Dimensions and Units with Engineering Notation

ENGR 1310 Introduction to Engineering
Dimensions and Units

Textbook Chapter 14

Today’s highlights:
– Different Unit Systems
– Unit Conversions
– Using your Calculator (TI-89)
– Engineering Notation with Metric Prefixes
Why Bother with Dimensions and Units?

Mars Climate Orbiter

“A failure to recognize and correct an error… led to the loss of the spacecraft in findings by NASA… The peer review preliminary findings indicate that one team used English units (e.g., inches, feet and pounds) while the other used metric units for a key spacecraft operation. This information was critical to the maneuvers required to place the spacecraft in the proper Mars orbit.”

Why Bother with Dimensions and Units?

- Not get fired
- Communication of design
- To aid in problem solving
Units and Dimensions

- **Dimensions**: length, mass, time, etc.
  - Dimensions describe the measurable quantities of something

- **Units**: inches, kilograms, seconds
  - Units describe the *currency* of the measurable quantities (dimensions)
Categories of Dimensions

- Two Categories
  - **Base or Fundamental** — cannot be broken down into other dimensions
  - **Derived** - obtained by any combination of base dimensions
    - Some derived dimensions are given specific names like Newton, Joule, etc.
Fundamental Dimensions

- 1. Length [L]
- 2. Mass [M]
- 3. Time [t] (sometimes “T”)
- 4. Temperature [T] (sometimes “Θ”)
- 5. Electric Current [I]
- 6. Amount of Substance [N]
- 7. Luminous Intensity [I]
Derived Dimensions

- See Table 14.2 in text
- Force \([\text{ML/T}^2]\)
- Area \([\text{L}^2]\)
- Volume \([\text{L}^3]\)
- Pressure (Force/Area) \([\text{M/LT}^2]\)
- Density \([\text{M/L}^3]\)
Units

- Arbitrarily chosen size subdivisions by which the magnitudes of dimensions are expressed

Unit Systems
- SI (Metric)
- English or British or United States Customary System (USCS)
  - Sometimes Old English Engineering System
- Must know both
<table>
<thead>
<tr>
<th>Dimension</th>
<th>SI Unit</th>
<th>English Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>Meter (m)</td>
<td>Foot (ft)</td>
</tr>
<tr>
<td>Mass</td>
<td>Kilogram (kg)</td>
<td>Pound-mass (lb\text{\textsubscript{m}})</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slug (slug)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1 slug = 32.2 lb\text{\textsubscript{m}})</td>
</tr>
<tr>
<td>Time</td>
<td>Second (s)</td>
<td>Second (s)</td>
</tr>
<tr>
<td>Electric Current</td>
<td>Ampere (A)</td>
<td>Ampere (A)</td>
</tr>
<tr>
<td>Temperature</td>
<td>Kelvin (K)</td>
<td>Rankine (\degree R)</td>
</tr>
<tr>
<td>Force</td>
<td>Newton (N) (N=kg\text{\cdot m/s}^2)</td>
<td>Pound-force (lb\text{\textsubscript{f}})</td>
</tr>
</tbody>
</table>
Units

- Based on physical standards
  - International Bureau of Weights and Standards - Paris, France
  - National Institute of Standards and Technology (NIST) - United States

Figure 10.1 The physical standard for the meter is based on the speed of light in a vacuum.
Consistent Dimensions and Units

- All science and engineering equations must be dimensionally consistent.
- This must be true of both the numerical values and the units.

\[ F = ma \]
\[ E = mc^2 \]
Common Errors

- Mixing systems (metric + English)
- Units raised to powers
- Examples
Conversions using the TI-89
Conversions using the TI-89
\[
\frac{299792458 \text{ m}}{\text{s}} \times \frac{\text{in}}{\text{ns}} = 11.80285268 \times 10^3 \text{ in/\text{ns}}
\]
\[
\frac{95 \text{ kg}}{\text{m}^3} \times \frac{\text{ton}}{\text{acre} \times \text{in}} = 10.8 \text{ ton}\]

\[
\frac{(... \text{m})^3 \times \text{ton}}{(... \text{acre} \times \text{in})}
\]
Engineering Notation

- Exponent a power of three
- Base between 1-999

<table>
<thead>
<tr>
<th>Standard</th>
<th>Scientific</th>
<th>Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0123</td>
<td>1.23 x 10^{-2}</td>
<td>12.3 x 10^{-3}</td>
</tr>
<tr>
<td>4,080,000</td>
<td>4.08 x 10^6</td>
<td>4.08 x 10^6</td>
</tr>
<tr>
<td>21,700</td>
<td>2.17 x 10^4</td>
<td>21.7 x 10^3</td>
</tr>
</tbody>
</table>
### Metric Prefixes

<table>
<thead>
<tr>
<th>$10^{-12}$</th>
<th>$10^{-9}$</th>
<th>$10^{-6}$</th>
<th>$10^{-3}$</th>
<th>$10^0$</th>
<th>$10^3$</th>
<th>$10^6$</th>
<th>$10^9$</th>
<th>$10^{12}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>p</td>
<td>n</td>
<td>μ</td>
<td>m</td>
<td>k</td>
<td>M</td>
<td>G</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>pico</td>
<td>nano</td>
<td>micro</td>
<td>milli</td>
<td>kilo</td>
<td>mega</td>
<td>giga</td>
<td>tera</td>
<td></td>
</tr>
</tbody>
</table>

- $12.3 \times 10^{-3} \text{ s} = 12.3 \text{ ms}$
- $4.08 \times 10^6 \text{ W} = 4.08 \text{ MW}$
- $21.7 \times 10^3 \text{ m} = 21.7 \text{ km}$
Summary

- Today we discussed:
  - Different Unit Systems
  - Unit Conversions
  - Using your Calculator (TI-89)
  - Engineering Notation with Metric Prefixes