ME 200 – Thermodynamics 1
In-Class Notes for Spring 2023

- Course Overview and Policy
- Chapter 1 (Moran and Shapiro)
  – Thermodynamics Intro. & Definitions
  – Properties
  – Processes & Cycles
  – Problem Solving

Divisions & Instructors

Jim Braun: 12:30 – 1:20 PM, Div. 4

– Office Hours: MWF, 1:30 – 2:30 PM
  – Office Location: ME 3003H
  – https://purdue-edu.zoom.us/my/jamesbraun
– Contact Info: jbraun@purdue.edu

Andrew Fix: Div. 4 Guest Lecturer (Deans Fellow)

S. Naik: 7:30 to 8:20 am, Div. 1

G. Jackson: 8:30 to 9:20 pm, Div. 2

K. Kircher: 9:30 to 10:20 pm, Div. 3

J.H. Choi: 3:30 to 4:20 pm, Div. 5

Course Overview & Policy

***** Be sure to read ME 200 policy document *****

- **Textbook**
  - Moran, M.J., Shapiro, H.N., Boettner, D. D., and Bailey, M. B., Fundamentals of Engineering Thermodynamics (7^{th}, 8^{th}, or 9^{th} edition), Wiley, 2018

- **Thermodynamic Properties**
  - Use property tables on website for homework
  - Do NOT use property tables from book

- **Lecture Notes**
  - Printed copies provided for each chapter
  - Mixture of prepared notes and blank areas for student note taking
  - **Get a 3-ring binder and add some blank paper!**

- **ME 200 Div. 4 Website**:
  - www.purdue.edu/freeform/me200/
  - Course policy and schedule
  - Thermodynamic properties (needed for homework)
  - Equation sheet
  - Tutorial room hours
  - Homework assignments and solutions
  - Exams and solutions
  - Examples not completed in class
  - Template for engineering paper

<u>Course Overview and Policy</u>

- **Homework (see schedule)**
  - Engineering style problems for each lecture
  - Must follow problem solution format provided. Use of Engineering paper is preferred
  - Submit through GradeScope **<u>11:59 pm</u>** on due date (no late homework accepted, but will drop 5 lowest homework grades)
  - Solutions will be posted on ME 200 website

- **GradeScope**
  - See homework instructions for link
  - Homework uploaded as pdf files
  - Exams scanned & uploaded
  - Graded homework and exams will be available electronically

- **In Class**
  - Only opportunity to see lectures (**will not be recorded; will not post completed notes**)
  - Opportunity to ask questions
  - Will provide homework guidance
  - Will give practice conceptual quizzes similar to exam conceptual problems

<u>Course Overview and Policy</u>

- **Exams**
  - Closed book
  - Equation sheet and properties provided
  - Bring calculator and pencils only
  - **Only TI-30XIIS model calculators may be used**

- **Grading**:

Three one-hour exams	60%
Final exam	25%
Homework	15%

- **How to be successful**
  1. Attend and prepare for lecture
     - Read text/notes before lecture
     - Review notes from last lecture
     - Read homework problems before lecture and ask questions

  2. Take advantage of help opportunities
     - Instructor office hours, TA office hours, supplemental instruction, (TA office hour times and SI information will be posted on website), and ME 200 blog (piazza)

Course Overview and Policy

Homework Format: use template in policy

System Diagram: *Identify system boundary, indicate energy & mass flows into/out of system*

Assumptions**:** *List all assumptions needed to eliminate terms in your basic equations.* e.g. "Steady state," "Uniform flow," "Ideal gas," etc.

Basic Equations**:** From ME 200 basic equation sheet

Solution**:** This includes correct units.

Answer precision**:** use three significant figures, except for entropy-related quantities (which should use five significant figures)

*** please use engineering paper ***

*** at top of each page include name, problem number, page number ***

Course Overview and Policy

- **Other notes**
  – Turn off cell phones in class
  – No cell phones or smart devices in exams

- **Academic Integrity**
  1. Homework
     - Can work together with others, but must prepare and submit your own solution
     - 1st instance of cheating: **zero** on all HW for the semester; reported to Dean of Students
     - 2nd instance of cheating: failing grade for ME 200; recommendation of expulsion from Purdue
     - Cheating includes copying solutions from classmates and online materials (Chegg, etc.)
  2. Cheating on Semester Exams
     - 1st instance: zero on the exam; reported to Dean of Students
     - 2nd instance: failing grade for ME 200; recommendation of expulsion from Purdue
  3. Cheating on Final Exam
     - Zero on the exam; reported to Dean of Students

Lecture 1
Introduction, Units, & Systems

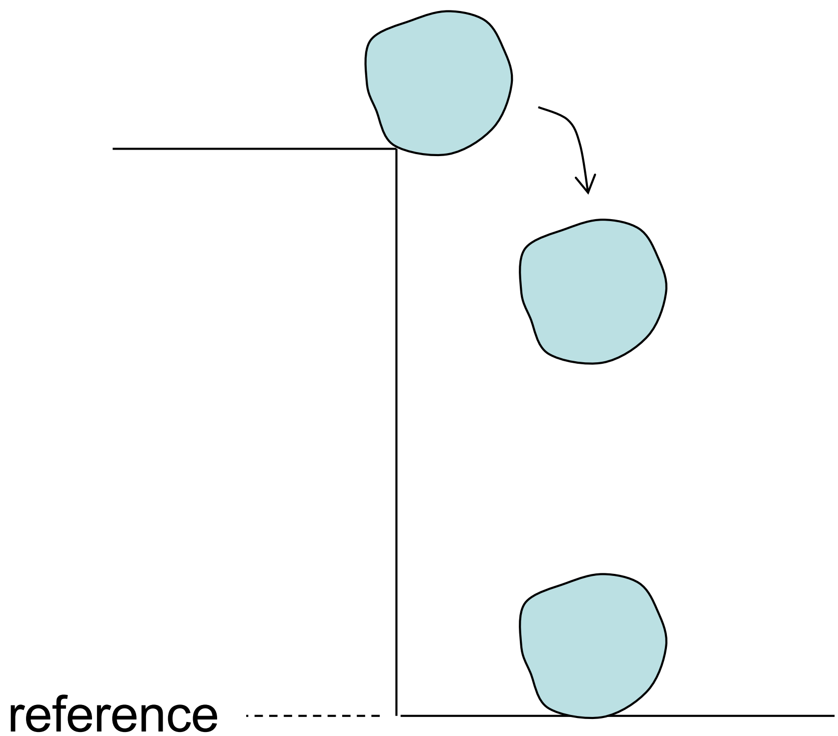
Objectives

- What is Thermodynamics and why do we care?
- Two thermodynamics laws
- Systems, boundaries, and surroundings

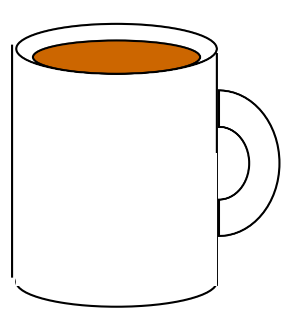
What is "Thermodynamics"?

1st Law of Thermodynamics

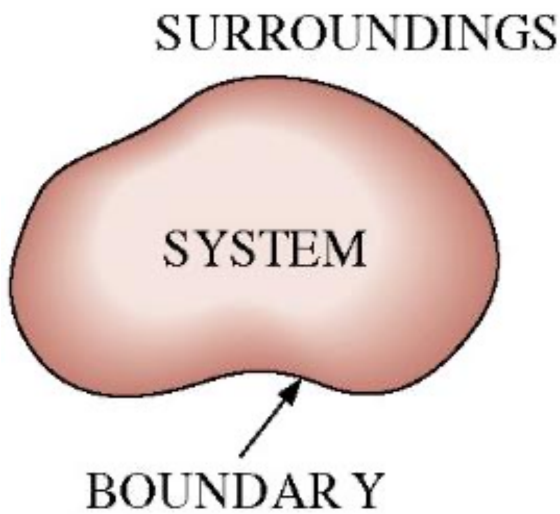
1st Law Example



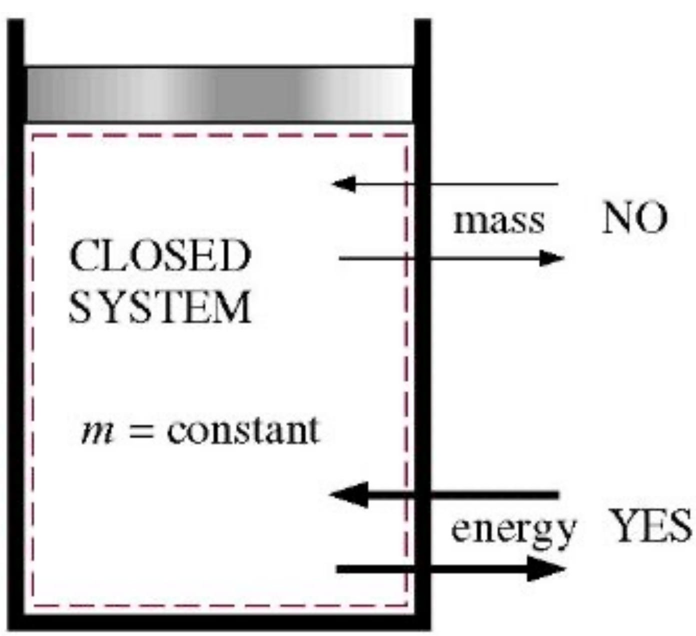
<u>2st Law of Thermodynamics</u>



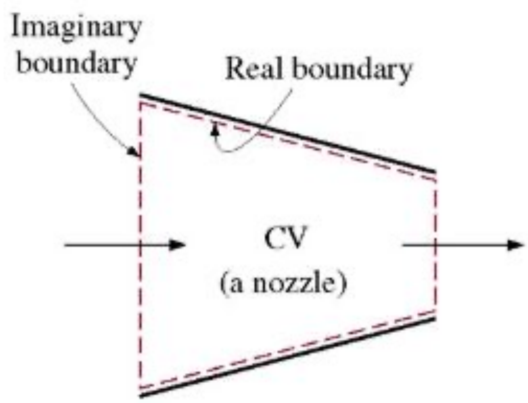
Systems

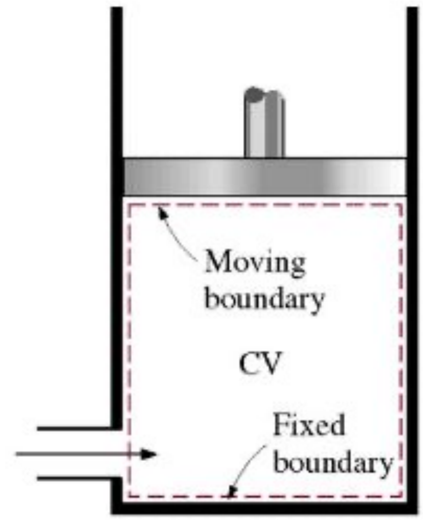


Closed System (or Control Mass)



Open System (or Control Volume)





Examples

Is this classroom an open or closed system?

What about an aircraft engine?

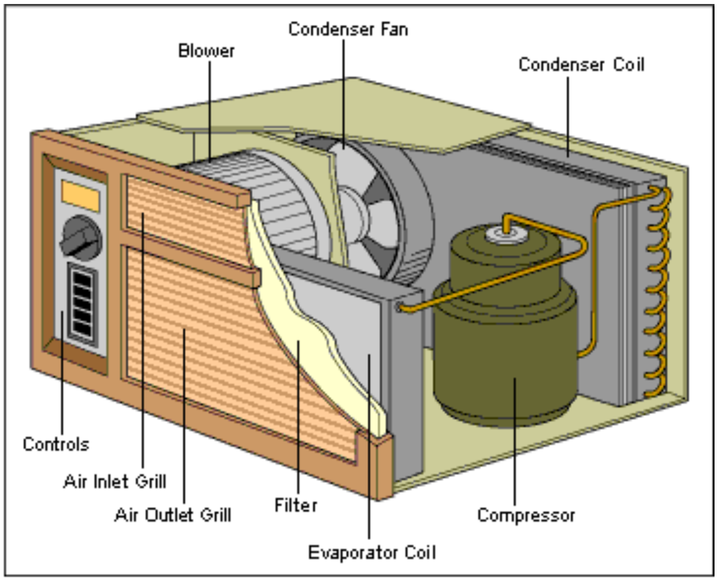
Systems and Energy Flows

- Classroom

- Air Plane Engine

Systems and Energy Flows

- Air Conditioner



- Bike and Rider

Lecture 2
Properties and States

Objectives

- General property definitions
- States and equilibrium definitions
- Processes and cycles
- Pressure

Properties

What is a property?

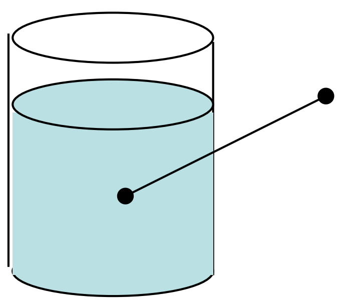
Independent properties:

Properties

Extensive properties:

Intensive Properties:

Example



Water with following properties:

ρ = 1000 kg/m^3

V = 1 m^3

m = 1000 kg

How many of these properties are independent?

Which properties are intensive?

State and Equilibrium

State: "condition" of a system as described by its properties

Equilibrium: a state of balance (no unbalanced forces)

State Postulate: the equilibrium state of a simple compressible substance is completely specified by 2 independent, intensive properites

Process and Cycles

Process: change of system from one equilibrium state to another

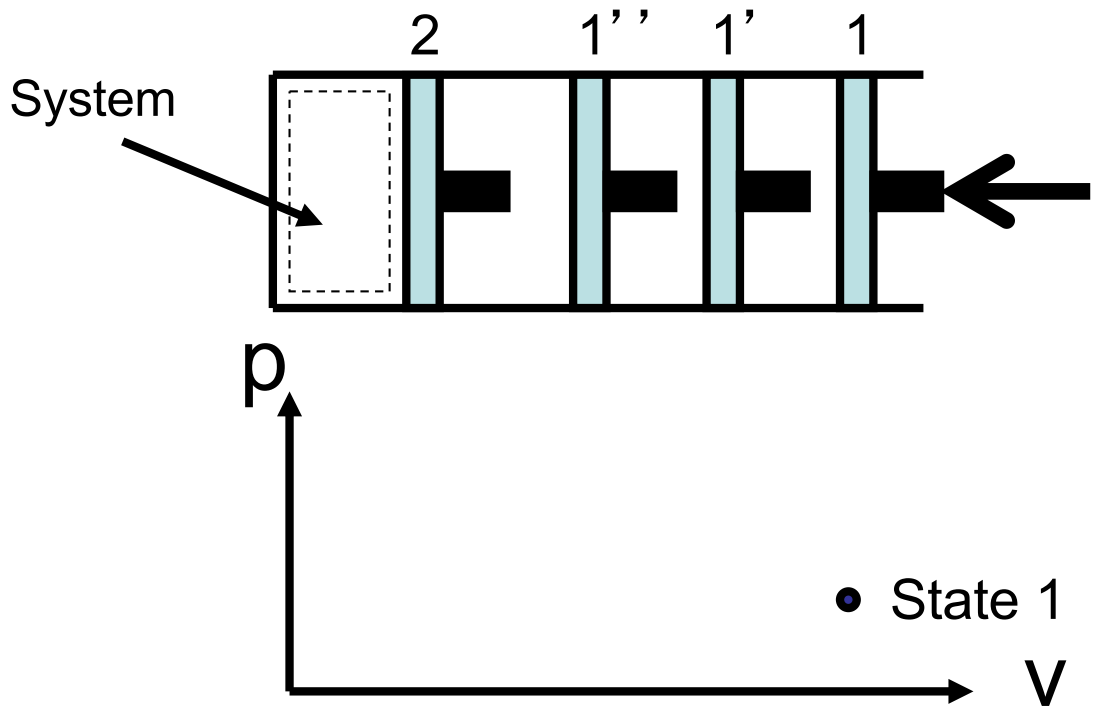
Quasistatic (Quasiequilibrium) Process: "slow enough" process so that system is always infinitesimally close to equilibrium

Path: series of states for process

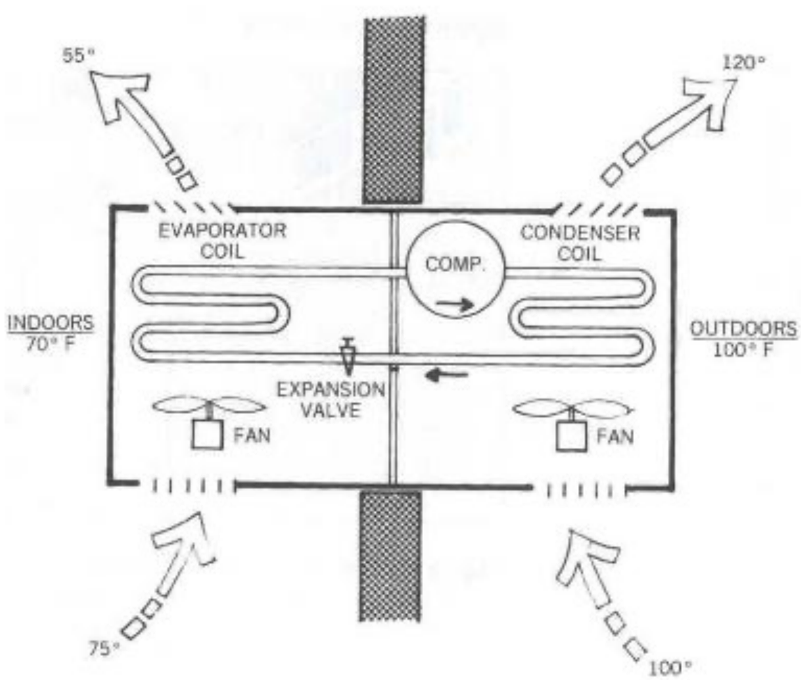
Cycle: system returns to initial state after end of processes

Cycle Efficiency:

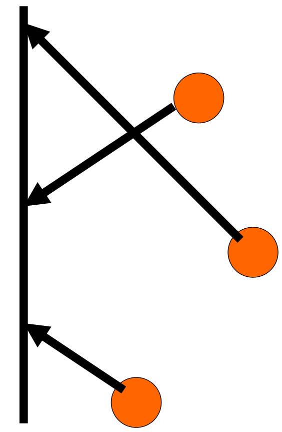
Compression Process Example



Cycle Efficiency Example

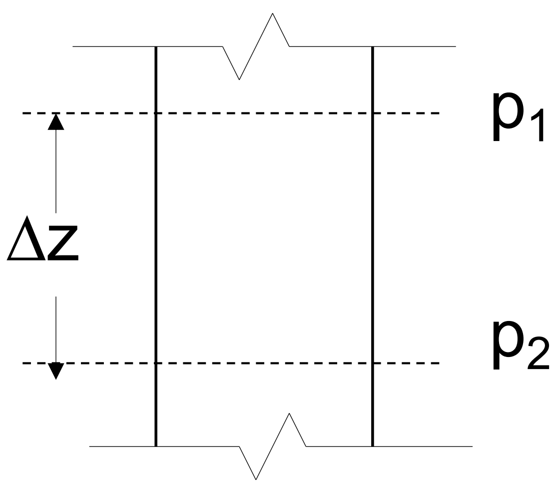


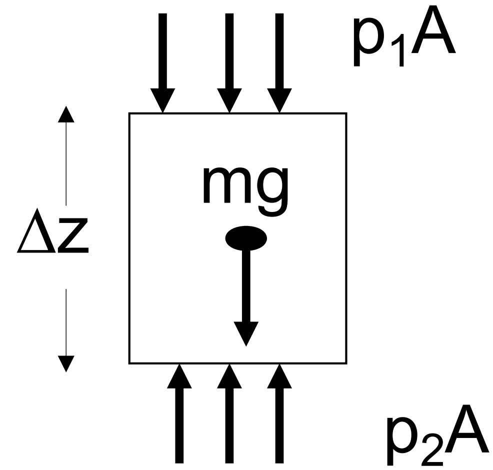
Pressure



For a column of fluid

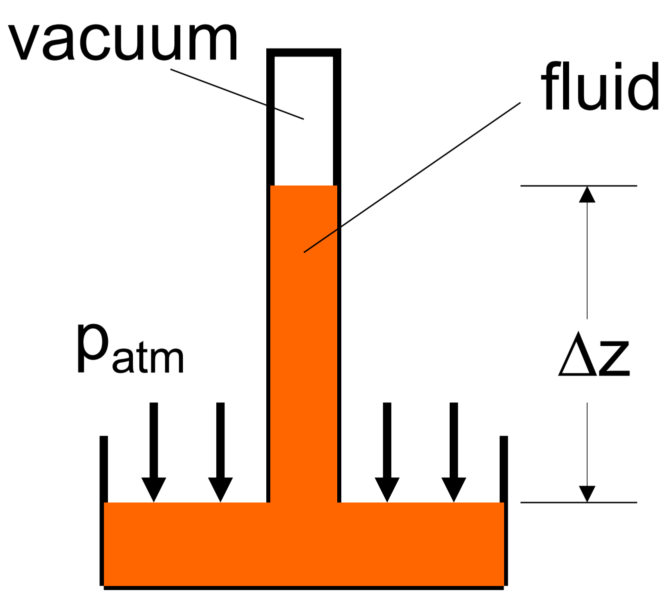
Free-body diagram



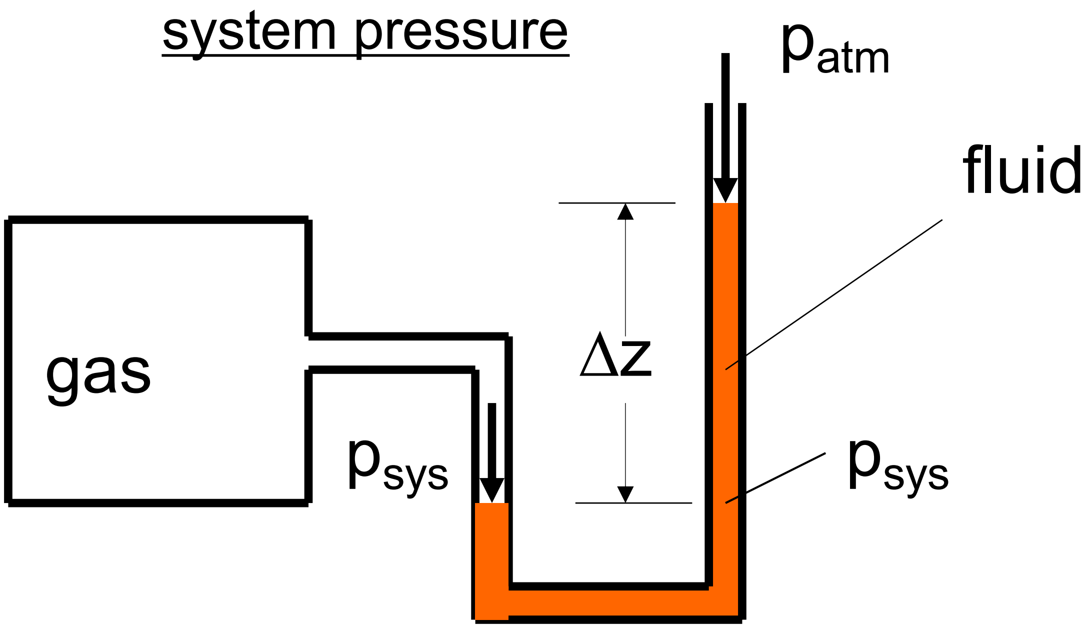


Simple Pressure Measurement

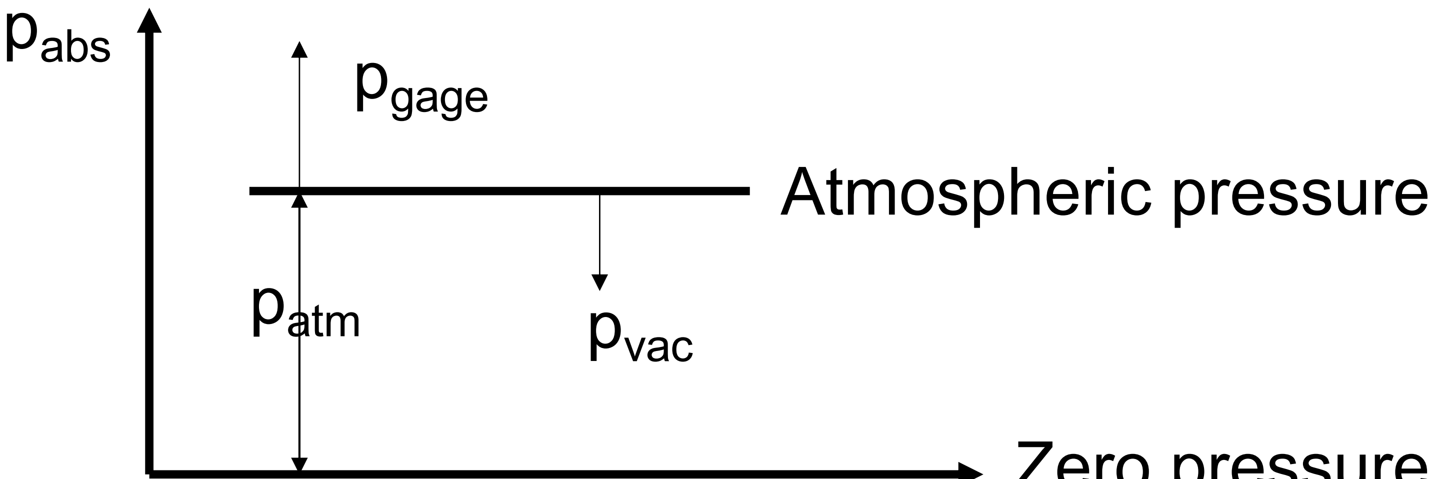
atmospheric pressure



system pressure



Absolute, Gage and Vacuum Pressures



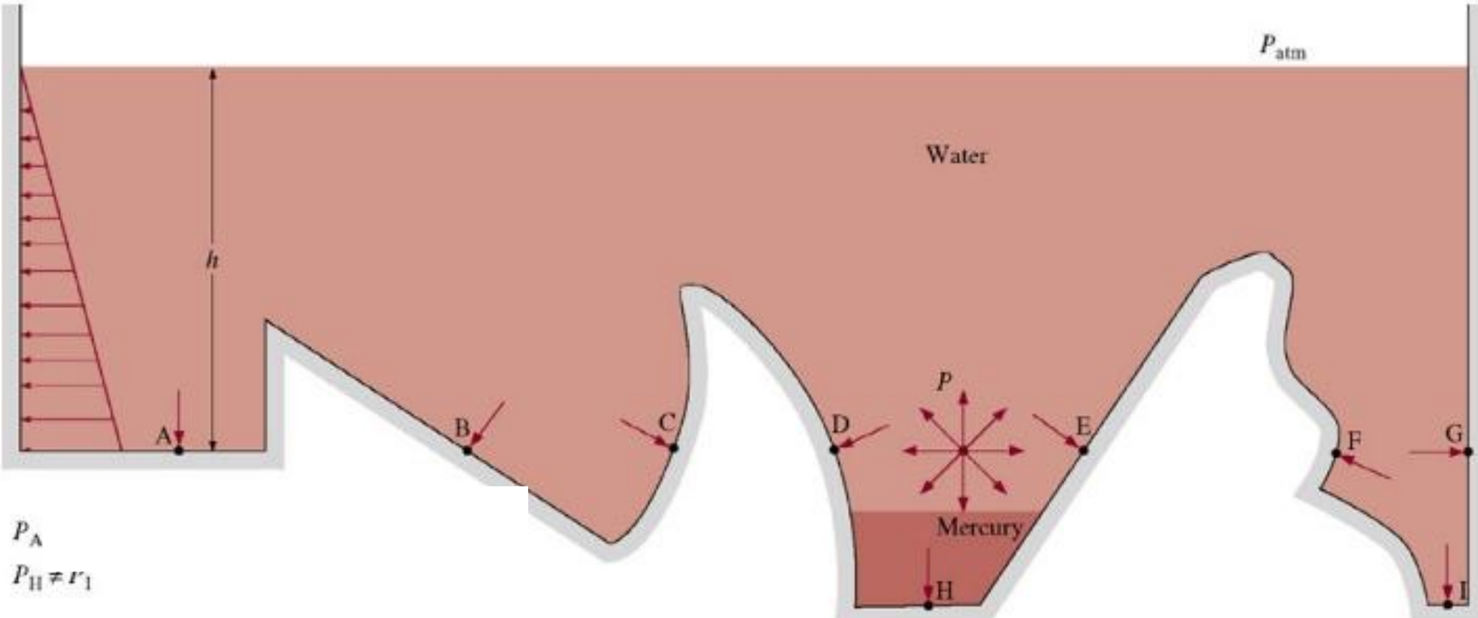
Pressure Units

1 Pa = 1 N/m^2

1 bar = 10^5 Pa = 100 kPa

1 atm = 1.013 bars = 14.7 psi

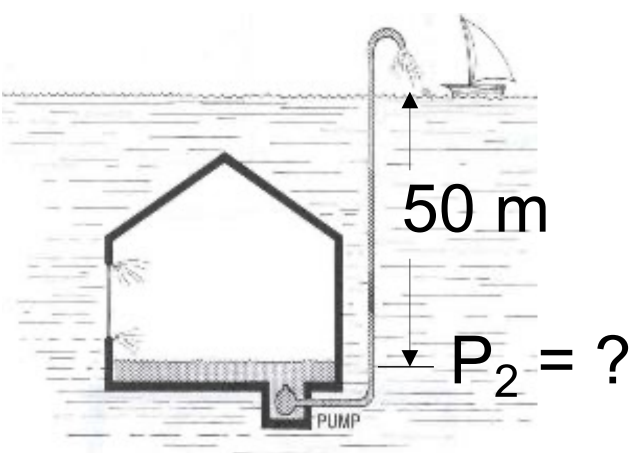
Examples



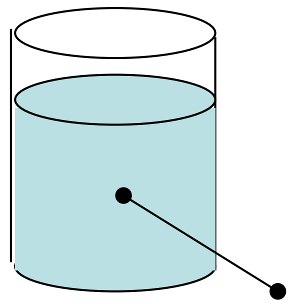
Which labeled point has the highest pressure?

Which labeled point has the lowest pressure?

P_{atm} = 1 bar



Specific Volume



Specific Volume: $$v = \frac{V}{m} = \frac{1}{\rho}$$

Units: m^3/kg or ft^3/lbm

V = Volume, m = mass,
n = number of moles

Molar Specific Volume: $$\overline{v} = \frac{V}{n} = \frac{m}{n} v = M \cdot v$$

Units: m^3/kmol or ft^3/lbmol

M = molecular weight (kg/kmol or lbm/lbmol)

Recall that 1 gmol has 6.022×10^{23} molecules

Lecture 3

Temperature, Problem Solving

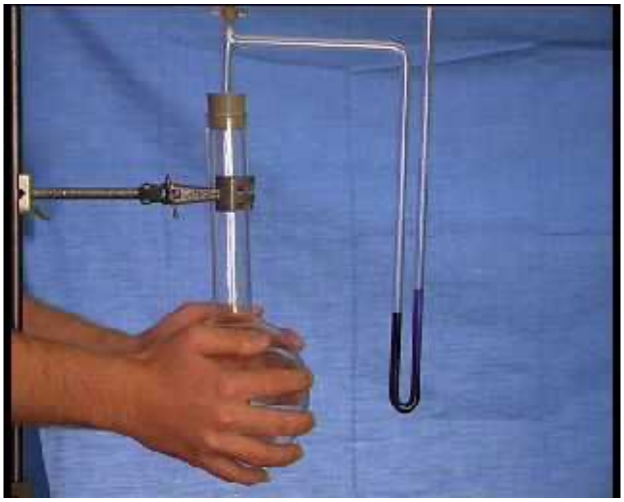
Temperature

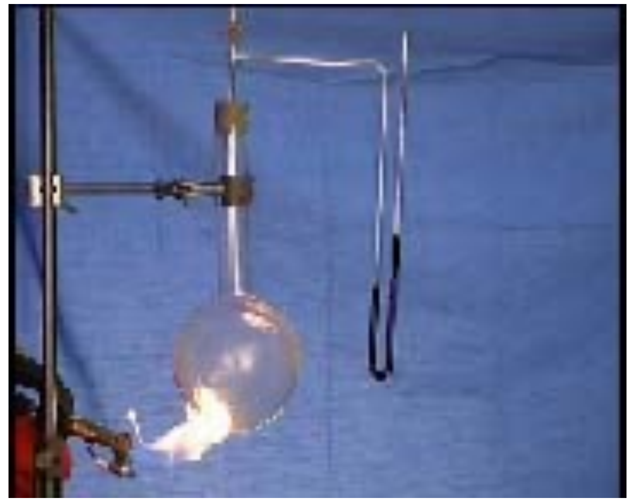
- Two objects in thermal equilibrium are at the same temperature
- Temperature is an intensive property that determines whether or not an object is in equilibrium with other objects
- Thermometers measure the temperature dependence of some physical property

Thermometers

Thermometer	Physical Property Measured
Ideal gas	Pressure and volume of dilute gas
Mercury bulb	Expansion or contraction of fluid
Bimetallic strip	Difference in expansion of two solids
RTD or Thermistor	Electrical resistance
Thermocouple	Voltage across dissimilar metals
Optical Pyrometer	Color of emitted light
Silicon diode	Electrical resistance

Gas Thermometer





Temperature scales are chosen so that

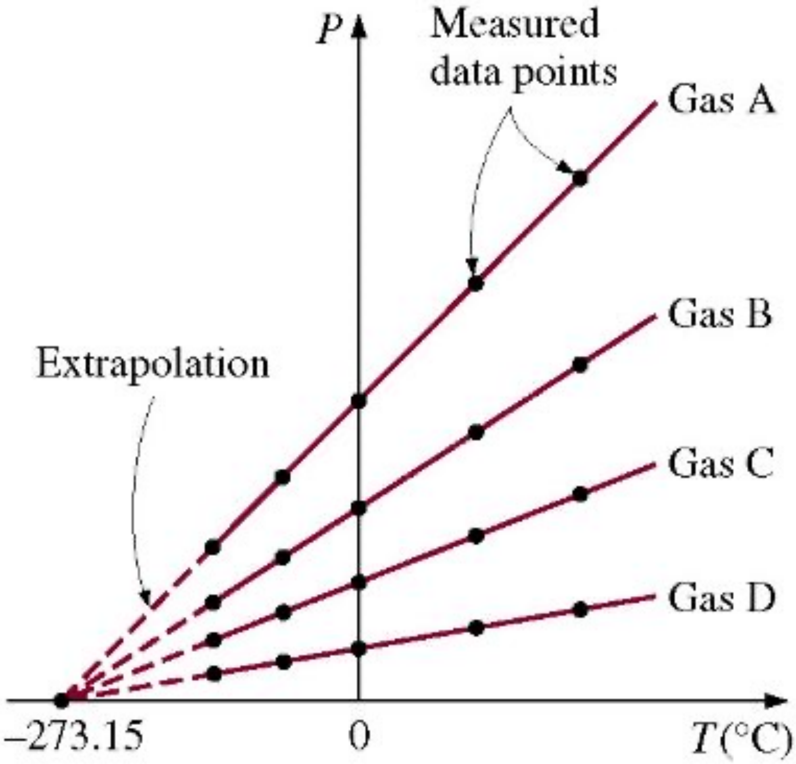
$$T = a + b\,P$$

For Celcius scale, assign

0^oC → freezing point of water at 1 atm

100^oC → boiling point of water at 1 atm

For gases at low pressures (ideal gases)



from experiments

a = -273.15°C

lowest possible temperature

For Fahrenheit scale, assign

32°F → freezing point of water at 1 atm

212°F → boiling point of water at 1 atm

Then

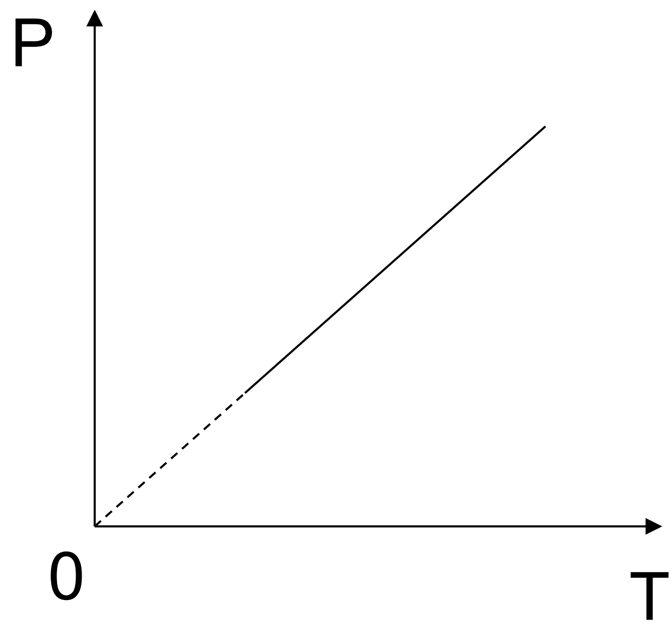
a = -459.67°F

Absolute Temperature Scales

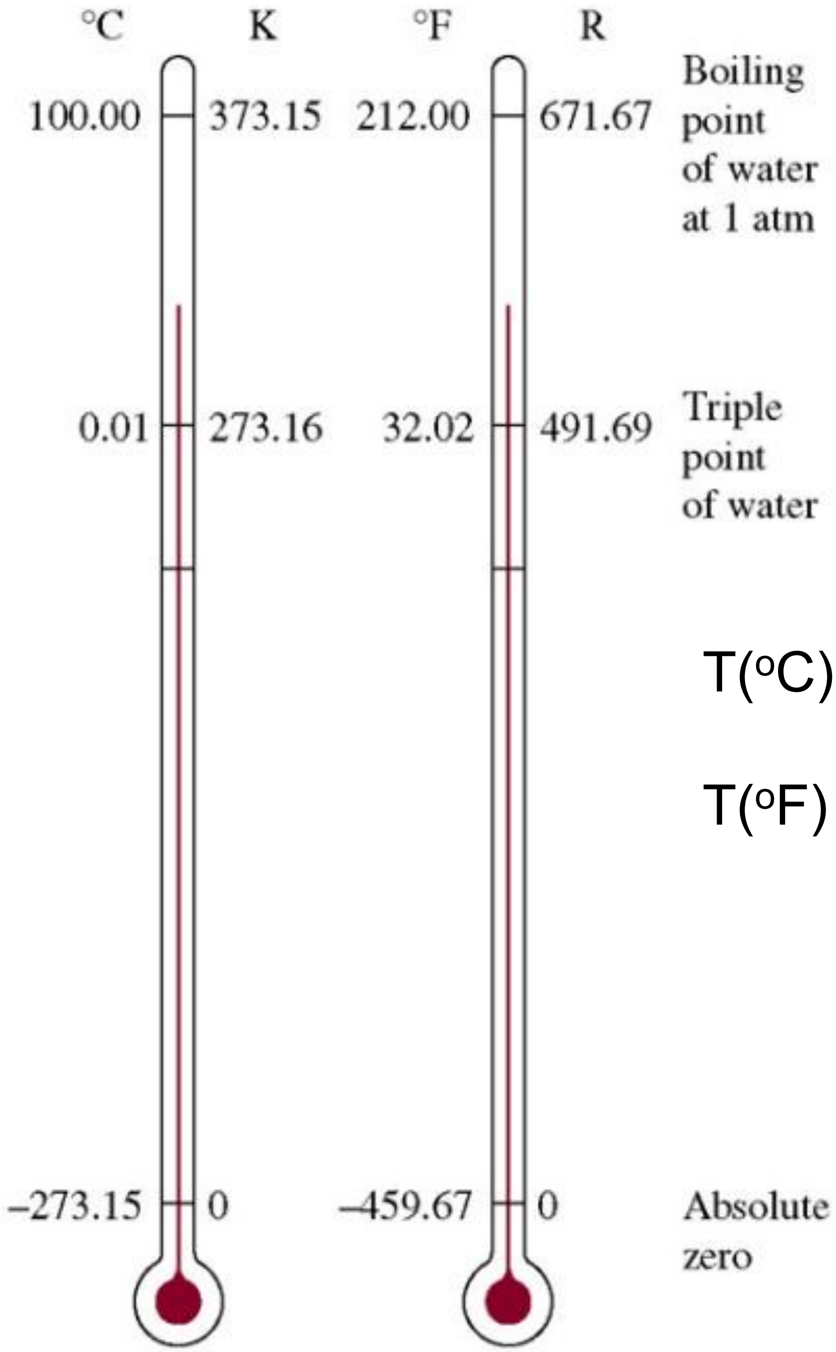
For absolute scales assign

$a = 0^o$

Then, for a given ideal gas



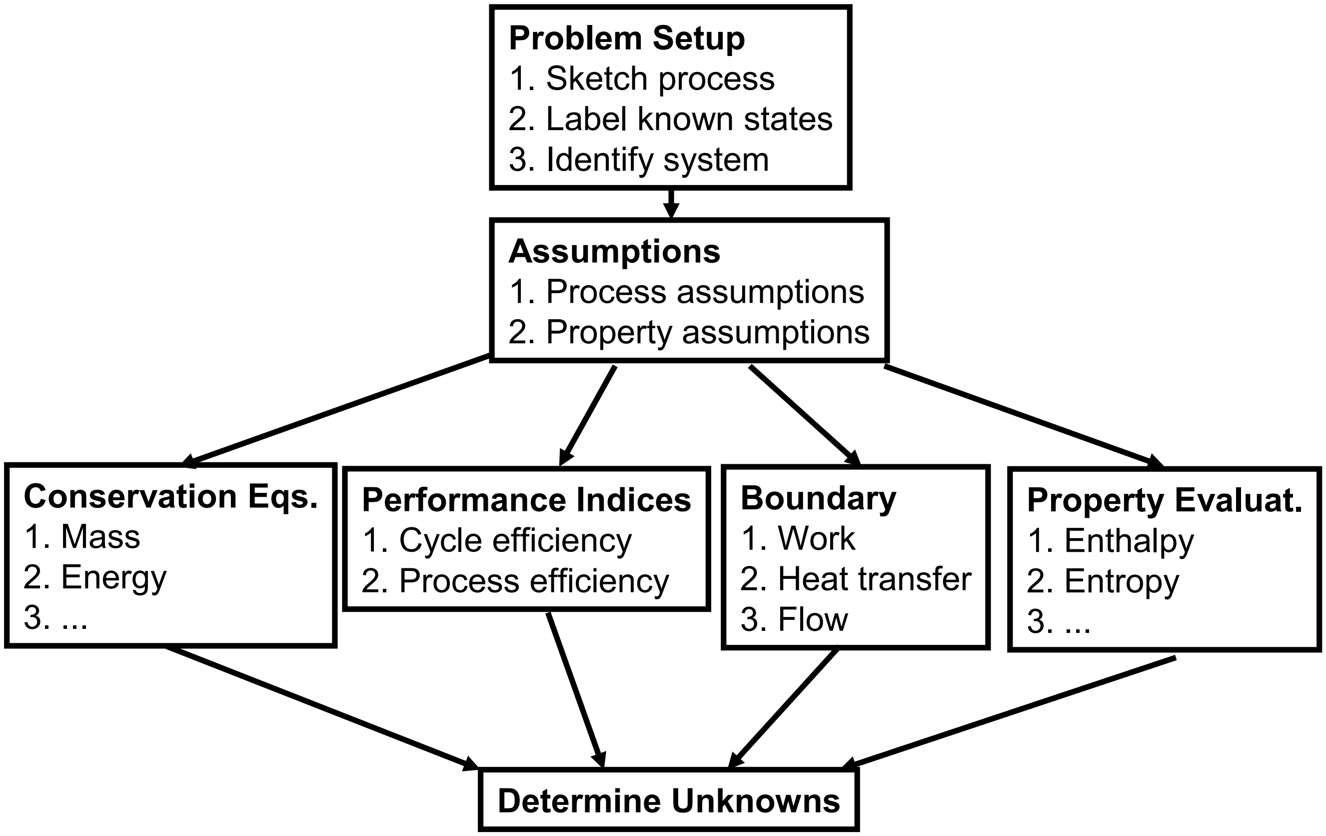
Temperature Scale Comparisons



$T(^oC) = 5/9\ (T(^oF) - 32)$

$T(^oF) = 9/5\ T(^oC) + 32$

Thermodynamic Problem Solving



Solution Format

- ***System Diagram:*** Show your system boundary (dashed line) and indicate energy flows (work, heat transfer, fluid flow).
- ***Assumptions***: Example: "Ideal gas."
- ***Basic Equations***: Your basic equation must be one listed on the ME 200 basic equation sheet.
- ***Solution:*** This includes correct units.