Evidences of Self Consistency of Natural laws appearing in different domains of physical science

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ABSTRACT

Self consistency is the essence of all laws in nature, ranging from quantum optics to biological science. This paper reviews various schemes of self consistency in natural laws appearing in different domains. We select few topics for our discussion and conclude that it is an universal phenomenon. We believe that our work will be helpful in working out an acceptable model for all type of physical laws. We also indicate that there are exceptions where self consistency is violated.

Key Word: Self Consistency.

1. INTRODUCTION

Natural phenomena are numerous. Physicists try to explain them with the help of appropriate theories which are often modified and each of a more accurate than the previous one. Thus all the theories are improved. One of the character features of all the theories appearing in physical science and also in other domain is the phenomenon of 'self consistency'. The present work is primarily concerned with a description of well established theories and principles and explores the self consistency nature of theories and models. In our work we have shown that all the laws follow from the requirement of overall self consistency. From a survey of available literature we can reasonably infer that this type of work has not been made earlier.

2. DIFFERENT THEORIES EXHIBITING SELF CONSISTENCY

We now being under our discussion some specific cases where overall self consistency is manifested (Table 1).

<table>
<thead>
<tr>
<th>S No</th>
<th>Theory</th>
<th>Self Consistent parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Semi classical Theory of Laser</td>
<td>(E = E)</td>
</tr>
<tr>
<td>2</td>
<td>Archimedes Principle</td>
<td>(W = W)</td>
</tr>
<tr>
<td>3</td>
<td>Raman Effect</td>
<td>(E = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2})</td>
</tr>
<tr>
<td>4</td>
<td>Gauss' Law</td>
<td>( \frac{12}{6} C_6 \equiv \frac{12}{6} C_6 )</td>
</tr>
<tr>
<td>5</td>
<td>Carbon Cycle</td>
<td>(T_1 \equiv T')</td>
</tr>
<tr>
<td>6</td>
<td>Carnot Cycle</td>
<td>(E_a \equiv E_c)</td>
</tr>
<tr>
<td>7</td>
<td>Climate Modelling</td>
<td>(R_{12} = R_{21})</td>
</tr>
</tbody>
</table>

2.1 Semi-classical theory of laser

The semiclassical theory of laser as developed by Lamb and co-workers \([1-5]\) has explained a large number of laser behaviours particularly in the gaseous phase (Fig.1). We depict the geometrical model based on which the semiclassical theory of laser has been built. Based on the geometrical model (or the self consistent model) two basic equations of semiclassical theory of laser are worked out as follows:
Let us now focus our attention to one of the oldest principle of physics which is universally true. This is none other than the Archimedes Principle, one of the most popular principles in science. According to this principle whenever a solid body of particular weight \( W_0 \) is submerged in a liquid partially or wholly it will undergo an apparent loss in weight \( W \) which is equal to the weight of the liquid displaced by the body \( W \), i.e. \( W = W_0 - W \). In this case self consistency is maintained as showed in Fig.2.

Like many other prominent natural phenomena Raman effect or Raman scattering may be considered as the one maintaining self consistency (Fig.3). The condition of self consistency presumably requires that the incident field \( E_0 \) is equal to the scattered fields \( E_s \) (wavelength \( \lambda_s \)).

2.4. Gauss’ law
A clear example of a natural law exhibiting self consistency is the Gauss’ law, a fundamental law in electrostatics. Coulomb’s law can be derived as a special case of Gauss’ law. The Gauss’ law is considered to be more fundamental then Coulomb’s law and is included as one of the four basic equations of Maxwell’s equations of electromagnetism. The Gauss’ law is also applicable in magnetism.

2.5. Carbon-cycle
The self consistency of a well-known natural law involved in stellar evolution in the so-called carbon-cycle (Fig.4).

2.6. Carnot cycle
Perhaps, Carnot cycle, the most efficient cycle for operation for a reversible heat engine indicates self consistency (Fig.5). Published in 1824 by NLS Carnot, it consists of four operations on the working substance in the engine: (1) isothermal expansion (2) Adiabatic expansion with fall of temperature to \( T_2 \) (3) Iso thermal compression at temperature \( T_2 \) with heat \( Q_0 \) given out (4) Adiabatic compression with rise in temperature to original value \( T_1 \).

2.7. Climate modelling of earth
Perhaps the self consistency nature can be conveniently observed in the radiative climate modelling of earth. There are numerous models for this. We may refer to the zero dimensional-model, of the climate [6]. A zero dimensional model would give climate parameters that represents on average for the entire system. The usual parameter is temperature representation of the mean temperature of earth’s surface. Since the primary energy input to the atmosphere system is solar radiation (cosmic ray and solar wind provides less than \( 10^{-5} \) of the total), an energy balance equation for the surface temperature \( T_s \) can be written [6] as

\[
\frac{S(1-A)}{f} = \sum_i B_{i\lambda}(T_i) \Delta \lambda_i + \sum_j B_{j\lambda}(T_j) \Delta \lambda_j
\]

\[
i.e. \quad E_a = E_e
\]

where the left side represents the solar energy absorbed by earth atmosphere system and the RHS, the energy emitted to space in the form of IR radiation. \( S \) is the solar energy at the mean distance of the earth from the sun and is known as solar constant \((340 \text{ Wm}^{-2})\). All this energy is not absorbed by the atmosphere and the earth; the albedo \( A \) is the fraction scattered by the clouds, atmosphere and ground back to space. The global albedo for the earth is \( \sim 30 \). \( f \) is the so-called flux factor and is the ratio of the area of the planet emitting IR radiation to the area receiving solar radiation. If there were no \( \text{H}_2\text{O}, \text{CO}_2 \) and \( \text{O}_3 \) in the atmosphere, then essentially all the long wavelength radiation from the surface would escape to space. In that case the less term in equation (1) would be zero, and the remaining term integrated over all wavelengths would give Stefan Boltzmann equation.
Spectral distribution of the incoming solar and outgoing terrestrial is similar. This is the manifestation of self-consistency nature of equ (1).

2.8. Einstein’s rate equation approach

It is of considerable interest to ask whether the self consistency is maintained in the famous rate equation approach of Einstein (1917) leading to black body radiation formulae of Plank. The answer is yes. When an atom has light of right frequency falling on it, it can absorb that photon and make a transition from lower state to the upper state (two level atoms), according to Boltzmann law and quantum theory (Fig.6). This is the process of stimulated absorption. The atom comes back to the ground state due to vacuum fluctuation (spontaneous emission). The atom may also come down to the lower state through stimulated emission. The loop is completed by the self consistency requirement that the rate of atom going up by stimulated absorption is equal to the rate of atom coming down by spontaneous and stimulated emission.

2.9. GENERAL relativity and cosmology

According to Einstein’s general relativity (1915), space and time are interwoven into a four dimensional fabric known as space-time. This fabric can be stretched or bent into a variety of shapes, each of which being a particular solution to what is known as the Einstein field equation. In Fig.7 we represent the evolution of the universe for different geometries. From this Fig.7, it is apparent that the self consistency is violated in the case of an accelerating universe (Nobel prize in Physics, 2011). There are thousands of natural laws that are self consistent. They also include laws of non physics context. We conclude with the following quote from Tao Te Ching

“Man follows the laws of earth; Earth follows the laws of heaven
Heaven follows the laws of nature; Tao follows the laws of intrinsic nature”.

3. CONCLUSION

From what has been discussed above, it is appropriate to make a conclusion and give an outlook for convenience of any future work. We have indicated only few cases where self-consistency of natural laws are evident. In environmental science the self consistency of natural laws should be more appropriate. Detailed accounts of all these aspects are left as future work.

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