Physics 1

Chapters 1:

Introduction to Physics

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1. Significant Figures

Physics is rooted in experiment, and experimental measurements have limited precision. We communicate the extent of a measurement's precision by the number of significant digits used to represent the measurement.

1.1. Which Digits are Significant?

A list of criteria to determine if a digit is or is not significant can be quickly found from a search on the world wide web. Here, we summarize those rules in the form of a helpful memory trick:

Number without a Decimal:

1. Starting at the right side of the number, draw a line through the zeros of the number.
2. Stop the line at the first nonzero number
3. The numbers that have **not** been crossed out are significant.

> Example: How many significant figures are in 130500?
>
> 1305~~00~~ $\Longrightarrow$ 4 significant digits

Number with a Decimal:

1. Starting at the **left** side of the number, draw a line through the zeros of the number.
2. Stop the line at the first nonzero number
3. The numbers that have **not** been crossed out are significant.

> Example: How many significant figures are in 0.0056078?
>
> ~~0.00~~56078 $\Longrightarrow$ 5 significant digits

Practice. Determine the number of significant digits for the following.

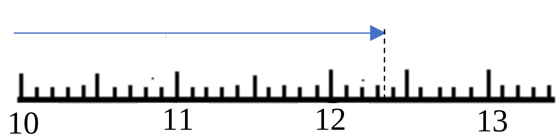
0.02	1030	0.00629000	880,000
_______	_______	_______	_______

If the values above were measurements of a spring's length, which measurement was made by a measuring tool that has the greatest precision? The least?

1.2.Significant Figures in the Lab

In creating lab reports, to correctly communicate the precision of a given measurement, we only include the significant digits of the measurement that we are confident in. For instance, in carrying out a calculation, suppose we conclude that the length of an arrow is 0.1234567 meters. If a meter stick was used to measure lengths, the large number of significant digits suggests a larger precision than we have. We can only be confident in the first three decimal places.

It is standard practice to also include an additional digit beyond those with confidence as a sort of extension to the lab equipment's precision resulting from the experimentalist's ability to approximate. With this practice, we would report the arrow's length as 0.1234 m, communicating the "confidence level" is 4 significant digits.



(Finest division is in mm)

1.3. Significant Figures and Math Operations

Multiplication/Division: Result must contain the same number of sig figs as the value in the operation with the fewest sig figs.

Addition/Subtraction: Result must contain the same number of decimal places as the value in the operation with the fewest decimal places.

Practice. report the solution to the following, rounded to the appropriate number of significant digits.

1. $(2.3004560) \times (20.3) =$_______________

2. (123.2987) + (2.31556) - (0.1) =_______________

2. Scientific Notation

A number is written in scientific notation when in the form $a \times 10^n$ where $1 \leq |a| < 10$ and n is an integer. Scientific notation is used to make very large or very small numbers with lots of zeros, like 18,300,000,000, more compact by writing them as a product of a power of 10.

Guiding Question: How do we convert numbers into and out of scientific notation?

Example. Write 2,000.0 in scientific notation.

1. Move the decimal so that the number has a value (absolute) between 1 and 10.
   In this example, we must move the decimal three places to the left.

$$2000.0 \Rightarrow 2.0000$$

2. Multiply the value you are left with by 10^n where n is the number of places the decimal was moved. If the decimal had to be moved to the left, make n positive, and if the decimal was moved to the right, make n negative.
   In this example, we moved the decimal 3 space to the left, so n is positive 3. Thus, in scientific notation, the value is

$$\Longrightarrow 2.0000 \times 10^3$$

Example: Write 0.000807 in scientific notation.

1. We must move the decimal 4 places to the right to get a number between 1 and 10.

$$0.000807 \Rightarrow 8.07$$

2. Multiply by 10^{-4} (where the 4 is negative since we moved the decimal to the **right**) to get the value in scientific notation:

$$\Longrightarrow 8.07 \times 10^{-4}$$

Practice.

Convert the following numbers into or out of scientific notation

1. .0000783
2. 9.3×10^6
3. 931.4
4. 4.5 x 10^{-7}

3. Unit Conversion

Often when working problems, you will have to convert to SI (International System) units. At the start of a problem, pull out all numerical quantities and immediately write them in terms of SI units. This will help you to avoid many headaches.

We will need the units for the following dimensions to start our study of physics. We will certainly be adding to this list.

SI Units:

Mass, m = Kilograms (kg)

Time, t = Seconds (s)

Length, x = Meters (m)

Note:

- Here and in future workshops, I will often denote the unit of a physical variable by placing brackets around the variable. For instance, $[m] = \text{kg}$ and $[x] = \text{m}$.

- $1 \text{ kilogram} = 1{,}000 \text{ grams}$, where the "gram" is the base unit (not the SI unit) for mass. There are many other prefixes used to denote multiples of a given SI base unit. The following table provides a few of the most important ones:

Name	Symbol	Multiplication Factor
kilo	k	10^3
mega	M	10^6
giga	G	10^9
tera	T	10^{12}

deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}

Practice.

1. 81 grams to kilograms**.**

2. 13 days to seconds.

3. 47 inches to millimeters. (39.37 inches = 1 meter)

4. How many cubic centimeters (1 cm^3) are in a cubic meter (1 m^3).

5. A discus thrower can cause a discus to reach speeds of 1.2×10^5 cm/minute. How fast is this in m/s? miles/hour (1 mile = 1,609.34 meters)?

4. Dimensions and Dimensional Consistency

- Only variables with the same dimension can be added, subtracted, or compared. The base dimensions need to know for now are length (L), mass (M), and time (T).

  Example: It makes sense to compare 5 inches to 3 meters (comparing two variables with length dimensions), but it does not make sense to compare 15 seconds to 20 kilograms (comparing variable of time dimension to a variable with mass dimension).

- I will denote the dimension of a variable by placing curly braces around it. For instance, if d is the distance of a car from a stop sign, $\{d\} = \mathrm{L}$.

- **All** dimensions can be multiplied together and raised to an integer following the regular rules of algebra to form new dimensions. For instance, $\mathrm{T}^{-1} = 1/\mathrm{T}$ means *something* per amount of time, so we can identify this dimension as a rate. $\mathrm{L} \cdot \mathrm{T}^{-1} = \mathrm{L}/\mathrm{T}$ means a *length* per amount of time, so we identify this dimension as speed.

- Physics equations contain variables on either side of an "equal" sign. Of course, an equal sign invokes a comparison… it means "are the left- and right sides equal?" Thus, for an equation to make sense in physics:
  (i) Both sides of an equation must have the same dimension.
  (ii) Any terms that are being added to or subtracted from each other on either side of the equation must have the same dimension.

  The process of making sure the above conditions are satisfied is a check on the equation's **dimensional consistency** or **dimensional homogeneity**. Any equation that is not dimensionally consistent must be wrong.

Practice.

Suppose…
- m_1 and m_2 are masses.
- L_a, L_b, L_c, and, x are lengths.
- t_1 and t_2 are times.

1. A **mass density** is defined as mass per volume, and volume has a dimension of L^3 as stated in the table. Which of the following equations could possibly represent a mass density?

a) $\frac{m_1 \cdot m_2}{L_a \cdot L_b}$ b) $\frac{m_1}{L_a^2 \cdot L_b^2} \cdot x$ c) $\frac{L_a \cdot L_b \cdot L_c}{m_1}$ d) $\frac{m_1}{L_a \cdot L_b \cdot \frac{x}{t_1} \cdot t_2}$

Quantity	Dimension
Distance	L
Area	L^2
Volume	L^3
Time	T
Velocity	L/T
Acceleration	L/T^2
Energy	$\mathrm{ML}^2/\mathrm{T}^2$

You don't have to know what these variables or units mean yet. We just need them to practice analyzing dimensional consistency.

5. Manipulating Physics Equations

Given a physics equation, we can usually use the rules of algebra to solve for (isolate on one side of the equation) any variable of interest.

Practice.

1. Use algebra to solve this equation for time, represented here by the symbol t.

$$v_{\mathrm{f}} = v_0 + at$$

2. Solve for final position represented by the variable x_{f}.

$$v = \frac{(x_{\mathrm{f}} - x_0)}{(t_{\mathrm{f}} - t_0)}$$

3. Solve for acceleration, a.

$$y_{\mathrm{f}} = y_0 + v_0 t + \frac{1}{2}at^2$$

5. Solve for initial velocity, v_0.

$$v_{\mathrm{f}}^2 = v_0^2 + 2a(x_{\mathrm{f}} - x_0)$$