**Review of Parameters, Dimensions, and Units**

**Learning Objectives**

After you complete the homework associated with this lecture, you should be able to:

- Estimate the order of magnitude of physical quantities.
- Correctly specify the number of significant figures (digits) appropriate for numerical answers.
- Use unit analysis to convert from one set of units to another and determine the plausibility of answers.

**Parameters in Physics Problems**

A *parameter* in a physical problem is, in this course, defined to be "a physical quantity that can conceivably be varied within a given physical situation". Examples are:

- an object’s mass
- an object’s length, width, or height
- the time an event occurs
- the force pulling or pushing an object

**Note:** The mass of the Earth is a parameter in a gravitational problem because one could conceivably "modify" it.

**Solving in Terms of Physical Parameters**

You’ll frequently be asked to express a physical quantity terms of "relevant parameters" in a problem. This means that the desired quantity appears on the left side of an equal sign, and an algebraic expression involving appropriate parameters specified in the problem appears on the right side.

For example: "What is the volume \( V \) of a rectangular solid of mass \( M \), length \( L \), width \( b \), and height \( h \)?"

**Ans:** \( V = L b h \)

**Caution:** Although the mass \( M \) is a parameter of the physical situation, it is not "relevant" in the answer.

**Constants**

If you were asked to express the density \( \rho \) (mass per volume) of a uniform sphere of mass \( M \) and radius \( R \), you would probably write:

\[
\rho = \frac{M}{V} = \frac{M}{4/3 \pi R^3}
\]

Note that \( M \) and \( R \) are stated parameters of the problem, but you used "\( \pi \)" even though it wasn’t listed. But that is fine because "\( \pi \)" is a mathematical constant with a very specific value (3.1415926...). It is not a physical parameter, and can be in an expression if it is not given in the description of a problem’s physical situation.
**Examples of Constants**

Other examples of mathematical and physical constants:

\[ e = \text{natural base} = 2.7183... \]
\[ g = \text{free-fall acceleration at Earth’s surface} = 9.8 \text{ m/s}^2 \]
\[ G = \text{universal grav constant} = 6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2 \]

These are not adjustable, and therefore need not be specified in a problem before you use them.

**Dimensions**

The dimension of a quantity refers to the physical nature of its mathematical measurement or characterization. For example, the separation between two points has the dimension length \([L]\) whether you measure the distance in inches or in meters.

*Philosophy is written in this grand book, the Universe, which stands continuously open to our gaze. But the book cannot be understood unless one first learns to comprehend the language and read the letters in which it is composed. It is written in the language of mathematics, ... without which it is humanly impossible to understand a single word of it. Without these, one wanders about in a dark labyrinth.*

Galileo

Examples of dimensions:

<table>
<thead>
<tr>
<th>Mass</th>
<th>Length</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>Force</td>
<td>Speed</td>
</tr>
</tbody>
</table>

**Units**

One measures how much a particular physical entity has of a dimension by following an operational definition of “measuring the quantity”.

To measure the length of an object, you put one end of a meter stick at one edge of the object and read off the number you find at the other edge of the object. This is an operational definition of the process of “measurement”.

*METER* is the UNIT of length in an interrelated system of units called SI (Système Internationale). It is the NAME of the STANDARD unit relative to which the quantity of the dimension LENGTH is measured.

The act of measurement answers the question “How many standard units are in this quantity of a dimension”.

**Mass [M], length [L], and time [T]** cannot be defined except operationally relative to some standard; other dimensions can be defined relative to these. For example, as you will see:

\[ \text{speed} \ V \text{ has dimension: } [V] = [L] / [T] \]
\[ \text{energy} \ E \text{ has dimension: } [E] = [M][L]^2 / [T]^2 \]

One meter is the length of the path traveled by light in a vacuum during the time interval of 1/299,792,458 of a second. Second and Kilogram have analogous definitions.
UNIT CONVERSION

Just multiply by ONE (i.e., unity) so that unwanted units cancel out! And what is ONE?

\[ 1 = \frac{a \text{ quantity}}{an \text{ equal quantity}} \]

\[ e.g., \quad 1 = \frac{1 \text{ hour}}{3600 \text{ seconds}} \]

Example: How many meters per second is 65 mi/hr?

\[ \frac{65 \text{ mi}}{hr} \times \frac{1 \text{ km}}{0.621 \text{ mi}} \times \frac{10^3 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ hr}}{3600 \text{ s}} = 29.1 \frac{\text{m}}{s} \]