1 • Introduction
The Scientific Method
(1 of 12)

This is an attempt to state how scientists do science. It is necessarily artificial. Here are MY five steps:

- Make observations
  the leaves on my plant are turning yellow
- State a Problem to be solved
  how can I get my plants healthy (non-yellow)
- Form a hypothesis
  maybe they need more water
- Conduct a controlled experiment
  water plants TWICE a week instead of once a week
- Evaluate results
  if it works, good... if not, new hypothesis (sunlight?)

1 • Introduction
Observations and Measurements
Qualitative, Quantitative, Inferences
(2 of 12)

Step 1 of the Scientific Method is Make Observations. These can be of general **physical** properties (color, smell, hardness, etc.) which are called **qualitative** observations. These can be **measurements** which are called **quantitative** observations.

There are also statements that we commonly make based on observations. *"This beaker contains water"* is an example.

You **infer** (probably correctly) it is water because it is a clear, colorless liquid that came from the tap. The **observations** are that it is clear, it is colorless, it is a liquid, and it came from the tap. Recognize the difference.

1 • Introduction
Graphing -- Great Graphs
(3 of 12)

5 Steps to a Great Graph
- **Descriptive Title**
- **Subtitle** (dependent variable vs. independent variable)
- **Label axes with variable name and units used**
- **Number axes so most of graph paper is used**
  (should the point 0,0 be included in graph)
- **Draw an appropriate line**
  straight line (if data looks like it is directly proprotional)
  smooth curve (if data looks like it follows a trend)
  dot-to-dot (if data looks like the two variables are unrelated to each other... like Dow Jones averages)

Also: if more than one line is on a graph, provide a Legend

2 • Measurement
Significant Digits I
What do they mean?
(4 of 12)

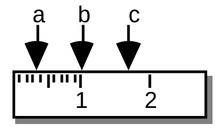
Consider: 16.82394 cm
In a measurement or a calculation, it is important to know which **digits** of the reported number are **significant**.

That means… if the same measurement were repeated again and again, some of the numbers would be **consistent** and some would simply be **artifacts**.

All of the digits that you are absolutely certain of plus one more that is a judgment are significant.

If all the digits are significant above, everyone who measures the object will determine that it is 16.8239 cm, but some will say …94 cm while others might say …95 cm.

2 • Measurement
Significant Digits II
Some examples with rulers.
(5 of 12)



(A composite ruler)

a- No one should argue that the measurement is between 0.3 and 0.4. Is it exactly halfway between (.35 cm)… or a little to the left (.34 cm)? The last digit is the judgment of the person making the measurement. The measurement has 2 significant digits.

b- The same ruler… so the measurement still goes to the hundredths place… 1.00 cm (3 significant digits).

c- A ruler with fewer marks reads 1.6 cm (2 sig digits).

2 • Measurement
Significant Digits III
Rules for Recognizing Sig. Digits
(6 of 12)

- All non-zero digits are significant.
  523 grams (3) 972,366 seconds (6)
- 0's in the MIDDLE of a number are ALWAYS significant.
  5082 meters (4) 0.002008 L (4)
- 0's in the FRONT of a number are NEVER significant.
  0.0032 kg (2) 0.00000751 m (3)
- 0's at the END of a number are SOMETIMES significant.
  - Decimal point is PRESENT, 0's ARE significant
    2.000 Liters (4) 0.000500 grams (3)
  - Decimal point is ABSENT, 0's are NOT significant
    2000 Liters (1) 550 m (2)

NOTE: textbook values are assumed to have all sig. digits

2 • Measurement
Significant Digits IV
Significant Digits in Calculations
(7 of 12)

When you perform a calculation using measurements, often the calculator gives you an incorrect number of significant digits. Here are the rules to follow to report your answers:

x and ÷: The answer has the same # of sig. digits as the number in the problem with the least number of sig. digits.
example: 3.7 cm x 8.1 cm = 29.97 ≈ 30. cm^2 (2 sig. digits)

+ and –: The last sig. digit in the answer is the largest uncertain digit in the values used in the problem.
example: 3.7 cm + 8.1 cm = 11.8 cm (3 sig. digits)

Know **how** to **ilustrate why** these rules work.

2 • Measurement
Accuracy vs. Precision
(8 of 12)

Accuracy refers to how close a measurement is to some **accepted** or **true** value (a **standard**).

Ex: an experimental value of the density of Al° is 2.69 g/mL. The accepted value is 2.70 g/mL. Your value is accurate to within 0.37%

% error is used to express accuracy.

Precision refers to the **reliability**, **repeatability**, or **consistency** of a measurement.

Ex: A value of 2.69 g/mL means that if you repeat the measurement over and over, you will get values that agree to the tenths place (2.68, 2.70, 2.71, etc.)

± uncertainty and sig. digits are used to express precision

2 • Measurement
Metric System
(9 of 12)

We generally use three types of measurements:

volume	Liters	(mL)
length	meters	(km, cm and mm)
mass	grams	(kg and mg)

We commonly use the prefixes:

centi-	$^{1}/_{100}$th
milli-	$^{1}/_{1000}$th
kilo-	1000

Occasionally you will encounter micro(μ), nano, pico, mega, and giga. You should know where to find these in Ch. 1.
Know that 2.54 cm = 1 inch and 2.20 lb = 1 kg

2 • Measurement
% and ppm
(10 of 12)

Percentage is a mathematical tool to help compare values. Two fractions, 3/17 and 5/31 are difficult to compare:
If we set up ratios so we can have a common denominator:

$$\frac{3}{17} = \frac{x}{100} = \frac{17.65}{100} \qquad \frac{5}{31} = \frac{x}{100} = \frac{16.13}{100}$$

so… we can see that $\frac{3}{17} > \frac{5}{31}$.

There are 17.65 **parts per 100** (Latin: parts ***per centum***) or 17.65 **percent** (17.65 %)… the **%** is a **"1 0 0"**
ppm (parts per million) is the same idea, (use 1,000,000 instead of 100)

$$\frac{3}{17} = \frac{x}{1\ 000\ 000} = 176{,}470 \text{ ppm}$$

3 • Problem Solving
Scientific Notation
Useful for showing Significant Digits
(11 of 12)

Scientific notation uses a number between 1 and 9.99 x 10 to some power. It's use stems from the use of slide rules.

Know how to put numbers into scientific notation:

$5392 = 5.392 \times 10^{3}$	$0.000328 = 3.28 \times 10^{-4}$
$1.03 = 1.03$	$550 = 5.5 \times 10^{2}$

Some 0's in numbers are placeholders and are not a significant part of the measurement so they disappear when written in sci. notation. Ex: 0.000328 above. In scientific notation, only the three sig. digits (3.28) are written.

Scientific Notation can be used to show more sig. digits. Values like <u>55</u>0 (2 sig. digits) can be written <u>5.50</u> x 10^{2} (3)

3 • Problem Solving
Unit Analysis
Converting between English and Metric Units
(12 of 12)

Consider the metric/English math fact: 2.54 cm = 1 inch
This can be used as the "conversion factor":

$$\frac{2.54 \text{ cm}}{1 \text{ inch}} \quad \text{or} \quad \frac{1 \text{ inch}}{2.54 \text{ cm}}$$

You can convert 25.5 inches to cm in the following way:
Given: 25.5 in
Desired: ? cm $\quad 25.5 \text{ in} \times \frac{2.54 \text{ cm}}{1 \text{ in}} = 64.77 \text{ cm} \approx 64.8 \text{ cm}$

This is the required way to show your work. You have **two** jobs in this class, to be able to **perform** the conversions and to be able to **prove** that you know why the answer is correct.