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THE SIXTH PARADIGM OF PHYSICS

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ABSTRACT

The present physics is based on a set of five paradigms, namely, the first law of thermodynamics, the second law of thermodynamics, the quantum phenomena, the curved spacetime and the nonlinearity of physical systems. These paradigms have changed the fundamental concepts of physicists about the relationship of space, time and matter. For some time physics seems to be in a static situation. Data keep on flowing without adequate theories to explain them. The time has come for a sixth paradigm of physics to be introduced. This paper formulates the new paradigm in terms of a generalized variational principle.

Keywords: Paradigms of physics, variational principles

INTRODUCTION

All scientific studies start with doubts and conflicts. The usual conflict is between a theory and an observation. It describes to match a conceptual model and the evidence our senses gather about the physical world. Then arises the conflict between the desire to hold the existing physical law and the need to change it through a scientific revolution. Description of the first conflict requires an understanding of the real world, which may be described by the senses, and then the conceptual world. A set of physical laws and the basic notions of mathematics may then, express this. The models, based on the fundamental physical laws, may be checked against the recorded observations. Deviation between the two becomes a standard. Smaller deviations mean a better model. Connection between a theoretical model and the real world comes from the observations. However, it is not always completely straightforward. The observer is a kind of model world itself and it generates controversies regarding the interpretation (Kamal, 1997*a*; *b*).

The usual requirement for a theoretical model is a prediction in terms of numbers. It has to have a quantitative nature. Sometimes, the numbers are not completely certain because of the approximations made during the computation. A theorist tries to understand the nature and builds an idea (hypothesis) on the basis of available knowledge and then suggests to an observer to look for certain predictions. An observer then goes out and sees if the theorist's idea is workable. If an idea matches the reality it becomes a model of the real world. Stated simply, a scientific model evokes a mental picture that tries to explain by analogy what we see in nature - an attempt to visualize the invisible (Zeilik, 1993). If the idea does not conform to the nature it becomes a conjecture. If an idea becomes a model many people check it in different circumstances. If the idea matches the real world in all the situations it becomes a theory. For example, it took 12 years (1967-1979) for the $SU(2)\times U(1)$ model of the electroweak interaction to become the Glashow-Weinberg-Salam Theory (Weinberg, 1967). If a theory holds good on a larger time scale and has verifiable predictions it becomes a natural law. Examples may be cited from the classical mechanics. Everyone is familiar with the Newton's Laws of Motion and the Law of Universal Gravitation.

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It implies that a natural law depends on the available information of the physical world and the basic axioms of mathematics used. A theorist goes on modeling in this way and always works for a better understanding of the natural world. There is always a possibility of change in the basic physical information or in the basic axioms of mathematics. Whenever it happens, a theorist searches for a new idea to revolutionize an understanding of the real world.

Science is dialectical in nature. It progresses with a change in paradigm. A paradigm is a set of rules. In physics, these rules are the laws of nature. The usual procedure is to replace the obsolete theories by the new ones. There may be some anomalies where these theories do not agree with the reality. To get a better estimate of nature one may try to modify these theories. One may be able to distinguish between a big change and a minor one. The big changes always occur with a change in the paradigm. Whenever this happens one sees a revolution in physics. Most of the time, when physics is not undergoing a revolution, the processes of normal science (evolution) are at work. The physicists spend their time in theory building, using the existing paradigms, and the world notices technical advances. The experimentalists approach the matching process from the other end discovering new patterns and anomalies that need explaining, such as normal superconductivity. The BCS theory is there to explain the phenomenon. However, it does not require a change in paradigm. Occasionally, the process of normal science stops and it becomes impossible to build a theory on the basis of an existing paradigm. It seems that the high temperature superconductivity is proving itself a problem requiring a change in the existing paradigms.

Usually an anomaly develops and grows. The theory and the reality refuse to be brought together. The physicists attack the anomaly in different ways and from different directions. If the anomaly resists all the persistent attacks a crisis develops. At this juncture the paradigm must be changed since the foundations are at stake. The physicists are well aware of the ultraviolet catastrophe appearing in the classical theory of blackbody radiation. Removal of infinities in the Rayleigh-Jeans'law required a change in the existing paradigm (Siddiqui & Kamal, 1986). Infinities appearing in the Poincaré transformations definitely pose a problem and methods need to be developed to avoid them.

A new paradigm appears after a chaotic period. If the new paradigm is acceptable to the scientific community it needs to explain the anomaly as well as the other known facts. A new paradigm usually brings in new predictions. It is the power of prediction, which makes the new paradigm important. String theories are not yet acceptable as a new paradigm being not yet capable of explaining all the related facts.

THE EARLY PHYSICS

Democritus was the greatest materialist of the Greek era. According to him only atoms and void exist. The atoms are extremely small, indivisible primitive elements, which differ in their shape, their magnitude and their position and are in perpetual motion. All the objects are derived from organization of the atoms. Democritus believed that the soul is material and is composed of the atoms. He argued that qualities of things are purely subjective and derivable from illusion of the senses. The real objective world does not contain such qualities and reason is essential to abstract these qualities in order to discover the atoms themselves. His basic paradigm of the atoms and the organization of these atoms to generate qualities is a brilliant prediction of the modern atomic theory. The Greek atomicists prevailed and promoted the concepts of Democritus till the arrival of Aristotle.

Aristotle is one of the greatest philosophers of antiquity. Aristotle starts his paradigm in a scientific realm with the concept of Idea. According to his idea, every being -- or substance -- consists of two basic parts: Matter and Form. Matter is crude, inert and amorphous mass. A form is required to make the matter something. This form must be applied to make the matter a useful entity. This form equals the idea and is active and specific. In fact, the form gives the matter its qualities. The supreme form, comprising all others, is God. Aristotle brought the non-natural force, God, to organize the universe. This is the finality of Aristotle, GOD, which rejects the mechanistic viewpoint of Democritus. The idea of development is the basic principle of his paradigm. The cosmic development, the organic development, the development of forms of state are all conceived of as an evolution from the imperfect to the perfect, from the general to the specific. Aristotle distinguished, in a debating manner, between the natural and the non-natural motion. He concluded, from motion of the heavenly bodies that motion in a circle is a natural motion. Any motion provoked by the external efforts is not natural. A body pulled or pushed over the ground stops, in general, when the force acting on it stops. From this Aristotle concluded that a body in the non-natural motion moves only if a force is acting on it. He believed that if a thrown stone is in motion it is the air, which is providing the force. Aristotle had no clue of friction. Idea of the natural and the non-natural motion differentiates between the motion of heavenly bodies and the motion on earth. It became the Aristotelian paradigm regarding the motion.

THE CURRENT PARADIGMS

The BBC English Dictionary (1992) describes a paradigm as "a model for something, which explains it or shows how it can be produced". All the players start at zero line if there is a change in the existing paradigm. In our context a paradigm is meant to be the foundation on which the infrastructure of physics is based. A change in paradigm would mean a change in the existing physics. Such a situation occurred when the physicists abandoned the ideas of well-defined trajectories and stopped viewing the energy and the momentum as continuous variables to prepare themselves to embrace the quantum domain.

After the Aristotelian period we experience the Newtonian period, the thermodynamic era, fantasies of the modern physics and the modern optics. There have been revolutions in the thinking of physicists. These may be described as:

a) **The first law of thermodynamics:** This could be considered as another statement of the law of conservation of energy. It states that the energy provided to a thermodynamic system is utilized in doing external work and increasing internal energy of the system.

One may also include other conservation laws related to spacetime symmetries (governed by Noether's Theorem) in the first paradigm. The generalized current (associated with a nonzero curl) and the generalized charge (associated with a nonzero divergence) shall, then, be related by the generalized equation of continuity.

b) **The second law of thermodynamics:** This law gives us concept of the amount of usable energy, which may be converted to work. A consequence of this law is that one cannot construct a heat engine with 100% efficiency. This law also introduces the concept of entropy, which could be related to the disorder associated with the system.

c) **The Quantum phenomena:** The quantum mechanics replaces the pinpointed classical trajectories of particles with the probabilities of finding particles in a certain region during a given interval of time. It also brings in the concept of discrete variation of quantities like the energy. This is in contrast to continuous variation taken for granted in the classical description.

A rather recent interpretation of the quantum mechanics, known under various names of consistent histories, or the logical interpretation, has brought the interpretation into a standard deductive theory and is now investigated in many places (Omnès, 1995).

d) **The Curved spacetime:** Einstein's introduction of special relativity, proposed in 1906, deals with properties of electromagnetic signals and particles traveling with a speed comparable to the speed of light.

His theory of general relativity, put forward in 1916, incorporates the behavior of particles in strong gravitational fields. These theories have changed thinking of the physicists. The concepts of absolute velocity, absolute time and ether as a medium filling the universe have been abolished. The Euclidean geometry has been replaced by the Riemannian geometry to deal with accelerated frames and strong gravitational fields. A uniform, homogeneous, gravitational field is considered to be indistinguishable from a uniform acceleration.

e) **The nonlinearity of physical systems:** The linear systems could only be found in the textbooks. In reality, the physical systems are nonlinear. For non-linear systems the principle of superposition does not hold good. Therefore, it is not possible to break the problem down to simpler units and recombine the solution using the superposition principle. Nonlinear equations, like the Navier-Stokes equations in fluid dynamics, are difficult to handle to generate the closed-form solutions (series solutions are of little use because these are valid only for a point). Climatic modeling is one of the classical examples of a nonlinear problem. A slight difference in the initial conditions shall, down the road, produce a large effect and the weather pattern shall be completely different from the one expected. Study of nonlinear systems is one of the hottest research topics in the present-day applied mathematics. Many problems of significance are coming as manifestations of the theory of chaos. The mathematicians have found out that there is some order and some predictability in an otherwise chaotic situation. Medical and biological problems like the heart attack, the epilepsy and aerodynamical problems like the wind shear may be modeled on these lines. All of these problems affect our lives very much and an understanding of the chaotic systems and the nonlinear phenomena shall certainly improve our quality of life.

Do we really need an additional paradigm in the form of a physical law or a basic axiom of mathematics? It seems that we need a sixth paradigm in physics because physics is static. We have the same situation as in the nineteenth century when we had enormous data with no physical theory to explain them (Siddqui & Jamila, 1996). At present people are resorting to simulations and ab initio calculations without really trying to build comprehensive theories for the systems.

THE SIXTH PARADIGM

Our paradigm should be able to incorporate the curved spacetime, the quantum phenomena, the many-body systems and the nonlinearity in one statement (Kamal & Siddiqui, 1997). All the different branches could be generated as special cases of this paradigm. A mathematical statement of the sixth paradigm may be given in the form of a generalized Hamilton's principle

$$\int \delta L(q_{\mathrm{i}}, \frac{dq_{\mathrm{i}}}{dt}, t, \Re, \Theta, \zeta, \eta, \xi) \prod dq_{\mathrm{i}} = 0; \; i, j = 1, 2, \ldots, n \tag{1}$$

where L is the Lagrangian density, $\Re$ the measure of curvature, Θ the quantum state measure (spin, antisymmetry, parity), ζ the measure of entropy, η the measure of nonlinearity and ξ describing distribution of mass (energy) in space.

If we take $\Re$, Θ, ζ, η, ξ all equal to zero Eq. (1) reduces to Hamilton's principle as employed in field theory. This holds also for nonlinear systems having terms like $\zeta \otimes \eta$, etc. The condition $\Re$ = constant corresponds to the principle of geodesic.

If we cannot write a potential, an alternate form may be the principle of least curvature: Between two points A and B the particle travels on such a path where the curvature is stationary, the curvature being determined by the properties of spacetime.

$$\delta\Re\left(q_i(A), q_i(B); \frac{dq_i(A)}{dt}, \frac{dq_i(B)}{dt}; t; \Theta; \zeta; \eta; \xi \right) = 0 \qquad (2)$$

CONCLUSION

The present-day physics available to us is inadequate to solve the real-world problems we are facing today. The cosmological principle assumes that spacetime is homogeneous and isotropic. The real world is different from that. Quantum mechanics assumes linear systems. But, then, we cannot combine it with general relativity to construct quantum gravity theories because gravity is a nonlinear theory. Similar problems arise in thermodynamics and statistical mechanics. The condition that a process is quasi-static can only be found in the textbooks. In reality, we must be able to handle non-equilibrium statistical mechanics. As the twentieth century was the century of development of quantum mechanics and relativity, the twenty-first century (which is also the start of the third millennium) must focus on nonlinear systems. Any new paradigm must be able to incorporate the nonlinearities. We must not be contented with the series solutions as they are of limited use. Methods must be developed to rigorously handle the nonlinear systems. Different approaches may be used, *e.g.* introducing the coördinate transformations and the dimensional extension to make the system linear, looking at projections on linear surfaces and trying to regenerate data from these linear projections. The biggest problem is that principle of superposition fails for the nonlinear systems. A nonlinear superposition principle must be developed to handle such problems. The theory of chaos, the catastrophe theory and other such exotic topics would engage the inquiring mind through the next century.

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