

CHAPTER

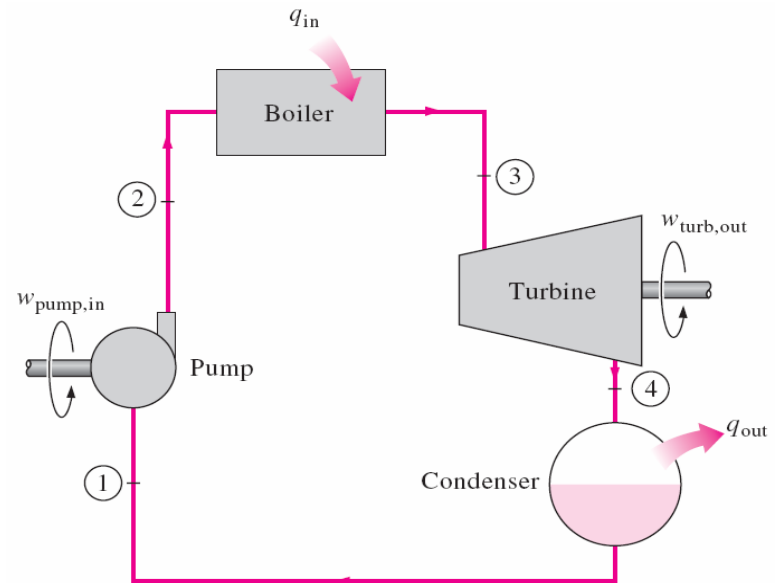
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Thermodynamics

Fundamental Concepts

What is Thermodynamics?

- ❖ The science of energy, that concerned with the ways in which energy is stored within a body.
- ❖ Energy transformations – mostly involve **heat** and **work** movements.
- ❖ The Fundamental law is the **conservation of energy** principle: energy cannot be created or destroyed, but can only be transformed from one form to another.



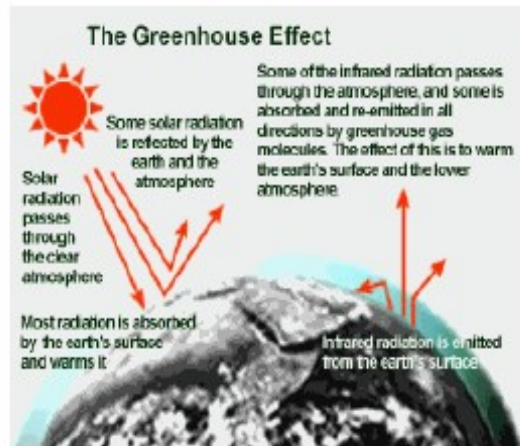
Application Areas of Thermodynamics

Practical uses of thermodynamics are unlimited.

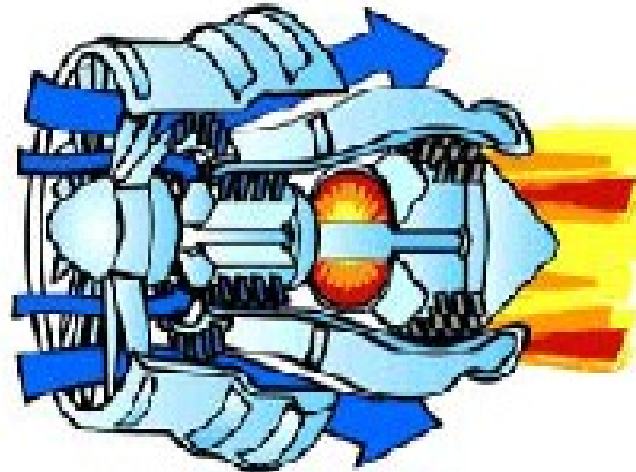
- ❑ human body,
- ❑ An ordinary house ,
 - ✓ air-conditioning systems,
 - ✓ the refrigerator,
 - ✓ the humidifier,
 - ✓ the pressure cooker,
 - ✓ the shower,
 - ✓ the iron,
 - ✓ the computer and TV.
- ❑ Large scale systems :
 - automotive engines, jet engines,
 - conventional or nuclear power plants,
 - rockets,
 - solar collectors,
 - heat engines, ,
 - and heat pumps.

Applications of Thermodynamics

☐ Global warming

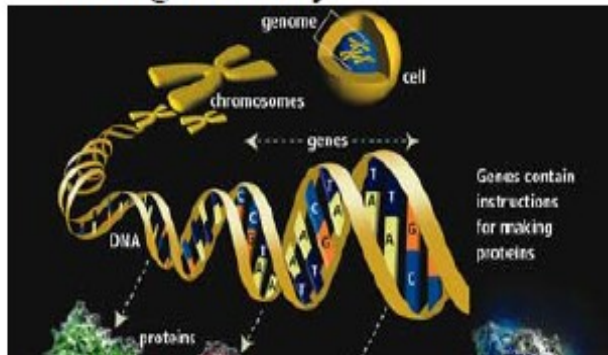


Combustion engine



☐ Biological thermodynamics

- Healing illness and disease
- Drug delivery

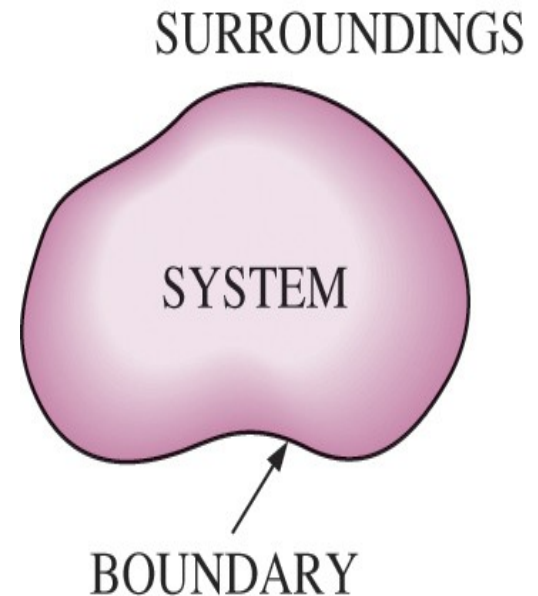


☐ Food engineering



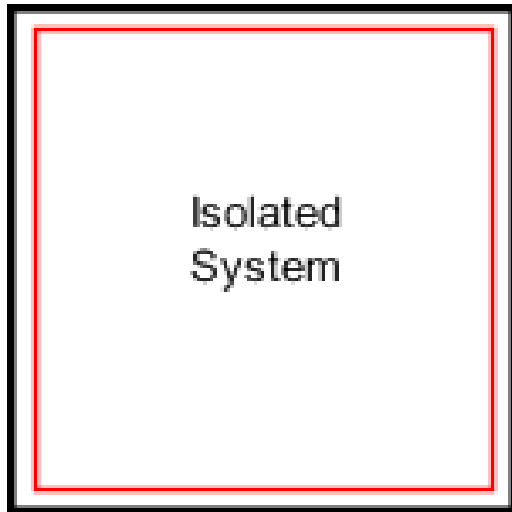
System, surroundings and boundary

- ❖ **System:** A quantity of matter or a region in space chosen for study.
- ❖ **Surroundings:** The mass or region outside the system
- ❖ **Boundary:** The real or imaginary surface that separates the system from its surroundings



Type of system

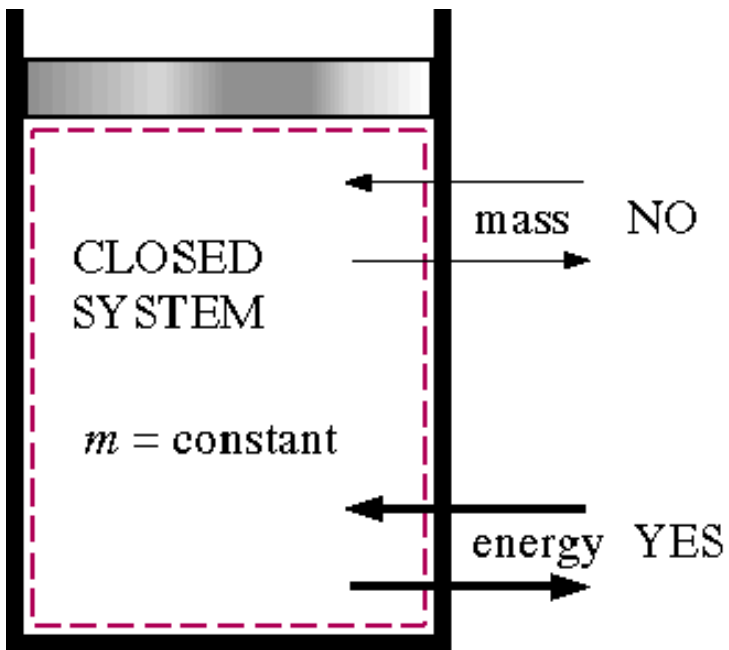
(isolated system)



- ❖ **Isolated system** – neither mass nor energy can cross the selected boundary
- ❖ Example (approximate): coffee in a closed, well-insulated thermos bottle

Type of system

(Closed system)

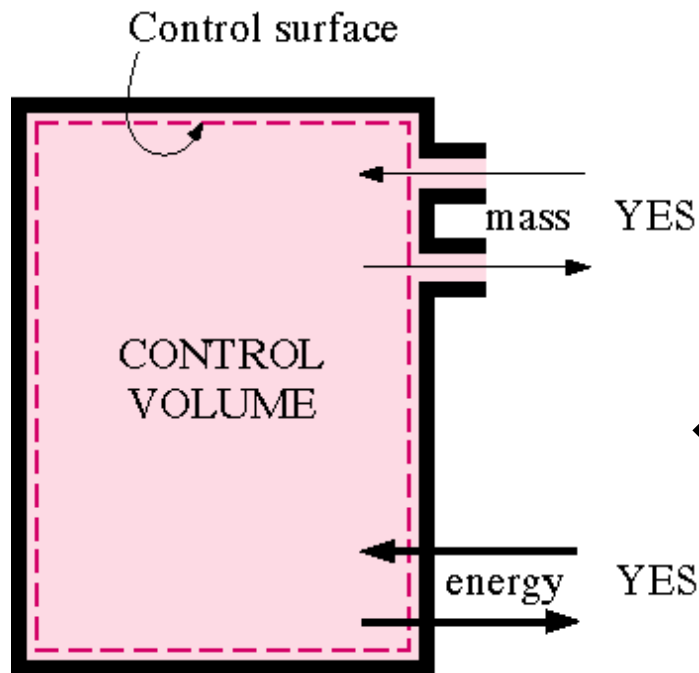


❖ **Closed system** – only energy can cross the selected boundary

❖ Examples: a tightly capped cup of coffee

Type of system

(Open system)



❖ **Open system** – both mass and energy can cross the selected boundary

❖ Example: an open cup of coffee

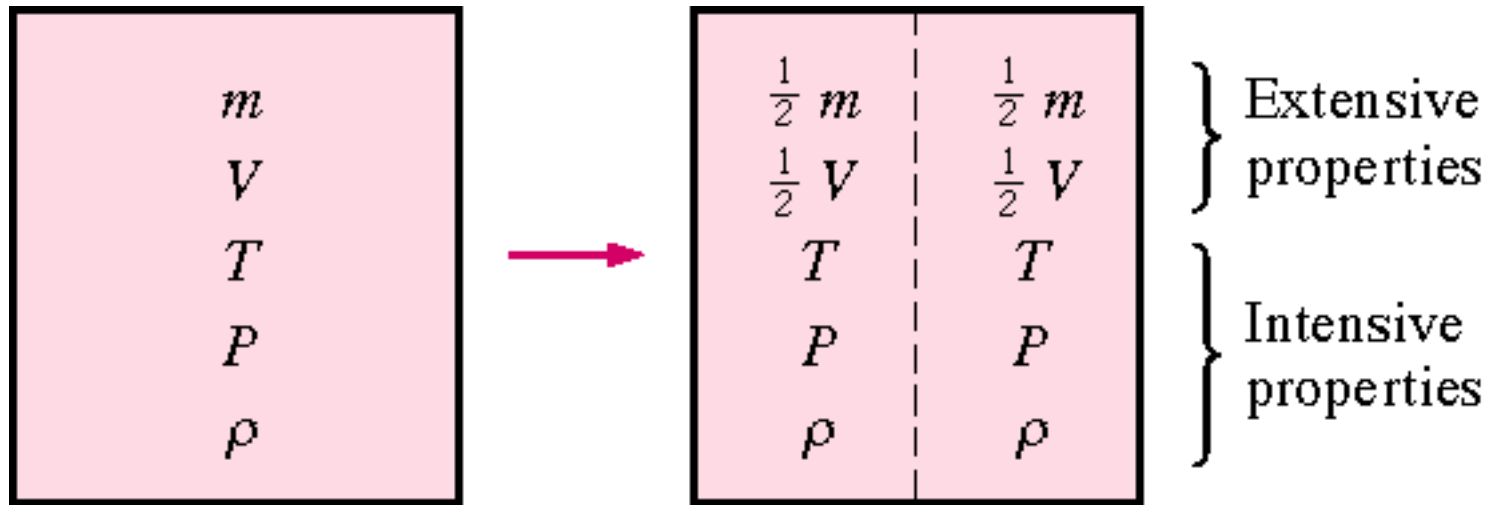
Properties of a system

- Properties of a system is a measurable characteristic of a system that is in equilibrium.
- Properties may be intensive or extensive.

❖ **Intensive** - Are independent of the amount of mass:

e.g: Temperature, Pressure, and Density,

❖ **Extensive** - varies directly with the mass
e.g: mass, volume, energy, enthalpy



Properties of a system

Specific properties – The ratio of any extensive property of a system to that of the mass of the system is called an average specific value of that property (also known as intensive property)

Specific Volume	$V/m = v$	m^3/kg
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Total Energy	$E/m = e$	J/kg
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Internal Energy	$U/m = u$	J/kg
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Classes of properties

Box with 3 sections after equilibrium



Extensive: Total :

$$V = V_1 + V_2 + V_3$$

$$E = E_1 + E_2 + E_3$$

$$m = m_1 + m_2 + m_3$$

Intensive: not size independent

$$v = v_1 = v_2 = v_3 = V/m$$

$$e = e_1 = e_2 = e_3 = E/m$$

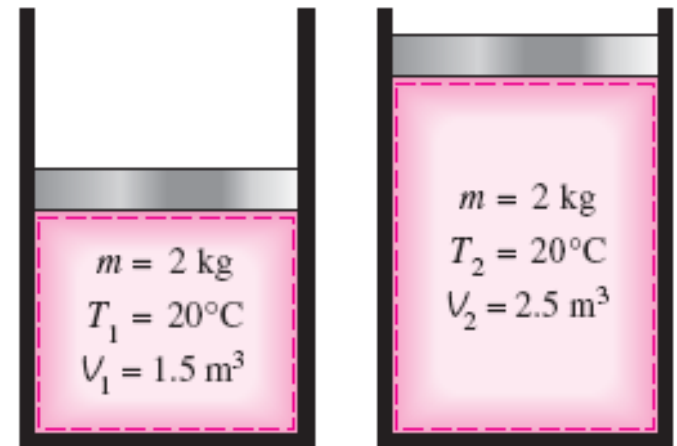
T, P

State, Equilibrium and Process

- ❖ **State** – a set of properties that describes the conditions of a system.
- ❖ a condition at which all the properties of a system having fixed values. Eg. Mass m , Temperature T ,

volume V
Thermodynamic equilibrium - the conditions where all of the *relevant* types of equilibrium are satisfied.

- **Thermal equilibrium**
- **Mechanical equilibrium**
- **Phase equilibrium**
- **Chemical equilibrium**



(a) State 1

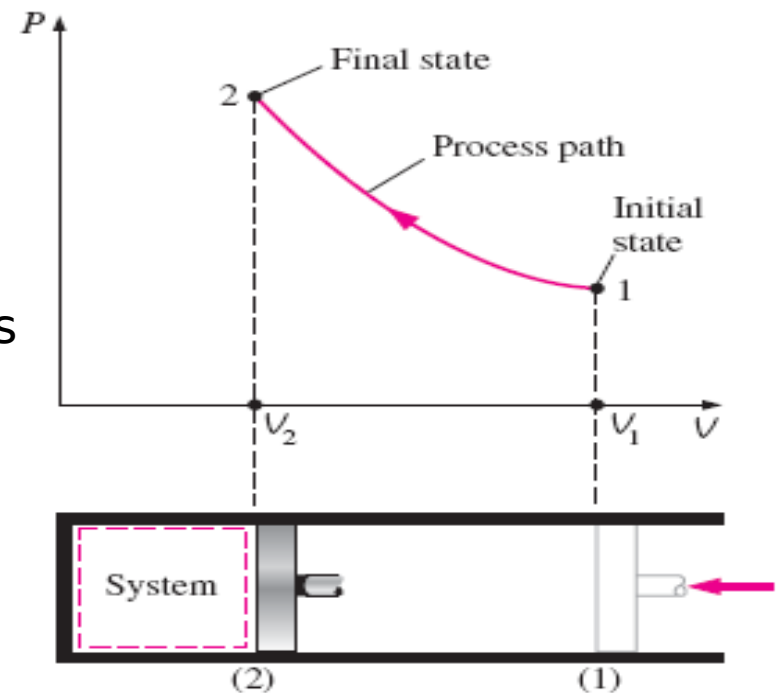
(b) State 2

State, Equilibrium and Process

❖ **Process** – change from one equilibrium state to another.

A **process** described completely with:

- *initial* and *final* states of the process
- the *path* it follows,
- and the *interactions* with the surroundings.

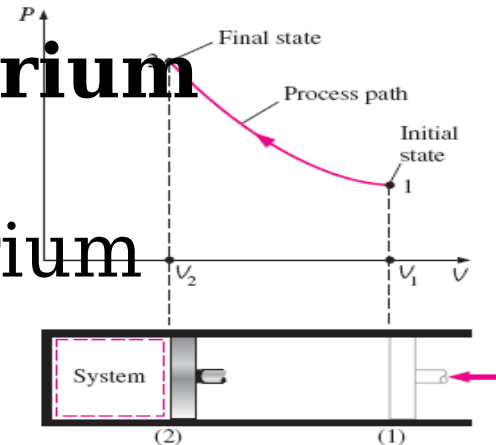


State, Equilibrium and Process

Generally Two types of processes:

1. Quasi-static, or quasi-equilibrium process: the system remains infinitesimally close to an equilibrium state at all times.

e.g. slow compression



1. Non quasi-equilibrium process:
the entire system can't be characterized by a single state.

❑ **steady-flow process:** Processes involving *no change with time*.

❑ **Uniform process** : implies *no change with location* over a specified region.

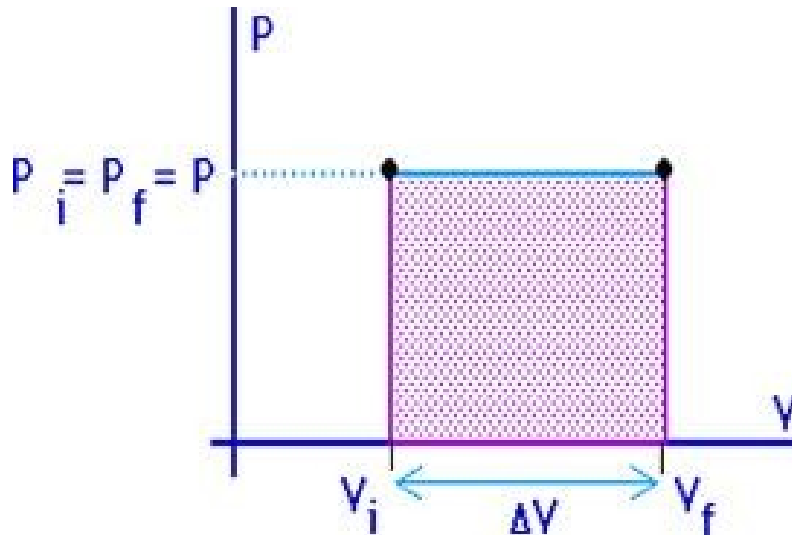
e.g. fast compression

State, Equilibrium and Process

The prefix *iso-* is often used to designate a process for which a particular property remains constant.

Isobaric process: A process during which the pressure P remains constant.

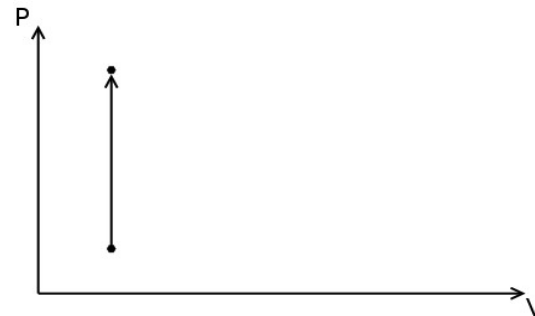
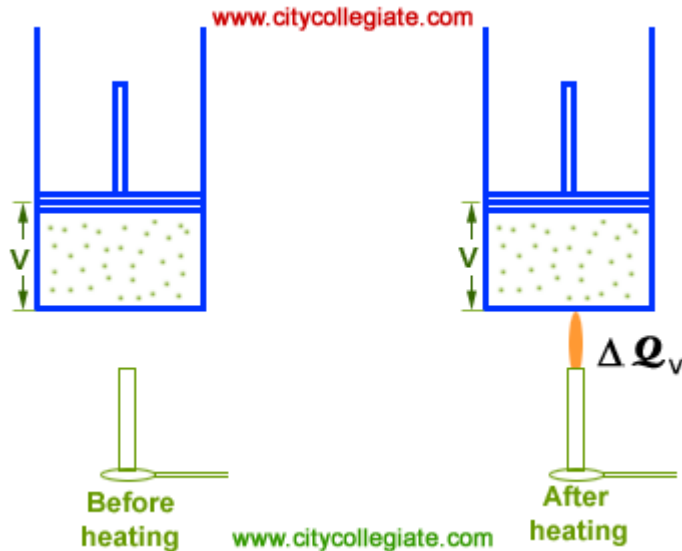
Pressure is Constant ($\Delta P = 0$)



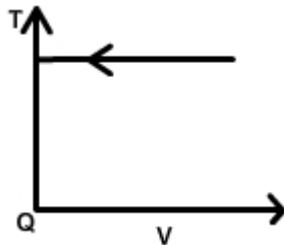
Process	Property held constant
isobaric	pressure
isothermal	temperature
isochoric	volume
isentropic	entropy

State, Equilibrium and Process

Isochoric (or isometric) process: A process during which the specific volume v remains constant



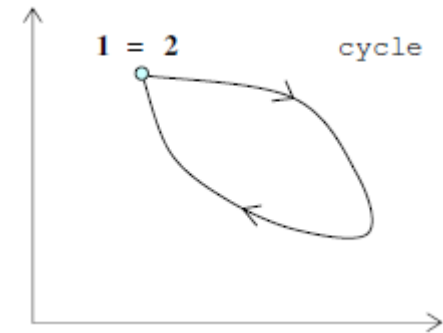
Isothermal process: A process during which the temperature T remains constant.



Process	Property held constant
isobaric	pressure
isothermal	temperature
isochoric	volume

Dominant Types of Thermodynamics Processes

- ❖ **Cyclic process** - when a system in a given initial state goes through various processes and finally return to its initial state, the system has undergone a cyclic process or cycle.
- ❖ **Reversible process** - it is defined as a process that, once having take place it can be reversed. In doing so, it leaves no change in the system or boundary.
- ❖ **Irreversible process** - a process that cannot return both the system and surrounding to their original conditions



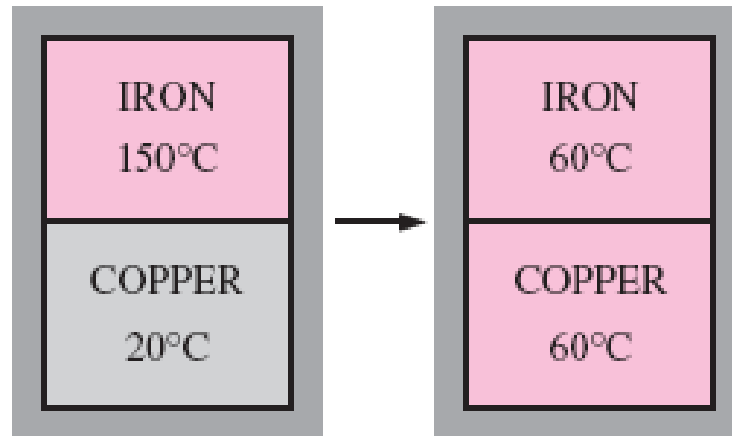
Types of Thermodynamics Processes

- ❖ **Adiabatic process** - a process that has no heat transfer into or out of the system. It can be considered to be perfectly insulated.
- ❖ **Isentropic process** - a process where the entropy of the fluid remains constant.
- ❖ **Polytropic process** - when a gas undergoes a reversible process in which there is heat transfer, it is represented with a straight line $PV^n = \text{constant}$.
- ❖ **Throttling process** - a process in which there is no change in enthalpy, no work is done and the process is adiabatic.

Zeroth Law of Thermodynamics

“ If two bodies are in thermal equilibrium with a third body, there are also in thermal equilibrium with each other.”

- ❖ The equality of *temperature* is the only requirement for **thermal equilibrium**.



Two bodies reaching thermal equilibrium after being brought into contact in an isolated enclosure.

temperature measurement

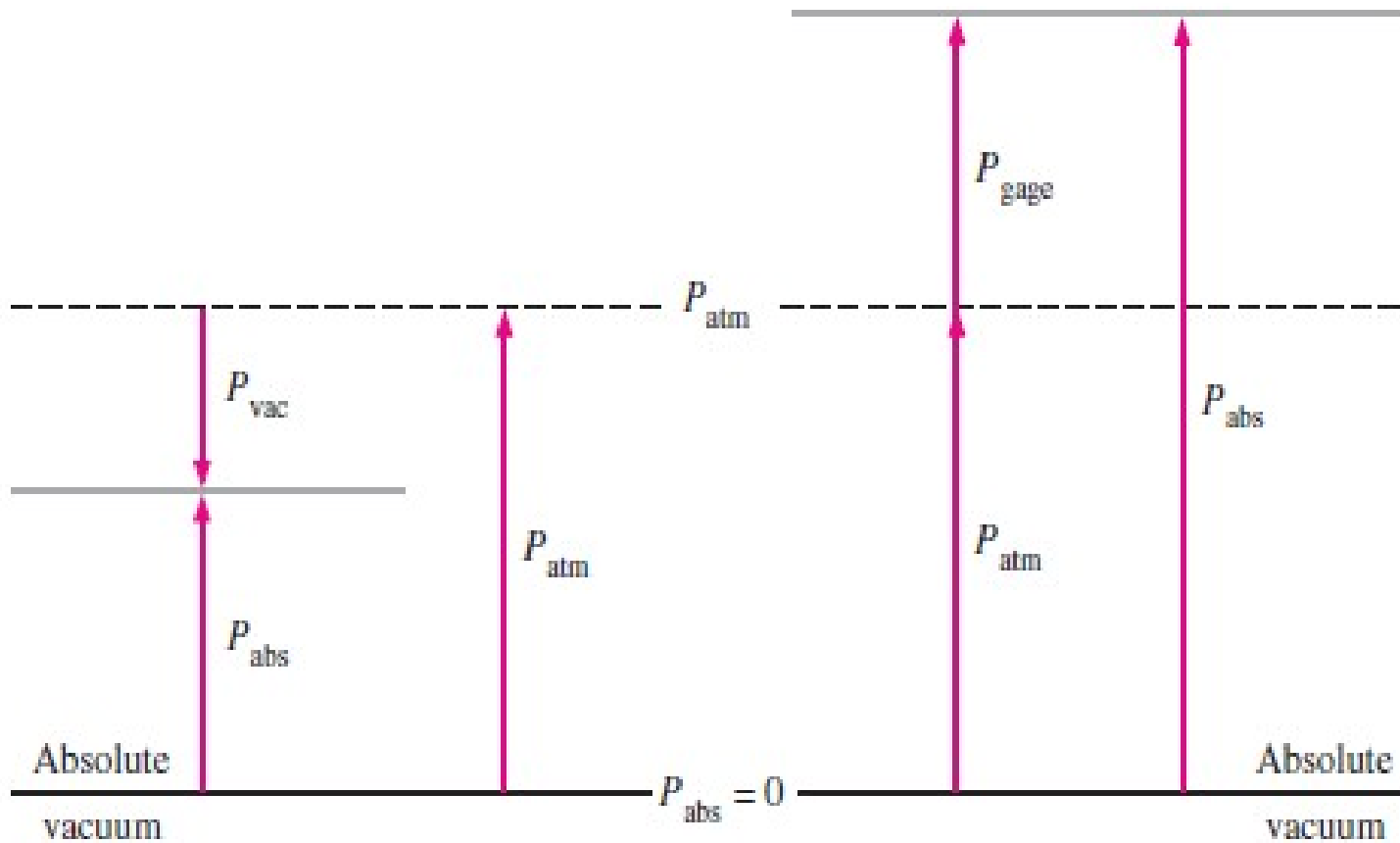
- **Temperature scales** are common basis for temperature measurements.
 - **Celsius scale**(°C)
 - **Fahrenheit scale**(°F)
- **Thermodynamic temperature scale:** a temperature scale that is independent of the properties of any substance or substances.
 - **K** $T(\text{K}) = T(^{\circ}\text{C}) + 273.15$ $T(\text{R}) = 1.8T(\text{K})$
 - **R** $T(\text{R}) = T(^{\circ}\text{F}) + 459.67$ $T(^{\circ}\text{F}) = 1.8T(^{\circ}\text{C}) + 32$
- **Th**

pressure measurements

- **Absolute pressure** : The actual pressure at a given position (boundary).
- **Vacuum pressures** : Pressures below atmospheric pressure
- **Absolute zero pressure = Absolute vacuum**
- **Gage pressure** : the difference between the absolute pressure and the local atmosphere
$$P_{\text{gage}} = P_{\text{abs}} - P_{\text{atm}}$$
 - the value measured by a vacuum gauge.
$$P_{\text{vac}} = P_{\text{atm}} - P_{\text{abs}}$$

PRESSURE

CONT...



PRESSURE

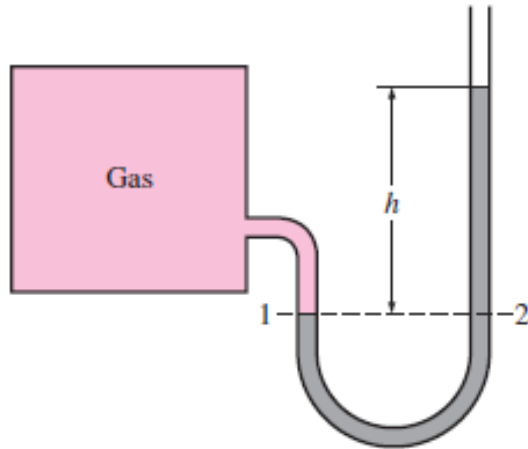
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- The **atmospheric pressure** is the pressure due to the weight of the atmospheric air. Torricelli
- **Barometer** : barometric pressure
 - Torricelli principle
 - $P_{\text{atm}} = \rho gh$
- **Manometer** : A device commonly used to measure small and moderate pressure differences.
 - used to measure the system pressure in a container.
 - If the system has a *pressure* p , the fluid in the manometer has a *density* ρ , and the surroundings are *atmospheric with pressure* p_{atm} , then the *difference in pressure* between the system and the surroundings is:

$$p - p_{\text{atm}} = \rho gh$$

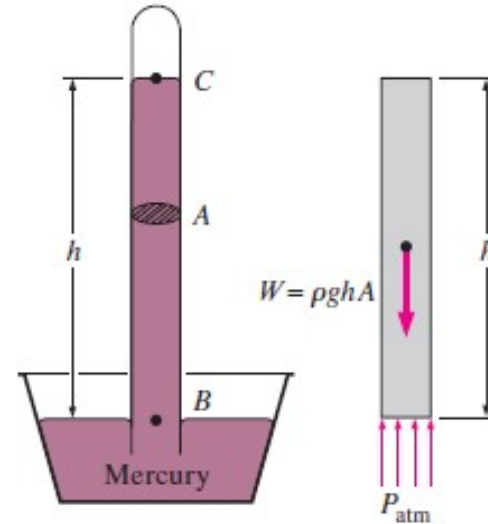
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$$P_2 = P_{\text{atm}} + \rho gh$$



The basic manometer.

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



The basic barometer

Other Pressure Measurement Devices

- ☐ mechanical pressure measurement device:
 - ✓ **Bourdon tubes**
- ☐ Modern pressure sensors: **pressure transducers**
 - ✓ **Strain-gage pressure transducers**
 - ✓ **Piezoelectric transducers**

Exercise

1. The water in a tank is pressurized by air, and the pressure is measured by a multi fluid manometer as shown in figure below. The tank is located on a mountain at an altitude of 1400 m where the atmospheric pressure is 85.6kPa. Determine the air pressure in the tank if $h_1 = 0.1$ m, $h_2 = 0.2$ m, and $h_3 = 0.35$ m. Take the densities of water, oil, and mercury to be 1000kg/m³, 850 kg/m³, and 13,600 kg/m³, respectively.

