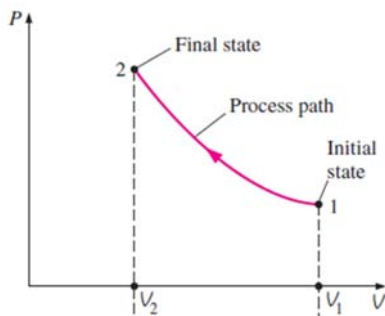
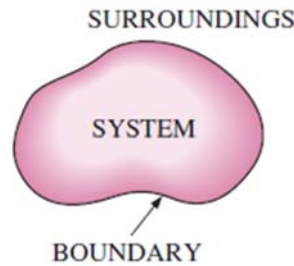
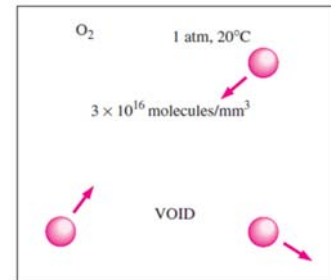


# Thermodynamics I

## Basic Concepts



$$\rho = \frac{m}{V} \quad (\text{kg/m}^3)$$

Dr.-Eng. Zayed Al-Hamamre

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Tel. +962 6 535 5000 | 22888



## Content



- Systems and Control Volumes
- Type of Systems
- System Properties
- State and Equilibrium
- Processes and Cycles
- The 0<sup>th</sup> law of Thermodynamics
- Review: Unit and Dimensions, Temperature and Pressures



# Systems and Control Volumes

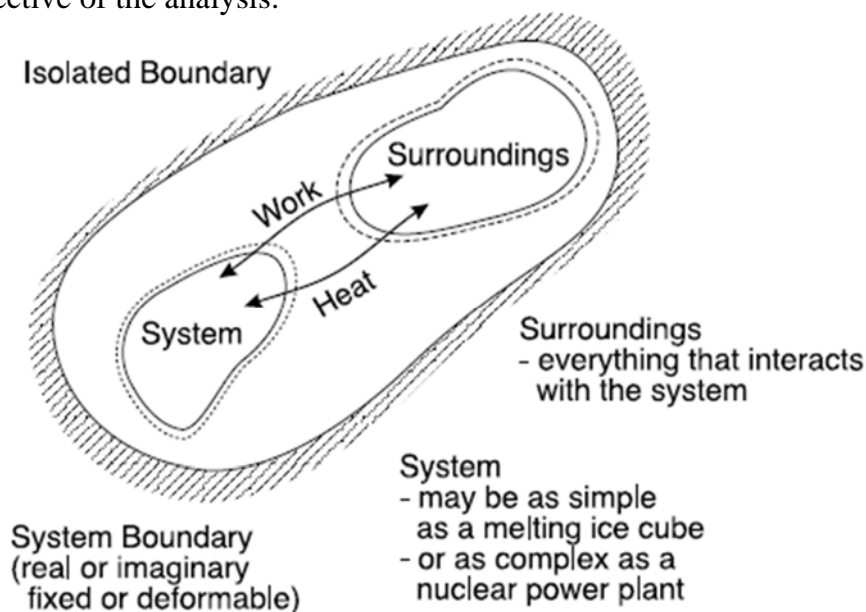
- A **system** is defined as a quantity of matter or a region in space chosen for study.
- The **surroundings** are the mass or region outside the system.
- The **boundary** is the real or imaginary surface that separates the system from its surroundings.
- It may be as simple as a free body or as complex 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.

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# 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.

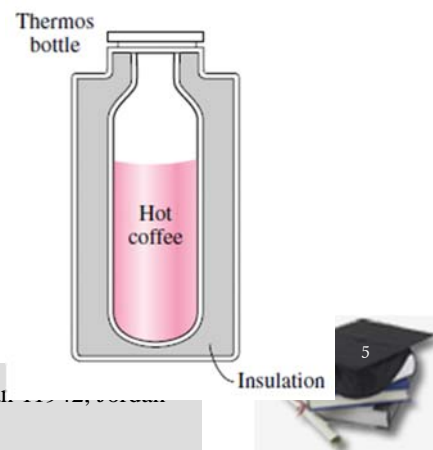
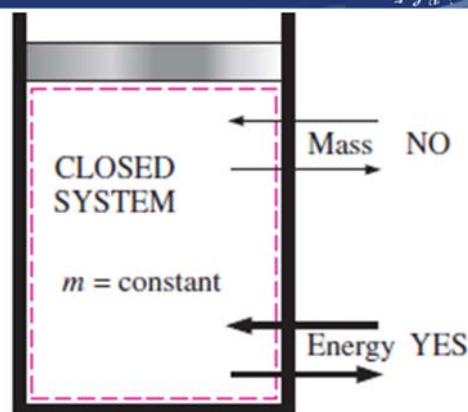


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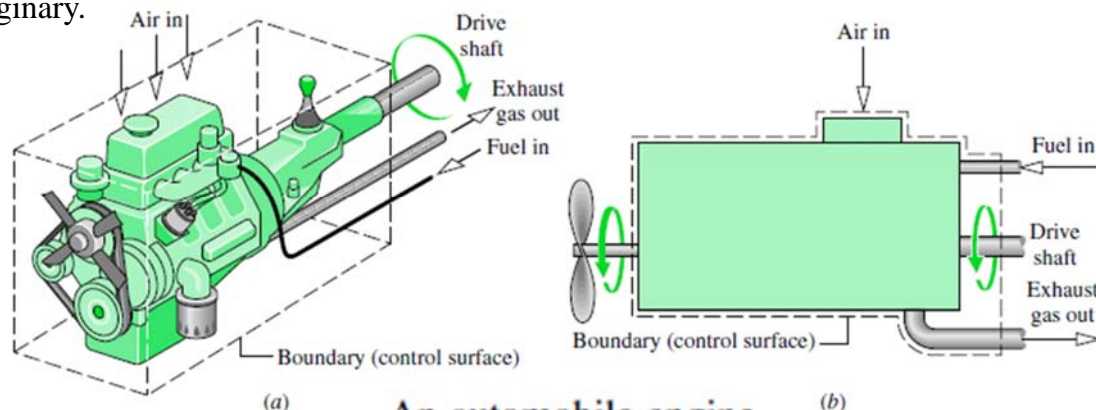
# Type of Systems

- **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



# Type of Systems

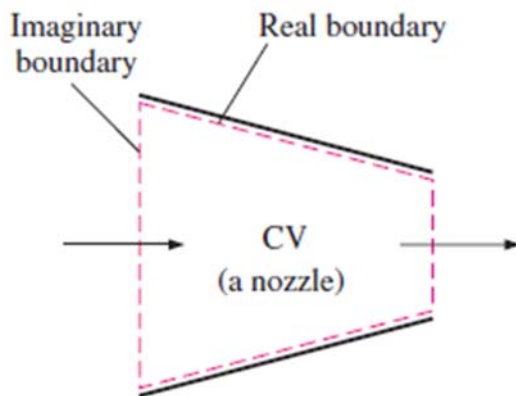
- An **open system**, or a **control volume**, as it is often called, is a properly selected region in space.
- It usually encloses a device that involves mass flow such as a compressor, turbine, or nozzle.
- Both mass and energy can cross the boundary of a control volume.
- A water heater, a car radiator, 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.



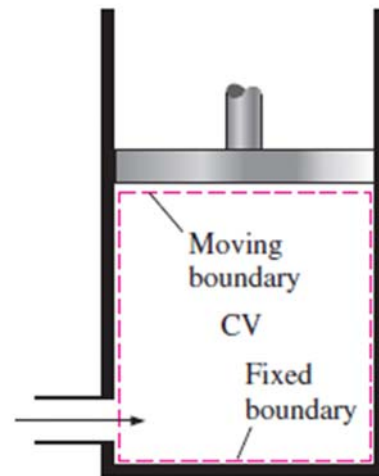
(a) An automobile engine (b)

# Type of Systems

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



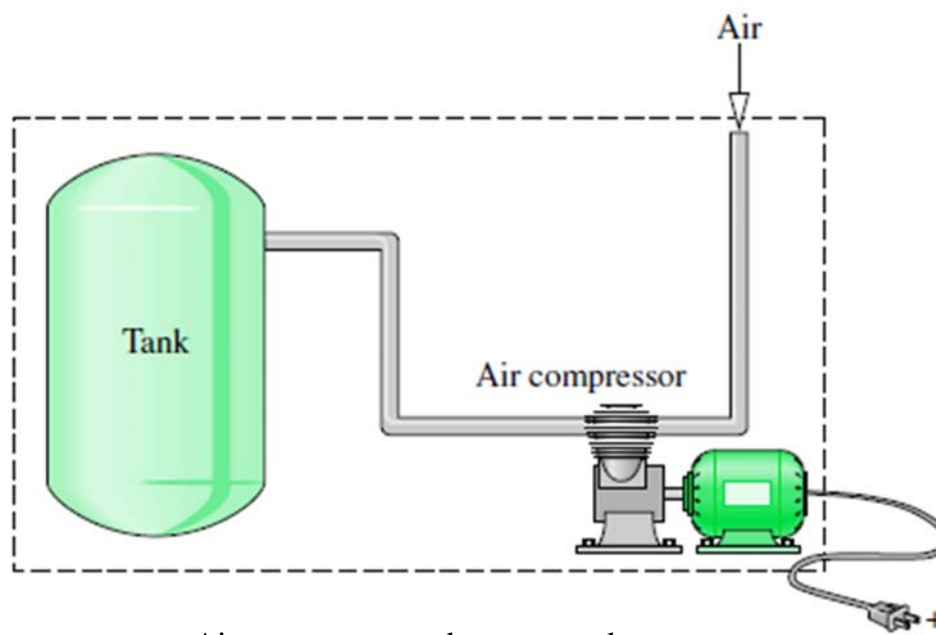
(a) A control volume with real and imaginary boundaries



(b) A control volume with fixed and moving boundaries



# Type of Systems



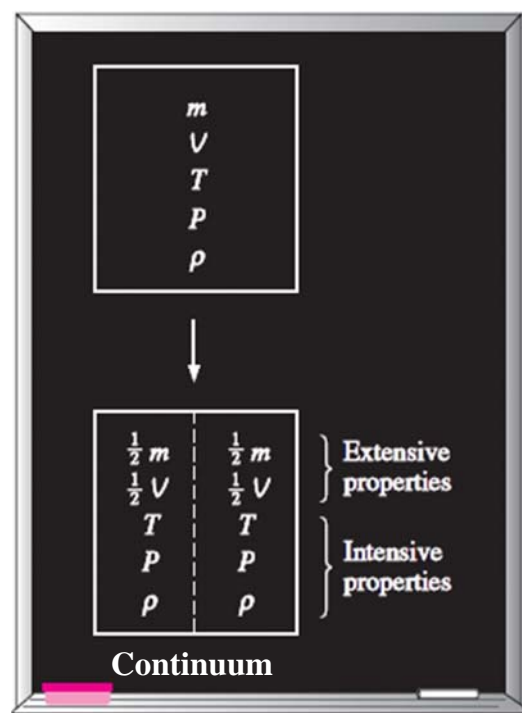
Air compressor and storage tank



# System Properties

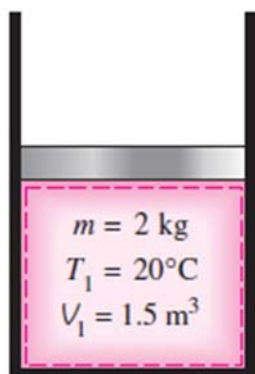
- A **property** is a macroscopic characteristic of a system such as mass, volume, energy, pressure, and temperature to which a numerical value can be assigned at a given time without knowledge of the previous behavior (*history*) of the system.
- Properties are **point functions** (i.e., they depend 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

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

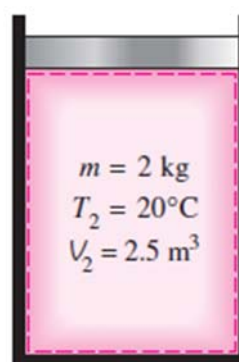


# A State

- 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

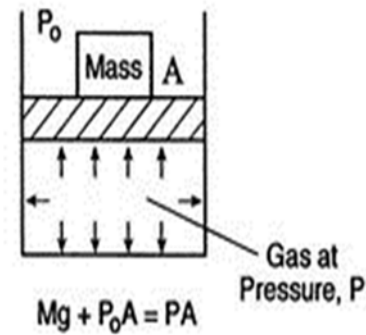
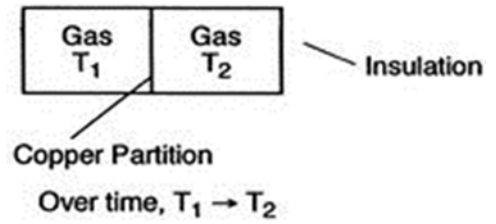


(b) State 2



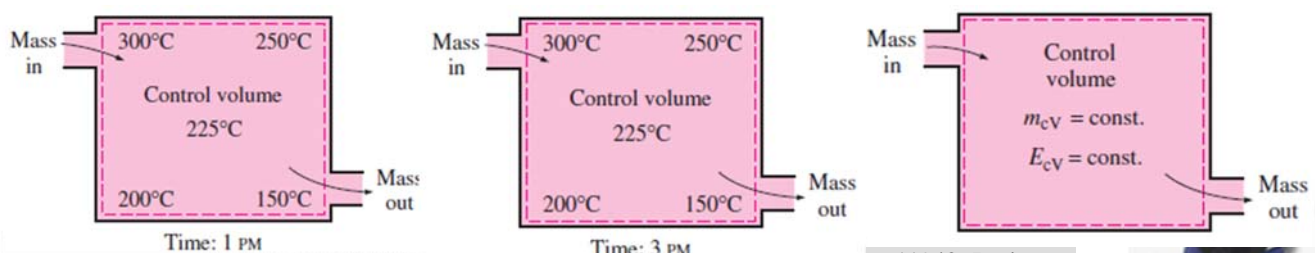
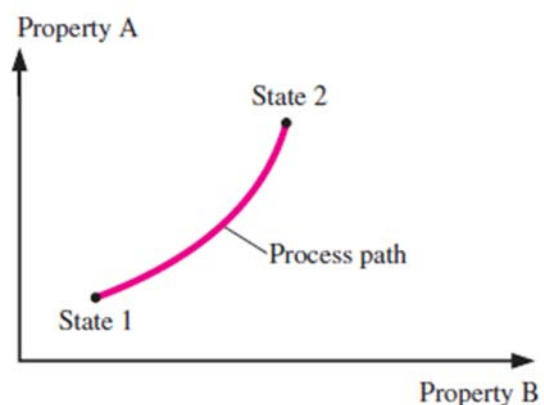
# Equilibrium

- 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.

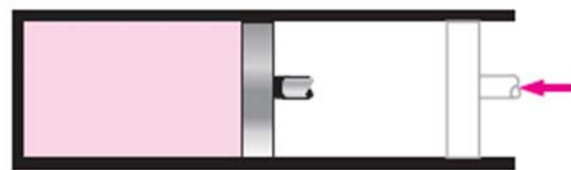


# Processes and Cycles

- 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)

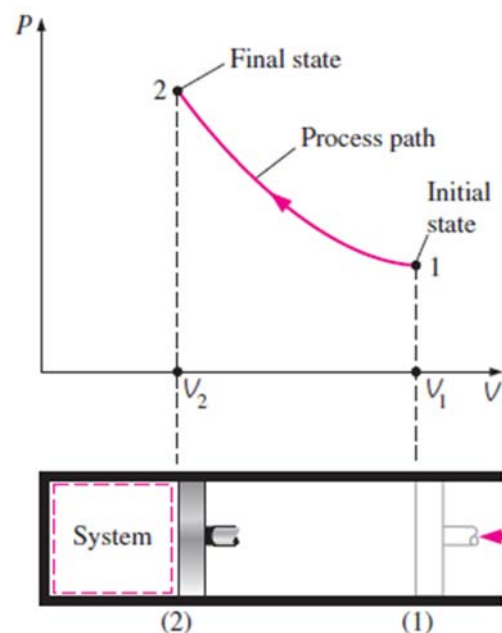
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# Processes and Cycles

- 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.

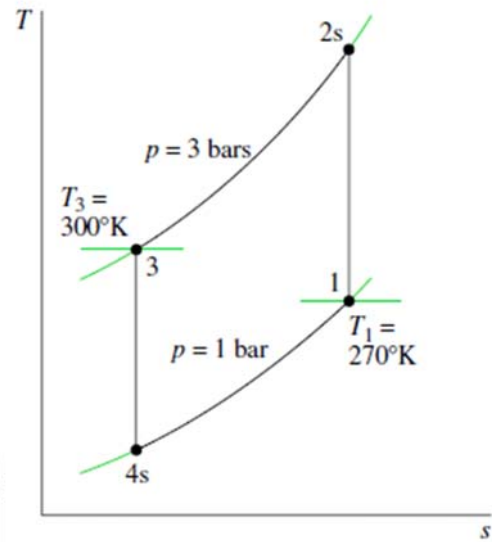
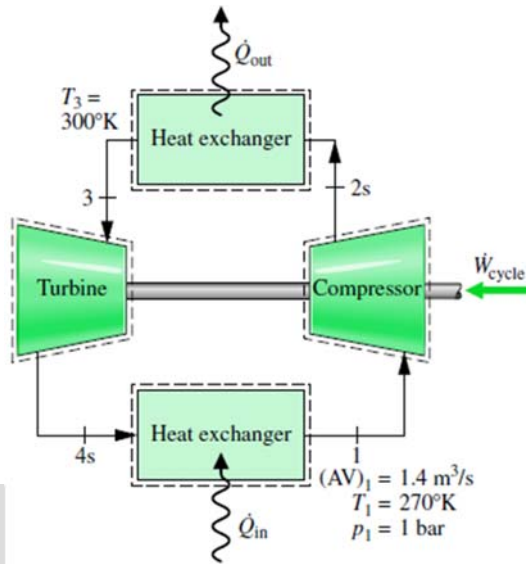


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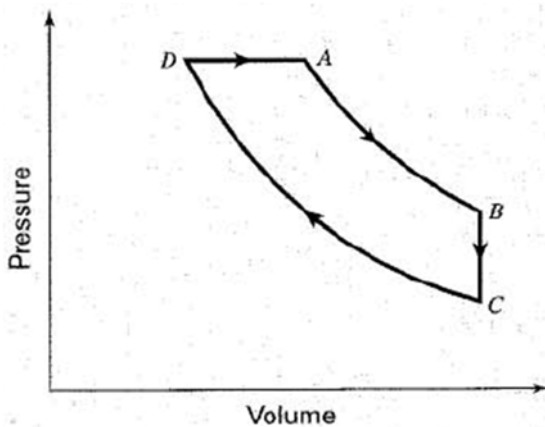


# Processes and Cycles

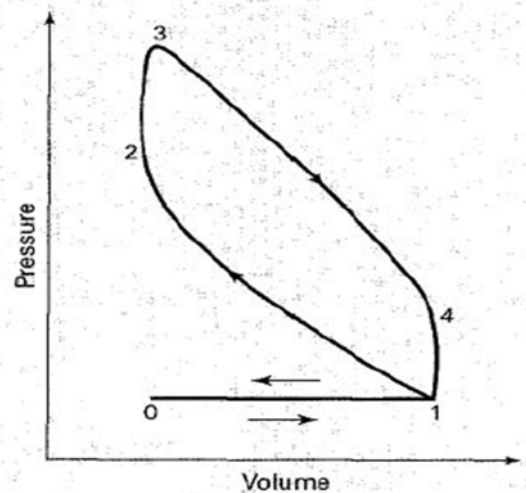
- A **thermodynamic cycle** is a sequence of processes that begins and ends at the same state.
  - ✓ At the conclusion of a cycle all properties have the same values they had at the beginning.
  - ✓ Consequently, over the cycle the system experiences no *net* change of state.
  - ✓ Cycles that are repeated 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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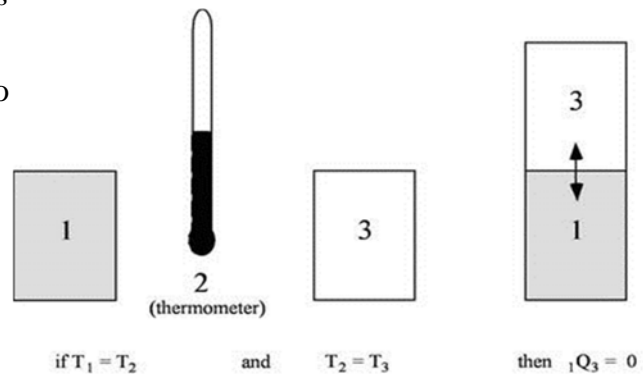


# Thermodynamics Laws

## ➤ 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.



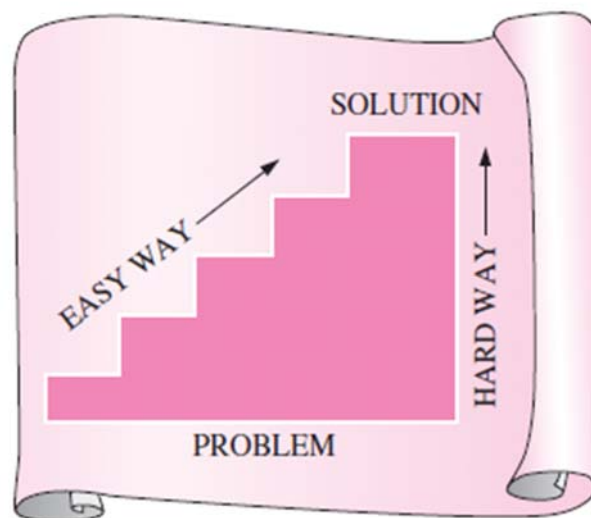
➤ By replacing the third body with a thermometer, the zeroth law can be restated as *two bodies are in thermal equilibrium if both have the same temperature reading even if they are not in contact.*

➤ The Zeroth Law thus *defines a property* (temperature) and *describes its behavior*

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## Tip



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

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