THERMODYNAMICS

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PETROLEUM &
MINING
ENGINEERING
DEPTMENT

Lecture ONE

Basic Concepts of Thermodynamics

K-W-L Chart

Topic *What is a Thermodynamic?*

What I Know	What I Want to Know	What I Learned

https://www.youtube.com/watch?v=bHPJxHKVkSM

Natural Gas 101 (youtube.com)

Lecture Content:

- Thermodynamics
- Application Areas of Thermodynamics
- Importance of Dimensions and Units
- Systems and Control Volumes
- Properties of a System
- Density and Specific Gravity
- State and Equilibrium
- Processes and Cycles
- Homogeneous and Heterogeneous System

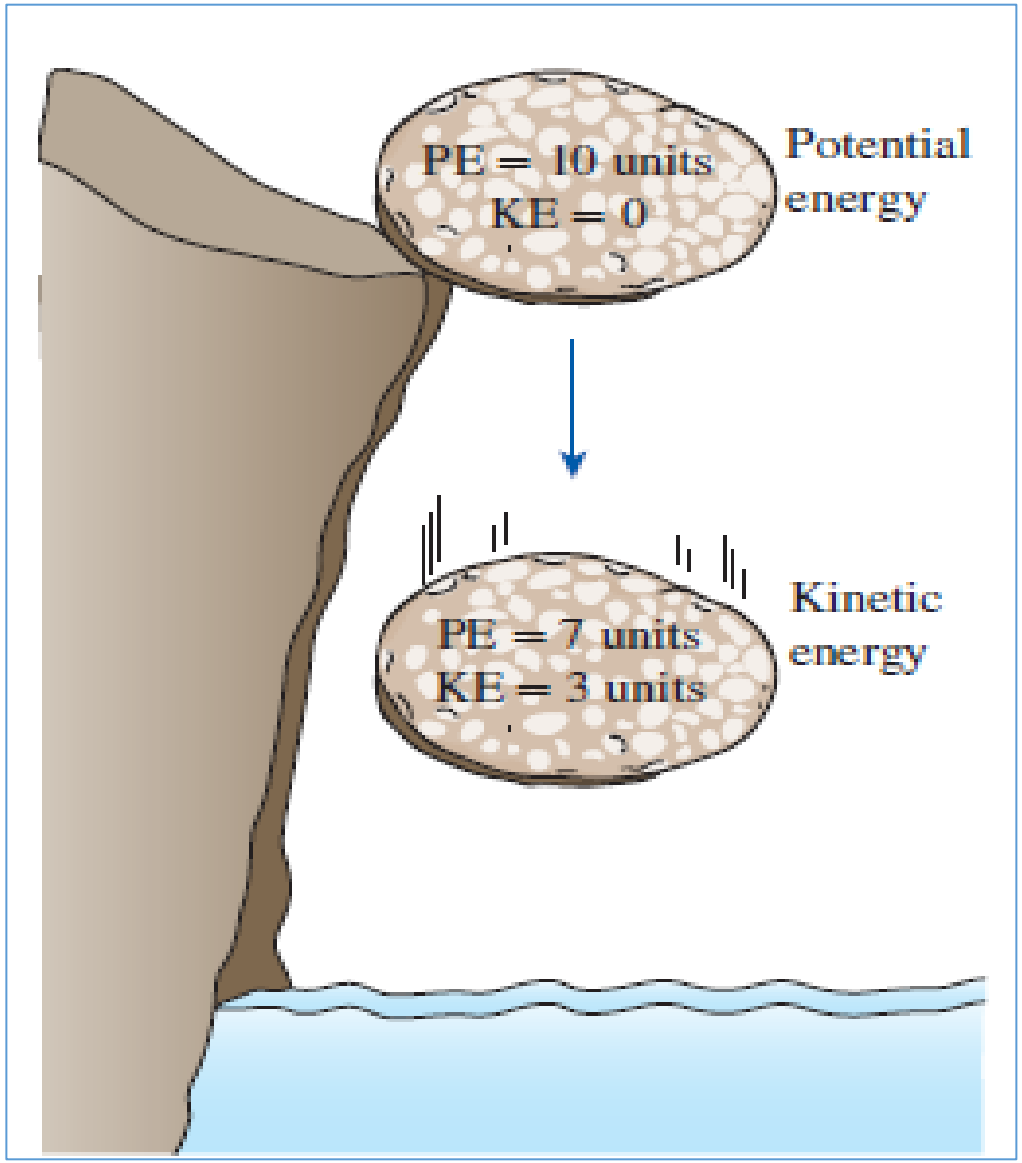
Lecture outcomes:

At the end of this lecture the students will be able to:

- Identify the unique vocabulary associated with thermodynamics.
- Review the metric SI and the English unit systems that will be used throughout the text.
- Explain the basic concepts of thermodynamics such as system, state, equilibrium, process, and cycle.
- Discuss properties of a system and define density, specific gravity, and specific weight.

1. THERMODYNAMICS:

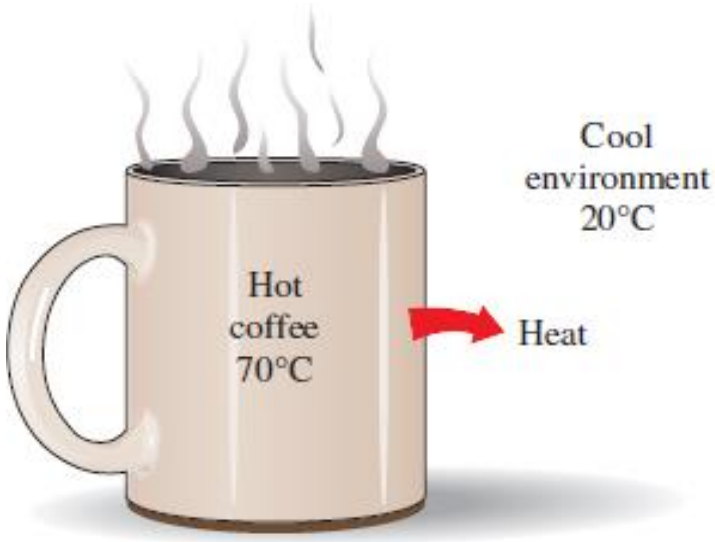
- The name comes from Greek word ***therme (Heat)*** and ***dynamis (Power).***
- Is the science that deals with properties of substance that near a relation to heat and work.
- The study of the patterns of energy change.
- More specifically, thermodynamics can be defined as the science of energy which deals with;
  a) Energy conversion
  b) The direction of change.



$$\Delta E = E_{in} - E_{out}$$

The principles of thermodynamics are summarized in the form of four laws known as:

- The **zeroth law** of thermodynamics deals with thermal equilibrium and provides a means of measuring temperature.
- The **first law** of thermodynamics deals with the conservation of energy and introduces the concept of internal energy.
- The **second law** asserts that energy has *quality* as well as *quantity*, and actual processes occur in the direction of decreasing quality of energy. For example, a cup of hot coffee left on a table eventually cools, but a cup of cool coffee in the same room never gets hot by itself.
- The **third law** defines the absolute zero of entropy.



2. APPLICATIONS OF THERMODYNAMICS

(a) Refrigerators

(b) Boats

(c) Aircraft and Spacecraft

(d) Power Plants

(e) Human body

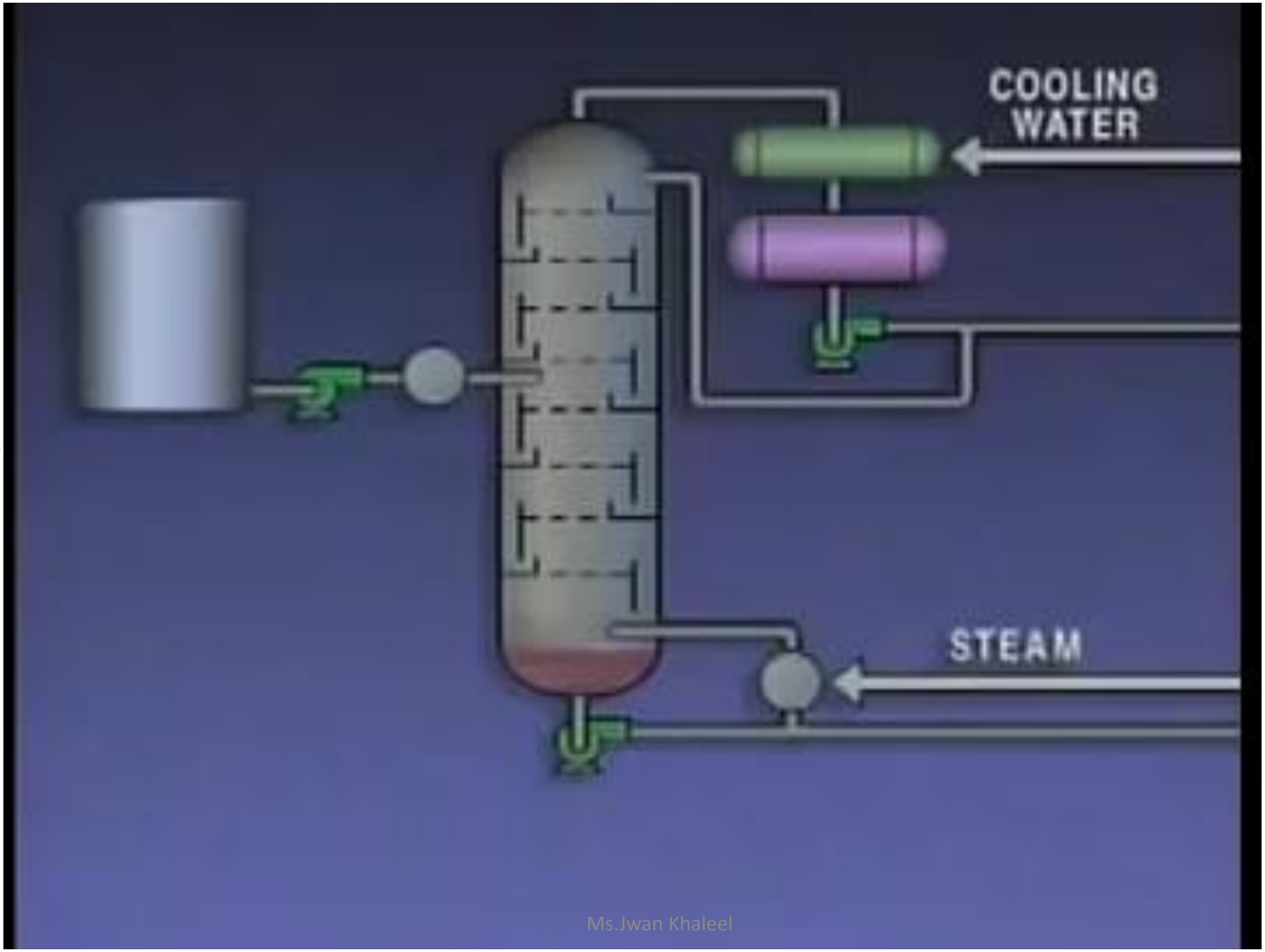
(f) Cars

(g) Wind Turbines

(h) Food Processing

(i) Pinping Network in an industrial facilities

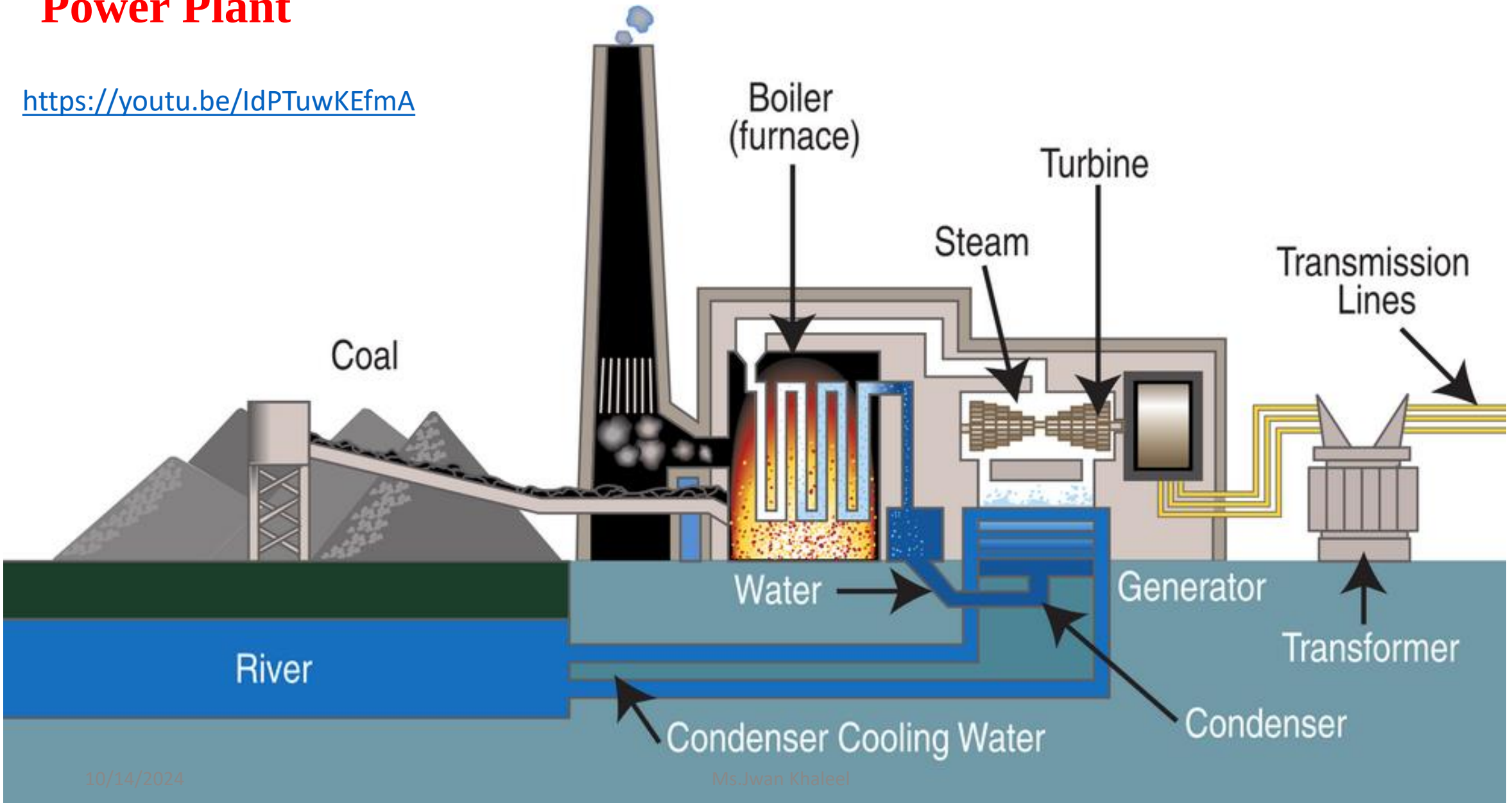
[Refinery Crude Oil Distillation Process Complete Full HD (youtube.com)]



https://www.youtube.com/watch?v=vD0kbdIS6kE

Power Plant

https://youtu.be/IdPTuwKEfmA



3. IMPORTANCE OF DIMENSIONS AND UNITS

- ***Dimensions:*** physical quantity need to be measured, there are two types:
  - ***Basic dimensions (primary or fundamental):*** mass (m), length (L), time (t), temperature (T).
  - ***Secondary dimensions (Derived):*** velocity (V), energy (E), and volume (V).
- ***Unit:*** there are two types:
  - SI (metric, international unit) kg, m, s, K
  - US (English, United state customary unit) Ibm, ft, s, R

Base Units

Quantity	SI	US
Length	Meter (m)	Foot (ft)
Mass	Kilogram (kg)	Pound mass (Ibm) or slug
Time	Second (s)	Second
Temperature	Kelvin (K)	Rankin ®

Derived Units

Quantity	Units
Area	m^2
Volume	m^3
Volume flowrate	m^3/s
Density	kg/m^3
Mass flowrate	kg/s
Force	N (kg. $m/s^{2)}$
Pressure	N/ m^2 , pa
Energy	J (N.m)
Power	J/s (watt)

There are relation between these quantities: $1\ Ibm = 0.453kg$ **,** $1ft = 0.3048m$ **others are available in the reference**

Prefix		
Factors	Name	Symbols
10^{9}	Giga	G
10^{6}	Mega	M
10^{3}	Kilo	K
10^{-3}	Milli	M
10^{-6}	Micro	µ
10^{-9}	Nano	N
Example : 1 kg = 1000 g, 1Mpa= 1*10^{6} pa,		

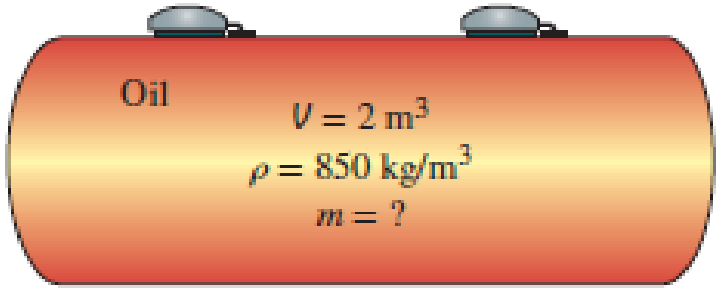
Example1: Convert 66000 Pascal to Mega Pascal

Solution: $66000 \text{ pa} \times \frac{1MPa}{10^{6}} = 0.066 \text{ MPa}$

- ***Density:*** Is the total mass of substance divided by the total volume of that substance. $\rho = \frac{m}{V}$ $\left(\frac{kg}{m^3}\right)$

($\rho\ for\ water = 1000\frac{kg}{m^3}$, for air $= 1.16\frac{kg}{m^3}$, for mercury $13560\frac{kg}{m^3}$)

Example 2: A tank is filled with oil whose density is ρ = 850 kg/m^3. If the volume of the tank is V = 2 m^3, determine the amount of mass m in the tank.



Solution: $\rho = 850\frac{kg}{m^3}$, $V = 2m^3$

$$\rho = \frac{m}{V} \quad , \quad m = \rho V = 850\ \frac{kg}{m^3} \times 2m^3 = 1700\ kg$$

- ***Weight:*** gravitational force applied to a body; its amount determined from newton's second law.
  - W=mg, g is the gravitational acceleration=9.81m/s2 , or 32.174 ft

- /s^2 at sea level and 45° latitude) at sea level and 45° latitude)

Example3: determine the mass and weight of the air contained in the room whose dimensions are 6 m×6m×8m
. Assume the density of air = 1.16 kg/m^3.

Solution:

$$m = \rho V = 1.16\ \frac{kg}{m^3} \times (6 \times 6 \times 8)m^3 = 334.1\ kg$$

$$W = mg = (334.1kg)\left(9.81\frac{m}{s^2}\right)\left(\frac{1N}{1kg.\frac{m}{s^2}}\right) = 3277N$$

- ***Work:*** which is a form of energy, can simply be defined as force times distance; therefore, it has the unit "newton-meter ($N \cdot m$)," which is called a joule (J).

That is; $1\ \text{J} = 1\ N \cdot m$

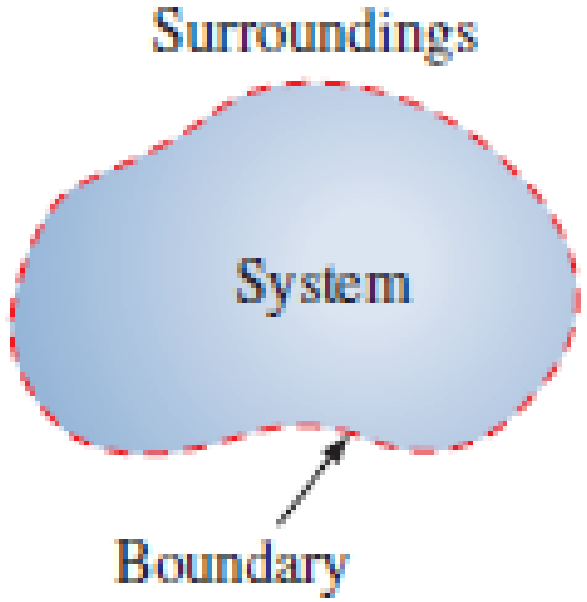
- ***Heat***: is the energy interaction between system and surroundings. (J or kJ)
  - A more common unit for energy in SI is the kilojoule ($1\ \text{kJ} = 10^3\ \text{J}$).
  - In the English system, the energy unit is the Btu (British thermal unit), which is defined as the energy required to raise the temperature of 1 lbm of water by 1°F.
  - In the metric system, the amount of energy needed to raise the temperature of 1 g of water by 1°C is defined as 1 calorie ($cal.$).
- ***Power:*** the time rate of energy $(\text{J/s}) = watt\ (W)$.

$$1\ horsepower\ (hp) = 746\ W$$

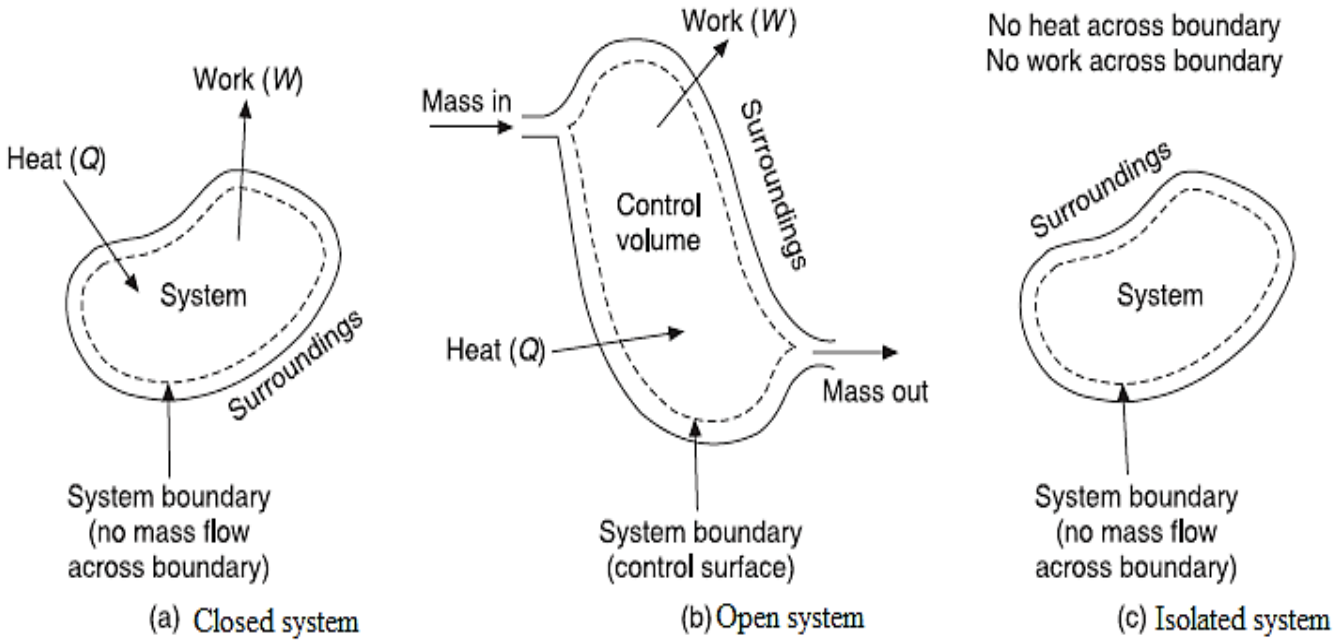
$$1\ kilowatt.hour\ (kWh) = 3600\ kJ$$

4. SYSTEMS AND CONTROL VOLUMES

- A **thermodynamic system** is defined as any region of space or a finite quantity that occupies a volume and has a boundary.
- Anything external to the system is called ***surroundings***.
- The system is separated from the surroundings by an imaginary envelope, which is known as ***boundary*** of the system as shown in Figure. The boundaries are the limits of the system. May be fixed or movable.

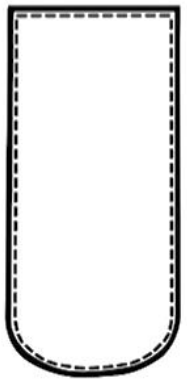


4. SYSTEMS AND CONTROL VOLUMES

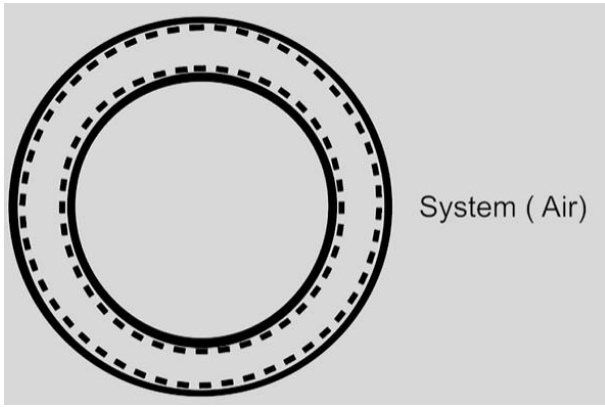


1. **Closed systems (Control mass):** A closed system consists of a constant amount of mass, and no mass can cross its boundary, but energy can.
2. **Open systems (control volume):** It usually encloses a device which involves flow of mass, such as a nozzle, diffuser, compressor, or turbine. Both energy and mass can cross the boundary of a control volume, which is called the control surface, but the shape of the control volume will remain unchanged.
3. **Isolated systems:** Neither mass nor energy can cross the boundary.

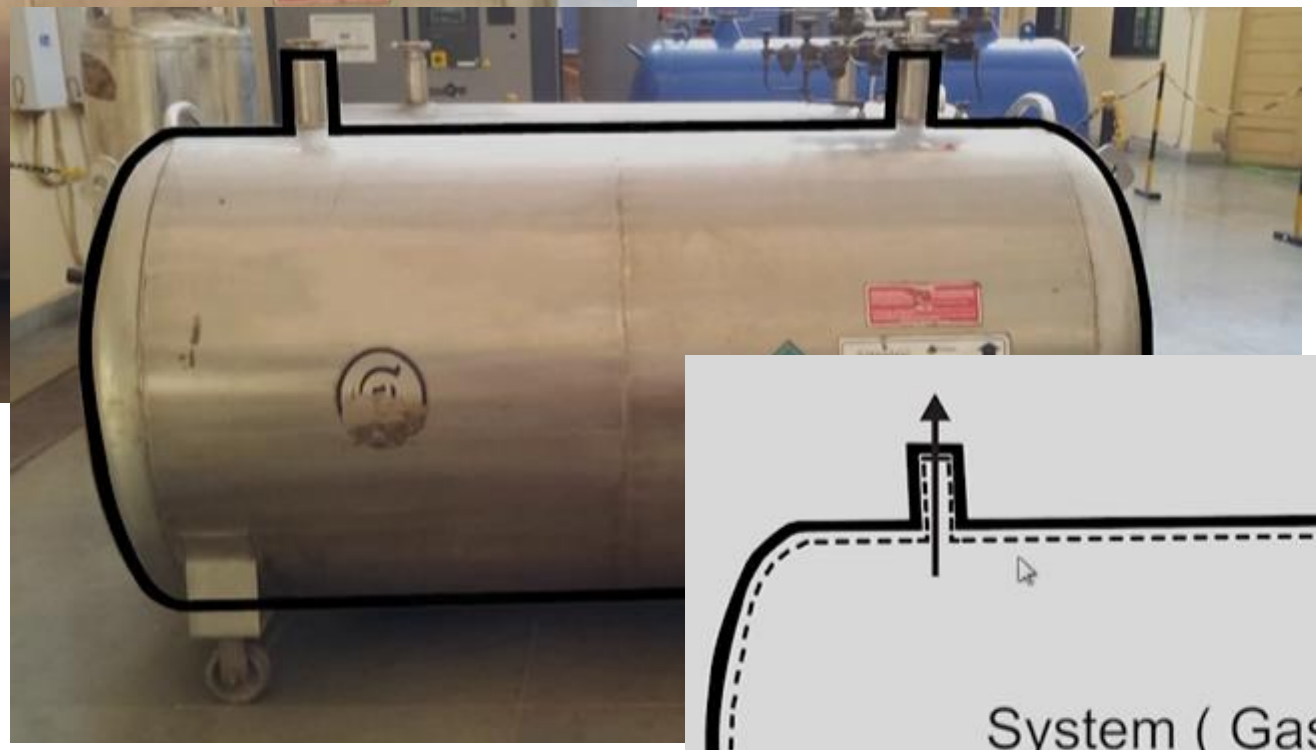

THERMOS

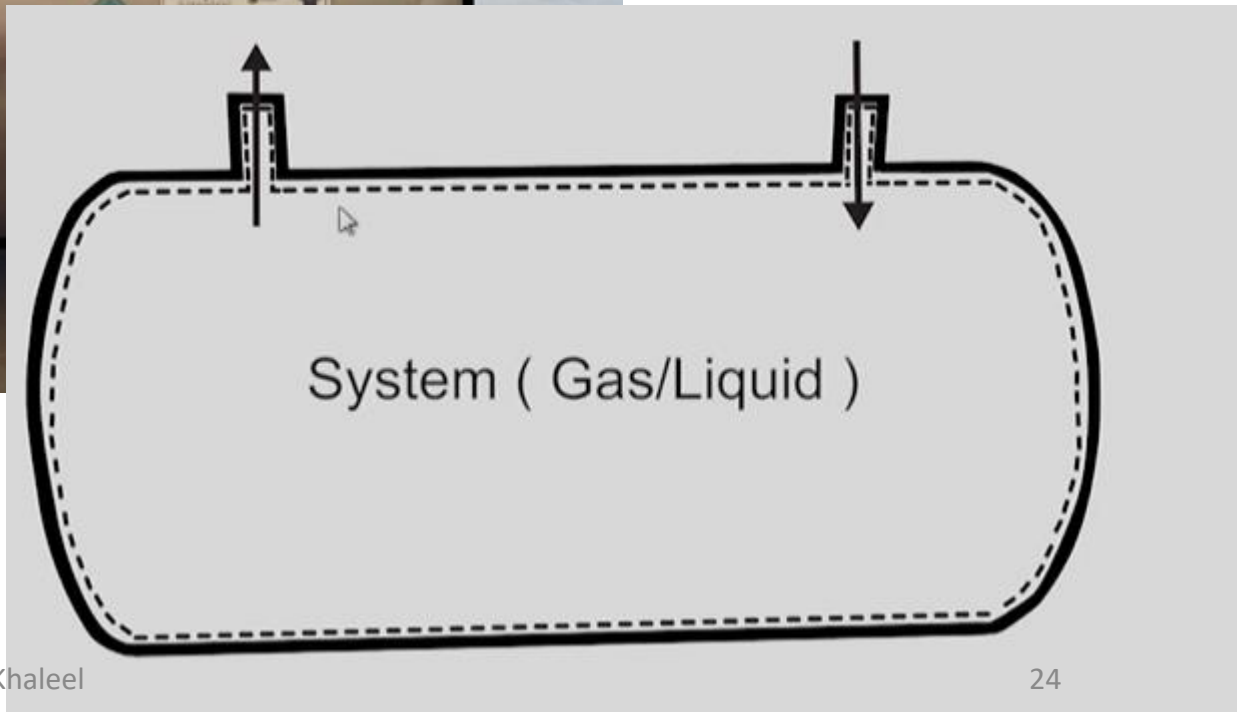


System (Water)

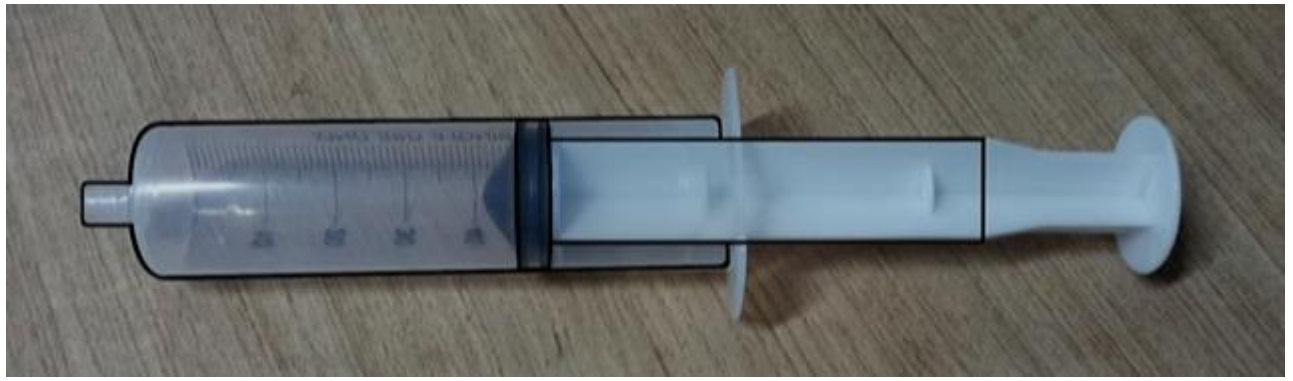

System (Air)

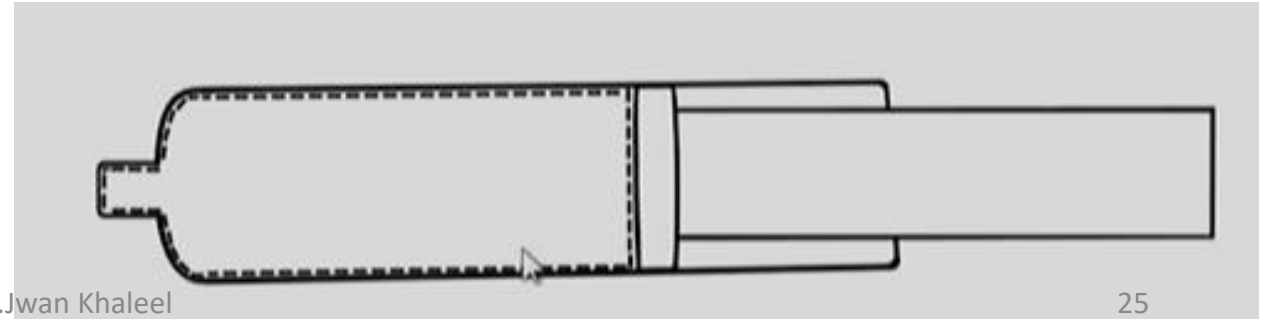
Tank of nitrogen



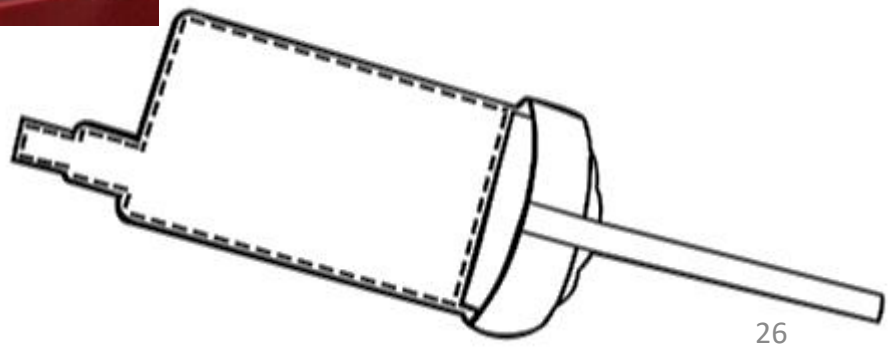


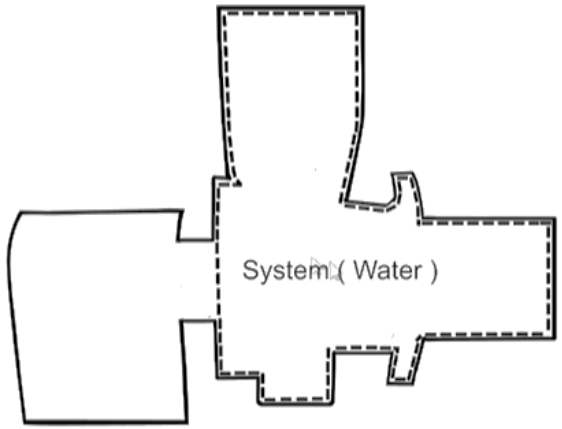
Syringe (Cylinder and piston principle)





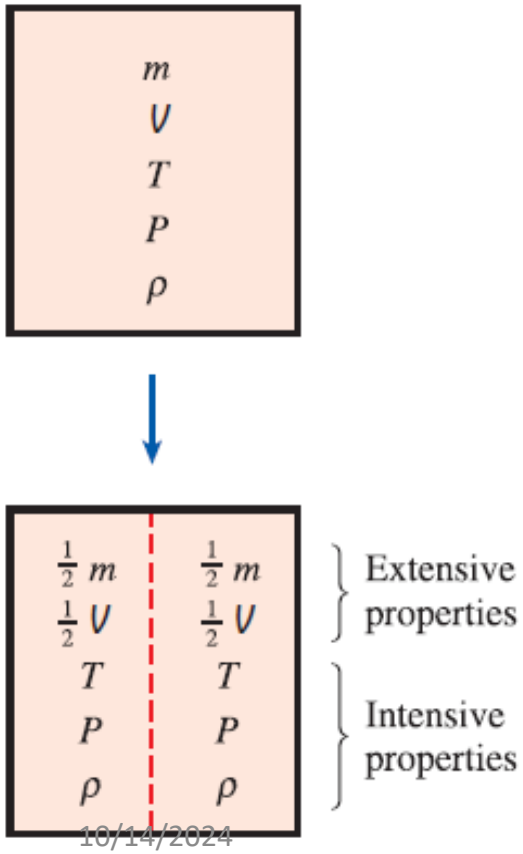
Foot pump (Cylinder and piston principle) used to inflate bicycle tires or sometimes even small car tires.





Water Pump, here you will see in a laboratory situation is a centrifugal water pump, it is driven by a motor which is inside this safety shield, the inlet pipe through which the pump sucks in water, the exhaust pipe through which the pump throws out water at a high pressure.

5. PROPERTIES OF A SYSTEM



Any characteristic of a system in equilibrium is called a **property**. Some familiar properties are pressure P, temperature T, volume V, and mass m. Property is independent the path of used to arrive the system condition.

Properties are either intensive or extensive:

- **Intensive properties:** are those that are independent of the mass of a system, such as temperature, pressure, and density.
- **Extensive properties:** are those whose values depend on the size or extent of the system. Total mass, total volume, and total momentum.

6. SPECIFIC VOLUME, GRAVITY & WEIGHT

Specific volume v, which is defined as volume per unit mass. $v = \frac{V}{m} = \frac{1}{\rho}$

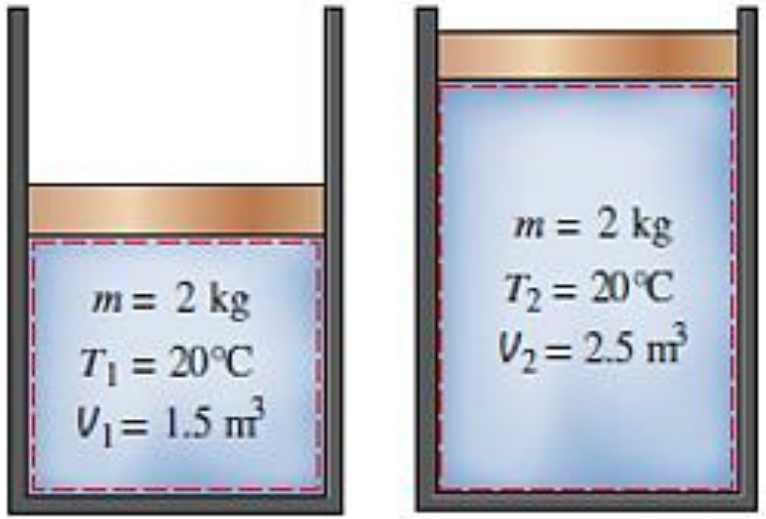
specific gravity, or relative density: is defined as the ratio of the density of a substance to the density of some standard substance at a specified temperature (usually water at 4°C, for which $\rho\ H_2O = 1000\ kg/m^3$). $S.G. = \frac{\rho}{\rho_{H_2O}}$

Specific weight: is the weight of a unit volume of a substance and is expressed as:

$$\gamma_s = \rho g \ \ (N/m^3)$$

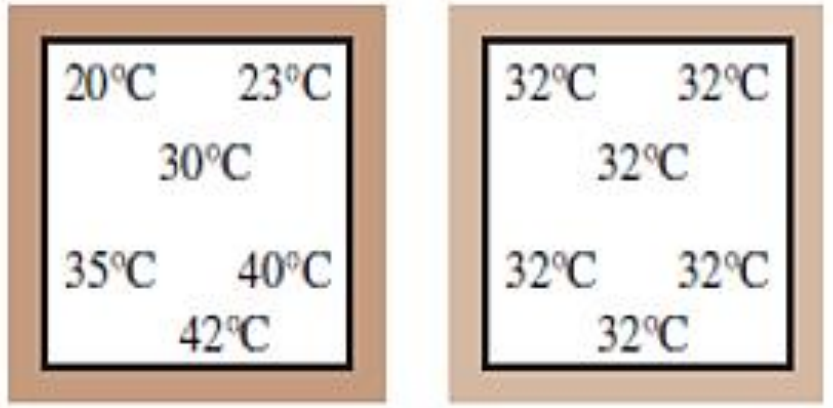
7. STATE AND EQUILIBRIUM

1. ***Thermal equilibrium*** means equality of temperature
2. ***Mechanical equilibrium*** means equality of pressure
3. ***Chemical equilibrium*** means equality of chemical potentials.



(a) State 1 (b) State 2

A system at two different states.

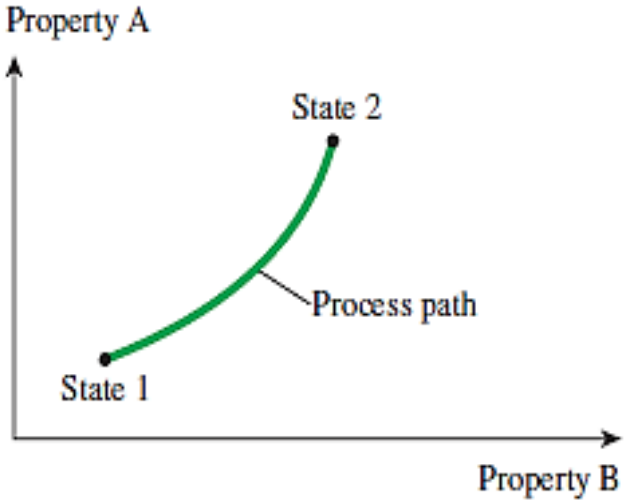


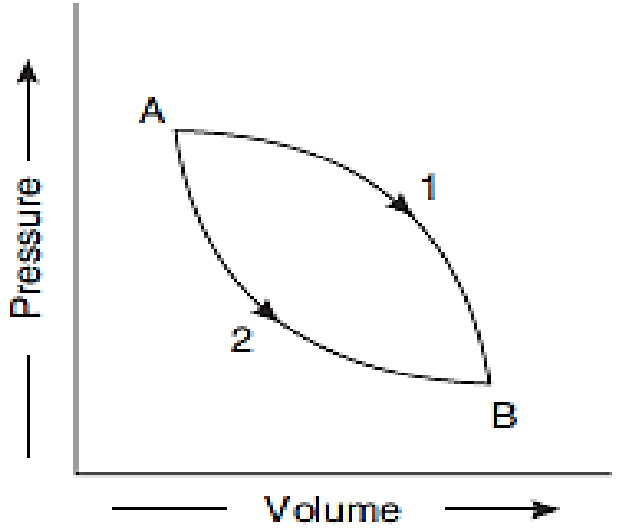
(a) Before (b) After

A closed system reaching thermal equilibrium.

8. PROCESSES AND CYCLES

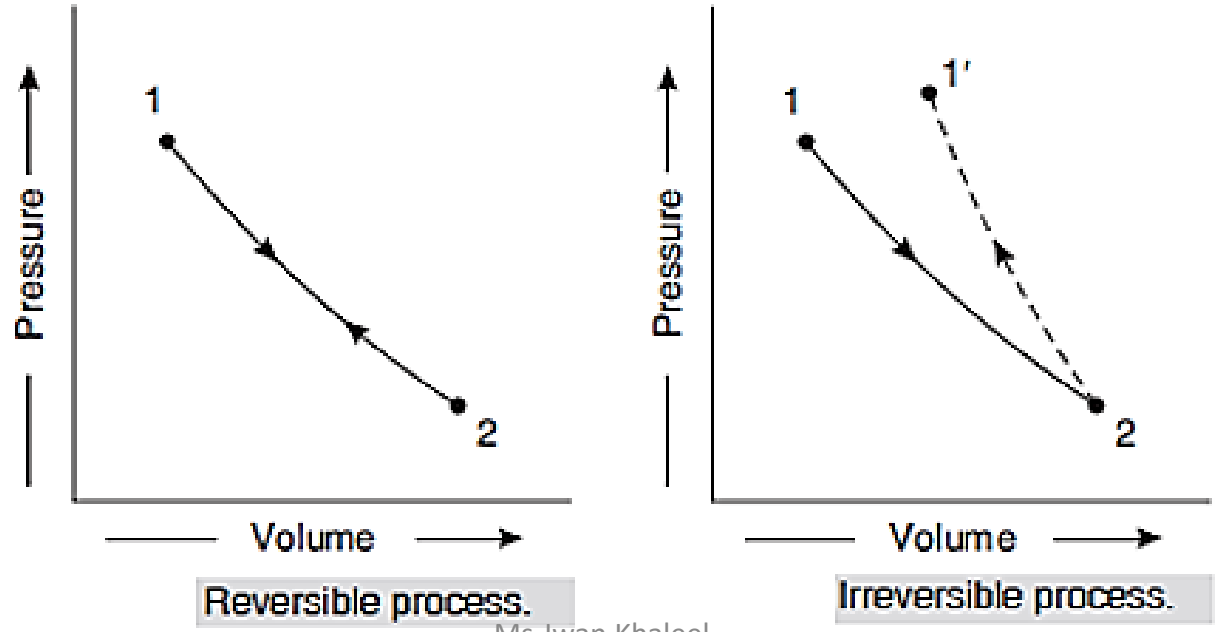
- **Process:** Any change that a system undergoes from one equilibrium state to another.
- **State:** The condition of physical existence of a system at any instant of time is called a state. It is described by properties such as pressure, temperature, volume etc.
- **Path:** the series of states through which a system passes during a process is called the path of the process.
- **Cycle:** A system is said to have undergone a cycle if it returns to its initial state at the end of the process. That is, for a cycle the initial and final states are identical.



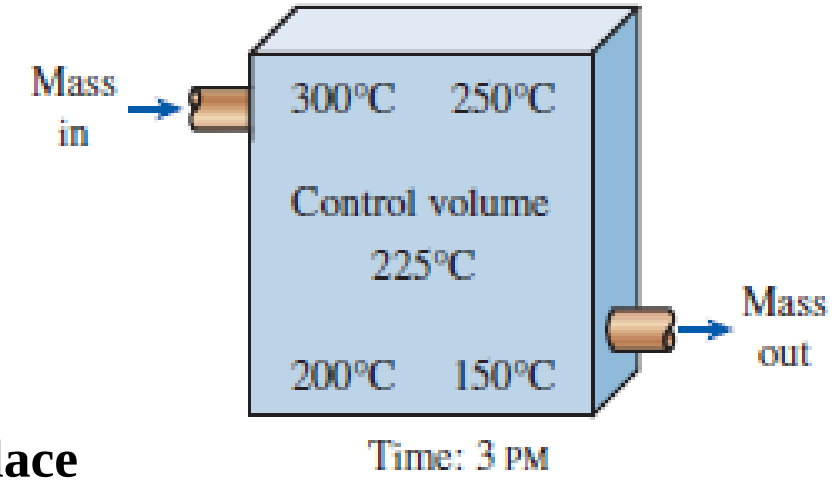


8. PROCESSES AND CYCLES

- **Reversible process:** A process that can be reversed resulting in no change to the system or surrounding.
- **Irreversible process:** A process if reversed results would change to the system or surrounding.
- **Isoprocess:** one thermodynamic property kept constant.
- **Working substance:** medium by which energy is carried through the cycle.
- **Steady state:** properties independent to time.

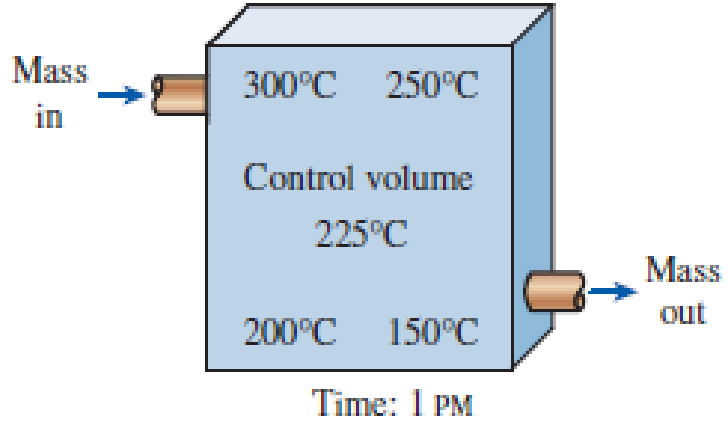


- **During a steady-flow process, fluid properties within the control volume may change with position but not with time.**



- **When a system undergoes a certain process, work transfer takes place across the boundary of the system. There are following three commonly used processes:**

1. Isometric or Isochoric process. This process takes place at constant volume.
2. Isopiestic or Isobaric process. This process takes place at constant pressure.
3. Isothermal process. This process takes place at constant temperature.



9. HOMOGENEOUS AND HETEROGENEOUS SYSTEM

- **Homogeneous system:** A system which consists of a single phase. The examples of this system are water, ice, mixture of air and water vapour, dry saturated steam, mixture of ammonia in water, water plus nitric acid, octane plus heptane etc.
- **Heterogeneous system**: A system which consists of more than one phase. The examples of this system are water plus steam, ice plus water, mixture of water and oil etc.

Notes:

(a) A mixture of a liquid and gas is a two-phase system.

(b) A mixture of water, ice and steam forms a three-phase system

10. LECTURE QUESTIONS -Review

1. Define thermodynamics. State the scope and applications of thermodynamics.
2. Define the following terms:
    a. Zeroth, first, second and third law of thermodynamics.
    b. Density, heat, work, Btu, calorie,
    c. system, boundary, state, cycle, path, working substance, Isoprocess, Equilibrium, steady state.
3. Explain the difference between reversible and irreversible process.
4. Explain the difference between Homogeneous system and Heterogeneous system.
5. What is a thermodynamic system? Discuss its types with suitable examples and sketch them.
6. What do you understand by path function and point function?
7. Explain the difference between Intensive and Extensive properties.

10. LECTURE QUESTIONS

8. Which of the following is an extensive property of a thermodynamic system?

a) Pressure
b) Volume
c) Temperature
d) Energy

9. A system consisting of a single phase is called a

a) closed system.
b) open system
c) homogeneous system
d) heterogeneous system

10. In an isolated system,

a) both mass and energy (i.e., heat and work) crosses the boundary of the system.
b) neither mass nor energy transfer takes place across the boundary of the system
c) only mass crosses the boundary of the system
d) only energy crosses the boundary of the system.

11. Explain the following terms as related to thermodynamics:

a) System
b) State
c) Property
d) Process
e) Cycle

References

1. Thermodynamic an engineering approach, by Y.A. Çengel, M. A. Boles, & M. Kanoğlu

2.Basic Thermodynamics by B.K. Venkanna

3. Engineering Thermodynamics, by Er. S.K. Gupta

The end of the lecture
Enjoy your time