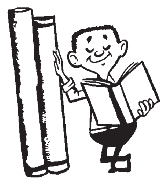
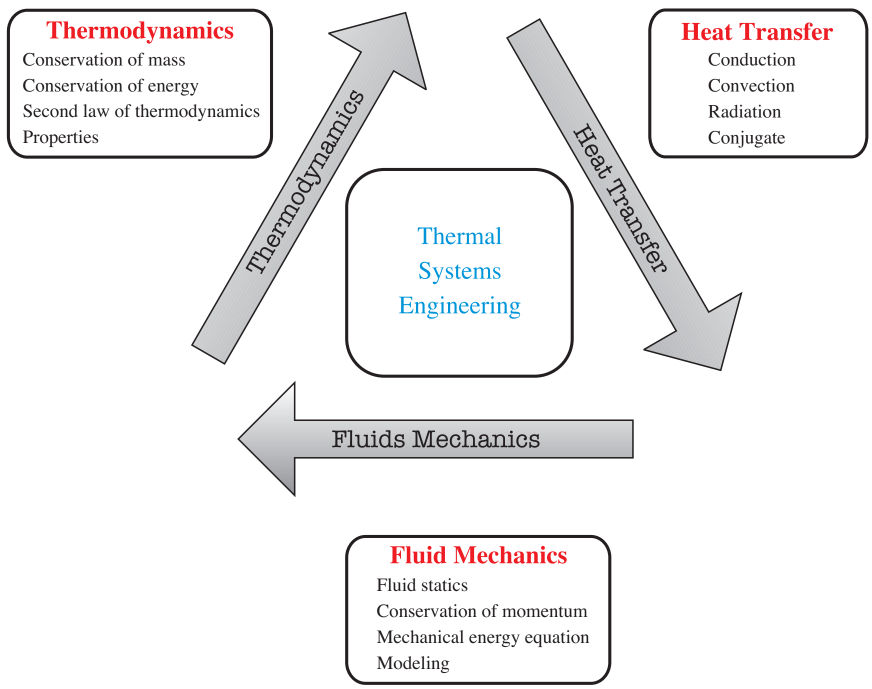
Introduction & Basic Concepts of Thermodynamics



Reading	**Problems**
2-1 $\rightarrow$ 2-8	2-53, 2-67, 2-85, 2-96

Introduction to Thermal Sciences

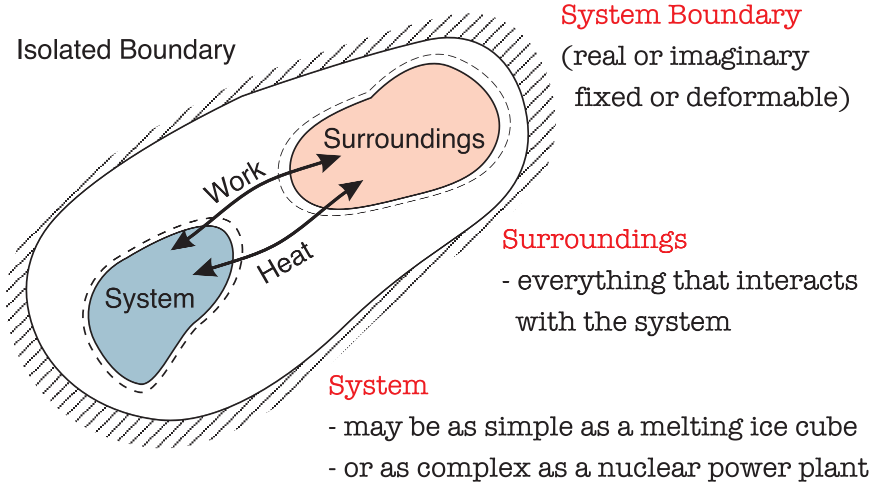


Thermodynamics: the study of energy, energy conversion and its relation to matter. The analysis of thermal systems is achieved through the application of the governing conservation equations, namely *Conservation of Mass*, *Conservation of Energy* (1st law of thermodynamics), the 2nd law of thermodynamics and the property relations.

Heat Transfer: the study of energy in transit including the relationship between energy, matter, space and time. The three principal modes of heat transfer examined are conduction, convection and radiation, where all three modes are affected by thermophysical properties, geometrical constraints and the temperatures associated with the heat sources and sinks used to drive heat transfer.

Fluid Mechanics: the study of fluids at rest or in motion. While this course will not deal extensively with fluid mechanics we will be influenced by the governing equations for fluid flow, namely *Conservation of Momentum* and *Conservation of Mass*.

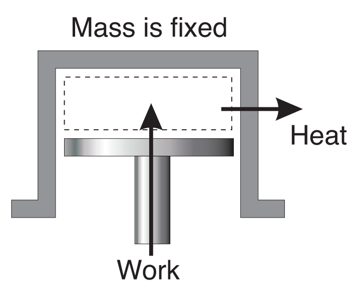
Thermodynamic Systems



System: thermodynamic systems are classified as either *closed* or *open*

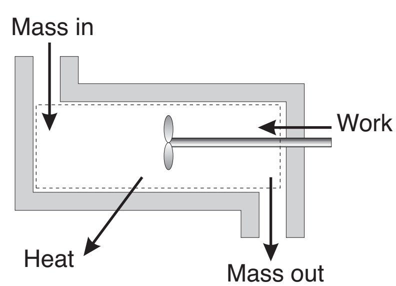
Closed System:

- consists of a fixed mass
- NO mass crosses the boundary



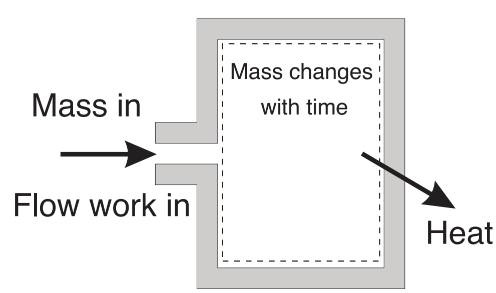
Open System: Steady

- consists of a fixed volume
- mass crosses the boundary
- no change with respect to time



Open System: Unsteady

- changes may occur with respect to time
- flow work in does not equal flow work out
- energy crosses the boundary as enthalpy and heat



Thermodynamic Properties of Systems

Thermodynamic Property: Any observable or measurable characteristic of a system or any mathematical combination of measurable characteristics

Extensive Properties: Properties that are dependent of the size or extent of the system, i.e. mass

- they are additive $\Rightarrow X_{A+B} = X_A + X_B$

Intensive Properties: Properties that are independent of the size (or mass) of the system

- they are **not** additive $\Rightarrow X_{A+B} \neq X_A + X_B$

Specific Properties: Extensive properties expressed per unit mass to make them intensive properties

- specific property (intensive) $\longrightarrow \dfrac{\text{extensive property}}{\text{mass}}$

Measurable Properties

- $P, V, T,$ and m are important because they are measurable quantities
  - pressure (P) and temperature (T) are easily measured intensive properties. Note: They are not always independent of one another.
  - volume (V) and mass (m) are easily measured extensive properties

Pressure

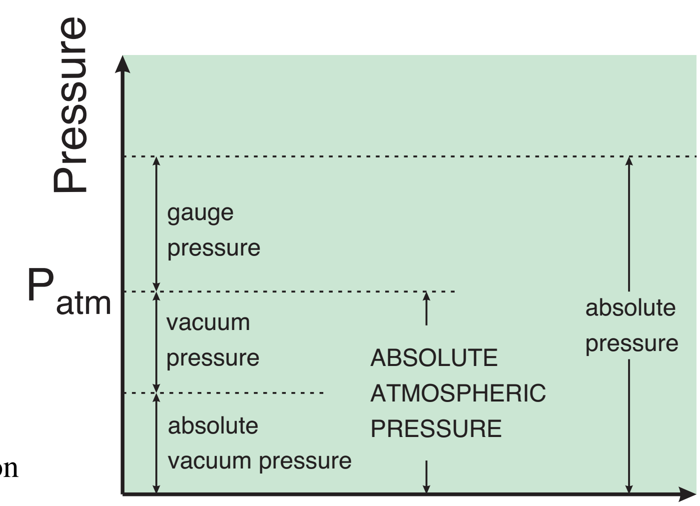
- $Pressure = \dfrac{Force}{Area}$
- gauge = absolute - atmospheric
  $\Rightarrow P_{abs} > P_{atm}$

$$P_{gauge} = P_{abs} - P_{atm}$$

- vacuum pressure $\Rightarrow P_{abs} < P_{atm}$

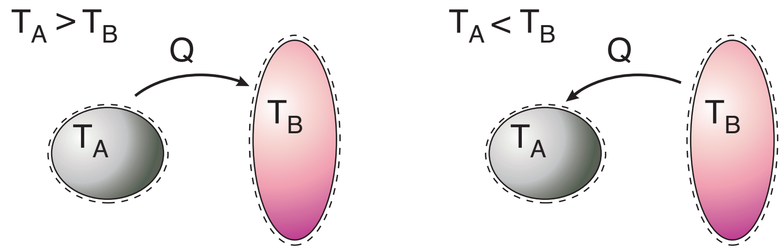
$$P_{vac} = P_{atm} - P_{abs}$$

- thermodynamics properties depend on absolute pressure



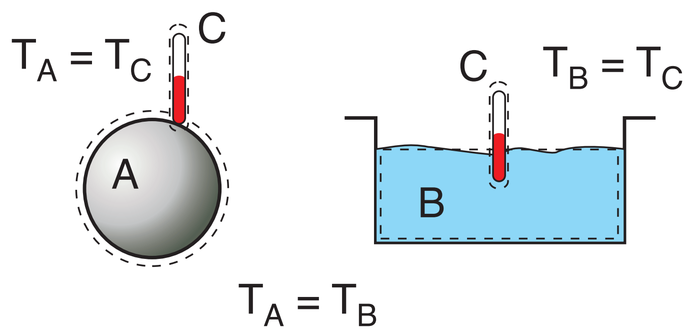
Temperature

- temperature is a pointer for the direction of energy transfer as heat



0^{th} ***Law of Thermodynamics:*** when two objects are in thermal equilibrium with a third object they are in thermal equilibrium with each other.

- the 0^{th} law makes a thermometer possible



- in accordance with the zeroth law, any system that possesses an equation of state that relates T to other accurately measurable properties can be used as a thermometer

Other Properties

- energy within a system can be stored as a combination of kinetic energy, potential energy or internal energy
- **Internal energy U $[kJ]$:**
  - associated with molecular motion i.e. translational, rotational or vibrational
  - extensive since it depends on the amount of matter in the system
- **Kinetic energy KE:**
  - the energy of motion relative to some reference frame $\Rightarrow$ $KE = \frac{1}{2}m(\mathcal{V})^2$
- **Potential energy PE:**
  - the energy of position within a gravitational field $\Rightarrow$ $PE = mgz$

State and Equilibrium

- the state of a system is its condition as described by a set of relevant energy related properties.
- a system at equilibrium is in a state of balance

Definitions

Simple Compressible System: A simple compressible system experiences negligible electrical, magnetic, gravitational, motion, and surface tension effects, and only PdV work is done.

State Postulate:

> **State Postulate (for a simple compressible system):** The state of a simple compressible system is completely specified by 2 independent and intensive properties.

Processes and Cycles

Definitions

1. **Process:** a transformation from one equilibrium state to another through a change in properties
2. **Quasi-equilibrium Process:** changes occurs sufficiently slow to allow the system to transition in a uniform manner
3. **Cycle:** a sequence of processes that begin and end at the same state i.e. see the Carnot cycle
4. **Steady:** no change with respect to time
    - if the process is not steady, it is *unsteady* or *transient*
    - often steady flow implies both *steady flow* and *steady state*
5. **Uniform:** no change with respect to position
    - if the flow field in a process is not uniform, it is *distributed*.

Example 1-1: A glass tube is attached to a water pipe. If the water pressure at the bottom of the glass tube is $115\ kPa$ and the local atmospheric pressure is $92\ kPa$, determine how high the water will rise in the tube, in m. Assume $g = 9.8\ m/s^2$ at that location and take the density of water to be $1000\ kg/m^3$.

Step 1: Draw a clearly labeled diagram to represent the system

Step 2: State what the problem is asking you to determine.

Step 3: State all assumptions used during the solution process.

Step 4: Prepare a table of properties.

Step 5: Solve (start by writing a force balance on the system)

Step 6: Clearly identify your answer