United by Units

My grandmother was a wonderful woman, naturally, since she was Irish. Like most Irish grandmothers, back in the day, she baked those delicious traditional Irish soda breads. I particularly liked her soda farls, a breakfast staple. I liked them so much, I decided to learn to bake them myself. I found a notepad and pen, and rose with the roosters, ready to record her recipe as she prepared to bake the mornings supply. She began with flour, four fistfuls to be exact, and then added a teacup of buttermilk...wait a minute, “How much buttermilk is in a teacup? “ I asked. “This much”, she said, holding up a cracked and battered teacup. My plan was in ruins, I had no way to record her recipe, the ingredients were measured in units that were inseparable from her. Alas, my grandmother has been gone for these many years, and her ancient teacup and calloused fists are gone with her. I'll never taste her farls again, and the world is smaller place from the loss, all for the lack of a standard measure.

*Use recipes to help make units of measure tactile - better yet, bake something for the students- **Teaching Tactic***

Science and engineering cannot function if it can't describe what it's investigating. Models require the language of mathematics, but physical objects need units to provide a scale on which to measure each attribute and every attribute needs it's own unit, so whats required is a system of units, but thats still not enough. My grandmother used a system of measurements, the Mary Hunter system, MHS. It consisted of the fist, the teacup, and god knows what else, but it was consistent to her and it worked for her, but only her. To be useful, there has to be a conversion and she never bothered setting one up, because it gave her job security, anyone messing with grandma didn't eat! One important way around this is standardization. If Grandpa and I had cast the teacup in some precious, non-corroding metal; massed produced copies of the teacup,and distributed them around the world, then anyone could measure out the correct amount of buttermilk. Or, we could join the rest of the world and get grandma to use the standards the governments of the world have negotiated to make everyone's life a little easier. Not that getting grandma,or the US public, to go metric could in any way be considered easy.

SI Units

Today, virtually all scientists, most engineers, and the vast majority of everyone else, use *Le Système International d'Unités,* the SI. The SI consists of seven base units. Each of the base units is associated with a particular standard that allows anyone, anywhere in the universe, to take the standard and determine how long a stick must be to be a meter long, well all but the kilogram anyway.

Most of the unit standards are tied to some fundamental physical quantity that can be measured. The meter for instance, is based on the fundamental constant *c*, the speed of light. Anyone in the universe, providing they can measure *c*, can recreate a meter stick, by marking off the distance light travels in 1/299,792,458th of a second. The table below lists the base units and their standards.

SI Base Units, Wikipedia has the details.

Name	Symbol	Quantity	Standard, roughly speaking.
meter	m	length	Distance traveled by light, in vacuum, in $^1/_{299,792,458}$ of a second
kilogram	kg	mass	International Prototype Kilogram, IPK
second	s	time	9,192,631,770 periods of oscillation of a transition of the Caesium-133 atom
ampere	A	electric current	Ampere's law
kelvin	K	thermodynamic temperature	1/273.16 of the triple point of water
mole	mol	amount of substance	Same number of particles as there are atoms in 0.012 kilograms of carbon-12
candela	cd	luminous intensity	$^1/_{683}$ watts per steradian (solid angle) radiant intensity of light at 540×10^{12} hertz

Unit Facts

The kilogram is a little different in that it's the only unit that has a standard based on a physical object. This is not a good thing, but there's another detail that must be mentioned before we go there. The kilogram is the unit of mass, not weight. Weight is a measure of the gravitational force acting on an object and it has units of a force. Mass is a fundamental concept of the physical universe and its unit is the kilogram. It's common, though inaccurate, to hear the terms used interchangably.It makes little difference in every day life, since gravity is essentially constant on the planets surface,which means mass is directly proportional to weight, but what if your not on Earths surface? Chinese astronaut Zhai Zhigang might have a weight and mass of 180 kg on earth, but during his space walk, while his mass remained the same, his weight decreased by roughly10%, not 0. Why?

Setup workshops to calculate the weight of an object at the surface of the planets and asteroids – ***Lesson Plan Idea***

Give students a list of solar system objects and have them research, on the Internet, some basic facts about the objects. Mass, diameter, density, etc... In Class calculate the surface gravity of each object.

I mentioned that on Earth gravity is essentially constant, that doesn't imply that it's exactly constant. In fact it can vary by 0.5% over the planets surface.

Estimate g as a function of distance from Earth's center, up to geosycrhonus orbit, and plot it – ***Lesson Plan Idea***
Confirm Zhai's weight in orbit. Compare mass and weight at several locations on earth. Investigate how changes in location can affect weight. See Earth's Gravity

To be legal for commercial use, the scale must be calibrated to weigh objects at a standard gravity, 9.80665 m/s^2 and this must be done at the location at which the scale will be used. This is the problem with having an object as a standard, every scale must, through some fantastic chain of comparisons, be calibrated to the International Prototype Kilogram, IPK, a platinum iridium block, sitting in a vault in France. We have an elaborate system for doing this on Earth, but what happens if we set up colonies on Mars, or the moon? They'll have to take copies of the IPKwith them.

Get professional help. Commercial calibration companies may be willing to speak to the class. - ***Teaching Tactic***

The other problem with an object based standard, is the lack immutability. Things change, including the mass of the IPK. But this is another story, facinating, but beyond the pale of this article.

The historyof the kilogram and the push to improve the standard,si a great topic for a research paper . - ***Resource***
What a kilogram really weighs Is a good geeral overview of the current situation.
Wikipedia is another good starting point.
The BIMP is the offical site of the SI

The Standard Prefixes

	Name		**deca-**	**hecto-**	**kilo-**	**mega-**	**giga-**	**tera-**	**peta-**	**exa-**	**zetta-**	**yotta-**
Multiples	**Symbol**		da	h	k	M	G	T	P	E	Z	Y
	Factor	10^0	10^1	10^2	10^3	10^6	10^9	10^{12}	10^{15}	10^{18}	10^{21}	10^{24}
	Name		**deci-**	**centi-**	**milli-**	**micro-**	**nano-**	**pico-**	**femto-**	**atto-**	**zepto-**	**yocto-**
Subdivisions	**Symbol**		d	c	m	µ	n	p	f	a	z	y
	Factor	10^0	10^{-1}	10^{-2}	10^{-3}	10^{-6}	10^{-9}	10^{-12}	10^{-15}	10^{-18}	10^{-21}	10^{-24}

I'm still looking at ideas for teaching the standard prefixes. I'm thinking about a flash demo, but any ideas would be welcome.

The 7 base units along with the standard prefixes make up the SI. All other units are derived from these. A few of the derived units are so important that they have been named, for instance, the Newton, and the Coulomb, the rest struggle along as strings of the base units, for instance, the unit of conductivity is ampere squared second cubed per kilogram meter cubed. A list of the derived units, named or otherwise, can be found on Wikipedia.

There are, of course, other systems of units; 3 countries,including this one, refuse to use the metric system, but everywhere else, the SI has supplanted the contenders in everyday life, and particularly in the Sciences. This dominance is largely due to the simplicity of having units that can be scaled by orders of magnitude with a move of a decimal point. That and politics, of course. In Part II I'll discuss how to make a measurement.