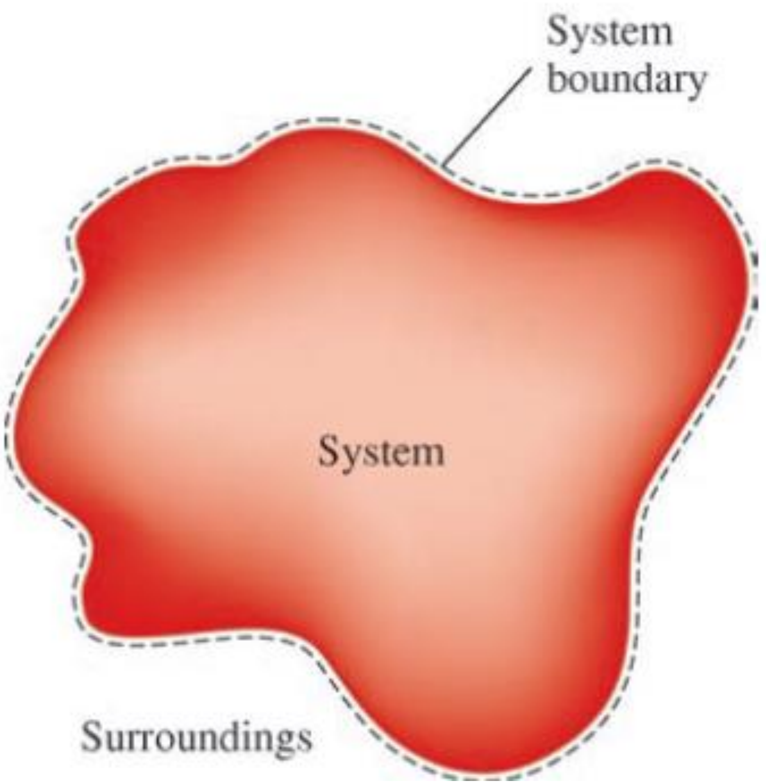
ME 266 Thermodynamics 1

Introductory Concepts and Definitions

D. A. Quansah, PhD, MGhIE
Department of Mechanical Engineering

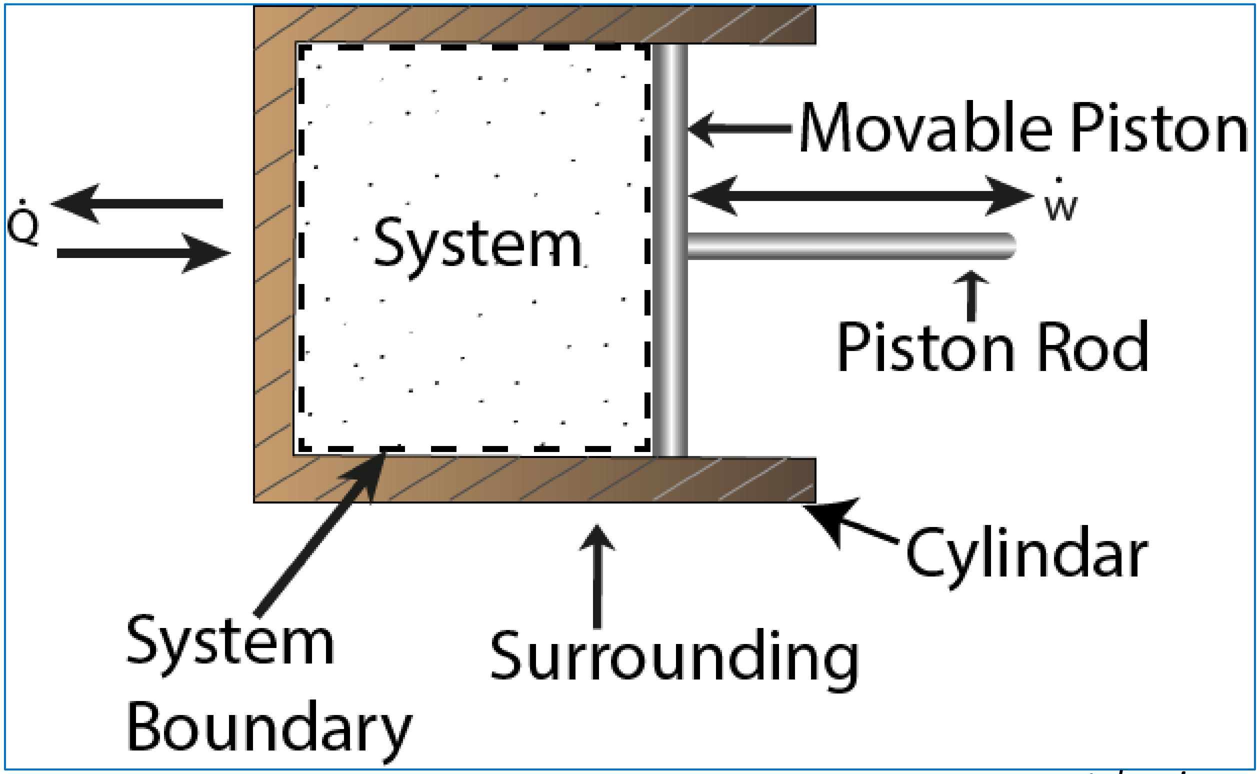
Introductory Concepts and Definitions

- *System*
  - *Closed*
  - *Open*
  - *Isolated*
- *surroundings*
- *system boundary*
- *working fluid*



Introductory Concepts and Definitions

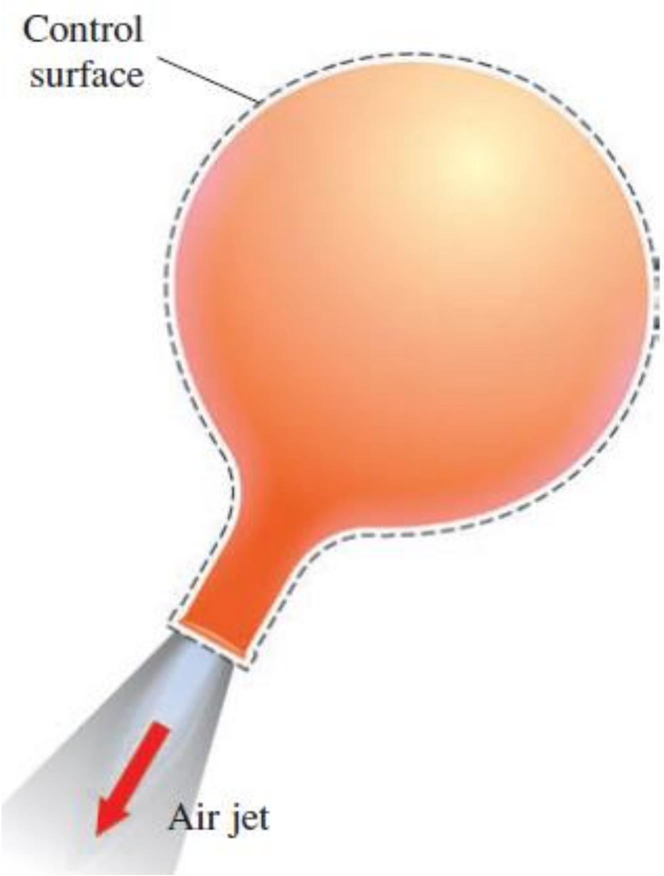
- System boundaries may be drawn to reflect the type of analysis one wishes to perform.



nptel.ac.in

Introductory Concepts and Definitions

Control Volume is defined by a surface (real or imaginary) enclosing a volume of interest.



Introductory Concepts and Definitions

- **Property**
- State
- Process
- Path
- Flow process
- Cycle
- Equilibrium
- Quasi-equilibrium

A property is a quantifiable macroscopic characteristic of a system.

e.g. mass, volume, density, pressure, temperature, etc

Introductory Concepts and Definitions

- Property
- **State**
- Process
- path
- Flow process
- Cycle
- Equilibrium
- Quasi-equilibrium

The *thermodynamic state of a system* is defined by the values of all of the system thermodynamic properties.

Introductory Concepts and Definitions

- Property
- State
- **Process**
- Path
- Flow process
- Cycle
- Equilibrium
- Quasi-equilibrium

A **process** occurs whenever a system changes from one state to another state.

E.g. when the temperature or pressure of a system changes.

Introductory Concepts and Definitions

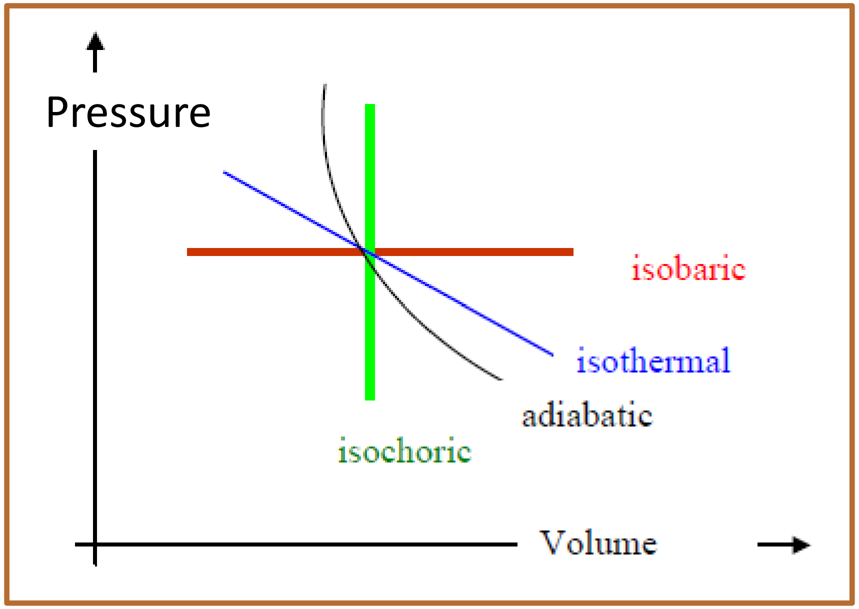
- Property
- State
- **Process**
- Path
- Flow process
- Cycle
- Equilibrium
- Quasi-equilibrium

Types of Processes

Constant-temperature process– Isothermal
Constant-Pressure process- Isobaric
Constant-Enthropy process- Isentropic
Constant-Volume – Isochoric
More will be encountered in this course!

Introductory Concepts and Definitions

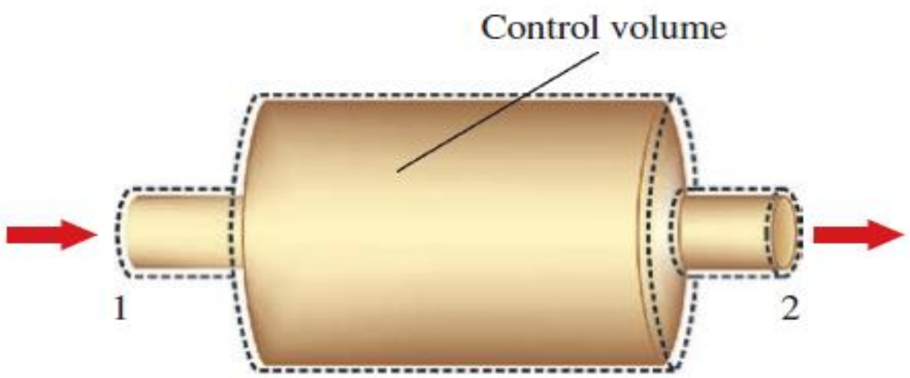
- Property
- State
- Process
- **Path**
- Flow process
- Cycle
- Equilibrium
- Quasi-equilibrium



A PATH is the series of states through which a system passes during a process.

Introductory Concepts and Definitions

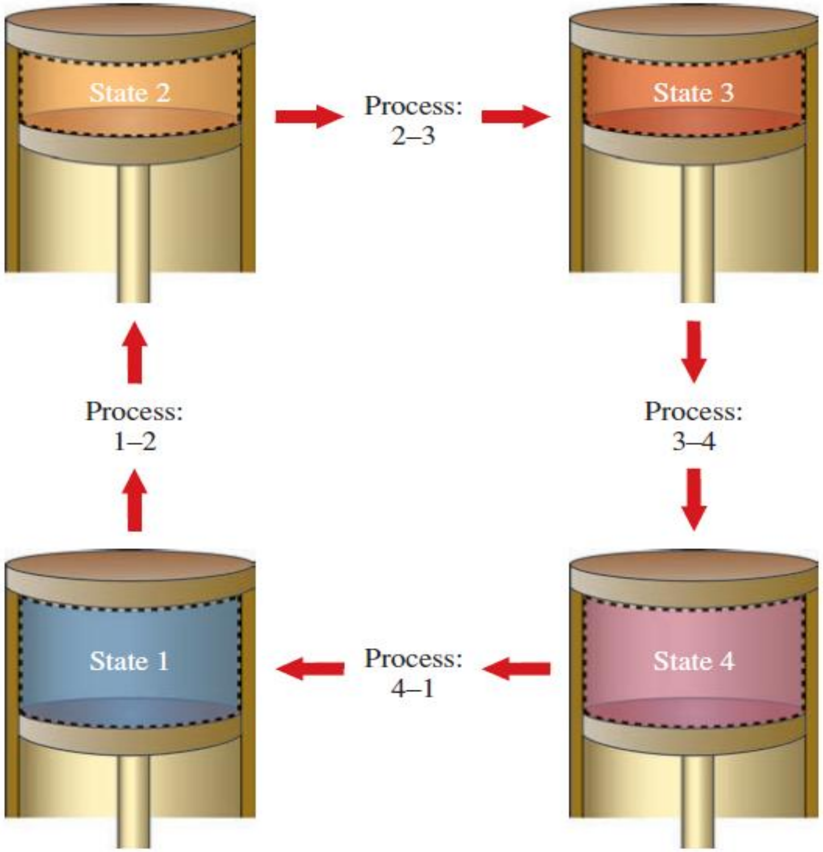
- Property
- State
- Process
- Path
- **Flow process**
- Cycle
- Equilibrium
- Quasi-equilibrium



A *flow process occurs whenever the state of a fluid entering* a control volume is different from the state of the fluid exiting the control volume.

Introductory Concepts and Definitions

- Property
- State
- Process
- Path
- Flow process
- **Cycle**
- Equilibrium
- Quasi-equilibrium



A **thermodynamic cycle** consists of a sequence of processes in which the working fluid returns to its original thermodynamic state.

Introductory Concepts and Definitions

- Property
- State
- Process
- Path
- Flow process
- Cycle
- **Equilibrium**
- Quasi-equilibrium

When the properties of a thermodynamic system are constant from point to point and when there is no tendency for change with time, a condition of *thermodynamic equilibrium* is said to exist.

Introductory Concepts and Definitions

- Property
- State
- Process
- Path
- Flow process
- Cycle
- **Equilibrium**
- Quasi-equilibrium

Conditions for Complete Equilibrium

✓ **Thermal equilibrium**

Uniform system temperature and is same temperature as its surroundings.

✓ **Mechanical equilibrium**

achieved when the pressure throughout the system is uniform and there are no unbalanced forces at the system boundaries.

✓ **Phase equilibrium**

Phase equilibrium requires that the amount of a substance in any one phase not change with time.

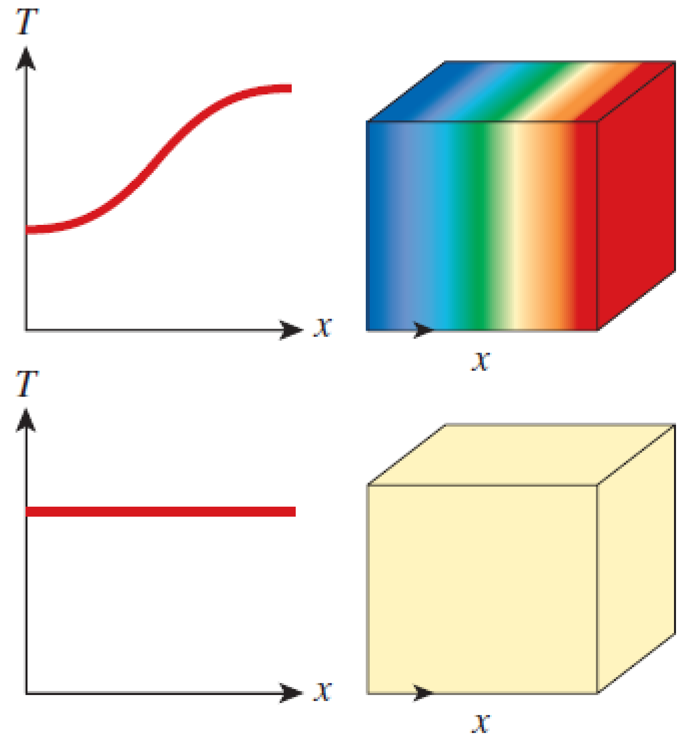
✓ **Chemical equilibrium**

system is in chemical equilibrium if its chemical composition does not change with time, that is, no chemical reactions occur.

Introductory Concepts and Definitions

- Property
- State
- Process
- Path
- Flow process
- Cycle
- **Equilibrium**
- Quasi-equilibrium

Illustration of Thermal equilibrium



Introductory Concepts and Definitions

- Property
- State
- Process
- Path
- Flow process
- Cycle
- Equilibrium
- **Quasi-equilibrium**

A quasi-static or quasi-equilibrium process is a process that happens sufficiently slow such that departures from thermodynamic equilibrium are always so small that they can be neglected.

NB: These are idealized processes.

On quasi-static processes

- ✓ Although they are idealized, engineers are interested in quasi-static processes because they are easy to analyze.
- ✓ work-producing devices deliver maximum work when they operate on quasi-static processes.
- ✓ Work-consuming devices consume minimum work when they operate on quasi-static processes.
- ✓ Quasi-static processes serve as standards to which actual processes can be compared.

Path and Point Functions

- The value of a property of a system is independent of the path of the process undergone by the system and is therefore referred to as a **point function (also called state function)**.

- Quantities such as heat and work which are not properties of the system and dependent on the path of the process undergone by the system are classified as **path functions**.

Path and Point Functions

- If X is a property, then the change in its value is independent of path, hence:

$$\boxed{\int_{1}^{2} dX = X_2 - X_1}$$

- This requires that dX be an exact differential, where X_2-X_1 represents the change in the property as the system changes from state 1 to state 2.

Path and Point Functions

- Quantities such as heat and work which are not properties of the system and are dependent on the path of the process undergone by the system are classified as path functions.

$$\boxed{\int_1^2 dQ = Q_{12}} \quad \textbf{and} \quad \boxed{\int_1^2 dW = W_{12}}$$

- NB: a quantity is a property only if, its change in value between states is independent of the path of the process.

Extensive and Intensive Properties

- An intensive property is one that does not depend on the mass of the system.
- Temperature, pressure, density, and velocity are examples.
- If two (or more) systems are brought together, intensive properties are not summed.

Extensive and Intensive Properties

- An ***extensive property*** is one that does depend on the mass of the system; mass, volume, momentum, and kinetic energy are examples.

- If two systems are brought together the extensive property of the new system is the sum of the extensive properties of the original two systems.

- If an extensive property is divided by the mass, a *specific property* is obtained.

Introductory Concepts and Definitions

- ***Mass density*** *(or simply* ***density****)- mass per unit volume.*

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

- ***Specific volume*** *- volume per unit mass.*

$$v = \frac{V}{m} = \frac{1}{\rho} \qquad (unit: m^3/kg)$$

- ***Weight density*** *(or* ***specific weight****) – Weight per unit volume.*

$$\gamma = \frac{W}{V} \qquad (unit: N/m^3)$$

Introductory Concepts and Definitions

Thermodynamic Pressure

- The ***pressure***, P, of a system is the total normal force, per unit area, exerted by the system within and at the boundary.
- *Collision with other molecules and with the walls of the containing vessel.*
- The SI unit of pressure and stress is the Pascal (Pa).

Thermodynamic Pressure

- The SI unit of pressure and stress is the Pascal (Pa)
  - 1 Pa = 1 N/m^2
- It is convenient sometimes to work in multiples of Pa.

$$1\ kPa = 10^3\ N/m^2$$
$$1\ bar = 10^5\ N/m^2$$
$$1\ MPa = 10^6\ N/m^2$$

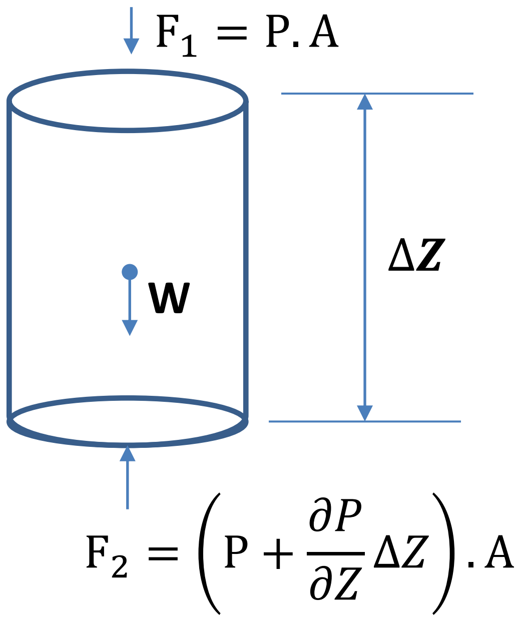
$$1\ atm = 101\ 325\ Pa = 1.013\ 25\ bar = 760\ mm\ Hg$$

Thermodynamic Pressure

- The pressure of a system is usually measured relative to the atmosphere, and it is called "gauge pressure".

Absolute pressure = Gauge pressure + Atmospheric pressure

Pressure Variation with Elevation



A Force Balance on the fluid element yields:

$$F_1 + W - F_2 = 0$$

$$PA + W - \left(P + \frac{\partial P}{\partial Z}\Delta Z\right)A = 0$$

Recall:

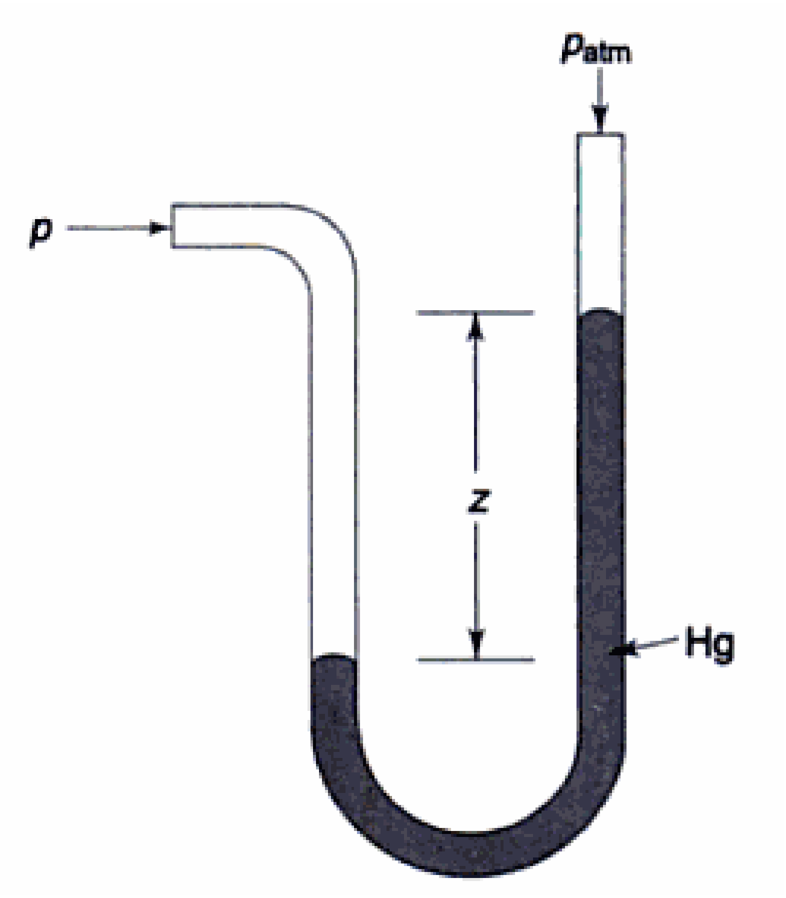
$$W = mg \Rightarrow W = \rho V g \Rightarrow W = \rho A \Delta Z g$$

$$PA + \rho A \Delta Z g - \left(P + \frac{\partial P}{\partial Z}\Delta Z\right)A = 0$$

$$\frac{\partial P}{\partial Z} = -\rho g \Rightarrow \int dP = \int \rho g \, dz \Rightarrow P = \rho g Z$$

<u>KEY LESSON:</u> Pressure varies with altitude or depth.

MANOMETRY - BASICS



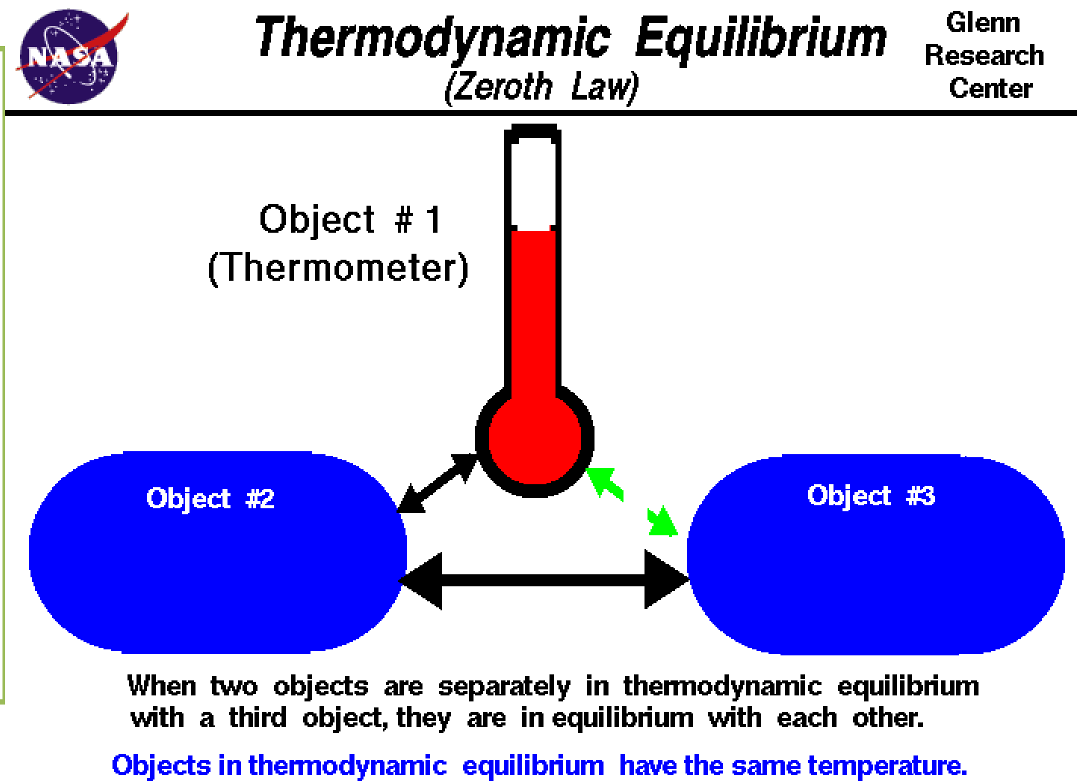
$P=P_{atm}+P_{Hg}$

Temperature Scale

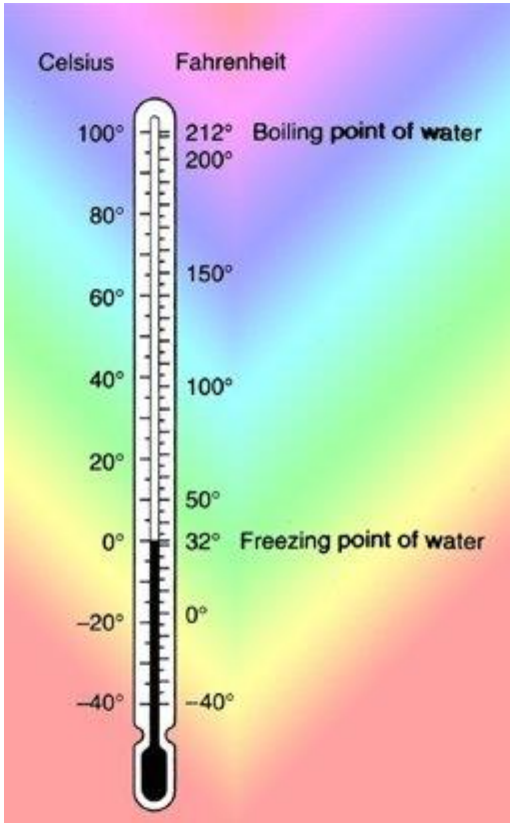
Temperature is a measure of molecular activity.

<u>Equality of Temperatures</u>

If two systems are equal in temperature to a third, they are equal in temperature to each other: ***Zeroth law of thermodynamics.***



Temperature Scale



To establish a temperature scale, the **ice point** and the **steam point** are chosen and a number of subdivisions, are created between them.

- ***ice point*** exists when ice and water are in equilibrium at a pressure of 101 kPa
- ***steam point*** exists when liquid water and its vapor are in a state of equilibrium at a pressure of 101 kPa.

Temperature Scale

Reference Point	^{o}F	^{o}C	K
Water boils	212	100	373
Water Freezes	32	0	273
Absolute Zero	-460	-273	0

Kelvin Scale

- There is a limit to how cold something can be.
- The Kelvin scale is designed to go to zero at this minimum temperature.
- At a temperature of **Absolute Zero** there is no motion and no heat. Absolute zero is where all atomic and molecular motion stops and is the lowest temperature possible. Absolute Zero occurs at 0 K or -273.15 ^{o}C or at -460 ^{o}F.