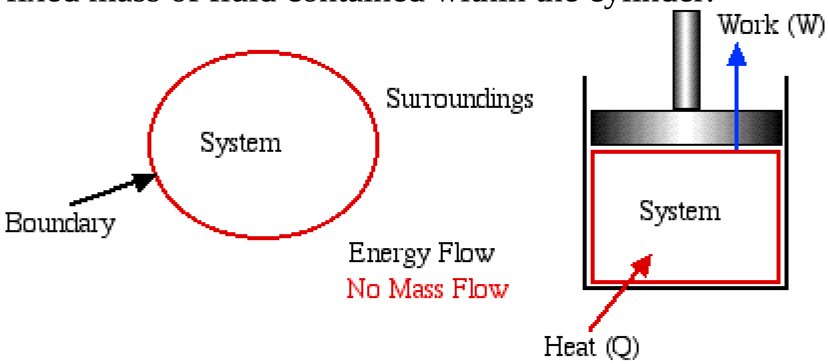
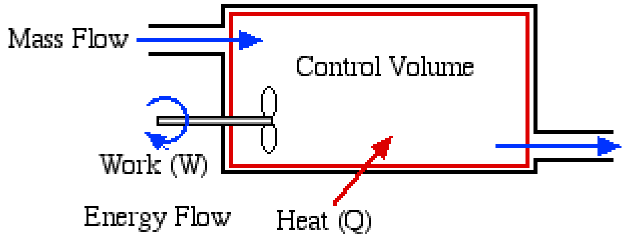
Thermodynamic Systems

For purposes of analysis we consider two types of Thermodynamic Systems:

- **Closed System** - usually referred to as a System or a Control Mass. This type of system is separated from its surroundings by a physical boundary. Energy in transit in the form of Work or Heat can flow across the system boundary, however there can be no mass flow across the boundary. One typical example of a system is a piston / cylinder device in which the system is defined as the fixed mass of fluid contained within the cylinder.



- **Open System** - usually referred to as a Control Volume. In this case, in addition to work or heat, we have mass flow of the working fluid across the system boundaries through inlet and outlet ports. In this course we will be exclusively concerned with steady flow control volumes, in that the net mass of working fluid within the system boundaries remains constant (ie mass flow in [kg/s] = mass flow out [kg/s]). The following sections refer mainly to systems - we will consider control volumes in more detail starting with Chapter 4a.



Properties of a System

The closed system shown above can be defined by its various Properties, such as its pressure (P), temperature (T), volume (V) and mass (m). We will introduce and define the various properties of thermodynamic interest as needed in context. Furthermore the properties can be either Extensive or Intensive (or Specific). An extensive property is one whose value depends on the mass of the system, as opposed to an intensive property (such as pressure or temperature) which is independent of the system mass. A specific property is an intensive property which has been obtained by dividing the extensive property by the mass of the system. Two examples follow - notice that specific properties will always have kilograms (kg) in the units denominater.

$$\text{Specific volume:}\quad v\left[\frac{m^3}{kg}\right] = \frac{\text{volume } V\left[m^3\right]}{\text{mass } m\ [kg]}$$

$$\text{Specific internal energy:}\quad u\left[\frac{kJ}{kg}\right] = \frac{\text{internal energy } U\ [kJ]}{\text{mass } m\ [kg]}$$

One often used exception to the above definitions is the concept of Specific Weight, defined as the weight per unit volume. We will not be using this concept throughout this text.

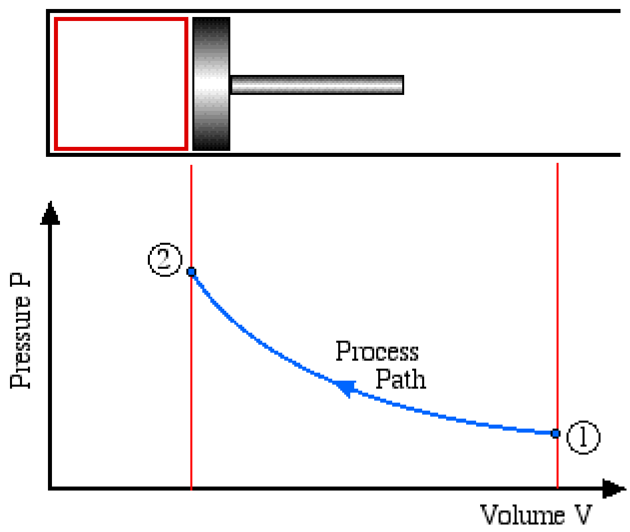
State and Equilibrium

The State of a system is defined by the values of the various intensive properties of the system. The State Postulate states that if two independent intensive property values are defined, then all the other intensive property values (and thus the state of the system) are also defined. This can significantly simplify the graphical representation of a system, since only two-dimensional plots are required. Note that pressure and temperature are not necessarily independent properties, thus a boiling liquid will change its state from liquid to vapor at a constant temperature and pressure.

We assume that throughout the system Equilibrium conditions prevail, thus there are no temperature or pressure gradients or transient effects. At any instant the entire system is under chemical and phase equilibrium.

Process and Cycle

A Process is a change of state of a system from an initial to a final state due to an energy interaction (work or heat) with its surroundings. For example in the following diagram the system has undergone a compression process in the piston-cylinder device.



The Process Path defines the type of process undergone. Typical process paths are:

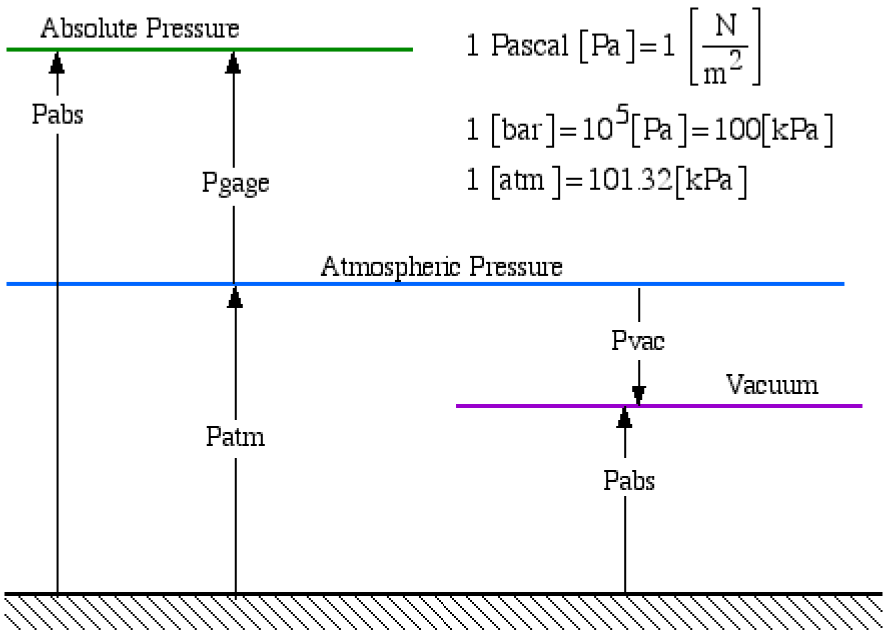
- Isothermal (constant temperature process)
- Isochoric or Isometric (constant volume process)
- Isobaric (constant pressure process)
- Adiabatic (no heat flow to or from the system during the process)

We assume that all processes are Quasi-Static in that equilibrium is attained after each incremental step of the process.

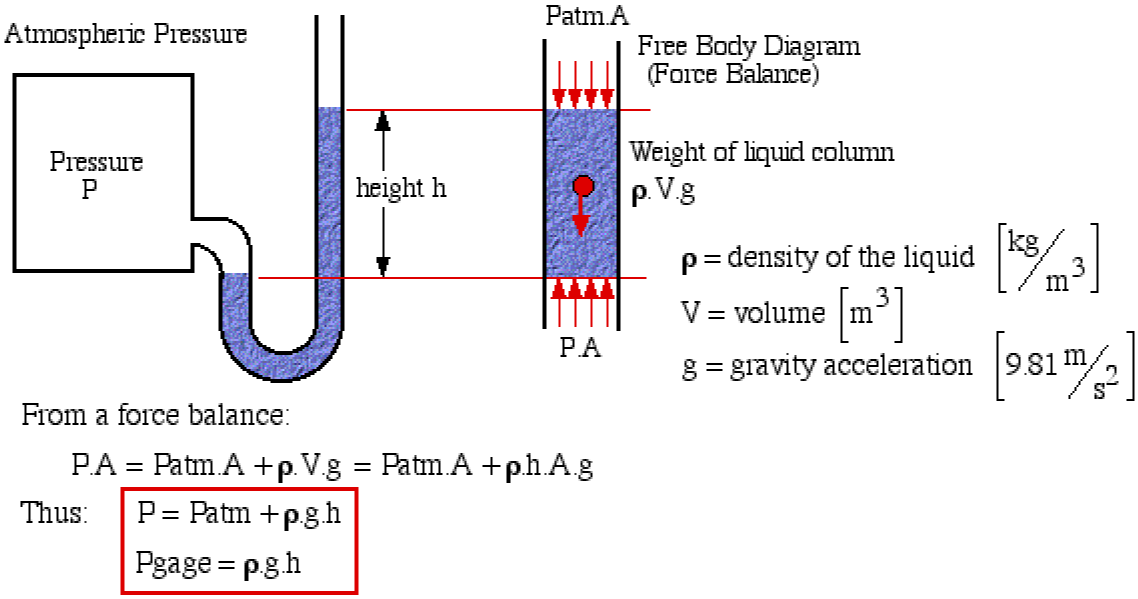
A system undergoes a Cycle when it goes through a sequence of processes that leads the system back to its original state.

Pressure

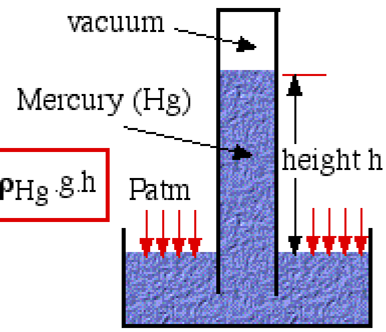
The basic unit of pressure is the Pascal [Pa], however practical units are kiloPascal [kPa], bar [100 kPa] or atm (atmosphere) [101.32 kPa]. The Gage (or Vacuum) pressure is related to the Absolute pressure as shown in the diagram below:



The basic method of measuring pressure is by means of a Manometer, as shown below:



The atmospheric pressure is measured by means of a Mercury Barometer as follows:



$$P_{atm} = \rho_{Hg}\, g\, h$$

Density of Mercury: $\rho_{Hg} \approx 13,600 \left[\frac{kg}{m^3}\right]$

$$\rho_{Hg} = (13595 - 2.47\ T[^\circ C]) \left[\frac{kg}{m^3}\right] \text{ (empirical)}$$

Standard Atmosphere is defined as:

$$h = 760mm\ (0.760m)$$
$$P_{atm} = 101.32\,[kPa]$$

Source: http://www.ohio.edu/mechanical/thermo/Intro/Chapt.1_6/Chapter1.html