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V.V. Ezhela, V.N. Larin

The Physical Constants for *Mathematica*

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Abstract

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The program package in *Mathematica* language, which is extension of the standard package Miscellaneous'PhysicalConstants' [1] is proposed, for usage in applications where the maximum completeness of the estimated uncertainties of the fundamental constant values and their correlations is needed. The package consists of the database for physical constants and corresponding data management module.

The database contains all constants of the standard *Mathematica* 'PhysicalConstants' package merged with the set of constants that presented by Particle Data Group [2]. Mainly constant values, their standard uncertainties and correlation coefficients are extracted as recommended by CODATA from the site [3]. Some constant values are extracted from other sources (refered by NIST [3], for instance [2]).

The prospects of the further development of the package are briefly considered.

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Аннотация

Ежела В.В., Ларин В.Н. Физические постоянные для системы *Mathematica*: Препринт ИФВЭ 2001–27. – Протвино, 2001. – 5 с., библиогр.: 3.

Представляется пакет программ, реализованных на языке *Mathematica*, который является расширением стандартного пакета Miscellaneous'Physical Constants' [1] и предназначен для использования в приложениях, где требуется максимально возможная полнота учета оцененных неопределенностей в значениях фундаментальных постоянных и их корреляций. Он включает в себя базу данных физических постоянных и пакет программ управления этой базой данных.

База данных содержит все константы, включенные в стандартный пакет, а также ряд постоянных, представленных Particle Data Group [2]. В основном она включает рекомендованные CODATA значения постоянных 1998 года с указанием стандартных отклонений и коэффициентов корреляции [3]. Некоторые значения констант извлечены из других источников (по ссылкам NIST [3], например, [2]).

Коротко рассматриваются перспективы развития пакета.

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Introduction

In the development of any subfield of physics the need for the high precision theoretical calculations of the observable quantities eventually emerged. As any physical law and observable are expressed in terms of state variables and fundamental physical constants, the special organization of data on fundamental constants is required to be suitable for the accurate calculations the uncertainties of the theoretical predictions for the observable quantities. To meet this apparent requirement the *Mathematica* system from the very beginning has the package Miscellaneous‘PhysicalConstants‘ [1], but unfortunately it is not complete and has no maintenance procedure to synchronize the versions of the *Mathematica* and regular readjustments of the physical constants by various authoritative metrology groups.

In this work we propose the extended data structure of the ‘Standard PhysicalConstants‘ in *Mathematica* system suitable for metrological purposes. The extension is proposed in two directions.

First, to make data stored as complete as possible. We propose to store not only world averaged values of the fundamental constants but their uncertainties as well and their correlation matrix as they released by the CODATA (the Committee on Data for Science and Technology).

Second, to create the special programs to extract data subsamples needed for the particular subfield of physics; recalculate the new set of constants used in that subfield, their uncertainties and conversion coefficients into subfield units.

Database ‘Dbfpc.m‘

The database contains all constants of the current *Mathematica* ‘PhysicalConstants‘ package merged with the set of constants that presented by Particle Data Group [2]. The values of all constants, their standard uncertainties and correlation coefficients are extracted as recommended by CODATA from the site [3] or other sources refered by NIST [3] (for instance [2]).

This database consists of the two basic tables:

- **basicl**; it presents names, typical symbols, values (with their uncertainties) and units of the constants (SI, as a rule). The fragments of this table is presented below.

1	*accelerationOfGravity*	g	**9.80665**	$m\ s^{-2}$
2	*ageOfUniverse*	t_O	**12-18**	Gyr
...	...	...	...	...
35	*planckConstant*	h	$\mathbf{6.62606876(52)\times10^{-34}}$	$J\ s$
...	...	...	...	...
40	*protonComptonWavelength*	$\lambda_{C,p}$	$\mathbf{1.321409847(10)\times10^{-15}}$	m
41	*protonMagneticMoment*	μ_p	$\mathbf{1.410606633(58)\times10^{-26}}$	$J\ T^{-1}$
42	*protonMass*	m_p	$\mathbf{1.67262158(13)\times10^{-27}}$	kg
...	...	...	...	...
60	*weakMixingAngle*	$\sin^2\Theta_W$	**0.2224(19)**	

Record (for example) 0.2224(19) means (0.2224±0.0019). Temporarily all constant names have the first letter in the lower-case to avoid conflict with the constant names in the current Package Version 1.3 [1].

- **cct**; this is the correlation coefficients table; it contains the correlation coefficients for all constants from **basicl** table (if they exist). The fragment of this table is as fallows.

i	j	x_i	x_j	r_{ij}
1	2	g	t_0	**Null**
...	...	...	...	...
1	35	g	h	**0.000**
...	...	...	...	...
1	40	g	$\lambda_{C,p}$	**0.000**
...	...	...	...	...
1	60	g	$\sin^2\Theta_W$	**0.000**
2	...	...	...	...
2	35	t_0	h	**Null**
...	...	...	...	...
2	60	t_0	$\sin^2\Theta_W$	**Null**
...	...	...	...	...
35	36	h	$\hbar$	**1.000**
...	...	...	...	...
35	40	h	$\lambda_{C,p}$	**0.002**
35	41	h	μ_p	**0.945**
35	42	h	m_p	**0.995**
...	...	...	...	...
35	60	h	$\sin^2\Theta_W$	**0.000**
36	...	$\hbar$	...	...
...	...	...	...	...

Here r_{ij} = Null means that the value of the corresponding correlation coefficient is absent in the NIST data [3] or it is unknown.

Data management module 'Manager.m'

Data management module allows to execute different manipulations with the fundamental constants data and to add new data. Some possibilities of the management system are outlined below.

- **InsertFPC** allows to insert information about new constant into the basic table (**basicl**) or into the user defined table (see below). This procedure for the present creates empty cells in the correlation coefficients table to input values of correlation coefficients by hands.

- **DeleteFPC** deletes the whole information about pointed out constant from both tables.

InsertFPC [{*n, "name", "symbol", "value", "unit"*}, *basicl, cct*]

DeleteFPC [*"name", basicl, cct*]

DeleteFPC [*n, basicl, cct*]

In place of the basic table names may be used names of other two tables, which were created by NewListFPC procedure (see below).

- **NewListFPC** allows to create user defined database from existing ones (for example, basic database — **basicl, cct**).

```
newt = NewListFPC [ { "speedOfLightInVacuum", "planckConstant",
                      "electronMass", "fineStructureConstant",
                      "faradayConstant" }, basicl, cct ];
```

newt[first] =

1	*speedOfLightInVacuum*	c_0	**299792458**	$m\ s^{-1}$
2	*planckConstant*	h	$\mathbf{6.62606876(52)\times10^{-34}}$	$J\ s$
3	*electronMass*	m_e	$\mathbf{9.10938188(72)\times10^{-31}}$	kg
4	*fineStructureConstant*	α	$\mathbf{7.297352533(27)\times10^{-3}}$	
5	*faradayConstant*	F	**96485.3415(39)**	$C\ mol^{-1}$

newt[last] =

i	**j**	x_i	x_j	r_{ij}
1	2	c_0	h	**0.000**
1	3	c_0	m_e	**0.000**
1	4	c_0	α	**0.000**
1	5	c_0	F	**0.000**
2	3	h	m_e	**0.996**
2	4	h	α	**0.002**
2	5	h	F	**−0.972**
3	4	m_e	α	**−0.092**
3	5	m_e	F	**−0.989**
4	5	α	F	**0.226**

- **PairCC** allows to get correlation coefficient for any pair of the constants from pointed out the database.

In[1] := **PairCC ["electronMass", "faradayConstant", First[newt], Last[newt]]**

Out[1] := { 3, 5, m_e, F, –0.989 }

- **GroupCC** allows to get the correlation coefficients for one constant and group of the constants.

grcc = GroupCC ["planckConstant", { "faradayConstant", "electronMass", "fineStructureConstant" }, First[newt], Last[newt]];

i	j	x_i	x_j	r_{ij}
2	5	h	F	**−0.972**
2	3	h	m_e	**0.996**
2	4	h	α	**0.002**

- **MakeCM** produces the matrix of correlation for basic (**cct**) or user defined table of the correlation coefficients.

ccm = MakeCM [Last[newt]];

ccm =

	c_0	h	m_e	α	F
c_0	1.000	0.000	0.000	0.000	0.000
h	0.000	1.000	0.996	0.002	–0.972
m_e	0.000	0.996	1.000	–0.092	–0.989
α	0.000	0.002	–0.092	1.000	0.226
F	0.000	–0.972	–0.989	0.226	1.000

The future of the package

- **Database maintenance**

  As the fundamental constants are periodically re-evaluated and new constants emerged in different subfields, some special procedures will be needed to maintain the database actual. Firstly we plan to make the 'StandardPhysicalConstants' in *Mathematica* as complete as possible using all known authorized sources, firstly PDG [2] data, and then NIST [3], and others.

- **Functionality development**

  We plan to continue developing the package to increase the number of operations automatically performed with constants. First of all, to create the "built-in" calculations of the average value of vector function depending upon several constants and corresponding covariance matrix as propagation of the current covariance matrix of the 'StandardPhysicalConstants'.

  It is planned to use proposed package 'StandardPhysicalConstants' *as the test bed for organizing the approximate calculations with controlled accuracies in different Mathematica applications, firstly in data and models comparisons in Particle Physics. It will be used also to design specifications for data structures required from the metrology resources to make the Mathematica and external information resources interoperable in the network calculations. In this respect the structure of the proposed package is not final one and are subject of restructuring in due course of usage in applications.*

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ГНЦ РФ Институт физики высоких энергий
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Индекс 3649

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