November 9, 2024

A Mathematica package for unit conversion in natural unit systems

Hong-Yi Zhang

Tsung-Dao Lee Institute & School of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai 201210, China

E-mail: hongyi18@sjtu.edu.cn

Abstract: Natural unit systems are measurement systems with selected physical constants set to 1, a practice that has proven useful in physics research. This article introduces an easy-to-use Mathematica package "UnitConversion" designed for unit conversion within customizable natural unit systems. The package includes predefined units and parameters commonly used in particle physics and cosmology, enabling efficient and flexible calculations across various physical systems.

Contents

1 Introduction 1

2 How to use UnitConversion version 1.0 2
- 2.1 What this package can do 2
- 2.2 Installation and update 2
- 2.3 Named units and parameters 2
- 2.4 Choosing a natural unit system 3
- 2.5 Unit conversion 3
- 2.6 Customizing named units and parameters 3

3 Summary 3

1 Introduction

In theoretical and computational physics, natural units streamline calculations by setting certain physical constants to 1, such as the speed of light c and the reduced Planck constant $\hbar$. These units simplify equations and allow physicists to focus on essential physical relationships without the added complexity of constants. Despite the benefits, switching between natural and standard units often requires repeated manual conversions, which can be time-consuming and error-prone, particularly in fields like particle physics and cosmology where diverse units are frequently used.

This article introduces UnitConversion, a Mathematica package developed to automate the conversion of physical quantities between standard and natural unit systems. With predefined units and parameters common to particle physics and cosmology and the flexibility to customize and extend the unit system, UnitConversion could provide a foundation for efficient, accurate computations in diverse physical contexts.

2 How to use UnitConversion version 1.0

2.1 What this package can do

The package "UnitConversion" is designed to perform unit conversion within a given natural unit system. It allows the conversion from a quantity in a natural system into another in physical units, e.g.,

$$\text{Electron mass: } 0.511 \text{ MeV} \quad (\text{with } c = 1) \to 9.11 \times 10^{-31}\text{kg} \quad (\text{in the SI units}) \ , \tag{2.1}$$

or the reverse, e.g.,

$$\text{Elementary charge: } 1.60 \times 10^{-19}\text{C} \quad (\text{in the SI units}) \to 0.303 \quad (\text{with } c = \hbar = \epsilon_0 = 1) \ . \tag{2.2}$$

2.2 Installation and update

"UnitConversion" is available on https://github.com/hongyi18/UnitConversion. There are two ways to use it. One can directly import the package from the web every time, using the `Import` method:

```
Import["https://raw.githubusercontent.com/hongyi18/UnitConversion/main/UnitCo⌟
↪  nversion.wl"]
```

Alternatively, one can download the package locally to the Applications subdirectory of Mathematica, using

```
URLDownload["https://raw.githubusercontent.com/hongyi18/UnitConversion/main/U⌟
↪  nitConversion.wl", FileNameJoin[{$UserBaseDirectory, "Applications",
↪  "UnitConversion.wl"}]]
```

Once the package is downloaded, it can be loaded by running

```
<< UnitConversion`
```

A 3-minute Mathematica notebook tutorial is available on the package website.

2.3 Named units and parameters

Only named units and parameters are supported. In this first release of version 1.0, "UnitConversion" supports five SI base units $\{\mathrm{s}, \mathrm{m}, \mathrm{kg}, \mathrm{A}, \mathrm{K}\}$, their derived units, and some useful constants and parameters in particle physics and cosmology. The other two SI base units $\{\mathrm{mol}, \mathrm{cd}\}$ and their derived units are not supported yet. The value of constants and physical parameters are specified based on references [1, 2]. To see a full list of named units and parameters along with their meanings, evaluate the command

```
UnitList[]
```

The named units and parameters are assigned with symbols commonly used in physics, hence one is also encouraged to guess the symbol and check if it has been internally defined. For example, to find out if the Hubble parameter today is a named parameter with the symbol `H0`, one can evaluate

```
?H0
```

The physical meaning of the symbol will be printed if it is a supported unit.

2.4 Choosing a natural unit system

The default natural unit system is the one with $c = \hbar = \varepsilon_0 = k_\mathrm{B} = 1$ (light speed = reduced Planck constant = vacuum permittivity = Boltzmann constant = 1). To use a custom natural unit system instead, one can use the function `SetUnitSystem`. For example, to take the geometrized unit system with $c = G_\mathrm{N} = 1$ (light speed = gravitational constant = 1), one can run the following command line

```
SetNaturalUnit[DefiningConstants->{c==1, GN==1}]
```

The information about the natural unit system in use can be checked via

```
NaturalUnitInfo[]
```

2.5 Unit conversion

Unit conversion is performed using the function `UC[quantity]` or `UC[quantity, targetunit]`. In the former case, the quantity will be simplified automatically in terms of the SI base units. In the latter case, the quantity will be converted into that with the target unit. To achieve the examples in (2.1) and (2.2), one can evaluate the following commands

```
UC[0.511 MeV, kg]
UC[1.60 10^-19 C]
```

within the default natural unit system. Since the electron mass and the elementary charge are named units with the symbols `mElectron` and `e`, one can also evaluate

```
UC[mElectron, kg]
UC[e]
```

2.6 Customizing named units and parameters

For convenience, units and parameters are assigned with symbols commonly used in physics. However, if you wish to rename units or add additional derived units, you can do so with two simple modifications in the package file "UnitConversion.wl":

1. Add/modify the usage information for the new/existing unit.

2. Add/modify its definition in `$Units` if it is a derived unit.

3 Summary

This paper introduces "UnitConversion", a Mathematica package designed to automate the conversion of physical quantities between standard and natural unit systems. It supports a variety of commonly used units and parameters and provides a simple method, `UC`, for performing conversions between different unit systems. The package is flexible, allowing users to customize unit systems, rename predefined units and parameters, and add new units and parameters as needed. This tool is intended to streamline research workflows by reducing the time spent on unit conversions and minimizing the potential for errors.

Acknowledgments

This work is partly supported by the National Natural Science Foundation of China (NSFC) through the grant No.12350610240.

References

[1] Particle Data Group collaboration, *Review of particle physics*, *Phys. Rev. D* **110** (2024) 030001.

[2] Wikipedia contributors, *International system of units — Wikipedia, the free encyclopedia*, 2024.