MENG 245 – Thermodynamics 1

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Book: **Thermodynamics: an Engineering Approach, Yunus A. Çengel, M. A. Boles, McGrawHill**

“Property Tables Booklet” by the same authors can be useful too

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Grading Policy

Mid-Term.........30%

Final Exam......50%

Quizes.............10%

Labs.................10%

NG Policy

1. **Students who do not attend any two of the above assessment activities (such as labs, mid-term exam, etc.)**
2. **Students attending less than 70% of the classes and/or labs**

will be given NG (Nil Grade).

CHAPTER

1

Basic Concepts of Thermodynamics

Thermodynamics can be defined as the science of energy.

Conservation of energy:

Simply states that during an interaction, energy can change from one state to another but that the total amount of energy remains constant. (Energy can not be created or destroyed)

Thermodynamics deals with :

- **The conversion of energy from one to another.**
- **Various properties of substances.**
- **The changes in properties due to energy transformations.**

Some basic laws are obtained from experimental observations:

- **First Law of Thermodynamics(expresses the conservation of energy)**
- **Second Law of Thermodynamics (asserts that processes occur in a certain direction but not in inverse)**

Some SI and English units:

Basic dimensions	Mass(m)	Length(L)	Time(t)
SI units	Kilogram(kg)	Meter(m)	Second(s)
English units	Pound-mass(lbm)	Foot(ft)	Second(s or sec)

1 lbm = 0.45359 kg
1 ft = 0.3048 m

Force = (Mass)(Acceleration)

$F = m\ a$ **(SI unit is in Newton, N)**

(English unit is Pound-force, lbf)

So:

1 Newton is the force required to accelerate a mass of 1kg at a rate of 1 m/s^2

The gravitational force applied to the body is called weight.

$W = m\ g$ (N)

m => mass

g => local gravitational acceleration

The weight of a unit volume of a substance is called the specific weight(w).

$w = \rho g$ (ρ is density)

Work=(Force)(Distance)

1 Joule = 1J=1 N.m (More commonly in the form of kilojoule)

The energy unit in English system is BTU(British Thermal Unit)

=> Energy required to raise the temperature of 1 lbm of water at 68 ^{o}F by 1^{o}F (1BTU=1.055kJ)

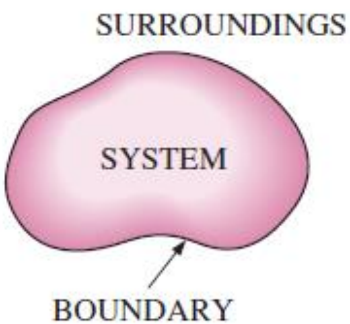
Dimensional Homogeneity:

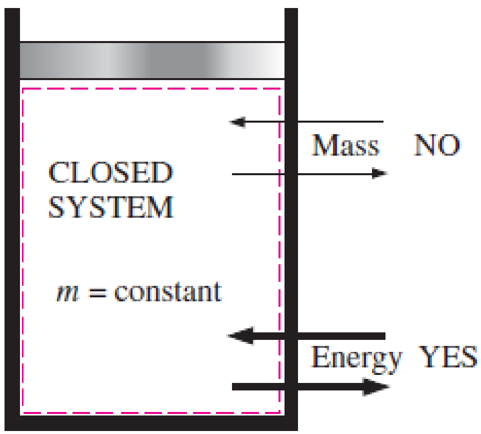
In engineering, equations must be dimensionally homogeneous i.e, every term in an equation must have the same units.

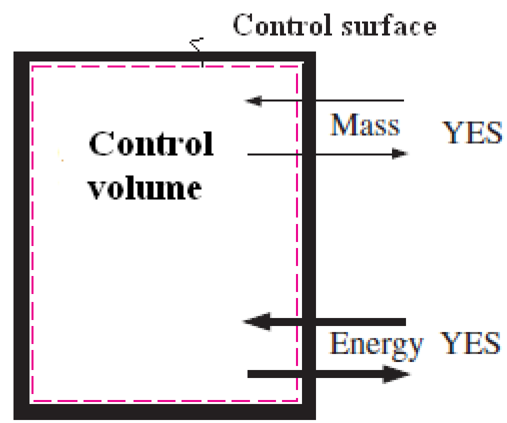
E=25 (kJ) + 7 (kJ/kg) ***is not correct!!!***

Closed and Open Systems

Thermodynamic system
a collection of matter within prescribed and identifiable boundaries







Closed and Open Systems

Surroundings: the region outside the system

boundary : imaginary surface that separates the system from its surroundings (can be fixed or movable)

Closed system (or control mass) : consists of a fixed amount of mass, and no mass can cross the boundary. But energy, in the form of heat or work can cross the boundary.

Open system (or a control volume) : is a property selected region in space involving mass transfer across the boundaries.

Isolated system : Neither mass or energy is allowed to cross the boundary

Forms of Energy

(thermal, mechanical, kinetic, potential, electric, magnetic, chemical and nuclear)

E = the sum of all forms of energy
e = E/m (kJ/kg)

Thermodynamics deals with the change of energy instead of its absolute value.
It is appropriate to assign the total energy of a system a value of zero (E=0) at some convenient reference point.

Forms of Energy

Kinetic energy

K.E. = $\frac{mV^2}{2}$ **(kJ)**

or, on a unit mass basis k.e. = $\frac{V^2}{2}$ **(kJ/kg)**

(V denotes the velocity of the system relative to some fixed reference frame)

Forms of Energy

Potential energy

P.E. = m g z **(kJ)**

or, on a unit mass basis, p.e. = g z **(kJ/kg)**

(where g is the gravitational acceleration and z is the elevation w.r.t. some reference point)

Forms of Energy

Internal energy

Is related to the molecular structure and the molecular activity of the system. The degree of molecular activity, which is said to be the internal energy is denoted by U (kJ).

The magnetic, electric , and surface tension effects are not significant for the purpose of this course and are not considered here.

The total energy of a system

$$E = U + KE + PE = U + \frac{mV^2}{2} + m\,g\,z \qquad \text{(kJ)}$$

or, on a unit mass basis,

$$e = u + ke + pe = u + \frac{V^2}{2} + g\,z \qquad \text{(kJ/kg)}$$

Properties of a system

Any characteristic of a system is called a property (e.g. pressure P, temperature T, volume V, mass m, viscosity, thermal conductivity, etc)

Some properties are defined in term of others, e.g. $\rho = \dfrac{m}{V}$

E.g. specific volume $v = \dfrac{V}{m} = \dfrac{1}{\rho}$

Intensive properties – are those properties which are independent of the size of the system, such as T, P, ρ, e, u

Extensive properties – vary directly with the size – or extent – of the system. e.g., m, V, E, U

Specific properties – extensive properties per unit mass e.g., specific energy $e = E/m$, specific internal energy, $u = U/m$

State of the system:

The set of properties which describe the condition of the system, is called the state of the system.

Steady state:

A system is said to be at steady state if none of its properties changes with time.

Equilibrium- a condition of balance

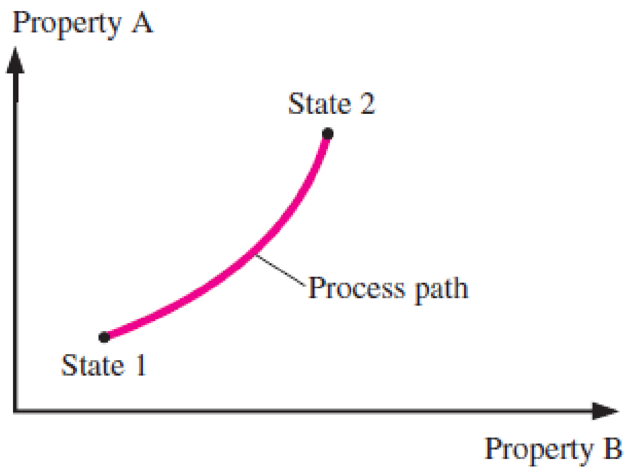
Thermodynamics deals with equilibrium states

A system which is in equilibrium experiences no changes when it is isolated from its surroundings.

Processes and Cycles

a <u>process</u> is a transformation from one equilibrium sate to another.

A path is the series of states through which a system passes



Processes and Cycles

A quasi equilibrium (or quasi static) process is one in which the deviation from thermodynamic equilibrium is infinitesimal, and all the states the system passes through, is considered as equilibrium states.

Although ideal, engineers are interested in this process since,
a) they are easy to analyze
b) work producing devices deliver the most work

e.g.
A system that may undergo a quasi equilibrium process

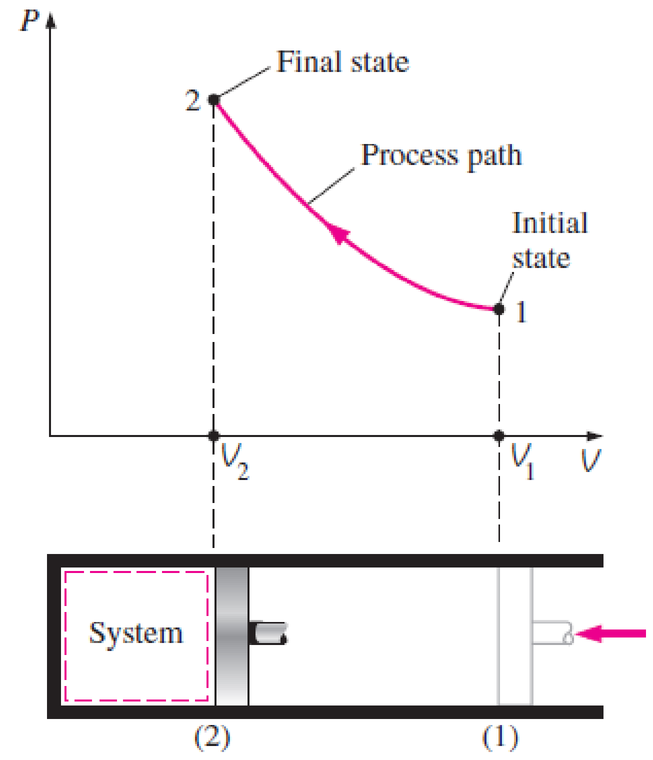
Processes and Cycles

A process diagram:

Isothermal process: process at constant temperature.

Isobaric process: process at constant pressure.

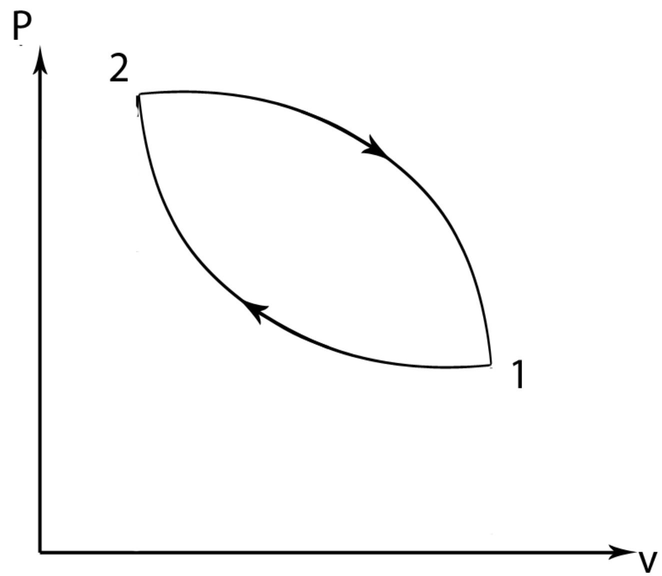
Isochoric (or isometric) process: process at constant volume.

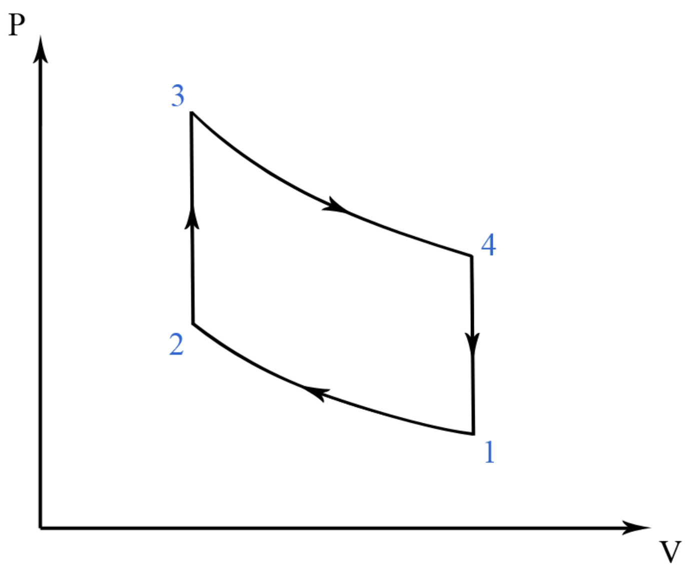


Processes and Cycles

a cycle: the system returns to initial state at the end of the process.

Initial state = Final state





The State Postulate

The state of of a simple compressible system is completely specified by two independent, intensive properties.
E.g. temperature and specific volume.

Note: temperature and pressure are dependent during a phase change process.
(at sea level (P=1 Atm) water boils at 100^{o}C.)

PRESSURE

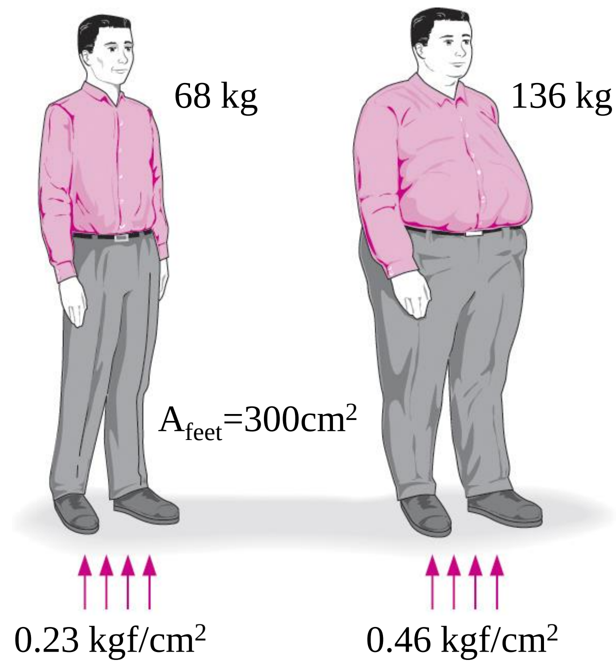
Pressure: A normal force exerted by a fluid per unit area

$$1 \text{ Pa} = 1 \text{ N/m}^2$$

$$1 \text{ bar} = 10^5 \text{ Pa} = 0.1 \text{ MPa} = 100 \text{ kPa}$$

$$1 \text{ atm} = 101{,}325 \text{ Pa} = 101.325 \text{ kPa} = 1.01325 \text{ bars}$$

$$1 \text{ kgf/cm}^2 = 9.807 \text{ N/cm}^2 = 9.807 \times 10^4 \text{ N/m}^2 = 9.807 \times 10^4 \text{ Pa}$$
$$= 0.9807 \text{ bar}$$
$$= 0.9679 \text{ atm}$$



P=68/300=0.23 kgf/cm^2

The normal stress (or "pressure") on the feet of a chubby person is much greater than on the feet of a slim person.

Some basic pressure gages.

In the English system, the unit of pressure is pound-force per square inch,
lbf/in or psi
1 atm = 14.696 psi

Pressure

Atmospheric pressure is used as a reference to define other pressures:

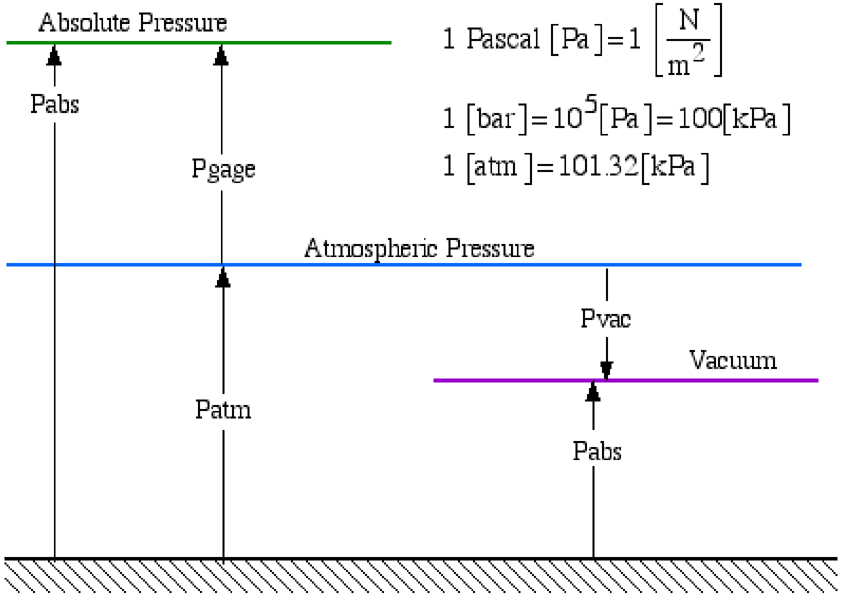
(absolute pressure) = (atmospheric pressure) + (Gage pressure)

Total pressure or actual pressure (absolute pressure)

pressure measuring device reads zero in the atmosphere (Gage pressure)

When the local atmospheric pressure is greater than the pressure in the system, the term <u>vacuum pressure</u> is used.

(vacuum Pressure) = (atmospheric pressure) – (absolute pressure)



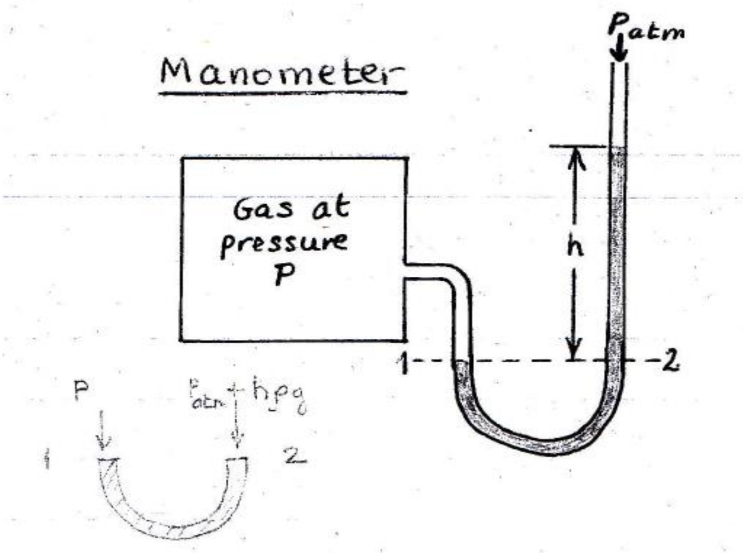
$$1 \text{ Pascal } [Pa] = 1 \left[\frac{N}{m^2}\right]$$

$$1 \; [bar] = 10^5 [Pa] = 100 [kPa]$$

$$1 \; [atm] = 101.32 [kPa]$$

In the tables and in this course absolute pressure is used and P will always denote absolute pressure.

Manometer



Since gravitational effects of gases are negligible, P is the same every where in the tank at position 1

$$P = P_1$$

Since position 2 at the same level is 1

$$P_1 = P_2$$

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

Alternitavely free body diagram of column h gives:

$$AP = AP_{atm} + W$$

$$\downarrow$$

mg = ρVg = ρAhg

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

Pressure difference $\Delta P = P - P_{atm} = \rho g h$

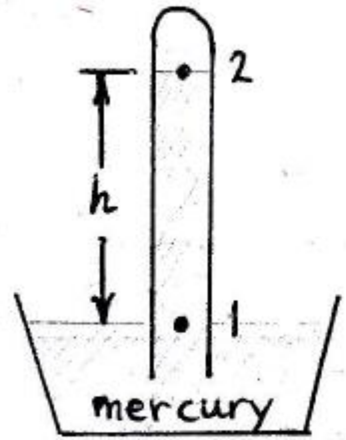
Barometer

Measures the atmospheric pressure.

P_{atm} **is often called the barometric pressure.**

Pressure at point 1 = atmospheric pressure

Pressure at point 2 = 0 (since above 2, there is only mercury vapor)



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

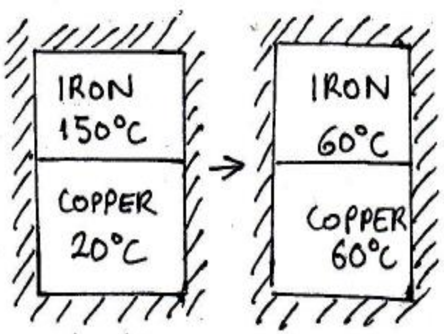
Standard atmosphere is defined as h= 760 mmHg at 0°C and $\rho_{Hg} = 13.595\ {}^{kg}/_{m^3}$ $\quad g = 9.807\ {}^{m}/_{s^2}$

(for water the same pressure is obtained at *h*=10.3 m)

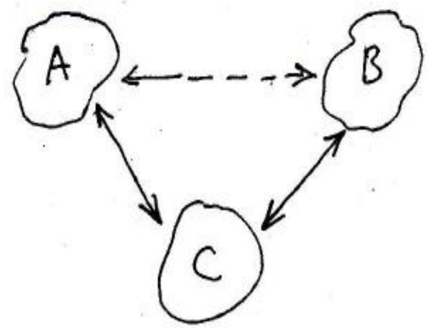
Temperature and The Zeroth Law of Thermodynamics

Temperature is a measure of the "hotness" or "coldness" of a body.

Zeroth law $\longrightarrow$ **Two bodies are in thermal equilibrium if both have the same temperature reading even if they are not in contact.**



Two bodies reaching thermal equilibrium



Two systems A and B in thermal equilibrium with system C are also in thermal equilibrium between themselves.

Temperature Scales

Celcius Scale

Anders Celcius, devided the temperature scale into 100 equal parts, assigning the value 0 and 100^{o}C to ice and steam points.

Farenheit scale

On the Farenheit scale, the values 32 and 212 are assigned to ice and steam point.

Absolute Scale

The absolute temperature scale in the SI units is kelvin scale.
The temperature measured at the absolute vacuum is designated the zero (which would read -273.15^{o}C with the celcius scale.)

Gas
P=0 kPa
T= 0 K
T=-273.15ºC

$$T\ (\mathrm{K}) = T\ (^{\circ}\mathrm{C}) + 273.15$$

In the english system, the absolute temperature scale is the Rankine scale.

$$T\ (\mathrm{R}) = T\ (^{\circ}\mathrm{F}) + 459.67$$

The other relations: $T\ (\mathrm{R}) = 1.8\ T\ (\mathrm{K})$

$$T\ (\mathrm{F}) = 1.8\ T\ (^{\circ}\mathrm{C}) + 32$$

Note that the magnitudes of each division of 1 K and 1 ºC is

Identical $\longrightarrow$ $\Delta T\ (\mathrm{K}) = \Delta T\ (^{\circ}\mathrm{C})$

similarly $\longrightarrow$ $\Delta T\ (\mathrm{R}) = \Delta T\ (^{\circ}\mathrm{F})$