Physical quantities and measurements

Everyday thing: we use quantities almost everywhere — a ten foot pole, five pounds of potatoes, a two-and-a-half hour long movie, six gallons of gas, etc.

It is physics because: What we have (or somebody else has) done is a measurement of a physical quantity as a multiple of a unit. In other words:

statement	multiple	unit	physical quantity
ten foot (pole)	10	foot	distance
five pounds (of potatoes)	5	pounds (lbs)	mass
two-and-a-half hour (movie)	2.5	hour	time

Let’s unpack this table and explain what we mean by:

- a physical quantity,
- a unit, and
- a measurement.

1. Physical quantity

“What is a physical quantity?” is actually a fairly deep philosophical question, which we won’t have time to get into. For now, we will say that **a physical quantity is a property of a part of nature that we can measure and reason about mathematically**.

Some of the most useful physical quantities are:

- time
- distance (or length)
- mass
- temperature
- electric current

Other physical quantities can be formed by combining those five quantities. For instance, the physical quantity of a (rectangular) area can be expressed by width and height, so it is equivalent to distance times distance. The average velocity of a vehicle is distance covered by time travelled, so it is equivalent to distance divided by time. Some other quantities we will use are:

- force
- energy (in many forms: kinetic, gravitational, etc.)
- electric charge

2. Physical unit

In order to be able to associate numbers with our physical quantity, we have to agree on a **unit**, which is a defined amount of that physical quantity. For example, we agree to call a certain amount of distance "a **yard**". This allows us to express any distance as multiples of that yard we agreed on (2 yards, 10 yards, etc.)

The choice is arbitrary, and in fact the US uses a different system than most of the rest of the world. For example, your humble lecturer is from Austria, where the fundamental unit of distance is the **meter** (which is a bit longer than a yard).

The meter is part of the **metric system**, or more precisely, it is one of the **SI units** (from the French "Système Internationale"), which are used in most parts of the world. SI are also the most important units in physics, which is why we are going to use them in Physics 106 too. Here is a table of some physical quantities, the US unit and the corresponding SI unit, as well as a rough translation between the two:

quantity	US unit	SI unit	rough conversion
distance	foot (ft)	meter (m)	10 ft ≈ 3 m
time	second (s)	second (s)	
mass	pound (lb)	kilogram (kg)	2 lbs ≈ 1 kg
volume	gallon (gal)	liter (L)	1 gal ≈ 4 L

→ Type "unit converter" into Google, and a nice unit converter will pop up. You can change the physical quantity on the top, and the units below either number. Use it to get a "feel" for the SI units: Translate the statements on page 1 ("five pounds" etc.) into the SI equivalents! Check the "rough conversion" formlas in the table above – how much off are they? When you get a 20-fl.oz. soda bottle from the vending machine, how much is that in liters? How tall are you in meters? How much do you weigh in kilograms?

But how do we agree precisely how much distance is a meter (or a foot)? Until 1960, there was a prototype meter bar (hosted in some vault in Paris), and however long that bar was, that was defined as exactly one meter. Thus, if you were to construct a ruler, you would use a copy of that bar and make sure that the one-meter mark of your ruler matched the length of the meter bar. Other units, like mass and time, were defined in a similar fashion.

Household items, like kitchen scales, wall clocks, and rulers are still calibrated by comparing them to a more accurate "prototype" item. For modern scientific instruments, the prototype method turned out to be too inaccurate. Therefore, nowadays, the SI units are defined in terms of fundamental constants of nature that can be measured very accurately, like the speed of light or the certain vibrations of an atom.

3. Measurement and error

Now that we know what a physical quantity and a unit is, we understand the statements made on the first page: by “five pounds of potatoes” we mean a mass, in this case of a sack of potatoes, which is the same mass as five one-pound weights put together. By “ten foot pole” we mean a distance, in this case from the bottom to the top of a pole. That distance is as great as ten one-foot long sticks put next to each other.

However, any ten-foot pole in real life cannot be made *exactly* ten foot (10.00000000... ft) tall. It will be a little bit off, maybe by an inch or so. In the same way, if we measure the length of that pole, we cannot measure it to arbitrary precision. For example, if we use a ruler with markings every 1 cm (= 0.01 m), and we measure the pole to be 3.05 m high, we know we might be off by anywhere less than 0.01 m (it may be anywhere between 3.04 and 3.06 m). Put in a scientific way, the **length of the pole is 3.05 m with an accuracy of 0.01 m.**

Whenever we do measurements, it is important to give these four quantities:

- physical quantity: length
- physical unit: meter (m)
- measured value: 3.05
- accuracy: 0.01

Sometimes figuring out the accuracy is not so simple, and for now we have to make an (hopefully educated) guess. We will learn ways to estimate the accuracy in a later lab.

→ Watch the following YouTube video: https://youtu.be/F6fltSqImFM