Consultative Committee for Units – 25th meeting September 21-23, 2021
Bureau International des Poids et Mesures (on-line meeting)

IUPAC report to the committee

Prof. Dr. Roberto Marquardt
Secretary of the Commission on Physicochemical Symbols, Terminology and Units
IUPAC

International Union of Pure and Applied Chemistry

Since the 24rd meeting of this committee, there has been no specific IUPAC activity in reference to the use of units.

In October 2020, members of IUPAC were called to comment on the proposed definitions of the terms "quantity", "quantity value" and "unit", which are currently under discussion at the Consultative Committee for Units (CCU).

A memorandum on this matter is attached in full length (2 pages) to this report. It is to be noted that this memorandum does not represent any official IUPAC position with respect to the matter.

At the 24th CCU meeting Prof. Ullrich proposed that the matter on units for angles and dimensionless quantities should be discussed within the organizations represented at the meeting. And that an official view should be returned for the next CCU meeting with a clear statement on the mechanisms used to arrive at that view.

To date, this question has not officially been discussed within the Union. Consequently, no official view can be presented in this report.

Appendix to the report from IUPAC presented at the 25th meeting of CCU

MEMORANDUM

TO: Juris Meija, *Member*, ICTNS, IUPAC

SUBJECT: **Core Metrological Terms (WG-CMT Version)**

FROM: Antonio Possolo, IUPAC Member (II.1), CIAAW
— *NIST Fellow*, Chief Statistician for NIST

DATE: August 17th, 2021

In their meeting on June 25th, 2021, the majority of the CCU Working Group on Core Metrological Terms agreed to define *quantity* as a

> *property of a phenomenon, body or substance that can be compared by ratio or by order to others of the same kind.*

The proposed definition

- Implies that ordinal properties are quantitative;
- Leaves in limbo quantitative properties for which differences are meaningful but ratios are not;
- Provides no guidance for how to categorize properties that may be quantitative from one viewpoint, and ordinal from another.

Both the United States and the Russian Federation use academic grading systems to measure students' performance in elementary and secondary schools that comprise five levels: in the U.S. these levels are labeled A, B, C, D, and F (in decreasing order of performance), while in Russia they are labeled with the numbers 5 (Excellent), 4 (Good), 3 (Satisfactory), 2 (Unsatisfactory), and 1 (Very Poor).

For neither system are ratios or differences meaningful. In the Russian system, neither does 4 signify performance that is two times better than 2, nor is the difference in performance between levels 5 and 3 the same as the difference in performance between levels 3 and 1.

In the U.S. system, letter grades are often "converted" into numerical scores using simple, *ad hoc* rules that vary between schools. These conversions serve to compute "equivalent" Grade Point Averages (GPAs), and also enable comparing the dispersion of grades among different groups of students in the same school: for example, to determine whether the dispersion of grades in English among fifth graders is greater or smaller than the dispersion of their grades in mathematics.

Such "conversions" are expedient but fundamentally flawed because they ignore the ordinal, hence non-quantitative nature of the grades. It is possible and meaningful to compute percentiles for sets of ordinal grades, but differences between such percentiles are still not meaningful.

Mosteller and Tukey [1977, 5F] describe a reasonable procedure whereby a frequency distribution of grades in a class may be re-expressed to allow meaningful quantification of the dispersion of the grades, but such procedure is far more involved than merely replacing the grade labels (letters in the U.S. system, numbers in the Russian system) with numerical values.

The pH of an aqueous solution [Covington et al., 1985] is a quantitative property for which differences are meaningful, but ratios are not. Therefore, it differs fundamentally from ordinal properties (for which neither differences nor ratios are meaningful), and from other quantities, like mass, for which both differences and ratios are meaningful.

Musical pitch is a property that has a hybrid nature, being quantitative from one viewpoint, and ordinal from another. Consider the well-tempered C major scale, which starts at the "middle" C on the piano and rises through D, E, F, G, A, and B, skipping all the intermediate flats and sharps.

On the one hand, the frequencies of these notes rise in a geometric progression by counting middle steps away from A (which are negative going "down" from A toward C, and positive going "up" toward B), and from this viewpoint the scale is quantitative [Berg and Stork, 2005, Page 368].

On the other hand, as perceived by a listener, even by someone with perfect pitch, their character becomes ordinal, their frequencies being mapped onto a perceptual, auditory scale that goes from "lower" to "higher" notes.

References

R. E. Berg and D. G. Stork. *The Physics of Sound*. Pearson Education, San Francisco, CA, 3rd edition, 2005. ISBN 978-0-13-145789-8.

A. K. Covington, R. G. Bates, and R. A. Durst. Definition of pH scales, standard reference values, measurement of pH and related terminology (recommendations 1984). *Pure and Applied Chemistry*, 57(3):531–542, 1985. doi: 10.1351/pac198557030531.

F. Mosteller and J. W. Tukey. *Data Analysis and Regression*. Addison-Wesley Publishing Company, Reading, Massachusetts, 1977. ISBN 0-201-04854-X.