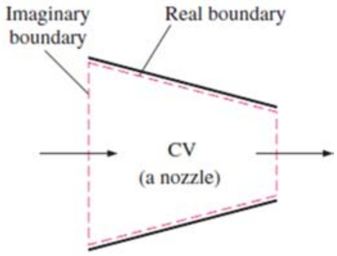
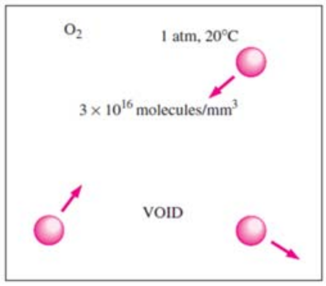
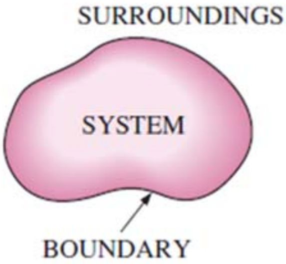
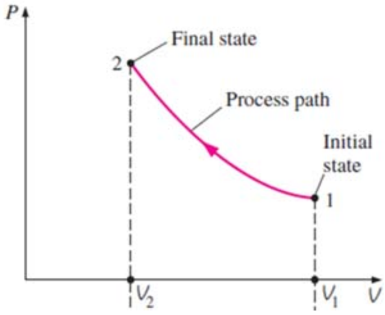



# Thermodynamics I

## Basic Concepts




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

Dr.-Eng. Zayed Al-Hamamre



# Content

- Systems and Control Volumes
- Type of Systems
- System Properties
- State and Equilibrium
- Processes and Cycles
- The $0^{th}$ law of Thermodynamics
- Review: Unit and Dimensions, Temperature and Pressures

# Systems and Control Volumes

- A **system** is defined as a quantity of matter or a region in space chosen for study.
- The **surroundings** **are** the mass or region outside the system**.**
- The **boundary** is the real or imaginary surface that separates the system from its surroundings.
- It may be as simple as a free body or as complex as an entire chemical refinery.
- Once the system is defined and the relevant interactions with other systems are identified, one or more physical laws or relations are applied.
- Work or heat can be transferred across the system boundary.
- All systems possess properties like mass, energy, entropy, volume, pressure, temperature, etc.

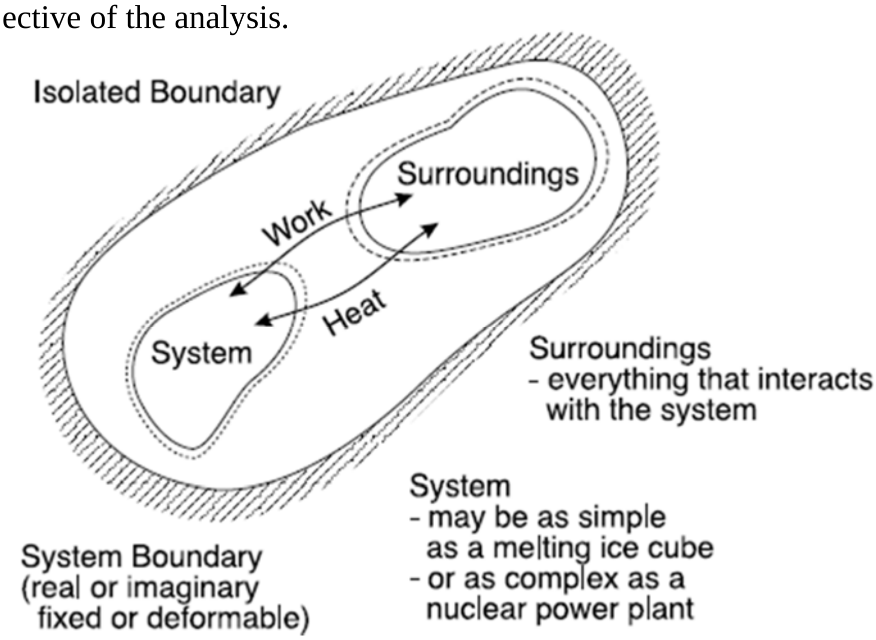


# System and Control Volumes

- The choice of system boundary is governed by two considerations:

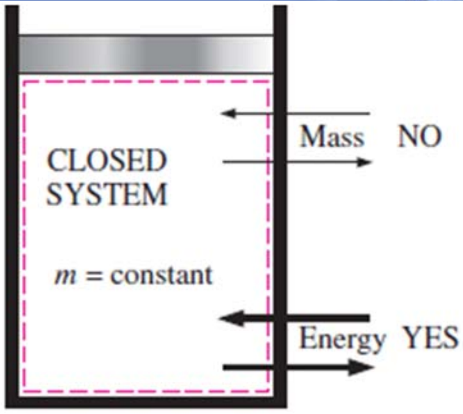
i. What is known about a possible system, particularly at its boundaries, and

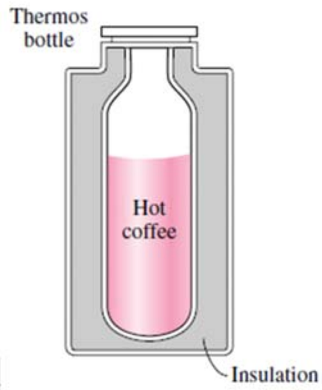
ii. The objective of the analysis.



# Type of Systems

- **Closed system** is defined when a particular quantity of matter is under study.
- A closed system always contains the same matter.
- There can be no transfer of mass across its boundary.
- A special type of closed system is called an **isolated system**
- Isolated system: Neither energy nor matter can be exchanged with the environment in fact, no interactions with the environment are possible at all.
- Example (approximate): coffee in a closed, well-insulated thermos bottle



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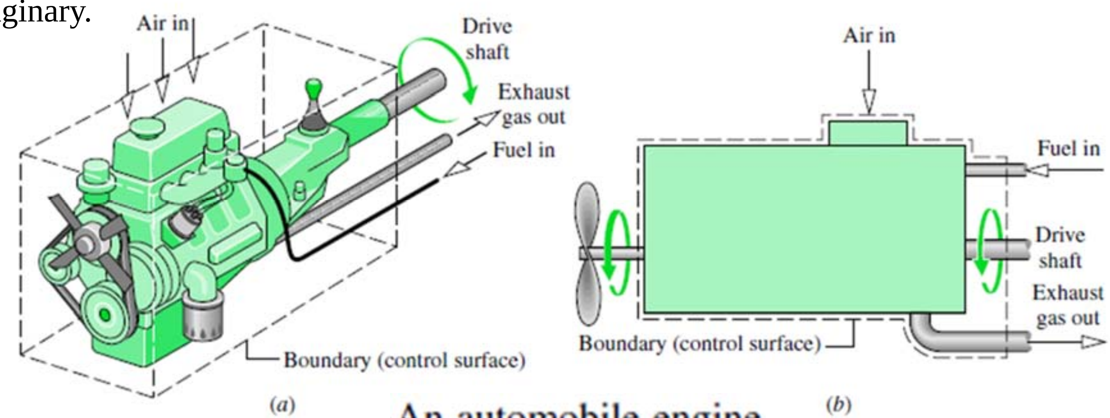
# Type of Systems

- An **open system,** or a **control volume,** as it is often called, is a properly selected region in space.
- It usually encloses a device that involves mass flow such as a compressor, turbine, or nozzle.
- Both mass and energy can cross the boundary of a control volume.
- A water heater, a car radiator, a turbine, and a compressor all involve mass flow and should be analyzed as control volumes (open systems).
- The boundaries of a control volume are called a *control surface,* and they can be real or imaginary.




An automobile engine



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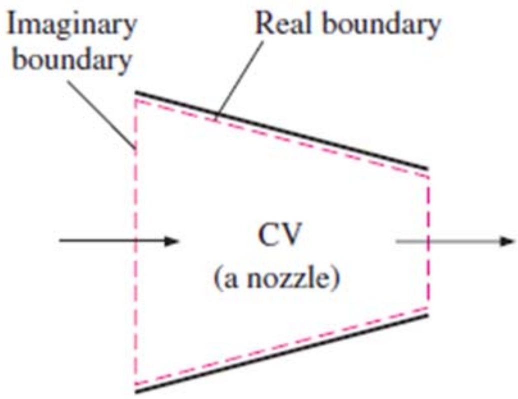
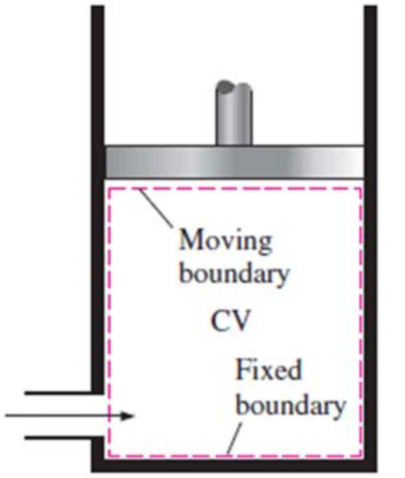
# Type of Systems

- A control volume can involve fixed, moving, real, and imaginary boundaries.




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




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



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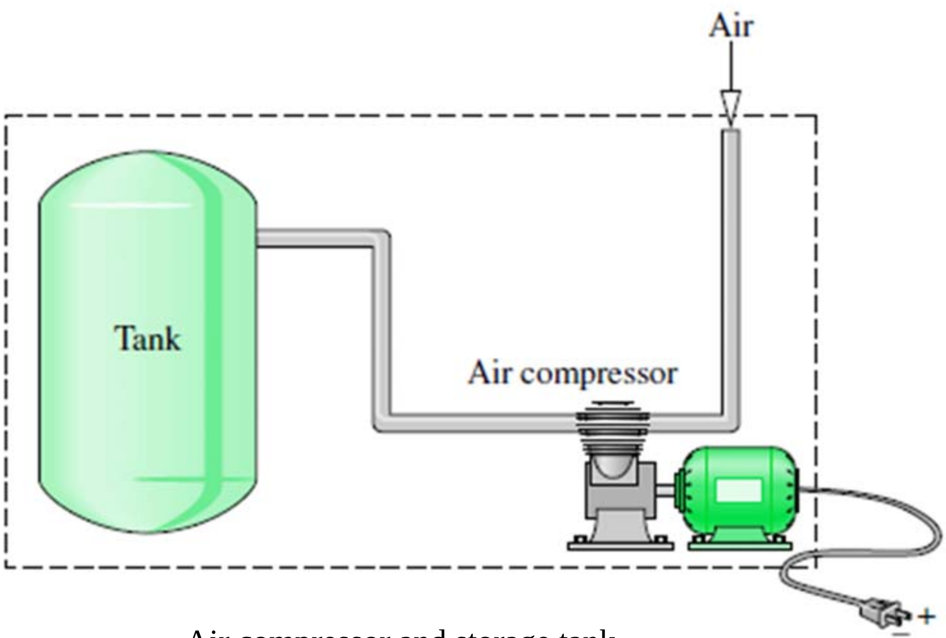
# Type of Systems




Air compressor and storage tank



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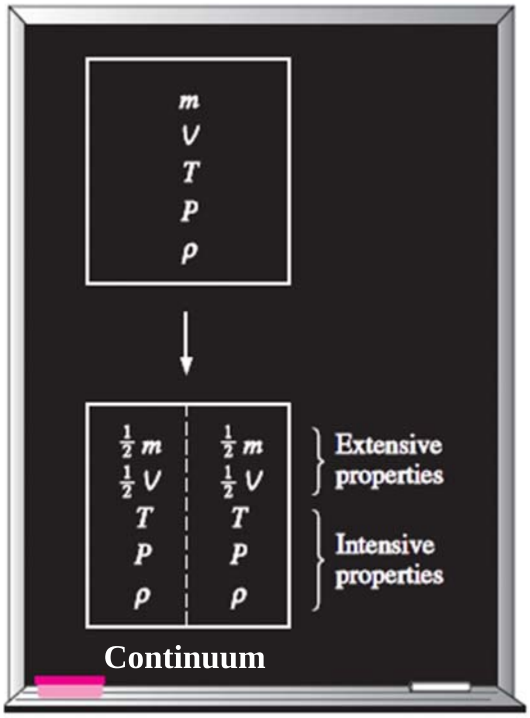
# System Properties

- A ***property*** is a macroscopic characteristic of a system such as mass, volume, energy, pressure, and temperature to which a numerical value can be assigned at a given time without knowledge of the previous behavior (*history*) of the system.
- Properties are **point functions** (i.e., they depend on the state only, and not on how a system reaches that state),
- They have **exact differentials** designated by the symbol *d*.
- A small change in volume, for example, is represented by $dV$, and the total volume change during a process between states 1 and 2 is

$$\int_1^2 dV = V_2 - V_1 = \Delta V$$

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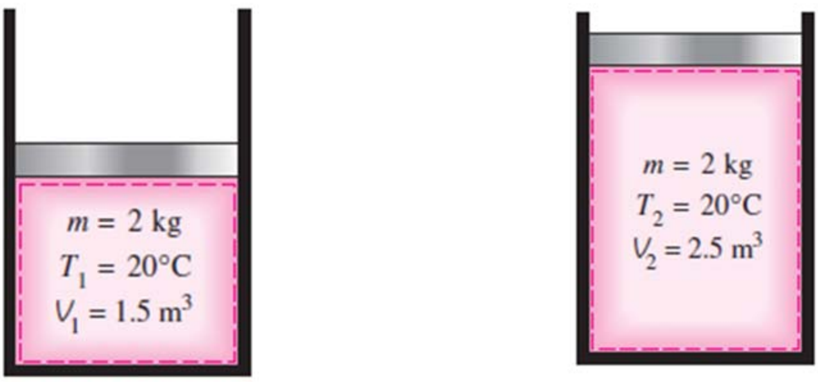
# A State

- The word **state** refers to the condition of a system as described by its properties.
- Since there are normally relations among the properties of a system, the state often can be specified by providing the values of a subset of the properties.
- At a given state, all the properties of a system have fixed values.
- If the value of even one property changes, the state will change to a different one.




(*a*) State 1 (*b*) State 2

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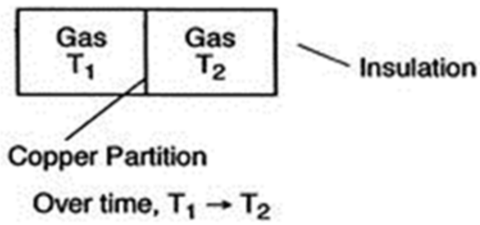
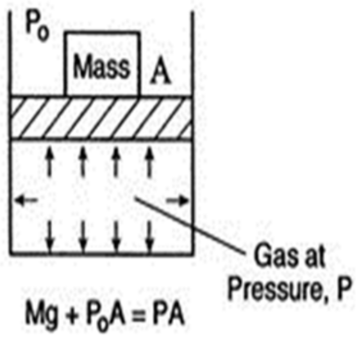
# Equilibrium

- A system is in **thermal equilibrium** if the temperature is the same throughout the entire system.
- That is, the system involves no temperature differential, which is the driving force for heat flow.
- **Mechanical equilibrium** is related to pressure, and a system is in mechanical equilibrium if there is no change in pressure at any point of the system with time.
- If a system involves two phases, it is in **phase equilibrium** when the mass of each phase reaches an equilibrium level and stays there.
- A system is in **chemical equilibrium** if its chemical composition does not change with time, that is, no chemical reactions occur.
- A system will not be in thermodynamic equilibrium unless all the relevant equilibrium criteria are satisfied.

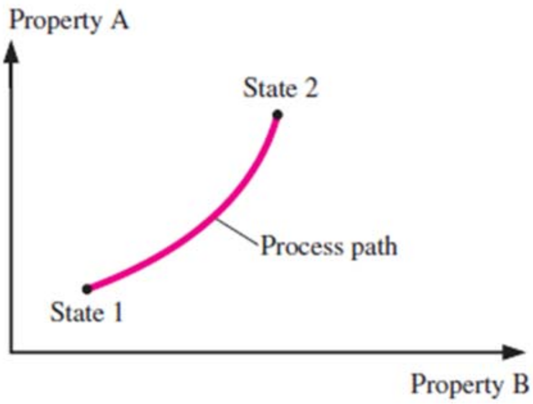


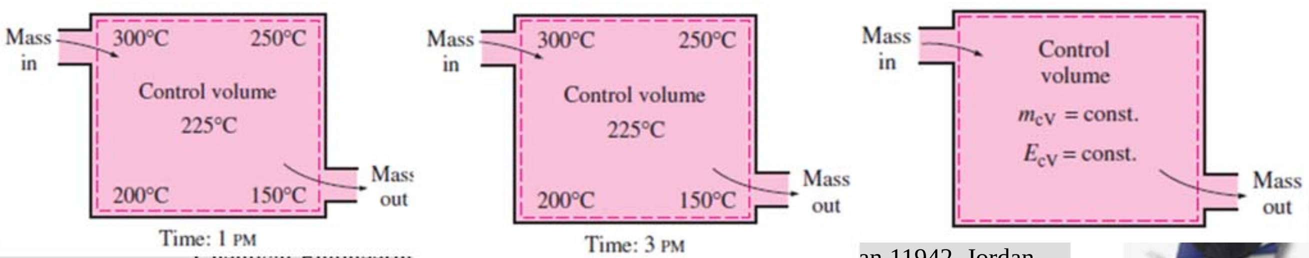






# Processes and Cycles

- When any of the properties of a system change, the state changes and the system is said to have undergone a ***process.***
  - ✓ A process is a transformation from one state to another. However,
  - ✓ if a system exhibits the same values of its properties at two different times, it is in the same state at these times.
  - ✓ A system is said to be at ***steady state*** if none of its properties changes with time.

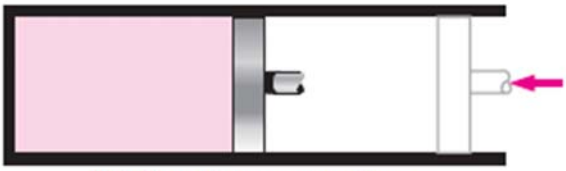


# Processes and Cycles

- When a process proceeds in such a manner that the system remains infinitesimally close to an equilibrium state at all times, it is called a **quasistatic,** or **quasi-equilibrium process.**
- A quasi-equilibrium process can be viewed as a sufficiently slow process that allows the system to adjust itself internally so that properties in one part of the system do not change any faster than those at other parts

(*a*) Slow compression (quasi-equilibrium)

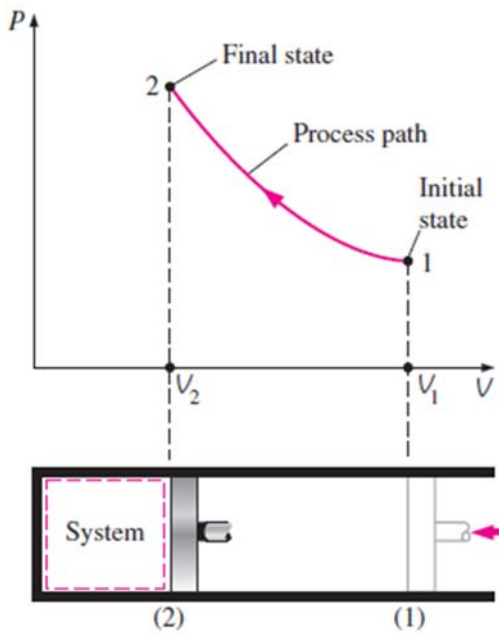


(*b*) Very fast compression (nonquasi-equilibrium)



# Processes and Cycles

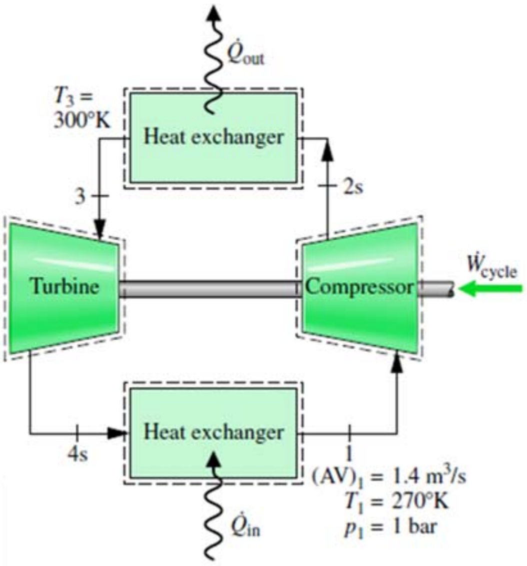
- Process diagrams plotted by employing thermodynamic properties as coordinates are very useful in visualizing the processes.
- Some common properties that are used as coordinates are temperature *T*, pressure *P*, and volume *V* (or specific volume *v*).

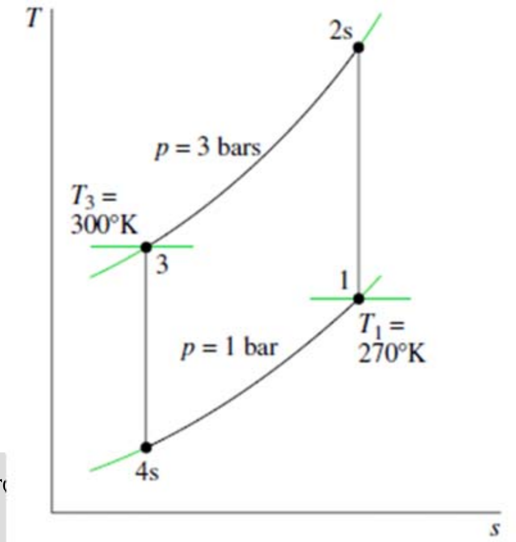



The *P-V* diagram of a compression process of a gas.

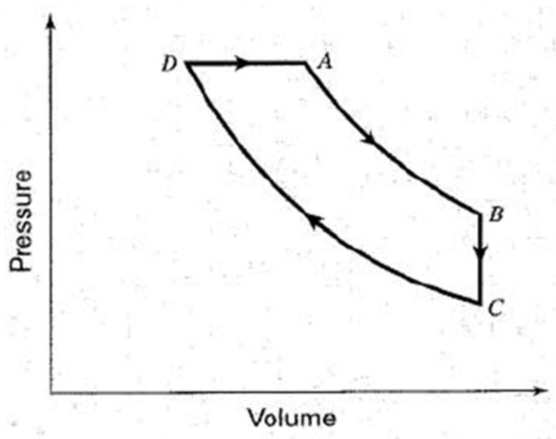
## Processes and Cycles

- A ***thermodynamic cycle*** is a sequence of processes that begins and ends at the same state.
  - ✓ At the conclusion of a cycle all properties have the same values they had at the beginning.
  - ✓ Consequently, over the cycle the system experiences no *net* change of state.
  - ✓ Cycles that are repeated periodically play prominent roles in many areas of application. For example, steam circulating through an electrical power plant executes a cycle.

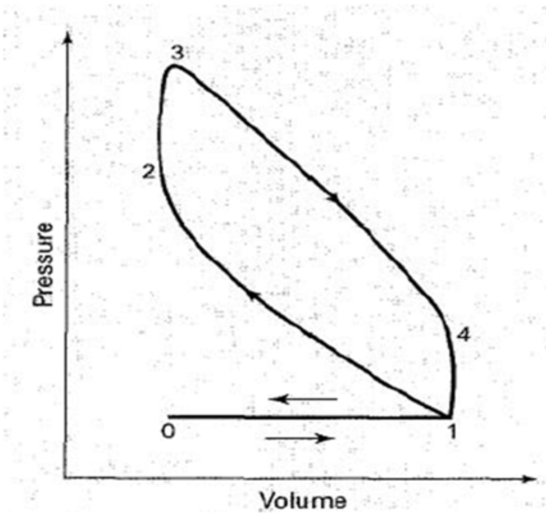



## Processes and Cycles




Air-standard Diesel cycle




Otto engine cycle

# Phase and Pure Substance

- The term ***phase*** refers to a quantity of matter that is homogeneous throughout in both chemical composition and physical structure.
- Homogeneity in physical structure means that the matter is all *solid,* or all *liquid,* or all *vapor* (or equivalently all *gas*).
- A system can contain one or more phases. For example, a system of liquid water and water vapor (steam) contains *two* phases.
- When more than one phase is present, the phases are separated by *phase boundaries.*
- A ***pure substance*** is one that is uniform and invariable in chemical composition.
- A pure substance can exist in more than one phase, but its chemical composition must be the same in each phase.

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# Review

- **Temperature**
  - ✓ Temperature Scales
  - ✓ International Temperature Scale
- **Pressure**
  - ✓ Variation of Pressure with Depth
  - ✓ Manometers
  - ✓ Other Pressure Measurement Devices
  - ✓ Barometer and Atmospheric pressure
- Unit and Dimensions

**Please refer to the Principle course or the fluid mechanics course for the details.**

**Note: You will be asked about this in quizzes and exams**

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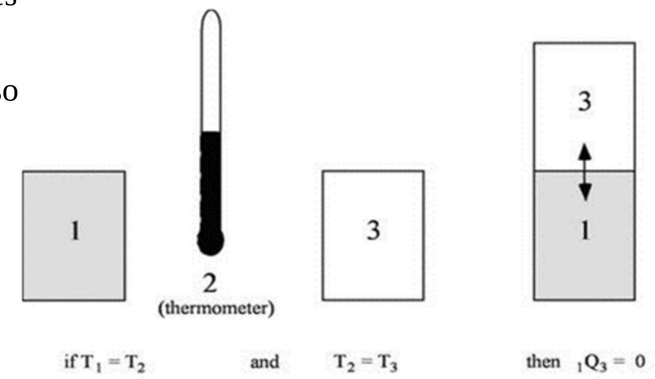
# Thermodynamics Laws

## ➢ The zeroth law of thermodynamics

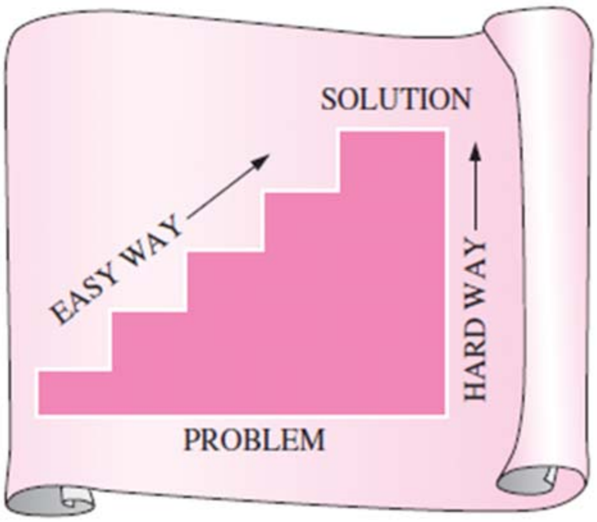
- The **zeroth law of thermodynamics** states that if two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other.
- It is called one of the basic laws of thermodynamics. However, it cannot be concluded from the other laws of thermodynamics, and it serves as a basis for the validity of temperature measurement.




- By replacing the third body with a thermometer, the zeroth law can be restated as *two bodies are in thermal equilibrium if both have the same temperature reading even if they are not in contact*.
- The Zeroth Law thus *defines a property* (temperature) and *describes its behavior*



# Tip




**A step-by-step approach can greatly simplify problem solving**