspect-dual-mode framework (Vimal, 2009b), (xiii) the pre-existence of SEs in Type-B materialism, where materialism and anti-materialism are linked via dual-aspect *optimal* framework (Vimal, 2009a), and (xiv) interpretation of empirical data of *samadhi* state using the dual-aspect dual-mode *optimal* framework (Vimal, 2009g).

Furthermore, (Hameroff and Penrose, 1998; Hameroff and Powell, 2009) follow neutral monism that is close to double aspect (in a sense that both have two aspects: matter and mental) and are protoconsciousness theorists, and sometimes Stapp conceives double aspect but in a different way. According to (Stapp, 1996), "The complexity of the physical carrier has undoubtedly co-evolved with the complexity of the associated experiential reality", which is consistent with our framework. However, According to (Stapp, 2009), "Von Neumann (orthodox) quantum mechanics is thus dualistic in the pragmatic and operational sense that it involves aspects of nature that are described in physical terms and also aspects of nature that are described in psychological terms, and these two parts interact in human brains in accordance with laws specified by the theory. This is all in close accord with classic Cartesian dualism. On the other hand, and in contrast to the application to classical mechanics, in which the physically described aspect is ontologically matterlike, not

mindlike, in quantum mechanics the physically described part is mindlike! So both parts of the quantum Cartesian duality are fundamentally mindlike. Thus quantum mechanics conforms at the *pragmatic/operational* level to the precepts of Cartesian duality, but reduces at a deep *ontological* level to a fundamentally mindlike nondual monism."

Thus, Stapp's double aspect framework is *close to* substance dualism at operational level in much weaker sense, which does not have 'the mind-brain interaction problem' and 'the mental causation problem' of Cartesian substance dualism (Vimal, 2009a).

To elaborate further, one could argue that as electric field and magnetic field are two aspects of electromagnetic (EM) field, in analogy to this, material and mental aspects are two aspects of every entity in dual-aspect view.

According to (Atmanspacher, 2006), "Such a "dual aspect" option, although not much emphasized in contemporary mainstream discussions, has a long tradition. Early versions go back as far as Spinoza and Leibniz. In the early days of psychophysics in the 19th century, (Fechner, 1861) and (Wundt, 1911) advocated related views. Whitehead, the modern pioneer of process philosophy, referred to mental and physical poles of "actual occasions", which themselves transcend their bipolar appearances (Whitehead, 1978). Many approaches in the tradition of (Feigl, 1967) and (Smart, 1963), called "identity theories", conceive mental and material states as essentially identical "central states", yet considered from different perspectives. Other variants of this idea have been suggested by (Jung and Pauli, 1955) [see also (Meier, 2001) and (Atmanspacher and Primas, 1996; Atmanspacher and Primas, 2006)], involving Jung's conception of a psychophysically neutral, archetypal order, or by Bohm and Hiley (Bohm, 1990; Bohm and Hiley, 1993; Hiley, 2001), referring to an implicate order which unfolds into the different explicate domains of the mental and the material."

We need to have predictions that can distinguish the *materialistic emergence* (SE somehow *emerges* from matter such as from neural-net) and the *mentalistic-emergence* based on the dual-aspect PE-SE framework. Both need neural-nets with necessary ingredients satisfied, such as the formation of neural-networks, re-entry, attention, working memory, wakefulness, and stimulus at or above threshold contrast (Vimal, 2009f). The dual-aspect PE-SE framework needs additional ingredient: neural-net PE. A matching process for material-signals exists in both. The matching of mental aspects and then selection occur in the PE-SE framework: the selection of a specific SE from the plenum or virtual reservoir of SEs/PEs during the assignment of the selected SE to the specific state of neural net at the onset of developmental *neural Darwinism* is needed. The matching and assignment processes are needed in both dual-aspect PE-SE framework and emergentism/materialism framework. However, the selection process is not needed in emergentism/materialism because it is assumed that the specific SE is either *emerged from* the interaction of feed forward signals and feedback signals in a neural-net or the specific SE is *identical with* related neural-net's specific state. Therefore, the PE-SE framework is rejected if the selection process is *somehow* made *inactive* and SEs still occur. Otherwise, under these conditions, if SEs do not *emerge* then emergentism/materialism will be rejected. This method of testing the prediction will not be an easy task. During meditation with eye-closed, there is no visual input and there is no feed-forward signal in visual pathway. Therefore, there is nothing to match with cognitive feedback signals and then nothing to select for the SE such as *redness*; hence, the SE *redness* is not experienced. However, feedback neural signals can still re-enter in the V4/V8/VO-color-neural-net; attention, working memory, and wakefulness state are still present for emergentism framework to act on, but redness does not emerge. This seems to reject emergentism/materialism

even in eye-closed normal awake state of brain-mind. One could argue that meditation-induced color can still be experienced if enough effort is made. However, this can be explained in both views as meditation-induced endogenous signals can occur in the feed forward pathways. One could further argue that a matching process and stimulus above threshold contrast are needed for *materialistic-emergence* framework; therefore, the above example does not reject it. However, there is no selection process in *materialistic-emergentism*. If the selection process during developmental *neural Darwinism* is made *inactive* and consequently a specific SE does not occur then *materialistic-emergentism* can be rejected. This prediction needs further research.

One could argue that none of views can reject the empirical observation of dual-aspect, namely, a neural-state has two aspects: (i) its material aspect is neural-net and its physiological, biophysical and electrochemical activities, and (ii) its mental aspect is experiences, thoughts, and other mental cognition and perception. The views differ in how mental phenomena occur in our brain. Materialistic-emergence framework hypothesizes that mind emerges from matter when neural-nets are formed, whereas dual-aspect view hypothesizes that the observed dual-aspect pervades at all levels including elemental level (see hypotheses **H₁**, **H₂**, and **H₃**). The former (*materialistic-emergence*) is attractive because it is more parsimonious (as it has a single parameter: the matter). Consciousness occurred in biological live systems perhaps during or after Cambrian explosion (about 540 millions years ago: (Hameroff, 1998)). But how mind *emerges* from the interactive neural activities is still a mystery because of the explanatory gap (Levine, 1983). The latter (the dual-aspect view) addresses this gap but it burdens nature to have mental-aspect down to elemental level.

According to (Vimal, 2009b), "One could argue that there are two possibilities of our

assumption that (cardinal) SEs/PEs are in superposed form in the mental aspect of every entity: (1) SEs *actually* pre-exist or (2) SEs *potentially* exist. (1) If SEs *actually* pre-exist, then for the source of SEs we eventually end up with Universal Consciousness (Psychical Power; *Shiva*) and Universal Energy (Physical Power or Objective Reality: *Shakti*) as mental and physical aspect, respectively. *Shiva* then has power to do anything and everything in real sense, and then we simply cannot escape calling *Shiva* as God or *Paramatman* like assumed in *Kashmir Shaivism* (Kaul, 2002; Kaw, 2002). However, (2) if SEs *potentially* exist, then we eventually end up with 'materialism' or dual-aspect 'physicalism'. This is because after the formation of neural-networks and when essential ingredients of consciousness are satisfied, specific SEs *somehow arise* or *actualize*. In that case *Shiva* does not have power to do anything, rather *Shiva* is simply latent *superposed potential* mental entity postulated to avoid the problems of materialism and address the Levine's explanatory gap (Levine, 1983). Neuroscience seems closer to the second possibility, namely, SEs *potentially* exist. Both possibilities (SEs *actually* pre-exist or *potentially* exist) can be explained via hypotheses H_1 , H_2 , H_3 and so on. However, hypotheses H_1 and H_2 are more suited for SEs *actually* pre-exist and H_2 and H_3 are more suited for SEs *potentially* exist. We need to investigate further whether SEs *actually* pre-exist or *potentially* exist.

If SEs *potentially* exist and are superposed in the mental aspect of entities, then when neural-networks are formed and when necessary ingredients of consciousness are satisfied, a specific SE is experienced via matching and selection mechanisms (Vimal, 2010a). However, (cardinal) SEs must pre-exist for collapse or selection. In Type-B materialism, SEs must pre-exist to pick them out *demonstratively* (Vimal, 2009a). Thus, in all cases, (cardinal) SEs must pre-exist. This implies that at the least a PE and three *gunas* must exist. In other words, *Shiva* as a PE must pre-exist at the least if *Shiva* as God or *Paramatman* does not exist. This is the middle path consistent with Buddhism, where extreme paths (such as materialism

on one extreme and substance-dualism on the other extreme) are avoided to minimize problems."

2. Introducing Consciousness in Classical Physics and Discussion

In this article, we focus on introducing the subjective experience (SE) aspect of consciousness in classical physics, such as electromagnetic theory, special and general theory of relativity.

The *methodology* is to examine the invariance of various components of theories under PE-SE transformations (similar to gauge transformation), where PEs (proto-experiences) are precursors of SEs.⁸ If the invariance is found, then introducing the SE aspect of consciousness in the dual-aspect view does not change the material aspect of physics. This means that physics remains the same. There is no need to change physical laws and theories when the SE aspect of consciousness is introduced.

We found that the invariance under the PE-SE transformation is indeed maintained for electromagnetic strength tensor, electromagnetic stress-energy tensor, the electromagnetic theory (Maxwell's equations), Newtonian gravitational field, special theory of relativity and Lorentz transformation, geodesic equation, general theory of relativity: Ricci curvature tensor $R_{\mu\nu}$, Ricci scalar curvature R , the cosmological constant Λ , the stress-energy tensor $T_{\mu\nu}$ and the metric tensor $g_{\mu\nu}$ (generalization of the gravitational field). Thus, classical physics remains invariant with the introduction of the SE aspect of consciousness in it under the PE-SE transformations.

In Part II (Vimal, 2010b), consciousness is introduced in orthodox quantum physics such as Schrödinger equation, current, Dirac Lagrangian, the Lagrangian for free gauge field, the Lagrangian for a charged self-interacting scalar field, and Standard Model.

⁸ See footnote 4.

In Part III (Vimal, 2010c), the subjective experience aspect of consciousness is introduced in modern quantum physics such as loop quantum gravity (LQG) and string theory and is unified with fundamental physical forces.

According to psychophysics, SE has logarithmic relationship with stimulus intensity (I): brightness or luminance is proportional to $\log(I)$, i.e. I is proportional to the exponential of (brightness or luminance). According to hypothesis **H₁** (or **H₂**), the multiple possible subjective experiences (or proto-experiences for **H₂**) are superposed in the mental aspects of strings or elementary particles. This is represented by

$$\mathcal{E}(\sigma, \tau) = [\sum_k \beta_k f(\varepsilon_k(\sigma, \tau))], \text{ where } \varepsilon_k \text{ is } k^{\text{th}} \text{ SE for hypothesis } \mathbf{H}_1: \text{ superposition is necessary} \quad (1a)$$

$$\mathcal{E}(\sigma, \tau) = [\sum_k \beta_k f(\varepsilon_k(\sigma, \tau))], \text{ where } \varepsilon_k \text{ is } k^{\text{th}} \text{ PE (not SE) for } \mathbf{H}_2: \text{ superposition is necessary} \quad (1b)$$

$$\mathcal{E}(\sigma, \tau) = \beta f(\varepsilon(\sigma, \tau)), \text{ where } \varepsilon \text{ is PE (not SE) for hypothesis } \mathbf{H}_3: \text{ no superposition} \quad (1c)$$

where $\mathcal{E}(\sigma, \tau)$ represents the superposition of SEs/PEs $\varepsilon_k(\sigma, \tau)$ in the mental aspect of an entity (such as boson, fermion, string, field, potential, etc); τ is time-like parameter for the entity, such as time t; σ is space-like parameter for the entity, such as x, y, z; $f(\varepsilon_k(\sigma, \tau))$ is a function of SE/PE ε_k , which could simply be equal to $\varepsilon_k(\sigma, \tau)$. β_k is the superposition-coefficient, where the subscript k represents k^{th} experience; $k=1$ to N_{SE} ; N_{SE} is the maximum number of experiences, which is very large; therefore, specificity is zero. The square of the coefficient $[\beta_k]^2$ for the mental aspect is the probability (index of possibility) of the k^{th} experience. For hypothesis **H₃**, $k=1$, i.e., there is one PE in the mental aspect of each entity; there is no superposition, rather a micro or macro entity has its PE in its mental aspect; hypothesis **H₃** is the dual-aspect quantum panpsychism. The

parameters (σ, τ) are precisely the same for both material and mental aspect, which are like two sides of the same coin in the dual-aspect view; in other words, $\mathcal{E}(\sigma, \tau)$ or $\varepsilon_k(\sigma, \tau)$ are attached to corresponding entity and hence they are exactly the same as that of the entity; if entity moves, then $\mathcal{E}(\sigma, \tau)$ or $\varepsilon_k(\sigma, \tau)$ moves with it and is never separated from each other.

For example, the psychophysical channel related to SE *redness* is Red-Green color opponent channel, which has neural correlate as red-green V4/V8/VO neural-net. Thus, the structure is the red-green V4/V8/VO neural-net; its function is to detect and discriminate colors with just noticeable difference (JND) between red to green, such as red, orange, orange-yellow, yellow, yellowish-green, and green. The related SEs are redness, orangeness, orange-yellowness, yellowness, yellowish-greenness, and greenness. In this example, $k=1$ to 6 for the red-green V4/V8/VO neural-net. When long-wavelength light is presented the SE *redness* occurs with specificity=1 in this network via matching and selection processes (detailed in (Vimal, 2010a)). In other words, for red-green color, (a) the structure is V4/V8/VO red-green neural-net, (b) the functions are the detection and discrimination of wavelengths, and (c) SEs are redness to greenness.

We use experience related transformations (called PE-SE transformations) in physics for introducing SEs/PEs aspect of consciousness.

2.1. The relevant PE-SE transformations

The PE-SE transformations for Part I of this series of 3 articles are as follows:⁹

$$\text{Scalar potential: } \phi \rightarrow \phi' = (\phi - \partial_t \mathcal{E}) \quad (2a)$$

$$\text{Vector potential: } A \rightarrow A' = A + \nabla \mathcal{E} \quad (2b)$$

Vector potential can also be written as:

$$A_\mu \rightarrow A'_\mu = A_\mu - (1/e) \partial_\mu \mathcal{E} \quad (2c)$$

where q and e are charges, g is gauge coupling constant, and $\mu = 0, 1, 2, 3$.

⁹ These PE-SE transformations will also be used in Part II (Vimal, 2010b) and Part III (Vimal, 2010c).

The PE-SE transformation for (i) the gravitational field derived from (2a) is given in (24a,b), (ii) Special Theory of Relativity (STR), i.e., the space-time multiplicative transformation related to Lorentz transformation in dual-aspect view, is given in (26a,b,c) and (29a,b,c), (iii) geodesic equation based on (29a,b) is given in (32a,b), (iv) metric $g_{\mu\nu}$ (generalization of the gravitational field) based on its decomposition (35a,b,c) and transformations (2a,b) is given in (37a-f), (v) Ricci curvature tensor $R_{\mu\nu}$ based on (37a) is given in (40), (vi) Ricci scalar curvature R based on (37a) is given in (46), and (vi) the metric tensor $g_{\mu\nu}$ based on transformations (2a,b) and (24b) is given in (50).

2.2. The electromagnetic strength tensor

It can be written as (Section 1.2.1 and Eq. 1.17 of (Novaes, 2000)):

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu \quad (3)$$

Applying the PE-SE transformation from Eq.(2c) in Eq.(3), we get,

$$F_{\mu\nu} \rightarrow F'_{\mu\nu} = \partial_\mu A'_\nu - \partial_\nu A'_\mu = \partial_\mu [A_\nu - (1/e)\partial_\nu \mathcal{E}] - \partial_\nu [A_\mu - (1/e)\partial_\mu \mathcal{E}] \quad (4a)$$

$$= \partial_\mu A_\nu - (1/e)\partial_\mu \partial_\nu \mathcal{E} - \partial_\nu A_\mu + (1/e)\partial_\nu \partial_\mu \mathcal{E} \quad (4b)$$

$$= \partial_\mu A_\nu - \partial_\nu A_\mu \text{ as } \partial_\mu \partial_\nu \mathcal{E} = \partial_\nu \partial_\mu \mathcal{E} \quad (4c)$$

$$= F_{\mu\nu} \quad (4d)$$

Thus, the electromagnetic strength tensor is invariant under the PE-SE transformations given in Eq.(2c).

2.3. The electromagnetic stress-energy tensor

As part of the source term in the Einstein field equations, the electromagnetic stress-energy tensor is a covariant symmetric tensor which can be written from (Vimal, 2009k) and (Einstein, 1916):

$$T_{\mu\nu} = - (1/\mu_0)(F_{\mu\alpha} g^{\alpha\beta} F_{\beta\nu} - (g_{\mu\nu}/4)F_{\sigma\alpha} g^{\alpha\beta} F_{\beta\rho} g^{\rho\sigma}) \quad (4e)$$

The electromagnetic stress-energy tensor is that portion of the stress-energy tensor that is due to the electromagnetic field. Since

electromagnetic strength or field tensors $F_{\mu\alpha}$, $F_{\beta\nu}$, $F_{\sigma\alpha}$, and $F_{\beta\rho}$ are invariant under the PE-SE transformation (2c), the electromagnetic stress-energy tensor $T_{\mu\nu}$ is also invariant if the metric tensor $g_{\mu\nu}$ that refer to the structure of space-time geometry is invariant.

2.4. The Lagrangian for free gauge field

It can be written as (Section 1.2.1 and Eq. 1.18 of (Novaes, 2000)):

$$\mathcal{L}_A = (-1/4) F_{\mu\nu} F^{\mu\nu} \quad (5)$$

Applying the PE-SE transformation from Eq.(4a-d) in Eq.(5), we get invariant Lagrangian,

$$\begin{aligned} \mathcal{L}_A \rightarrow \mathcal{L}'_A &= (-1/4) F'_{\mu\nu} F'^{\mu\nu} \\ &= (-1/4) F_{\mu\nu} F^{\mu\nu} = \mathcal{L}_A \end{aligned} \quad (6)$$

This Lagrangian together with Dirac Lagrangian (Vimal, 2010b) describes the quantum electrodynamics, which is invariant under the PE-SE transformation.

2.5. Electromagnetic Theory: Maxwell's equations

The behavior of electric and magnetic fields is governed in a vacuum by Maxwell's equations (Vimal, 2009k). The electric and magnetic fields can be described in terms of the potentials $A_\mu = (\phi, A)$ as:

$$E = -\nabla\phi - \partial_t A \quad (7a)$$

$$B = \nabla \times A \quad (7b)$$

in which we apply the PE-SE transformations Eqs.(2a,2b) as,

$$\begin{aligned} E \rightarrow E' &= -\nabla\phi' - \partial_t A' \\ &= -\nabla\phi + \nabla\partial_t \mathcal{E} - \partial_t A - \partial_t \nabla \mathcal{E} \\ &= -\nabla\phi - \partial_t A = E \text{ (invariant)} \end{aligned} \quad (8)$$

$$\begin{aligned} B \rightarrow B' &= \nabla \times A' = \nabla \times A + \nabla \times \nabla \mathcal{E} \\ &= \nabla \times A = B \quad \because (\nabla \times \nabla \mathcal{E})=0 \text{ (invariant)} \end{aligned} \quad (9)$$

Let us examine the four Maxwell Equations under the above PE-SE transformations as follows:

(1) Gauss' law:

$$[\nabla \cdot \mathbf{E} = \rho/\epsilon_0] \rightarrow [\nabla \cdot \mathbf{E}' = \rho/\epsilon_0] \quad (10a)$$

$$\Rightarrow \nabla \cdot (-\nabla\phi' - \partial_t \mathbf{A}') = \rho/\epsilon_0 \quad (10b)$$

$$\Rightarrow \nabla \cdot [-\nabla(\phi - \partial_t \mathcal{E}) - \partial_t(\mathbf{A} + \nabla \mathcal{E})] = \rho/\epsilon_0 \quad (10c)$$

$$\Rightarrow \nabla \cdot [-\nabla\phi + \nabla\partial_t \mathcal{E} - \partial_t \mathbf{A} - \partial_t \nabla \mathcal{E}] = \rho/\epsilon_0 \quad (10d)$$

$$\Rightarrow \nabla \cdot [-\nabla\phi - \partial_t \mathbf{A}] = \rho/\epsilon_0 \quad \because \nabla\partial_t \mathcal{E} = \partial_t \nabla \mathcal{E} \quad (10e)$$

$$\Rightarrow \nabla \cdot \mathbf{E} = \rho/\epsilon_0 \quad \text{from (7a)} \quad (10f)$$

(2) Gauss' law for magnetism

$$[\nabla \cdot \mathbf{B} = 0] \rightarrow [\nabla \cdot \mathbf{B}' = 0] \quad (11a)$$

$$\Rightarrow \nabla \cdot (\nabla \times \mathbf{A}') = 0 \quad (11b)$$

$$\Rightarrow \nabla \cdot [\nabla \times (\mathbf{A} + \nabla \mathcal{E})] = 0 \quad (11c)$$

$$\Rightarrow \nabla \cdot [(\nabla \times \mathbf{A}) + (\nabla \times \nabla \mathcal{E})] = 0 \quad (11d)$$

$$\Rightarrow \nabla \cdot (\nabla \times \mathbf{A}) = 0 \quad \because (\nabla \times \nabla \mathcal{E}) = 0 \quad (11e)$$

$$\Rightarrow \nabla \cdot \mathbf{B} = 0 \quad \text{from (7b)} \quad (11f)$$

(3) Faraday's law

$$[\nabla \times \mathbf{E} = -\partial \mathbf{B} / \partial t] \rightarrow [\nabla \times \mathbf{E}' = -\partial \mathbf{B}' / \partial t] \quad (12a)$$

$$\Rightarrow \nabla \times (-\nabla\phi' - \partial_t \mathbf{A}') = -\partial_t (\nabla \times \mathbf{A}') \quad (12b)$$

$$\Rightarrow \nabla \times [-\nabla(\phi - \partial_t \mathcal{E}) - \partial_t(\mathbf{A} + \nabla \mathcal{E})] = -\partial_t (\nabla \times (\mathbf{A} + \nabla \mathcal{E})) \quad (12c)$$

$$\Rightarrow \nabla \times [-\nabla\phi + \nabla\partial_t \mathcal{E} - \partial_t \mathbf{A} - \partial_t \nabla \mathcal{E}] = -\partial_t (\nabla \times \mathbf{A} + \nabla \times \nabla \mathcal{E}) \quad (12d)$$

$$\Rightarrow \nabla \times [-\nabla\phi - \partial_t \mathbf{A}] = -\partial_t (\nabla \times \mathbf{A}) \quad \because (\nabla \times \nabla \mathcal{E}) = 0 \quad (12e)$$

$$\Rightarrow \nabla \times \mathbf{E} = -\partial \mathbf{B} / \partial t \quad \text{from (7a) and (7b)} \quad (12f)$$

(4) Ampère-Maxwell law

$$[\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \partial \mathbf{E} / \partial t] \rightarrow [\nabla \times \mathbf{B}' = \mu_0 \mathbf{J}' + \mu_0 \epsilon_0 \partial \mathbf{E}' / \partial t] \quad (13a)$$

$$\Rightarrow \nabla \times (\nabla \times \mathbf{A}') = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \partial_t (-\nabla\phi' - \partial_t \mathbf{A}') \quad (13b)$$

$$\text{where } \mathbf{J}' = \mathbf{J} \text{ from (Vimal, 2010b)} \quad (13b)$$

$$\Rightarrow \nabla \times (\nabla \times (\mathbf{A} + \nabla \mathcal{E})) = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \partial_t [-\nabla(\phi - \partial_t \mathcal{E}) - \partial_t(\mathbf{A} + \nabla \mathcal{E})] \quad (13c)$$

$$\Rightarrow \nabla \times (\nabla \times \mathbf{A}) = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \partial_t [-\nabla\phi + \nabla\partial_t \mathcal{E} - \partial_t \mathbf{A} - \partial_t \nabla \mathcal{E}] \quad \because (\nabla \times \nabla \mathcal{E}) = 0 \quad (13d)$$

$$\Rightarrow \nabla \times (\nabla \times \mathbf{A}) = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \partial_t [-\nabla\phi - \partial_t \mathbf{A}] \quad (13e)$$

$$\Rightarrow \nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \partial \mathbf{E} / \partial t \quad \text{from (7b) and (7a)} \quad (13f)$$

In above equations, ρ is the charge density, ϵ_0 is the permittivity of free space, μ_0 is the permeability of free space, \mathbf{J} is the current density vector, $\partial_t = \partial/\partial t$, and symbol \because means 'because'. From (10)-(13), Maxwell's equations in the vector field formalism remain invariant under the PE-SE transformations.

The invariance of all four Maxwell's Equations can also be derived from Eq. (59) of Einstein's General Theory of Relativity (Einstein, 1916):

$$F_{\rho\sigma} = \partial\varphi_\rho/\partial x_\sigma - \partial\varphi_\sigma/\partial x_\rho \quad (14)$$

where F is the covariant six-vector of the electromagnetic field and φ is the electromagnetic potential vector,¹⁰

$$\varphi = [\mathbf{A}, \phi] \quad (15)$$

The PE-SE transformations (2a, 2b) lead to the PE-SE transformation for φ_ρ and φ_σ as follows:

$$\begin{aligned} \varphi_\rho \rightarrow \varphi'_\rho &= [\mathbf{A}', \phi']_\rho \\ &= [(A + \nabla \mathcal{E}), (\phi - \partial_t \mathcal{E})]_\rho \\ &= \varphi_\rho + \partial \mathcal{E} / \partial x_\rho \end{aligned} \quad (16)$$

Similarly,

$$\begin{aligned} \varphi_\sigma \rightarrow \varphi'_\sigma &= [\mathbf{A}', \phi']_\sigma \\ &= [(A + \nabla \mathcal{E}), (\phi - \partial_t \mathcal{E})]_\sigma \\ &= \varphi_\sigma + \partial \mathcal{E} / \partial x_\sigma \end{aligned} \quad (17)$$

Eqs. (16) and (17) in (14) lead to

$$F_{\rho\sigma} \rightarrow F'_{\rho\sigma} = \partial\varphi'_\rho/\partial x_\sigma - \partial\varphi'_\sigma/\partial x_\rho \quad (18a)$$

$$= \partial\varphi_\rho/\partial x_\sigma + \partial^2 \mathcal{E} / \partial x_\rho \partial x_\sigma - \partial\varphi_\sigma/\partial x_\rho - \partial^2 \mathcal{E} / \partial x_\sigma \partial x_\rho \quad (18b)$$

$$= \partial\varphi_\rho/\partial x_\sigma - \partial\varphi_\sigma/\partial x_\rho \quad \because \partial^2 \mathcal{E} / \partial x_\rho \partial x_\sigma = \partial^2 \mathcal{E} / \partial x_\sigma \partial x_\rho \quad (18c)$$

$$= F_{\rho\sigma} \quad (18d)$$

Thus $F_{\rho\sigma}$ is invariant under the PE-SE transformation. Therefore, the Maxwell's Equations derived from it are also invariant

¹⁰ We are using electromagnetic potential vector as $[\mathbf{A}, \phi]$ or $[\phi, \mathbf{A}]$ format depending on the context as originally developed by previous authors.

under the PE-SE transformations (2a, 2b). The detail derivation of Maxwell's Equations from $F_{\rho\sigma}$ is given in Section 20 of (Einstein, 1916).

Although here we are introducing consciousness in classical physics, but after we have shown how to obtain a PE-SE transformation invariant quantum description of a particle in an electromagnetic field, could we reverse the argument? In other words, when we demand that a theory is invariant under a PE-SE transformation, can this procedure impose the specific form of the interaction leading to the dual-aspect view? That is, can a theory invariant under PE-SE transformation entail the dual-aspect view? Further research is needed to address this query.

2.6. *Newtonian gravitational potential and field: Invariance of gravitational field*

A gravitational field is a model used within physics to explain how gravity exists in the universe. In its original concept, gravity was a force between point masses. Following Newton, Laplace attempted to model gravity as some kind of radiation field or fluid, and since the 19th century explanations for gravity have usually been sought in terms of a field model, rather than a point attraction. In a field model, rather than two particles attracting each other, the particles distort space-time via their mass, and this distortion is what is perceived subjectively as a "force". In fact there is no force in such a model, rather matter is simply responding to the curvature of space-time itself; see also (Vimal, 2009k).

The gravitational potential is a scalar field created by any mass (M), such as the earth or the Sun. The gravitational potential at a distance r from a point mass M is given by

$$V(r) = -GM/r \quad (19)$$

where G is the gravitational constant (Vimal, 2009k).

The gravitational field is a vector field that describes the gravitational force which would be applied on an object in any given point in space, per unit mass. It is actually equal to the gravitational acceleration at that point. Gravitational fields are also conservative; that is, the work done by gravity from one position to another is path-independent. This has the consequence that there exists a gravitational potential field $V(r)$ such that

$$G(r) = -\nabla V(r) = -GM/r^2 \quad (20a)$$

Newton' law of universal gravitation can be written as a vector equation to account for the direction of the gravitational force on an object of mass m; its magnitude is given as:

$$\begin{aligned} F(r) &= m G(r) = -m \nabla V(r) \\ &= -m \nabla(-GM/r) = -G mM/r^2 \end{aligned} \quad (21)$$

The gravitational force is the gradient of this potential, and follows an inverse square law. In this way, the gravitational potential is analogous to the electrostatic potential and the gravitational force is analogous to the electrostatic force. In mathematics, the potential is known as the Newtonian potential, and is fundamental in the study of potential theory.

Gravitational energy is the potential energy associated with gravitational force. If an object falls from point A to point B inside a gravitational field, the force of gravity will do positive work on the object and the gravitational potential energy will decrease by the same amount. The gravitational potential energy of a system of masses m and M at a distance r is (Vimal, 2009k):

$$U = F.r = -G mM/r \quad (22)$$

The potential energy (U) should not be confused with the gravitational potential (V). Whereas the potential energy refers to the energy that can be released by a small material object that is in the gravitational field of the massive body, the gravitational

potential is the scalar field created by a massive body.

The PE-SE transformation for scalar gravitational potential $V(r)$ from (2a) is

$$V(r) \rightarrow V'(r) = V(r) - \partial_t \mathcal{E} \quad (23)$$

$$G(r) = -\nabla V(r) \quad (20b)$$

$$G(r) \rightarrow G'(r) = -\nabla V(r) + \nabla \partial_t \mathcal{E} \quad (24a)$$

The PE-SE transformation for the gravitational field derived from (2a) is

$$G(r) \rightarrow G'(r) = G(r) + \nabla \partial_t \mathcal{E} + \partial_\sigma \partial_t \mathcal{E} \quad \text{where } \sigma = 1, 2, 3 \quad (24b)$$

If the gravitational field is invariant analogous to electric and magnetic field, then

$$\nabla \partial_t \mathcal{E} = \partial_\sigma \partial_t \mathcal{E} = 0 \quad \text{where } \sigma = 1, 2, 3 \quad (24c)$$

This implies that \mathcal{E} is a constant with respect to space-time for gravitation. In other words, \mathcal{E} is the same at all x, y, z , and t for gravitational field. This seems to be true if SEs/PEs are embedded in space-time geometry in superposed form. This will be elaborated further below in Sections 2.8 and 2.11.

2.7. The Entropic Force is the Origin of Gravity

Recently, it is argued (van Calmthout, 2010) that:¹¹ (i) Newton was the first one who showed how gravity works on large scales by treating it as a force between objects. (ii) Then Einstein refined Newton's model with his theory of general relativity. In this theory, Einstein showed that gravity is described by the way an object warps the fabric of the universe. Objects including us are all pulled towards the Earth because the mass of the planet is curving the surrounding space-time. (iii) However, Verlinde argued that Newton and Einstein explained how gravity works, but did not explain where it comes from. (iv) It is argued that gravitational attraction could be the

consequence of the way information about material objects is organized in space. (v) One could argue that gravity is a phenomenon that emerges from the fundamental properties of space and time. (vi) The gravitational force is not something ingrained in matter itself; rather it is an extra physical effect that emerges from the interplay of mass, time and space. (vii) Verlinde emphasizes real physical concepts like mass and force in his entropic force framework (Verlinde, 2010). (viii) In Verlinde's theory, gravity exists because of a difference in concentration of information in the empty space between two masses and its surroundings. Verlinde does not consider gravity as fundamental; rather he proposes that gravity is an emergent phenomenon that arises from a deeper microscopical reality. (ix) It is argued that gravity arises from statistical behavior of microscopic particles acting according to laws of entropy either from an information theory view of entropy acting on a holographic universe (Verlinde, 2010) or a thermodynamics viewpoint (Jacobson, 1995; Padmanabhan, 2009).

According to (Verlinde, 2010), "Starting from first principles and general assumptions Newton's law of gravitation is shown to arise naturally and unavoidably in a theory in which space is emergent through a holographic scenario. Gravity is explained as an entropic force caused by changes in the information associated with the positions of material bodies. A relativistic generalization of the presented arguments directly leads to the Einstein equations. When space is emergent even Newton's law of inertia needs to be explained. The equivalence principle leads us to conclude that it is actually this law of inertia whose origin is entropic. [...] the central notion needed to derive gravity is information. More precisely, it is the amount of information associated with matter and its location, in whatever form the microscopic theory likes to have it, measured in terms of entropy. Changes in this entropy when matter is displaced leads to an entropic force, which as we will show takes the form of gravity. Its origin therefore lies in the tendency of the microscopic theory to maximize its entropy. [...] The presented ideas are consistent with our knowledge of string theory, but if correct they should have important implications for this theory as

¹¹ See also (Vimal, 2009c).
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well. In particular, the description of gravity as being due to the exchange of closed strings can no longer be valid. In fact, it appears that strings have to be emergent too. [...] One can think about the boundary as a storage device for information. Assuming that the holographic principle holds, the maximal storage space, or total number of bits, is proportional to the area A. In fact, in an theory of emergent space this how area may be defined: each fundamental bit occupies by definition one unit cell. [...] M represents the mass that would emerge in the part of space enclosed by the screen ... Even though the mass is not directly visible in the emerged space, its presence is noticed though its energy. [...] the origin of gravity: it is an entropic force [...] We start from microscopic information. ... macroscopic theories [such as the gravitational or closed strings], ... [are] the dual of a microscopic theory without gravity. [...] If gravity is emergent, so is space time geometry. Einstein tied these two concepts together, and both have to be given up if we want to understand one or the other at a more fundamental level. ... gravity arises as an entropic force, once space and time themselves have emerged. [...] Integrating out the open strings produces the closed strings, and leads to the emergence of space and gravity. ... the existence of gravity or closed strings is not assumed microscopically: they are emergent as an effective description. ... gravity and closed strings are emergent and only present as macroscopic concept. [...] gravity and inertia are entropic forces [...] the holographic hypothesis provides a natural mechanism for gravity to emerge.”

Thus, the origin of gravity is an entropic force, which is caused by temperature that is required to cause acceleration. The temperature comes from the total energy and information-bits present in the system. Mass emerges in space and space emerges from information-bits. In other words, gravity is not a fundamental force rather it is a derived entity from information i.e., from a difference in concentration of information in the empty space between two masses and its surroundings.

Critics argue that Verlinde is using “circular reasoning in his equations, by "starting out" with gravity. Others have

expressed concern about the almost trivial mathematics involved, leaving most of the theory based on very general concepts of space, time and information” (van Calmthout, 2010).

In the dual-aspect-dual-mode PE-SE framework (Vimal, 2008b; Vimal, 2010a), the fundamental entity ‘information’, from which gravity is derived as entropic force, has dual-aspect: its material aspect is discussed above. Its mental aspect contains SEs/PEs in superposed form for hypotheses H₁ and H₂ and information-related PE for H₃.

The PE-SE transformation for the entropic force can be written from (21), (24b) and (2a) as

$$F(r) \rightarrow F'(r) = F(r) + m \nabla \partial_i \mathcal{E} = F(r) + m \partial_\sigma \partial_i \mathcal{E} \text{ where } \sigma = 1, 2, 3 \quad (24d)$$

The entropic force is invariant if

$$\nabla \partial_i \mathcal{E} = \partial_\sigma \partial_i \mathcal{E} = 0 \text{ where } \sigma = 1, 2, 3 \quad (24e)$$

This implies that \mathcal{E} is a constant with respect of space-time for gravitation as in (24c).

2.8. Special Theory of Relativity: Invariance of Lorentz Transformation

The Special Theory of Relativity (STR) is a theory of 4-dimensional space-time: three of space and one of time. An event is defined as a single moment in space and time, characterized uniquely by (t, x, y, z). The space-time interval between two events can be written as (Carroll, 1997):

$$\Delta s^2 = -(c\Delta t)^2 + (\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2 \quad (25a)$$

This can be re-written in a more compact form as,

$$\Delta s^2 = \eta_{\mu\nu} \Delta x^\mu \Delta x^\nu \quad (25b)$$

$$= (\Delta x)^\dagger \eta (\Delta x) \quad (25c)$$

where $\eta_{\mu\nu}$ is 4x4 diagonal matrix (the metric) with diagonal elements (-1, 1, 1, 1), and the

superscript \dagger represents conjugate transpose, Hermitian transpose, or *adjoint* of a matrix.

The multiplicative transformation is to multiply x^μ by a (space-time-independent) matrix:

$$x^\mu \rightarrow x'^\mu = \Lambda^\mu{}_\nu x^\nu \quad (26a)$$

which is consistent with the Lorentz transformation and can be re-written in more conventional matrix notation as,

$$x \rightarrow x' = \Lambda x \quad (26b)$$

$$\Delta x \rightarrow \Delta x' = \Lambda \Delta x \quad (26c)$$

For the invariance of space-time interval, we need

$$\begin{aligned} \Delta s^2 &\rightarrow \Delta s'^2 = (\Delta x')^\dagger \eta (\Delta x') \\ &= (\Delta x)^\dagger \Lambda^\dagger \eta \Lambda (\Delta x) \\ &= (\Delta x)^\dagger \eta (\Delta x) = \Delta s^2 \end{aligned} \quad (27)$$

This implies that

$$\eta = \Lambda^\dagger \eta \Lambda \quad (28)$$

This is the Lorentz transformation for the invariance of space-time interval under the linear multiplicative coordinate transformation in space-time in the STR.

Since PEs/SEs are embedded in space-time geometry as per (Hameroff and Penrose, 1998), $\mathcal{E}(t; x, y, z) = \mathcal{E}(t'; x', y', z')$.¹² In dual-aspect view, multiplicative transformation (26a,b,c) is appropriate, which in turn requires that the Lorentz transformation must remain invariant under the PE-SE transformation, namely,

$$\Lambda \rightarrow \Lambda' = \exp(j\mathcal{E}) \Lambda \quad (29a)$$

$$x \rightarrow x' = \Lambda' x = \exp(j\mathcal{E}) \Lambda x \quad (29b)$$

$$\begin{aligned} \Delta x &\rightarrow \Delta x' \\ &= \exp(j\mathcal{E}) \Lambda \Delta x + j \exp(j\mathcal{E}) \Delta \mathcal{E} \Lambda x \end{aligned}$$

$$= \exp(j\mathcal{E}) \Lambda [\Delta x + j x \Delta \mathcal{E}] \quad (29c)$$

which in (28) implies that,

$$\begin{aligned} \Lambda^\dagger \eta \Lambda &\rightarrow \Lambda'^\dagger \eta \Lambda' \\ &= \exp(-j\mathcal{E}) \Lambda^\dagger \eta \exp(j\mathcal{E}) \Lambda \\ &= \Lambda^\dagger \eta \Lambda \end{aligned} \quad (30)$$

$$\Delta s'^2 = \eta_{\mu\nu} \Delta x'^\mu \Delta x'^\nu \quad (25d)$$

$$= (\Delta x')^\dagger \eta (\Delta x') \quad (25e)$$

$$= [\exp(j\mathcal{E}) \Lambda \Delta x + j \exp(j\mathcal{E}) \Delta \mathcal{E} \Lambda x]^\dagger \eta [\exp(j\mathcal{E}) \Lambda \Delta x + j \exp(j\mathcal{E}) \Delta \mathcal{E} \Lambda x] \quad (25f)$$

$$= \exp(-j\mathcal{E}) [(\Delta x)^\dagger - j x^\dagger (\Delta \mathcal{E})^\dagger] \Lambda^\dagger \eta \exp(j\mathcal{E}) \Lambda [\Delta x + j x \Delta \mathcal{E}] \quad (25g)$$

$$= [(\Delta x)^\dagger - j x^\dagger (\Delta \mathcal{E})^\dagger] \Lambda^\dagger \eta \Lambda [\Delta x + j x \Delta \mathcal{E}] \quad (25h)$$

$$= [(\Delta x)^\dagger - j x^\dagger (\Delta \mathcal{E})^\dagger] \eta [\Delta x + j x \Delta \mathcal{E}] \quad \text{from (28)} \quad (25i)$$

$$= [(\Delta x)^\dagger \eta \Delta x] - [j (\Delta \mathcal{E})^\dagger x^\dagger \eta \Delta x] + [j \Delta \mathcal{E} (\Delta x)^\dagger \eta x] + [(\Delta \mathcal{E})^\dagger \Delta \mathcal{E} x^\dagger \eta x] \quad (25j)$$

$$= \Delta s^2 - [j (\Delta \mathcal{E})^\dagger x^\dagger \eta \Delta x] + [j \Delta \mathcal{E} (\Delta x)^\dagger \eta x] + [(\Delta \mathcal{E})^\dagger \Delta \mathcal{E} x^\dagger \eta x] \quad (25k)$$

$$= \Delta s^2 + [(\Delta \mathcal{E})^\dagger \Delta \mathcal{E} x^\dagger \eta x] \quad \text{where} \quad (25l)$$

$$\begin{aligned} (\Delta \mathcal{E})^\dagger &= \Delta \mathcal{E} \text{ and } [x^\dagger \eta \Delta x = (\Delta x)^\dagger \eta x] \\ &= \Delta s^2 \text{ if } [(\Delta \mathcal{E})^\dagger \Delta \mathcal{E} x^\dagger \eta x] = 0 \\ &\Rightarrow \Delta \mathcal{E} = 0 \end{aligned} \quad (25m)$$

From Eq. (30), we suggests that the Lorentz transformation and (hence) STR-physics are invariant under the PE-SE transformation (29).

2.9. Geodesic Equation

According to (Carroll, 1997), “A geodesic is the curved-space generalization of the notion of a “straight line” in Euclidean space. We all know what a straight line is: it’s the path of shortest distance between two points. But there is an equally good definition – a straight line is a path which parallel transports its own tangent vector.” (p. 68). The geodesic equation from Eq. (3.47) of (Carroll, 1997) can be written as,

$$(d^2 x^\mu / d\lambda^2) + \Gamma^\mu_{\rho\sigma} (dx^\rho / d\lambda)(dx^\sigma / d\lambda) = 0 \quad (31)$$

This equation (related to the General Theory of Relativity) is invariant under the PE-SE transformation,

¹² For substance-dualism in panpsychism, one could use additive coordinate linear transnational transformation in space-time. For this, the PE-SE transformation $x \rightarrow x' = x + x_0 \exp(j\mathcal{E})$, which implies that Δx is invariant as $\Delta x' = \Delta x$. Thus, Δs^2 in (25) is invariant. This implies that the STR-physics is invariant under the transformation related to the substance-dualism in panpsychism. However, both macro and micro substance-dualism have problems; the problems of dualism are concisely mentioned in (Vimal, 2009h).

$$\lambda \rightarrow \lambda' = \exp(j\mathcal{E}) \lambda \quad (32a)$$

$$x^\mu \rightarrow x'^\mu = \exp(j\mathcal{E}) x^\mu \quad (32b)$$

The substitution of Eqs. (32a) and (32b) in (31) implies that $\mathcal{E}(t; x, y, z) = \mathcal{E}(t'; x', y', z')$ is constant.

2.10. General Theory of Relativity: Gravitational Field

General theory of relativity (GTR) needs to address “how the curvature of space-time acts on matter to manifest itself as “gravity”, and how energy and momentum [of matter] influence space-time to create curvature. [...] The impossibility of comparing velocities (vectors) at widely separated regions corresponds to the path-dependence of parallel transport on a curved manifold. These considerations were enough to give Einstein the idea that gravity was a manifestation of space-time curvature. [...] Einstein’s field equations [...] govern how the metric responds to energy and momentum” (Carroll, 1997).

A field equation is an equation in a physical theory that describes how a fundamental force (or a combination of such forces) interacts with matter. The four fundamental forces are the gravitational force, the electromagnetic force, the strong force and the weak force. Before the theory of quantum mechanics was fully developed, there were two known field theories, namely gravitation and electromagnetism (these two are sometimes referred to as classical field theories, as they were formulated before the advent of quantum mechanics, and hence do not take into account quantum phenomena). Modern field equations tend to be tensor equations R (Vimal, 2009k).

The Einstein field equations (EFE) can be written as follows from (Vimal, 2009k) and (Einstein, 1916):

$$[R_{\mu\nu} - (g_{\mu\nu}/2) R + g_{\mu\nu} \Lambda] = [(8\pi G/c^4)T_{\mu\nu}] \quad (33a)$$

$$= G_{\mu\nu} \quad (33b)$$

where $G_{\mu\nu}$ is the Einstein tensor, $R_{\mu\nu}$ is the Ricci curvature tensor (measure of volume distortion: how much Riemannian metric might differ from that of ordinary Euclidean n-space) (Vimal, 2009k), R is the scalar curvature (Ricci scalar), $g_{\mu\nu}$ is the metric tensor, Λ is the cosmological constant, G is

the gravitational constant, c is the speed of light, and $T_{\mu\nu}$ is the stress-energy tensor. In the left hand side of (33a), $R_{\mu\nu}$, $g_{\mu\nu}$, and R refer to the structure of space-time. In the right hand side of (33a), $T_{\mu\nu}$ refers to matter and energy (thought of as affecting that structure). When Λ is zero, this reduces to the original field equation of general relativity. When $T_{\mu\nu}$ is zero, the field equation describes empty space (the vacuum) without matter, where matter refers to non-gravitational fields such as fields related to electromagnetic, weak, and strong forces. The above form of the Einstein field equations (33a, b) is the standard established by (Misner *et al.*, 1973).

2.10.1. Metric $g_{\mu\nu}$: generalization of the gravitational field

“In general relativity, the metric tensor (or simply, the metric) is the fundamental object of study. It may loosely be thought of as a generalization of the gravitational field familiar from Newtonian gravitation. The metric captures all the geometric and causal structure of space-time, being used to define notions such as distance, volume, curvature, angle, future and past. [...] Mathematically, space-time is represented by a 4-dimensional differentiable manifold M and the metric is given as a covariant, second-rank, symmetric tensor on M , conventionally denoted by g . [...] Explicitly, the metric is a symmetric bilinear form on each tangent space of M which varies in a smooth (or differentiable) manner from point to point. Given two tangent vectors u and v and a point x in M , the metric can be evaluated on u and v to give a real number: $g_x(u,v) = g_x(v,u) \in \mathbb{R}$. This can be thought of as a generalization of the dot product in ordinary Euclidean space [...] the tensor g is actually a tensor field defined at all points of a space-time manifold [...] $g = g_{\mu\nu} dx^\mu dx^\nu$ [...] The factors dx^μ are one-form gradients of the scalar coordinate fields x^μ [...] The metric g completely determines the curvature of space-time. According to the fundamental theorem of Riemannian geometry, there is a unique connection ∇ on any Lorentzian manifold that is compatible with the metric and torsion-free. This connection is called the Levi-Civita connection ∇ . The Christoffel symbols of this connection are given in

terms of partial derivatives of the metric in local coordinates x^μ by the formula¹³:

$$\Gamma^\lambda_{\mu\nu} = (g^{\lambda\rho}/2) [(\partial g_{\rho\mu}/\partial x^\nu) + (\partial g_{\rho\nu}/\partial x^\mu) - (\partial g_{\mu\nu}/\partial x^\rho)] \quad (34a)$$

$$= (g^{\lambda\rho}/2) (\partial_\nu g_{\rho\mu} + \partial_\mu g_{\rho\nu} - \partial_\rho g_{\mu\nu}) \quad (34b)$$

$$= (g^{\lambda 1}/2) (\partial_\nu g_{1\mu} + \partial_\mu g_{1\nu} - \partial_1 g_{\mu\nu}) + \dots + (g^{\lambda 4}/2) (\partial_\nu g_{4\mu} + \partial_\mu g_{4\nu} - \partial_4 g_{\mu\nu}) \quad (34c)$$

Similarly as in (34b),

$$\Gamma^\rho_{\nu\mu} = (g^{\rho\alpha}/2) (\partial_\mu g_{\alpha\nu} + \partial_\nu g_{\alpha\mu} - \partial_\alpha g_{\nu\mu}) \quad (34d)$$

$$\Gamma^\rho_{\rho\mu} = (g^{\rho\alpha}/2) (\partial_\mu g_{\alpha\rho} + \partial_\rho g_{\alpha\mu} - \partial_\alpha g_{\rho\mu}) \quad (34e)$$

$$\begin{aligned} \Gamma^\rho_{\nu\mu,\rho} &= \partial_\rho \Gamma^\rho_{\nu\mu} \\ &= (\partial_\rho g^{\rho\alpha}/2) (\partial_\mu g_{\alpha\nu} + \partial_\nu g_{\alpha\mu} - \partial_\alpha g_{\nu\mu}) + (g^{\rho\alpha}/2) (\partial_\rho \partial_\mu g_{\alpha\nu} + \partial_\rho \partial_\nu g_{\alpha\mu} - \partial_\rho \partial_\alpha g_{\nu\mu}) \end{aligned} \quad (34f)$$

$$\begin{aligned} \Gamma^\rho_{\rho\mu,\nu} &= \partial_\nu \Gamma^\rho_{\rho\mu} \\ &= (\partial_\nu g^{\rho\alpha}/2) (\partial_\mu g_{\alpha\rho} + \partial_\rho g_{\alpha\mu} - \partial_\alpha g_{\rho\mu}) + (g^{\rho\alpha}/2) (\partial_\nu \partial_\mu g_{\alpha\rho} + \partial_\nu \partial_\rho g_{\alpha\mu} - \partial_\nu \partial_\alpha g_{\rho\mu}) \end{aligned} \quad (34g)$$

$$\Gamma^\rho_{\rho\lambda} = (g^{\rho\alpha}/2) (\partial_\lambda g_{\alpha\rho} + \partial_\rho g_{\alpha\lambda} - \partial_\alpha g_{\rho\lambda}) \quad (34h)$$

$$\Gamma^\lambda_{\nu\mu} = (g^{\lambda\alpha}/2) (\partial_\mu g_{\alpha\nu} + \partial_\nu g_{\alpha\mu} - \partial_\alpha g_{\nu\mu}) \quad (34i)$$

$$\Gamma^\rho_{\nu\lambda} = (g^{\rho\alpha}/2) (\partial_\lambda g_{\alpha\nu} + \partial_\nu g_{\alpha\lambda} - \partial_\alpha g_{\nu\lambda}) \quad (34j)$$

$$\Gamma^\lambda_{\rho\mu} = (g^{\lambda\alpha}/2) (\partial_\mu g_{\alpha\rho} + \partial_\rho g_{\alpha\mu} - \partial_\alpha g_{\rho\mu}) \quad (34k)$$

Since the gravitational field is weak, we can decompose the metric $g_{\mu\nu}$ into the flat Minkowski metric $\eta_{\mu\nu}$ (= diag(-1, +1, +1, +1)) plus a small perturbation $h_{\mu\nu}$ as follows (Carroll, 1997); p.142):

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu} \quad \text{where } |h_{\mu\nu}| \ll 1 \quad (35a)$$

One can define a family of perturbations parameterized by J using diffeomorphism (active co-ordinate transformation) with some vector ξ_ν (Carroll, 1997; p.145) as:

$$(h_{\mu\nu})^{(J)} = h_{\mu\nu} + 2J \partial_\mu \xi_\nu \quad (35b)$$

$$= h_{\mu\nu} + 2J (\partial_\mu \xi_\nu + \partial_\nu \xi_\mu) \quad (35c)$$

The linearized Riemann tensor $R_{\mu\nu\rho\sigma}$ ((Carroll, 1997).p.143.(6.5)) is given by:

$$R_{\mu\nu\rho\sigma} = (1/2)(\partial_\rho \partial_\nu h_{\mu\sigma} + \partial_\sigma \partial_\mu h_{\nu\rho} - \partial_\sigma \partial_\nu h_{\mu\rho} - \partial_\rho \partial_\mu h_{\nu\sigma}) \quad (36)$$

which remains invariant under the above co-ordinate transformation (35b, c), as per Eq.(6.14) of ((Carroll, 1997).

We can formulate the PE-SE transformation from the metric's decomposition (35b, c) and transformations (2a, b) as,

$$h_{\mu\nu} \rightarrow h'_{\mu\nu} = h_{\mu\nu} + j(\partial_\mu \mathcal{E}_\nu + \partial_\nu \mathcal{E}_\mu) \quad (37a)$$

One can show that the PE-SE transformation (37a) is related to the dual-aspect framework as follows:

$$\begin{aligned} h_{\mu\nu} \rightarrow h'_{\mu\nu} &= h_{\mu\nu} + j(\partial_\mu \mathcal{E}_\nu + \partial_\nu \mathcal{E}_\mu) \\ &= H_{\mu\nu} \cos(\zeta) + j H_{\mu\nu} \sin(\zeta) \\ &= H_{\mu\nu} \exp(j\zeta) \end{aligned} \quad (37b)$$

$$\text{where } H_{\mu\nu} \cos(\zeta) = h_{\mu\nu} \quad (37c)$$

$$H_{\mu\nu} \sin(\zeta) = (\partial_\mu \mathcal{E}_\nu + \partial_\nu \mathcal{E}_\mu) \quad (37d)$$

$$H^2_{\mu\nu} = h^2_{\mu\nu} + (\partial_\mu \mathcal{E}_\nu + \partial_\nu \mathcal{E}_\mu)^2 \quad (37e)$$

$$\tan(\zeta) = (\partial_\mu \mathcal{E}_\nu + \partial_\nu \mathcal{E}_\mu) / h_{\mu\nu} \quad (37f)$$

Applying (37a) in (36), we get:

$$\begin{aligned} R_{\mu\nu\rho\sigma} &\rightarrow R'_{\mu\nu\rho\sigma} \\ &= (1/2)(\partial_\rho \partial_\nu h'_{\mu\sigma} + \partial_\sigma \partial_\mu h'_{\nu\rho} - \partial_\sigma \partial_\nu h'_{\mu\rho} - \partial_\rho \partial_\mu h'_{\nu\sigma}) \end{aligned} \quad (38a)$$

$$\begin{aligned} &= (1/2)[\partial_\rho \partial_\nu h_{\mu\sigma} + \partial_\sigma \partial_\mu h_{\nu\rho} - \partial_\sigma \partial_\nu h_{\mu\rho} - \partial_\rho \partial_\mu h_{\nu\sigma} + \\ & j (\partial_\rho \partial_\nu \partial_\mu \mathcal{E}_\sigma + \partial_\rho \partial_\nu \partial_\sigma \mathcal{E}_\mu + \\ & \partial_\sigma \partial_\mu \partial_\nu \mathcal{E}_\rho + \partial_\sigma \partial_\mu \partial_\rho \mathcal{E}_\nu - \partial_\sigma \partial_\nu \partial_\mu \mathcal{E}_\rho - \partial_\sigma \partial_\nu \partial_\rho \mathcal{E}_\mu - \\ & \partial_\rho \partial_\mu \partial_\nu \mathcal{E}_\sigma - \partial_\rho \partial_\mu \partial_\sigma \mathcal{E}_\nu)] \end{aligned} \quad (38b)$$

$$= (1/2)[\partial_\rho \partial_\nu h_{\mu\sigma} + \partial_\sigma \partial_\mu h_{\nu\rho} - \partial_\sigma \partial_\nu h_{\mu\rho} - \partial_\rho \partial_\mu h_{\nu\sigma}] \quad (38c)$$

$$= R_{\mu\nu\rho\sigma} \quad (38d)$$

$$\begin{aligned} \text{where } \partial_\rho \partial_\nu \partial_\mu &= \partial_\rho \partial_\mu \partial_\nu, \partial_\rho \partial_\nu \partial_\sigma = \partial_\sigma \partial_\nu \partial_\rho, \\ \partial_\sigma \partial_\mu \partial_\nu &= \partial_\sigma \partial_\nu \partial_\mu, \text{ and } \partial_\sigma \partial_\mu \partial_\rho \\ &= \partial_\rho \partial_\mu \partial_\sigma \end{aligned} \quad (38e)$$

Thus, the linearized Riemann tensor $R_{\mu\nu\rho\sigma}$ is invariant under the dual-aspect PE-SE transformation (37a-f).

¹³ See (Vimal, 2009k).
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Alternative treatment of metric tensor $g_{\mu\nu}$ is given in Section 2.11.

2.10.2. Ricci curvature tensor $R_{\mu\nu}$

Ricci curvature tensor $R_{\mu\nu}$ comes from contracting the linearized Riemann tensor $R_{\mu\nu\rho\sigma}$ (36) over μ and ρ (Carroll, 1997). p.143. (6.6)), i.e., raise the index μ of the metric $h_{\mu\sigma}$ and $h_{\mu\rho}$ and the index ρ of the metric $h_{\nu\rho}$ and then replace μ with ρ in (36):

$$R_{\sigma\nu} = R^{\rho}_{\nu\rho\sigma} = (1/2)(\partial_{\rho}\partial_{\nu}h^{\rho}_{\sigma} + \partial_{\sigma}\partial_{\rho}h^{\rho}_{\nu} - \partial_{\sigma}\partial_{\nu}h^{\rho}_{\rho} - \partial_{\rho}\partial_{\rho}h_{\nu\sigma}) \quad (39a)$$

Replace σ with μ in (39a):

$$R_{\mu\nu} = (1/2)(\partial_{\rho}\partial_{\nu}h^{\rho}_{\mu} + \partial_{\mu}\partial_{\rho}h^{\rho}_{\nu} - \partial_{\mu}\partial_{\nu}h^{\rho}_{\rho} - \partial_{\rho}\partial_{\rho}h_{\nu\mu}) \quad (39b)$$

Rearranging indices, we get:

$$R_{\mu\nu} = (1/2)(\partial_{\mu}\partial_{\rho}h^{\rho}_{\nu} + \partial_{\nu}\partial_{\rho}h^{\rho}_{\mu} - \partial_{\mu}\partial_{\nu}h^{\rho}_{\rho} - \partial_{\rho}\partial_{\rho}h_{\mu\nu}) \quad (39c)$$

We can re-formulate the transformation from (37a) such as,

$$h^{\rho}_{\nu} \rightarrow h'^{\rho}_{\nu} = h^{\rho}_{\nu} + j(\partial_{\rho}\mathcal{E}_{\nu} + \partial_{\nu}\mathcal{E}_{\rho}) \quad (40)$$

Applying the transformation (40) in (39c), we get:

$$R_{\mu\nu} \rightarrow R'_{\mu\nu} = (1/2)(\partial_{\mu}\partial_{\rho}h'^{\rho}_{\nu} + \partial_{\nu}\partial_{\rho}h'^{\rho}_{\mu} - \partial_{\mu}\partial_{\nu}h'^{\rho}_{\rho} - \partial_{\rho}\partial_{\rho}h'_{\mu\nu}) \quad (41a)$$

$$= (1/2)[\partial_{\mu}\partial_{\rho}h^{\rho}_{\nu} + \partial_{\nu}\partial_{\rho}h^{\rho}_{\mu} - \partial_{\mu}\partial_{\nu}h^{\rho}_{\rho} - \partial_{\rho}\partial_{\rho}h_{\mu\nu} + j(\partial_{\mu}\partial_{\rho}\partial_{\rho}\mathcal{E}_{\nu} + \partial_{\mu}\partial_{\rho}\partial_{\nu}\mathcal{E}_{\rho} + \partial_{\nu}\partial_{\rho}\partial_{\rho}\mathcal{E}_{\mu} + \partial_{\nu}\partial_{\rho}\partial_{\mu}\mathcal{E}_{\rho} - \partial_{\mu}\partial_{\nu}\partial_{\rho}\mathcal{E}_{\rho} - \partial_{\mu}\partial_{\nu}\partial_{\rho}\mathcal{E}_{\rho} - \partial_{\rho}\partial_{\rho}\partial_{\mu}\mathcal{E}_{\nu} - \partial_{\rho}\partial_{\rho}\partial_{\nu}\mathcal{E}_{\mu})] \quad (41b)$$

$$= (1/2)[\partial_{\mu}\partial_{\rho}h^{\rho}_{\nu} + \partial_{\nu}\partial_{\rho}h^{\rho}_{\mu} - \partial_{\mu}\partial_{\nu}h^{\rho}_{\rho} - \partial_{\rho}\partial_{\rho}h_{\mu\nu}] \quad (41c)$$

$$= R_{\mu\nu} \quad (41d)$$

where $\partial_{\mu}\partial_{\rho}\partial_{\rho} = \partial_{\rho}\partial_{\rho}\partial_{\mu}$, $\partial_{\mu}\partial_{\rho}\partial_{\nu} = \partial_{\mu}\partial_{\nu}\partial_{\rho}$, $\partial_{\nu}\partial_{\rho}\partial_{\rho} = \partial_{\rho}\partial_{\rho}\partial_{\nu}$, and $\partial_{\nu}\partial_{\rho}\partial_{\mu} = \partial_{\mu}\partial_{\nu}\partial_{\rho}$ (41e)

Thus, the Ricci curvature tensor $R_{\mu\nu}$ is invariant under PE-SE transformation (40).¹⁴

2.10.3. Ricci scalar curvature R

Ricci scalar curvature is the simplest curvature invariant of a Riemannian manifold. It is defined as the trace of the Ricci curvature tensor with respect to the metric (Vimal, 2009k):

$$R = g^{\mu\nu} R_{\mu\nu} = g^{\mu\nu} [\Gamma^{\rho}_{\mu\nu,\rho} - \Gamma^{\rho}_{\mu\rho,\nu} + \Gamma^{\rho}_{\rho\lambda} \Gamma^{\lambda}_{\mu\nu} - \Gamma^{\rho}_{\nu\lambda} \Gamma^{\lambda}_{\mu\rho}] \quad (42)$$

where $\Gamma_{\mu\nu} = \Gamma_{\nu\mu}$

Ricci scalar curvature R comes from contracting the Ricci curvature tensor $R_{\mu\nu}$ (39c) over ν and μ (Carroll, 1997). p.143. (6.7)), i.e., raise the index ν of the metric h^{ρ}_{ν} and $h_{\mu\nu}$ and the index μ of the metric h^{ρ}_{μ} and then replace ν with μ in (39c):

$$R = R_{\mu}^{\mu} = (1/2)(\partial_{\mu}\partial_{\rho}h^{\rho\mu} + \partial_{\mu}\partial_{\rho}h^{\rho\mu} - \partial_{\mu}\partial_{\mu}h^{\rho}_{\rho} - \partial_{\rho}\partial_{\rho}h^{\mu}_{\mu}) \quad (43a)$$

which can be re-written by replacing index ρ with ν as,

$$R = (1/2)(2 \partial_{\mu}\partial_{\nu}h^{\mu\nu} - \partial_{\mu}\partial_{\mu}h^{\nu}_{\nu} - \partial_{\nu}\partial_{\nu}h^{\mu}_{\mu}) \quad (43b)$$

$$= \partial_{\mu}\partial_{\nu}h^{\mu\nu} - \Upsilon h \quad (43c)$$

where Υ is the D'Alembertian that is one form flat space, and h is the trace of the perturbation.

$$\Upsilon = \partial_{\mu}\partial_{\mu} = \partial^2_{\mu} = -\partial^2_t + \partial^2_x + \partial^2_y + \partial^2_z \quad (44)$$

$$\text{and } h = h^{\mu}_{\mu} = \eta^{\mu\nu} h_{\mu\nu} \quad (45)$$

We can re-formulate the PE-SE transformation from (37a) such as,

¹⁴ Furthermore, the curvature of space-time is given by the Riemann curvature tensor, which is defined in terms of the Levi-Civita connection ∇ . In local coordinates, this tensor is given by: $R^{\rho}_{\sigma\mu\nu} = \partial_{\mu}\Gamma^{\rho}_{\nu\sigma} - \partial_{\nu}\Gamma^{\rho}_{\mu\sigma} + \Gamma^{\rho}_{\mu\lambda}\Gamma^{\lambda}_{\nu\sigma} - \Gamma^{\rho}_{\nu\lambda}\Gamma^{\lambda}_{\mu\sigma}$ (39d) where $\partial_{\mu} = \partial X^{\mu}$. The curvature can then be expressed in terms of the metric g and its derivatives as follows ($\mu \rightarrow \rho$ in (39d)):

$$R_{\sigma\nu} = R^{\rho}_{\sigma\rho\nu} = \Gamma^{\rho}_{\nu\sigma,\rho} - \Gamma^{\rho}_{\rho\sigma,\nu} + \Gamma^{\rho}_{\rho\lambda}\Gamma^{\lambda}_{\nu\sigma} - \Gamma^{\rho}_{\nu\lambda}\Gamma^{\lambda}_{\rho\sigma} \quad (39e)$$

where $\Gamma^{\rho}_{\nu\sigma,\rho} = \partial_{\rho}\Gamma^{\rho}_{\nu\sigma}$ and Eq. (39e) can be re-written by $\sigma \rightarrow \mu$ as:

$$R_{\mu\nu} = R^{\rho}_{\mu\rho\nu} = \Gamma^{\rho}_{\nu\mu,\rho} - \Gamma^{\rho}_{\rho\mu,\nu} + \Gamma^{\rho}_{\rho\lambda}\Gamma^{\lambda}_{\nu\mu} - \Gamma^{\rho}_{\nu\lambda}\Gamma^{\lambda}_{\rho\mu} \quad (39f)$$

$$h^{\mu\nu} \rightarrow h'^{\mu\nu} = h^{\mu\nu} + j(\partial_\mu \mathcal{E}_\nu + \partial_\nu \mathcal{E}_\mu) \quad (46)$$

Applying (46) in (43b), we get:

$$R \rightarrow R' = (1/2)[2 \partial_\mu \partial_\nu h'^{\mu\nu} - \partial_\mu \partial_\mu h'^\nu_\nu - \partial_\nu \partial_\nu h'^\mu_\mu] \quad (47a)$$

$$= (1/2)[2 \partial_\mu \partial_\nu h^{\mu\nu} - \partial_\mu \partial_\mu h^\nu_\nu - \partial_\nu \partial_\nu h^\mu_\mu + j(2\partial_\mu \partial_\nu \partial_\mu \mathcal{E}_\nu + 2\partial_\mu \partial_\nu \partial_\nu \mathcal{E}_\mu - 2 \partial_\mu \partial_\mu \partial_\nu \mathcal{E}_\nu - 2\partial_\nu \partial_\nu \partial_\mu \mathcal{E}_\mu)] \quad (47b)$$

$$= R \quad (47c)$$

where $\partial_\mu \partial_\nu \partial_\mu = \partial_\mu \partial_\mu \partial_\nu$

$$\text{and } \partial_\mu \partial_\nu \partial_\nu = \partial_\nu \partial_\nu \partial_\mu \quad (48)$$

Thus, the Ricci scalar curvature R is invariant under the PE-SE transformation (46).

2.10.4. The cosmological constant Λ

In physical cosmology, the cosmological constant (Λ) was proposed by Einstein as a modification of his original theory of general relativity to achieve a stationary universe (Vimal, 2009k). Einstein abandoned the concept after the observation of the Hubble red shift indicated that the universe might not be stationary (rather universe is expanding), as he had based his theory on the idea that the universe is unchanging. However, the discovery of cosmic acceleration in the 1990s has renewed interest in a cosmological constant. Astronomical observations imply that this constant cannot exceed 10^{-46} km^{-2} . The cosmological constant has the same effect as an intrinsic energy density of the vacuum, ρ_{vac} (and an associated pressure). In this context it is commonly defined with a proportionality factor of 8π : $\Lambda = 8\pi \rho_{\text{vac}}$, where modern unit conventions of general relativity are followed (otherwise factors of G and c would also appear).

If move the term $\Lambda g_{\mu\nu}$ in (33a) to the right hand side, and “think of it as a kind of energy-momentum tensor, with $T'_{\mu\nu} = -g_{\mu\nu} \Lambda$ (it is automatically conserved by metric compatibility). Then Λ can be interpreted as the “energy density of the vacuum,” a source of energy and momentum that is present even in the absence of matter

fields. This interpretation is important because quantum field theory predicts that the vacuum should have some sort of energy and momentum. In ordinary quantum mechanics, a harmonic oscillator with frequency ω and minimum classical energy $E_0 = 0$ upon quantization has a ground state with energy $E_0 = 1/2 \hbar \omega$. A quantized field can be thought of as a collection of an infinite number of harmonic oscillators, and each mode contributes to the ground state energy. The result is of course infinite, and must be appropriately regularized, for example by introducing a cutoff at high frequencies. The final vacuum energy, which is the regularized sum of the energies of the ground state oscillations of all the fields of the theory, has no good reason to be zero and in fact would be expected to have a natural scale

$$\Lambda \sim m_p^4 \quad (49)$$

where the Planck mass m_p is approximately 10^{19} GeV , or 10^{-5} grams . Observations of the universe on large scales allow us to constrain the actual value of Λ , which turns out to be smaller than (49) by at least a factor of 10^{120} . This is the largest known discrepancy between theoretical estimate and observational constraint in physics, and convinces many people that the “cosmological constant problem” is one of the most important unsolved problems today. On the other hand the observations do not tell us that Λ is strictly zero, and in fact allow values that can have important consequences for the evolution of the universe” (Carroll, 1997).p.118-9.

2.10.5. The stress-energy tensor $T_{\mu\nu}$

A general definition of $T_{\mu\nu}$ is the flux of four-momentum p_μ across a surface of constant x_ν . $T_{\mu\nu}$ is the energy tensor for matter, where matter is non-gravitational entity that includes remaining 3 forces, namely electromagnetic, electroweak, and strong forces. If $T_{\mu\nu} = 0$, then the Einstein field equations represent the field equations of gravitation in the absence of matter (matter-free gravitational field equations) (Einstein, 1916). “The stress-energy tensor (sometimes stress-energy-momentum tensor) is a tensor

quantity in physics that describes the density and flux of energy and momentum in space-time, generalizing the stress tensor of Newtonian physics. It is an attribute of matter, radiation, and non-gravitational force fields. The stress-energy tensor is the source of the gravitational field in the Einstein field equations of general relativity, just as mass is the source of such a field in Newtonian gravity. [...] In general relativity, the symmetric stress-energy tensor acts as the source of space-time curvature, and is the current density associated with gauge transformations of gravity which are general curvilinear coordinate transformations. [...] In general relativity, the partial derivatives used in special relativity are replaced by covariant derivatives. What this means is that the continuity equation no longer implies that the non-gravitational energy and momentum expressed by the tensor are absolutely conserved, i.e. the gravitational field can do work on matter and vice versa. In the classical limit of Newtonian gravity, this has a simple interpretation: energy is being exchanged with gravitational potential energy, which is not included in the tensor, and momentum is being transferred through the field to other bodies. However, in general relativity there is not a unique way to define densities of gravitational field energy and field momentum. Any pseudo-tensor purporting to define them can be made to vanish locally by a coordinate transformation. In curved space-time, the spacelike integral now depends on the spacelike slice, in general. There is in fact no way to define a global energy-momentum vector in a general curved space-time". T_{00} = energy density; T_{11}, T_{22}, T_{33} = pressure; T_{01}, T_{02}, T_{03} = energy flux; T_{10}, T_{20}, T_{30} = momentum density; T_{12}, T_{13}, T_{23} = shear stress; T_{21}, T_{31}, T_{32} = momentum flux.

The stress-energy tensor $T_{\mu\nu}$ is invariant if the metric tensor $g_{\mu\nu}$ that refer to the structure of space-time geometry is invariant under the PE-SE transformation (2c) as elaborated in Section 2.3.

Thus, the Einstein field equations (33) are invariant under the PE-SE

transformations as elaborated above in Section 2.10.1 to 2.10.5.

2.11. The PE-SE transformation for the metric tensor $g_{\mu\nu}$

On the right hand side of (33a), $T_{\mu\nu}$ is invariant under the PE-SE transformation (2c) if the metric tensor $g_{\mu\nu}$ that refer to the structure of space-time geometry is invariant, as shown in Section 2.3.

The PE-SE transformation for the metric tensor $g_{\mu\nu}$ in analogy to (24b) is

$$g_{\mu\nu} \rightarrow g'_{\mu\nu} = g_{\mu\nu} + \partial_\sigma \partial_t \mathcal{E} \quad \text{where } \sigma = 1, 2, 3 \quad (50)$$

$$\Gamma^\lambda_{\nu\mu} \rightarrow \Gamma'^\lambda_{\nu\mu} = ((g^{\lambda\rho} + \partial_\sigma \mathcal{E})/2) (\partial_\mu g_{\rho\nu} + \partial_\nu \partial_\sigma \mathcal{E} + \partial_\nu g_{\rho\mu} + \partial_\nu \partial_\sigma \mathcal{E} - \partial_\rho g_{\nu\mu} - \partial_\rho \partial_\sigma \mathcal{E}) \quad (51)$$

$$\Gamma^\rho_{\rho\lambda} \rightarrow \Gamma'^\rho_{\rho\lambda} = ((g^{\rho\rho} + \partial_\sigma \mathcal{E})/2) (\partial_\nu g_{\rho\mu} + \partial_\nu \partial_\sigma \mathcal{E} + \partial_\mu g_{\rho\nu} + \partial_\mu \partial_\sigma \mathcal{E} - \partial_\rho g_{\mu\nu} - \partial_\rho \partial_\sigma \mathcal{E}) \quad (52)$$

The left hand side of (33a) must be invariant because the right hand side is invariant. This necessitates that the metric tensor $g_{\mu\nu}$ that refers to the structure of space-time geometry is invariant. This implies:

$$\partial_\sigma \partial_t \mathcal{E}(\mu=\sigma, \tau) = \partial_t \partial_\sigma \mathcal{E}(\mu=\sigma, \tau) = 0 \quad \text{where } \mu=(\tau=0=t; \sigma=1=x, 2=y, 3=z) \quad (53)$$

Eq. (53) implies the following possibilities:

$$(I) \quad \begin{aligned} \partial_\sigma \partial_t \mathcal{E}(\mu=\sigma, \tau) &= 0 \\ \Rightarrow \partial_t \mathcal{E}(\sigma, \tau) &= \text{constant}, \\ \Rightarrow \mathcal{E}(\sigma, \tau) &\text{ can vary with time but} \\ &\text{constant} \\ &\text{with respect to space} \end{aligned} \quad (54)$$

$$(II) \quad \begin{aligned} \partial_t \partial_\sigma \mathcal{E}(\mu=\sigma, \tau) &= 0 \\ \Rightarrow \partial_\sigma \mathcal{E}(\sigma, \tau) &= \text{constant}, \\ \Rightarrow \mathcal{E}(\sigma, \tau) &\text{ can vary with space but} \\ &\text{constant with respect to time} \end{aligned} \quad (55)$$

$$(III) \quad \mathcal{E}(\mu=\sigma, \tau) = \text{constant with respect to both space and time} \quad (56)$$

The possibilities (54) and (55) contradict each other; therefore, (56) is the valid condition. This can be called *the condition of invariance for the introduction of subjective*

experiences aspect of consciousness in classical physics. It is an elegant conclusion because it can be interpreted that $\mathcal{E}(\mu)$ is the same at every spatiotemporal point. In other words, experiences are embedded in space-time geometry in superposed form.

The matter field is represented by $T_{\mu\nu}$, which is invariant if the metric tensor $g_{\mu\nu}$ is invariant under the PE-SE transformation (2c). The metric tensor $g_{\mu\nu}$ is invariant if $\partial_\mu \mathcal{E}(\mu) = 0$ or $\mathcal{E}(\mu=\sigma,\tau) = \text{constant}$ (from (53)). This implies that all SEs \mathcal{E} are in superposed form in each matter, i.e., in each elementary particle, fermion, and an inert matter and hence constant because all SEs are in superposed form in each entity. This means if matter moves, SEs also move with them because SEs are superposed in the mental aspect of matter.

However, one could argue that our SEs change with stimuli in space and time. This seems to contradict above statement. However, there is no contradiction at all. This is because a specific SE is matched and then selected depending on stimuli and their spatiotemporal characteristics. One must note that SEs are in superposed form in each entity both in external stimuli and internal cognitive system. The SEs represented by \mathcal{E} (which is constant with respect to time and space) refers to this superposition in matter, not to the specific SE we experience. Our experiences are the result of matching and selection process when essential ingredients of SE aspect of consciousness are satisfied. For example, experiencing *redness* has neural correlates of V4/V8/VO-red-green neural-net with redness state. When a subject moves, the specific SE *redness* also moves with the subject's correlated neural-net. This specific SE depends on the spatiotemporal characteristics of stimuli and our cognitive system, whereas all kinds of SEs are superposed in the mental aspect each entity of stimuli and cognitive system and hence remain constant with space and time. Thus, there is no contradiction.

In other words, since PEs/SEs are embedded in space-time geometry (as (Hameroff and Penrose, 1998) also hypothesize), $\mathcal{E}(t; x, y, z) = \mathcal{E}(t'; x', y', z')$, i.e.,

SEs are superposed in the mental aspect of space-time geometry. Similarly, for matter, since PEs/SEs are superposed in the mental aspect of fermions and bosons (including gravitons), $\mathcal{E}(t; x, y, z)$ moves with them to conserve SEs, i.e., to make \mathcal{E} constant with space and time. However, our specific SE is the result of matching and selection processes and can change with space and time.

In the quantum field theory of point particles, the graviton is a hypothetical elementary particle that mediates the force of gravity. This is similar to (a) photon that mediates the electromagnetic interaction, (b) the gluons that mediate the strong interaction, and (c) the W and Z bosons that mediate the weak interaction in the Standard Model (Vimal, 2010b). If the graviton exists, "the graviton must be massless (because the gravitational force has unlimited range) and must have a spin of 2 (because gravity is a second-rank tensor field). In this framework, the gravitational interaction is mediated by gravitons, instead of being described in terms of curved space-time as in general relativity. In the classical limit, both approaches give identical results, which are required to conform to Newton's law of gravitation". In Standard Model (Vimal, 2010b), gravitation is nonrenormalizable because of infinities arising due to quantum effects and point particle. String theory addresses this problem, where gravitons and other particles are states of strings rather than that of point particles, and hence the infinities do not arise (Vimal, 2010c). In perturbative string theory, a graviton is a closed string with a specific low-energy vibration state. In quantum field theory of point particles, the description in terms of gravitons still serves as a low-energy effective theory (Vimal, 2009k).

This will be clearer when we consider loop quantum gravity and string theory in Part III (Vimal, 2010c).

3. Discussion and Conclusions

3.1. Hypotheses in the PE-SE framework: There are three competing hypotheses¹⁵: *superposition* based H_1 , *superposition-then-integration* based H_2 , and *integration* based H_3 where superposition is not required. In H_1 , the fundamental entities and inert matter are the *carriers* of superimposed fundamental subjective experiences (SEs)/proto-experiences (PEs). In H_2 , the fundamental entities and inert matter are the *carriers* of superimposed fundamental PEs (not SEs); there is a PE attached to every level of evolution, which are *integrated* by *neural-Darwinism* (co-evolution, co-development, and sensorimotor co-tuning); here the (mysterious) principle of *emergence* of SEs from PEs is required. In H_3 , a string has its own string-PE; matter is not a *carrier*; rather matter has two aspects at every level. These two aspects are rigorously *integrated* together by *neural-Darwinism* (co-evolution, co-development, and sensorimotor co-tuning). H_3 is a dual-aspect proto-panpsychism that has seven problems including the combination problem (Vimal, 2009h; Vimal, 2010a).

3.2. Four essential constituting factors for the PE-SE framework: The dual-aspect-dual-mode PE-SE framework (Vimal, 2008b; Vimal, 2010a) consists of four essential factors that lead to structural and functional coherence between mind and brain: (1) *dual-aspect primal entities*; (2) *neural-Darwinism*: co-evolution and co-development of SEs and associated neural-nets from elemental PEs and the associated material aspect of fundamental entities, respectively and co-tuning via sensorimotor interaction; (3) *matching and selection processes*: interaction of two modes (Vimal, 2010a), namely, (a) the non-tilde mode that is the material and mental aspect of cognition (memory and attention) related feedback signals in a neural-network, which is the cognitive nearest past approaching

towards present; and (b) the tilde mode that is the material and mental aspect of the feed forward signals due to external environmental input and internal endogenous input, which is the nearest future approaching towards present and is a entropy-reversed representation of non-tilde mode; and (4) *the necessary ingredients of SEs* (such as wakefulness, attention, re-entry, working memory, stimulus at or above threshold level, and neural-net PEs). The PE-SE framework addressed the explanatory gap (how SEs can emerge from non-experiential matter).

3.3. Prediction of hypotheses H_1 and H_2 : Since elementary particles and inert matters are *carriers* of SEs/PEs (as in H_1 and H_2), inert matters behave as if they are non-experiential entities. Therefore, the prediction of hypotheses H_1 and H_2 of the PE-SE framework is that physics remains invariant with the introduction of the SE aspect of consciousness. This prediction is tested in a series of three articles.

3.4. Classical, quantum, and subquantum level physics: Since the dual-aspect-dual-mode PE-SE framework is valid at all 3 levels (classical, quantum, and subquantum physics) (Vimal, 2008b; Vimal, 2009f; Vimal, 2009i; Vimal, 2009j; Vimal, 2010a), the introduction of consciousness in classical, (both orthodox and modern) quantum, and subquantum physics is also valid.

3.5. Classical Physics: Invariants under the PE-SE transformations: In this Part I of series of 3 articles, the followings, in classical physics, are invariants under the PE-SE transformations: electromagnetic strength tensor, electromagnetic stress-energy tensor, the electromagnetic theory (Maxwell's equations), Newtonian gravitational field, the entropic force, special theory of relativity and Lorentz transformation, geodesic equation, general theory of relativity: the metric $g_{\mu\nu}$ (generalization of the gravitational

¹⁵ There are two more hypotheses H_4 and H_5 ; see footnote 6.

field), Ricci curvature tensor $R_{\mu\nu}$, Ricci scalar curvature R , and the stress-energy tensor $T_{\mu\nu}$.

3.6. Classical Physics: Condition of invariance and its interpretation: The condition of invariance for the introduction of subjective experiences aspect of consciousness in classical physics is $\partial_\mu \mathcal{E} = 0$ or $\mathcal{E}(\tau, \sigma) = \text{constant}$, where \mathcal{E} is SE; τ is time-like parameter, such as time t ; and σ is space-like parameter, such as x, y, z . We interpret it as follows: (a) For the structure of space-time (empty space or the vacuum without matter), SEs are superposed in the mental aspect of space-time and are embedded in space-time geometry. (b) For matter field, SEs are superposed in the mental aspect of each elementary particle (fermion or boson including graviton); wherever these particles move, superposed SEs must also move with them to conserve SEs, i.e. to make \mathcal{E} constant with space and time. (c) Our specific SE is the result of matching and selection processes and can change with space and time. For example, experiencing *redness* has neural correlates of V4/V8/VO-red-green neural-net with redness-state. When a subject moves, the specific SE *redness* also moves with the subject's correlated neural-net. In addition, SEs can change with time as stimuli change. In other words, SEs in a subject change with space-time. Thus there is no contradiction between (a)-(b) and (c).

3.7. Parts II (orthodox quantum physics) and III (modern quantum physics): In Part II (Vimal, 2010b), consciousness is introduced in orthodox quantum physics such as Schrödinger equation, current, Dirac Lagrangian, the Lagrangian for a charged self-interacting scalar field, and Standard Model (the Lagrangian for free gauge field and Lagrangian for the electromagnetic interaction of a charged scalar field (Higgs Mechanism)). In Part III (Vimal, 2010c), subjective experience aspect of consciousness is introduced in modern quantum physics such as LQG and string theory, and consciousness is unified with fundamental forces.

3.8. Subquantum physics: The introduction of the SEs/PEs aspect of consciousness in subquantum physics is beyond the scope of this series of three articles because the mathematical theory of physics at subquantum level is not yet available. However, the qualitative treatment of the SEs/PEs aspect of consciousness at subquantum level is given in (Vimal, 2009i).

3.9. TOE: From above, it is possible to unify consciousness with known four fundamental forces, which leads us closer to the theory of everything.

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Competing interest statement

The author declares that he has no competing financial interests.

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