Thermodynamics ENME 333
Chapter 2
Concepts and Definitions

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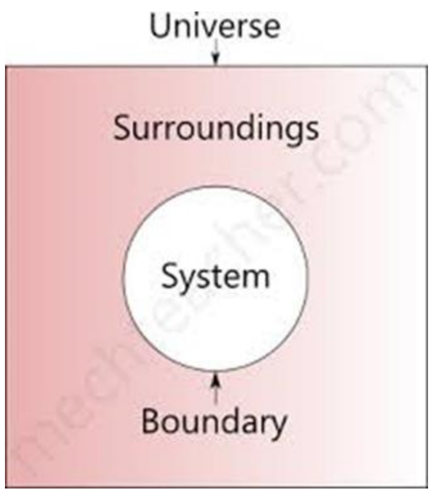
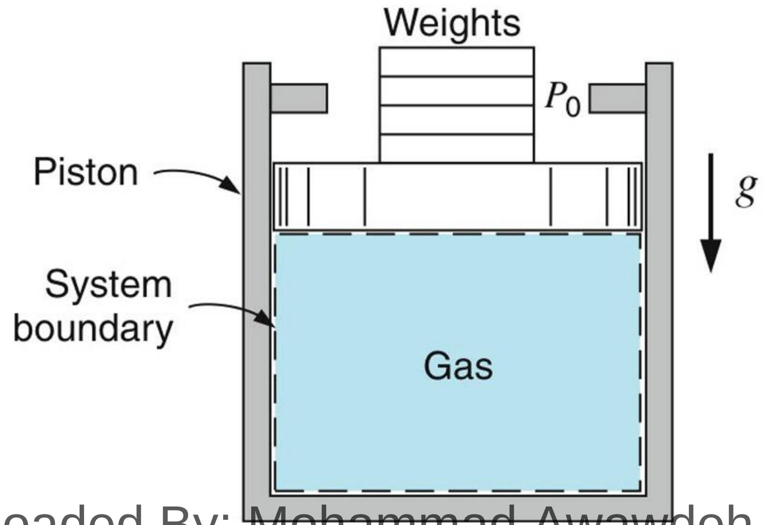
Outline

- Systems
- Control mass and control volume
- Property and state
- Process and cycle
- Specific volume, pressure, temperature
- Zeroth Law of thermodynamics

Thermodynamic system

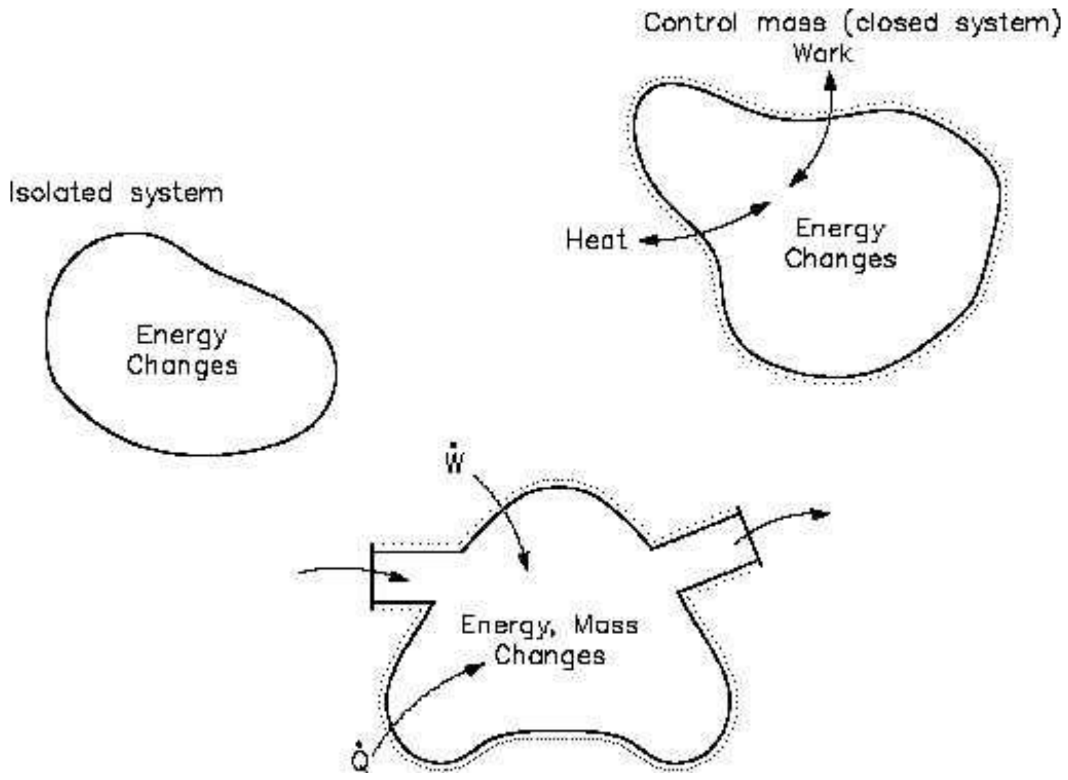
- **Thermodynamic system**: is a fixed quantity of mass or a region in space upon which attention is focused for purpose of analysis.
- **Surroundings**: everything external to the thermodynamic system. Usually the immediate surroundings are of concern.
- **System boundary**: System is separated from surroundings by the system boundary. System boundary might be real physical boundaries or imaginary ones assumed for the purpose of our analysis.





Systems types

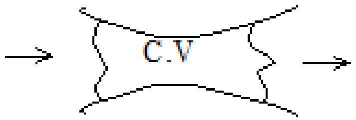
- Thermodynamic systems are of three types:
  - close system or control mass , cm
  - open system or control volume, CV
  - isolated system.



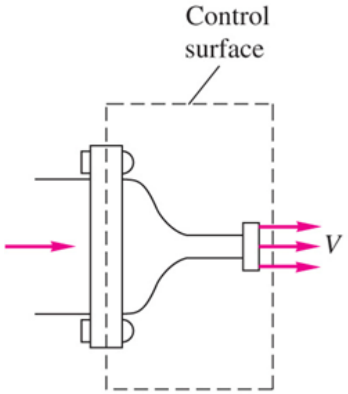
Control mass

- A fixed quantity of matter is considered for analysis. This fixed mass of mater is separated from the surrounding by real physical boundaries. The boundaries can be movable that change shape. The mass inside the system is constant and it contains the same matter.
- Energy may cross the boundary in forms of work or heat, matter cannot cross the system boundaries.
- A block of iron can be considered as a control mass, a bucket of water is another example of a control mass.
- *Suggest some control mass systems and specify their boundary and surroundings?*

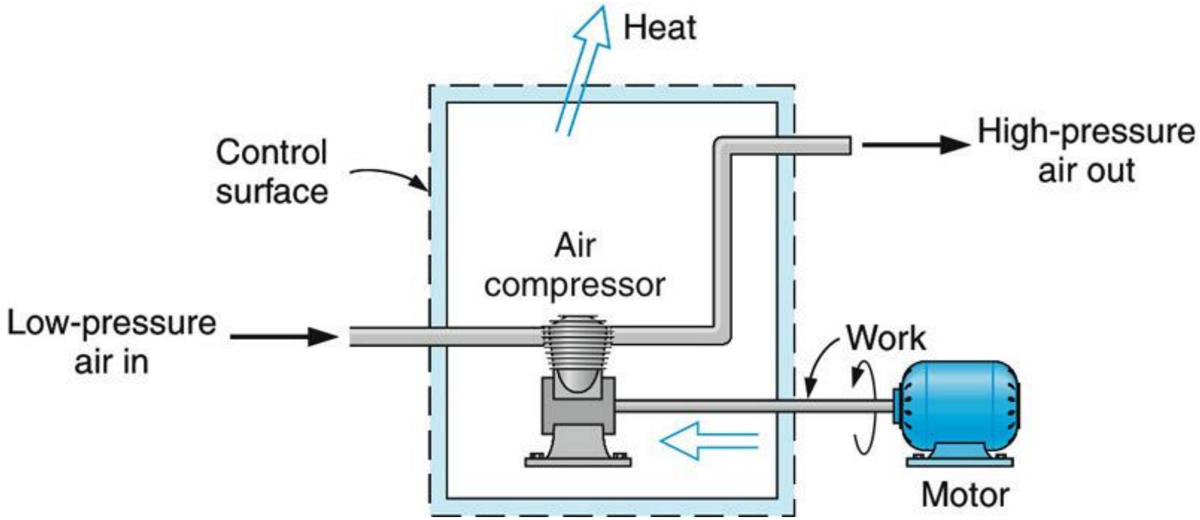
Control volume (open system)



- Control volume is a region of space being considered for analysis.
- The boundary of the control volume is known as the control surface. Control surface might be imaginary or some parts might be imaginary.
- Matter inside the control volume changes as mass crosses the system boundary. Energy as well might cross the control surface.
- Examples of CV
  - A section of water pipe might be considered as control volume.
  - A water pump is considered as a control volume. Water flows in and out of the control volume and work is supplied to the pump.
  - Water tank in the roof of the house can be treated as control volume where water flows into the tank, also water might be withdrawn from the tank.



CV



- Give some examples of a control volume from your body?

Isolated system

- An isolated system is a control mass without energy transfer a cross its boundaries.
- *Give an example of such system*.

Macroscopic versus microscopic point of view

- In microscopic point of view behavior of each molecule in the system is considered, or some average value of all particles is considered, this is the subject of statistical thermodynamics.
- Macroscopic point of view is concerned with gross or average effect of many particles. These effects can be measured by some instruments such as pressure or temperature devices. The macroscopic point of view is the subject of classical thermodynamics.
- From macroscopic view point we are concerned with volumes that are very large when compared with molecule sizes, though there are spaces between molecules system is considered as continuous medium or treated as continuum.

Property

- **Property**: is some observable character of the substance.
- Some examples: volume, mass, temperature and pressure.
- Some properties can be calculated from the measured ones, others are result of laws of thermodynamics such as energy.
- Extensive properties: properties which are mass dependent such as mass or total energy.
- Intensive property: properties which are mass independent such as pressure and temperature.
- Similarly properties per unit mass such as specific volume and specific heats are considered intensive properties.

Phase

- **Phase**: a homogenous quantity of matter.
- Substance can exist in different phases, for example water can exist in solid phase as ice or snow, a liquid phase or the gaseous phase.
- Also one or more phases can exist at the same time, for example when water boils it contains the liquid and the vapor at the same time.


Ice cube


Liquid drop


Cloud*

Equilibrium

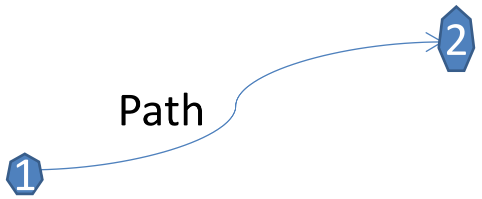
- **Thermal equilibrium:** when temperature is the same through out the system.
- **Mechanical equilibrium**: it is related to pressure, and the system at mechanical equilibrium when its pressure does not change with time.
- **Chemical equilibrium**: when system has a fixed composition.
- **Thermodynamic equilibrium:** when system has all above equilibrium then it is in thermodynamic equilibrium.

State

- State of substance is the condition of the substance. The condition of the substance is described by value of some of its properties.
- For example state of water can be described by its temperature and pressure. When state of system is described then the system must be in thermodynamic equilibrium.
- Once state of substance is specified then value of all its properties is specified as well, since at a given state property of substance has only one definite value regardless how it arrives at this state.
- In other words state is a path **in**dependent function.

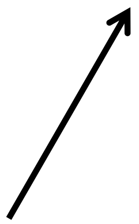
Thermodynamic process

- **Thermodynamic process**: a change of state of system to another state.
- Path of process: a succession of states through which the system goes as it changes from one state to another.
- For example when water in a cylinder changes from state 1 where T= 20^{o}C, P=1 atmosphere to state 2 where T=50^{o}C, P = 2 atmosphere.

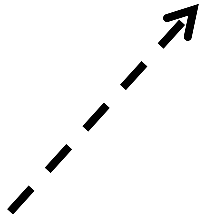


Process types

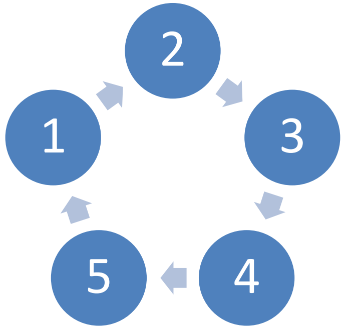
- **A quasi-equilibrium process**: A process in which the deviation from equilibrium is infinitesimal such that all state system will go through will be considered in state of equilibrium. Thus the path of the process can be described. Such process is an ideal process.



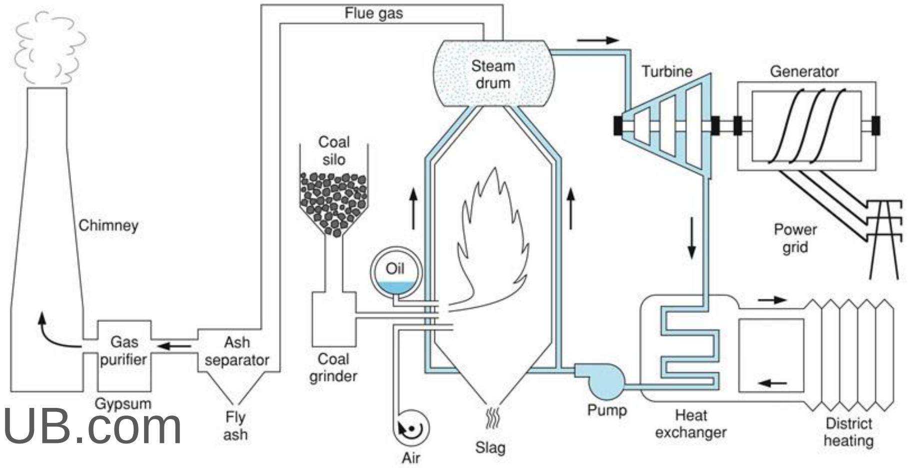
- **Non-equilibrium process**: is a process where only the initial and final states are known but the path of the process cannot be described. For example, sudden expansion of cylinder / piston system.

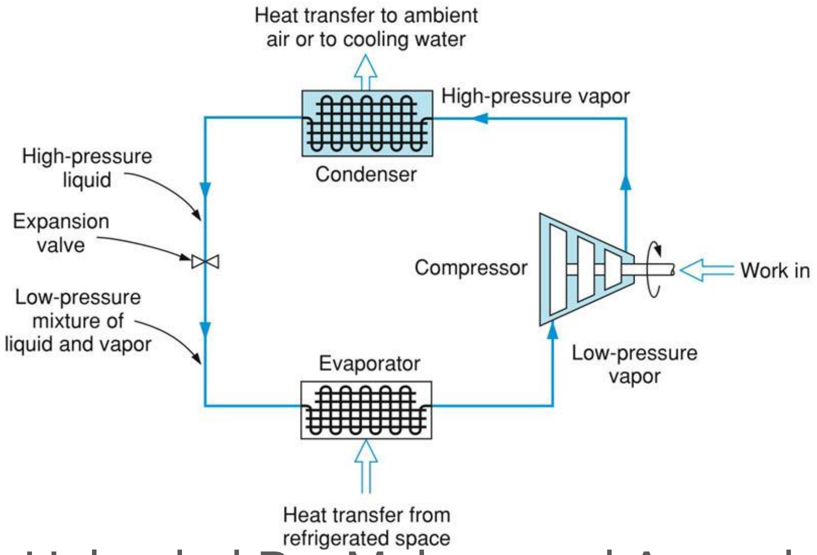


Thermodynamic cycle



- **Thermodynamic cycle**: a system in a given initial state goes through a number of different states and return back to the initial state.
- For example, steam in the simple steam power plant explained in chapter one.
- *Give another example of thermodynamic cycle.*





Units

- SI units will be used in this course.
- Basic dimensions are;
  - mass in kilogram, kg
  - length in meter, m
  - time in seconds, s
  - temperature in centigrade, ^{o} C.
- Derived unit, for force is Newton, N.
- Other derived; Joule, Watt, g=9.8 m^2/s, Pascal

Specific volume

- Specific volume: volume per unit mass, v.

  v = V/m

Units of v are m^3/kg , note that specific volume is reciprocal of density.

$$v = 1/\rho$$

- Molal specific volume is the volume per mole, or

  $\bar{v}$ = V/ n

  where n is the number of kg-moles. The kg-mole is the mass of substance in kg which is equal to its molecular weight.

  $[\bar{v}]$ m^3/kg-mole

Example

- One kilogram of diatomic oxygen (O_2 molecular weight 32) is contained in a 500-L tank. Find the specific volume on both a mass and mole basis (v and $\bar{v}$).
- From the definition of the specific volume
- $v = V/m = 0.5/1 = \mathbf{0.5\ m^3/kg}$

$$\bar{v} = \frac{V}{n} = \frac{V}{m/M} = M\,v = 32 \times 0.5 = \mathbf{16\ m^3/kmol}$$

Pressure

- Pressure: normal force per unit area.
- Unit of pressure is the Pascal, Pa which is Newton per meter square, or

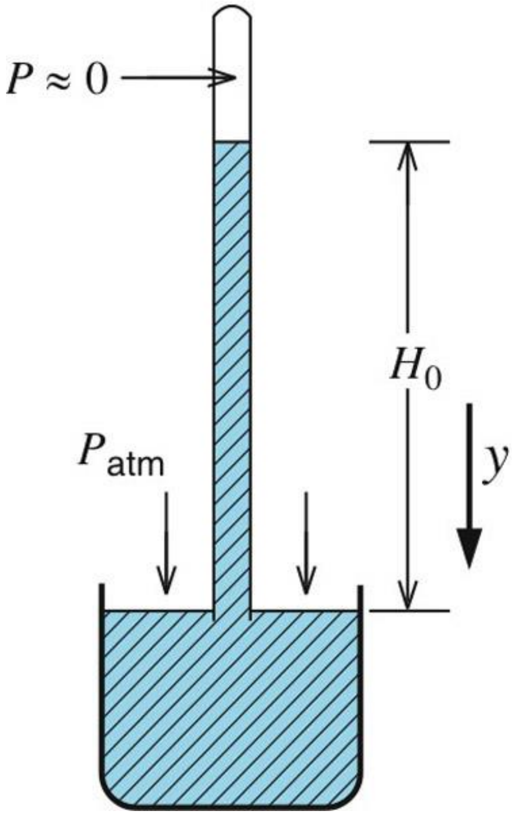
$$1 \text{ Pa} = 1 \text{ N/m}^2$$

- Multiple of Pa are kPa and MPa.
- 1 bar $=10^5$ Pa = 0.1 MPa.
- The standard atmosphere 1 atm = 101325 Pa

  = 760 mm Hg

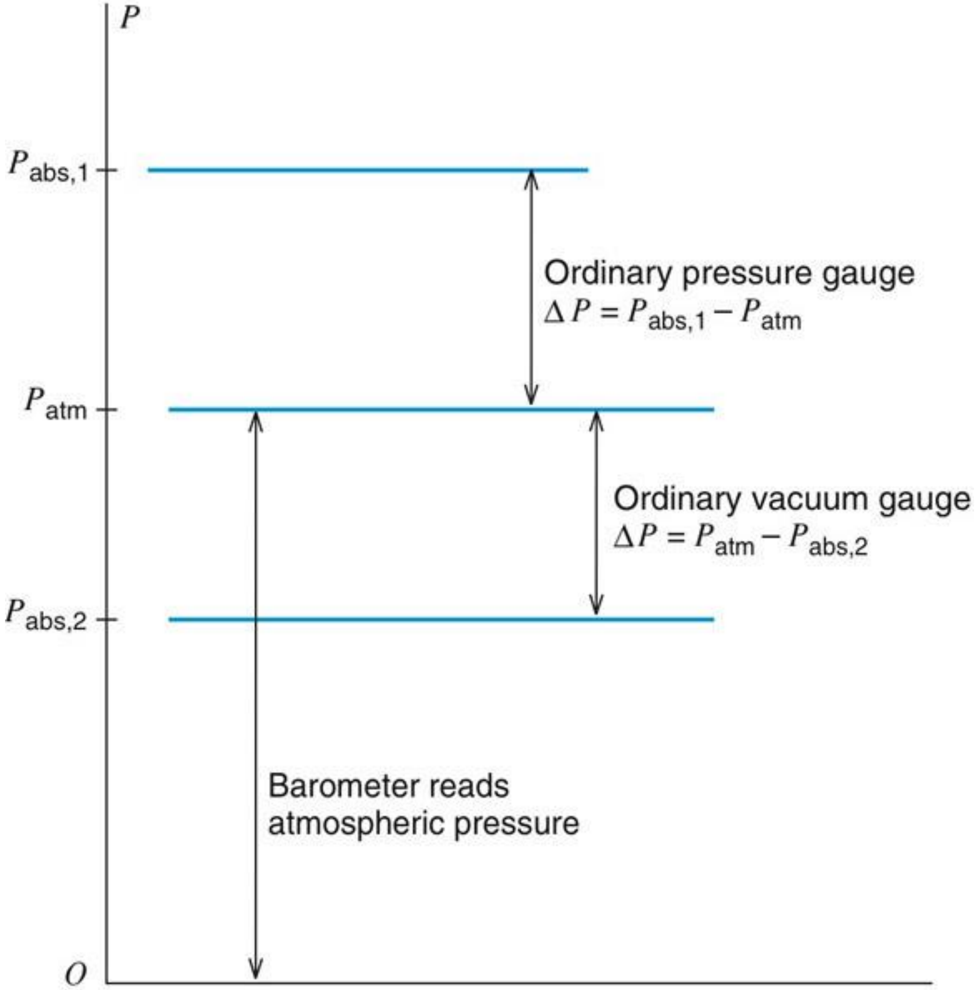
Atmospheric pressure

- Atmospheric pressure is measured by the barometer, while the gauge pressure is measured by gauge pressure.



Gauge pressure

- Gauge pressure is the difference between the absolute and atmospheric pressures.
- $P_{guage} = Pa_{bsolute} - Pa_{tm}$



Example

A valve in a cylinder has a cross sectional area of 11 cm2 with a pressure of 735 kPa inside the cylinder and 99 kPa outside. How large a force is needed to open the valve?

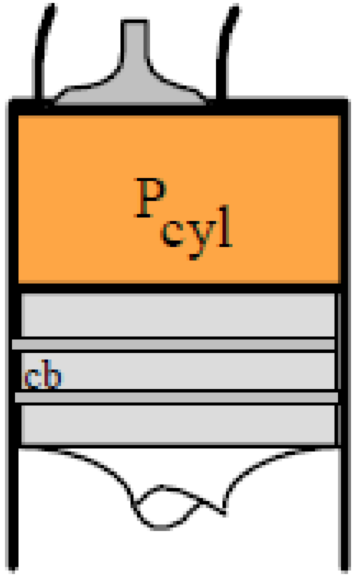
$$F_{net} = P_{in}A - P_{out}A$$

$$= (735 - 99)\ \text{kPa} \times 11\ \text{cm}^2$$

$$= 6996\ \text{kPa cm}^2$$

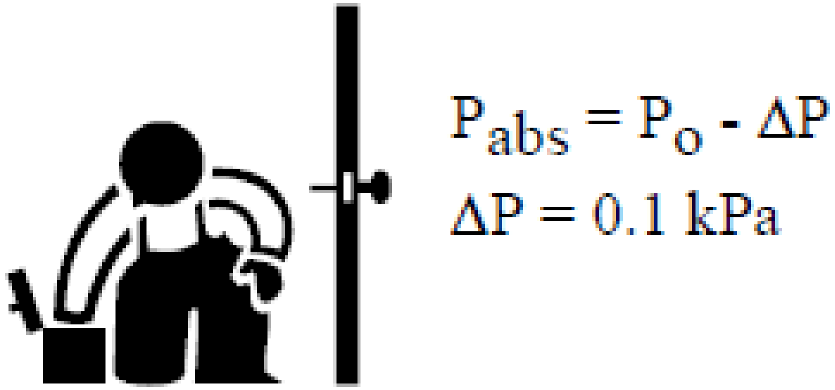
$$= 6996 \times \frac{\text{kN}}{\text{m}^2} \times 10^{-4}\ \text{m}^2$$

$$= \mathbf{700\ N}$$



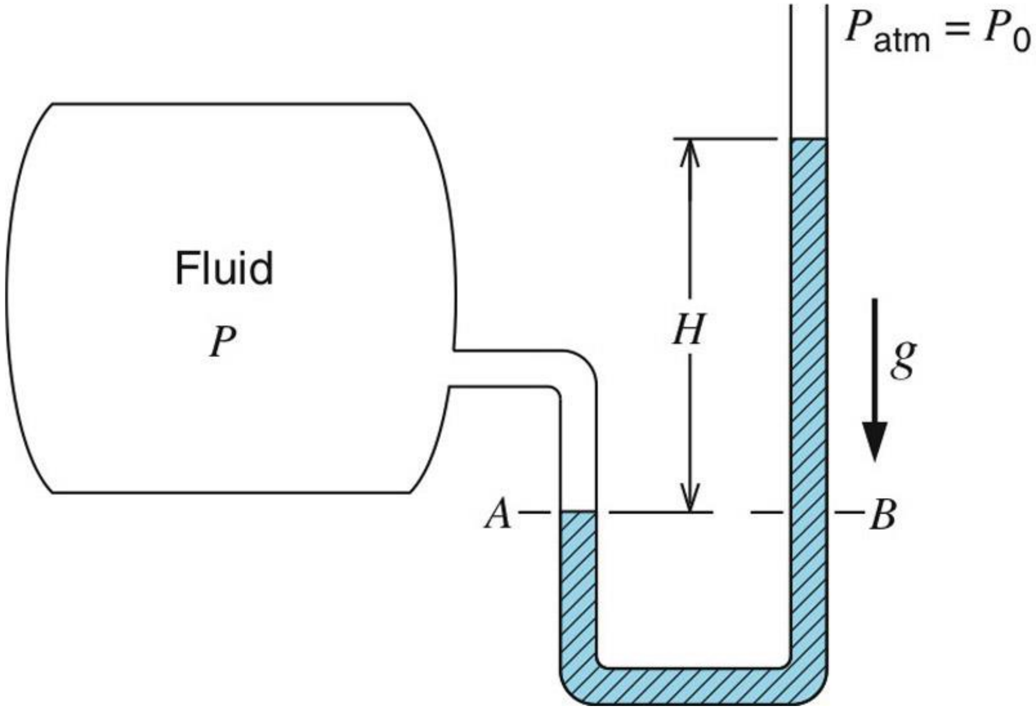
Example

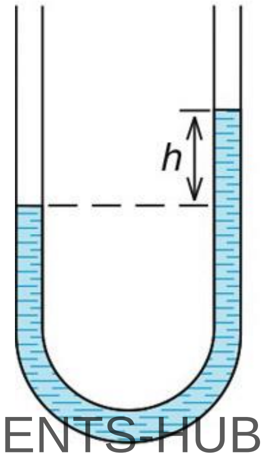
- A laboratory room keeps a vacuum of 0.1 kPa. What net force does that put on the door of size 2 m by 1 m?
- The net force on the door is the difference between the forces on the two sides as the pressure times the area
- F = Poutside* A – Pinside* A = ΔP *A = 0.1 kPa × 2 m × 1 m = **200 N**

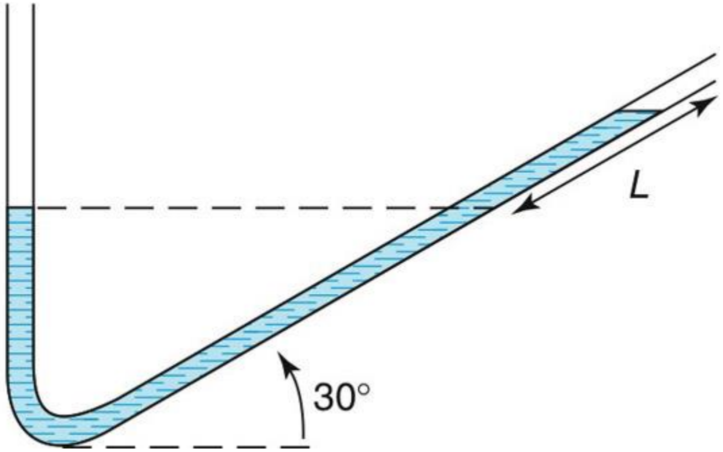


Manometers

- Pressure difference in a fluid is calculated by the multiplying the density and the gravity acceleration and the vertical distance.
- $\Delta P = \rho g H = \gamma H$
- $P_{down} = Pu_p + \gamma h$







Example

- At the beach, atmospheric pressure is 1025 mbar. You dive 15 m down in the ocean and you later climb a hill up to 250 m elevation. Assume the density of water is about 1000 kg/m3 and the density of air is 1.18 kg/m^3. What pressure do you feel at each place?
- $\Delta P = \rho g h$,
- Units from A.1: 1 mbar = 100 Pa (1 bar = 100 kPa).
- $P_{ocean} = P0 + \Delta P = 1025 \times 100 + 1000 \times 9.81 \times 15$

  $= 2.4965 \times 105$ Pa = **250 kPa**
- $P_{hill} = P0 - \Delta P = 1025 \times 100 - 1.18 \times 9.81 \times 250$

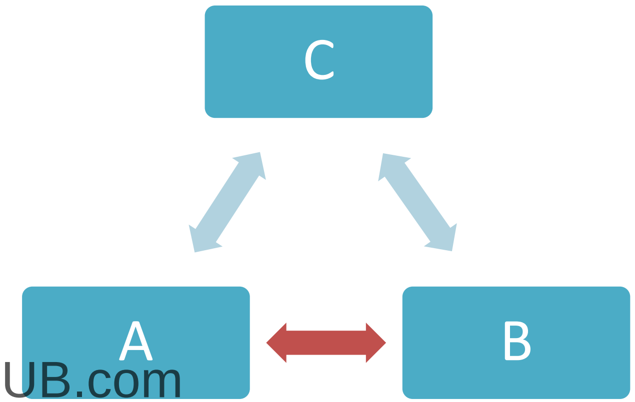
  $= 0.99606 \times 105$ Pa = **99.61 kPa**

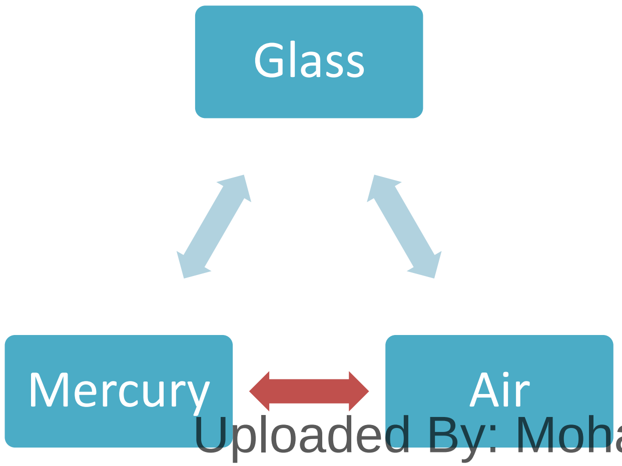
Equality of temperature

- **Equality of temperature**: two bodies have equality of temperature when there is no change in observable properties as they are brought in thermal contact.

Zeroth law of thermodynamics

- When two bodies have equality of temperature with a third body, they are in tern have equality of temperature with each other. For example body A and B have equality of temperature with C then A and B have equality of temperature with each other.
- Zeroth law of thermodynamic is used whenever temperature is measured. *Apply this law to mercury thermometer measuring temperature of air.*





Temperature

- **Temperature scale**: Celsius or centigrade scale is related to the absolute Kelvin scale in the form:

$$K = {}^{o}C + 273.2$$