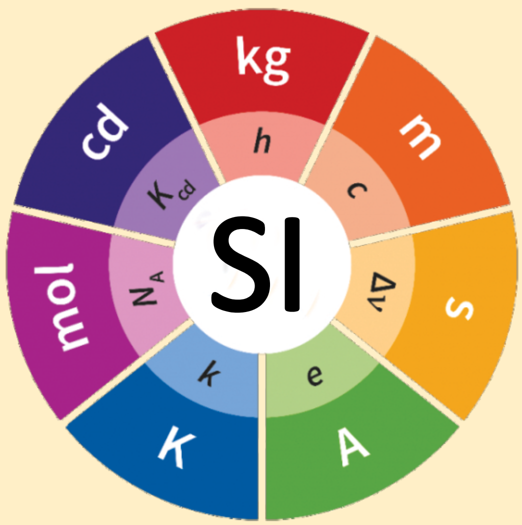
Recommendations for Revision of SI Units and other Necessary Changes to be Incorporated in Syllabi of NCERT Text Books



सी एस आई आर - राष्ट्रीय भौतिक प्रयोगशाला

CSIR-NATIONAL PHYSICAL LABORATORY

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Dr. K.S. Krishnan Marg, New Delhi-110012, India

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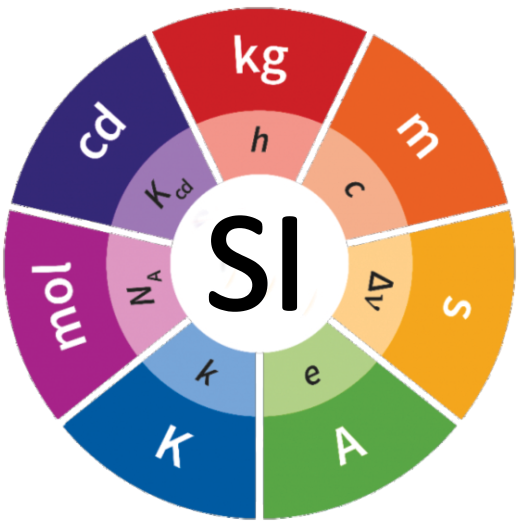

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Content

Foreword

Metrology, defined as the science of measurement, plays vital role in every sphere of human life, including safety and quality of the life.

In the view of recent redefinition of SI base units, voted unanimously by the global metrology community for adoption, it requires to be percolated in the form of revision of text books of school levels adding new changes to propagate the globally accepted new definition of SI units among the students.

The recommendation made in this document for the purpose are purely suggestive in nature and implementing agency have their own discretion to incorporate the revisions in full or partial, as the case may be, that is fit for the purpose to impart contemporary education to students as per global trends.

1. INTRODUCTION

Metrology is the science of measurement, encompassing both experimental and theoretical determinations. However, measurement science is not purely the preserve of Scientists or researchers, it is something of vital importance having a direct impact on regular basis on all of us as all forms of physical and chemical measurements affect the quality of the world in which we live. In fact, the quality and level of measurement in any nation is directly related to its technological advancement and dictates its connections to rest of the world, which encourages nations to render continuous effort in R&D in metrology.

CSIR-National Physical Laboratory, New Delhi is mandated to be 'National Measurement Institute' (NMI) of the country by an Act of Parliament and its associated rules for legal metrology. NPL India has been the custodian of 'National Standards' with a responsibility of realization, establishment, upgradation, maintenance and dissemination of standards at par with the international level through continuous R and D and latest technology.

Apart from playing the role of National custodian of measurement Standards, NPL, further contribute to its huge responsibilities, as special invitee, member or chairperson of various scientific, technical experts' committees, administrative, accreditation boards of premier Government organizations and Regulators. NPL also plays vital role in formulating country specific policy documents, preparing guidelines and recommendations on evolving metrology for Government agencies, Institutions and Regulators in the National interests.

Presently, the system of units, which is, internationally recognized for measurement, is the *Système Internationale d' Unites* (French for International System of Units), abbreviated as SI. The SI, with standard scheme of symbols, units and abbreviations, was developed and recommended by General Conference on Weights and Measures (CGPM) in 1971 for international usage in scientific, technical, industrial and commercial work.

Very recently on November 16, 2018, in its 26th meeting of General Conference on Weights and Measures (CGPM), organized by BIPM Versailles, France, it was agreed upon unanimously to accept the landmark change for introducing new SI system defined in terms of fundamental constants. NPL, India along with global metrology community, participated in this meeting and voted in support of redefinition of four base SI units namely the kilogram, ampere, kelvin and mole. This redefined SI system would come into force from May 20, 2019, the World Metrology Day.

2. RECOMMENDATION

Keeping in view of the importance and recognition of newly defined SI units, it is the duty of NPL to propagate these updates in the country and high time for National Council of Educational Research and Training (NCERT), New Delhi, the central organization for qualitative improvement in school education system,to revise its text books adding new changes to propagate the globally accepted new definition of SI units among the students.

In view of the redefinition of the SI units, NPL, New Delhi, therefore proposes modifications to the textbooks of Physics of NCERT to encompass the contemporary revision in SI system of units and new definitions.

Especially, following are some of the addition/modifications that may be incorporated in the NCERT textbook of ***Physics Part I, Text book for Class XI*** (First Ed., Reprinted January, 2011) in view of the recent developments in world metrology community :

Sr. No.	Section no./ Table no. & Page no. in Textbook	Existing content	Proposed content/Comments
1.	Sec. 2.1, Page 16	Measurement of any physical quantity involves comparison with a certain basic, arbitrarily chosen, internationally accepted reference standard called unit. The result of a measurement of a physical quantity is expressed by a number (or numerical measure) accompanied by a unit. Although the number of physical quantities appears to be very large, we need only a limited number of units for expressing all the physical quantities, since they are inter-related with one another. The units for the fundamental or base quantities are called fundamental or base units. The units of all other physical quantities can be expressed as combinations of the base units. Such units obtained for the derived quantities are called derived units. A complete set of these units, both the base units and derived units, is known as the system of units.	CSIR-National Physical Laboratory, New Delhi is mandated to be National Measurement Institute (NMI) of the country by an Act of Parliament. Measurement of any physical quantity involves comparison with a certain basic, arbitrarily chosen, inter-nationally accepted reference standard called unit. The result of a measurement of a physical quantity is expressed by a number (or numerical measure) accompanied by a unit. Although the number of physical quantities appears to be very large, we need only a limited number of units for expressing all the physical quantities, since they are inter-related with one another. The units for the fundamental or base quantities are called fundamental or base units. The units of all other physical quantities can be expressed as combinations of the base units. Such units obtained for the derived quantities are called derived units. A complete set of these units, both the base units and derived units, is known as the system of units.
2.	Sec. 2.2, Page 16	**Definition:** The SI, with standard scheme of symbols, units and abbreviations, was developed and recommended by General Conference on	The SI, with standard scheme of symbols, units and abbrevia-tions, was developed and recommended by General Conference on Weights and

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		Weights and Measures in 1971 for international usage in scientific, technical, industrial and commercial work.	Measures in 1971 for international usage in scientific, technical, industrial and commercial work. However, very recently BIPM, France organized 26^{th} meeting of General Conference on Weights and Measures (CGPM) on November 16, 2018, and NPL, India along with global metrology community, agreed upon to accept the landmark change for introducing new SI system based upon redefinition of four. SI base units, namely the kilogram, ampere, kelvin and mole.
3.	Table No. 2.1, Page 17 Column 4, row 1	**Definition:** The metre is the length of the path travelled by light in vacuum during a time interval of 1/299,792,458 of a second.	**Definition:** The metre, is defined by taking the fixed numerical value of the speed of light in vacuum *c* to be 299 792 458 when expressed in the unit m/s, where the second is defined in terms of $\Delta\nu_{Cs}$.
4.	Table No. 2.1, Page 17 Column 4, row 2	**Definition:** The kilogram is equal to the mass of the international prototype of the kilogram (a platinum-iridium alloy cylinder) kept at international Bureau of Weights and Measures, at Sevres, near Paris, France. (1889).	**Definition:** The kilogram is defined by taking fixed numerical value of the Planck constant *h* to be $6.62607015 \times 10^{-34}$ when expressed in the unit J-s, which is equal to kg m^2s^{-1}, where the meter and the second are defined in terms of *c* and $\Delta\nu_{Cs}$.
5.	Table No. 2.1, Page 17 Column 4, row 3	**Definition:** The second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom. (1967).	**Definition:** The second, is defined by taking the fixed numerical value of the caesium frequency capital $\Delta\nu_{Cs}$, the unperturbed ground-state hyperfine transition frequency of the caesium 133 atom, to be 9 192 631 770 when expressed in the unit Hz, which is equal to s^{-1}.

Sr. No.	Section no./ Table no. & Page no. in Textbook	Existing content	Proposed content/Comments
6.	Table No. 2.1, Page 17 Column 4, row 4	**Definition:** The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} Newton per meter of length. (1948).	**Definition:** The ampere, is defined by taking the fixed numerical value of the elementary charge e to be $1.602176634 \times 10^{-19}$ when expressed in the unit C, which is equal to A.s, where the second is defined in terms of $\Delta\nu_{Cs}$.
7.	Table No. 2.1, Page 17 Column 4, row 5	**Definition:** The kelvin, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water. (1967).	**Definition:** The Kelvin, is defined by taking the fixed numerical value of the Boltzmann constant k to be 1.380649×10^{-23} when expressed in the unit J K^{-1}, which is equal to kg m^2 s^{-2} K^{-1}, where the kilogram, meter and the second are defined in terms of h, c and $\Delta\nu_{Cs}$.
8.	Table No. 2.1, Page 17 Column 4, row 6	**Definition:** The mole is the amount of substance of a system, which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon - 12. (1971).	**Definition:** The mole, which contains exactly $6.02214076 \times 10^{23}$ elementary entities. This number is the fixed numerical value of the Avogadro constant, N_A, when expressed in the unit mol^{-1} and is called the Avogadro number. The amount of substance, symbol n, of a system is a measure of the number of specified elementary entities. An elementary entity may be an atom, a molecule, an ion, an electron, any other particle or specified group of particles.
9.	Table No. 2.1, Page 17 Column 4, row 7	**Definition:** The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant	**Definition:** The candela, is the luminous intensity in a given direction and is defined by taking the fixed numerical value of the luminous efficacy of monochromatic radiation of

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		intensity in that direction of 1/683 watt per steradian. (1979).	frequency 540 × 10^{12} Hz, K_{cd}, to be 683 when expressed in the unit lm W^{-1}, which is equal to cd sr W^{-1}, or cd sr kg^{-1} m^{-2} s^3, where the kilogram, metre and second are defined in terms of h, c and $\Delta\nu_{Cs}$.
10.	Sec 2.4, Page 21	Mass is a basic property of matter. It does not depend on the temperature, pressure or location of the object in space. The SI unit of mass is kilogram (kg). The prototypes of the International standard kilogram supplied by the International Bureau of Weights and Measures (BIPM) are available in many other laboratories of different countries. In India, this is available at the National Physical Laboratory (NPL), New Delhi.	It is defined by taking fixed numerical value of the Planck constant h to be 6.62607015 × 10^{-34} when expressed in the unit J-s, which is equal to kg m^2s^{-1}, where the meter and the second are defined in terms of c and $\Delta\nu_{Cs}$.
11.	Sec 2.4, Page 21	In India, this is available at the National Physical Laboratory (NPL), New Delhi.	In India, this is available at the National Physical Laboratory (NPL), New Delhi, which is recently redefined by taking fixed numerical value of the Planck constant h to be 6.62607015 × 10^{-34}.
12.	Sec 2.5, Page 22	The efficient cesium atomic clocks are so accurate that they impart the uncertainty in time realization as 1 × 10^{-13}, *i.e.* 1 part in 10^{-13}. This implies that the uncertainty gained over time by such a device is less than 1 part in 10^{-13}; they lose or gain no more than 3 μs in one year.	The efficient cesium atomic clocks are so accurate that they impart the uncertainty in time realization as 1 × 10^{-15}, *i.e.* 1 part in 10^{15}. This implies that the uncertainty gained over time by such a device is less than 1 part in 10^{-15}; they lose or gain no more than 32 ns in one year.
13.	Sec 2.6, Page 22	Measurement is the foundation of all experimental science	This whole section may be revised in context with 'Guide

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		and technology. The result of every measurement by any measur-ing instrument contains some uncertainty. This uncertainty is called error.	to the expression of uncertainty in measurement' [Ref-6].
14.	Any other section of the book	Any other section of the book that might be revised in line with the current redefinition of SI units.	In the context of redefinition of SI units based upon fundamental constants of nature, Ref. 1-7.

In addition to this, Global metrology community has also agreed upon to adopt 'concept of uncertainty', rather than 'errors in the measurement', to specify ambiguity in measured results. Accordingly, it may be suggested to include uncertainty determination procedure, as per international practice, *'Guide to the expression of uncertainty in measurement'*, together with brief emphasis on errors in measurement in the text book.

The same concern of revision may also be paid while revising other text books, dealing concepts of units and measurements.

3. CONCLUSION

Therefore, in the light of latest development in the international system of measurement, *i.e.* after redefined SI in terms of fundamental constants, adopted by world metrology community, it is advisable that the redefined SI system may be adopted and added as an update and improvement in school education system text books.

REFERENCE

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[2] Resolution 1 of the 26th CGPM (2018): https://www.bipm.org/en/CGPM/db/26/1/

[3] Information for users about the proposed revision of the SI: https://www.bipm.org/utils/common/pdf/SI-statement.pdf

[4] Unit of mass (kilogram): https://www.bipm.org/en/publications/si-brochure/kilogram.html

[5] Resolution 1 of the 24th CGPM (2011): On the possible future revision of the International System of Units, the SI: https://www.bipm.org/en/CGPM/db/24/1/

[6] BIPM: JCGM 100:2008: Evaluation of measurement data - Guide to the expression of uncertainty in measurement: https://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf

[7] International vocabulary of metrology - Basic and general concepts and associated terms (VIM), 3rd Edition: https://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf

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