Chemical Engineering (Thermodynamics I) (UCH305)

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THAPAR INSTITUTE
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Lecture 3

Thermodynamic system & properties

Outline

- Thermodynamic system
- Thermodynamic properties
- Thermodynamic equilibrium

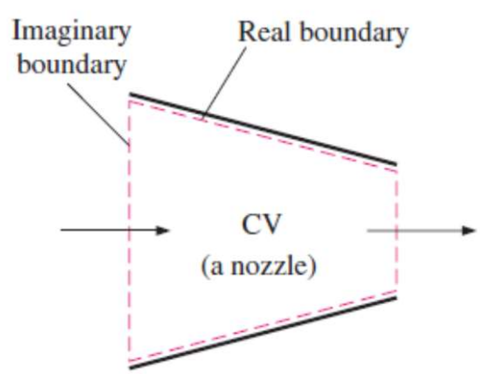
Basic definitions

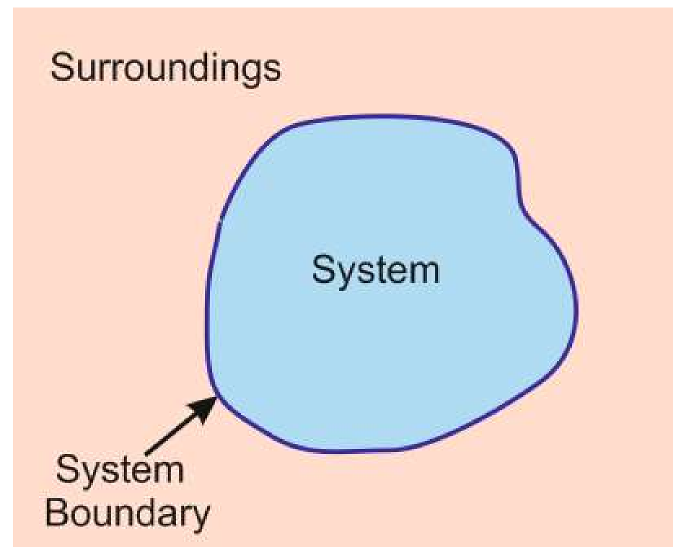
System- A system is defined as a *quantity of matter or a region in space chosen for study*.

Surrounding- The mass or region *outside the system* is called the surroundings.

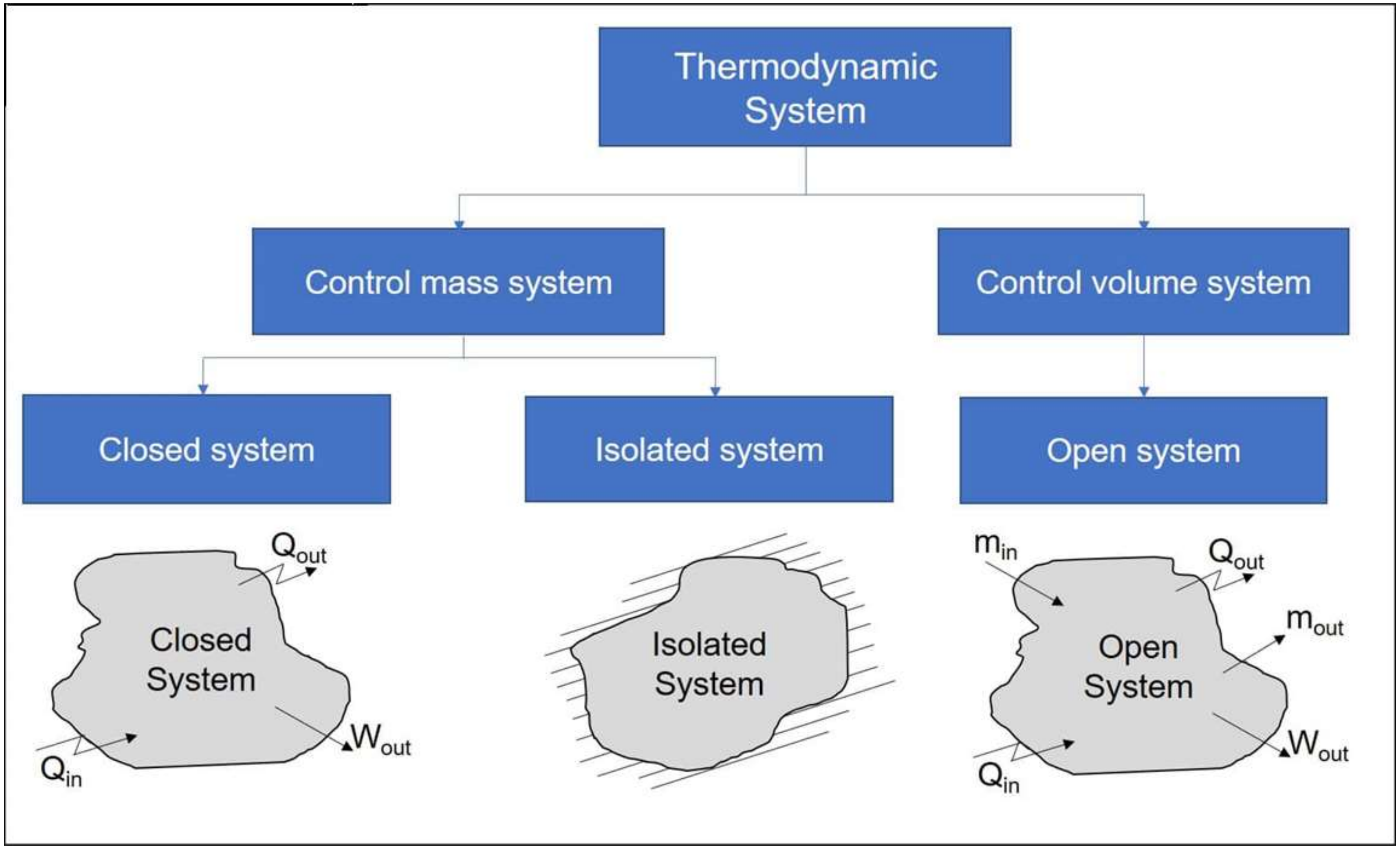
Boundary- The *real or imaginary surface* that separates the system from its surroundings is called the boundary.

- *zero thickness (zero mass & volume)*
- *fixed or movable*
- *Flexible or rigid*
- *Insulated/adiabatic*





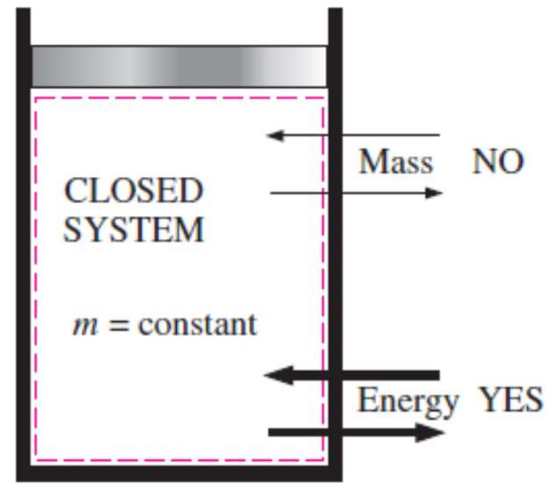
Types of Thermodynamic systems

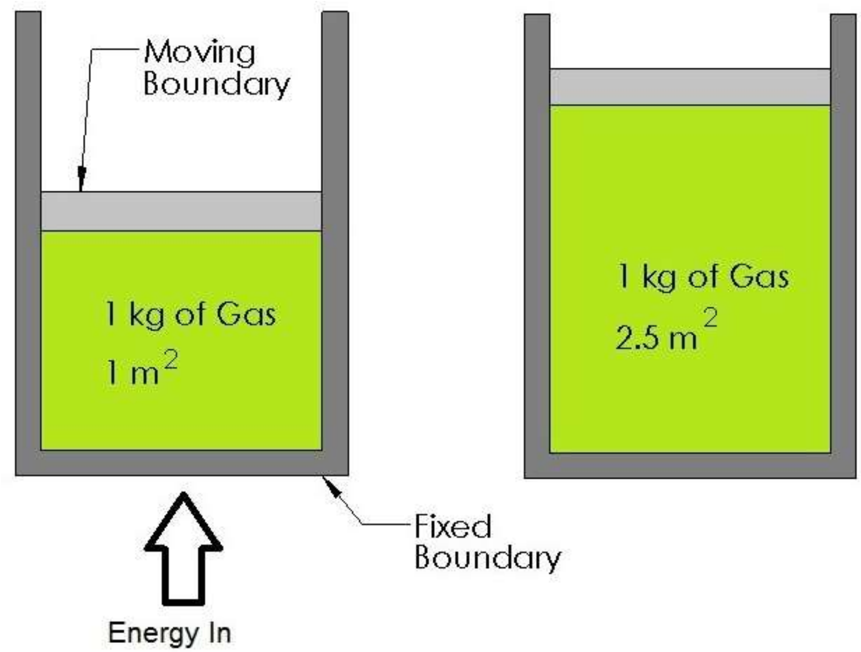


Systems may be considered to be *closed* or *open,* depending on whether a *fixed mass* or a *fixed volume* in space is chosen for study.

Closed system *(control mass)*

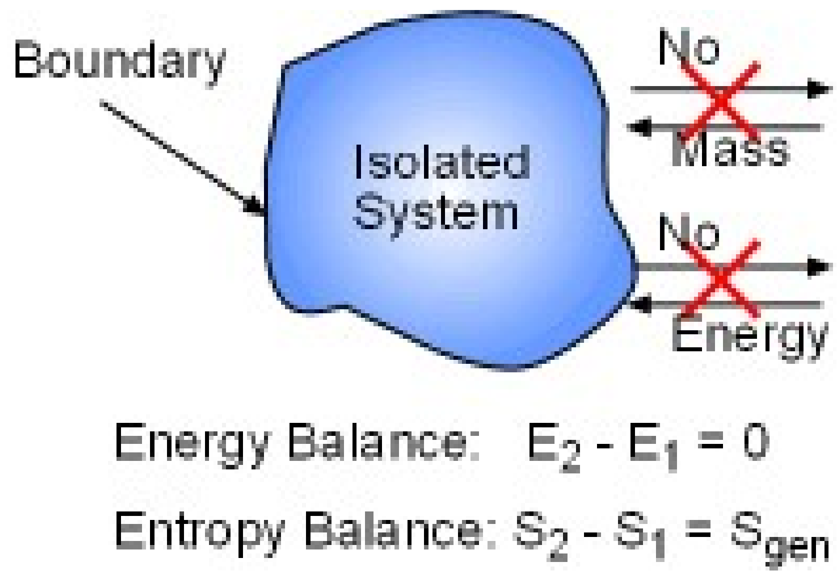
- Consists of a fixed amount of mass.
- No mass can enter or leave a closed system.
- Energy (in the form of heat or work) can cross the boundary.
- Volume of a closed system does not have to be fixed (*movable boudnary*).





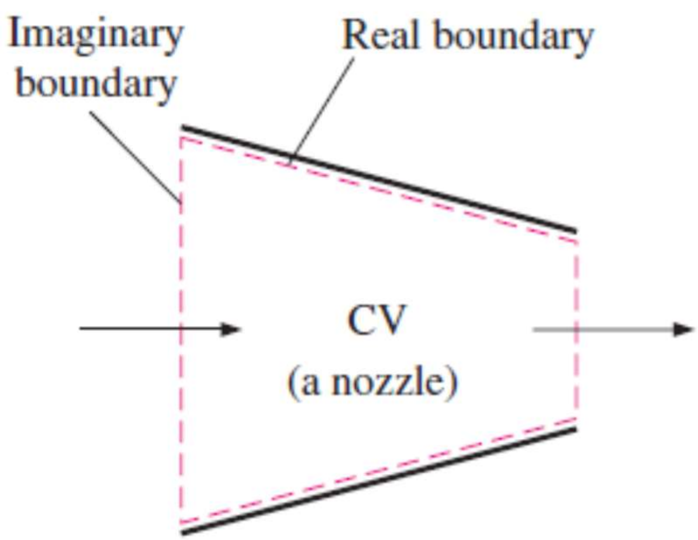
Isolated system

Isolated system- If, as a special case, even energy is not allowed to cross the boundary, that system is called an ***isolated system*.**

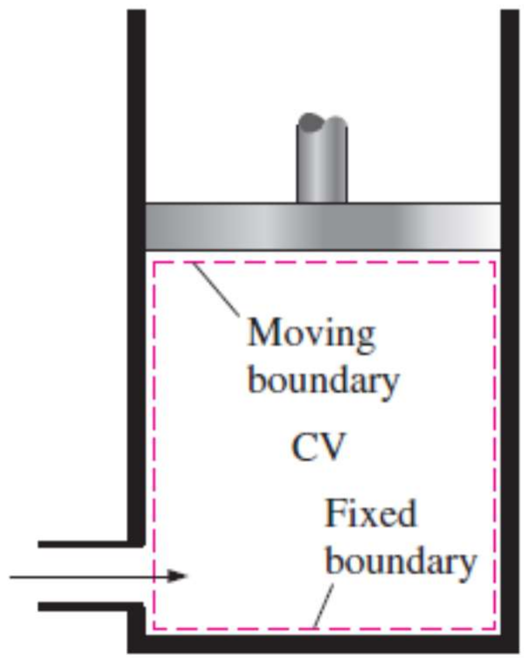


Open system *(control volume)*

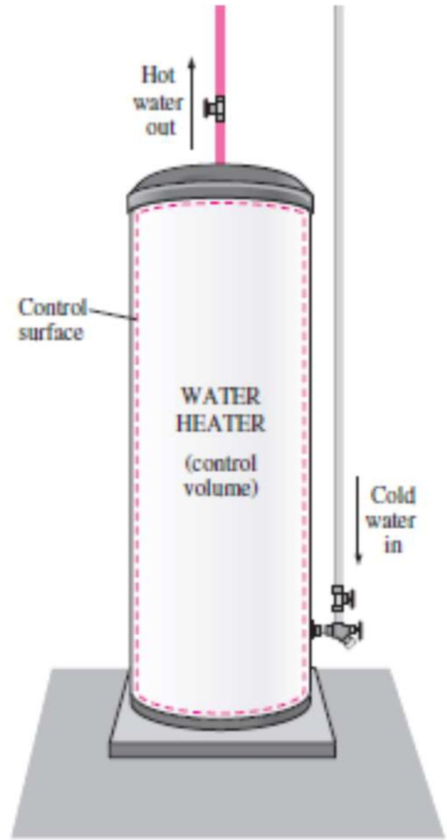
- Both *mass* and *energy* can cross the boundary of the control volume. Examples: compressor, nozzle, turbine



A control volume with real and imaginary boundaries



A control volume with fixed and moving boundaries



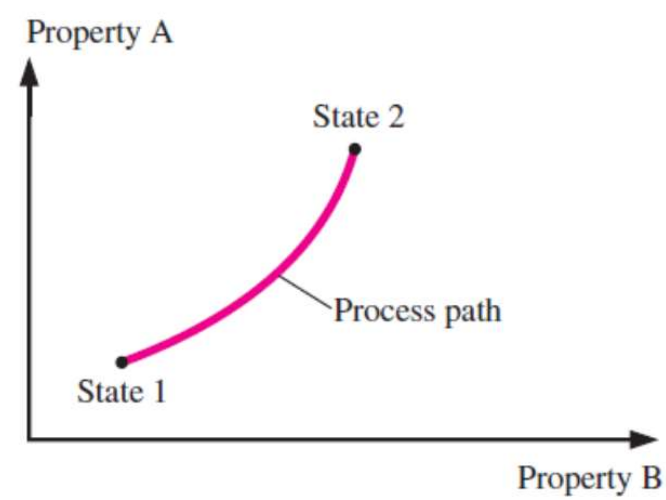
Properties of a system

- Any characteristic of a system is called a property.

- A property can be defined as any quantity that depends on the state of the system and is independent of the path by which the system arrived at the given state.

- Property is any quantity whose changes are defined only by the end states and by the process

- Some familiar properties are:
  - Temperature, T
  - Pressure, p
  - Volume V, and
  - Mass, m,



- Less familiar properties are:
  - Density, ρ
  - Viscosity, μ
  - Thermal conductivity, k
  - Velocity, v
  - Elevation, h
  - Modulus of elasticity, E
  - Thermal expansion coefficient, β
  - Electric resistivity, ρ

Types of Thermodynamic Properties

Thermodynamic properties can be divided into TWO general classes:

- Intensive properties: independent of the mass of the system.
- Extensive properties: dependent on the mass, or, size, or varies directly with the mass.

Intensive properties

Examples:

- Temperature, T
- Pressure, p
- Density, ρ

Extensive properties

Examples:

- Total mass, m
- Total volume, V
- Total momentum

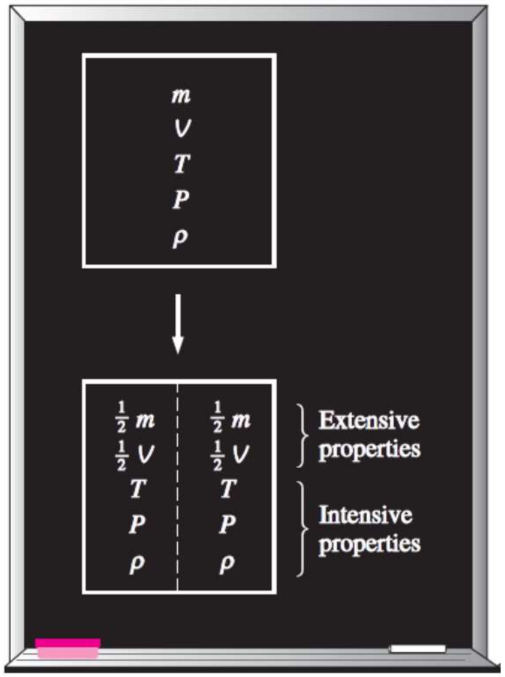
Extensive properties per unit mass is also called as intensive property

- Example: specific volume

How?

- An easy way to determine whether a property is intensive or extensive is to divide the system into two equal parts with an imaginary partition, as shown in figure.

Criterion to differentiate intensive and extensive properties. →



- Each part will have the same value of intensive properties as the original system, but half the value of the extensive properties.

- Generally, uppercase letters are used to denote extensive properties (with mass m being a major exception), and lowercase letters are used for intensive properties (with pressure P and temperature T being the obvious exceptions).

- Extensive properties per unit mass are called **specific properties**.

- Some examples of specific properties are specific volume ($v = V/m$) and specific total energy ($e = E/m$).

Density

- **Density** is defined as *mass per unit volume.*
  - *Density:* $\rho = m/V$ *(kg/m³)*

- The reciprocal of density is the **specific volume** v, which is defined as *volume per unit mass*.
  - Specific volume: $v = V/m = 1/\rho$ (m^3/kg)

- For a differential volume element of mass δm and volume δV, density can be expressed as:
  - Density, $\rho = \delta m/\delta V$

Specific Gravity

- ✓ Sometimes the density of a substance is given relative to the density of a well-known substance.
- ✓ Then it is called **specific gravity**, or **relative density**.
- ✓ It is defined as *the ratio of the density of a substance to the density of some standard substance at a specified temperature* (usually water at 4°C, for which $\rho_{water} = 1000\ kg/m^3$).
  - ✓ *Specific gravity:* $SG = \rho/\rho_{water}$
- ✓ Substances with specific gravities less than 1 are lighter than water, and thus they would float on water.

Specific gravity values (examples)

Fluid	Temperature (^oC)	Specific gravity (SG)
Mercury	25	13.633
Acetone	25	0.787
Alcohol, ethyl (ethanol)	25	0.787
Oil, Castor	25	0.959
Dichlorodifluoromethane refrigerant R-12	25	1.315
Sea water	25	1.028

Pressure

- In most thermodynamic investigations, absolute pressure (total pressure) is considered.

- Pressure gauges and vacuum gauges, however, read the difference between the absolute pressure and the atmospheric pressure existing at the gauge.

- Pressures below atmospheric and slightly above atmospheric, the pressure differences are measured with a manometer, which contains water, mercury, alcohol, oil, or other fluids.

- Absolute pressure = Atmospheric pressure + Pressure gauge pressure
  - $p_{absolute} = p_{atmospheric} + p_{pressure\ gauge}$
- Absolute pressure = Atmospheric pressure – Vacuum gauge pressure
  - $p_{absolute} = p_{atmospheric} - p_{vacuum\ gauge}$

Figure - Pressures

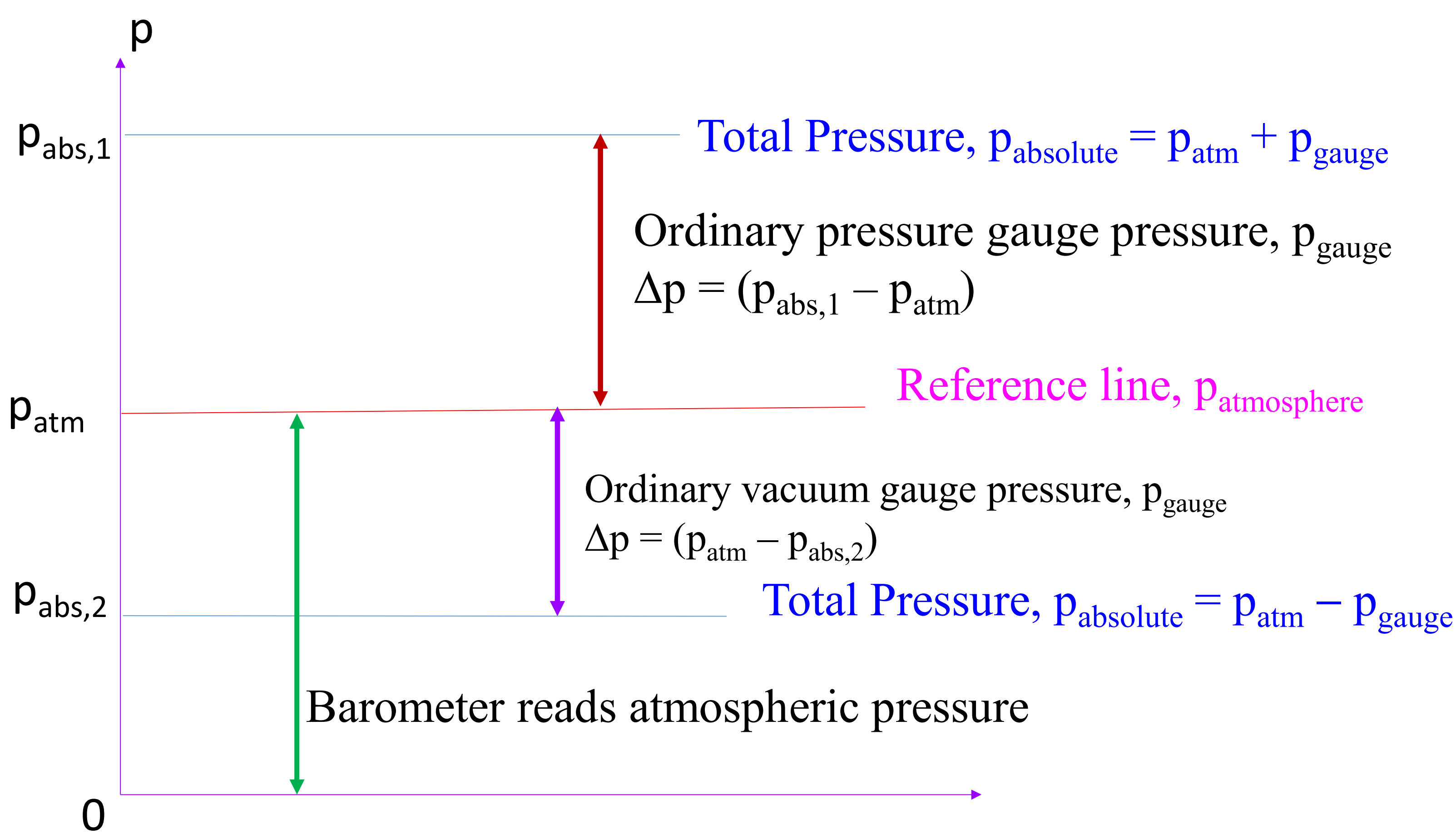
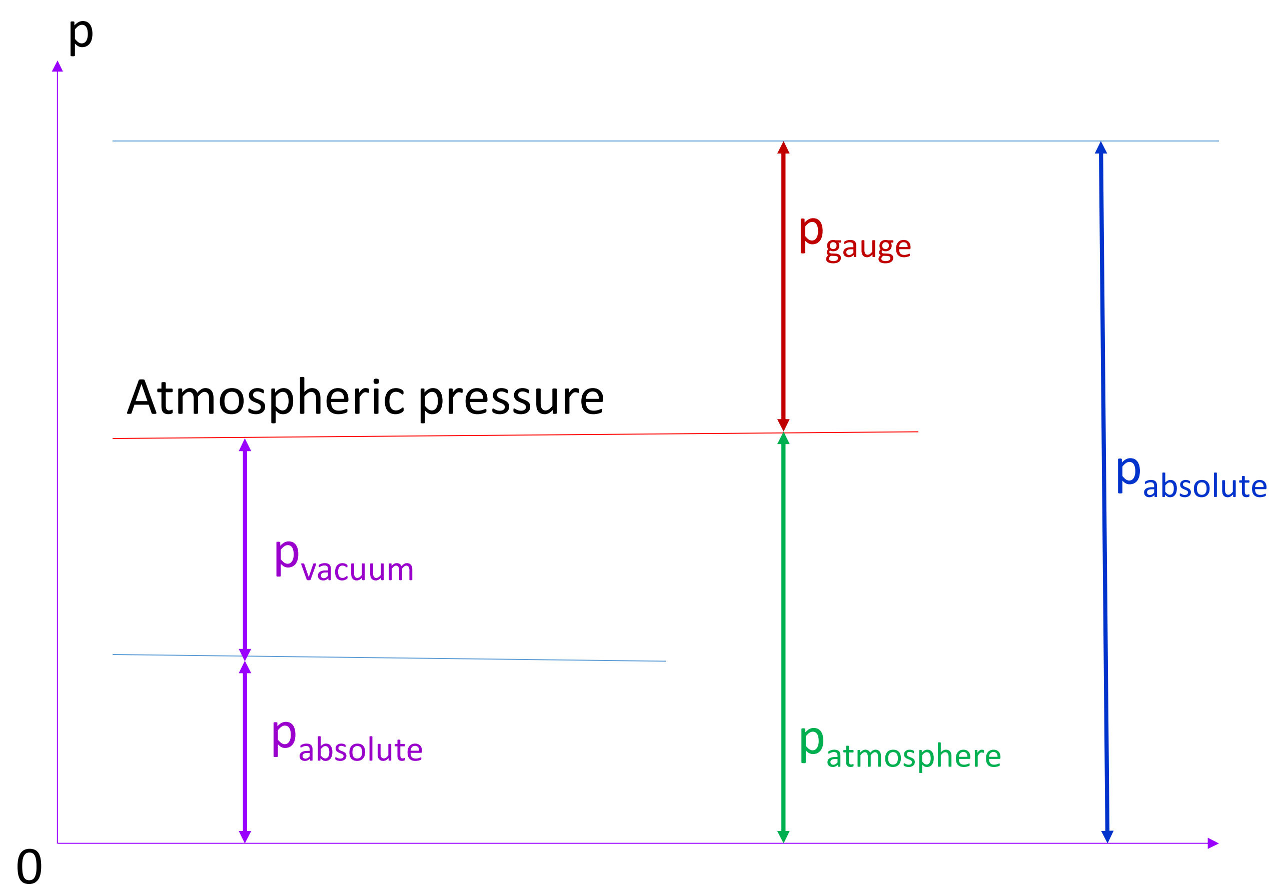


Figure - Pressures



Pressure - Pressure & Vacuum Gauges

Atmospheric Pressure

- Atmospheric pressure is measured by a device called a **barometer,** thus, the atmospheric pressure is often referred to as the ***barometric pressure***.
- The atmospheric pressure can be measured by inverting a mercury-filled tube into a mercury container that is open to the atmosphere as shown in figure.
- The pressure at point B is equal to the atmospheric pressure.
- The pressure at C can be taken to be zero since there is only mercury vapor above point C and the pressure is very low relative to P_{atm} and can be neglected to an excellent approximation.

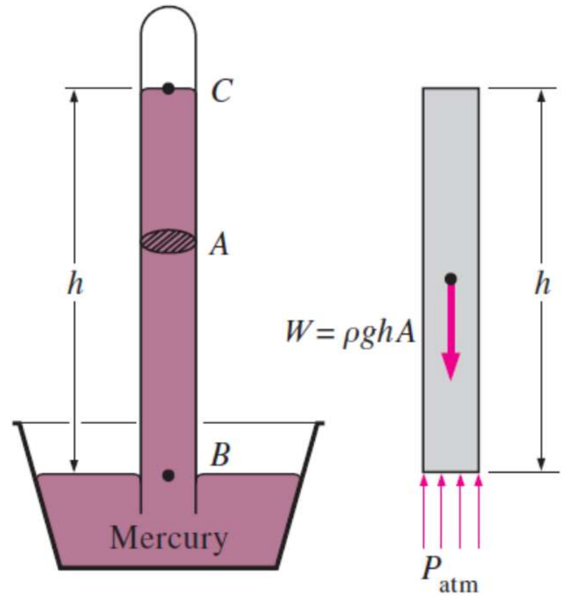
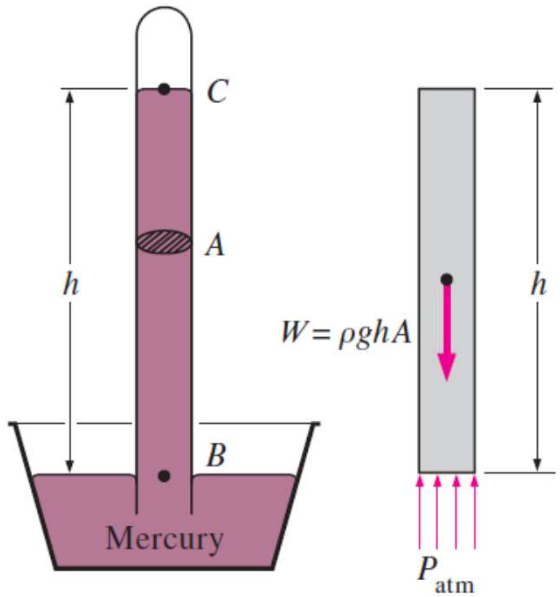


Figure: The basic barometer

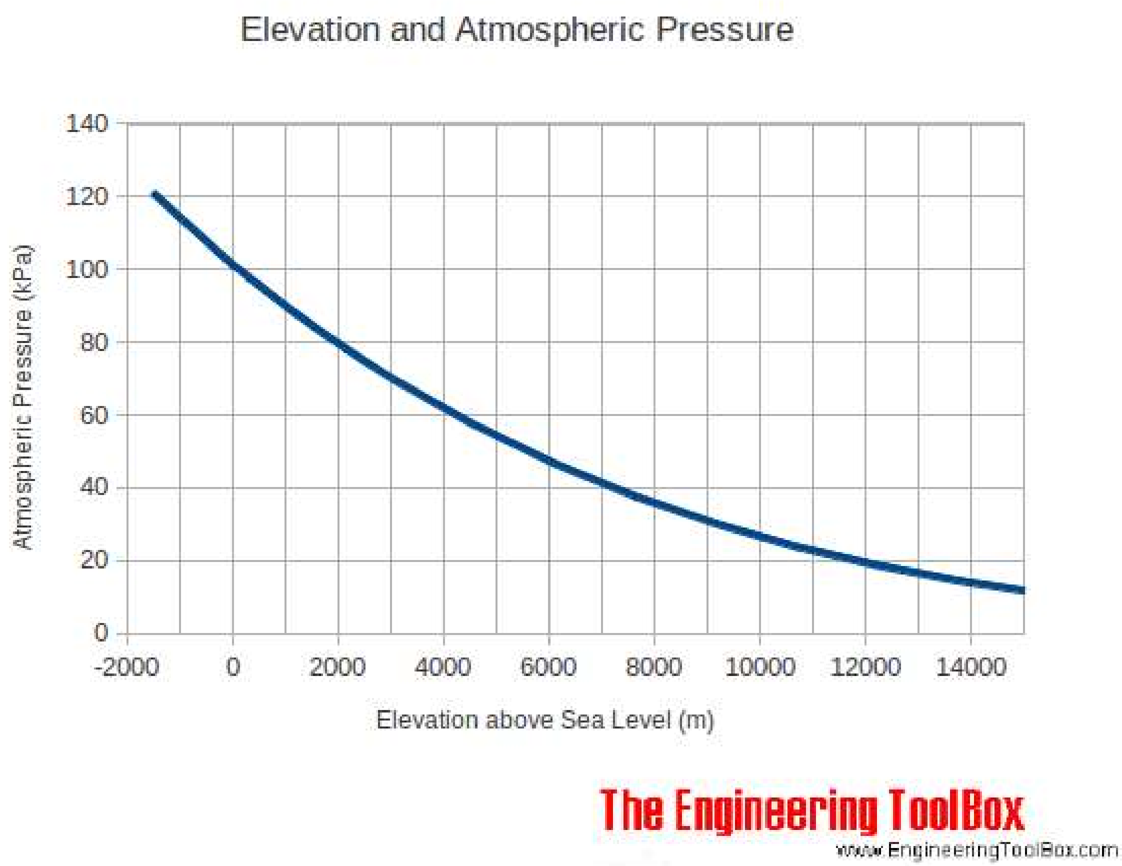
Atmospheric Pressure
(Barometer)



- Writing a force balance in the vertical direction gives:

$$P_{atm} = \rho g h$$

- The unit of mmHg is also called the **torr**.
- Therefore, 1 atm = 760 mmHg = 760 torr.


Elevation and Atmospheric Pressure
Atmospheric Pressure (kPa)
140
120
100
80
60
40
20
0
-2000
0
2000
4000
6000
8000
10000
12000
14000
Elevation above Sea Level (m)
The Engineering ToolBox
www.EngineeringToolBox.com

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3. *Nag, P.K., Engineering Thermodynamics, Tata McGraw Hill (2008) 3rd ed.*
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Thank you for your Patience