Engineering Survival Skills

- Dimensions & Units
- Conversion Factors

Fundamental Dimensions

- Length - L
- Time - T
- Mass - M
- Force - F

Mass and Force are not independent fundamental dimensions!!

one of them is derived from the other!
Two basic dimensional systems

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Absolute</th>
<th>Gravitational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>$L$</td>
<td>$L$</td>
</tr>
<tr>
<td>Time</td>
<td>$T$</td>
<td>$T$</td>
</tr>
<tr>
<td>Mass</td>
<td>$M$</td>
<td>$F L^{-1} T^{-2}$</td>
</tr>
<tr>
<td>Force</td>
<td>$M L T^{-2}$</td>
<td>$F$</td>
</tr>
<tr>
<td>Velocity</td>
<td>$L T^{-1}$</td>
<td>$L T^{-1}$</td>
</tr>
<tr>
<td>Pressure</td>
<td>$M L^{-1} T^{-2}$</td>
<td>$F L^{-2}$</td>
</tr>
<tr>
<td>Momentum</td>
<td>$M L T^{-1}$</td>
<td>$F T$</td>
</tr>
<tr>
<td>Energy</td>
<td>$M L^2 T^{-2}$</td>
<td>$F L$</td>
</tr>
<tr>
<td>Power</td>
<td>$M L^2 T^{-3}$</td>
<td>$F L T^{-1}$</td>
</tr>
<tr>
<td>Torque</td>
<td>$M L^2 T^{-2}$</td>
<td>$F L$</td>
</tr>
</tbody>
</table>

Mechanical units

<table>
<thead>
<tr>
<th>Quantity</th>
<th>MKS (SI)</th>
<th>Type I</th>
<th>Type II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>m</td>
<td>ft</td>
<td>ft</td>
</tr>
<tr>
<td>Mass</td>
<td>kg</td>
<td>slug</td>
<td>lbm</td>
</tr>
<tr>
<td>Time</td>
<td>s</td>
<td>s</td>
<td>s</td>
</tr>
<tr>
<td>Force</td>
<td>N</td>
<td>lbf</td>
<td>lbf</td>
</tr>
<tr>
<td>Velocity</td>
<td>m s$^{-1}$</td>
<td>ft s$^{-1}$</td>
<td>ft s$^{-1}$</td>
</tr>
<tr>
<td>Acceleration</td>
<td>m s$^{-2}$</td>
<td>ft s$^{-2}$</td>
<td>ft s$^{-2}$</td>
</tr>
<tr>
<td>Torque</td>
<td>N m</td>
<td>lbf ft</td>
<td>lbf ft</td>
</tr>
<tr>
<td>Pressure</td>
<td>N m$^{-2}$</td>
<td>lbf ft$^{-2}$</td>
<td>lbf ft$^{-2}$</td>
</tr>
<tr>
<td>Energy</td>
<td>J</td>
<td>ft lbf</td>
<td>ft lbf</td>
</tr>
<tr>
<td>Power</td>
<td>W</td>
<td>ft lbf s$^{-1}$</td>
<td>ft lbf s$^{-1}$</td>
</tr>
<tr>
<td>Momentum</td>
<td>kg m s$^{-1}$</td>
<td>slug ft s$^{-1}$</td>
<td>lbm ft s$^{-1}$</td>
</tr>
</tbody>
</table>
Physical “Feel” for Units

• Many students treat units as something arbitrary - just “made up”
• In engineering, virtually all math problems have units associated with both constants and variables
• “Good” engineers (and students!) develop a “feel” for units
  – gives a “reality” check on answers!

Units - Human Perspective

• Even in flat terrain, our ability to see clearly usually ends after about a mile or a kilometer
  – Latin “milia passuum” - 1000 paces
• Degrees Fahrenheit or Celsius are about the smallest increments of temperature we can feel
• We can sense about one volt with our tongue
Units - Human Perspective

• A kilowatt and a horsepower are pretty similar -- roughly the power most people can produce in a short sprint up the stairs.
  - close to the rate the sun pours energy on us when we lay out in the sun at the beach
  - close to the rate we consume energy when taking a hot shower

Other Common Units

<table>
<thead>
<tr>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>inch</td>
<td>thumb digit</td>
</tr>
<tr>
<td>foot</td>
<td>human foot</td>
</tr>
<tr>
<td>yard or meter</td>
<td>distance from nose to tip of outstretched arm</td>
</tr>
<tr>
<td>quart or liter</td>
<td>most liquid we could drink at one sitting</td>
</tr>
<tr>
<td>decibel</td>
<td>least change in sound level we can hear</td>
</tr>
<tr>
<td>Btu, kcal, or Joule</td>
<td>least energy we can sense in our coffee cup</td>
</tr>
</tbody>
</table>
Question #1

Does \( 5 \, \text{feet} \, = \, 60 \, \text{inches} \) ?

YES!

How do we get from one side to other?

Conversion Factors

Where do conversion factors come from?

Definitions of units!

• Define \( 1 \, \text{ft} = 12 \, \text{in} \)
• Divide both sides by the term (1 ft),

\[
1 = \frac{12 \, \text{in}}{1 \, \text{ft}}
\]
Conversion Factors

• We can certainly multiply 5 ft by 1,

\[ 5 \text{ ft} = (5 \text{ ft}) \times (1) \]

• Insert our conversion factor,

\[ 5 \text{ ft} = (5 \text{ ft}) \times \left( \frac{12 \text{ in}}{1 \text{ ft}} \right) = (5 \text{ ft}) \times \left( \frac{12 \text{ in}}{1 \text{ ft}} \right) = 60 \text{ in} \]

Units in Engineering

• If you work a problem and your dimensions are inconsistent, or
• If you work a problem and your units are incorrect, or
• If you work a problem and you leave off the units,

Your answer is WRONG!
Units in Engineering

Fundamental Rule for Unit Conversions:

You can multiply any quantity by 1!

Question #1a

Convert $u = 112 \text{ km/hr}$ to units of miles/hr

$$u = \left(112 \frac{\text{km}}{\text{hr}}\right)(1)$$

- from unit conversion table note that

$1\text{km} = 0.621\text{mi}$

$1 = \frac{0.621\text{mi}}{1\text{km}}$
Question #1b

Convert \( u = 112 \text{ km/hr} \) to units of miles/hr

\[
u = \left(112 \frac{\text{km}}{\text{hr}}\right) \left(\frac{0.621 \text{mi}}{1 \text{km}}\right) = 69.6 \frac{\text{mi}}{\text{hr}}
\]

Question #2a

Convert \( u = 112 \text{ km/hr} \) to units of miles/hr

\[
u = \left(112 \frac{\text{km}}{\text{hr}}\right) (1)
\]

■ But no unit conversion table available!

1 mile = 5280 ft \hspace{1cm} 1 inch = 2.54 cm
Question #2b

Convert $u = 112 \text{ km/hr}$ to units of miles/hr

$$u = \left( 112 \frac{\text{km}}{\text{hr}} \right) \left( \frac{1000 \text{m}}{1 \text{km}} \right) \left( \frac{100 \text{cm}}{1 \text{m}} \right) \left( \frac{1 \text{inch}}{2.54 \text{cm}} \right) \left( \frac{1 \text{ft}}{12 \text{inch}} \right) \left( \frac{1 \text{mile}}{5280 \text{ft}} \right)$$

$$= 69.6 \frac{\text{miles}}{\text{hr}}$$

Question #3a

A 1250 acre (1 acre = 43,560 ft$^2$) lake receives 3.24 inches of rain. Find the volume of water added to the lake, units of

$$V = (1250 \text{ac}) (3.24 \text{in}) \left( \frac{43560 \text{ft}^2}{1 \text{acre}} \right) \left( \frac{1 \text{ft}}{12 \text{in}} \right) \left( \frac{1 \text{gal}}{0.13368 \text{ft}} \right) = 1.1058 \text{ gal}$$
Question #3b

A 1250 acre (1 acre = 43,560 ft²) lake receives 3.24 inches of rain. Find the volume of water added to the lake, units of liters.

\[
V = (1250 \text{ acres})(3.24 \text{ in})(43560 \text{ ft}^2/\text{acre})(1 \text{ ft}^2/12\text{ in})(1 \text{ L}/0.03531 \text{ ft}^3) = 4.16 \times 10^8 \text{ L}
\]