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Informational Restrictions in the Formulation of Physical Laws by Researchers †

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Abstract: By combining the information-oriented and theoretically proven method with the construction of the realized SI, it is possible to formulate the accuracy limit of any physical law or formula describing the observed phenomenon. This has never been described in the literature. Example is given.

Keywords: information theory; international system of units; limits of measurement accuracy; finite information quantity

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1. Introduction

The concept of information is becoming a pillar of modern science [1]. There is great potential for modeling physical processes using the concepts and mathematical apparatus of information theory, taking into account the qualitative and quantitative sets of variables in the model. However, over the centuries, it has proved difficult to choose and define a system of units for the study of natural and technological processes and phenomena. Since each variable selected from the system of units contains a finite amount of information about the object of interest [2], scientists and engineers may consider using the concept of "amount of information" contained in the model to achieve a minimum threshold discrepancy between the model and the phenomenon or process under study.

Combining the information-oriented and theoretically proven method with the construction of the realized international system of units, shortly SI (the two look like unrelated branches of science), it is possible to formulate the accuracy limit of any physical law or formula describing an observed phenomenon. This has never been described in the literature.

The purpose of this research article is to provide a theoretically substantiated application of the phenomenon of random choice of a variable observed when formulating a model of any physical process. The article is based on the use of the basic element—the finite information quantity (FIQ) [2]—and the implementation of the information method described in [3,4]. Examples are introduced.

2. Method: FIQ-Based Approach

The main provisions of the FIQ-based method are as follows [4]:

1. The observer selects variables from any system of units to build a model on an equiprobable basis. This means that the selected variables can be considered as stochastic quantities; alternatively, any variable is chosen by the researcher with a priori equiprobability (the lowest possible predictability).
2. The resulting formulae are applicable to the models containing any FIQs, both dimensional and dimensionless.

3. SI is a kind of Abelian group for which you can calculate the number of its elements (cardinality) μ_{SI} = 38,265. Each FIQ element (quantity q) is expressed as a unique combination of dimensions of the main base quantities (*L*—length, *M*—mass, *T*—time, Θ—thermodynamic temperature, *I*—electric current, *J*—luminous intensity and *F*—amount of substance) to different powers.
4. FIQ is defined as the scalar parameter time, universal constant, one-dimensional component of the position or momentum, and dimensionless number, which acquire values from the set of real numbers, R.
5. A model constructed by an observer in accordance with his knowledge, experience and intuition belongs to a certain class of phenomena (CoP). CoP is a set of physical phenomena and processes described by a finite number of base quantities and derived variables that characterize certain features of the material object with qualitative and quantitative aspects. For example, when formulating the integral law of radiation of an absolutely black body, variables with a dimension including the base SI quantities length *L*, mass *M*, time *T* and thermodynamic temperature Θ are usually used; that is, the model belongs to the class of $CoP_{SI} \equiv LMT\Theta$ phenomena.
6. As a criterion for the closeness of the model to the phenomenon under study (minimum threshold discrepancy [5]), the theoretically justified and calculated comparative uncertainty ε_Σ [6] inherent in a certain CoP_{SI} is used. ε_Σ is the ratio of the total absolute uncertainty of measurement/calculation of the main investigated variable Δ_Σ to the value of the interval of its observation *S*

$$\varepsilon_\sum = \Delta_\sum / S = [(z' - \beta')/\mu_{SI} + (z'' - \beta'')/(z' - \beta')] \quad (1)$$

where z′ is the number of FIQs in the selected CoP_{SI}, β′ is the number of base quantities in the selected CoP_{SI}, z″ is the number of FIQs recorded in a model, and β″ is the number of independent quantities recorded in a model.

ε_Σ is a more acceptable and reliable criterion for the likelihood of a model formulated by the researcher in comparison with the relative uncertainty r_M, widely used in science and technology. This is because r_M does not indicate the direction in which the true value of the variable of interest may be found, does not quantify any individual components of uncertainty, and may reflect subjective judgment [7]. Undoubtedly, the analysis of measurement uncertainty should be free from any subjective probability or degree of confidence [8].

3. Results: Example of the FIQ-Based Application

In the current state of science, hundreds of articles daily suggest new phenomena or physical principles. The publish-or-die paradigm certainly plays a role in this problem.

Usually, a researcher, studying a physical phenomenon, tries to establish a relationship between, from his point of view, the main variable and the independent variables by formulating a model. As a result, a solution follows, aimed either at improving the process, or even at discovering a new dependence. Thus, any claimed model is based on verifiable observation, although it was constructed according to the logic of a conscious observer, equipped with knowledge, experience and intuition. Therefore, the question always has a right to life, whether a scientist or an engineer made a mistake in explaining what she or he investigated.

The results of scientific research are analyzed from the perspective of comparing the comparative uncertainty achieved in the model ε_{mod} with the theoretically justified ε_{opt} [9]. The similarity between these two uncertainties proves the applicability of the proposed model in describing the process being studied. Conversely, a significant difference between these uncertainties indicates that the proposed model is unreliable.

Dimensionless Constant Providing the Upper Bound for the Speed of Sound

In [10] it is shown that a combination of two important dimensionless fundamental constants, the fine structure constant α and the electron-to-proton mass ratio, provides an upper bound for the speed of sound in condensed phases,

$$v_u/c = \alpha \cdot (m_e/(2 \cdot m_p))^{1/2} \tag{2}$$

where c is the speed of light in vacuum, m_e is the electron mass, m_p is the proton mass.

This result was obtained on the basis of a large set of experimental data and ab initio calculations for atomic hydrogen. This expands the current understanding of how fundamental constants can impose new boundaries on important physical properties. The theoretical calculations were compared with experimental data for 36 elementary solids, including semiconductors and metals with high binding energies. According to the authors, the ratio of calculated and experimental v_u is within an acceptable range.

The research was carried out in the framework of $CoP_{SI} \equiv LMTIF$. This means that the dimension of the variables used was expressed as a combination of the dimensions of the five base quantities: L, M, T, I, and F, in different degrees [11]. A total of 22 (z'') variables were used to calculate v_u. For the case involving selection of four independent variables (β'' = 4), in accordance with the π-theorem [12], the number of dimensionless criteria in a model, γ_{mod}, equals $\gamma_{mod} = z'' - \beta'' = 18$.

From (1), as well as the number of FIQs inherent in CoP_{SI}, $\gamma_{CoP} = z' - \beta' = 1412$ for the established $CoP_{SI} \equiv LMTIF$ [9], the achieved comparative uncertainty of a model ε_{mod}, can be calculated as:

$$\varepsilon_{mod} = [1412/38{,}265 + 18/1412] = 0.0596 \tag{3}$$

Upon comparing ε_{mod} (10) and ε_{opt} = 0.0738 [9], $\varepsilon_{mod}/\varepsilon_{opt} \approx 0.8$ (ε_{mod} is closed to ε_{opt}) is obtained. This is owing to the difference in the number of variables considered in the model γ = 18 and the recommended γ_{opt} = 52 [9]. Unfortunately, in that study [10], the authors did not indicate the ranges of variation and the measurement of uncertainty for each considered variable. Additionally, the total absolute uncertainty of the key parameter (the speed of sound in condensed phases) was not calculated. This information allows for the possibility to compare the theoretical comparative uncertainty, ε_{opt}, calculated using (1), with the experimental comparative uncertainty, ε_{exp}, calculated as the ratio of the achieved absolute total uncertainty of the measurement of v_u to a value of the declared range of its changes. Despite the lack of knowledge about the proposed information method, the study authors presented a very plausible model and results comparable to those obtained in [13], where $\varepsilon_{mod}/\varepsilon_{opt} \approx 0.9$ with 130 variables selected in the model.

Thus, the notion that simplicity (a small number of variables in a model representing the object under study) is the path to truth turns out to be far from reality. It is this characteristic of simplicity in the laws of nature, discovered so far, that it would be erroneous to generalize, since it is obvious that simplicity was one of the reasons for their discovery and, therefore, cannot serve as a basis for the assumption that other undiscovered laws are as simple.

It can be seen from the presented example that the achieved maximum accuracy of representing the observed physical phenomenon actually depends on the qualitative and quantitative set of variables in the model.

4. Conclusions

Much of the variety of models (interpretations) of physical phenomena in nature that we see is not the result of a hidden hand of a higher power, but rather the result of the luck of researchers. If they (researchers), using the mathematical apparatus and intuition, are able to identify such concepts as space, energy, time, information, mass with the observed objects, then there is a chance to adequately (plausibly) represent the phenomenon under study. Whether we like to admit it or not, chance always subtly affects the world. The information method provides the basis for making this randomness known and measurable.

The author is sure that the proposed FIQ-based method is not alone in providing a correct description of the process of modeling the process under study and, in general, nature. However, this is the only consistent and complete method known to us today and it allows us to understand the perception of a physical phenomenon by a researcher, without neglecting the accumulated knowledge of previous generations. The FIQ-based method is free from any subjective probability or degree of confidence and shows that it is impossible to create a plausible model that allows making quantitative predictions without taking into account the qualitative and quantitative set of variables. Any "beautiful" models in any field of human knowledge with variables whose dimensions are based only on length, mass and time do not give a plausible picture of the world around them.

The FIQ-based method leads to the realization of the existence of two limits of physical knowledge:

1. The act of measurement changes the observed reality, at least, at the subatomic level. Classical physics assumed that the measurement accuracy was theoretically unlimited. However, Heisenberg showed that since you can never measure more than one property of a particle with great certainty, you can only work with probability and mathematical formulations. This uncertainty is usually thought to be unimportant in large-scale astronomical observations, however.
2. The act of formulating a model by a conscious observer of the phenomenon under study imposes an additional limit on the accuracy of the actual measurement, and also acts as the principle of finiteness [14], which defines the limits of application of various formulas or physical laws.

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