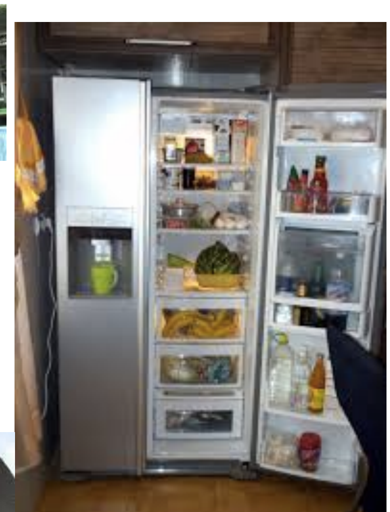
Introduction to Thermodynamics
Definitions

Why take Thermodynamics I?

- Develop basic problem solving, organizational, time management, and professional skills.

- Introduce critical topics for the analysis of thermal-fluid systems:
    - fluid properties
    - incompressible and ideal gas behavior
    - systems and control volumes
    - Conservation of Mass
    - First Law of Thermodynamics
    - Second Law of Thermodynamics
    - Prerequisites for courses on Fluid Mechanics, Heat and Mass Transfer, Gas Dynamics, Power and Refrigeration Cycles, HVAC, Combustion, Acoustics, Statistical Thermodynamics, …
- High level application of these topics to the design and operation of:
    - compressors, pumps
    - turbines
    - heat exchangers
    - evaporators, condensers, boilers, combustors
    - valves
    - nozzles, diffusers
    - thermodynamic cycles for power generation, refrigeration, and heat pumps



Definitions

- Systems (aka closed systems)
- Control volumes (aka open systems)
- Others…

Properties

- Specific volume, pressure, temperature, internal energy, enthalpy, entropy
- Property tables
- Models: incompressible substance and ideal gas

Work

- Pressure (aka "p dV" work)
- Shaft work
- Electrical work
- Spring work

Fundamental Laws

- Conservation of Mass
- The First Law of Thermodynamics
- The Second Law of Thermodynamics

Heat Transfer

Limits of performance

- Thermal efficiency

Problem solving

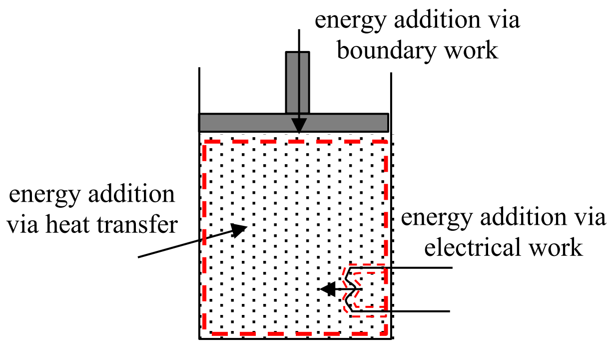
- Systems and control volumes
- Steady and transient analyses
- Cycles

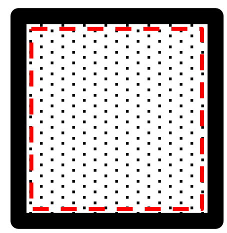
Thermodynamic cycles of practical significance

- Study Tips
    - Read assignments before lecture.
    - Attend lecture, take notes, and participate.
    - Re-read your book and notes after lecture.
    - Practice application of the course concepts:
        - book examples,
        - lecture examples,
        - homework assignments,
        - additional problems from your book, and
        - previous exams.
    - Work problems on blank pieces of paper. Don't just look at the solutions and convince yourself you understand them.
    - Work the problems on your own and only seek help after sincere effort.
    - Don't do too many steps in your head. You'll make fewer mistakes and understand things better if you write down all of your steps, including schematics, basic equations, assumptions, math, and unit conversions.
    - Don't view engineering modeling as "finding the right formula". Engineering modeling involves defining the problem; modeling the physics of the problem while making reasonable assumptions; analyzing the model mathematically to make one or more predictions; and using the prediction(s) to make decisions.
    - Compare, discuss, and defend your solutions to those of classmates.
    - Seek help from the course staff early. You can approach all lecturers and TAs for help.
    - Work neatly and stay organized.

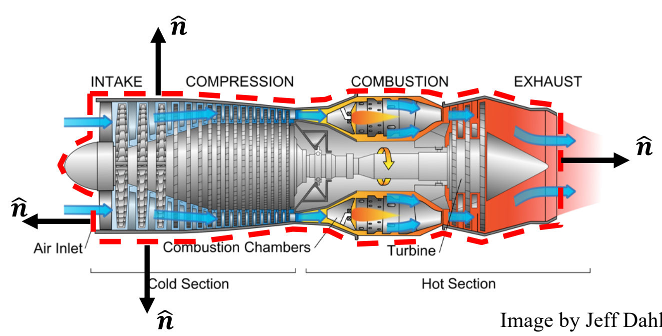
Some Definitions

- A **system** (aka closed system, aka control mass) is a particular <u>quantity of matter</u> chosen for study. The system may change shape and location, but it is always the same matter.
- The **surroundings** consist of everything that is not the system.
- The **boundary** of a system is the surface separating the system and surroundings.
- An **isolated system** is a closed system that does not interact with its surroundings. For example, if the system consists of air in a sealed, rigid, insulated container, then the air may be considered an isolated system since it has no mass, work, or heat transfer with the surroundings.



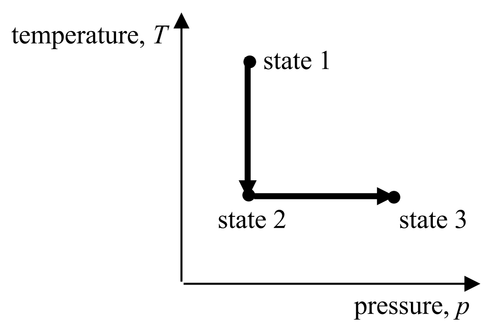


- A **control volume** (CV) (aka open system) is a particular <u>volume</u> chosen for study. Unlike a system, matter may change within a control volume. Note that the control volume does not need to remain fixed in size or location; it may move or change size and shape.
- A **control surface** (CS) is the surface enclosing a control volume. The orientation of the CS at a particular location is given by the direction of its outward-pointing unit normal vector, $\hat{\boldsymbol{n}}$, at that location. The outward-pointing unit normal vector has a magnitude of one, is perpendicular to the control surface, and always points out of the CV.



- **Properties** are macroscopic characteristics of a system. Example properties include mass, volume, energy, pressure, and temperature. A quantity is a property if and only if its change in value between two states is independent of the process between these states. For example, pressure is a property since its value only depends on the current state, but the work done on a system is not since the work depends on the process taken to reach a given state.
    - An **extensive property** is one that depends on the mass in the system. For example, kinetic energy and mass are extensive properties since their values are proportional to the mass in the system.
    - An **intensive property** is one that is independent of the mass in the system. For example, temperature and pressure are intensive properties since their values are independent of how much mass is in the system.
    - An easy way to determine whether a property is extensive or intensive is to divide the system into two parts and see how the property is affected.
    - A **specific property** is an extensive property per unit mass. A specific property is also an intensive property. An example of a specific property is specific volume $v = V/m$ where V is the system property and m is the system mass.

- The **state** of a system is the system's condition or configuration as described by its properties in sufficient detail so that it is distinguishable from other states. Often only a subset of properties is needed to define a state since some properties may be related.
- A **process** is the transformation of a system from one state to another. A few common processes include:
    - <u>isothermal process</u>: A process that occurs at constant temperature.
    - <u>isobaric process</u>: A process that occurs at constant pressure.
    - <u>isochoric or isometric process</u>: A process that occurs at constant volume.
    - <u>adiabatic process</u>: A process in which there is no heat transfer between the system and surroundings.
    - <u>isentropic process</u>: A process that occurs at constant entropy.



    - A process is in **steady state** if the system's state does not change with time.
    - A system is in a state of **equilibrium** if there are no potentials driving the system to another state. Examples of driving potentials include unbalanced forces, unbalanced temperatures, an electric potential (aka voltage).
    - A process **path** is the series of states that a system passes through during some process.
    - A **quasi-equilibrium** process is one where the process proceeds in such a manner that the system remains infinitesimally close to an equilibrium state at all times. One can interpret a quasi-equilibrium process as occurring slowly enough so that the system has time to adjust internally such that properties in part of the system do not change any faster than those properties in other parts of the system.