UCR-TR-2022-FLIP-00X

P165: **Introduction to Particle Physics**

Flip Tanedo
flip.tanedo@ucr.edu
Department of Physics & Astronomy, University of California, Riverside, CA 92521

Abstract

This is a 10 week course on the theory of the Standard Model geared towards undergraduates who have taken at least the first of a three-quarter sequence in quantum mechanics. Last Compiled: March 29, 2022

Contents

1 Introduction

To be filled in.

2 Units and Natural Units

Imagine that you have three apples. This is a number (three) an a unit (apple). The meaning of the unit depends on what you're using it to measure. For example, if apples are \$1 each, then you could use an apple as a unit of currency. The way to do this is to simply *multiply by one*:

$$(3 \text{ apples}) \times \left(\frac{\$\ 1}{\text{apple}}\right) = \$3 \ . \tag{2.1}$$

We have used the fact that the exchange rate is simply the statement that

$$1 \text{ apple} = \$1 \qquad\qquad \Rightarrow \qquad\qquad 1 = \frac{\$1}{1 \text{ apple}} \ . \tag{2.2}$$

Exercise 2.1. *An apple is also roughly 100 dietary calories. If a friend buys me a coffee for \$2, does this mean that I can pay that friend back in 200 dietary calories? Comment on the relative merits of using apples as an exchange between monetary value and dietary energy.*

Exercise 2.2. *At the time of this writing, one dollar is worth three-fourths of a British pound sterling:* $\$1 = 0.75$. *Write an expression that is equal to one that is a ratio of pound sterling to dollars. Use this ratio to convert the cost of two apples in the UK. Is the exchange rate a good conversion factor? What if a friend of mine bought me coffee in Riverside, and I promised to pay them back in pound sterling in two years?*

All that matters is that the conversion is constant. Indeed, the constants of nature make very good 'exchange rates.' For example, in particle physics we like to use **natural units**. This is the curious statement that

$$\hbar = c = 1 \ . \tag{2.3}$$

At face value, this doesn't make sense. $\hbar$ has units of action, c is a speed, and 1 is dimensionless. However, because nature gives us a *fundamental* unit of action and a *fundamental* unit of speed, we may use them as conversion factors (exchange rates),

$$c = 3 \times 10^{10} \text{ cm/s} \ . \tag{2.4}$$

If $c = 1$, then this means

$$1 \text{ s} = 3 \times 10^{10} \text{ cm} \ . \tag{2.5}$$

This, in turn, connects a unit of time to a unit of distance. By measuring time, the constant c automatically gives us an associated distance. The physical relevance of the distance is tied to the nature of the fundamental constant: one second (or 'light-second') is the distance that a photon travels in one second. Observe that this only works because c is a constant.

Acknowledgments

PT thanks the Winter 2018, Winter 2020, and Spring 2022 cohorts of students for their patience as this course was developed. PT thanks the Aspen Center for Physics (NSF grant #1066293) for its hospitality during a period where part of this work was completed. PT is supported by a NSF CAREER award.