Introduction to Physics

By the end of this unit you will be able to:

- Define science and the requirements for something to be scientific
- Describe why certain topics are not scientific
- Describe the scientific method
- Describe the difference between fundamental and derived units
- Perform unit conversion calculations with time and the metric system
- Apply accuracy and precision to various situations
- Calculate the standard deviation using Excel for lab data

What is Science?

- Science
  - Science is an organized body of knowledge that is gathered through research
  - It usually exhibits symmetry and patterns
    - Example
      - Both the gravitational force equation and the electromagnetic force equation are very similar
      - While the variables stand for different quantities, the structure of the equation is the same

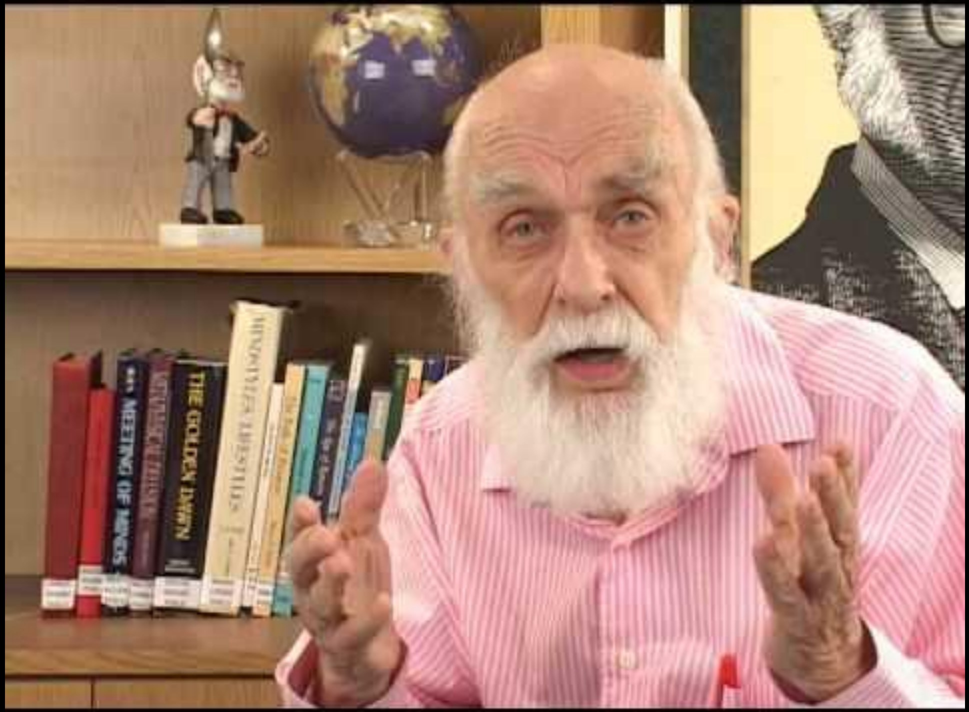
$$F = G\frac{m_1 m_2}{r^2}$$

$$F = k\frac{q_1 q_2}{r^2}$$

- Must have a "fair test"
  - In other words, experiments must have the chance of being proven wrong
  - The chances of different outcomes do not have to be equal, just that multiple outcomes are possible
  - Example
    - You drop a pen from a height of 2 meters
    - As long you are not restricting its motion in ANY direction, then the pen can move in ANY direction
    - Since it can move in any direction, it is a fair test
    - This is a fair test to answer the question:
      - » "What direction does a pen fall when it is dropped?"
    - Same pen, this time you put it in a device so that the pen can only fall up or down
      - » Is this a fair test? Why do you think the way you do?

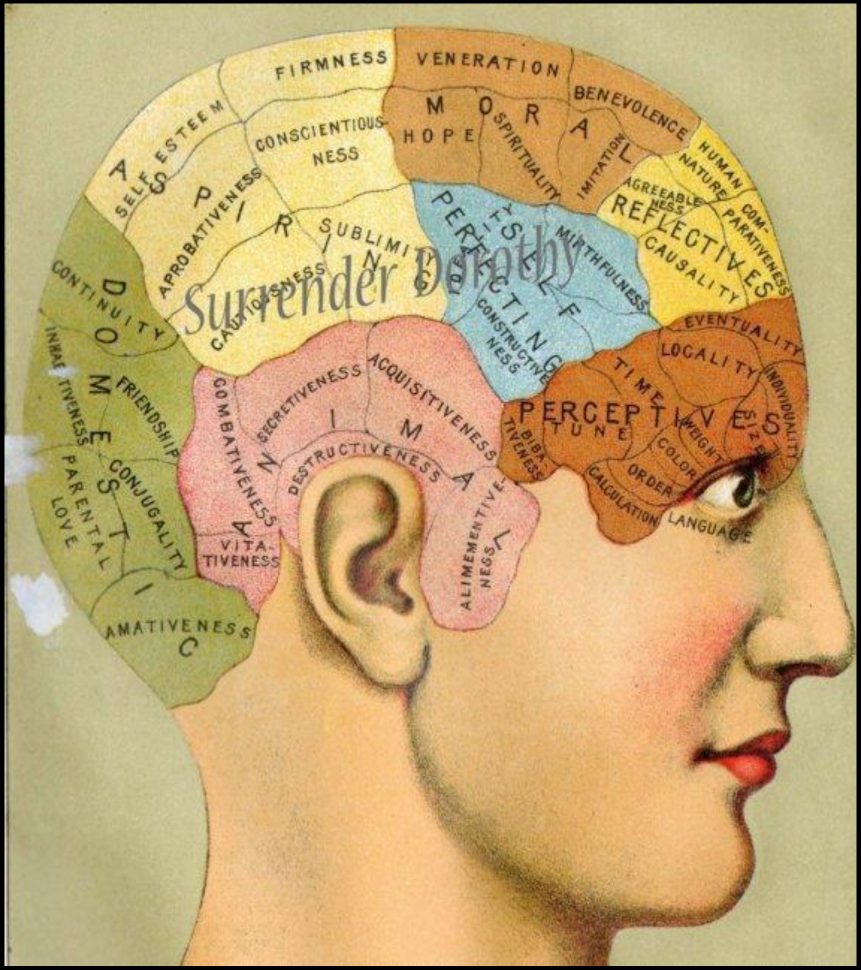
- Pseudoscience
  - An organized body of knowledge that appears scientific, but lacks a basis in research
  - Pseudoscience typically uses fake studies or studies that have been shown to be faulty to support their beliefs
  - Examples
    - Astrology
      - The idea that chunks of rock millions of miles away have an effect on your daily life
    - Link between Autism and the MMR vaccine
      - In 1998, Andrew Wakefield published a fraudulent paper about the link between the MMR vaccine and Autism
      - Since then, multiple groups have attempted to replicate the study and all of them have come to the conclusion that the MMR vaccine does not cause Autism

- Dowsing
  - The idea that you can detect a substance (originally used with water and precious metals) underground by holding a wooden branch or wire above ground
  - In 2013, Jim McCormick was convicted of fraud for selling dowsing rods designed to detect explosives to the Iraqi police
  - Watch the below video on Dowsing



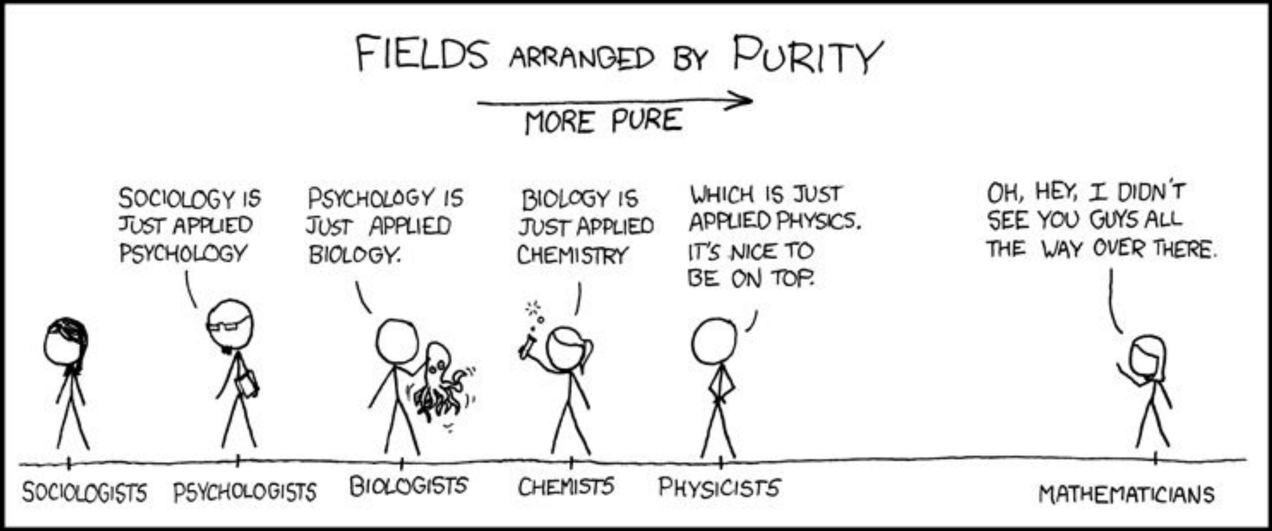
- Homeopathy
  - The idea that people can develop cures for diseases by diluting the disease
  - Believers think that by diluting the disease it makes it more potent
    - » In other words, that diluting the substance actually concentrates it
  - Seems harmless enough until you realize that there are stores selling cures for cancer that people are counting on to cure them
  - Watch the video below about homeopathy

- **Phrenology**
  - **The idea that you could predict someone’s personality and behavior based on the bumps on that person’s skull**
  - **The idea has fallen out of favor with the rise of neuroscience and knowledge of the brain**



This picture represents the behavior and personality traits and where early scientists believed they are located under the skull.

- **Physics**
  - **The study of energy, motion, and matter**
  - **The most basic of sciences**
    - **You cannot truly understand any other science without first understanding physics**



xkcd.com/435

- Classical Physics
  - Started with the early Greeks (Aristotle, Archimedes, and company)
  - Encompasses everything from the Greeks to Einstein
    - From roughly 500 BCE to 1905 CE
  - Topics include: Gravity, Heat Transfer, Electricity and Magnetism
- Modern Physics
  - From 1905 CE to the present
  - Scientists in this period include Einstein, Feynman and Bohr
  - Topics include: Radioactivity, Relativity, Quantum Mechanics

- Francis Bacon (1561 – 1626)
  - English Philosopher
  - Credited for establishing a method of gathering scientific data
  - Scientific Method
    - Recognize a problem / Raise a question
    - Conduct research on the subject
    - Formulate a hypothesis
    - Perform an experiment
    - Collect your data
    - Test and retest the experiment (Peer Review)
      - This is the most important part!
    - Formulate a theory

- **Units**
  - **Fundamental Quantities**
    - **There are only seven fundamental quantities**
    - **Those quantities cannot be formed from any other quantities**
      - **Time (seconds or s)**
      - **Length (meter or m)**
      - **Mass (kilogram or kg)**
      - **Temperature (Kelvin or K)**
      - **Electric Current (Ampere or A)**
      - **Luminosity (candela or cd)**
      - **Amount of Matter (mole or mol)**
    - **Any other unit can be broken down to be a combination of these seven**

- Derived Quantities
  - Combinations of fundamental quantities
    - Velocity (m/s)
    - Momentum (kg*m/s)
    - Thermal Conductivity ($m*kg/s^3/K$)
    - Luminance (cd/m^2)
- In physics, the metric system (mks) is used
  - m (meter), kg (kilogram), s (second)
  - Throughout the entire course, you should always be converting units into meters, kilograms, and seconds
  - There will be VERY few situations when it is acceptable NOT to convert

- Unit Conversion
  - Since different quantities have different units they can be measured in, it is helpful to be able to convert from one to another
  - You should remember how to convert units from Chemistry and/or Introduction To Engineering
  - Example
    - Convert .021 years into seconds

$$.021\ yr \times \frac{365.25\ d}{1\ yr} \times \frac{24\ hr}{1\ d} \times \frac{3600\ s}{1\ hr} = 6.62\text{x}10^5\ s$$

- You need to know the following prefixes for this year
- The easiest way to convert using this chart is to convert to the base unit first, then convert away to what you are looking for

Prefix	Symbol	Conversion Factor
Mega-	M	10^{6}
Kilo-	k	10^{3}
Centi-	c	10^{-2}
Milli-	m	10^{-3}
Micro-	µ	10^{-6}
Nano-	n	10^{-9}
Pico-	p	10^{-12}
Femto-	f	10^{-15}

- Examples
  - Convert 341 grams into kilograms

$$341\, g \times \frac{1\, kg}{10^3\ g} = .341\, kg$$

  - Convert 26.2 kilometers into femtometers

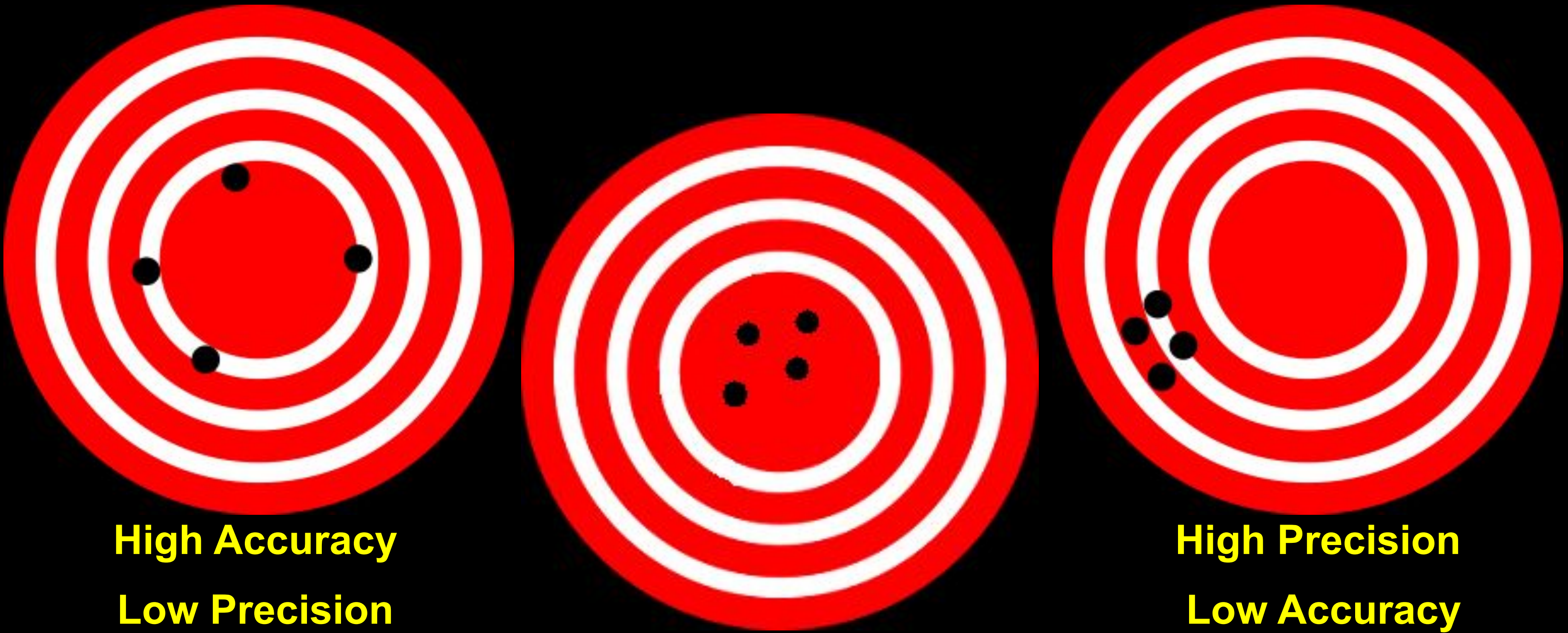
$$26.2\, km \times \frac{10^3\, m}{1\, km} \times \frac{1\ fm}{10^{-15}\ m} = 26.2 \text{ x } 10^{18}\ fm$$

- No more just moving the decimal point to a different place
  - If you insist on this, you will not develop number sense which is vital for this course

- **Proper Scientific Notation**
  - Common way to write very large or very small numbers
  - Numbers are written with a decimal multiplied by a power of ten
  - Example 1
    - 42,163.6 meters in a marathon
    - In proper scientific notation, it is written as 4.21×10^4 m
  - Example 2
    - Wavelength of red light is .000000751 meters
    - In proper scientific notation, it is 7.51×10^{-7} m
  - As a general rule:
    - If the number was larger than 1, the power of ten is positive
    - If the number was smaller than 1, the power of ten is negative

- Improper Scientific Notation
  - Typically, you will see numbers written in improper scientific notation
  - Let's go back to the number of meters in a marathon
  - We wrote the number as 4.21×10^4 m in proper scientific notation
  - Often, you would see this number written as 42.1×10^3 m
    - Why do you think this is the case?
    - What is the value of writing it this way compared to the proper way?

- **Accuracy**
  - How your data compares to the accepted value
- **Precision**
  - How your data compares to itself



High Accuracy

Low Precision

High Accuracy

High Precision

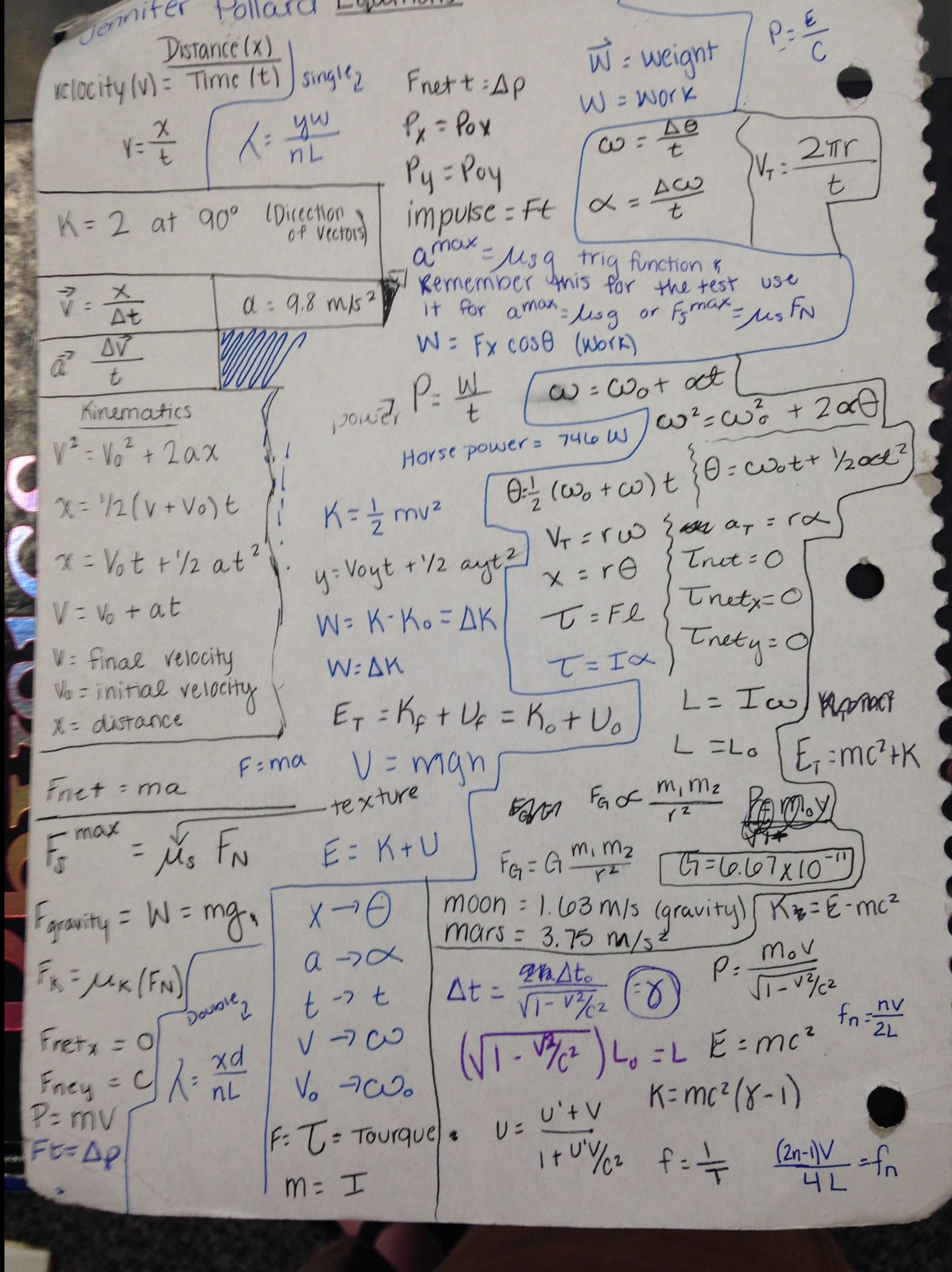
High Precision

Low Accuracy

- So how does accuracy and precision apply to our lab data?
  - Suppose you were trying to measure the boiling point of water and you collected the following data:

Trial	Temperature Water Boiled
1	101°C
2	100°C
3	96°C
4	98°C
5	102°C
6	101°C
7	99°C
8	100°C
9	108°C
10	97°C

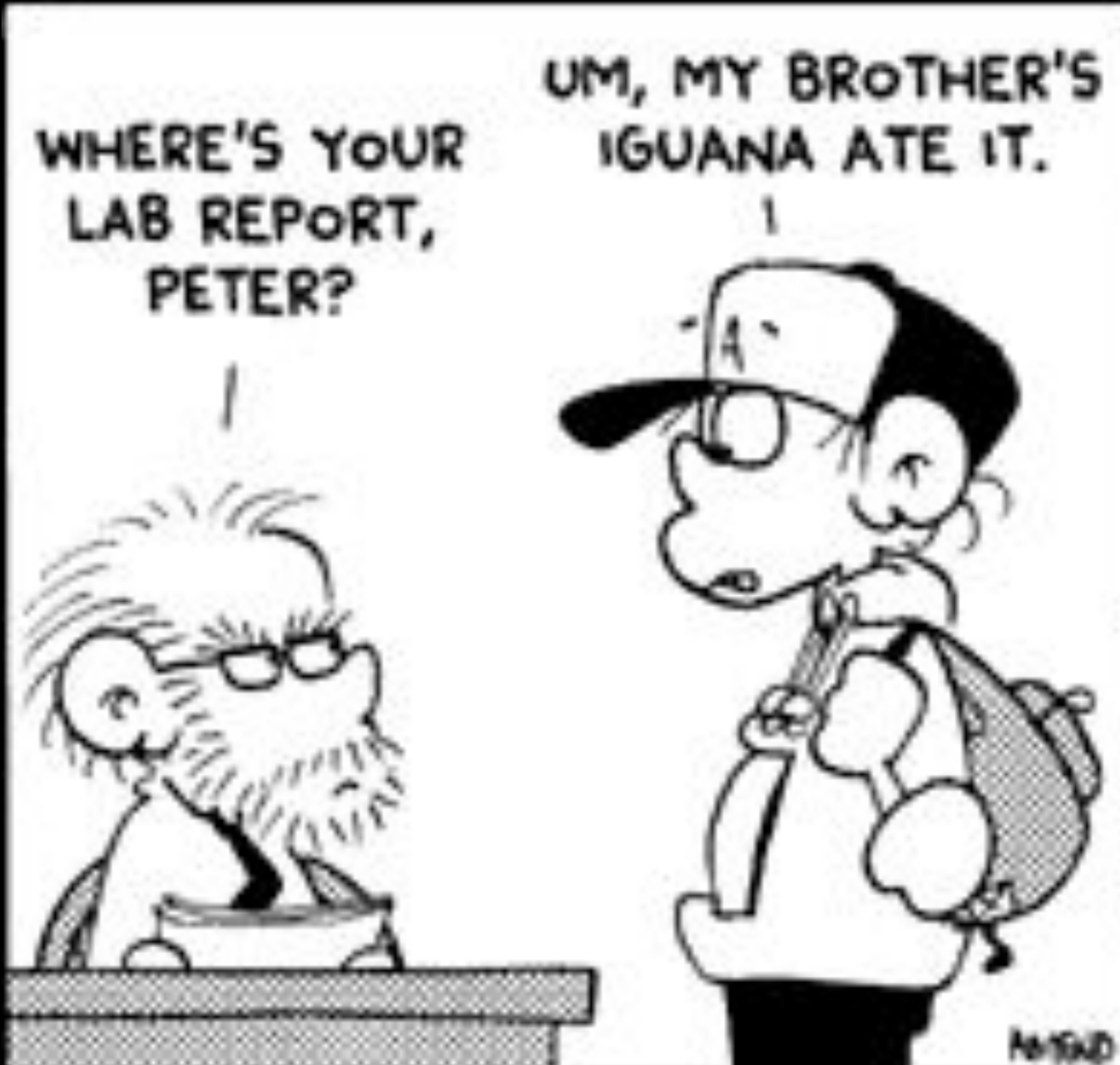
- How can you tell if your data is precise?
  - Find the standard deviation
  - For this class we will consider data good data if it is within 2 standard deviations of the expected value
    - Data within 2 standard deviations is data that is only under the influence of normal variation
    - Data outside 2 standard deviations is considered to have causal variation

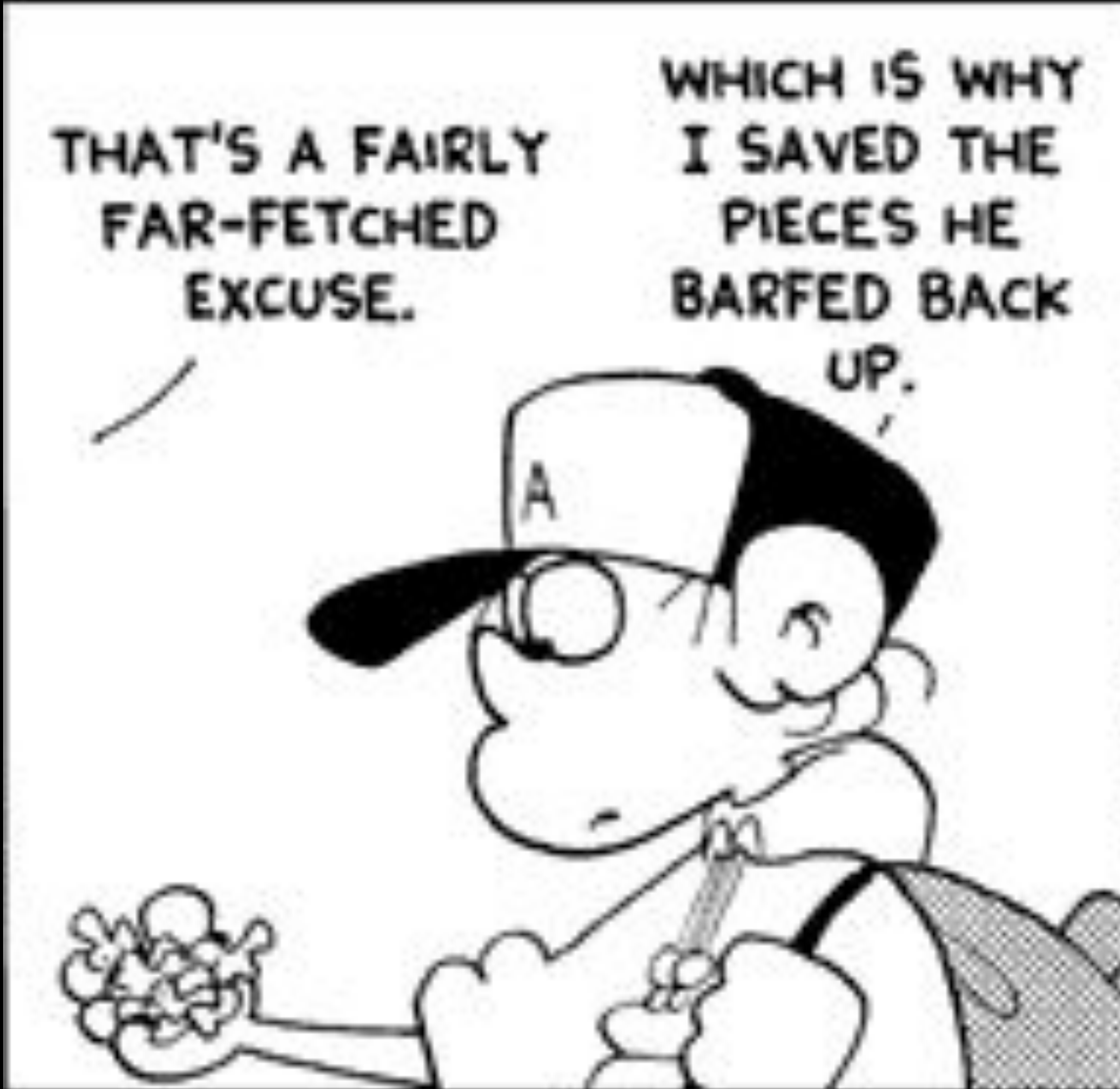


Front cover of equations

I would highly suggest this as a way to compile your equations

For the record, you do not need to write all of these down now. We will get to them over the course of the year. I am just suggesting that you write down your equations on the cover of your notebook so that they are handy.


WHERE'S YOUR LAB REPORT, PETER?
UM, MY BROTHER'S IGUANA ATE IT.


THAT'S A FAIRLY FAR-FETCHED EXCUSE.
WHICH IS WHY I SAVED THE PIECES HE BARFED BACK UP.
A


DO YOU ENJOY BEING THE TALK OF THE TEACHERS' LOUNGE, SON?
OH, WAIT — THIS ONE'S FROM MY ENGLISH ESSAY.
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