CHAPTER 1

INTRODUCTION AND BASIC CONCEPTS

1.Thermodynamics and energy

- Thermodynamics can be defined as the since of energy and entropy.
- An alternate definition: is the since that deals with heat and work

- Energy cannot be created or destroyed, but it transforms from one form to another.

(conservation of energy 1st law)

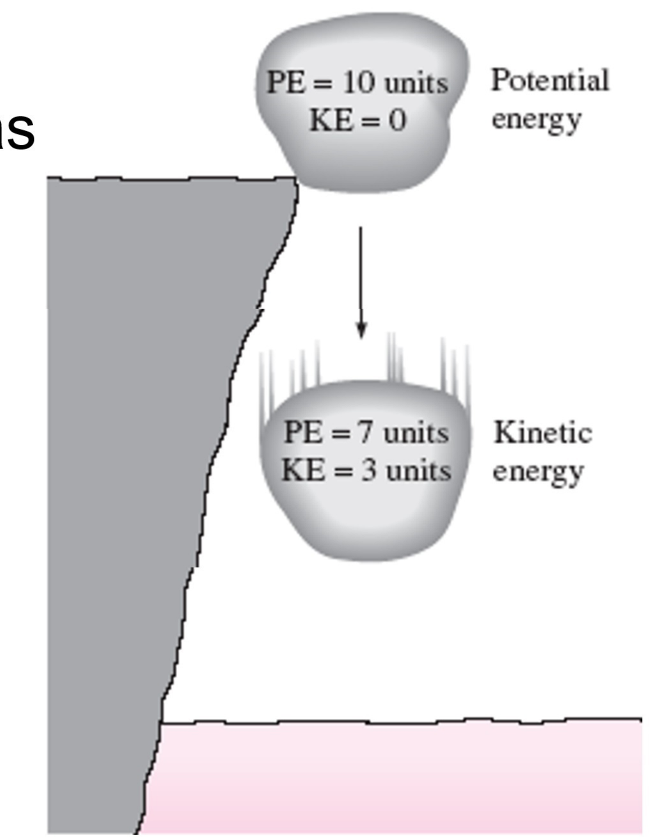
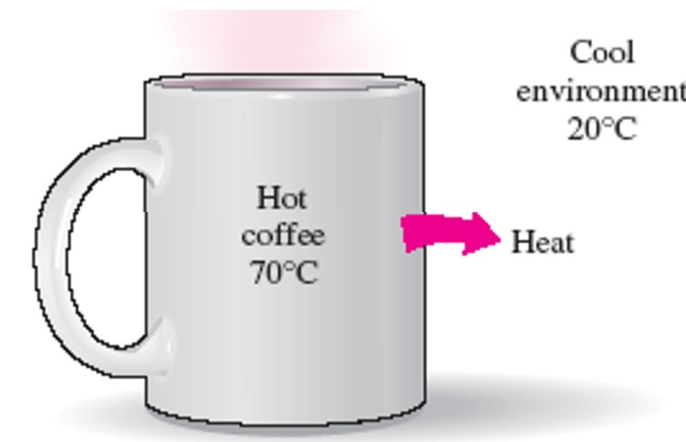


FIGURE 1–1
Energy cannot be created or destroyed; it can only change forms (the first law).

Work
heat } Energy interaction

The macroscopic approach to thermodynamics is concerned with the average or overall behavior.



called **classical thermodynamics.**

The microscopic approach to thermodynamics, known as **statistical thermodynamics**, is concerned directly with the structure of matter.

2.Dimensions and units

The seven fundamental dimensions and their units in SI

Dimension	Unit
Length	meter (m)
Mass	kilogram (kg)
Time	second (s)
Temperature	kelvin (K)
Electric current	ampere (A)
Amount of light	candela (c)
Amount of matter	mole (mol)

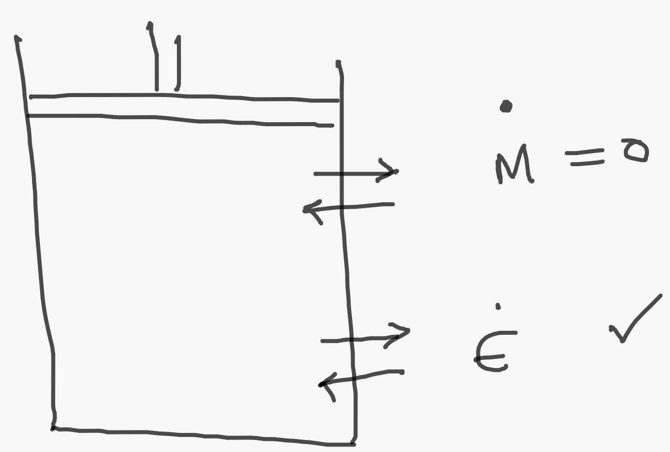
System

Surroundings

Boundary

Closed System

Ch 4



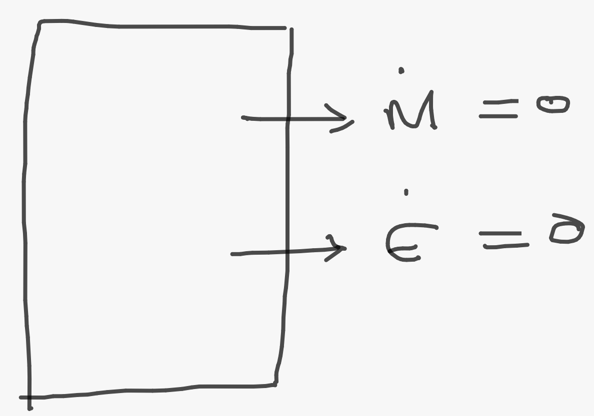
Control Mass

M = Constant

$\dot{M}$ = Zero

only Energy transfer

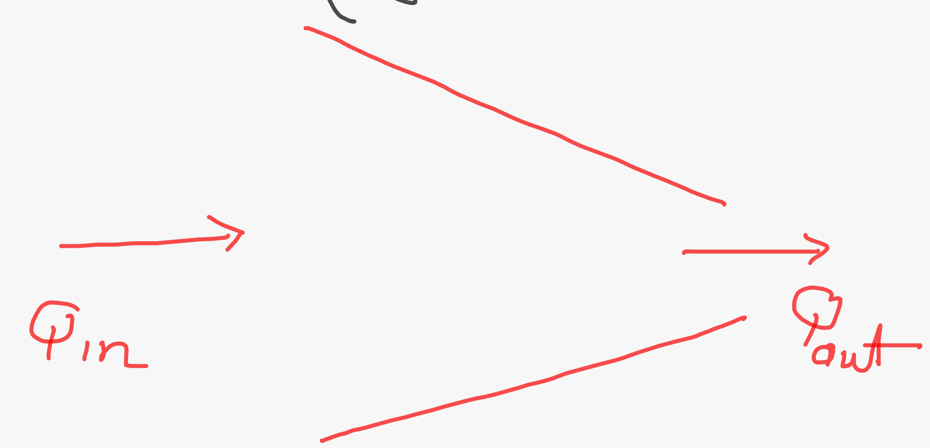
Isolated System



Open System

Ch 5

(Control volume)



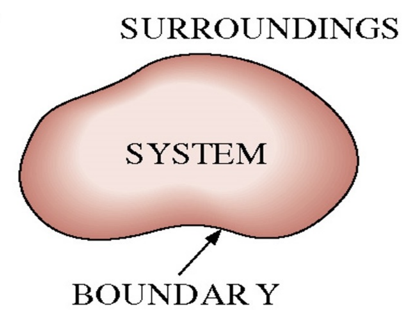
Mass transfer

Energy transfer

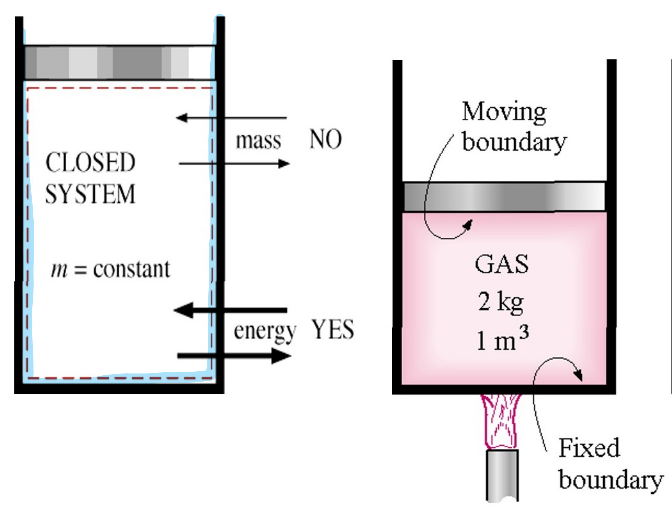
work heat

3.Systems and control volumes

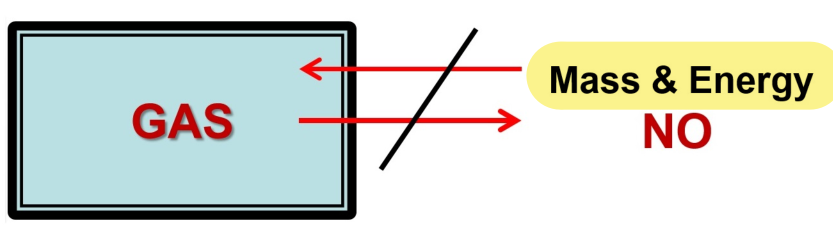
- **The system is a quantity of matter we want to study.**



- **A closed system** refers to a fixed quantity of matter.



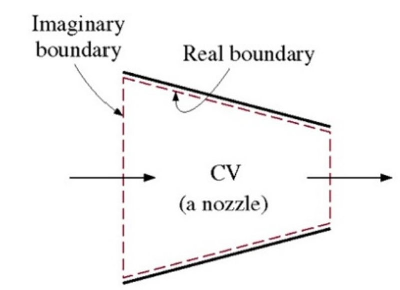
- **An Isolated system**



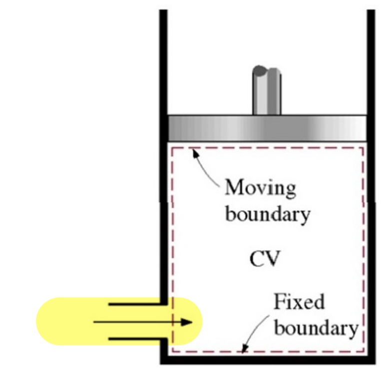
An open system (control volume)

is a properly selected region in space.

It encloses a device that involves mass flow such as nozzle, compressor, turbine.



(*a*) A control volume with real and imaginary boundaries

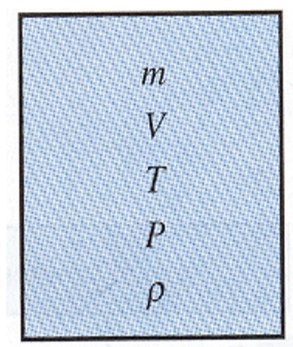


(*b*) A control volume with fixed and moving boundaries

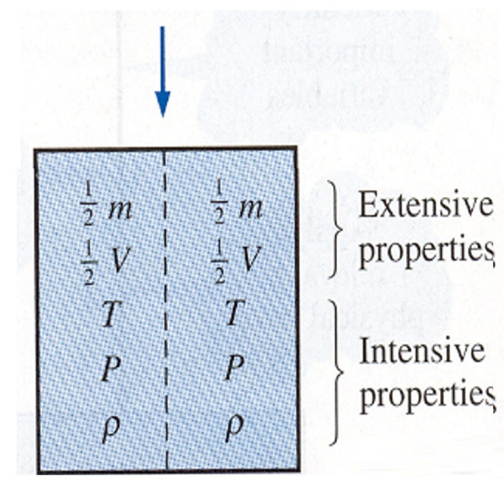
4.Properties of a system

- **Any characteristic of a system is called a property. Some familiar properties are pressure P, temperature T, volume V, and mass m.**

1. Intensive properties are those that are independent of the size of system, such as temperature, pressure, and density.



2. Extensive properties are dependent on the size (or extent) of the system. Mass m, volume V, and total energy E are some examples of extensive properties.



5.Density and specific gravity

Density ρ is defined as mass per unit volume.

$$\rho = \frac{m}{V} \qquad kg/m^3$$

Specific volume v is defined as volume per unit mass.

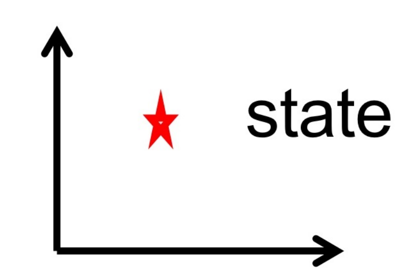
$$v = \frac{V}{m} = \frac{1}{\rho}$$

Specific Gravity (SG) or Relative Density (RD) is the density of a substance to the density of water at 4ºC.

$$SG = \frac{\rho}{\rho_{H2O}}$$

6.State and equilibrium

- **A state is defined as a condition of a substance that can be described by certain observable macroscopic properties. (T, P, ρ, ν etc.)**



Density

$$\rho = \frac{M}{V} \qquad \frac{Kg}{m^3}$$

Specific Weight

$$\gamma = \frac{W}{V} = \rho g \qquad \frac{N}{m^3}$$

Specific volume

$$v = \frac{V}{m} = \frac{1}{\rho} \qquad \frac{m^3}{Kg}$$

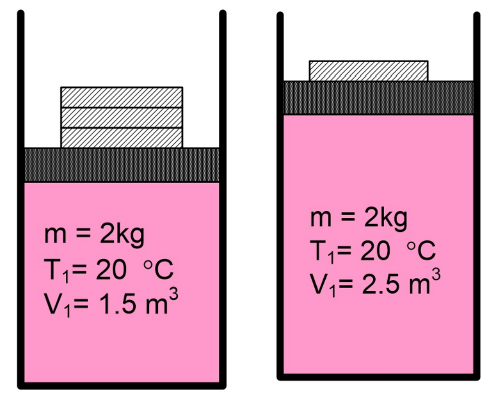
Specific Energy

$$e = \frac{E}{m} \qquad \frac{Kj}{Kg}$$

Specific gravity

$$S.G = \frac{\rho_F}{\rho_{H_2O}} = \frac{\gamma_F}{\gamma_{H_2O}}$$

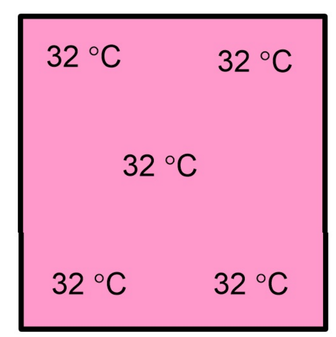
Equilibrium state means that there are no unbalanced potentials (or driving forces) within the system.



State 1 State 2

Thermal Equilibrium

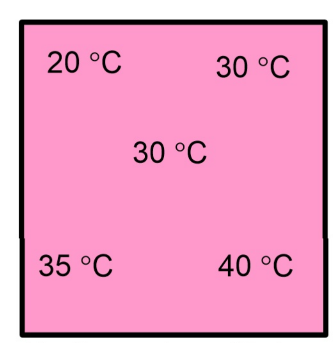
- Thermal equilibrium means that there is no temperature differential through the system.



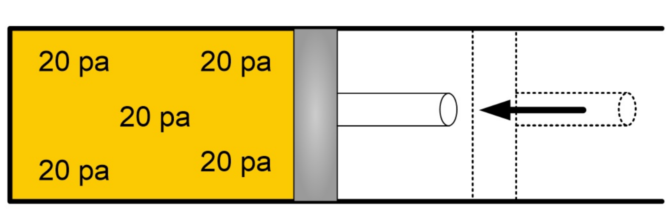
Thermal equilibrium

Mechanical Equilibrium

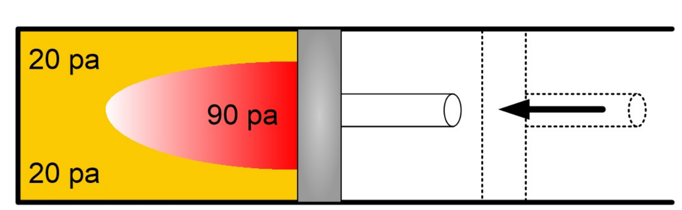
- Mechanical equilibrium means that there is no change in pressure



No thermal equilibrium



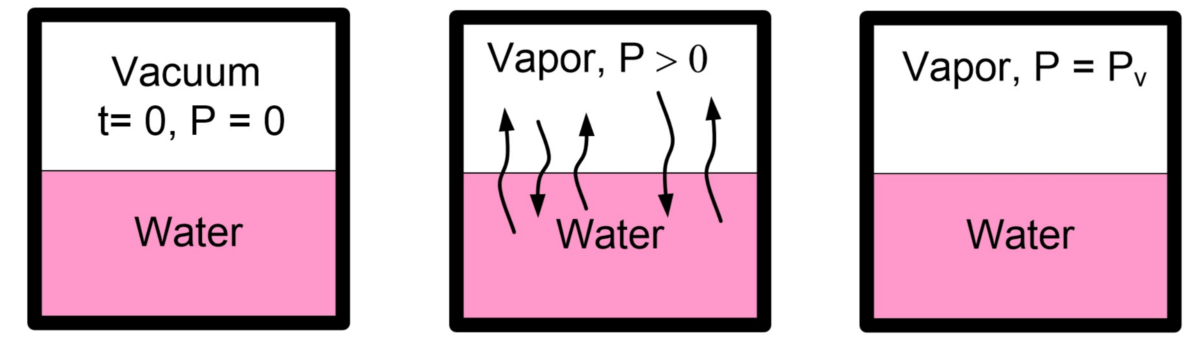
(a) Slow compression (quasi-equilibrium)



(b) fast compression (non quasi-equilibrium)

Phase Equilibrium

. Phase equilibrium means that the mass of each phase reaches an equilibrium level and stays there.



At t = 0 After some time After long time

Chemical Equilibrium

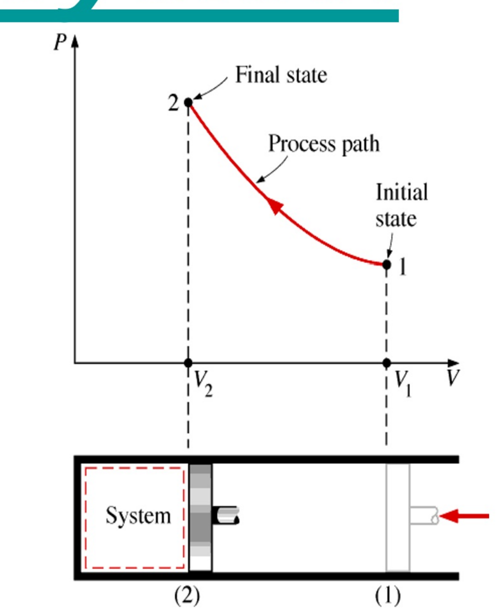
- Chemical equilibrium means that the chemical composition of the system does not change with time

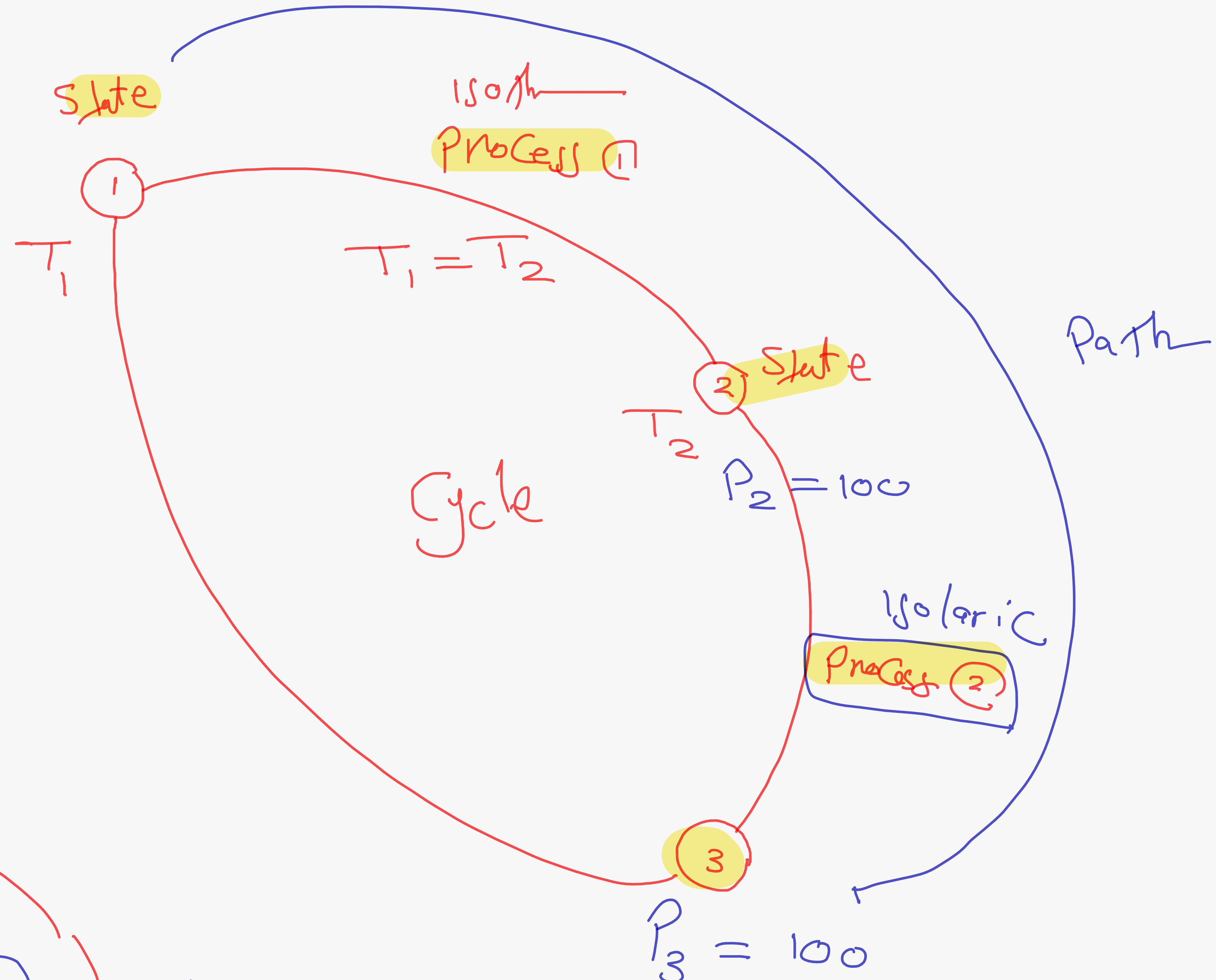
The State Postulate

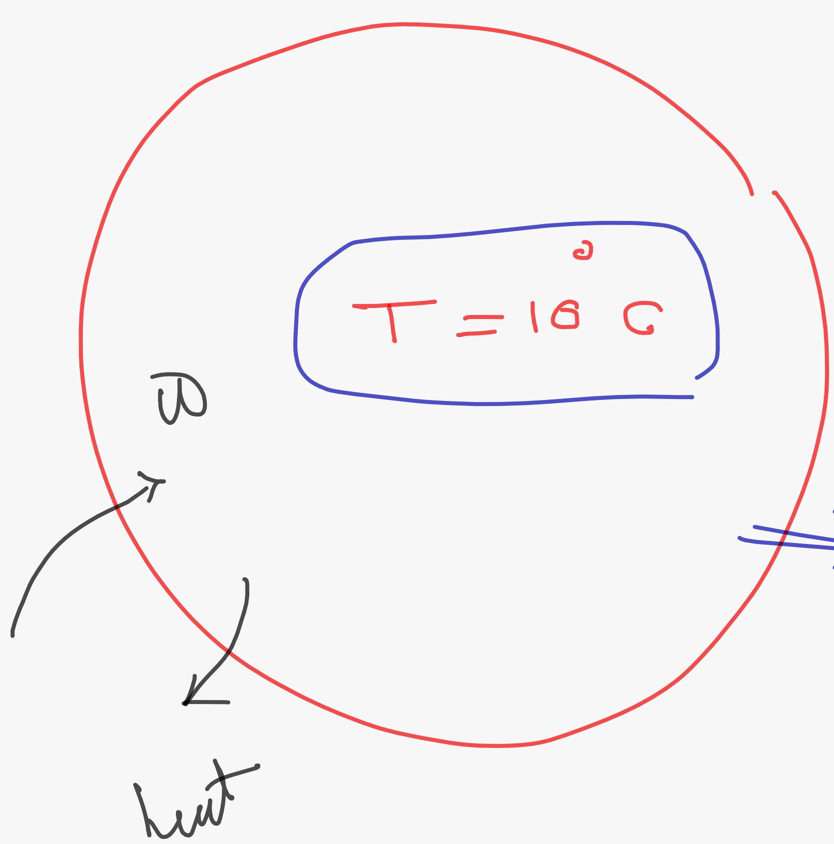
- According to what is called "state postulate", the number of properties required to completely specify the state of such system is two <u>independent, intensive proerties.</u>

7.Processes and cycles.

- Any change from one equilibrium state to another is called a process.

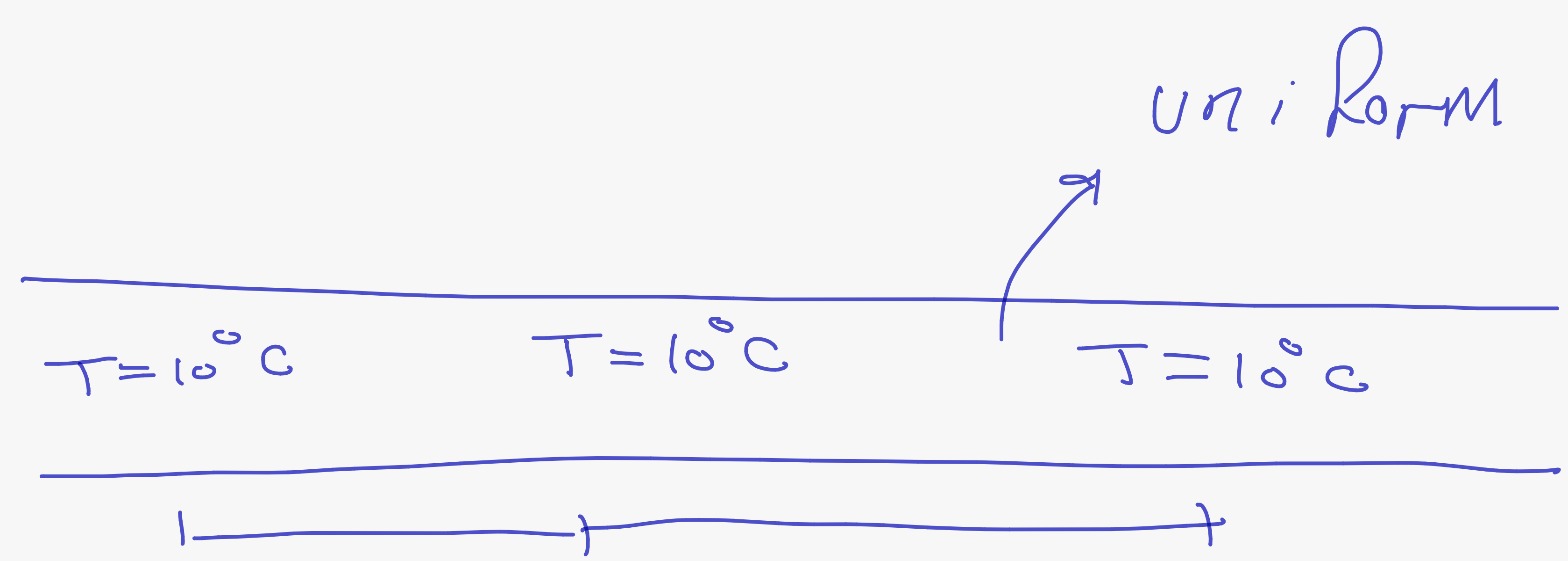




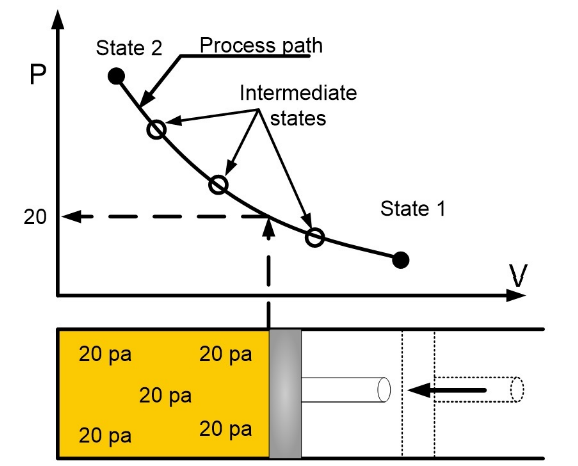


$\frac{dT}{dt} \neq 0$

$\Rightarrow$ Steady



- The series of states through which a system passes during a process is called a path
- A process with identical end states is called a cycle

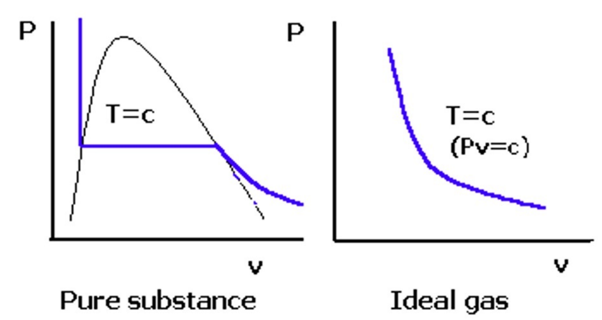


(a) Slow compression (quasi-equilibrium)

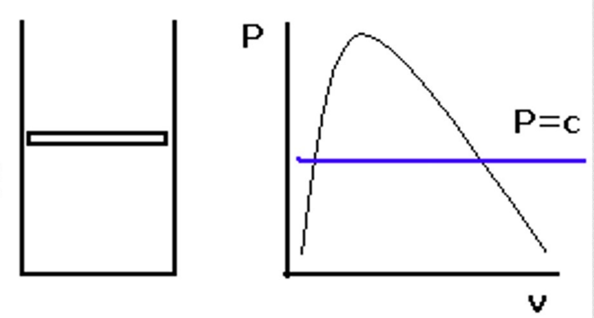
•Quasi-static or quasi-equilibrium process.

When the system remains close to an equilibrium state all the time during the process.

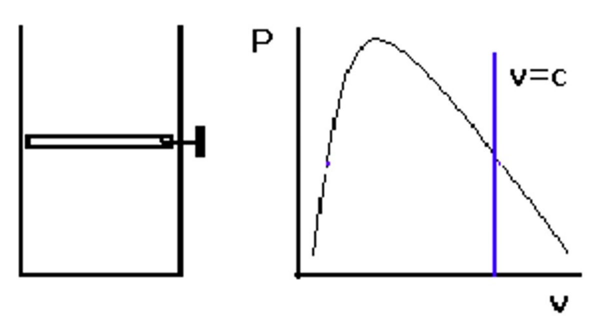
- Isothermal process means a process at constant T.



- Isobaric process means a process at constant pressure



- Isochoric (isometric) process means a process at constant volume



- Steady-flow process

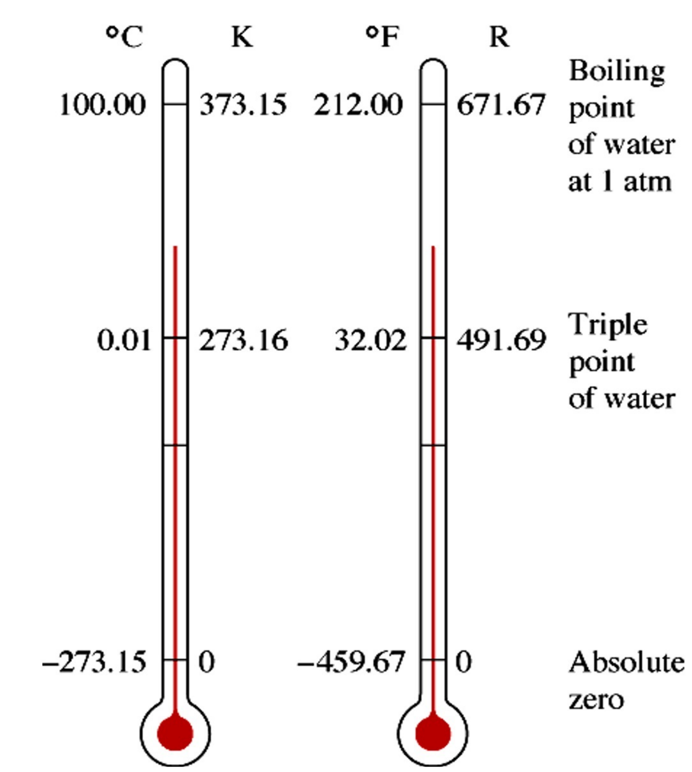
Steady means no change with the time.

Uniform means no change with the location over a specific region.

8.Temperature and the zeroth law of thermodynamics.

- The zeroth law of thermodynamics states that: If two bodies are in thermal equilibrium with the third body, they are also in thermal equilibrium with each other.

Temperature scales



$$T(K)=T(^\circ C)+273.15$$
$$T(R)=T(^\circ F)+459.67$$
$$T(R)=1.8T(K)$$
$$T(^\circ F)=1.8T(^\circ C)+32$$
$$\Delta T(K)=\Delta T(^\circ C)$$
$$\Delta T(R)=\Delta T(^\circ F)$$

Temperature Scale

SI → K, C

$$T(K) = T(C) + 273.15$$

US → R, F

$$T(R) = T(F) + 459.67$$

$$T(R) = 1.8\, T(K)$$

$$T(F) = 1.8\, T(C) + 32$$

$$\Delta T(K) = \Delta T(C^\circ)$$

$$\Delta T(R) = \Delta T(F)$$

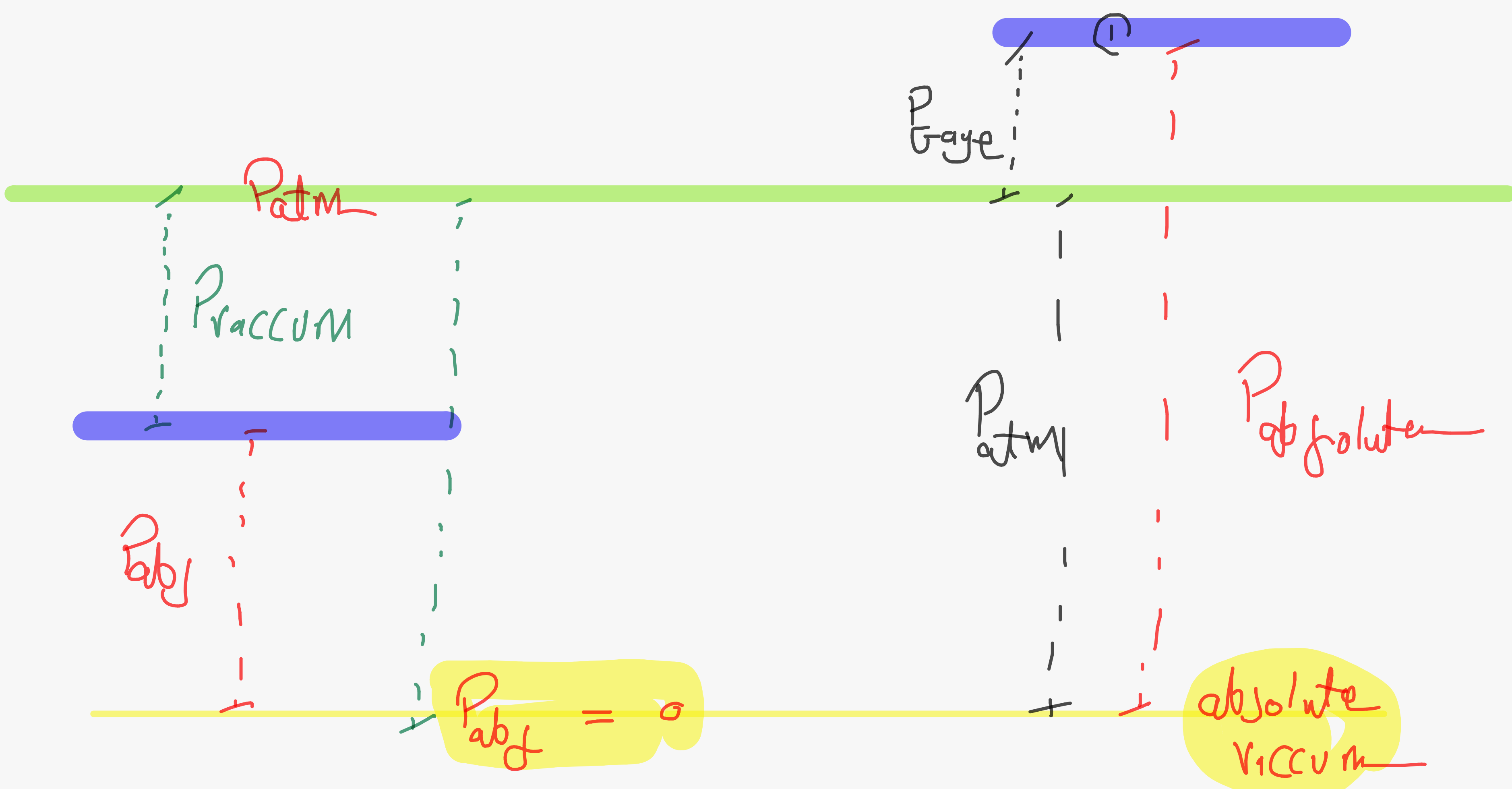
$$\Delta T(R) = 1.8\, \Delta T(K)$$

$$\text{Pressure} = \frac{F}{A} \qquad \frac{N}{m^2} = Pa$$

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

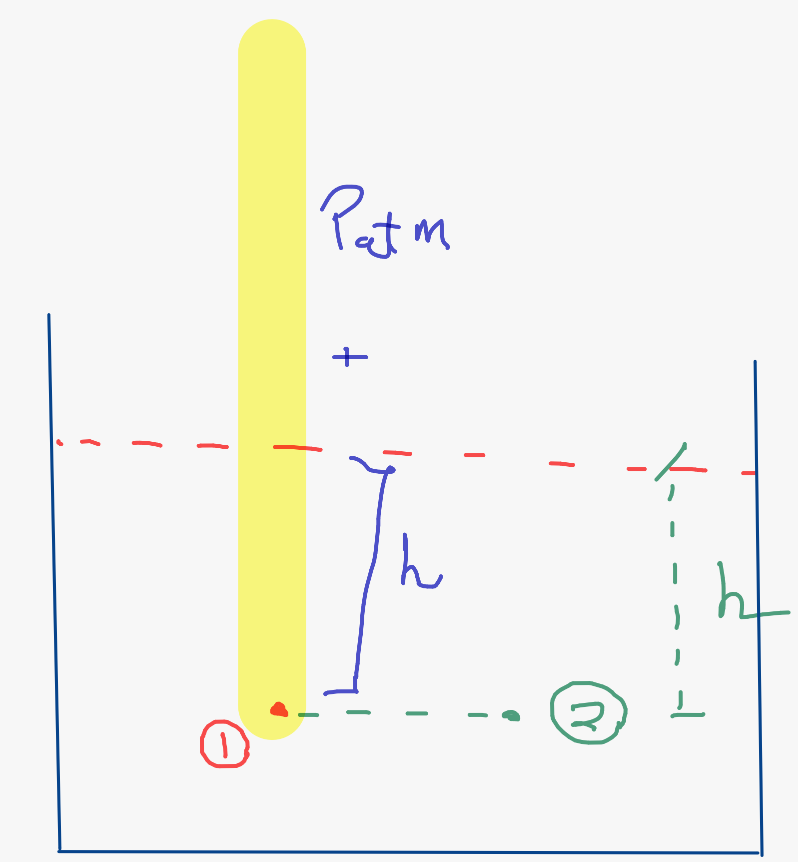
$$1\ atm = 101325\ Pa = 101.325\ kPa$$

$$= 1.01325\ bars = 14.696\ psi$$



$$P_{Gage} = P_{abs} - P_{atm}$$

$$P_{vaccum} = P_{atm} - P_{abs}$$



$$P_{1,abs} = \rho g h + P_{atm}$$

$$P_{1,gage} = P_{1,abs} - P_{atm} = \rho g h$$

$$P_1 = P_2$$ } → same level; → same Fluid

9.Pressure

Pressure is defined as the <u>normal</u> force exerted by a fluid per unit area.

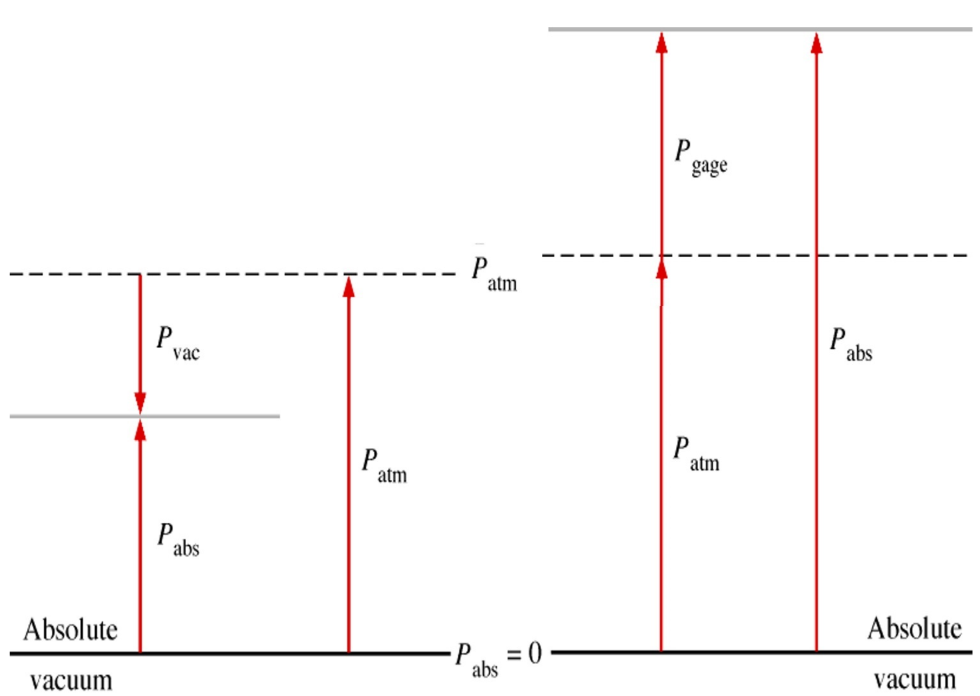
$$1\,bar = 10^5\ Pa = 0.1\,MPa = 100\,kPa$$

$$1\,atm = 101{,}325\,Pa = 101.325\,kPa = 1.01325\ bars = 14.696\,psi$$

***Absolute pressure*, is measured relative to absolute vacuum (i.e., *absolute zero pressure*.)**

***Gauge pressure*, is measured relative to atmospheric pressure**

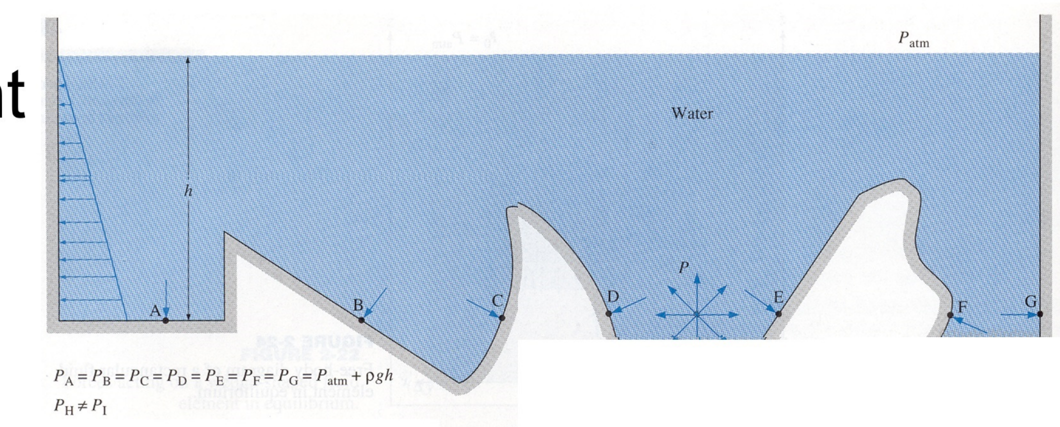
$$P_{gage} = P_{abs} - P_{atm}$$
$$P_{vac} = P_{atm} - P_{abs}$$



Variation of Pressure with Depth

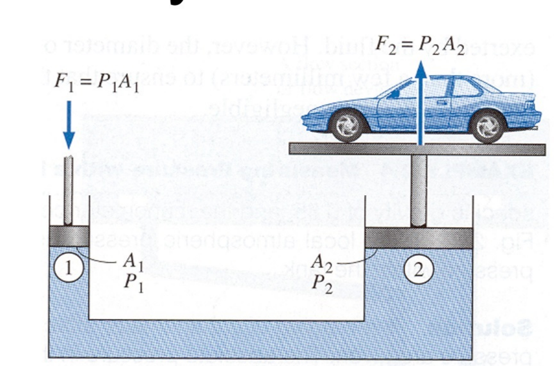
Pressure at a Point

$$P_{abs} = P_{atm} + \rho gh$$
$$P_{gage} = \rho gh = \gamma h$$



Pressure Variation in horizontal planes

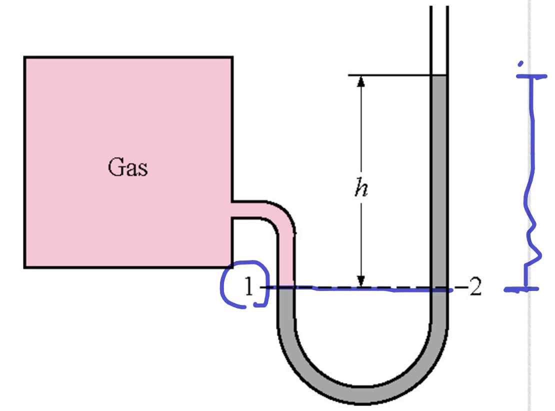
***Pascals' law*: the pressure applied to a confined fluid increases the pressure throughout by the same amount.**



10.The Manometer

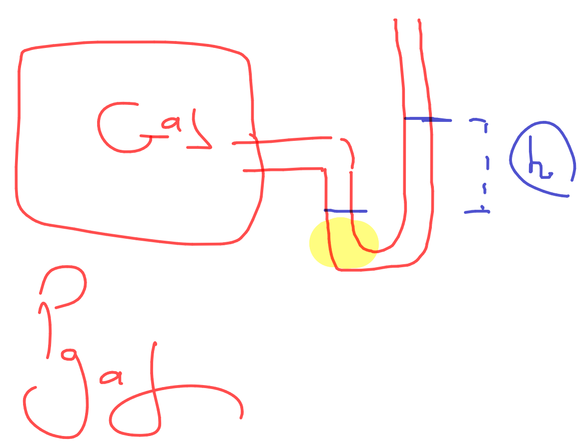
$P_1 = P_2$

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



$P_1 = P_2 = P_{atm} + \rho g h$

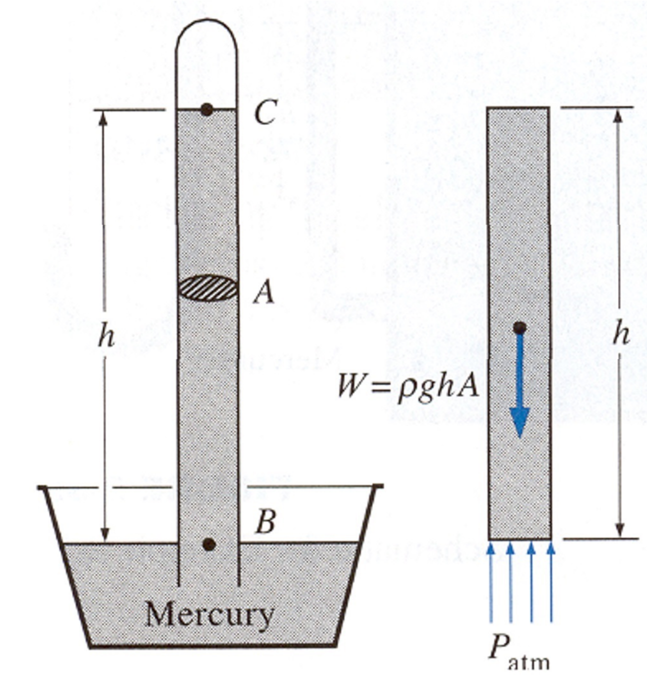
$P_{Gas,\,Gage} = \rho g h$

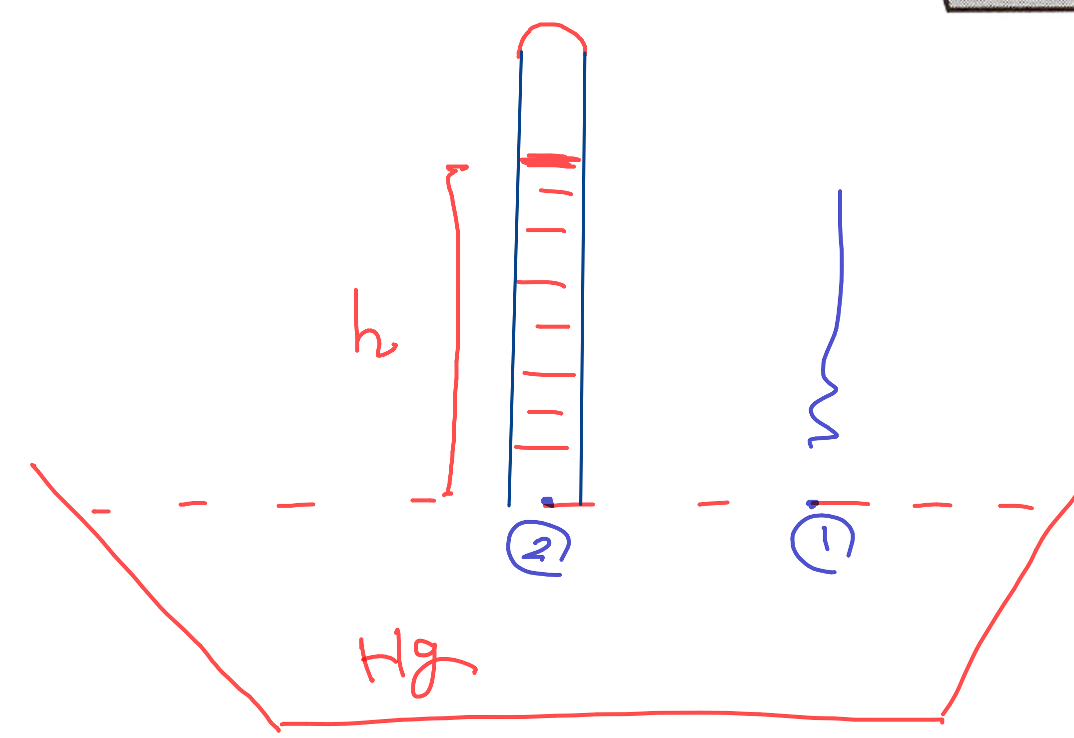


11.Barometer and the Atmospheric Pressure

- The atmospheric pressure is measured by a device called a barometer; thus the

barometric pressure.





$P_1 = P_2$

$P_{atm} = \rho g h_{Hg}$

EXAMPLE 1–4 Expressing Temperature Rise in Different Units

During a heating process, the temperature of a system rises by 10°C. Express this rise in temperature in K, °F, and R.

SOLUTION

$$\Delta T(C) = 10^\circ C$$

$$* \ \Delta T(K) = \Delta T(C) = 10^\circ K$$

$$* \ \Delta T(R) = 1.8\, \Delta T(K) = 1.8 * 10$$

$$= 18^\circ R$$

$$* \ \Delta T(F) = \Delta T(R) = 18^\circ F$$

EXAMPLE 1–5 Absolute Pressure of a Vacuum Chamber

A vacuum gage connected to a chamber reads 5.8 psi at a location where the atmospheric pressure is 14.5 psi. Determine the absolute pressure in the chamber.

SOLUTION

$$P_{vac} = 5.8 \text{ Psi}$$

$$P_{atm} = 14.5$$

$$P_{vac} = P_{atm} - P_{abs}$$

$$P_{abs} = P_{atm} - P_{vac}$$

$$= 14.5 - 5.8$$

$$= 8.7 \text{ Psi}$$

EXAMPLE 1–6 **Measuring Atmospheric Pressure with a Barometer**

Determine the atmospheric pressure at a location where the barometric reading is 740 mmHg and the gravitational acceleration is $g = 9.805$ m/s^2. Assume the temperature of mercury to be 10°C, at which its density is 13,570 kg/m^3.

SOLUTION

$h = 740$ mm

$\rho_{Hg} = 13570$ kg/m^3

$g = 9.805$ m/s^2

$P_{atm} = \rho g h$

$= 13570 \text{ (kg/m}^3) * 9.805 \text{ (m/s}^2) * 0.74 \text{ (m)}$

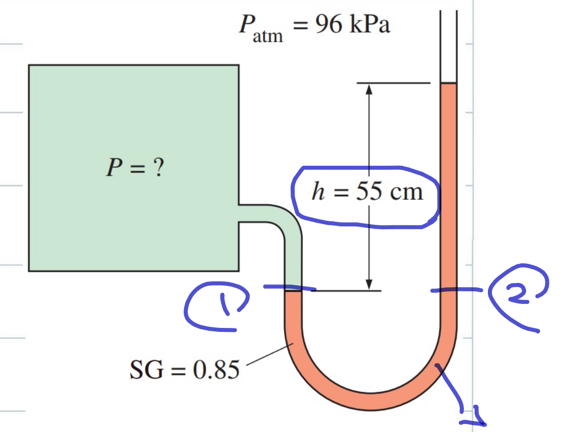
$= 98459.849$ Pa

$= 98.5$ kPa

EXAMPLE 1–9 **Measuring Pressure with a Manometer**

A manometer is used to measure the pressure of a gas in a tank. The fluid used has a specific gravity of 0.85, and the manometer column height is 55 cm, as shown in Fig. 1–56. If the local atmospheric pressure is 96 kPa, determine the absolute pressure within the tank.

SOLUTION



$S.G = 0.85$

$h = 55$ cm

$P_{atm} = 96$ kPa

* $S.G = \dfrac{\rho_F}{\rho_{H_2O}}$

$\rho_F = S.G \; \rho_{H_2O} = 0.85 * 1000$

$= 850$ kg/m^3

$P_1 = P_2$

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

$= 850 \text{ (kg/m}^3) * 9.8 \text{ (m/s}^2) * 0.55 \text{ (m)} * 1/1000 + 96$ kPa

$= 100.6$ kPa

1.55

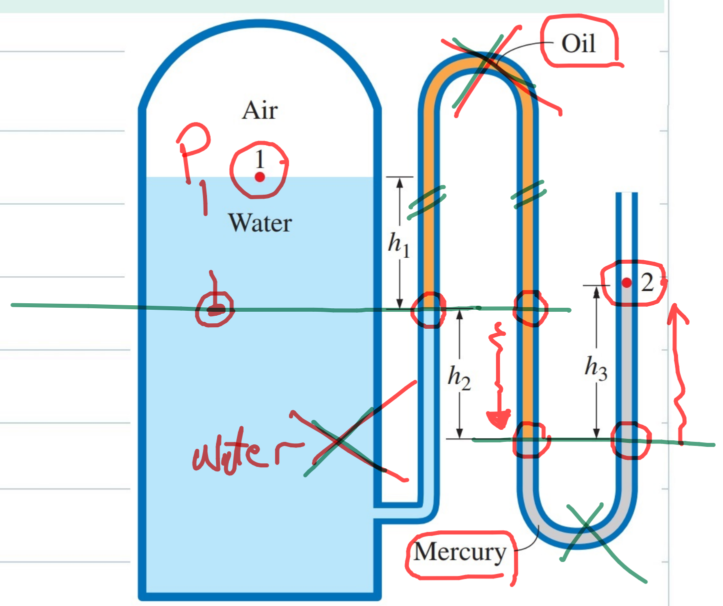
The basic barometer can be used to measure the height of a building. If the barometric readings at the top and at the bottom of a building are 675 and 695 mmHg, respectively, determine the height of the building. Take the densities of air and mercury to be 1.18 kg/m^3 and 13,600 kg/m^3, respectively.

EXAMPLE 1–10 Measuring Pressure with a Multifluid Manometer

The water in a tank is pressurized by air, and the pressure is measured by a multifluid manometer as shown in Fig. 1–59. The tank is located on a mountain at an altitude of 1400 m where the atmospheric pressure is 85.6 kPa. Determine the air pressure in the tank if $h_1 = 0.1$ m, $h_2 = 0.2$ m, and $h_3 = 0.35$ m. Take the densities of water, oil, and mercury to be 1000 kg/m^3, 850 kg/m^3, and 13,600 kg/m^3, respectively.

SOLUTION

* start From P_1 to Point P_2
* adding $\rho g h$ as we go down
* Subtracting $\rho g h$ as we go up
* setting the Result = P_{atm} if asked For P_{abs}; = 0 if asked For P_{gage}



$$P_1 + \rho_{H_2O}\, g\, h_1 + \rho_{oil}\, g\, h_2 - \rho_{Hg}\, g\, h_{Hg} = P_{atM}$$

$$P_1 = P_{atM} - \rho_{H_2O}\, g\, h_1 - \rho_{oiL}\, g\, h_2 + \rho_{Hg}\, g\, h_{Hg}$$

$$= 85.6\,(\text{KPa}) - (1000 * 9.81 * 0.1 * 1/1000)$$

$$- (850 * 9.81 * 0.2 * 1/1000)$$

$$+ (13600 * 9.81 * 0.35 * 1/1000)$$

$$= 130 \text{ KPa}$$

$h = 675$ MM

h — air Column Pressure

$h = 695$ MM

$$P_{top} = (\rho g h)_{top}$$

$$= (13600 * 9.81 * 0.675 * 1/1000)$$

$$= 90.06 \text{ KPa}$$

$$P_{bottom} = (\rho g h)_{bott}$$

$$= (13600 * 9.81 * 0.695 * 1/1000)$$

$$= 92.72 \text{ KPa}$$

$$(\rho g h)_{air} = P_{bot} - P_{top}$$

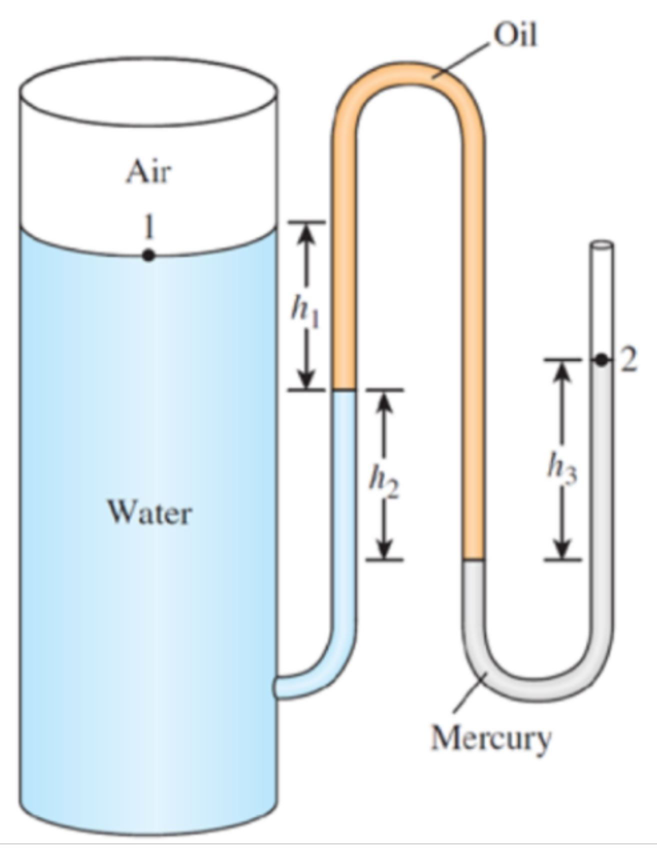
$$1.18 * 9.81 * h = (92.72 - 90.06) * 1000$$

$h = 231$ M } the height of the building

Chapter 1

1. (1-4C) An office worker claims that a cup of cold coffee on his table warmed up to 80°C by picking up energy from the surrounding air, which is at 25°C. Is there any truth to his claim? Does this process violate any thermodynamic laws?

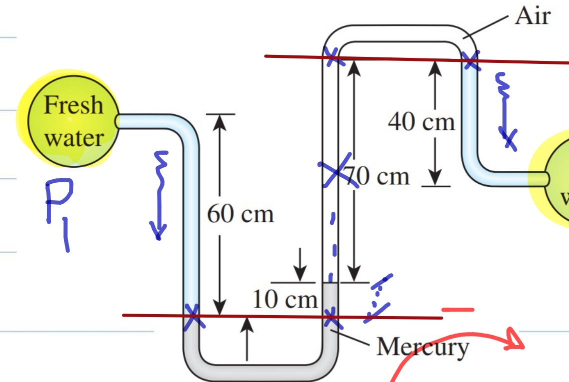
2. **(1-50)** The water in a tank is pressurized by air, and the pressure is measured by a multifluid manometer as shown in the Figure below. Determine the gage pressure of air in the tank if h_1 = 0.2 m, h_2 = 0.3 m, and h_3 = 0.4 m. Take the densities of water, oil, and mercury to be 1000 kg/m^3, 850 kg/m^3, and 13,600 kg/m^3, respectively.



Midterm 1

Quiz

1-71 Freshwater and seawater flowing in parallel horizontal pipelines are connected to each other by a double U-tube manometer, as shown in Fig. P1–76. Determine the pressure difference between the two pipelines. Take the density of sea-water at that location to be $\rho = 1035\ kg/m^3$. Can the air column be ignored in the analysis?



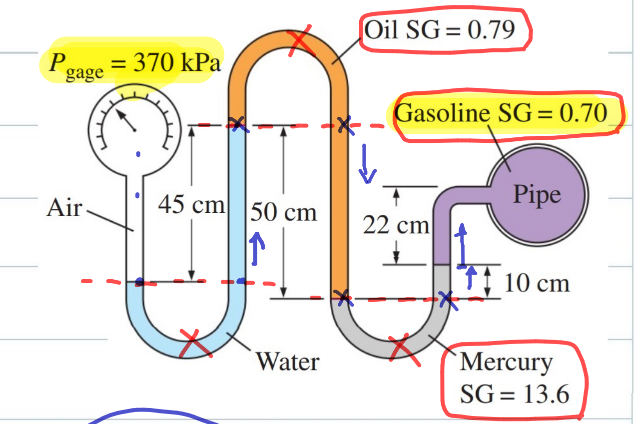
$$P_1 + \rho_w g h_w - \rho_{Hg} g h_{Hg} + \rho_{sea} g h_{sea} = P_2$$

$$P_1 - P_2 = -\rho_w g h_w + \rho_{Hg} g h_{Hg} - \rho_{sea} g h_{sea}$$

$$= -\left(1000 * 9.81 * 0.6 * \frac{1}{1000}\right) + \left(13600 * 9.81 * 0.1 * \frac{1}{1000}\right) - \left(1035 * 9.81 * 0.4 * \frac{1}{1000}\right)$$

$$= 3.39\ kN/m^2 = 3.39\ kPa$$

1-103 A gasoline line is connected to a pressure gage through a double-U manometer, as shown in Fig. P1–112 on the next page. If the reading of the pressure gage is 370 kPa, determine the gage pressure of the gasoline line.



$$P_{gage} - \rho_w g h_w + \rho_{oil} g h_{oil} - \rho_{Hg} g h_{Hg} - \rho_{gas} g h_{gas} = P_{gasoline}$$

$$\rho_{oil} = S.G_{oil}\ \rho_w = 0.79 * 1000 = 790\ kg/m^3$$

$$\rho_{Hg} = S.G_{Hg}\ \rho_w = 13.6 * 1000 = 13600\ kg/m^3$$

$$\rho_{gas} = S.G\ \rho_w = 0.7 * 1000 = 700$$

$$P_{gasoline} = 370 - \left(1000 * 9.81 * 0.45 * \frac{1}{1000}\right) + \left(790 * 9.81 * 0.5 * \frac{1}{1000}\right) - \left(13600 * 9.81 * 0.1 * \frac{1}{1000}\right) + \left(700 * 9.81 * 0.22 * \frac{1}{1000}\right) = 354.6\ kPa$$