



THERMO DYNAMICS I

CHAPTER 1

Basic Concepts of Thermodynamics

2

Thermodynamics

Why do we need to study thermodynamics?

- ❖ Knowledge of thermodynamics is required to design any device involving the:-
 - Interchange between heat and work,
 - Conversion of material to produce heat (combustion).

Thermodynamics

❖ From Greek,

➤ Thermo = heat,

➤ Dynamics = power, force

What is thermodynamics?

➤ The study of the relationship between work, heat, and energy.

➤ Deals with the conversion of energy from one form to another.

➤ Deals with the interaction of a system and its surroundings.

Thermodynamics

- ✓ Thermodynamics **predicts**
 - ❖ whether a process will occur given long enough time.
 - ❖ driving force for the process.
- ✓ Thermodynamics does **not predict**
 - ❖ How fast a process will occur.
 - ❖ Mechanism of the process.

Thermodynamics

- ✓ Engineers seek to achieve **improved designs** and **better performance**, as measured by factors such as:-
 - An increase in the output of some desired product.
 - A reduce input of a scarce resource
 - A reduction in total costs
 - A lesser environmental impact
- ✓ The principles of engineering thermodynamics play an important part in achieving these goals.

Two Fundamental Principles

First Law

- Energy is always conserved.
- Energy may be transferred between objects and change from one type to another, but the total amount of energy is conserved.

Second Law

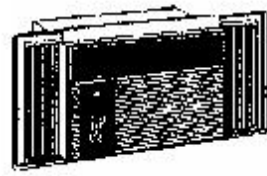
- Energy has quality and quantity.
- Real changes occur only in a direction of decreasing quality of energy.

Applications

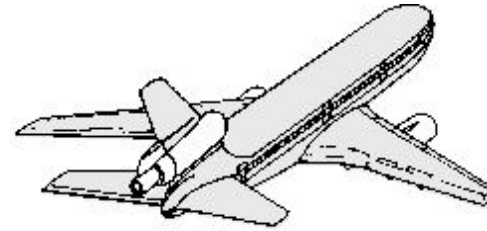
- Energy conversions within human body
- Air-conditioners
- Refrigerators
- Internal combustion engines
- Gas and steam turbines
- Energy transmission through objects



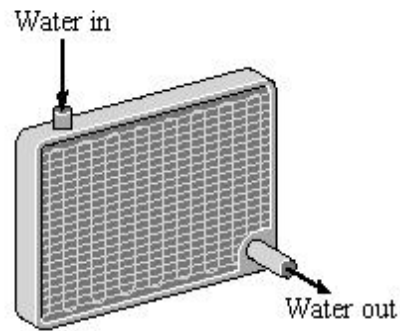
The human body



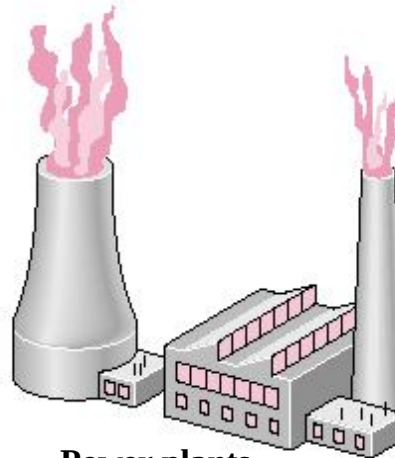
Air-conditioning systems



Airplanes



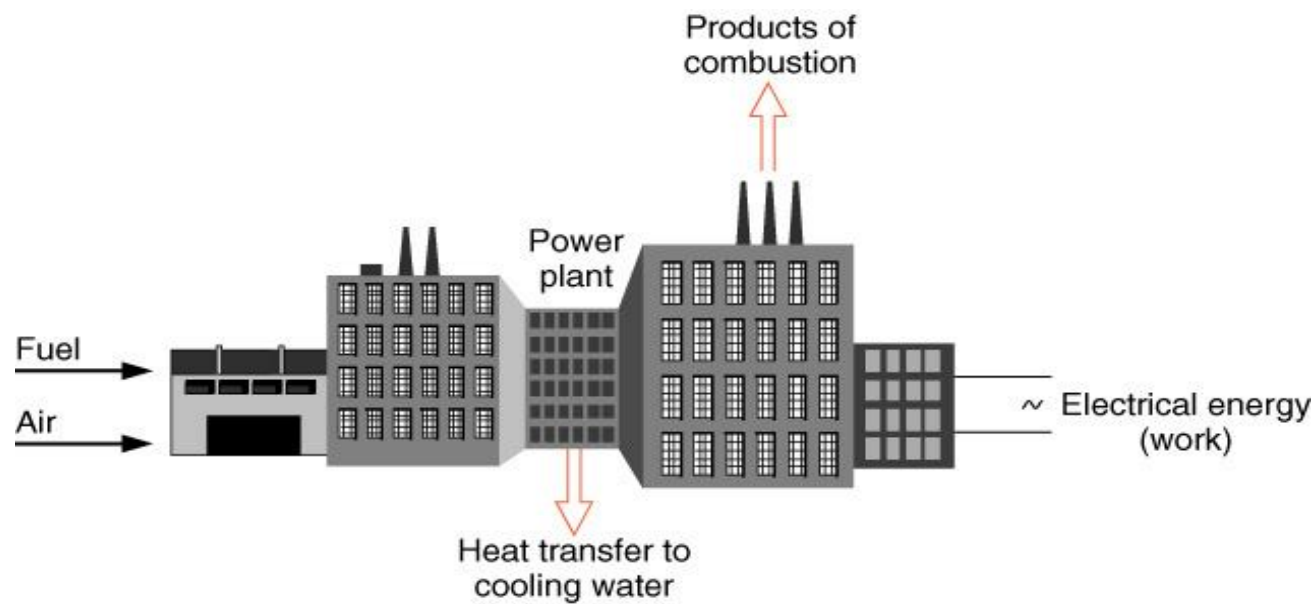
Car radiators

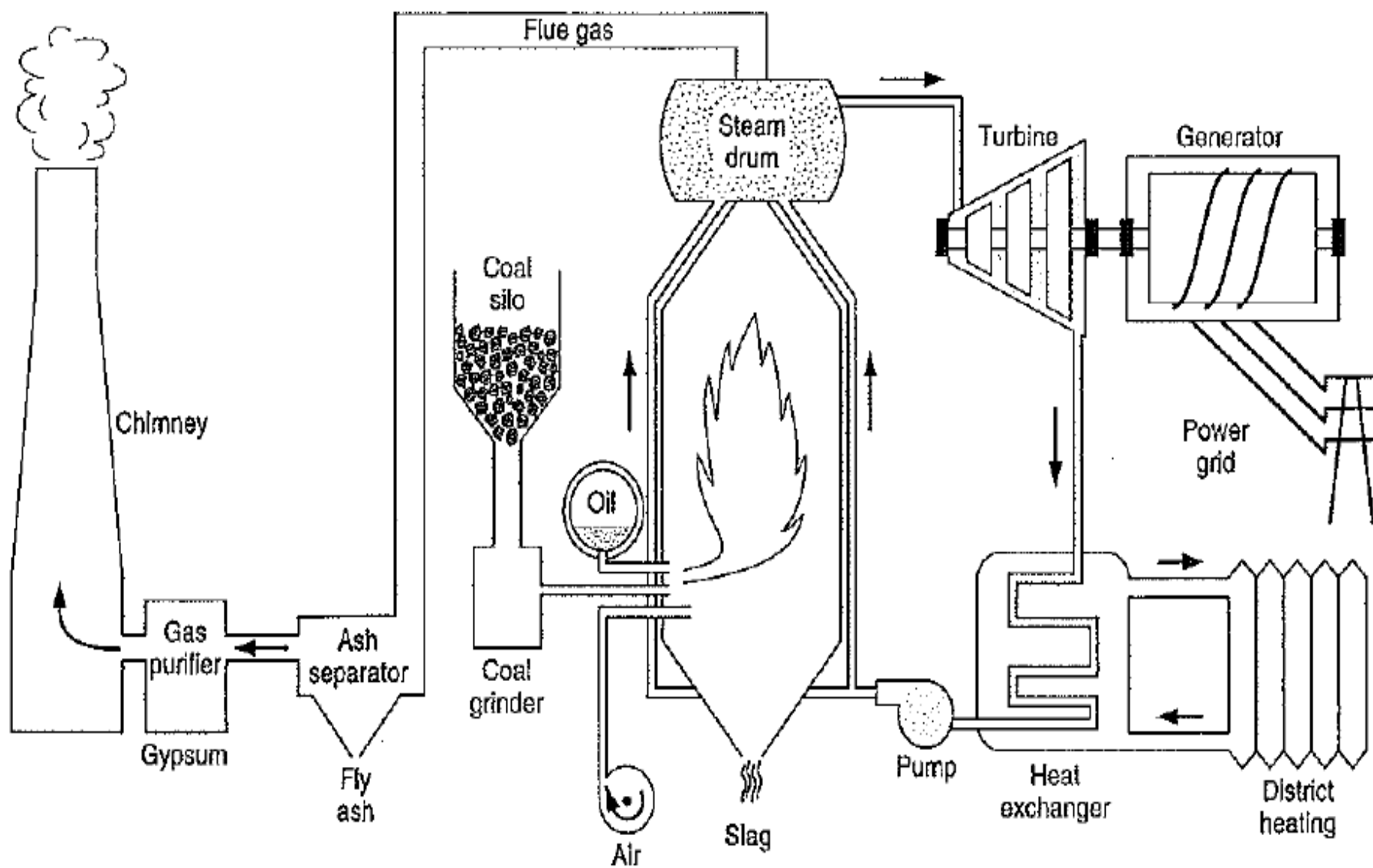


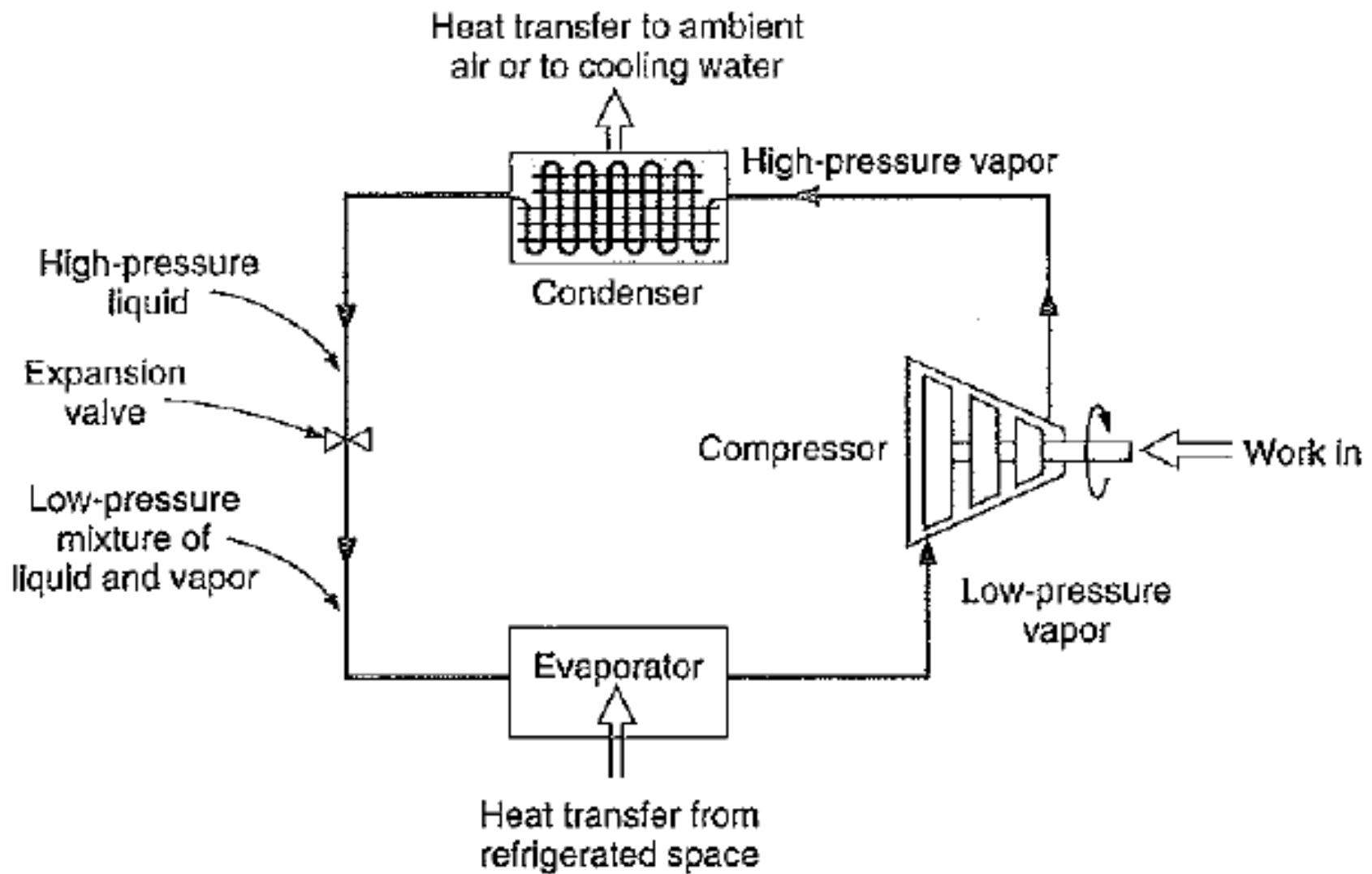
Power plants

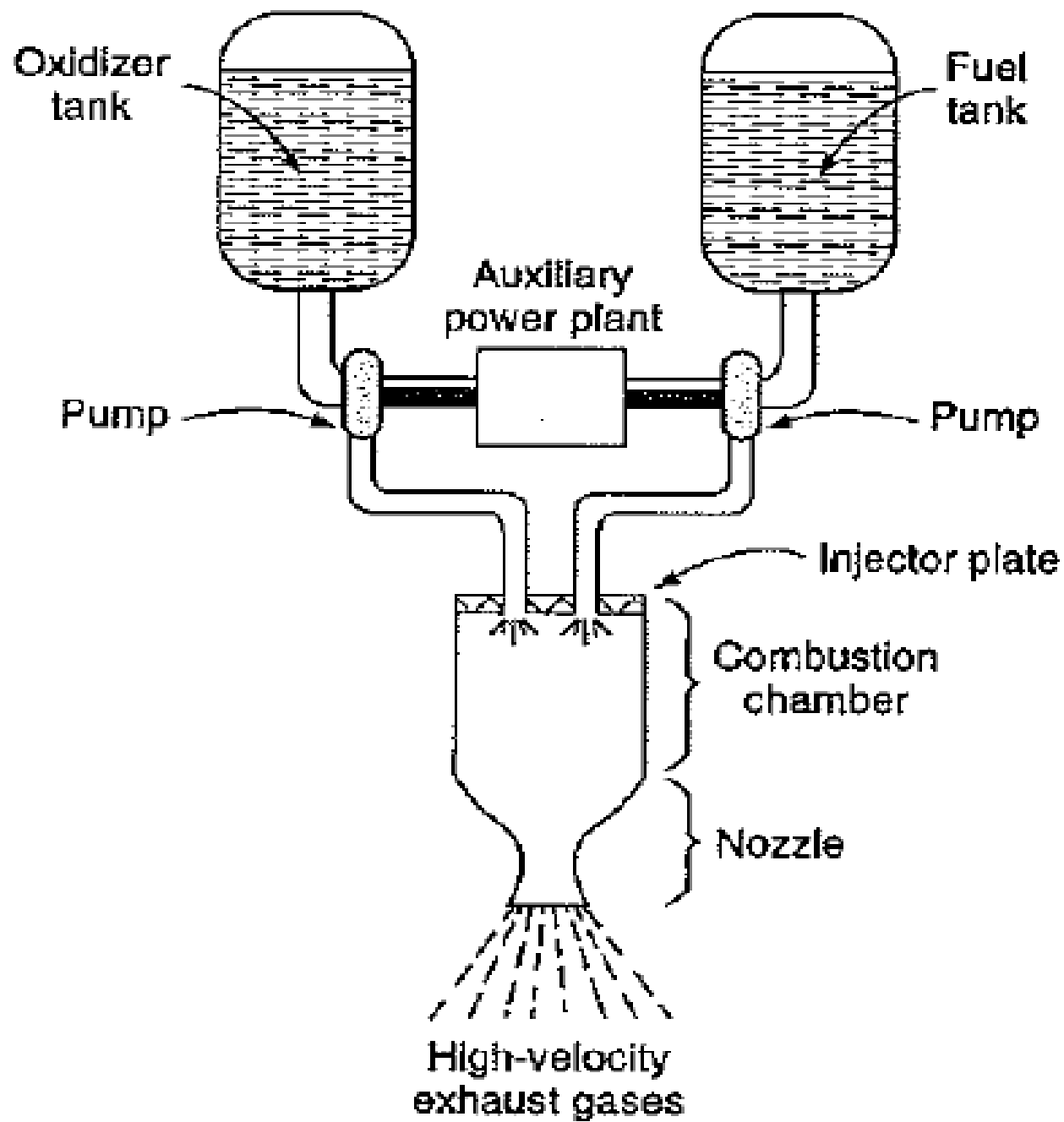


Refrigeration systems









Thermodynamics Structure

❖ The behaviors of the system can be studied from:-

1. Macroscopic point of view

❖ The macroscopic approach to thermodynamics is concerned with the **gross** or **overall behavior**.

❖ This is some times called **classical thermodynamics**

❖ No model of the structure of matter at the molecular, atomic and subatomic levels is directly used in classical thermodynamics.

Thermodynamics Structure

2. Microscopic point of view

- concerned with the **structure of matter**.
 - This is some times called **statistical thermodynamics**
 - Average behavior of the particles making up a system.
- ❖ For the great majority of engineering application, classical thermodynamics not only provides a considerably more **direct approach for analysis** and design but also requires far fewer **mathematical application**.

Thermodynamics System

- ❖ An important step in any engineering analysis is to describe precisely **what is being studied**.
- ❖ In mechanics, if the motion of a body is to be determined normally:-
 - the first step is to define a free body diagram.
 - Identifying all the forces exerted on it by other bodies
 - Newton's second law of motion is then applied

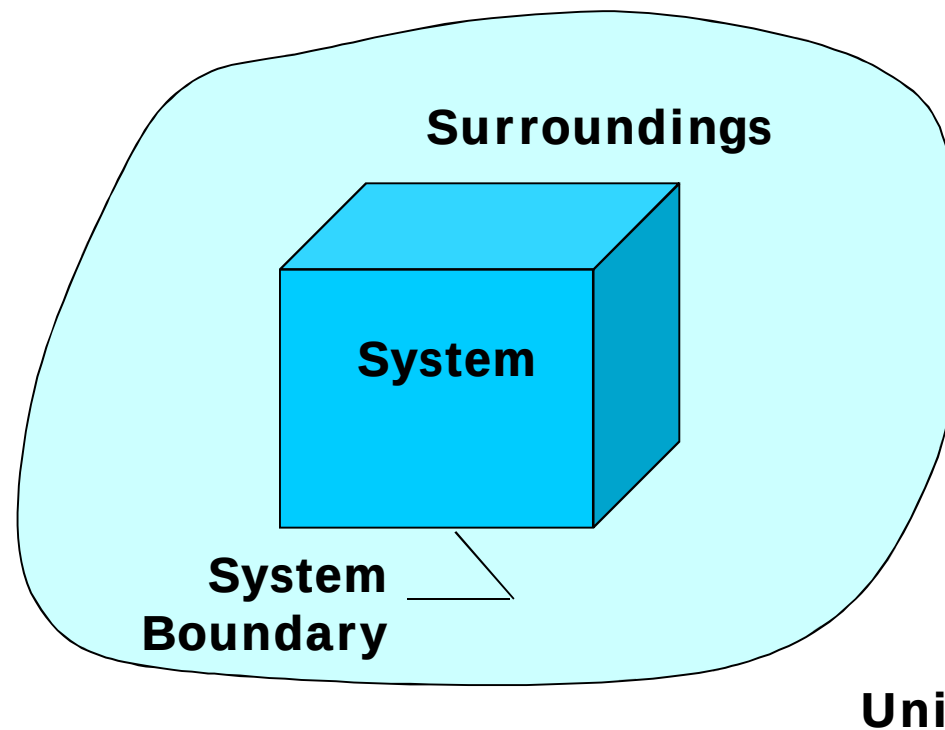
Thermodynamics System

❖ In thermodynamics :-

- the first step is to define a system.
- Once the system is defined and the relative interaction with the other systems are identified.
- One or more physical laws are applied

Thermodynamic System

- ❖ **System:** the portion of the universe that is to be examined.
- ❖ **Surroundings:** the rest of the universe.
- ❖ **Boundary:** the invisible and infinitesimally thin surface that separate the system from the surroundings.



❖ Two types of exchange can occur between system and surroundings:-

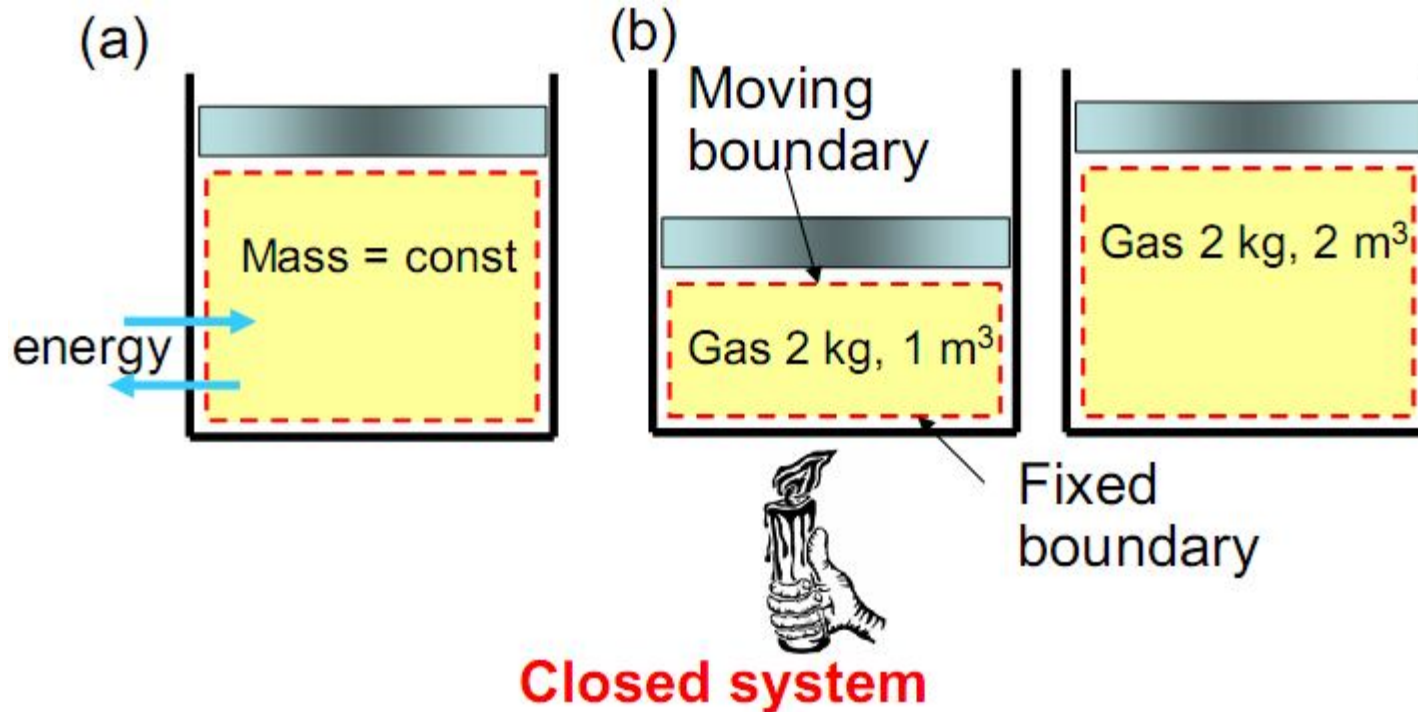
1. energy exchange (heat, work, etc.)
2. matter exchange (movement of molecules across the boundary of the system and surroundings).

❖ Based on the types of exchange which take place or don't take place, we will define three types of systems:

Closed system (Control mass)

- ❖ A fixed amount of mass chosen for study (no mass can cross its boundary).
- ❖ Heat and work can cross the boundary, volume may also change.

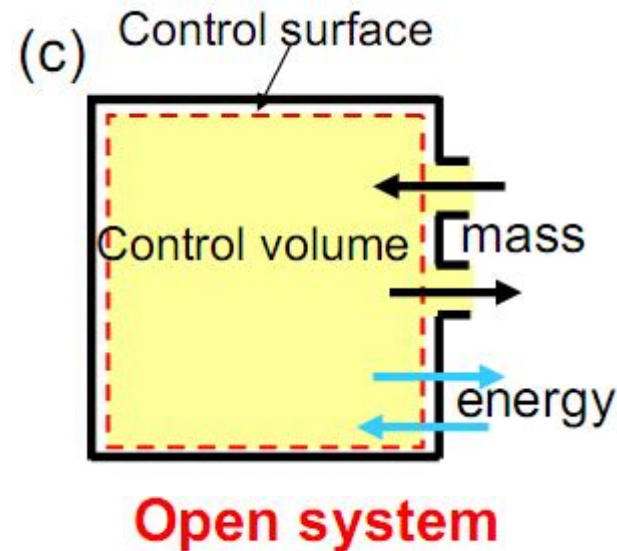
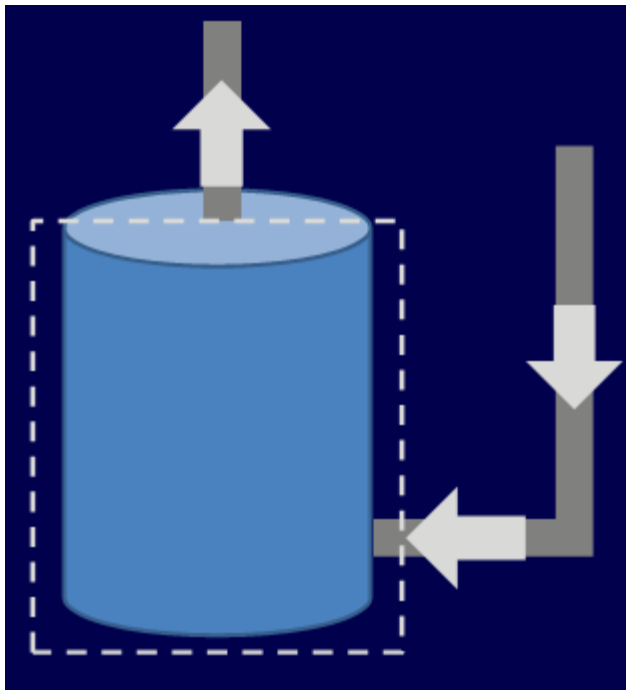
e.g. piston cylinder.



Open system (Control volume)

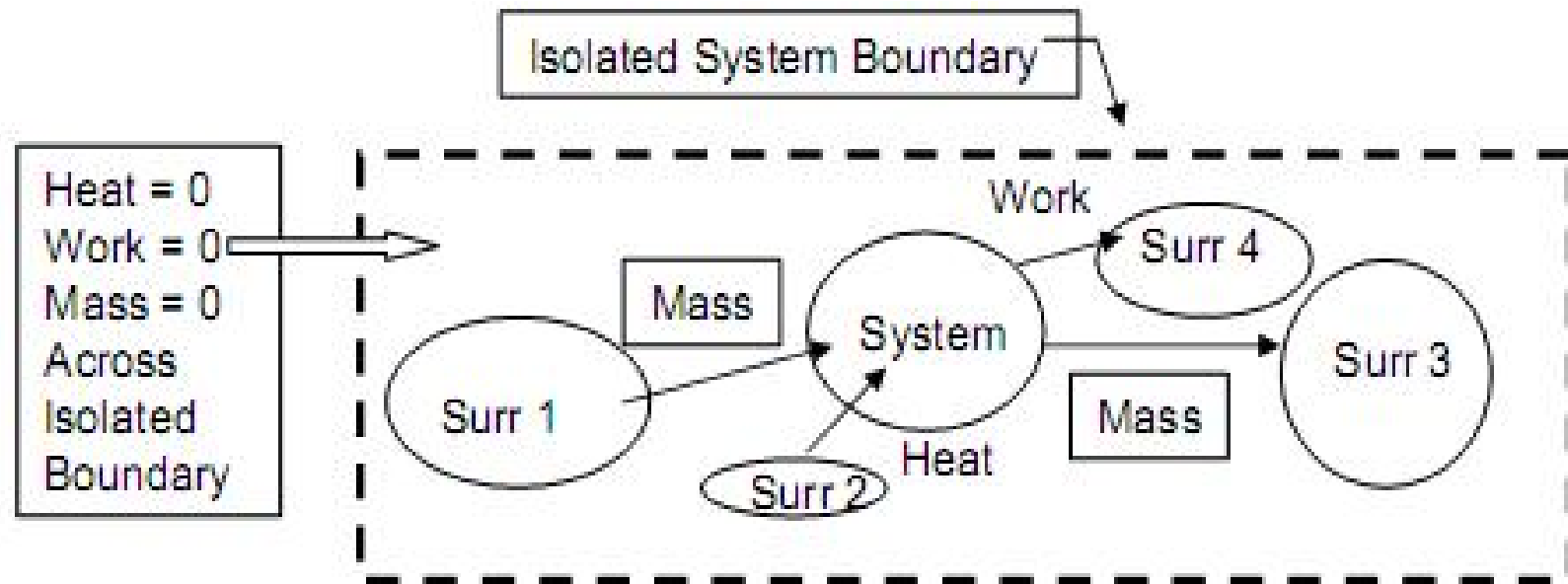
- ❖ A selected region chosen for study.
- ❖ Mass, heat and work can cross its boundary, volume may also change.

e.g. water heater, car radiator, turbine, nozzle.



Isolated system

- ❖ A system closed to mass, heat and work flows. It is not affected by the surroundings.



- ❖ Adiabatic systems – heat does not cross the boundary.
- ❖ Diathermic systems – heat can cross the boundary.

System Properties

- ❖ A property is any quantity that serves to describe a system.
- ❖ It's a macroscopic characteristic of a system that can be assigned a numerical value at a given time without knowledge of the previous history of the behavior of the system.
e.g., mass, volume, pressure...
- ❖ The property of a system should have a definite value when the system is in a particular state.
- ❖ Thermodynamic property is a point function.

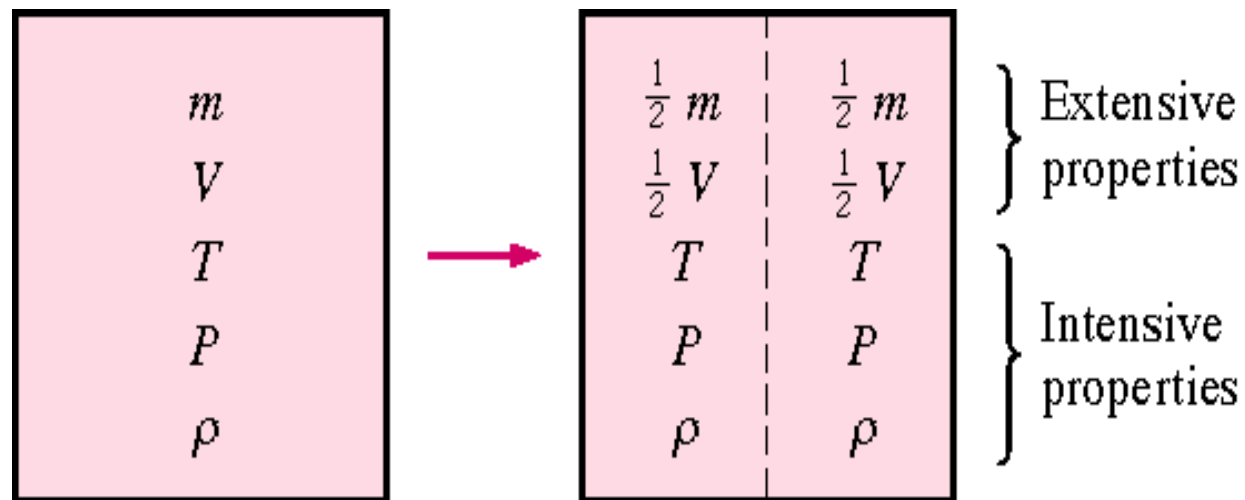
There are two types of properties:

- **Extensive** – the property value for the system is the sum of the values of the parts into which the system is divided (depends on the system size)

e.g., mass, volume, energy, weight...

- **Intensive** – the property is independent of system size (value may vary throughout the system),

e.g., pressure, temperature, color...



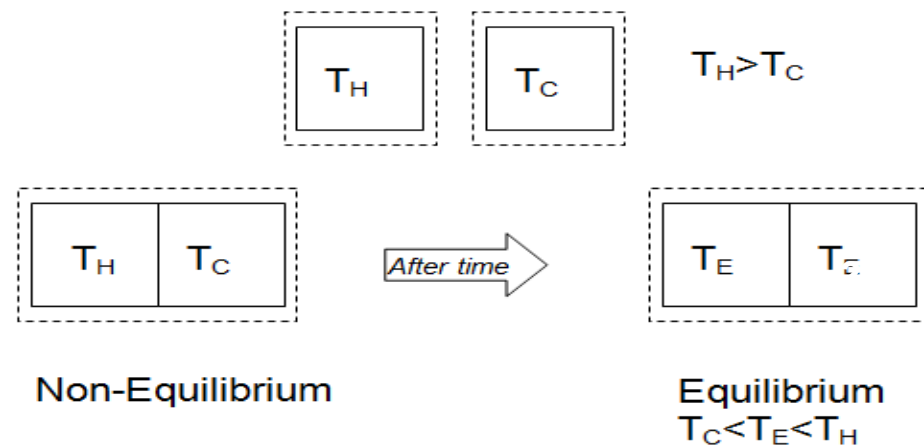
State

- ❖ Consider a system that is not undergoing any change.
- ❖ The properties can be measured or calculated throughout the entire system.
- ❖ This gives us a set of properties that completely describe the condition or state of the system.
- ❖ At a given state all of the properties are known; changing one property changes the state.

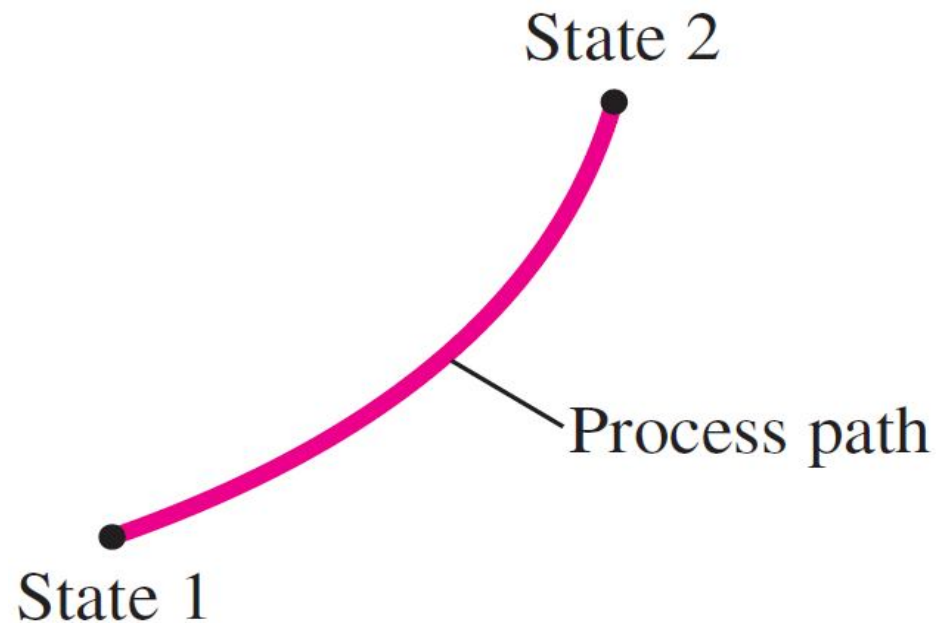
Equilibrium

- ❖ A system is in **equilibrium** if when the system is isolated from its surroundings there are no changes in its properties.
- ❖ A system is said to be in **thermodynamic equilibrium** if it maintains thermal (uniform temperature), mechanical (uniform pressure), phase (the mass of two phases, e.g., ice and liquid water, in equilibrium) and chemical equilibrium.

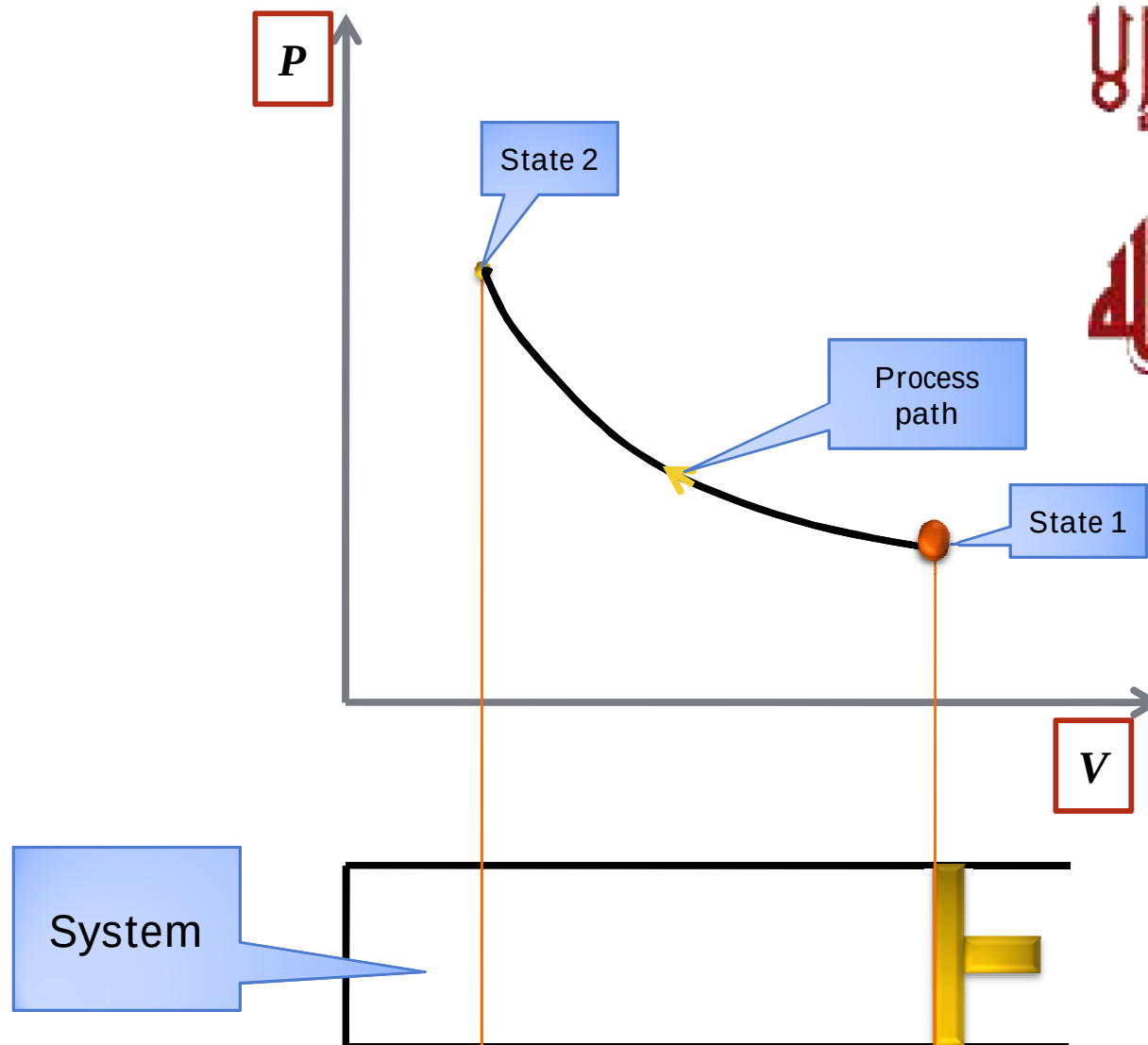
e.g.: thermal equilibrium



❖ A **process** is the transformation of a system from one state to another state.



❖ In order to plot a graph from $1 \rightarrow 2$ the system must pass through a series of intermediate states (which are in equilibrium).

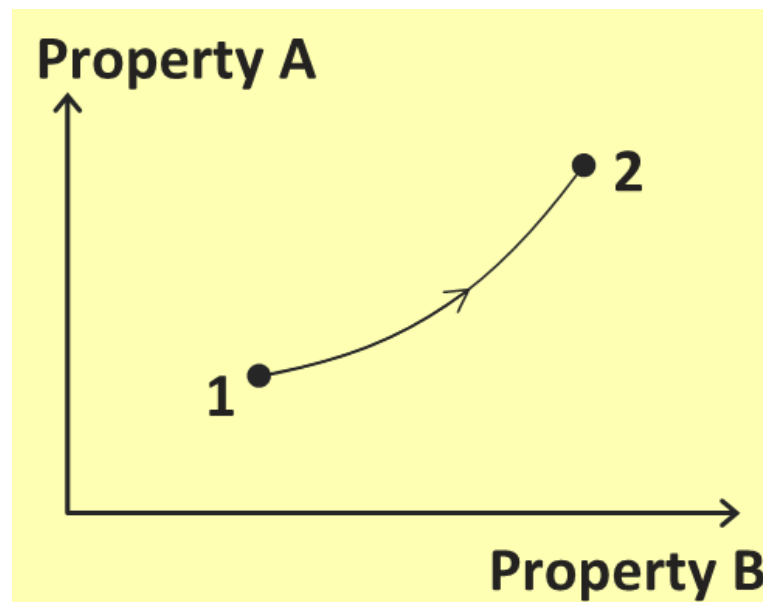


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Quasi-static process

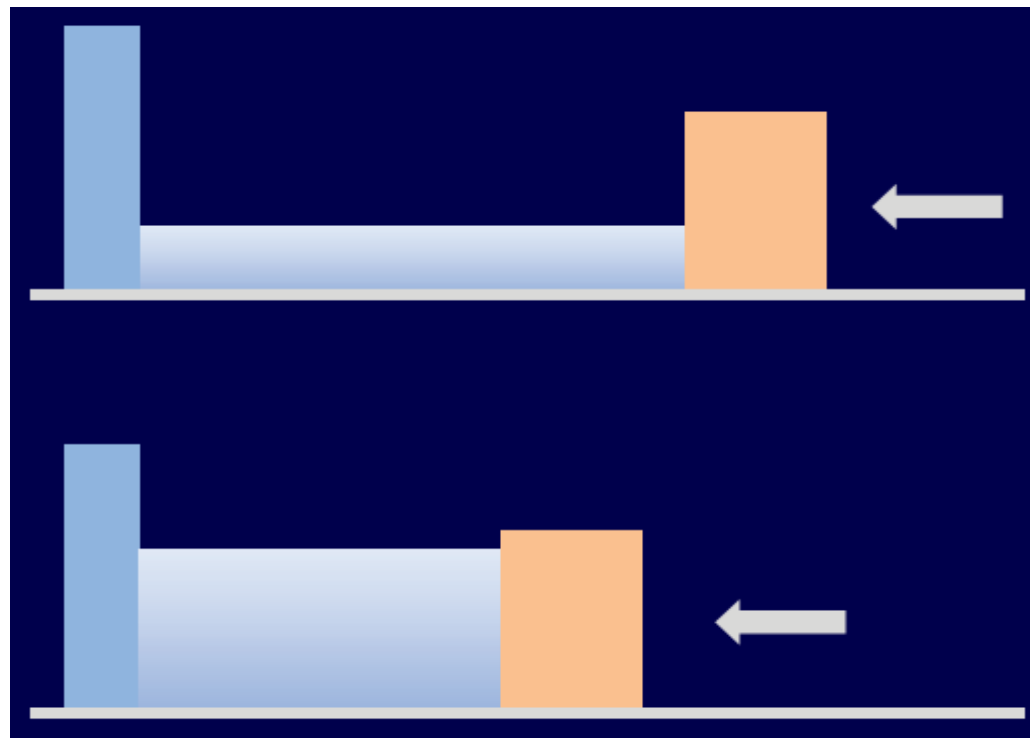
- ❖ A quasi-static process occurs sufficiently slowly so that the system passes through a succession of states that are in equilibrium. Sometimes called quasi-equilibrium.
- ❖ A quasi-static process is an idealization of what actually happens, but it is a reasonable approximation.



Fluid Mechanics Equivalent Example A.

For a Quasi-equilibrium Process

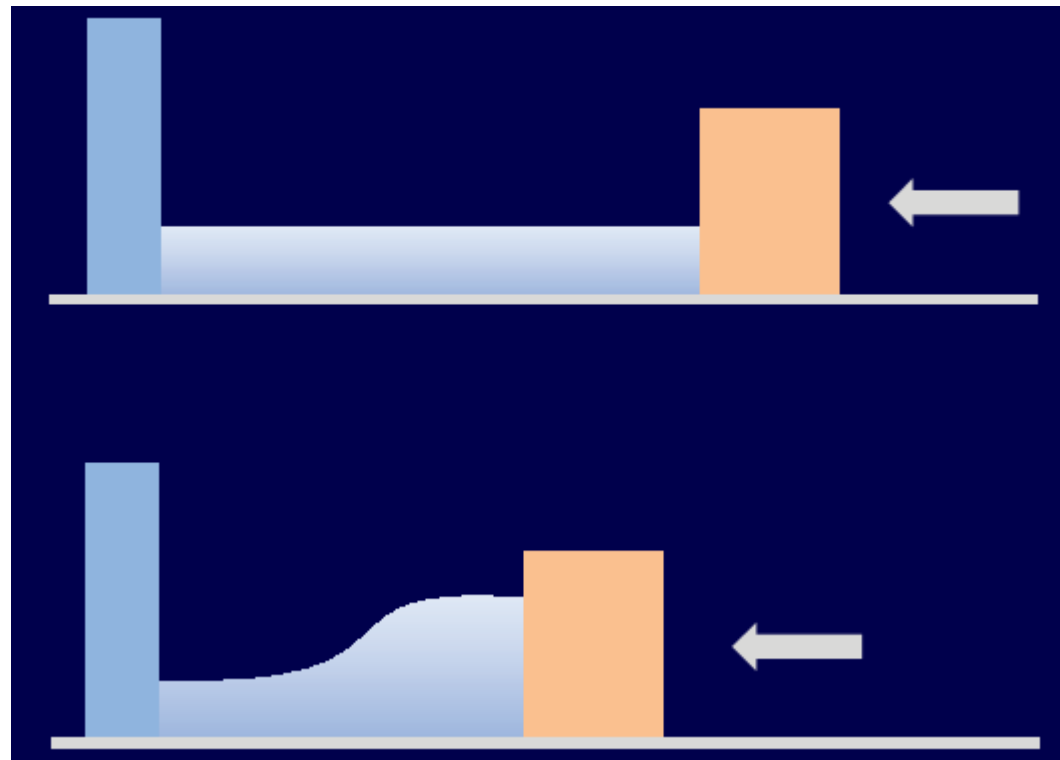
- ❖ The following is a fluid mechanics equivalent for a Quasi-equilibrium process. The piston is pushing very slowly against a pool of water and then withdraw. The water always remain horizontal.



Fluid Mechanics Equivalent Example B.

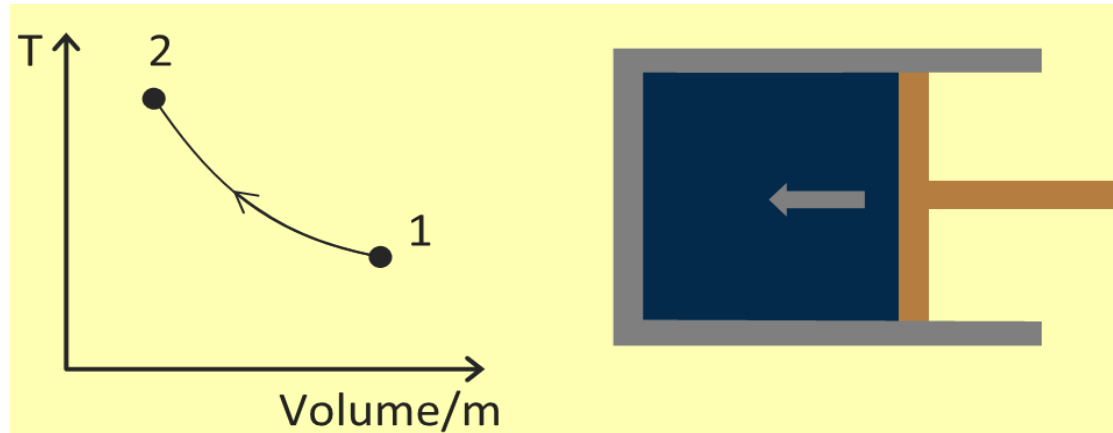
For a Non-Quasi-equilibrium Process

- ❖ The following is a non-quasi-equilibrium process where the piston is moving too quickly causing the formation of water waves which generates random motions.



Path

- ❖ This is the series of states the system passes through.



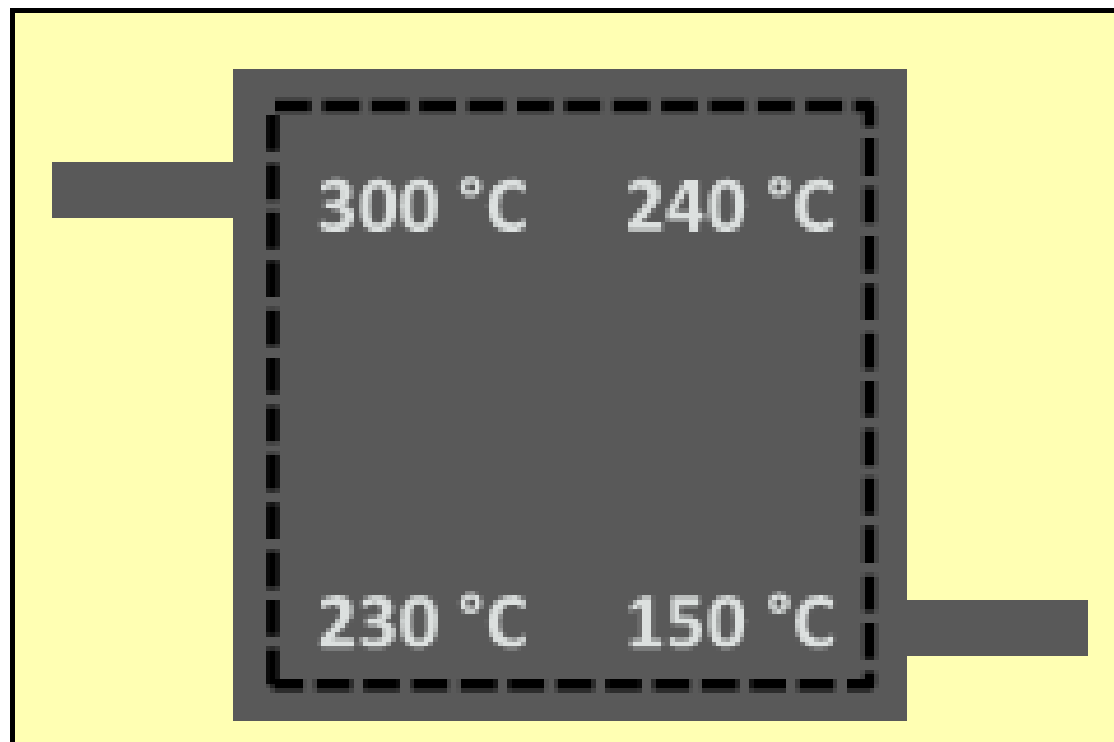
- ❖ As the piston head is pushed in the volume decreases and the temperature increases.
- ❖ Piston compressions are treated as quasi-static since typical piston head speed (~ 10 [m/s]) are much smaller than speed of sound in gas (~ 300 [m/s]).

Types of Process

- ❖ Iso $\rightarrow$ means a process in which some aspect of the system is held constant.
 - ✓ Isobaric $\equiv$ constant pressure
 - ✓ Isothermal $\equiv$ constant temperature
 - ✓ Isochoric $\equiv$ constant volume
(Isometric) (specific volume)
 - ✓ Iso-entropic $\equiv$ constant entropy
(entropy defined later)
 - ✓ Adiabatic $\equiv$ No heat transfer with environment

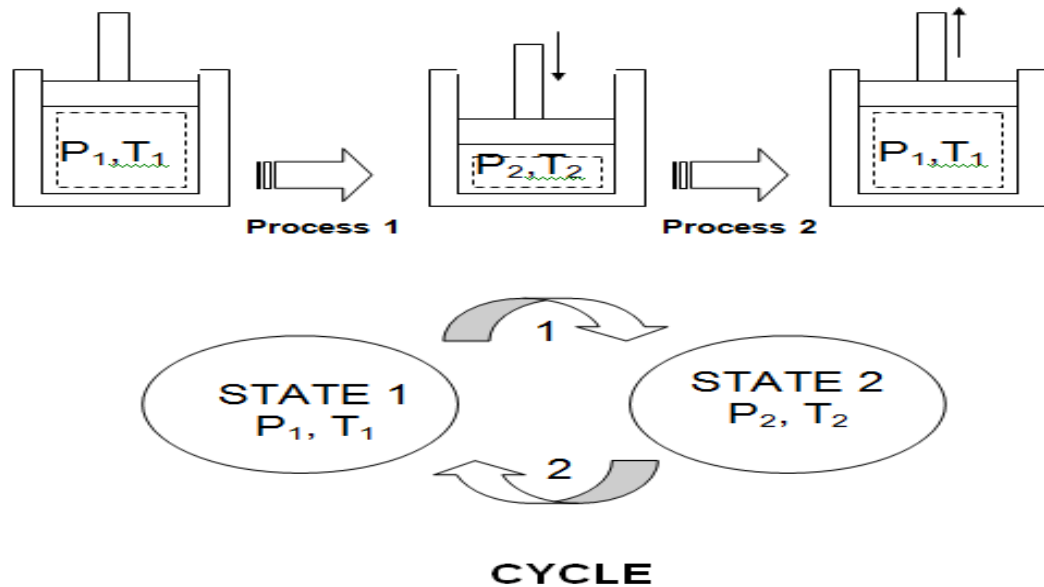
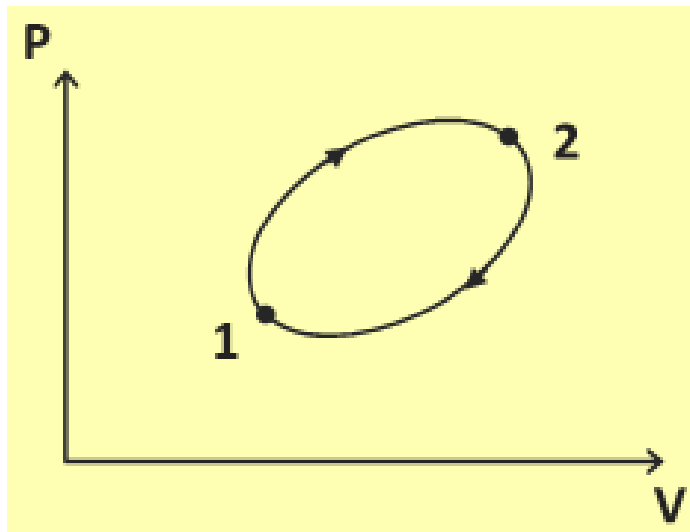
Steady-Flow Processes

- ❖ There may be changes with position but there are no change with time.
- ❖ Examples: turbines, pumps, boilers, heat exchangers, air conditioners, condensers, engines.



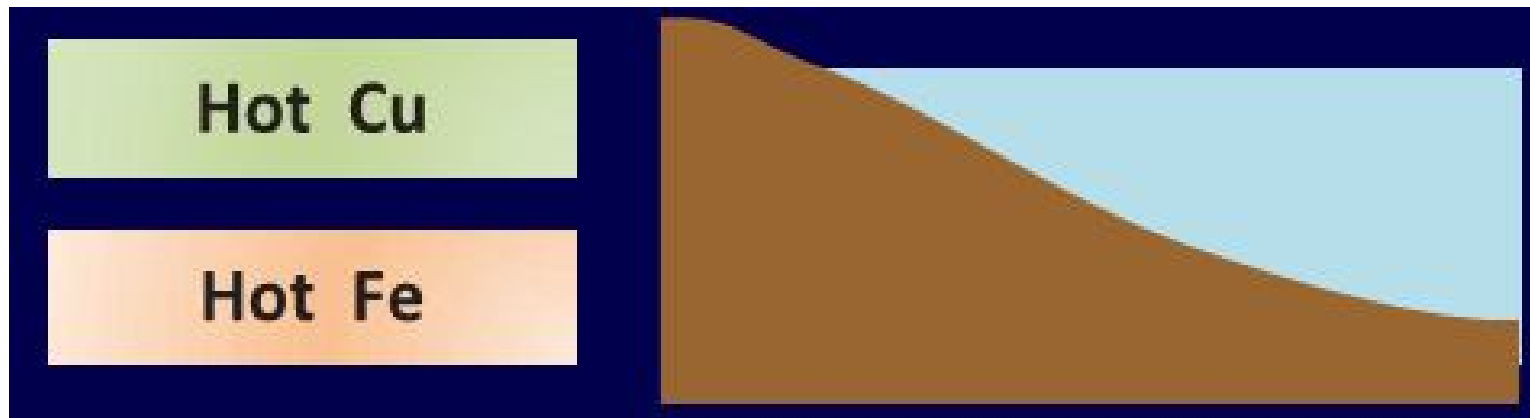
Cycle

❖ When a system in a given initial state goes through a number of different changes of state or processes and finally returns to its initial state, the system has undergone a cycle.



Zeroth Law

- ❖ Put Cu bar in cool lake. Cu bar will cool down until in thermal equilibrium with lake.
- ❖ Put Fe bar in cool lake. Fe bar will cool down until in thermal equilibrium with lake.
- ❖ When Fe bar and Cu bar are removed from lake and brought together, they will already be in thermal equilibrium.



- ❖ If two objects are in thermal equilibrium with a third object, then they are in thermal equilibrium with each other.

Thermal equilibrium $\Rightarrow$ same temperature

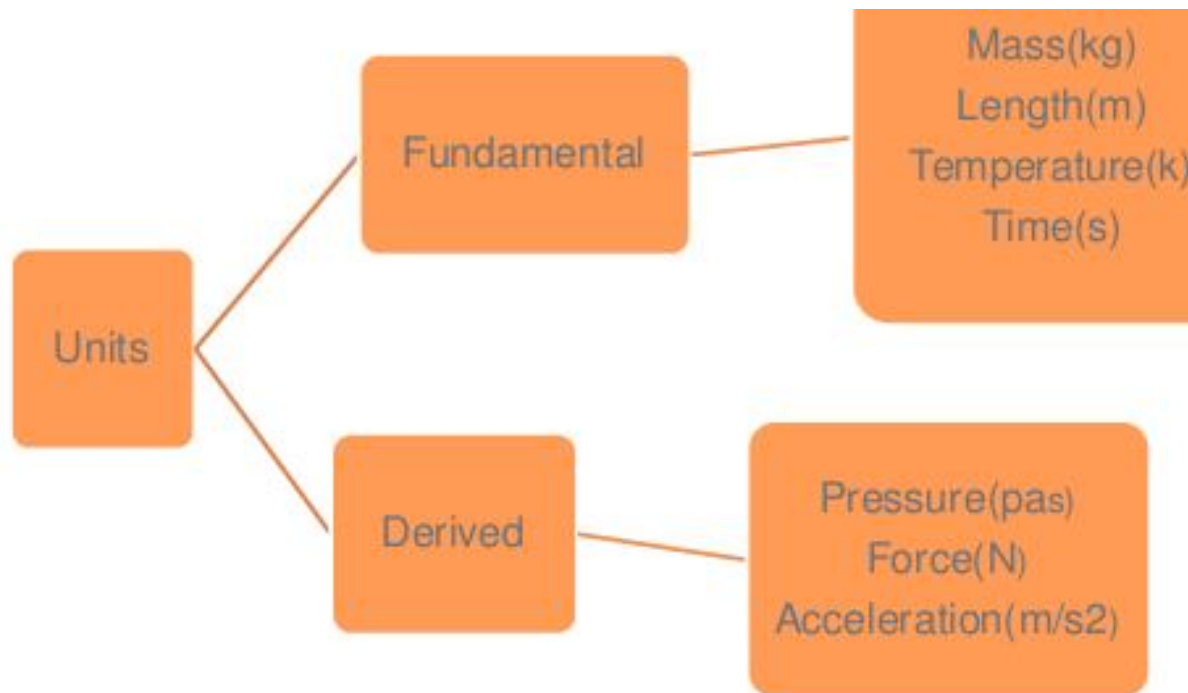
- ❖ The Zeroth Law gives a formal underpinning (foundation) of the thermometer concept.
- ❖ The thermometer is the third object that tells us the temperature of the iron and copper bars are the same.

Dimension and Units

- ❖ Any physical quantity can be characterized by dimension.

Example:- long distance, heavy weight

- ❖ The arbitrary magnitude assigned to a dimension is called Units.

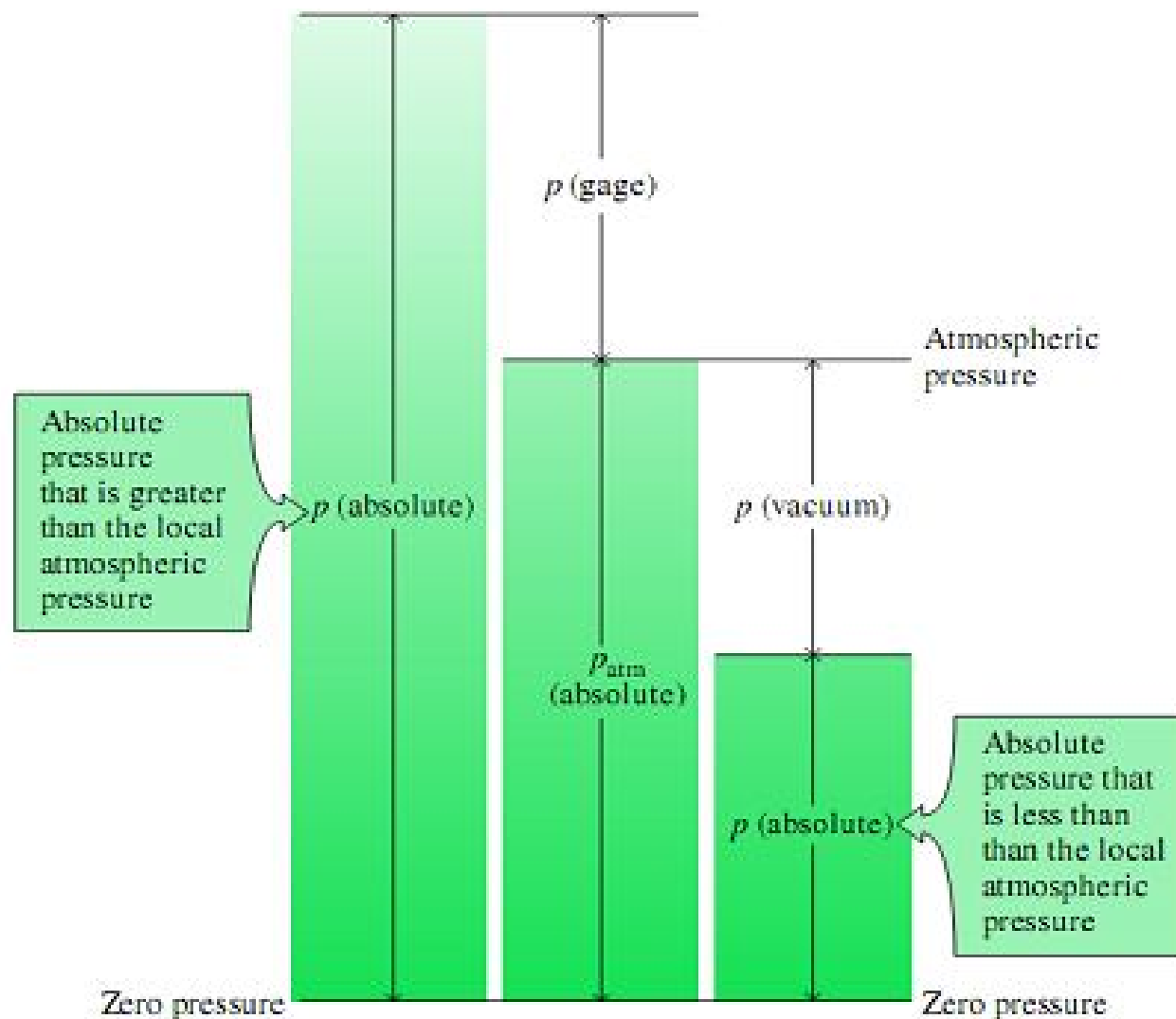


Pressure

- ❖ The normal component of Force per unit area is called pressure, and its unit is the Pascal, $1\text{Pa} = 1\text{N/m}^2$.

$$\text{pressure} = \frac{\text{Force}}{\text{Area}} = \frac{m * g}{A} = \frac{mgh}{V} = \rho gh$$

- ❖ The pressure used in all calculations of state is the **absolute pressure** measured relative to absolute zero pressure (a vacuum).



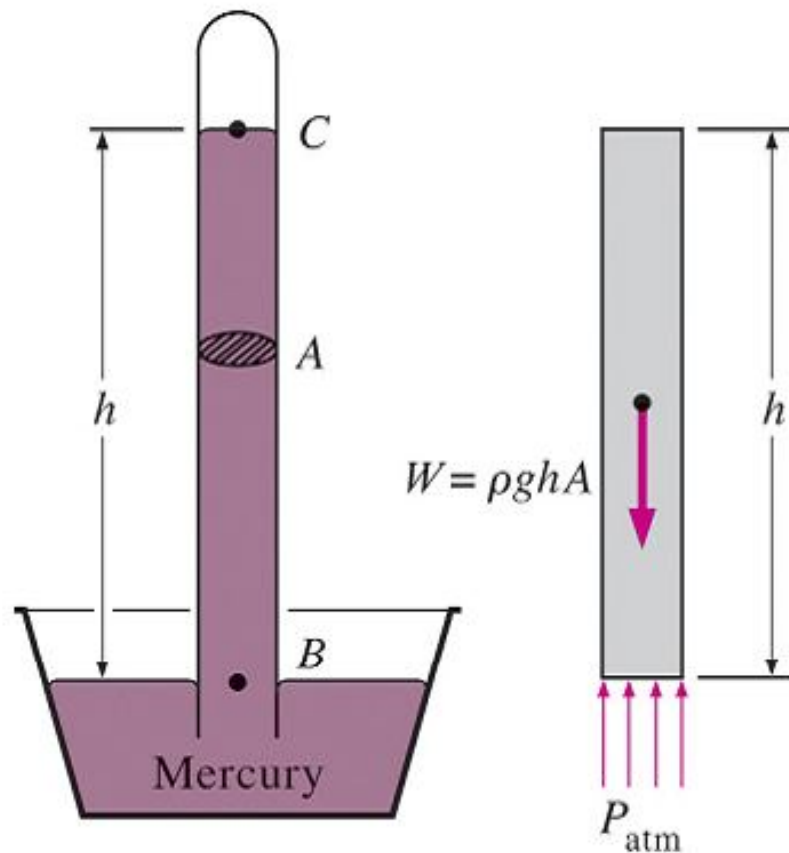
$$P_{abs} = P_{atm} + P_{gage}$$

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

$$1\text{atm} = 101.325\text{kpa} = 760\text{mmHg}$$

$$1\text{bar} = 10^5\text{pa}$$

A Barometer Measures P_{atm}



$$P_{\text{atm}} = \rho gh + P_c$$

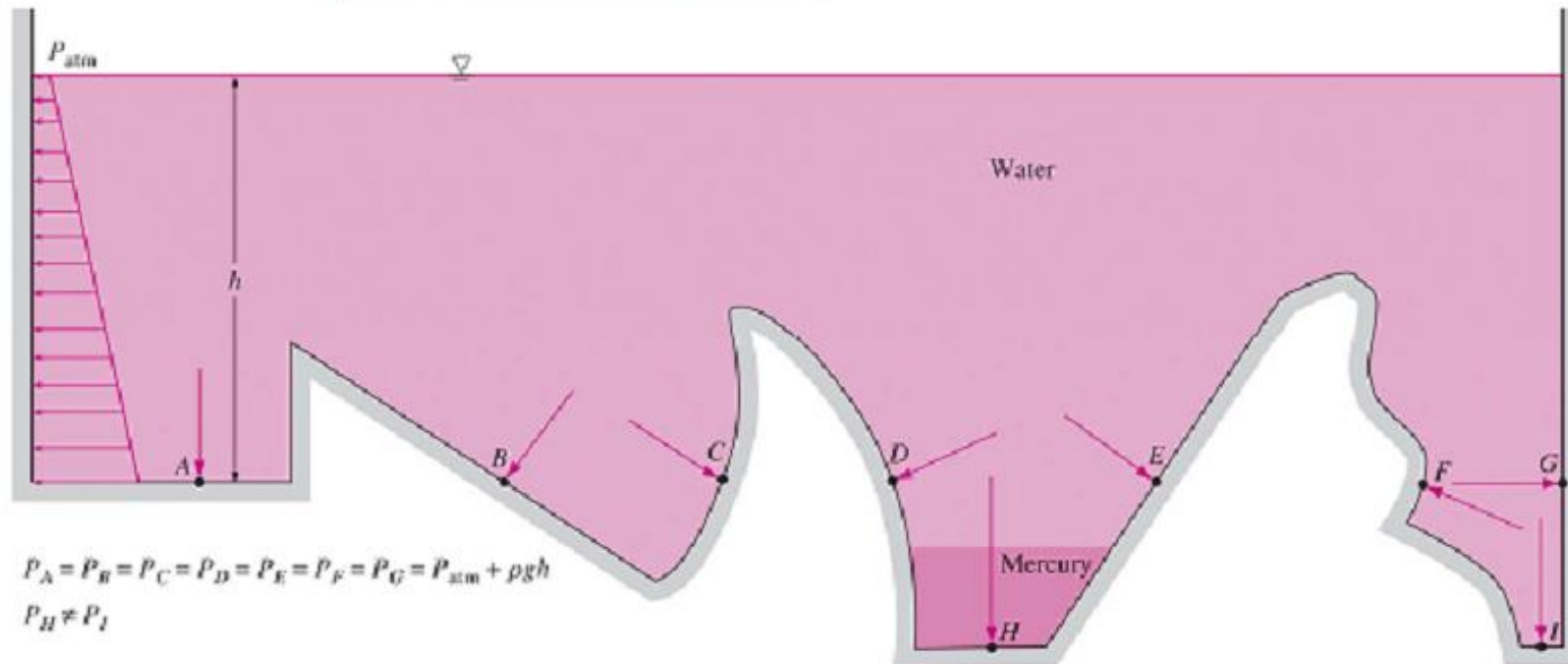
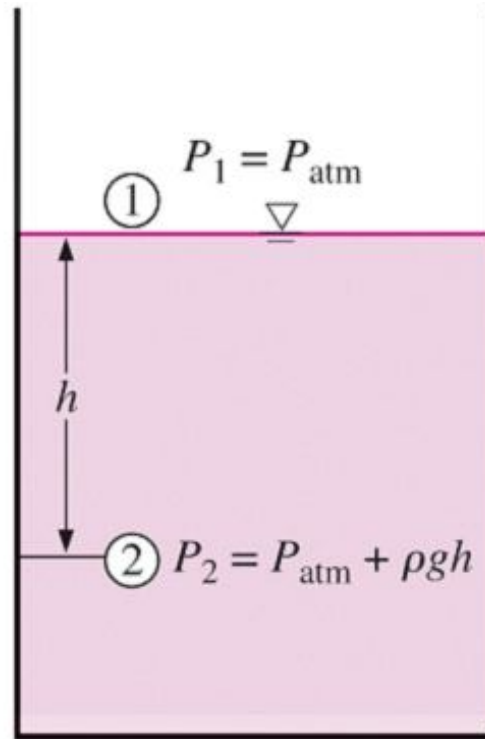
$$P_{\text{atm}} = \rho gh$$

➤ Assuming zero pressure at point C

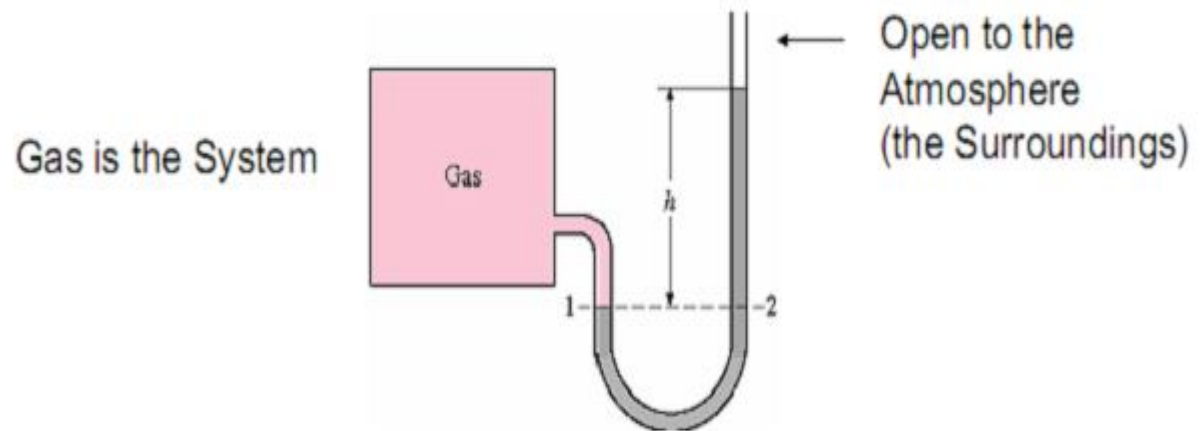
Pressure Rules of Thumb (PRoT) for Static Fluids (Gas or Liquid)

- ❖ Pressure cannot change abruptly across a static interface between two fluids, i.e., the pressure is the same on each side of an interface.
- ❖ If you can swim through a static fluid from one point A to another point B both having the same vertical position and without ever having to leave the fluid, then the pressure must be the same at points A and B

- ❖ Moving an amount h down (toward the ground) through a static fluid (having constant density ρ) causes a pressure rise of ρgh .
- ❖ Moving an amount h up (away from the ground) through a static fluid (having constant density ρ) causes a pressure drop of ρgh .
- ❖ The density of a gas is usually small so that pressure changes within a gas can be ignored (compared to that of a liquid).



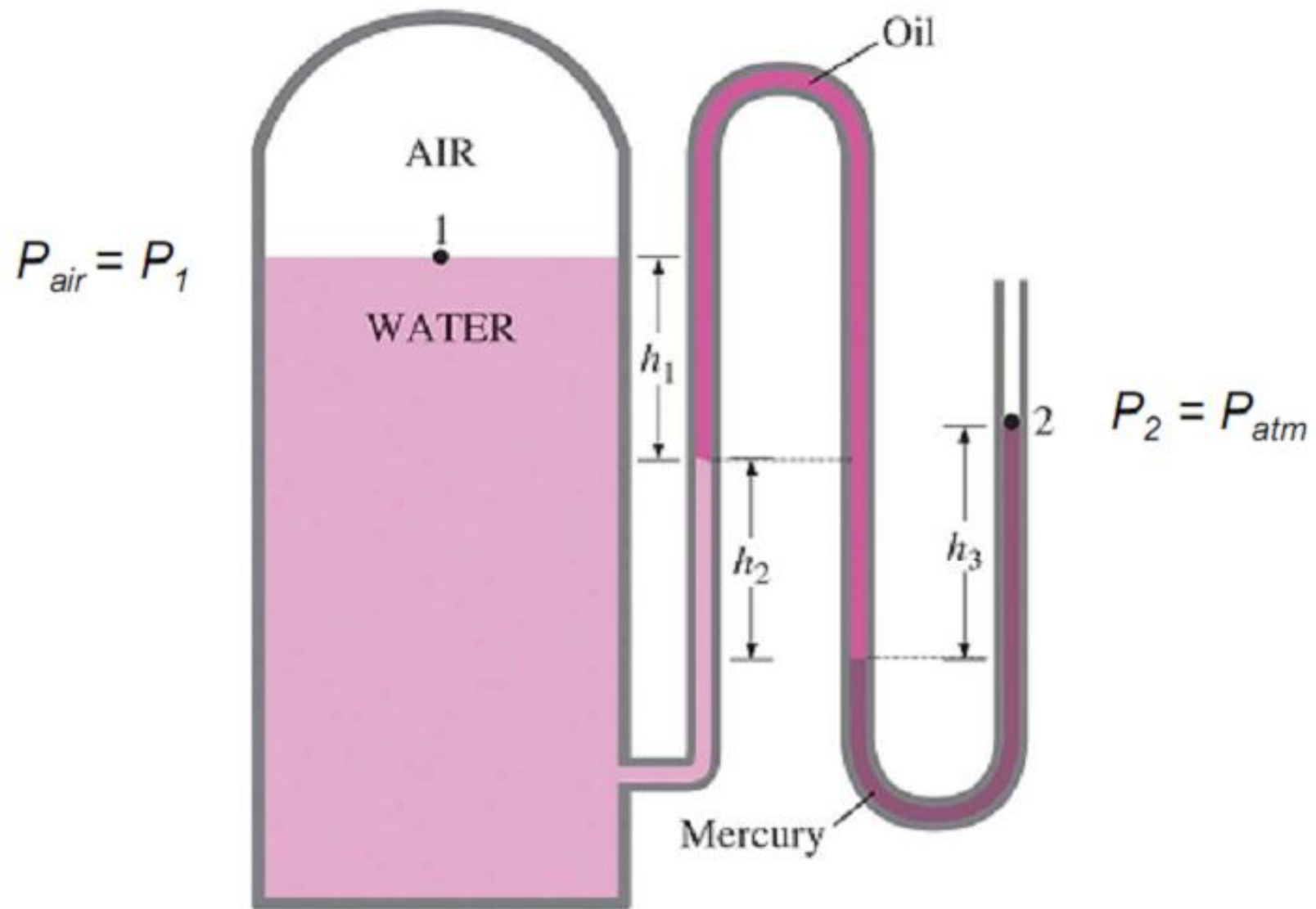
❖ **Small to moderate pressure differences** are measured by a manometer and a fluid column of height h corresponds to a pressure difference between the system and the surroundings of the manometer.



❖ This pressure difference is determined from the manometer fluid (with density ρ) displaced height as

$$P_{\text{gas,absolute}} = P_1 = P_2 = P_{\text{atm}} + \rho gh$$

$$P_{\text{gas,gauge}} = P_1 - P_{\text{atm}} = \rho gh$$



$$P_1 + \rho_{water}gh_1 + \rho_{oil}gh_2 - \rho_{mercury}gh_3 = P_2$$

Temperature

- ❖ Although we are familiar with temperature as a measure of “hotness” or “coldness,” it is not easy to give an exact definition of it.
- ❖ Temperature is considered a thermodynamic property and it is a measure of **the energy content of a mass**.
- ❖ When heat energy is transferred to a body, the body's energy content increases and so does its temperature.

Specific Volume

- ❖ The volume occupied by a unit mass of a substance, and it is designated by **n**.

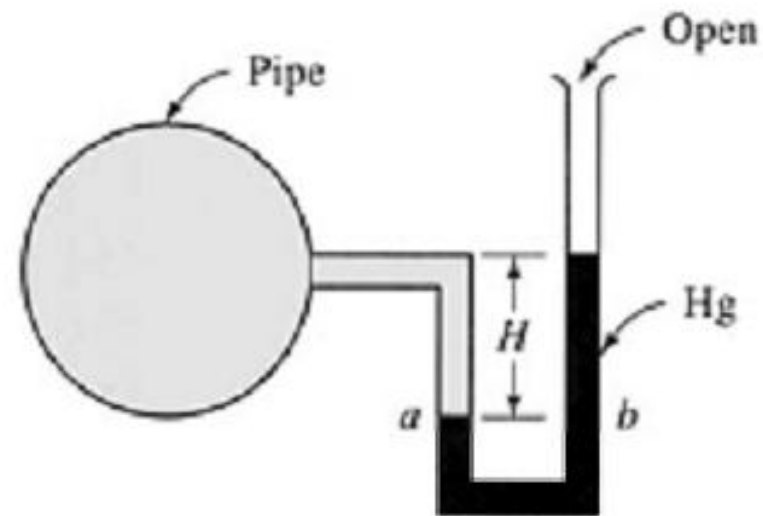
$$v = \frac{\text{Volume}}{\text{mass}} = \frac{V}{m} (m^3 / kg) = \frac{1}{\rho}$$

- ❖ Specific density /specific gravity

- The density of substance divided by the density of water.

$$\rho_s = \frac{\rho}{\rho_{H_2O}}, \rho_{H_2O} = 1000kg / m^3$$

1. The manometer shown in figure below is used to measure the pressure in the water pipe. Determine the water pressure if the manometer reading is 0.6 m. Mercury is 13.6 times heavier than water.



2. Calculate the force due to the pressure acting on the 1-m-diameter horizontal hatch of a submarine submerged 600 m below the surface.

3. The hydraulic piston/cylinder system shown in the figure below has a cylinder diameter of $D=0.1\text{m}$ with a piston and rod mass of 25kg . The rod has a diameter of 0.01m with an outside atmospheric pressure of 101kPa . The inside hydraulic fluid pressure is 250kPa . How large a force can the rod push within the upward direction?

