Measurement

With the simple act of using a tape measure or a scale, we bridge a great divide between the lofty abstractions of mathematics and the physical world. There is something very interesting and important going on here that is easily overlooked because of the familiarity of measuring. We are saying that not only do these strange entities called numbers capture the notion of “quantity,” further there are physical attributes whose quantities correspond exactly to numbers: that attributes like size lie on a scale, and that scale is the real number line.

A number which is recorded as a measurement of a physical quantity takes on additional features that purely mathematical numbers don’t have. The first of the features is the type of physical quantity the measurement gives. This quality is discussed in Dimensional Analysis: Dimensions and Units. The second feature is the precision of the measurement, which is represented by the number of digits, here called significant figures, used to record the quantity.

# Dimensional Analysis

## Dimension vs. Unit

You cannot add 5 seconds to 5 centimeters no matter how hard you try. They’re different physical dimensions. Not, like, “dimension c-137” dimensions – for this sense you should use “universe”. This prior usage is a clear indication that you have no technical education. Please stop using it.

Dimension (in measurement) := A type of physical quantity. Length, mass, time, and some other exotic ones, like electric charge.

A unit is a particular reference quantity. How do we decide which of two objects is longer? We put them side by side. How do we do the same, when the objects are in different places and times? We compare both of them to a third object which has been copied and distributed. Until 2019, most scales could trace back their calibration to the mass of the International Prototype Kilogram, a chunk of Platinum alloy kept near Paris. Behind all measurement instruments is a chain of comparisons going back to a standard reference.

Unit := A reference quantity for a given dimension.

To reiterate, a measurement “1.01 kg” has units of kilograms and dimensions of mass.

“So I told him, ‘gimme the blemflarks’, ya know, it’s, this guy doesn’t understand interstellar currency.” – nondescript alien, Rick and Morty episode 1

## Unit Conversion

Just as “inches” act as a middleman standard to compare the lengths of different objects, a given quantity compares the lengths of different unit systems. That is to say, an object has the same length whether you measure it in inches or centimeters; the ratio of the two numerical values you get in those two measurement systems is called a conversion factor. Here’s how you find and use unit conversions.

1. Find an equivalence of two units, preferably by looking it up. 1 inch = 2.54 cm

# Accuracy and Precision

## Significant Figures

When I write “0.25” in math class, this quantity is identical to “1/4” – ie, these are different names for the same number on the number line. When I write “0.25 cm” in a science class, it is understood that the likelihood that some physical object is EXACTLY 0.25 cm is astronomically small, which is to say, impossible. So the object we’ve measured to be “0.25 cm” is in fact “0.2502108… cm”, with additional digits on to infinity or until they’re smaller than the Plank length.

We do not, however, have an infinitely precise ruler. The marks on this particular ruler go down to 100ths of a centimeter, and that’s that.

What happens when I have a less precise ruler, only measuring down to whole centimeters, with which I measure the length of a second object to be 1 cm, and then add these two lengths? What is the precision of the resultant length?

Consider the consequences of defining the resultant precision to be the greater of the two constituent precisions. I could arbitrarily increase the precision of sloppy measurements simply by bringing a precise instrument along. For example, I might know the length of a stretch of road to an accuracy of whole meters, say 204 meters in total. Then my buddy comes along with his precision machining calipers, and from the mark where I stopped measuring, measures an additional two millions of a meter: 0.000002 m. Is the total length 204.000002 meters? Heck no. We can’t improve imprecise measurements by adding more precise measurements to them. If we wanted to know the length of road to millions of a meter, we’d need an instrument with the range and precision to do this in a single measurement. The length of the two added lengths of roads remains 204; the digits that my buddy added do not count, because the precision of our joint measurement is the precision of the least precise constituent measurement.

Rigorously calculating the measurement error of combined measurements can get a little involved. Thus, for most purposes we use a simplified system to keep track of precision, called Significant Figures.

## Error Calculation

## Scientific Notation