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2 Original Research Article  
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4 **Calculation of Relative Uncertainty when**  
5 **Measuring Physical Constants: CODATA**  
6 **Technique vs Information Method**  
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8 **Boris Menin<sup>1</sup>**

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10 email: [meninbm@gmail.com](mailto:meninbm@gmail.com)

11 <sup>1</sup>Mechanical & Refrigeration Consultation Expert  
12 Beer-Sheba Israel

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14 - What do you think about Newton's third law?  
15 - I did not watch, I did not like the first two.  
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20 **ABSTRACT**  
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**Aims:** To analyze the results of measurements of the Boltzmann, gravitational and Planck constants using a theoretically sound information approach in comparison with the CODATA technique.

**Place and Duration of Study:** Beer-Sheba, between January 2019 and May 2019.

**Methodology:** Using the concepts of information theory, the amount of information contained in the measurement model of a physical constant is calculated. This allows us to find the value of the comparative uncertainty proposed by Brillouin, and the achievable value of the relative uncertainty, taking into account the basic SI values used on each test bench when measuring physical constants.

**Results:** An unsolved question was to find the amount of information contained in the model of the measurement of a physical constant, which can be converted to the value of the achievable absolute uncertainty. This value now has an exact analytical formula. It is notoriously difficult to study the consistency of the measurement results of physical constants, but the proposed mathematical tool, developed using the concepts of information theory, allow us to simplify the analysis completely.

**Conclusion:** The information method leads to an intuitive and logically justified calculation of the relative uncertainty, which is compatible with the current practice of CODATA. This allows you to identify the threshold discrepancy between the model and the object under study. Proof of this is the calculation of the achievable value of the relative uncertainty when measuring the Boltzmann, gravitational and Planck constants. The proposed information-oriented method for calculating the relative uncertainty in measuring physical constants represents a new tool when formulating a modernized SI.

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23 *Keywords: Boltzmann, gravitational and Planck constants, CODATA, Information theory,*  
24 *Least squares correction, Relative uncertainty*  
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## 1. INTRODUCTION

The Committee's decision [1], seemingly so far from the consciousness and understanding of the majority of the 7.5 billion population of the Earth, opened a new era not only in measurement theory and metrology but also in all areas of human life. Over the last decade, thanks to huge investments, unique test benches, advanced mathematical methods, super-powerful computers and accumulated knowledge, the modification of the International system of units (SI) has become possible. It lies in the fact that four new definitions and four fixed numerical values of the basic constants have been established [1]. In this case, the uncertainty, necessarily associated with the data used, is discarded, and the value is assumed to be exact by agreement.

The process of fixing the value of the constant is carried out using the method of least squares correction (LSA). There is no published evidence that the latest adjustments can be considered equivalent, therefore, CODATA can only be trusted for the correctness of their work [2].

The LSA method is aimed at checking the consistency of the results, and for this, the initial experimental values are "corrected," that is, changed to optimize the final dispersion of the set. However, in these cases, the initial values are adjusted. This shortcoming is not available to the scientific community because the adjustments are not presented in CODATA publications.

The purpose of this article is to point out some features inherent in the approved CODATA method for calculating the value of the constants and their relative uncertainty. A positive discussion of this becomes important in view of the implementation of the revision of the International System of Measurement Units (SI) in 2019. The existing statistical features of the CODATA method, along with the mandatory discussion and formulation of an expert opinion, may still raise doubts about the complexity and possible subjectivity of the tools used. The application of the LSA method and its influence on the decisions made by CODATA causes some skepticism. Don't forget the joke: statistics is one form of lies.

Unlike the accepted CODATA procedure for processing the results of experiments using LSA, we propose a new procedure for finding the recommended value of relative uncertainty, which simulates the results using the comparative uncertainty proposed by Brillouin and takes into account the basic SI values implemented on each test bench when measuring physical constants.

## 2. PROVISIONS AND SOME FORMULAS RELATED TO THE INFORMATION METHOD

Background premises and evidence are presented in previously published works [3-6]. Below, in a condensed form, the data necessary for subsequent reasoning and analysis of the results of measurements of physical constants are given.

The total number of the dimensionless criteria  $\mu_{SI}$  in SI equals

$$\mu_{SI} = 38,265 \quad (1)$$

SI is a set of dimensional quantities, base and derived, used for descriptions of different classes of phenomena (*CoP*), which depend on seven base quantities: meter, the length  $L$ ;

80 kilogram, the mass  $M$ ; second, the time  $T$ ; kelvin, the thermodynamic temperature  $\theta$ ;  
 81 ampere, the electrical current  $I$ ; mole, the amount of substance  $F$ ; candela, the luminous  
 82 intensity  $J$  [7]. For example, when measuring the gravitational constant by electromechanical  
 83 methods, the basis {the length  $L$ , weight  $M$ , time  $T$ , electrical current  $I$ } is used, i.e.,  $CoP_{SI} \equiv$   
 84  $LMTI$ .

85  
 86 The dimensionless measurement absolute uncertainty  $\Delta u$  of the dimensionless quantity  $u$   
 87 with a changed interval  $S$  can be calculated

$$88 \quad \Delta u = S \cdot (z' - \beta') / \mu_{SI} + (z'' - \beta'') / (z' - \beta'), \quad (2)$$

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 90 where  $\beta'$  is the number of the base quantities of the chosen  $CoP$ ,  $z'$  is the total number of the  
 91 dimensional quantities of the chosen  $CoP$ ,  $z''$  is a given number of the dimensional physical  
 92 quantities recorded in the model,  $\beta''$  is the number of the base quantities recorded in the  
 93 model,  $\varepsilon$  is the comparative uncertainty suggested by Brillouin [8],  $\varepsilon = \Delta u / S$ .

94  
 95 Equation (2) sets an ultimate limit on the accuracy of measuring a physical constant, which  
 96 cannot be overcome by any measuring instruments, perfect mathematical methods, and  
 97 using unique materials or software. This limit already exists before performing any  
 98 calculations or implementing algorithms on a computer. Its value depends on the class of the  
 99 phenomenon and the number of quantities taken into account.

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 101 The information-oriented method can be applied for measurements of *any dimensional or*  
 102 *dimensionless physical constant* because the relative and comparative uncertainties of the  
 103 dimensional quantity  $U$  and the dimensionless quantity  $u$  are equal:

$$104 \quad \Delta U / S^* = (\Delta U / a) / (S^* / a) = (\Delta u / S), \quad (3)$$

$$105 \quad (r/R) = (\Delta U / U) / (\Delta u / u) = (\Delta U / U) \cdot (a / \Delta U) \cdot (U / a) = 1,$$

106  
 107 where  $\Delta u$  is the total absolute uncertainty in determining the dimensionless quantity  $u$ ;  $S^*$   
 108 and  $\Delta U$  are dimensional quantities (respectively, the range of variations and the total  
 109 absolute uncertainty in determining the dimensional quantity  $U$ );  $a$  is the dimensional scale  
 110 parameter with the same dimension as that of  $U$  and  $S^*$ ;  $r$  is the relative uncertainty of the  
 111 dimensional quantity  $U$ ; and  $R$  is the relative uncertainty of the dimensionless quantity  $u$ .

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 113 Taking into account (2), one can verify conditions for calculating the minimum comparative  
 114 uncertainty for a particular  $CoP$ :

$$115 \quad (z' - \beta')^2 / \mu_{SI} = (z'' - \beta''). \quad (4)$$

116  
 117 According to (4), it is possible to check (Table 1) the optimal number of quantities in the  
 118 model and the achievable comparative uncertainties recommended in the framework of the  
 119 information method, as well as the  $CoP$  commonly used when measuring the Boltzmann,  
 120 gravitational and Planck constants:

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 126 **Table 1. Comparative uncertainties and recommended number of dimensionless**  
 127 **criteria**

$CoP_{SI}$	Comparative uncertainty	Recommended number of criteria
$LMT$	0.0048	$0.2 < 1$
$LMTF$	0.0146	$\cong 2$
$LMTI$	0.0245	$\cong 6$
$LMT\theta F$	0.1331	$\cong 169$

<b>LMT<math>\theta</math>I</b>	0.2220	$\cong 471$
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It should be noted that the comparative uncertainty and the recommended number of values in the model are different and depend to the choice of *CoP*. From the data in Table 1, it can be seen that **LMT** and **LMTF** are not recommended for use in measurements of physical constants because there are very few criteria that can be used in the model. This causes a situation where an increase in the number of variables/criteria taken into account leads to an increase in experimental comparative uncertainty that can be achieved, which is much more than the recommended. Consequently, the discrepancy between the model and the really emerging process of measuring a physical constant increases.

An objective assessment of the achieved accuracy of measuring a physical constant, within the framework of the information approach, is confirmed using two metrics, denoted as *IARU* (information approach with relative uncertainty) and *IACU* (information approach with comparative uncertainty). In *IARU*, the interval of change of the physical constant **S** is calculated as the difference between the maximum and minimum values of the physical constant measured by various research groups in recent years. This is due to the need to consider the appearance of each experimental result in a given range as an independent event. In this case, knowing the comparative uncertainty inherent in the chosen class of phenomena, the recommended relative uncertainty is calculated. Its value, in turn, is compared with the relative uncertainty of each published study.

For *IACU*, **S** is calculated in accordance with the technical limitations of measurement devices [8]. In this case, the standard uncertainty calculated in the experiment when measuring a physical constant is taken as the possible interval for the placement of its true value. The experimental absolute uncertainty is calculated by multiplying the value of the fundamental physical constant and its relative uncertainty achieved in each experiment. The achieved experimental comparative uncertainty of each published study is calculated by dividing the experimental absolute uncertainty by the standard uncertainty. Then, the experimentally calculated comparative uncertainty is compared with the selected comparative uncertainty (Table 1), which is inherent in the model describing the measurement of the fundamental constant.

### 3. ANALYZING RESULTS OF MEASURING THE BOLTZMANN, GRAVITATIONAL AND PLANCK CONSTANTS

A detailed analysis of the measurement of the Boltzmann, gravitational and Planck constants from the positions of *IARU* and *IACU* is presented in [4-6]. Methods and results with data on the values of physical constants, relative measurement uncertainties and standard uncertainties, published in scientific journals during 2000–2018 and confirmed by CODATA, were taken into account. Below, we present a summary of these studies (Tables 1, 2, 3), taking into account the application of *IARU*.

From the data presented in Tables 2–4, you can simply draw the following obvious conclusions.

**Table 2. Summarized data of the Boltzmann constant, *k***

Variable	AGT	DCGT	JNT	DBT
<i>CoP</i>	<b>LMT<math>\theta</math>F</b>	<b>LMT<math>\theta</math>I</b>	<b>LMT<math>\theta</math>I</b>	<b>LMT<math>\theta</math>F</b>
Comparative uncertainty according to <i>CoP</i> <sub>SI</sub>	0.1331	0.2220	0.2220	0.1331
Possible observed range <i>S<sub>k</sub></i> of <b>k</b> placing,	$2.4 \cdot 10^{-29}$	$2.7 \cdot 10^{-29}$	$9.2 \cdot 10^{-29}$	$2.2 \cdot 10^{-27}$

$m^2 \cdot kg / (s^2 \cdot K)$				
Relative uncertainty according to $CoP_{SI}, r_k$	$2.3 \cdot 10^{-7}$	$4.3 \cdot 10^{-7}$	$1.4 \cdot 10^{-6}$	$2.1 \cdot 10^{-5}$
Achieved experimental lowest relative uncertainty, $r_{kexp}$	$6.0 \cdot 10^{-7}$	<b><math>3.7 \cdot 10^{-7}</math></b>	$2.7 \cdot 10^{-6}$	$2.4 \cdot 10^{-5}$
Ratio of $r_{kexp}/r_k$	2.6	0.9	1.9	1.1

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Impressive advances in measuring physical constants have been achieved using DCGT for  $k$ . This is because of the significant difference in the magnitude of the comparative uncertainties between  $CoP_{SI} \equiv LMT\text{OF}$  (AGT – 0.1331) and  $CoP_{SI} \equiv LMT\text{O}$  (DCGT – 0.2220). The only concern is that the experimental relative uncertainty is less than the relative uncertainty theoretically calculated (Table 2), which contradicts the information method. Therefore, a researcher using DCGT needs to recheck everything, if possible, and within the framework of the information approach—necessarily, potential sources of uncertainty;

**Table 3. Summarized data of the Planck constant,  $h$**

Variable	KB	XRCD
$CoP$	<b><i>LMTI</i></b>	<b><i>LMTF</i></b>
Comparative uncertainty according to $CoP_{SI}$	0.0245	0.0146
Possible observed range $S_h$ of $h$ placing, $m^2 \cdot kg/s$	$1.2 \cdot 10^{-40}$	$4.6 \cdot 10^{-41}$
Relative uncertainty according to $CoP_{SI}$ ( <i>IARU</i> ), $r_k$	$4.5 \cdot 10^{-9}$	$1.0 \cdot 10^{-9}$
Achieved experimental lowest relative uncertainty, $r_{kexp}$	$1.3 \cdot 10^{-8}$	$9.1 \cdot 10^{-9}$
Ratio of $r_{kexp}/r_k$	3.0	9.1

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**Table 4. Summarized data of the gravitational constant,  $G$**

Variable	Mechanistic methods	Electromechanical methods
$CoP$	<b><i>LMT</i></b>	<b><i>LMTI</i></b>
Comparative uncertainty according to $CoP_{SI}$	0.0048	0.0245
Possible observed range $S_G$ of $G$ placing, $m^3/(kg \cdot s^2)$	$2.1 \cdot 10^{-14}$	$1.7 \cdot 10^{-14}$
Relative uncertainty according to $CoP_{SI}$ ( <i>IARU</i> ), $r_G$	$1.5 \cdot 10^{-6}$	$6.3 \cdot 10^{-6}$
Achieved experimental lowest relative uncertainty, $r_{Gexp}$	$1.9 \cdot 10^{-5}$	$1.2 \cdot 10^{-5}$
Ratio of $r_{Gexp}/r_G$	12.7	1.9

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- KB for  $h$ . This is because there is a twofold difference between the comparative uncertainties for  $CoP_{SI} \equiv LMTF$  (XRCD – 0.0146) and  $CoP_{SI} \equiv LMTI$  (KB – 0.0245) and almost equal placement interval of  $h$ ;

- Electromechanical methods for  $G$ . This is due to the huge difference in comparative uncertainties between  $CoP_{SI} \equiv LMT$  ( $\varepsilon_{LMT} = 0.0048$ ) and  $CoP_{SI} \equiv LMTI$  ( $\varepsilon_{LMTI} = 0.0245$ ) and the closeness of the achieved lowest experimental value of relative uncertainty ( $1.2 \cdot 10^{-5}$ ) to the recommended one ( $6.3 \cdot 10^{-6}$ ). That is why further and detailed research of the current electromechanical methods should be continued.

Within the framework of the information method, several methods seem limited for future improvement:

200 - DBT ( $CoP_{SI} \equiv LMT\theta F$ ) for  $k$  in terms of the possibility of achieving higher accuracy. This is  
 201 because the values of relative uncertainty, theoretically calculated and achieved in the  
 202 experiment, are very close ( $2.1 \cdot 10^{-5}$  and  $2.4 \cdot 10^{-5}$ );  
 203 - AGT ( $CoP_{SI} \equiv LMT\theta F$ ) for  $k$ . Given the fact that the interval of the possible placement of  $k$   
 204 for the AGT method ( $2.4 \cdot 10^{-29} \text{ m}^2 \text{ kg}/(\text{s}^2 \text{ K})$ ) is the smallest compared with other methods, it  
 205 is difficult to expect any achievements in increasing its accuracy;  
 206 - Mechanistic methods ( $CoP_{SI} \equiv LMT$ ) for  $G$ . There are two reasons to stick to that point of  
 207 view. The latest results for the relative uncertainty of the gravitational constant are very  
 208 different from the relative uncertainty calculated by the *IARU* method (Table 4). Second, and,  
 209 perhaps more importantly, in this case, the use of even one or several variables leads to an  
 210 increase in the attainable experimental uncertainty, which is much more than the  
 211 theoretically recommended value of the comparative uncertainty (Table 1).  
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213 To compare all the methods used, Table 5 was compiled. As shown in Table 5, despite the  
 214 huge differences between the methods in order of magnitude of relative values according to  
 215  $CoP_{SI}$ , relative uncertainty according to  $CoP_{SI}$  (*IARU*)  $r_{SI}$ , and experimental minimum relative  
 216 uncertainty  $r_{exp}$ , the ratio  $r_{exp}/r_{SI}$  varies in a rather small interval (0.9–3.0) compared with  
 217 models V (mechanistic methods, gravitational constant) and VIII (XRCD, Planck constant).  
 218 Consistency is a basic requirement for a new SI, but you may ask why V and VIII stand out?  
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220 **Table 5. Comparison data of measuring the Boltzmann, gravitational and Planck**  
 221 **constants**

Fundamental constant	Boltzmann constant				Gravitational constant		Planck constant	
	AGT	DCGT	JNT	DBT	Mechanistic methods	Electro-mechanical methods	KB	XRCD
	I	II	III	IV	V	VI	VII	VIII
$CoP$	$LMT\theta F$	$LMT\theta I$	$LMT\theta I$	$LMT\theta F$	$LMT$	$LMTI$	$LMTI$	$LMTF$
Comparative uncertainty according to $CoP_{SI}$	0.1331	0.2220	0.2220	0.1331	0.0048	0.0245	0.0245	0.0146
Relative uncertainty according to $CoP_{SI}$ ( <i>IARU</i> ), $r_{SI}$	$2.3 \cdot 10^{-7}$	$4.3 \cdot 10^{-7}$	$1.4 \cdot 10^{-6}$	$2.1 \cdot 10^{-5}$	$1.5 \cdot 10^{-6}$	$6.3 \cdot 10^{-6}$	$4.5 \cdot 10^{-9}$	$1.0 \cdot 10^{-9}$
Achieved experimental lowest relative uncertainty, $r_{exp}$	$6.0 \cdot 10^{-7}$	$3.7 \cdot 10^{-7}$	$2.7 \cdot 10^{-6}$	$2.4 \cdot 10^{-5}$	$1.9 \cdot 10^{-5}$	$1.2 \cdot 10^{-5}$	$1.3 \cdot 10^{-8}$	$9.1 \cdot 10^{-9}$
Ratio of $r_{exp}/r_{SI}$	<b>2.6</b>	<b>0.9</b>	<b>1.9</b>	<b>1.1</b>	<b>12.7</b>	<b>1.9</b>	<b>3.0</b>	<b>9.1</b>

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 223 We wonder if it arises straight from the application of the LSA method, or is it due to any  
 224 further culling of the data—including by CODATA [9]? In fact, this degree of consistency can  
 225 exist simply due to the application of the LSA method and as a result of reducing the  
 226 uncertainty of the measurement data. Perhaps the situation will change for the better if the  
 227 new method of processing the results of measurements of physical constants is used in the  
 228 CODATA technique [10].  
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230 However, there is another reason to explain this situation in the context of an information-  
 231 oriented approach.  
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233 Already in the process of formulating the method of measuring the physical constant, there is  
 234 an unremovable uncertainty, called comparative uncertainty, due to the number of variables  
 235 and the qualitative set of base quantities in the model. It is not constant and changes  
 236 depending on the number of recorded base quantities. In addition, according to the

237 calculations formulated within the framework of the presented approach, the use of **LMT** and  
238 **LMTF** is not recommended because the achievement of the theoretical value of comparative  
239 uncertainty in practice is impossible. This is because when using these *CoP*, numerous  
240 potential effects are not taken into account, and the recommended number of selected  
241 criteria is less than two. That is why, within the framework of the information-oriented method  
242 in contrast to the method adopted in CODATA, it is inappropriate to establish only one value  
243 of relative uncertainty when measuring physical constants by various methods. This is  
244 explained by the fact that for models inherent in different *CoP*, there are different values of  
245 comparative uncertainties and a different number of quantities, which is recommended to  
246 choose.

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#### 248 **4. CONCLUDING REMARKS**

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250 An unsolved question was to find the amount of information contained in the model of the  
251 measurement of a physical constant, which can be converted to the value of the achievable  
252 absolute uncertainty. This value now has an exact analytical formula. It is notoriously difficult  
253 to study the consistency of the measurement results of physical constants, but the proposed  
254 mathematical tool, developed using the concepts of information theory, allowed us to simplify  
255 the analysis completely.

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257 It is obvious from the analyzed data that an information approach is a universal tool for  
258 verifying accuracy and recommended values of relative uncertainties. The information-  
259 oriented method does not depend on the subjective judgment of the expert and is free from  
260 any inaccuracies, weighting factors inherent in statistical methods and accessible to all  
261 (meaning no hierarchy). It is very easy to use; it is available even to students, user  
262 understandable and it does not require complex calculations and is performed in a short  
263 time. It is not unimportant that this method is theoretically justified and conceptually correct.

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265 The approach implements a simple and reliable way of formulating a model with the optimal  
266 number of quantities taken into account. Thus, the duration of the experiments and their cost  
267 could be significantly reduced.

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269 From the point of view of the author, the information method leads to a theoretically proven,  
270 intuitive, and logically sound calculation of relative uncertainty, which is compatible with  
271 modern CODATA practice. This allows you to identify the threshold discrepancy between the  
272 model and the object under study. Proof of this is the calculation of the achievable value of  
273 the relative uncertainty when measuring the Boltzmann, gravitational and Planck constants.

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275 The author does not want to look like a person who automatically criticizes the CODATA  
276 methodology. Of course, recent years have been marked by great achievements in  
277 measuring fundamental constants with reduced uncertainty, which led to outstanding results.  
278 However, one should keep in mind the possible "enthusiasm" of CODATA scientists in  
279 search of the threshold value of uncertainty. Therefore, the information approach can serve  
280 as a theoretically justified tool for confirming certain values of relative uncertainties.

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282 Based on the foregoing, it seems correct to assume that the proposed information-oriented  
283 method for calculating the relative uncertainty in measuring physical constants represents a  
284 new tool when formulating a modernized SI.

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286 In the end, the author expresses the hope that the proposed method, along with the current  
287 version of SI, can be labeled as "for all times, for all people."

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## COMPETING INTERESTS

The author has declared that no competing interests exist.

## ETHICAL ISSUES

1. I, the alone corresponding author, am authorized to submit this manuscript.
2. Submission of the manuscript represent that the manuscript has not been published previously and is not considered for publication elsewhere.
3. The manuscript, or any part thereof, is in no way a violation of any existing original or derivative copyright.
4. The manuscript contains nothing obscene, indecent, objectionable or libelous.

## REFERENCES

1. Schlamminger S, Abbott P, Kubarych Z, Jarrett D, Elmquist RE. The units for mass, voltage, resistance, and current in the SI. *IEEE Instrum Meas.* 2019;22(3):1-16. Accessed 5 June 2019. Available: [DOI: 10.1109/MIM.2019.8716269](https://doi.org/10.1109/MIM.2019.8716269).
2. Pavese F. The new SI and the CODATA recommended values of the fundamental constants 2017 compared with 2014. 2018;1-11. Accessed 5 June 2019. Available: <https://arxiv.org/ftp/arxiv/papers/1512/1512.03668.pdf>.
3. Menin B. Simplest method for calculating the lowest achievable uncertainty of model at measurements of fundamental physical constants. *Journal of Applied Mathematics and Physics.* 2017;5(11):2162-71. Accessed 5 June 2019. Available: <https://goo.gl/XcCCX5>.
4. Menin B. The Boltzmann constant: Evaluation of measurement relative uncertainty using the information approach. *Journal of Applied Mathematics and Physics.* 2019;7(3):486-504. Accessed 5 June 2019. Available: [10.4236/jamp.2019.73035](https://doi.org/10.4236/jamp.2019.73035).
5. Menin B. Precise measurements of the gravitational constant: Revaluation by the information approach. *Journal of Applied Mathematics and Physics.* 2019;7(6):1272-1288. Accessed 29 June 2019. Available: [http://file.scirp.org/pdf/JAMP\\_2019062614403787.pdf](http://file.scirp.org/pdf/JAMP_2019062614403787.pdf).
6. Menin B. Progress in reducing the uncertainty of measurement of Planck's constant in terms of the information approach. *Physical Science International Journal.* 2019;21(2):1-11. Accessed 5 June 2019. Available: <http://www.journalpsij.com/index.php/PSIJ/article/view/30104/56478>.
7. NIST Special Publication 330 (SP330). The International System of Units (SI). 2008. Accessed 5 June 2019. Available: <http://physics.nist.gov/Pubs/SP330/sp330.pdf>.
8. Brillouin L. *Science and information theory.* New York: Dover; 2004.
9. Mohr PJ, Newell DB, Taylor BN, Tiesinga E. Data and analysis for the CODATA 2017 special fundamental constants adjustment for the revision of the SI. *Metrologia.* 2018;55(1):125-46. Accessed 5 June 2019. Available: <https://iopscience.iop.org/article/10.1088/1681-7575/aa99bc/pdf>.
10. Merkatas C, Toman B, Possolo A, Schlamminger S. Shades of dark uncertainty and consensus value for the Newtonian constant of gravitation. 2019;1-39. Accessed 5 June 2019. Available: [arXiv:1905.09551v1](https://arxiv.org/abs/1905.09551v1) [physics.data-an] 23 May 2019.