Introduction to Engineering I
Lecture 5

Units and Unit Conversions
Simple Conversions
SI and US Unit Systems
Studio Problems
Equality

- $X = Y$
- Numerical value of $X = \text{numerical value of } Y$
  - $15 = 15$
- Units of $X = \text{Units of } Y$
- Example: energy units
  - $15 \text{ J} = 15 \text{ J}$
Equality

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- Example: energy units
  - 15 J = 15 J
  - 15 J = 15 N · m
Equality

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  - \( 15 = 15 \)
- Units of \( X \) = Units of \( Y \)
- Example: energy units
  - \( 15 \, J = 15 \, J \)
  - \( 15 \, J = 15 \, N \cdot m = 15 \, (kg \cdot m/s^2) \cdot m \)
Equality

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  - $15 \text{ J} = 15 \text{ W} \cdot \text{ s} = 15 \text{ A} \cdot \text{V} \cdot \text{ s} = 15 \text{ A} \cdot (\text{kg} \cdot \text{m}^2 \cdot \text{s}^{-3} \cdot \text{A}^{-1}) \cdot \text{s}$
1 Day = ? Seconds

\[ 1 \text{ d} = 1 \text{ d} \]

\[ 1 \text{ d} = 1 \text{ d} \times 24 \frac{\text{h}}{\text{d}} \]

\[ 1 \text{ d} = 1 \text{ d} \times 24 \frac{\text{h}}{\text{d}} \times 60 \frac{\text{min}}{\text{h}} \]

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\[ 1 \text{ d} = 86400 \text{ s} \]
1 Day = ? Seconds

\[
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\]

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\]

1 d = 86 400 s  

The numbers and units on each side are different, yet this is still an equality.
Convert days to seconds

• 1 d = 86 400 s
• Conversion factor = 1

\[
1 \text{ d} = 86 \, 400 \text{ s} \\
1 \text{ d} \times 1 \frac{1}{\text{d}} = 86 \, 400 \text{ s} \times 1 \frac{1}{\text{d}} \\
1 = 86 \, 400 \frac{s}{\text{d}}
\]

• Example: 3 d = (3 d)(86 400 s/d) = 259 200 s
Studio Problem 1

• What is the volume, in m³ and L, of 1 mole (mol) of an ideal gas at standard temperature and pressure (STP)?
Studio Problem 1

• What is the volume, in m³ and L, of 1 mole (mol) of an ideal gas at standard temperature and pressure (STP)?

• Ideal gas law: PV = nRT

• From text: R = 8.31 J/(mol⋅K)

• From Wikipedia*: P = 10^5 Pa, T = 273 K
  • 1 Pa = 1 N/m²

• From problem statement: n = 1 mol

\[ V = \frac{nRT}{P} = \frac{1 \text{ mol} \times 8.31 \frac{\text{J}}{\text{mol} \cdot \text{K}} \times 273 \text{ K}}{10^5 \text{ Pa}} \]

*https://en.wikipedia.org/wiki/Standard_conditions_for_temperature_and_pressure
\[ V = \frac{nRT}{P} = \frac{1 \text{ mol} \times 8.31 \frac{\text{J}}{\text{mol} \cdot \text{K}} \times 273 \text{ K}}{10^5 \text{ Pa}} \]

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\[ V = 0.0227 \frac{\text{J}}{\text{N} \cdot \text{m}^2} = 0.0227 \frac{\text{N} \cdot \text{m}}{\text{N} \cdot \text{m}^2} = 0.0227 \text{ m}^3 \]
Volume in liters (L)

1 L = 0.1 m × 0.1 m × 0.1 m = (0.1 m)^3

1 L = (10^{-1} m)^3 = 10^{-3} m^3

1 = 10^3 \frac{L}{m^3}

V = 0.0227 m^3 = 0.0227 m^3 × 10^3 \frac{L}{m^3}

V = 22.7 L
US Customary Units

• Archaic unit system still in use in the United States
• Need to learn how to convert between this system and SI units
• Some commonly used units
  • Length: inch (in), foot (ft), yard (yd), mile (mi)
  • Weight/force: pound (lb) and pound-force (lbf)
  • Mass: pound mass (lbm), ton, slug
  • Energy: British Thermal Unit (BTU)
  • Temperature: degrees Fahrenheit (°F), degrees Rankine (°R)
  • Power: horsepower (hp), BTU/h

https://en.wikipedia.org/wiki/United_States_customary_units
Example of Unit Confusion

• “Due to complications arising from human error, the [Mars Climate Orbiter] encountered Mars at a lower than anticipated altitude and disintegrated due to atmospheric stresses.”

• “The primary cause of this discrepancy was that one piece of ground software produced results in a United States customary unit, while a second system that used those results expected them to be in metric units.”

• “Software that calculated the total impulse produced by thruster firings calculated results in pound-seconds. The trajectory calculation used these results to correct the predicted position of the spacecraft for the effects of thruster firings. This software expected its inputs to be in newton-seconds.”

• “The cost of the mission was $327.6 million total for the orbiter and lander, $193.1 million for spacecraft development, $91.7 million for launching it, and $42.8 million for mission operations.”

https://en.wikipedia.org/wiki/Mars_Climate_Orbiter
http://mars.jpl.nasa.gov/msp98/orbiter/
Studio Problem 2

• A marathon foot race has a defined length of 26 miles + 385 yards (exactly). Convert this length into kilometers.

• Conversion factors
  • 1 mile (mi) = 1760 yards (yd)
  • 1 yard = 3 feet (ft)
  • 1 foot (ft) = 12 inches (in)
  • 1 in = 0.0254 m = 25.4 x 10^{-3} m = 25.4 x 10^{-6} km

\[
26 \text{ mi} = 26 \text{ mi} \times 1760 \frac{\text{yd}}{\text{mi}} = 45760 \text{ yd}
\]

\[
45760 \text{ yd} + 385 \text{ yd} = 46145 \text{ yd}
\]
46 145 yd \times 3 \frac{ft}{yd} \times 12 \frac{in}{ft} \times 25.4 \times 10^{-6} \frac{km}{in}

= 42.194988 \text{ km}

All digits are significant since every quantity is exact.
Today

• Do Studio problems 3 and 4
• Be sure you understand Example Problem 7.10 in the text
• Don’t confuse m (meter) or mi (mile) with the US unit mil (1 mil = $10^{-3}$ in = 0.0254 mm = 25.4 $\mu$m)