Class 2: Experiments

On a slip of paper, have each student write down his/her favorite musical artist (solo performer or group) and collect the data.

- Next, have each student hypothesize as to the favorite artist for the group as a whole. Announce my hypothesis to the group: “the favorite performing artist is Rush”, and explain the flawed reasoning.
- My hypothesis is biased, because I’m not willing to accept that my musical tastes are outdated; Rush are holdovers from the 70s and 80s to whom few people listen anymore. It is not logical, because Rush gets little radio airplay.
- Take a sample from the batch of collected responses and announce it as the most popular artist. Explain that this is an incorrect methodology, and that when taking samples, one must take great care to ensure that the sample is truly representative of the group as a whole. Statistics play a vital role in ensuring this.
- Next reveal the tallied votes and pose the question: “does this experiment demonstrate that the favorite artist of students at UMASS-Lowell is _____?” Probably not, because the students in the class aren’t necessarily a representative sample.
Experiment 2

- Barry Bonds (2001) hit 73 home runs in a single Major League Baseball season. Does this make him the greatest home-run hitter in baseball history?

  - Define your experiment. What criteria will you use to measure “greatness”?  
    • Number of home runs in a single season?  
    • Number of home runs over an entire career?  
    • Number of home runs per at-bat?

  - A proper control group is difficult to create for this experiment (considering many of the great sluggers have long since passed away).
In different eras, the pitchers and pitching conditions were different. The pitcher’s mound used to be higher, making pitchers more formidable prior to the late 60s.

- Also, it is widely held that all of the new expansion teams have diluted the pitching talent pool, making home-run hitting easier today.
- Players today have better exercise regimens. Compare the routines of Bonds or Mark McGwire to Babe Ruth’s lifestyle.
- Or BALCO could have sold them some “Cream” to help their sore muscles……..
- Different hitters faced different pressures from the fans and media. Mark McGwire and Sammy Sosa are widely idolized, while Roger Maris, who broke Babe Ruth’s single-season record of 60 home runs with 61 of his own in 1961, was greeted with indifference and was vilified by some who wanted to see Mickey Mantle break Ruth’s record. In fact, the day Maris broke the record (against the Red Sox- go figure…). Yankee Stadium was not even sold out.
Final Remark About Critical Thinking

♦ Keep the elements of critical thinking and the scientific method in mind if you write a position paper.

♦ The position you take will be your hypothesis, which you will state in your introduction. The main body of the paper will be a critical analysis of the topic and a presentation of facts. In the conclusion you will again mention your hypothesis and whether or not it was supported by the facts (don’t forget “Strunk and White!”).

♦ To conclude: think critically!
What Are Quantities?

- The goal of physics is to numerically evaluate our observations to explain the natural world. Before we do this, we must identify what it is we are observing. These observations can be explained in terms of fundamental and derived quantities.
- A quantity is a “property”.
- A quantity in the general sense is a property ascribed to phenomena, bodies, or substances that can be quantified for, or assigned to, a particular phenomenon, body, or substance. Examples are mass and electric charge.

(http://physics.nist.gov/cuu/Units/introduction.html)
For purposes of this class, I will state that mass is the quantity of matter in a body (the amount of “stuff”) regardless of its volume or of any forces acting on it. There are two more scientifically accurate ways of referring to mass, that we won’t consider in depth.

- The inertial mass of a body is a measure of the body's resistance to acceleration by some external force (as we will see when discussing Newton’s Second Law of Motion).
- The other way to think of mass is in terms of the gravitational mass of a body. This is best illustrated by an example. If two objects have different masses, the earth’s gravitational field will “pull harder” on the more massive of the two. Be careful to distinguish between mass and weight in this instance. Mass is an amount of “stuff”, while weight is the pull of gravity on that “stuff”. If I stand on the moon, my mass remains identical to what it was on the earth. However, because the moon’s gravitational pull on my mass is roughly 1/6th that of the earth’s, my weight will only be 1/6th as great on the moon.
- Incidentally, all evidence seems to indicate that the gravitational and inertial masses are equal.
Distance/Length (L)
- Not all objects in the universe are touching- distance is the separation between them.

Time (T)
- Not everything happens at once- time quantifies a sequence.
- Time is a dimension representing a succession of such actions or events. Time is one of the fundamental quantities of the physical world, similar to length and mass in this respect. The concept that time is a fourth dimension—on a par with the three dimensions of space: length, width, and depth—is one of the foundations of modern physics. Time measurement involves the establishment of a time scale in order to refer to the occurrence of events. 
(http://www.encarta.msn.com)
Temperature

- All objects have energy associated with them due to vibration of internal molecules and/or atoms. The temperature of a substance measures the average kinetic energy of its molecules. (http://www.encyclopedia.com)

- In the case of two bodies at different temperatures, heat will flow from the hotter to the colder until their temperatures are identical and thermal equilibrium is reached. Thus, temperatures and heat, although interrelated, refer to different concepts, temperature being a property of a body and heat being an energy flow to or from a body by virtue of a temperature difference. (http://www.encarta.msn.com)

Current, Luminosity, etc...

- There are other fundamental quantities that we won’t discuss in this class.
Units of Measurement

- Units of measurement can then be used to numerically evaluate the fundamental and derived quantities; in fact, this is a necessity.
  - For instance, suppose you hear that the distance between two objects is “25”. “25” what? Centimeters? Feet? Light years?

International System of Units

- The most widely accepted system is the International System of Units (or SI, Système International d'Unités).
  (http://www.bipm.fr/enus/3_SI/)
Mass is measured in kilograms (kg).

- At the end of the 18th century, a kilogram was the mass of a cubic decimeter (roughly 4”x4”x4”) of water. In 1889, the 1st CGPM sanctioned the international prototype of the kilogram, made of platinum-iridium, and declared: This prototype shall henceforth be considered to be the unit of mass. The prototype is kept at the International Bureau of Weights and Measures under conditions specified by the 1st CGPM in 1889. (http://physics.nist.gov/cuu/Units/kilogram.html)

- A kilogram is equal to the mass of the international prototype of the kilogram. (http://physics.nist.gov/cuu/Units/current.html)
Distance is measured in meters (m).

♦ The meter was intended to equal \(10^{-7}\) or one ten-millionth of the length of the meridian through Paris from pole to the equator. However, the first prototype was short by 0.2 millimeters because researchers miscalculated the flattening of the earth due to its rotation. Still this length became the standard.

– In 1889, a new international prototype was made of an alloy of platinum with 10 percent iridium, to within 0.0001, that was to be measured at the melting point of ice.... The original international prototype of the meter, which was sanctioned by the 1st General Conference on Weights and Measures (or CGPM, Conférence Générale des Poids et Mesures) in 1889, is still kept at the International Bureau of Weights and Measures (or BIPM, Bureau International des Poids et Mesures) in Paris under the conditions specified in 1889. (http://physics.nist.gov/cuu/Units/meter.html and http://physics.nist.gov/cuu/Units/acronyms.html)

– The meter is the length of the path traveled by light in vacuum during a time interval of 1/299 792 458 of a second. (http://physics.nist.gov/cuu/Units/current.html)
Time is measured in seconds (s).

- The unit of time, the second, was defined originally as the fraction 1/86 400 of the mean solar day. The exact definition of "mean solar day" was left to astronomical theories. However, measurement showed that irregularities in the rotation of the Earth could not be taken into account by the theory and have the effect that this definition does not allow the required accuracy to be achieved. ([http://physics.nist.gov/cuu/Units/second.html](http://physics.nist.gov/cuu/Units/second.html))

- The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom. ([http://physics.nist.gov/cuu/Units/current.html](http://physics.nist.gov/cuu/Units/current.html))

- NIST-F1, a cesium fountain clock housed at the National Institute of Standards and Technology (Boulder, CO), is the most precise clock in the world. It is accurate to 1.5x10^{-15} seconds. In other words, if it were to run for twenty-million years, it would neither lose nor gain a second. (Discover, June 2000, p. 52)
Temperature is measured in terms of Kelvin (K).

- One kelvin equals one degree Celsius.
  - The definition of the unit of thermodynamic temperature was given in substance by the 10th CGPM (1954) which selected the triple point of water as the fundamental fixed point and assigned to it the temperature 273.16 K, so defining the unit. The 13th CGPM (1967) adopted the name kelvin (symbol K) instead of "degree Kelvin" (symbol °K).
    (http://physics.nist.gov/cuu/Units/kelvin.html)
  - The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water. (http://physics.nist.gov/cuu/Units/current.html)
  - The lowest temperature theoretically achievable is 0 K. As of 1994, physicists had cooled atoms to 700 nanokelvins, the coldest temperature ever recorded for matter. NIST scientists chilled a cloud of cesium atoms very close to absolute zero using lasers to catch the atoms in an optical lattice. The atoms reached 700 nanokelvins, or 700 billionths of a kelvin. Zero kelvin (minus 273 degrees Celsius), or absolute zero, is the temperature at which atomic thermal motion would cease. (http://physics.nist.gov/News/Update/940815.html)
Derived Quantities

- Often times when numerically evaluating our observations to explain the natural world, it is necessary to perform mathematical operations on quantities to properly express their relationships.
- Derived quantities result when mathematical operations have been performed on the fundamental (or other derived) quantities.
- Having a rough feel for the following derived quantities will be necessary to investigate radiation.

♦ **Velocity**
- Velocity is L/T, or m/s in SI units.
- For example, if a sprinter runs 100 m (L) in 10 seconds, his average velocity over the time interval is 10 m/s (L/T).
♦ **Acceleration**
- Acceleration is \( \frac{L}{T^2} \) (change in velocity per unit time), or m/s\(^2\) in SI units.
- For example, if you start driving from a complete stop, and at the end of 4 seconds are traveling 40 MPH (17.88 m/s), your average acceleration over the time interval is 10 MPH/s, or 4.47 \( \text{m/s}^2 \) (= 4.47 m/s\(^2\)).
- Note that an acceleration represents a change in velocity, which can be an increase, a decrease, or a change in direction.

♦ **Force**
- Force is measured in kg* m/s\(^2\) in SI units; or equivalently, it can be expressed in terms of the newton (N), which is nothing more than a shorthand expression.
- Despite the complex units, force is nothing more than a push or pull, whether it is at a distance (the pull of the earth's gravity on me), or by contact (when I push on a desk, table, or chair).
- Incidentally the earth exerts a force (pull) of about 620 N on me (140 lb / 2.205 lb/kg x 9.8 m/s\(^2\)).
- The unit is named in honor of Sir Isaac Newton (1642-1727). ([http://www.encarta.msn.com](http://www.encarta.msn.com)).
Other Systems of Units

♦ Other systems of units include the U.S. Customary system. U.S. Customary units include the pound (weight), the yard, and the second. These units are probably more familiar to you than are SI units; however, they have many drawbacks: the differences between American and British units, the use of the same name for different units (e.g., ounce for both weight and liquid capacity, quart and pint for both liquid and dry capacity), and the existence of three different systems of weights (avoirdupois, troy, and apothecaries').
(http://www.infoplease.com/ce5/CE016990.html)

♦ Additionally performing mathematical operations with this system can be much more cumbersome (SI units are all decimal).
Note:

– all units of measure are written in lower case, even when named for an individual (for example: the kelvin, the newton, etc…). However, when referring to a “degree celsius” or a “degree fahrenheit”, Celsius and Fahrenheit are capitalized because the unit of measure is the degree, which remains lower case.

– When in using abbreviations i.e. C for Celsius the abbreviation is capitalized if unit is based on a proper name.