Chapter 1 - Matter and Measurement

Section 2 – Units and Measurement

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Introduction

- When we study matter, it involves measurement, which means collecting data. Data should have significance and units to be meaningful.
- In this section will learn how to carry out measurements in the lab.
- We will learn about how we determine what data is significant and what is accurate.
- We will learn the basics of math skills: exponents, rounding off, significant figures in calculations etc.
- Not all data is collected in the same unit, so conversion from one to the other is also important.

Units

In the **EXPERIMENT** part of the scientific method, data is collected. Numbers are meaningless unless there is a unit attached to it. Units express what quantity has been measured. The table below gives the most common units we will use for now. There are many more units than below. There are two types of units listed – SI and non SI. SI units are accepted globally. See next slide for more.

Measuring	SI Units	Some Non SI Units	Measuring Device
Weight	Kilograms (g)	Pounds, ounces	Balance or scale
Length	Meters (m)	Miles, feet	Ruler, measuring tape
Time	Seconds (s)	Seconds	Stopwatch, clock
Temperature	Kelvin (K)	Fahrenheit, Celsius or Centigrade	Thermometer
Volume	Liters (L)	Gallons, quarts	Graduated cylinder, beaker, volumetric flask
Pressure	Newtons (N)	Atm, torr, Pascal	barometer

Why use SI Units

SI units are also called standard units. These were accepted in the scientific community in 1875 in Paris and were globally accepted. They play a significant role in global trade and scientific innovation.

SI Units

- SI units are all based on 10.
- All have easy conversion from one to the other by multiplying or dividing by 10, 100, 1000 etc.
- Bigger and smaller units (weight, volume etc.) have the same prefixes to denote the size of the unit.

Non SI Units

- Conversions within non SI units from one to the other is not always a consistent number e.g. 12 inches in foot and 3 feet in a yard.
- It is harder to tell which unit is larger than the other, e.g. gallon or quart? How many gallons in a quart and vice versa?

SI Units

Below are the prefixes for the SI units are based on the power of 10. The base unit has no prefix e.g., meters, liter. Prefixes are used to indicate larger or smaller than that base unit. For e.g. base unit of weight is gram (g); Kilogram kg) is 1000 times larger than gram; milligram (mg) is 1000 times smaller or one thousandth of a gram. Same for liters – kL is 1000 times more than L and mL is 1000 times smaller.

Increasing Unit

Base Unit:

Liter (L)
Meter (m)
Seconds (s)

Decreasing Unit

Prefix		One Observation	Another Observation
Giga (G)	10^9	1 Gg has 10^9 g	1 g has 10^{-9} Gg
Mega (M)	10^6	1 Mg has 10^6 g	1 g has 10^{-6} Mg
Kilo (k)	10^3	1 kg has 10^3 g	1 g has 10^{-3} kg
Deci (d)	10^{-1}	1 dg has 10^{-1} g	1 g has 10 dg
Centi (c)	10^{-2}	1 cg has 10^{-2} g	1 g has 10^2 cg
Milli (m)	10^{-3}	1 mg has 10^{-3} g	1 g has 10^3 mg
Micro (μ)	10^{-6}	1 mg has 10^{-6} g	1 g has 10^6 μg
Nano (n)	10^{-9}	1 ng has 10^{-9} g	1 g has 10^9 ng
Pico (p)	10^{-12}	1 pg has 10^{-12} g	1 g has 10^{12} pg

Converting Units

This is the most common computation you will do in class and in lab. The best way to set up conversion of units is to use Dimensional Analysis. In this type of set up you can do complex conversions with ease.

Converting one unit to another requires a "conversion factor". For example, there are 3 feet in a yard, so conversion factor is 3 ft = 1 yd. Other examples are 1 m = 39.37 in; 1 kg = 2.2 lbs. The significant figures (sig fig) in these conversion factors are not used to determine the sig figs in the final answer.

You will need to remember the SI to SI unit conversion factors yourself. The SI to non SI and non SI to non SI are harder to remember, so I can provide the conversion factors to you.

Examples of unit conversion is given in later slides as we need to cover significant figures and exponents first.

Scientific Notation

Scientific notation is an easy way to represent large numbers.

The representation of a number in the form $X \times 10^n$. Where X is >1 and < 10 and n can be a positive or negative whole number depending on the value of X.

Solved Problem: Writing in scientific notations

Write the numbers given on the left in scientific notation.

Answers

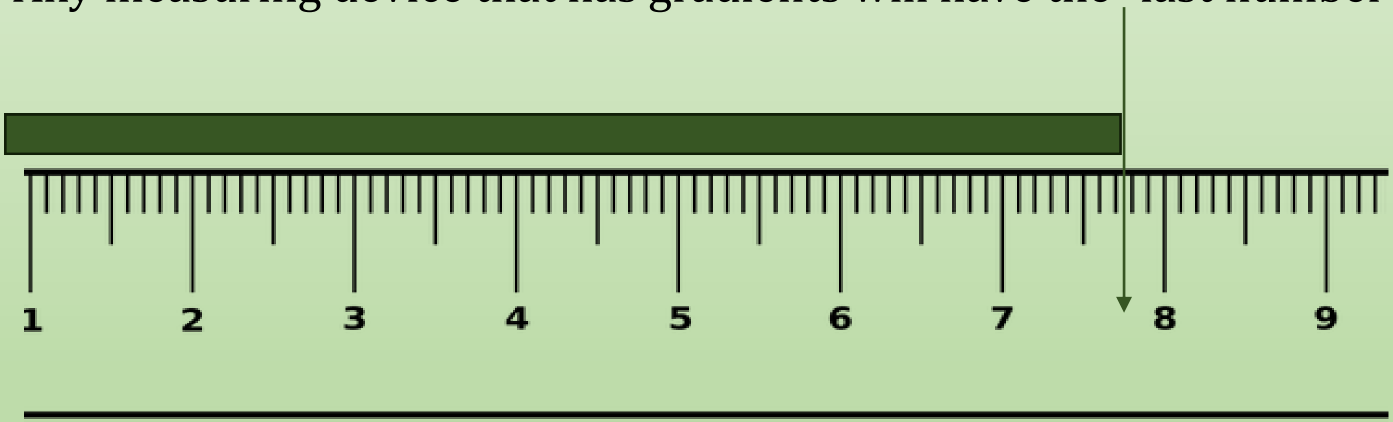
0.000623 = 6.23×10^{-4}

340,000 = 3.4×10^{5}

0.03700 = 3.700×10^{-2}

Significant Figures

- Significant numbers are measured and counted numbers.
- In lab certain instruments one can have one last digit of uncertainty but still considered significant, e.g., volume. In 5.1**2** mL, the number 2 may have been estimated and not measured.
- Same with rulers – see the figure example below.
- Weight measurements are usually measured to the last number e.g., 5.12**4** g, the number 4 is measured and significant.
- Any measuring device that has gradients will have the "last number estimated".



7.78 cm

(The hundredth place (number 8) is estimated)

Guidelines for Significant Figures

There is a guideline to follow for calculations where you can have different data of different sig figs (SF). (The underlined zeros below are significant).

1. Any non-zero digit is significant (1-9).
2. Zeros between numbers are significant (1<u>0</u>1).
3. Zeros to the left of the first number are not significant (010).
4. Zeros to the right of the last number and after a decimal are significant (1<u>00</u>.<u>00</u>).
5. Zeros to the right of the last non-zero digit are not significant if decimal is not present (100), unless it is a counted number, e.g. 10 pencils – that is 2 SF.

Solved Problem: Determining significant figures

How many significant figures are in each of the following measurements?

a. 310.00 kg = 5 sig figs

b. 0.2248 m = 4 sig figs

c. 0.05903 kg = 4 sig figs

d. 6.380×10^{-8} m = 4 sig figs

e. 30.00 s = 4 sig figs

f. 91,000 = 2 sig figs

Significant Figures in Calculations

- **Multiplication and Division**: In all the numbers, use the lowest sig fig number to round off for final answer.

  E.g. $\frac{2.459\ x\ \mathbf{1.55}}{6.3359}$ = 0.601564103 = 0.602

- **Addition and Subtraction**: In all the numbers, use the lowest decimal number and round off to that number.

  E.g. 1.9851 – 0.034 = 1.9511 = 1.951

- **Rounding off**: Find out the correct sig figs you need from the first number, then, look at the number on the immediate right of the last number and if it is 5 or more than 5 then round off the previous number to +1; if lower than 5 then drop that number and all the numbers that follow.

Solved Problem: Calculating to the correct significant figures and rounding off.

Carry out the following calculations to the correct significant figures. If the number is larger than 5 significant figures, then round it off to 4 and use exponents to show your answer.

36.543 x 29.001 x 1.246 = ? = 1320.49 = 1320. or 1.320×10^3

12.52 – 1.5 – 0.72 = ? = 9.9052 = 9.9

$\frac{3.24 \times 10^{-5} \times 4.692 \times 10^{7} - 2.98}{4.62 \times 10^{-6}}$ = ? 328404329 = 3.28×10^8

$\frac{22.16 \text{ cm} \times 0.00578 \text{ cm}}{1.35 \times 28}$ = ? = 1.00457 cm^2 = 1.0 cm^2

Dimensional Analysis

- Using units to systematically setup calculations.
- Starting with what you know and then sequentially using conversion factors with correct units to get the right answer.
- Tips for Problem Solving
  - Read carefully; find information given and what is asked for.
  - Find appropriate equations, constants, conversion factors.
  - Check for sign, units and significant figures.
  - Check for reasonable answer.

Conversion Factors

LENGTH 1 m = 1.0936 yd 1 cm = 0.3937 in 1 in = 2.54 cm 1 km = 0.62137 mi 1 mi = 5280 ft 1 mi = 1.6093 km	**TEMPERATURE** 0 K = 272.15 ^oC 1 J = 0.23901 cal 1 cal = 4.184 J	**PRESSURE** 1 Pa = 1 N/m^2 1 atm = 101.325 Pa 1 atm = 760 torr 1 atm = 14.70 lb/in^2 1 bar = 10^5 Pa 1 torr = 1 mmHg
VOLUME 1 L = 10^{-3} m^3 1 L = 1.0567 qt 1 gal = 4 qt 1 cm^3 = 1 mL 1 in^3 = 16.39 cm^3 1 qt = 32 fl oz	**MASS** 1 kg = 2.2046 lb 1 lb = 453.59 g 1 lb = 16 oz 1 metric ton = 1000 kg 1 metric ton = 22.04 lb	**VOLUME FORMULAS** $\pi = 3.14159$ Circumference = $2\pi r$ Area of circle = πr^2 Surface area of circle = $4\pi r^2$ Volume of circle = $4/3\pi r^3$ Volume of cylinder = $\pi r^2 h$

Solved Problem: Unit conversions - SI to SI

Carry out the following conversions.

a) 230.2 g to kg.

b) 4.5 x 10^7 L to mL.

c) 107 nm to km.

In conversions the first step is to always start with the data given and then use conversion factors. Always write units so you can see which unit to write next. If direct conversion is not possible then you might need more than one step (as in example c). Finally, give the answer in the correct significant figures.

a) $230.2\ \cancel{g} \times \frac{1\ \text{kg}}{1000\ \cancel{g}} = \boxed{0.2302\ \text{kg}}$

b) $4.5 \times 10^7\ \cancel{L} \times \frac{1000\ \text{mL}}{1\ \cancel{L}} = \boxed{4.5 \times 10^{10}\ \text{mL}}$

c) $107\ \cancel{nm} \times \frac{1\ \cancel{m}}{10^9\ \cancel{nm}} \times \frac{1\ \text{km}}{1000\ \cancel{m}} = \boxed{1.07 \times 10^{-10}\ \text{km}}$

you can write 1000 as 10^3 also

Note: in SI to SI conversions the main number does not change since all conversions are based on factors of tens.

Solved Problem: Unit conversions – non SI to SI

Convert 11.10 inches to meters. (1 in = 2.54 cm)

Conversion factors needed:

2.54 cm = 1 in and 100 cm = 1 meter

$$11.10\ \text{in} \times \frac{2.54\ \text{cm}}{1\ \text{in}} \times \frac{1\ \text{m}}{100\ \text{cm}} = 0.28194\text{m} = \boxed{0.2819\ \text{m}}$$

Solved Problem: Unit conversions – SI to non SI

The Food and Drug Administration (FDA) recommends that dietary calcium intake be 1300 mg per day. What is this mass in pounds (lb), if 1 lb = 453.6 g?

$$1300\ \text{mg} \times \frac{1\ \text{g}}{1000\ \text{mg}} \times \frac{1\ \text{lb}}{453.6\ \text{g}} = 0.002865961\ \text{lb} = \boxed{2.8 \times 10^{-3}\text{lb}}$$

Solved Problem: Unit conversions non SI to SI

Carry out the following conversions.

a) 23.2 g to lb. (1 lb = 254 g)

b) 2.65 x 10^3 L to quart. (1 quart = 946 mL)

c) 50.5 km/hour to miles/min. (1 mi = 1609 m)

Follow the same conversion rules as given in the previous slide on conversion.

a) $23.2\ \cancel{g} \times \frac{1\ \text{lb}}{254\ \cancel{g}} = 0.09133858 = \boxed{0.0913\ \text{lb}}$

b) $2.65 \times 10^3\ \cancel{L} \times \frac{1000\ \text{m}\cancel{L}}{1\ \cancel{L}} \times \frac{1\ \text{quart}}{946\ \text{m}\cancel{L}} = 2801.268\ \text{qt} = \boxed{2.80 \times 10^3\ \text{qt}}$

c) $\frac{50.5\ \text{k}\cancel{m}}{1\ \cancel{hr}} \times \frac{1000\ \cancel{m}}{1\ \cancel{km}} \times \frac{1\ \text{mi}}{1609\ \cancel{m}} \times \frac{1\ \cancel{hr}}{60\ \text{min}} = 0.523099 = \boxed{0.523\ \text{mi/min}}$

<u>Accuracy and Precision</u>

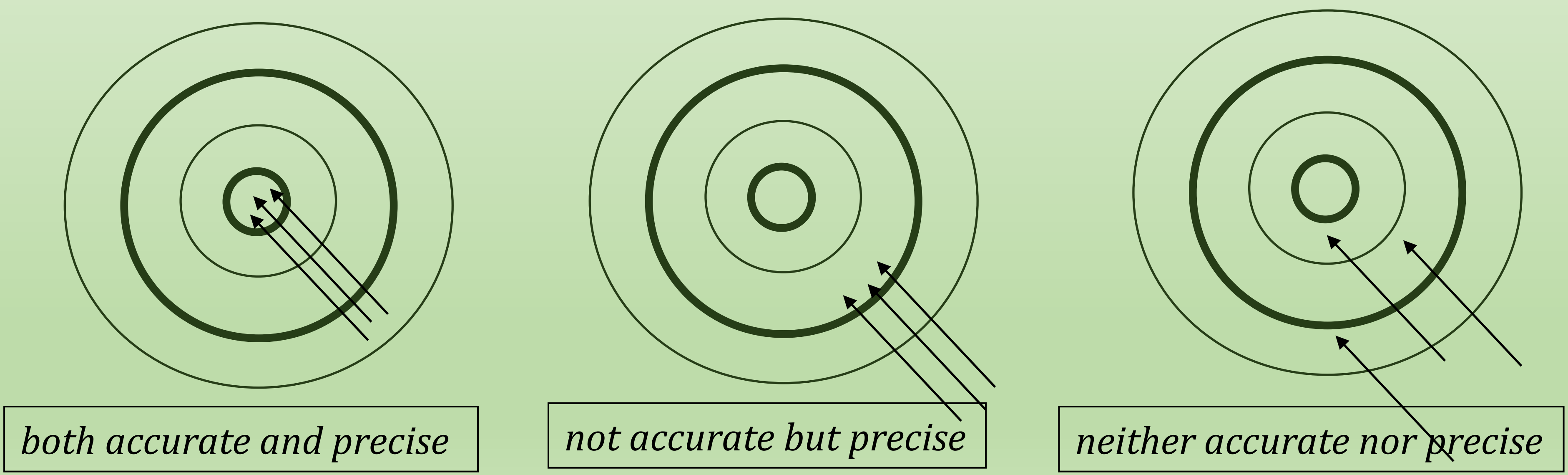
Measurements can be Precise or Accurate.

<u>Precision</u> is when measured values close to each other.

<u>Accuracy</u> is when measured value close to actual value.

Precision is also good measurement in the lab. It shows that lab technique is good. Sometimes when data is precise and not accurate the instrument may need calibration.

Accuracy of data can be determined only when the actual value is given.



Solved Problem: Determining accuracy and precision of data

Given the data sets below, determine if the data is accurate or precise or both or neither and give and explanation for your answer.

a) A beaker is weighed 3 times with the following data collected:
22.56 g, 22.52g , 22. 58 g

Data is precise but accuracy cannot be determined because actual weight of beaker is not given.

b) Density of lead (11.34 g/mL)was calculated and found to be:

9.34 g/ml, 9.28 g/mL, 9.05 g/ml

Data is neither precise nor accurate on comparing with the actual density of lead given.

Key Words/Concepts

- Units of Measurement
- SI and non SI units
- Accuracy and Precision
- Significant figures