PHYS 1114, Lecture 3, January 23

Contents:

1° First the announcements of last lecture were repeated, see page 1 of the notes of Lecture 2. ExpertTA homework for Chapter 1 was also created, but it was recommended to first do the orientation homework announce last week.

2° A brief treatment of Chapter 1 was given. There seems no need to go into extensive detail as every following chapter gives further examples of what Chapter 1 is about.

   a. In the opening remarks, we discussed the terms law, principle, theory and model, as they are commonly used in science.

   b. Next we discussed the international metric (SI) and the British engineering (BE) unit systems. Originally, every city had their own units, which was a problem. Some British cities, therefore, defined one foot as the average of the length of the right feet of the first 12 men leaving church on Sunday. Nowadays most unit systems are defined in terms of the units in the SI system.

   c. We also discussed the rounding to accurate digits, and more examples will be given in later chapters.

   d. We treated some examples of unit conversions and how to do it in the most safe way.

   e. Finally, we discussed how to estimate the height of a building, using one of the methods of land surveyors.
Opening Remarks

Each chapter ends with a summary and some with a glossary (kind of dictionary), just before the problem section. Be sure to check that out.

**Law:** A description, using concise language or a mathematical formula, a generalized pattern in nature that is supported by scientific evidence and repeated experiments.

**Principle:** Description of a pattern in a specific situation, (for example Archimedes’ Principle describing things like the floating of objects on a fluid and the sinking of other objects).

**Theory:** An explanation for patterns in nature that is supported by scientific evidence and verified multiple times by various groups of researchers. (It can involve a collection of models, laws and principles. Example: Classical mechanics.)

**Model:** Representation of something that is often too difficult (or impossible) to display directly. (It is usually a simplified representation, like a model of the solar system representing sun and planets by point masses and planets only interacting with the sun.)
British Engineering Length Units

1 mile = 1 mi = 8 furlongs = 1609.344 m (exactly)

1 furlong = 10 chains

1 chain = 4 rods

1 rod = 5.5 yards (originally 5 yd)

1 yard = 1 yd = 3 ft

1 foot = 1 ft = 1' = 12 in

1 inch = 1 in = 1" = 2.54 cm (exactly)

1 inch = 64 times $\frac{1}{64}$" (powers of 2)

So 1 mi = $8 \times 10 \times 4 \times 5.5$ yd = 1760 yd = 5280 ft.

Clearly, it is easier to work with decimals and factors of 10 in the metric system, rather than with all kinds of different fractions.

The first proposal for a metric (decimal) system was made in 1586 by the Flemish/Dutch mathematician-physicist-engineer Simon Stevin. He introduced decimal fractions. He was also a major inventor of tools for reclaiming land from sea and lakes. Currently more than a third of the Netherlands is below sea level.
**Units**

<table>
<thead>
<tr>
<th>Base Units</th>
<th>SI</th>
<th>cgs</th>
<th>BE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>meter (m)</td>
<td>centimeter (cm)</td>
<td>foot (ft)</td>
</tr>
<tr>
<td>Mass</td>
<td>kilogram (kg)</td>
<td>gram (g)</td>
<td>slug (sl)</td>
</tr>
<tr>
<td>Time</td>
<td>second (s)</td>
<td>second (s)</td>
<td>second (s)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Secondary</th>
<th>SI</th>
<th>cgs</th>
<th>BE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>m/s</td>
<td>cm/s</td>
<td>ft/s</td>
</tr>
</tbody>
</table>

For mechanics the SI and cgs unit systems are basically the same: 1 m = 100 cm, 1 kg = 1000 g. The BE units are nowadays defined in terms of the SI units, 1 ft = 12 in, 1 in = 2.54 cm, and 1 sl is about 14.54 kg (1 sl = 1 lb⋅s²/ft, 1 kg has a weight of 2.205 lb where the acceleration due to gravity is 32.174 ft/s²). Federal law now requires SI units in official documents.

There is quite a history of these units. The second used to be 1/86400 day, but as the days are not all quite the same, it is now defined by a cesium clock.

The kilogram is the mass of a certain platinum-iridium cylinder in Paris. Accurate copies exist in many other places.

The meter used to be 1/40,000,000 of the circumference of the earth. Then it became the distance between two marks on a platinum-iridium bar at the freezing point of water in Paris. Recently, it has been defined in terms of the wavelength of certain light emission lines. Now it is defined in terms of the speed of light in vacuum, as $c = 299,792,458$ m/s.

For powers of ten special abbreviations exist, see Table 1.2! You should learn to use kilo, deci, centi, milli, and micro soon:
## Some Metric Prefixes for Powers of 10

<table>
<thead>
<tr>
<th>Name</th>
<th>Prefix</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>nano</td>
<td>n</td>
<td>$10^{-9} = 1/1,000,000,000$</td>
</tr>
<tr>
<td>micro</td>
<td>$\mu$</td>
<td>$10^{-6} = 1/1,000,000$</td>
</tr>
<tr>
<td>milli</td>
<td>m</td>
<td>$10^{-3} = 1/1,000$</td>
</tr>
<tr>
<td>centi</td>
<td>c</td>
<td>$10^{-2} = 1/100$</td>
</tr>
<tr>
<td>deci</td>
<td>d</td>
<td>$10^{-1} = 1/10$</td>
</tr>
<tr>
<td>—</td>
<td>—</td>
<td>$10^0 = 1$</td>
</tr>
<tr>
<td>deka</td>
<td>da</td>
<td>$10^1 = 10$</td>
</tr>
<tr>
<td>hecto</td>
<td>h</td>
<td>$10^2 = 100$</td>
</tr>
<tr>
<td>kilo</td>
<td>k</td>
<td>$10^3 = 1,000$</td>
</tr>
<tr>
<td>mega</td>
<td>M</td>
<td>$10^6 = 1,000,000$</td>
</tr>
<tr>
<td>giga</td>
<td>G</td>
<td>$10^9 = 1,000,000,000$</td>
</tr>
</tbody>
</table>

### Examples:

- $1 \text{ m} = 1,000 \text{ mm}$
- $1 \text{ km} = 1,000 \text{ m}$
- $1 \text{ kg} = 1,000 \text{ g} = 1,000 \text{ gram}$

- $1 \text{ MB} = 2^{20} \text{ bytes} \approx 10^6 \text{ bytes}$  (1 megabyte)

### Remark:
Computers use powers of 2 and $2^{10} = 1,024$. 
Examples Treated in Class

Powers of 10

Examples: \[ 36,000 = 3.6 \times 10^4, \quad 0.00678 = 6.78 \times 10^{-3} \]

Significant Digits

Addition example: \[ 3.6 \times 10^4 + 6.78 \times 10^{-3} = 3.6 \times 10^4 \]

(Two significant digits. Calculator would show \(36,000.006,78\), giving insignificant digits.)

Division example: \[ \frac{3.0}{4.5} = 0.67 \]

(Two significant digits. Calculator would give \(0.666,666,667\), showing insignificant digits.)

Multiplication example: (Multiply prefactors, add exponents!)

\[ (3.6 \times 10^4) \times (6.78 \times 10^{-3}) = 24.408 \times 10^1 = 2.4 \times 10^2 = 240 \]

Drop

Here, if we write 240, we have to remember and/or state that only two digits are significant. Just writing 240 it is not clear if two or three digits are significant. It is a good habit to keep extra digits (guard digits) in intermediate steps, but only report significant digits in final answers.
Unit Conversion Examples

The safest way is to do this in full detail like:

\[
80 \frac{\text{km}}{\text{h}} = 80 \frac{\text{km}}{\text{h}} \times \frac{1000 \text{m}}{1 \text{km}} \times \frac{1 \text{h}}{3600 \text{s}} = 80 \times \frac{1000 \text{m}}{3600 \text{s}} = 22 \frac{\text{m}}{\text{s}}
\]

multiplying with factors 1 such that original units cancel. We had to round the answer to two significant figures.

Again, using 1 km = 1000 m and 1 h = 3600 s,

\[
1 \frac{\text{km}}{\text{h}} = \frac{1000 \text{m}}{3600 \text{s}} = \frac{1 \text{ m}}{3.6 \text{ s}}
\]

As this answer is correct to an infinite number of digits, relating to the exact inverse relation 1 m/s = 3.6 km/h, it is better not to evaluate the 1/3.6 here.

Another example, converting inches to centimeters:

\[
5.0 \text{ in} = 5.0 \frac{\text{in}}{} \times \frac{2.54 \text{ cm}}{1 \text{ in}} = 13. \text{ cm}
\]

Now the original answer had two significant digits, so we also round the answer to two leading digits.


**Height of a Building**

![Diagram of a building and a bus-stop pole]

A person sees the top of a building lined up with the top of a bus-stop pole. The person is 2 m from the pole and 18 m from the building. His/Her eyes are 1.5 m above the ground and the pole is 3 m tall. We can recognize two similar triangles drawing a simpler diagram:

![Simpler diagram with labeled dimensions]

We find \( \frac{x}{18 \text{ m}} = \frac{1.5 \text{ m}}{2 \text{ m}} \), so that \( x = 18 \text{ m} \times \frac{1.5 \text{ m}}{2 \text{ m}} = 13.5 \text{ m} \) and the estimated height is \( x + 1.5 \text{ m} = 15 \text{ m} \).