Unit 1: Units and process variables (F&R Ch. 2-3)

Reminders

Announcements

- **Homework #1** is posted and due on Friday, September 6.

Office Hours:

Day	Time	Location	Personnel
Monday	TBD	TBD	TBD
Tuesday	TBD	TBD	TBD
Wednesday	TBD	TBD	TBD
Thursday	TBD	TBD	TBD

Learning Objectives

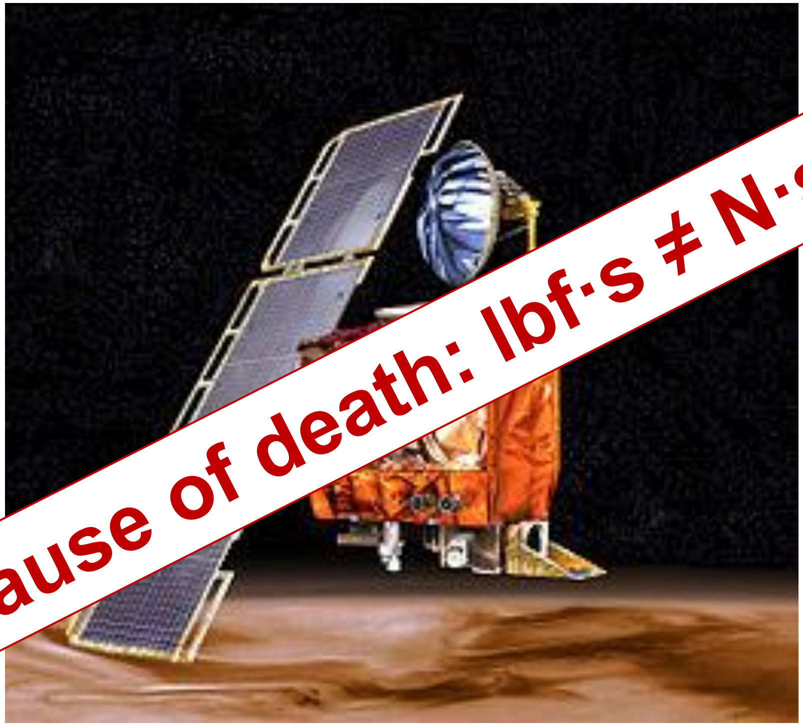
- **Students are expected to know how to do the following (pre-reqs)**
  - Differentiate between dimensions and units
  - Differentiate between base units and derived units
  - Perform dimensional analysis of equations
  - If you need a refresher, there is a video with examples on Canvas

- **After today's class, students should be able to:**
  - Identify process variables
  - Convert between mass, moles, and volumetric flowrate for liquids
  - Convert between mass, moles, and volume for ideal gases
  - Calculate a weighted average property

Why do units matter?

<u>Mars Climate Orbiter</u>

- **$327.6 million** probe
- Dec. 11, 1998: Launched
- Sept. 23, 1999: Miscommunication with navigation system and enters upper atmosphere—instantly disintegrating



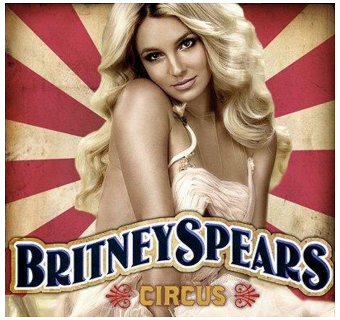
Cause of death: lbf·s ≠ N·s


Why do units matter?

<u>Mixed Oxide Fuel (MOX) Facility, Savannah River Site</u>

- In 2008, DOE NNSA commissioned Chicago Iron & Steel and AREVA to build a MOX facility to convert weapons grade Pu to nuclear fuel
- The plant design was a <u>replica</u> of an existing French facility, projected to cost **$4.8 billion**
- As of May 2018, the project was defunded after spending **$17.6 billion**


Cause of death:
Improper conversion of SI to English units

Significant Digits

Significant

- All non-zero digits like 3.05
- All zeros between non-zeros like 1.01
- Trailing zeros to the right of the decimal place like 1.00
- Exact numbers (Pi) and unit conversions have an infinite number of significant digits (3.14159…)

Not Significant

- Leading zero are not significant, 0.67
- Trailing zeros without a decimal point like 250 or 25000

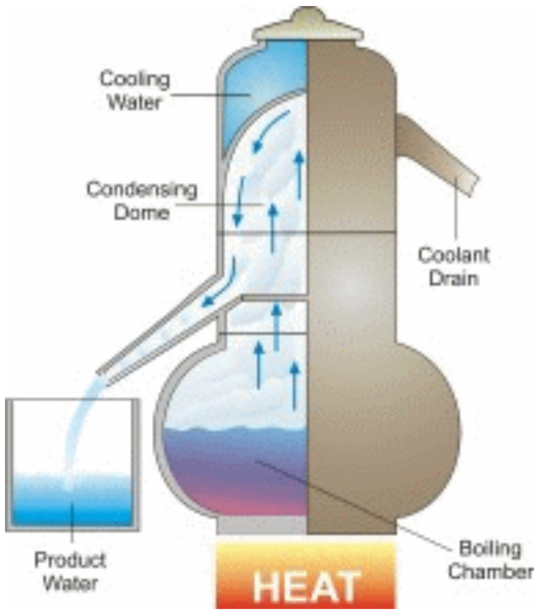
A calculated value can only be as precise as our measurements

Process Variable

- Value or parameter which can be monitored or controlled in a given system

Process 1: Salt Water Desalination

- Motivation
  - According to the WHO[1], water scarcity is one of the largest threats to human health worldwide
  - Historically employed, thermally driven processes like distillation or evaporation are energy intensive
  - Chemical engineers have turned to membrane separations, like reverse osmosis, as a lower cost desalination process



Figures from: water.usgs.gov

[1] WHO = World Health Organization not 

Process 1: Salt Water Desalination

- **SW Reverse Osmosis**: Membrane separation process in which water selectively permeates across a membrane in the direction opposite to natural (forward) osmosis when subjected to sufficient hydrostatic pressure

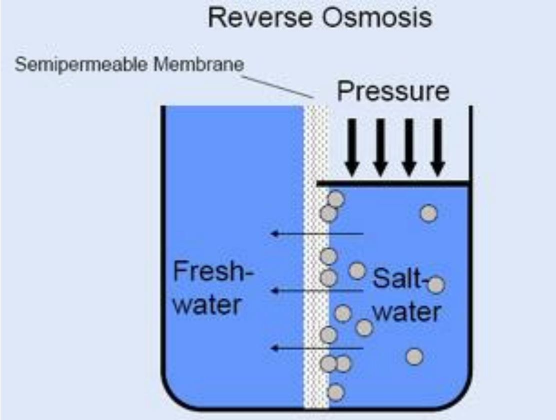


Photo cred: worldpumps.com

Photo cred: Oceanleadership.org

Process 1: Salt Water Desalination

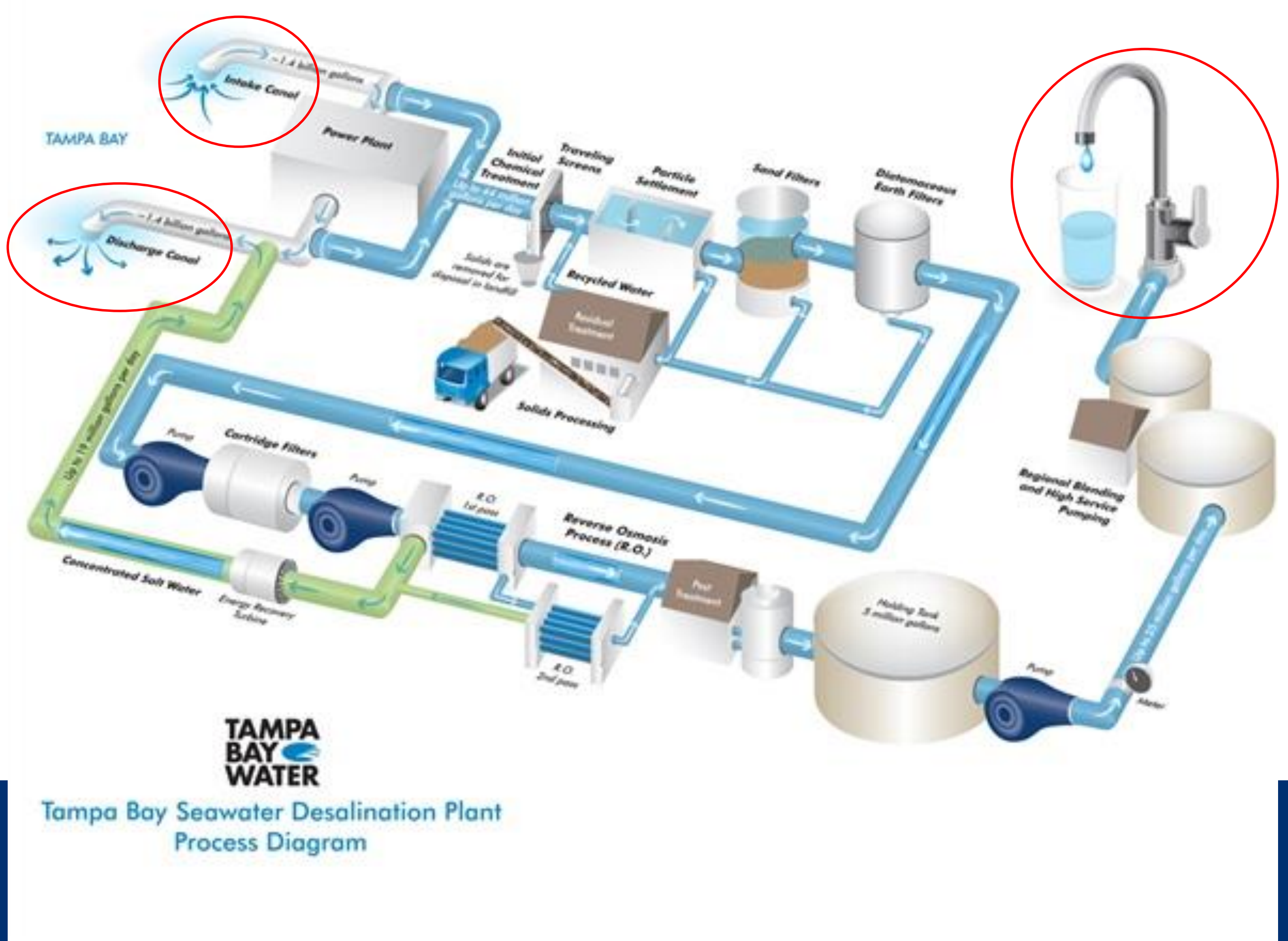
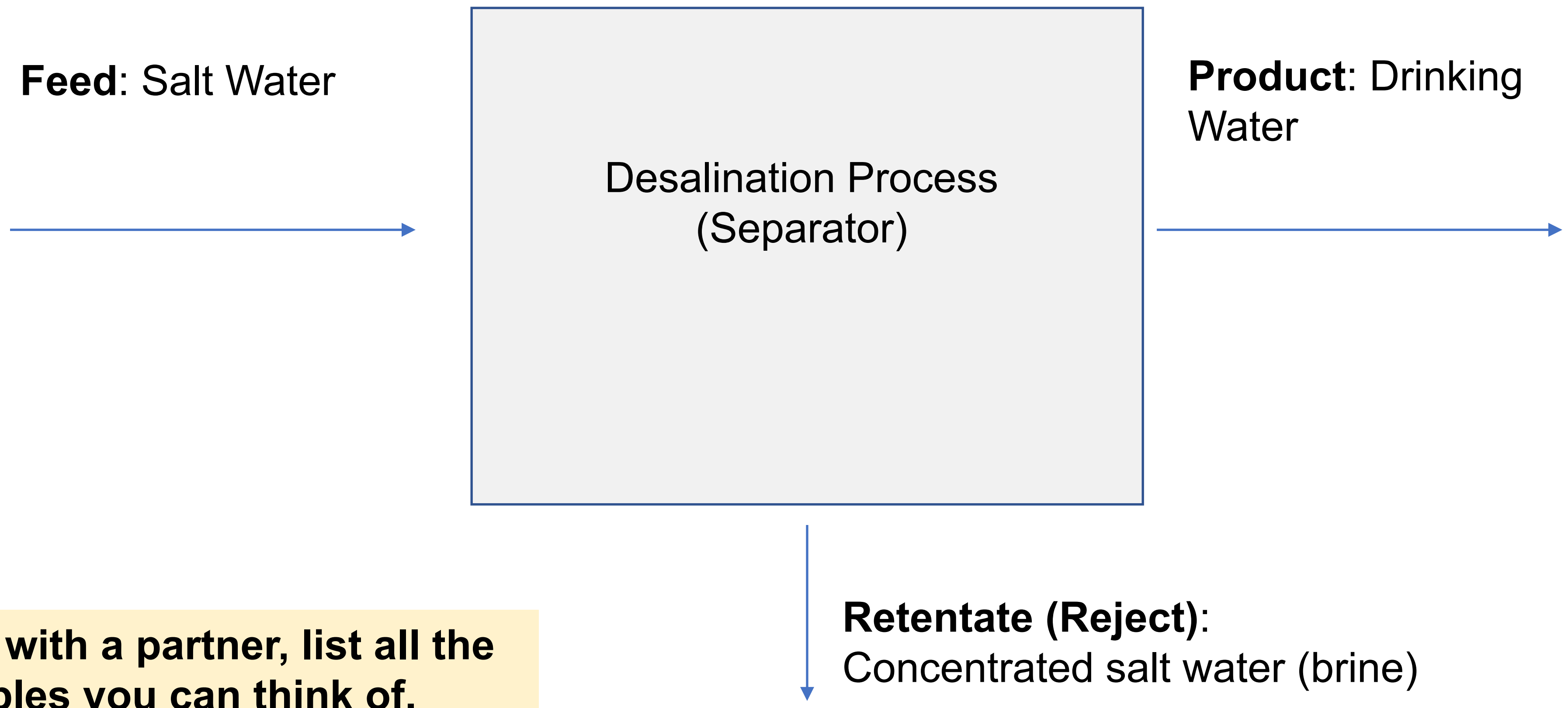


Diagram from: Tampabaywater.org

Process 1: Salt Water Desalination



Take a minute with a partner, list all the process variables you can think of.

Process 1: Flowrate Calculations

The desalination plant produces 25 million gallon per day of drinking water.

- What is the mass flowrate of drinking water?

- What is the molar flowrate of drinking water?

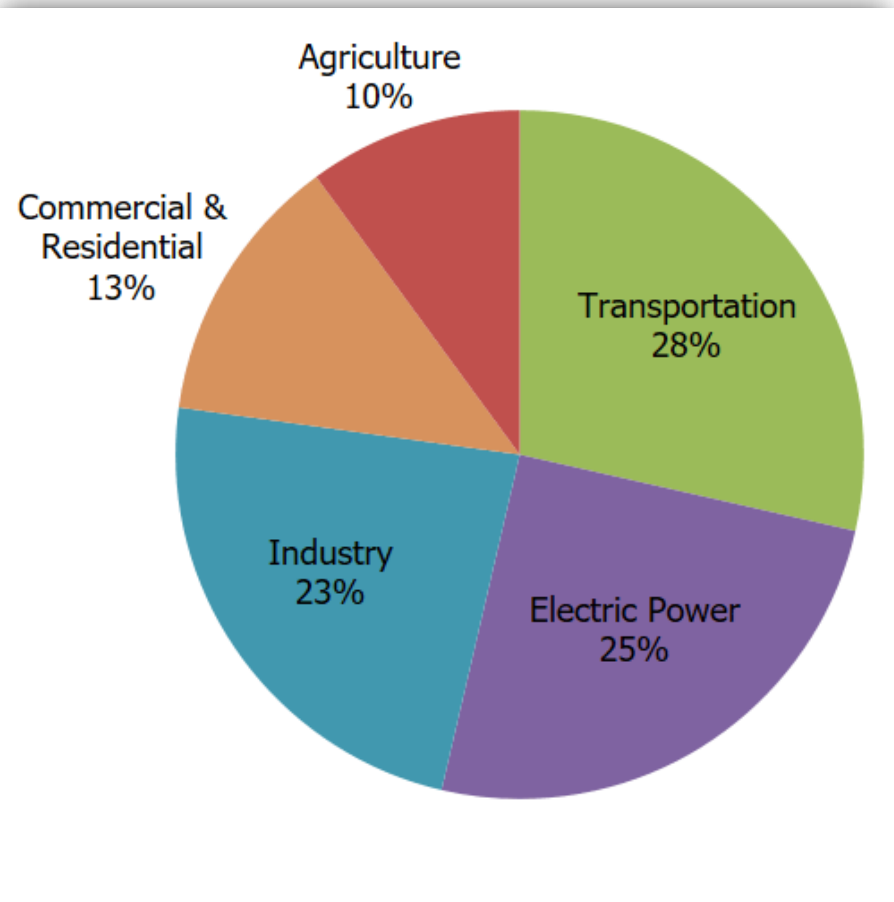
Process 1: Composition Calculations

The salinity of seawater is 3.5% by mass.

- What is the mole fraction of salt in sea water?

Process 2: CO_2 capture

- Motivation
  - Greenhouse gas emissions (CO_2, CH_4) are driving climate change worldwide
  - On strategy for mitigating climate change is capturing excess CO_2 and sequestering it
  - Chemical engineers can design pollution control systems (absorbers and membranes) to remove CO_2 from industrial waste streams

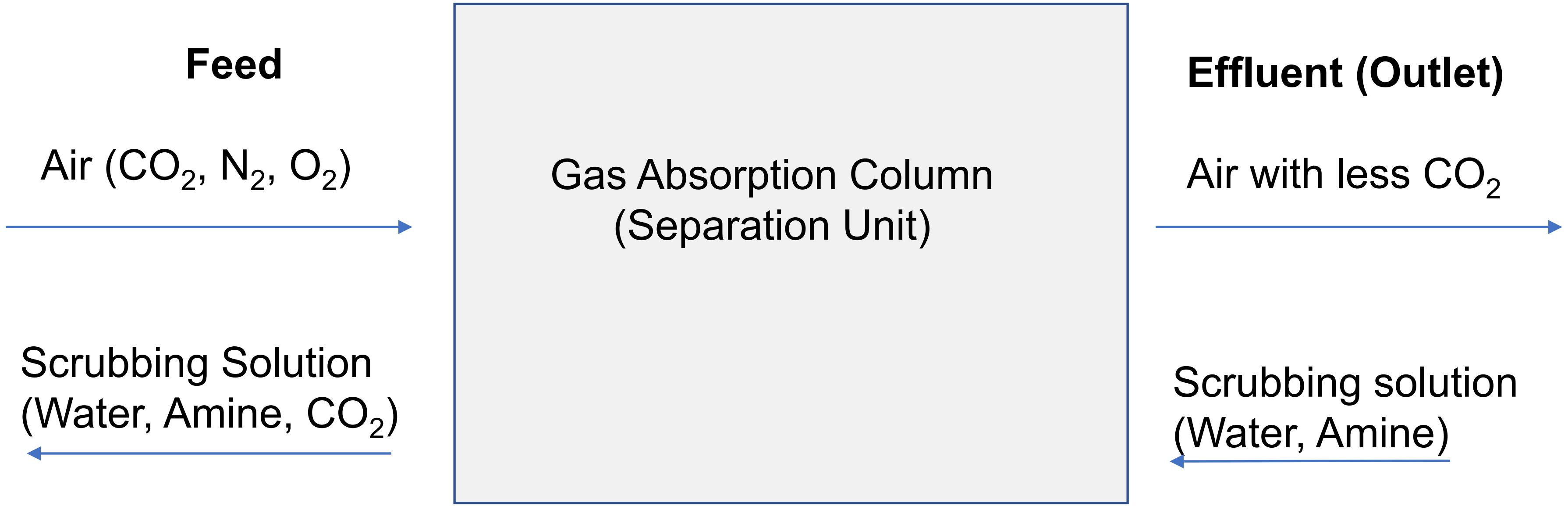


Total U.S. Greenhouse Gas Emissions by Economic Sector in 2021.
https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

Process 2: CO_2 Capture

- **Gas absorption columns:** Gas absorption columns use chemical reactions to chemically capture CO_2. Once concentrated, it can be stored or used for chemical synthesis.

Process 2: CO_2 Capture



Take a minute, list all the process variables you can think of.

Process 2: Flowrate Calculations

Assume air behaves like an ideal gas and enters the absorber at $\dot{n}$ = 1 mol/min.

- Write the equation for the volumetric flowrate ($\dot{V}$) of the air.

Process 2: Concentration Calculations

By mass, dry air contains 75.5% nitrogen, 0.05% CO_2 and 23% oxygen.

- What is the average molecular weight of air?

- What is the mol fraction of CO_2 entering the absorber?

Unit 1 (and pre-req) Learning Objectives

- After this unit, students should be able to:
  - Differentiate between dimensions and units
  - Differentiate between base units and derived units
  - Perform dimensional analysis of equations
  - Identify process variables
  - Convert between mass and mol fractions
  - Convert between mass, mol and volumetric flow rates
  - Calculate the average property of a mixture
  - Apply the rules of significant digits to calculations