CHAPTER 1: MEASUREMENTS

UNITS

INTERNATIONAL SYSTEM OF UNITS

1. METER (m)  length
2. KILOGRAM (kg)  mass
3. SECOND (s)  time
4. Kelvin (temperature)  5. Mole
6. Candela  7. Ampere (current)

1. How these units were initially defined?

The meter: \(10^7 \text{ m}\)

The meter was chosen in such a way that the distance from the Equator and the North Pole along the meridian through Paris would be 10 millions meters.
The second:

\[ = \frac{1}{24} \frac{1}{60} \frac{1}{60} \text{ mean solar day} \]

What is the difference between the mean solar day and the sidereal day?

Mean solar day = \(8.640 \times 10^4\) s (\(P \Rightarrow P''\))

Sidereal day = \(8.616 \times 10^4\) s (\(P \Rightarrow P'\))

The kilogram = 1000 grams

Standard block kept in Paris
Other units:

- $cm = 10^{-2} \, m$
- $in = 2.54 \, cm$
- $1 \, foot = 12 \, in$
- $min = 60 \, s$
- $mile = 1.609 \, Km$
- $yard = 36 \, in = 3 \, ft$
- $yard = 0.9144 \, m$
- $gram = 10^{-3} \, kg$

Prefixes for SI units

- $10^{-9} \, nano \ (n)$
- $10^{-6} \, micro \ (\mu)$
- $10^{-3} \, milli \ (m)$
- $10^{9} \, giga \ (G)$
- $10^{6} \, mega \ (M)$
- $10^{3} \, kilo \ (k)$

2. Changing units

**Method:** Chain-link conversion

**Example 1:**

$V_{\text{max}} = 67 \, Km/s \ \text{to} \ \text{miles/hour}$

$$67 \frac{Km}{s} = \frac{67 \, Km}{s} \times 1 \times 1$$

$mile = 1.609 \, Km \ \implies 1 = \frac{mile}{1.609 \, Km}$

$hour = 3600 \, s \ \implies 1 = \frac{3600 \, s}{hour}$
\[
67 \frac{Km}{s} = 67 \frac{Km}{s} \times \frac{\text{mile}}{1.609 \, Km} \times \frac{3600 \, s}{\text{hour}} \\
= 15 \times 10^4 \, \text{miles/h} \quad \text{answer}
\]

If we had punched all these numbers in our calculator, we would have obtained:

149906.7744 \quad \text{Why not to use this more precise number then?}

Let’s use this question as a motivation for the following Section 3.
3. Precision, accuracy, significant figures

**Math:** Interested in the logic of symbolic algebraic expression and numbers

**Physics:** Deals with **measurements**

Numbers (math) represent real values of measurements

Measurements have **uncertainties** (random errors, systematic errors, etc)

The use of **significant figures** is one way (although no the best method) to express the **precision** of a measurement

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**Example-1** About precision and accuracy

- **precise but inaccurate**
- **less precise better accuracy**
- **precise and accurate**
Example-1 About precision and accuracy

If we do not notice the offset on the left-side ruler: the ruler on the right will provide a more accurate measurement of the student’s height ($h_1=5$ f). The ruler at the left would provide a more precise measurement (more decimal points, $h_2=4.1$ f) but it would be inaccurate.

About significant figures

- By convention
  When an experimental measurement is given as $h = 5$ cm it means $4.5$ cm $< h < 5.5$ cm.
  Similarly $x = 2.4$ $\mu$m means $2.35$ $\mu$m $< x < 2.45$ $\mu$m
• **Exponential notation** provides a convenient way to identify the order of magnitude of a quantity and the number of significant figures (precision of the measurement).

**By convention:**

\[ y = 2.0 \times 10^1 \quad \text{means} \quad 19.5 < y < 20.5 \]

\[ y = 2 \times 10^1 \quad \text{means} \quad 15 < y < 25 \]

• **How to deal with significant figures**

\[ \frac{67 \text{ Km}}{s} = \frac{67 \text{ Km}}{s} \times \frac{\text{ mile}}{1.609 \text{ Km}} \times \frac{3600 \text{ s}}{\text{ hour}} \]

2 significant figures

3.600 x 10^3

1.609 x 10^0

4 significant figures

**Procedure-1:** all quantities reduced to 2 significant. figures
\[
67 \frac{Km}{s} = 6.7 \times 10^1 \frac{3.6 \times 10^3}{1.6 \times 10^0} \frac{miles}{hour} = \\
= 15 \times 10^4 \frac{miles}{hour}
\]

Procedure-2: keep all the significant figures during the calculation and take the 2 significant figures only at the end.

• Justification for throwing out significant figures

In the example below let’s consider, for the sake of the argument, that the only magnitude introducing uncertainties in the calculation is the value of 67 (its values is somewhere between 66.5 and 67.5)

The value of \(67 \times \frac{3600}{1.609}\) is, then, between:

- maximum value \(67.5 \times \frac{3600}{1.609} = 151025\)
- minimum value \(66.5 \times \frac{3600}{1.609} = 148788\)
Notice there is a difference of about 2000 between the max and min values. So to provide 149906.7744 as an answer (suggested at the end of Section 2), which has precision over the decimal point, does not make any sense. We do not know the number with such decimal point precision.

The answer that we obtained before 15x10^4, by keeping only two significant figures throughout the calculation, was close enough.

Final note: Keep in mind that significant figures is just one way to express the precision of a measurement (in some cases it may provide ambiguous result.) Is for that reason that more powerful methods of error analysis have been developed (you’ll be exposed to that in physics lab courses.)