THERMODYNAMICS

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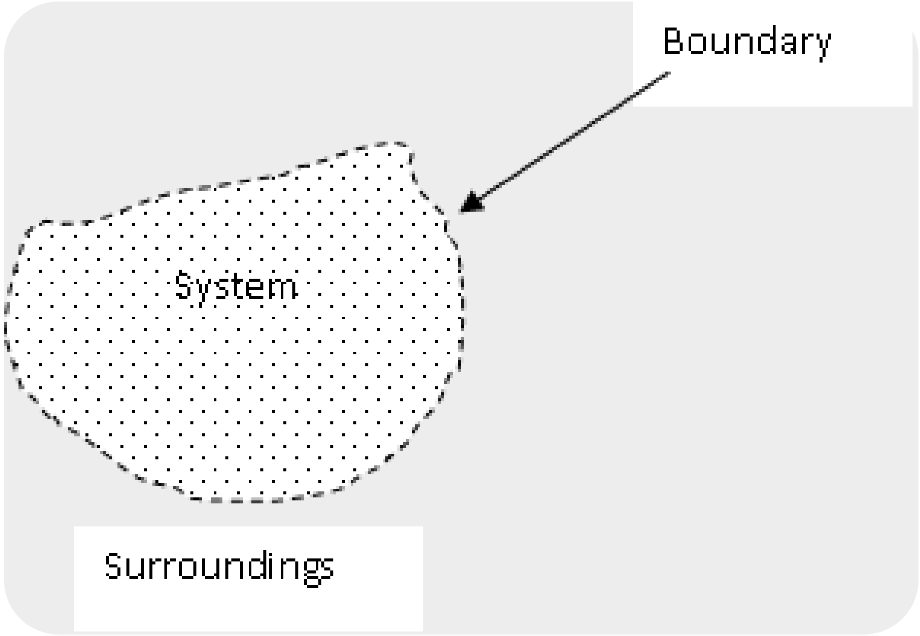
CHAPTER 2
BASIC DEFINITIONS AND CONCEPTS

BASIC DEFINITIONS AND CONCEPTS

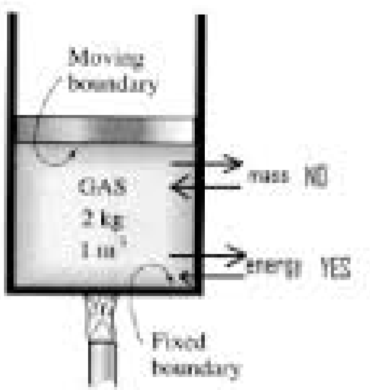
Thermodynamic system: a region of space or an amount of matter, bounded by an arbitrary surface



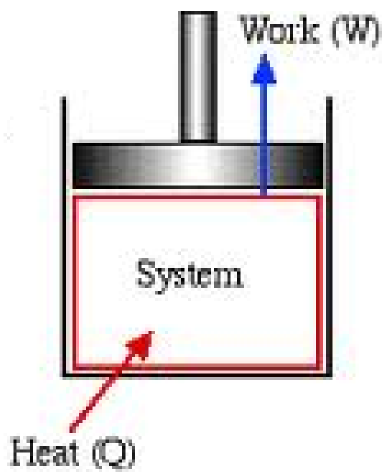
CLASSIFICATION OF SYSTEMS

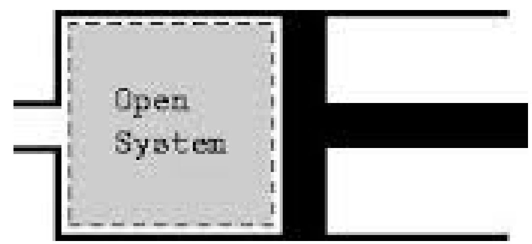
A system interacts with its surroundings in three ways:

- by exchanging work
- by exchanging heat
- by exchanging mass through its boundary



Closed System



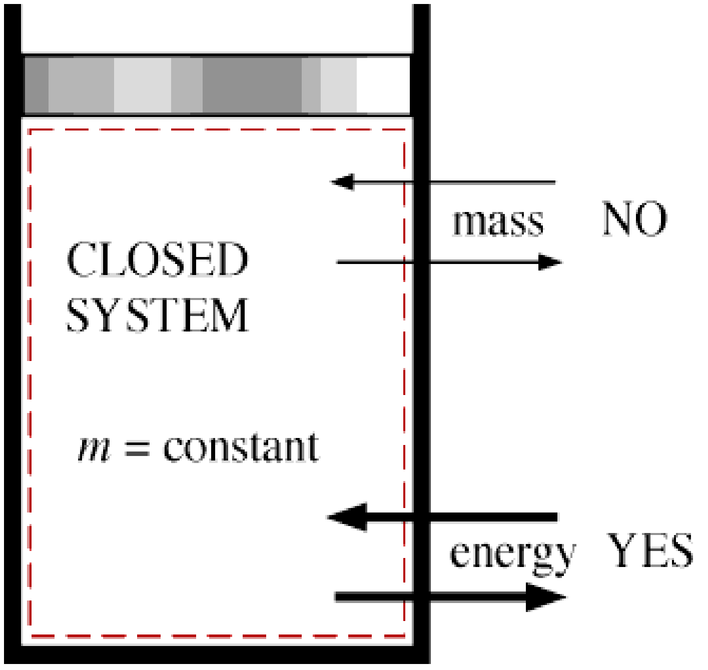


CLASSIFICATION OF SYSTEMS

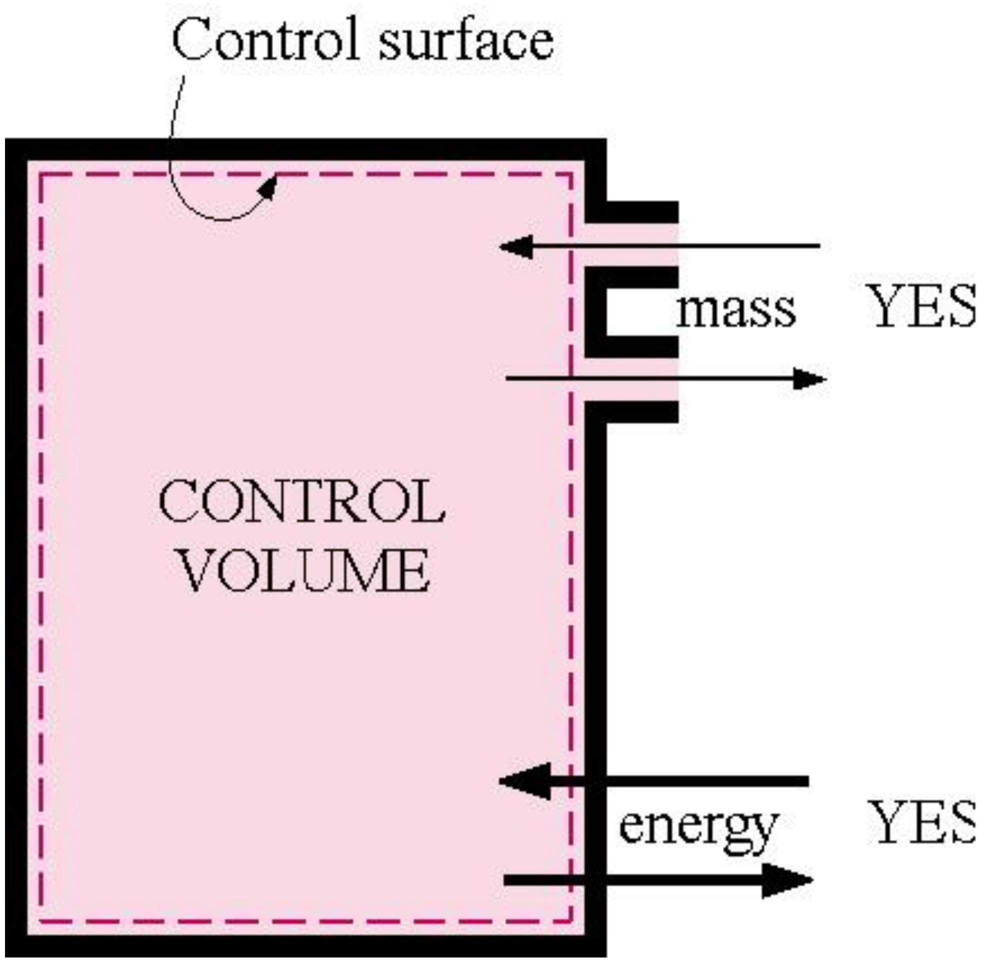
Depending on the nature of the boundary, a system may be classified as open, closed or isolated

	WORK	HEAT	MATTER (MASS)
OPEN	YES	YES	YES
CLOSED	YES	YES	NO
ISOLATED	NO	NO	NO

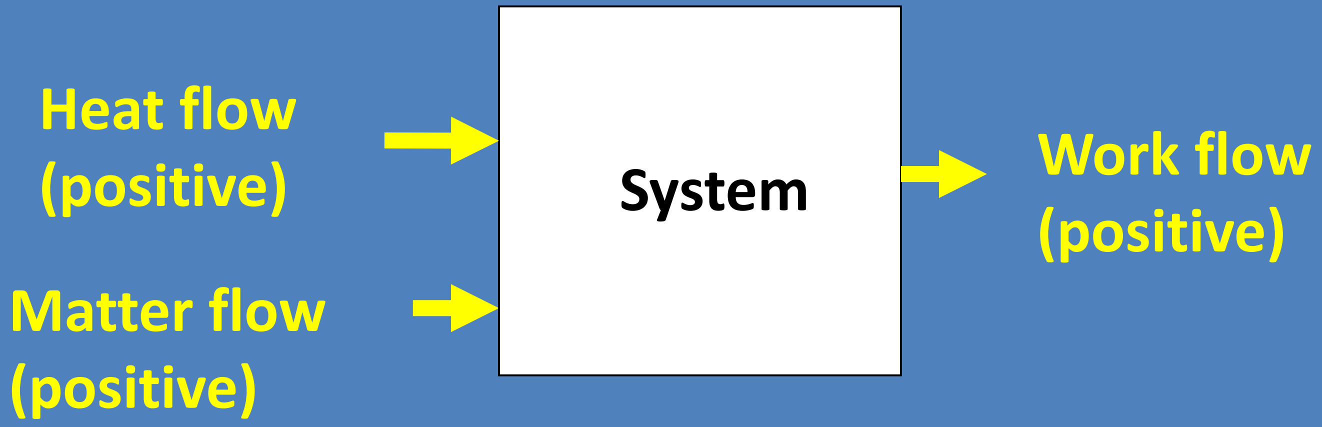
CLOSED SYSTEM



OPEN SYSTEM OR CONTROL VOLUME



SIGN CONVENTION



THERMODYNAMIC PROPERTIES

A property is a characteristic of a system. A property is used to specify the condition of a system. e.g. pressure P; temperature T; mass m; volume V

$$\int_1^2 dy = y_2 - y_1 = \Delta y$$

STATE FUNCTION AND PATH FUNCTION

Thermodynamic quantities can be divided into 2 categories State functions and Path (process) functions.

The change in value of a state function depends solely on its values at the initial and final states and not on the path. Example: Thermodynamic properties

The change in value of a path function depends on the path of the process. Example: work and heat

EXTENSIVE AND INTENSIVE PROPERTIES

Extensive properties depend on the extent or size of the system and hence vary directly with the mass. Ex. mass, volume

Intensive properties are independent of the size of the system. Ex. Pressure, temperature.

Specific properties (denoted by lower case letters) are defined as the value of an extensive property per unit mass; they are, therefore, independent of mass and are intensive.

EXTENSIVE AND INTENSIVE PROPERTIES

Subsystem 1	Subsystem 2
V_1, m_1, T, P	V_2, m_2, T, P

Boundary between subsystems

$$V_{syst} = V_1 + V_2$$

$$m_{syst} = m_1 + m_2$$

$$T_{syst} = T_1 = T_2$$

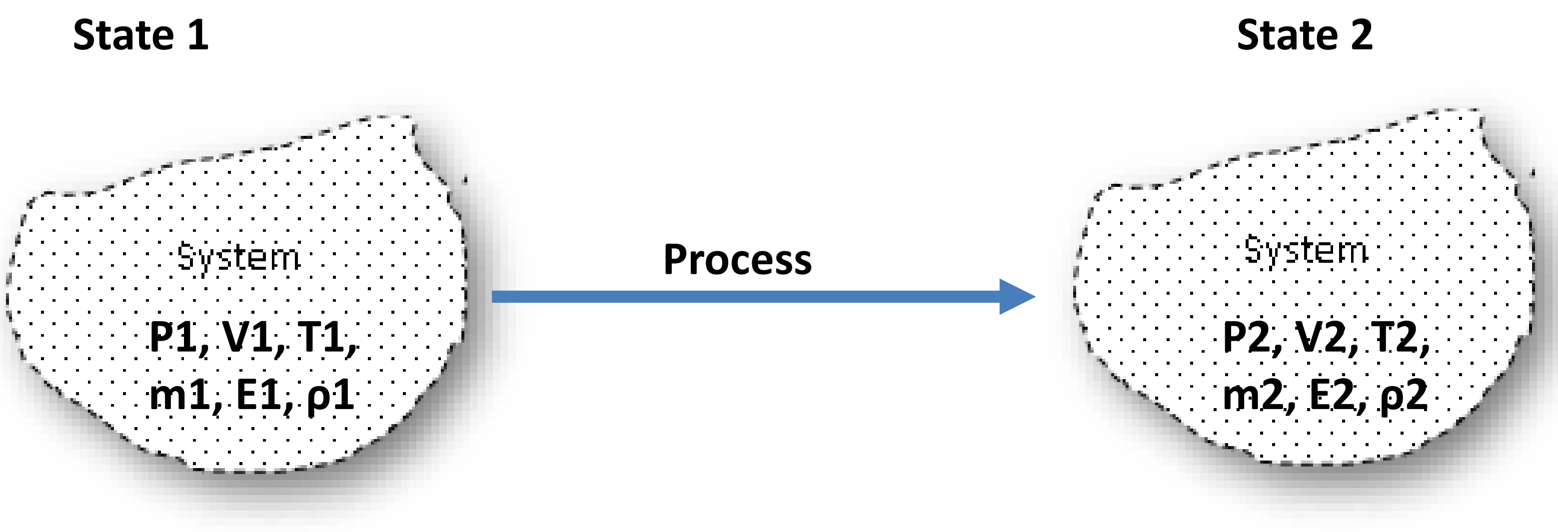
$$P_{syst} = P_1 = P_2$$

Extensive and intensive relationship

THERMODYNAMIC STATE, PROCESS

- The word **state** refers to the condition of a system as described by its properties.

- When any of the properties of a system changes, the state changes and the system is said to have undergone a **process**; a process is a transformation from one state to another.



THERMODYNAMIC STATE, PROCESS

- A system is said to be at steady state if none of its properties changes with time.
- An isothermal process occurs at constant temperature.
- An isobaric process is at constant pressure.
- An isometric (isochoric) process is one of constant volume

THERMODYNAMIC CYCLE

A thermodynamic cycle is a sequence of processes that begins and ends at the same state. In a cycle, the net change of any property y is equal to zero.

$$if\ y\ is\ a\ property, then \oint dy = \ \Delta y\ =\ 0\ \ and\ vice - versa$$

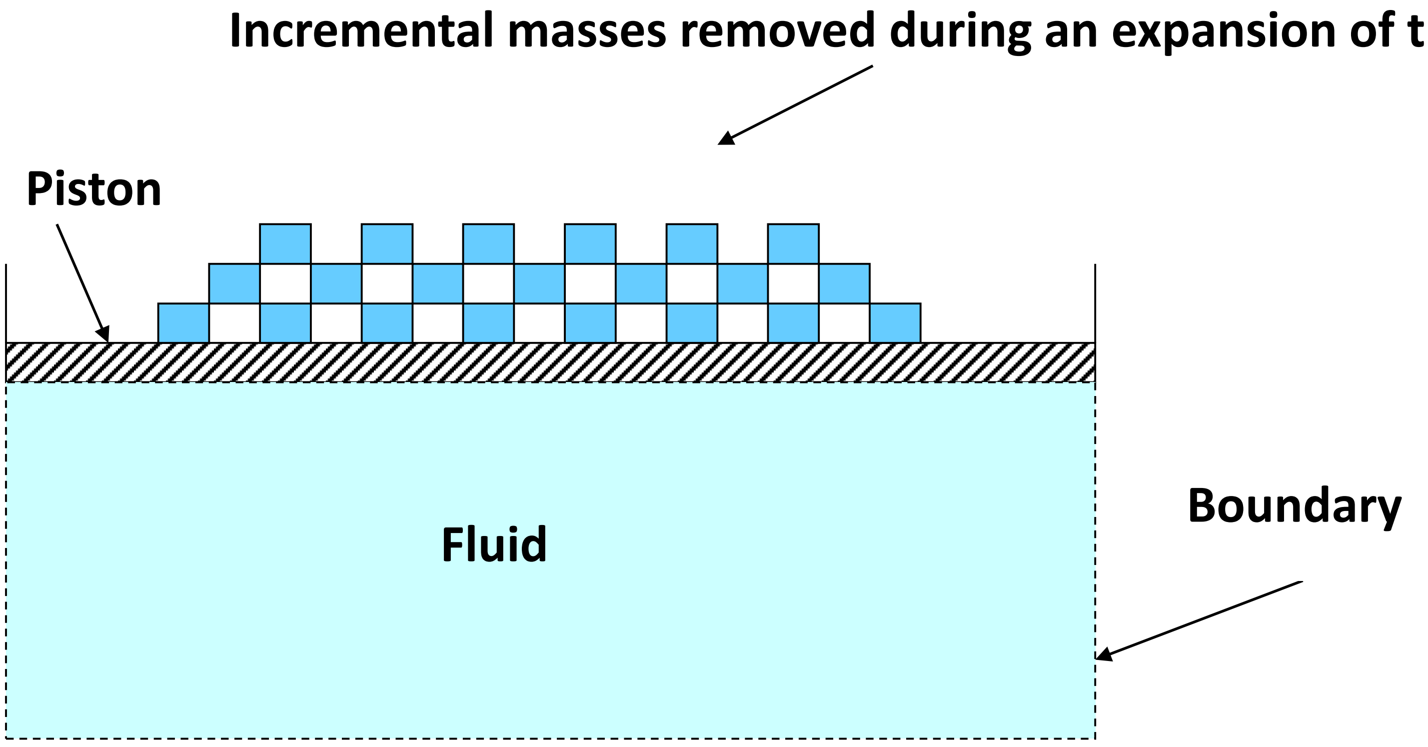
THERMODYNAMIC EQUILIBRIUM AND PROCESS

A system is in **thermodynamic equilibrium** with its surroundings if no further changes occur in its properties: 3 conditions are satisfied:

- mechanical equilibrium: forces are balanced
- thermal equilibrium: temperature is uniform
- chemical equilibrium: no change in composition and no transfer of matter

QUASI-STATIC PROCESS

During a quasi-static or quasi-equilibrium process, the system remains practically in equilibrium at all times



Quasi-static expansion or compression

REVERSIBLE PROCESS, IRREVERSIBLE PROCESS

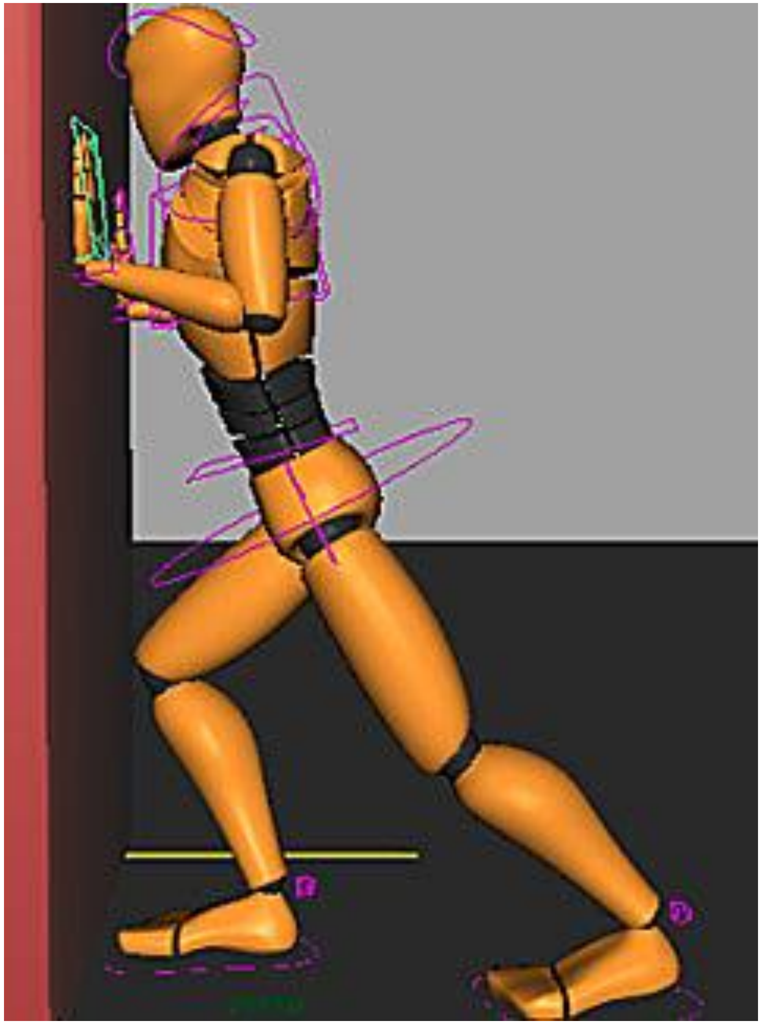
A process is reversible if the system and its surroundings can be exactly restored to their respective initial states after the process has taken place.

Reversible processes are always quasi-static but the converse is not always true.

A process that is not reversible is termed irreversible.

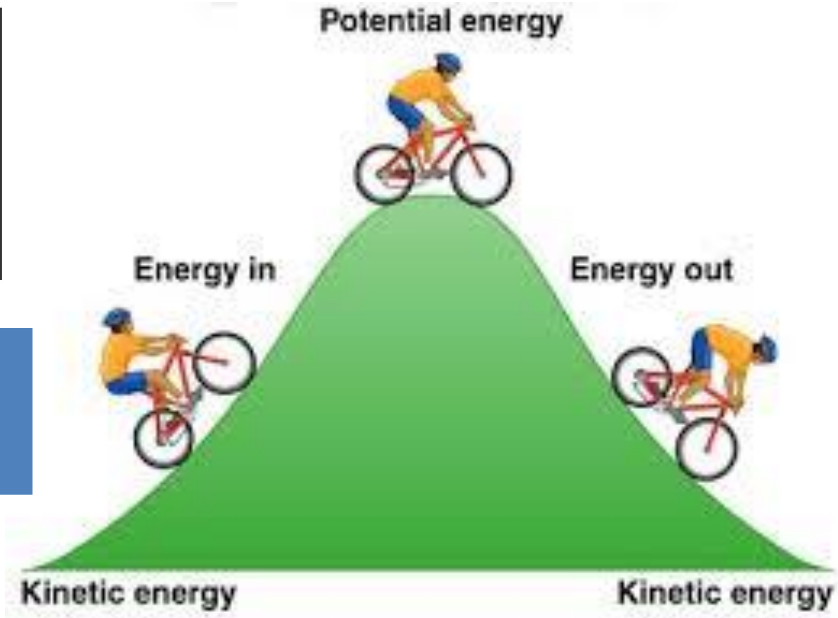
ENERGY

It is hard to give a precise definition of energy. Energy can be viewed as the ability to cause change.



TOTAL ENERGY OF A SYSTEM

$$E = U + E_k + E_P$$

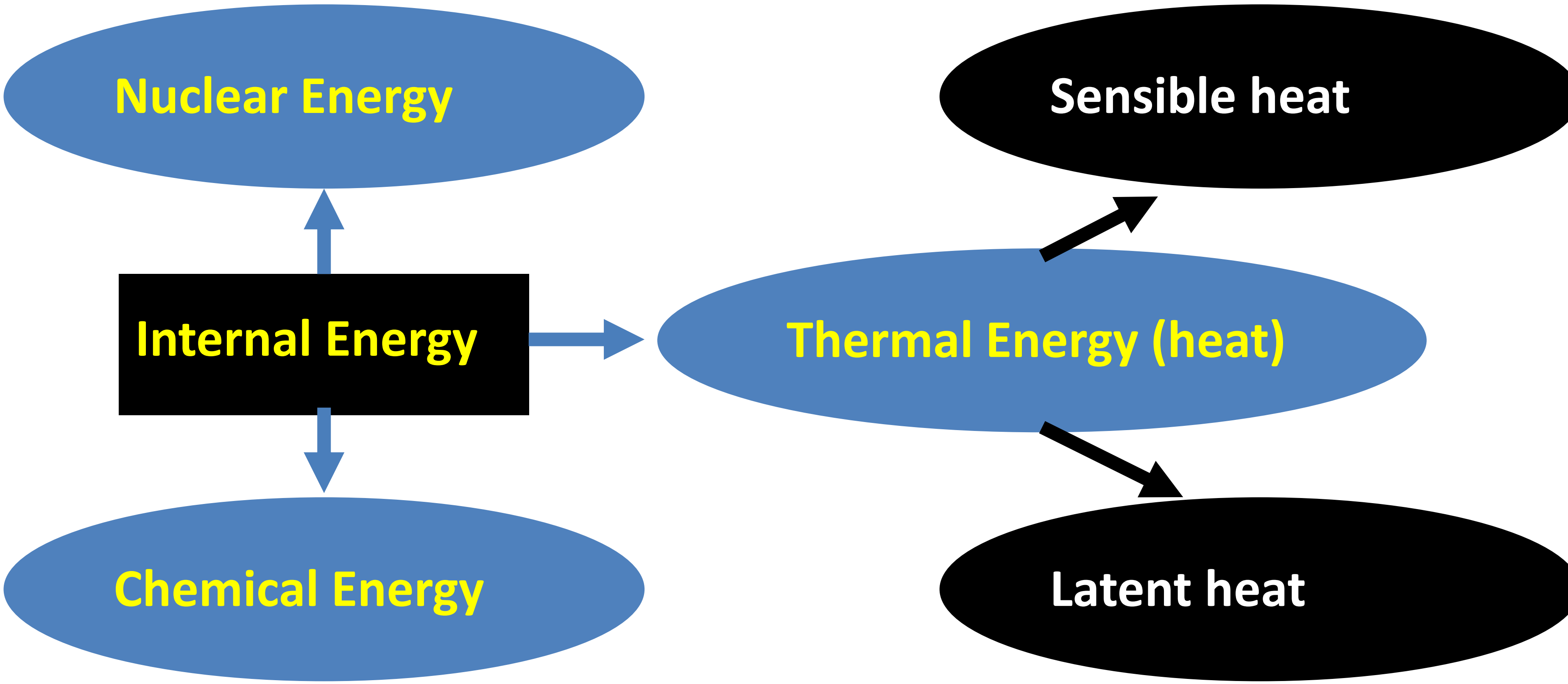


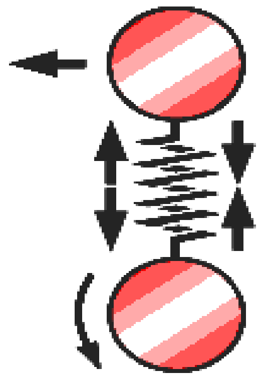
Kinetic energy: motion energy

Gravitational Potential energy: associated with the position of the system

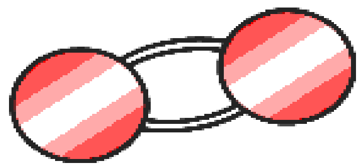
Internal Energy: associated with the microscopic structure of matter (molecules, atoms and nuclei)

INTERNAL ENERGY





SENSIBLE
AND LATENT
ENERGY



CHEMICAL
ENERGY

NUCLEAR
ENERGY

CONSERVATION OF MASS PRINCIPLE

- Mass like energy cannot be created or destroyed.
- However, mass m and energy E can be converted to each other according to the famous formula proposed by Einstein

$$E = m\,c^2$$

HEAT AND WORK

- **Heat and work are concepts which describe the two modes of energy transfer when there is absence of thermodynamic equilibrium between a system and its surroundings.**

- **Heat and work are transient forms of energy which appear only at the boundary of systems**

HEAT AND WORK

Heat is energy flow by virtue of a temperature difference. Heat is not contained in a system. Heat only exists as energy crossing the boundary.

Here distinction is made between Thermal energy and Heat. Thermal energy is part of the internal energy, hence contained in the system. Heat is thermal energy crossing the boundary.

Three distinct mechanisms of heat flow: conduction, convection and radiation. Heat transfer is a separate course.

HEAT AND WORK

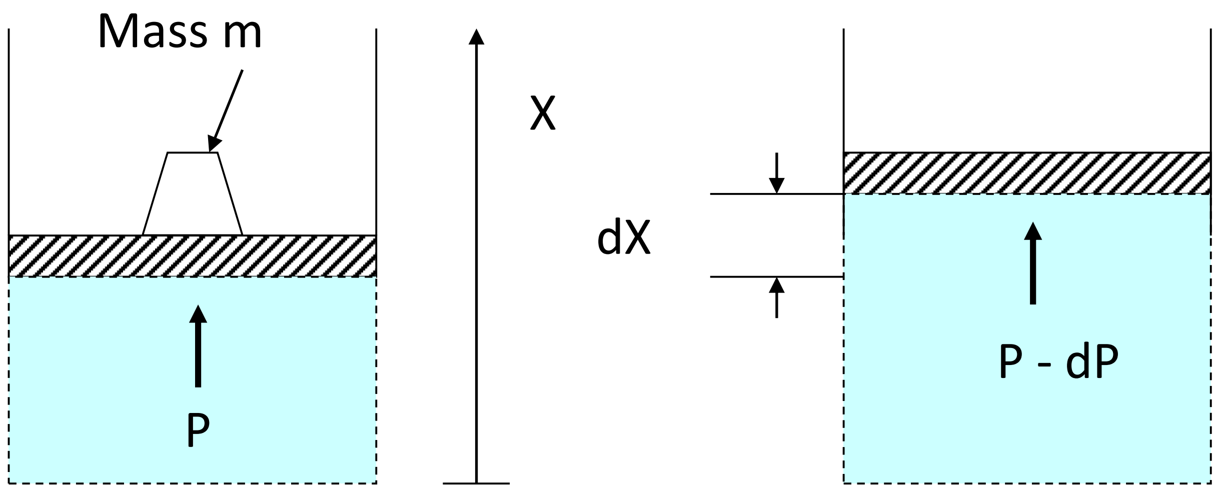
Work is defined in mechanics as the product of force and distance, measured in the direction of application of the force. Work, like heat, is energy in transit and not a property of a system.

There are many forms: electrical, magnetic, chemical and mechanical work. In this course we shall consider only <u>mechanical work</u>, including expansion and compression.

SIMPLE COMPRESSIBLE SYSTEMS

The term simple system is applied when there is only one form of work (either mechanical, or electrical, or magnetic, or chemical) as the system undergoes a quasi-static process. When expansion or compression is the only mode of work transfer, the system is said to be a simple compressible system.

EXPANSION OR COMPRESSION WORK BOUNDARY WORK



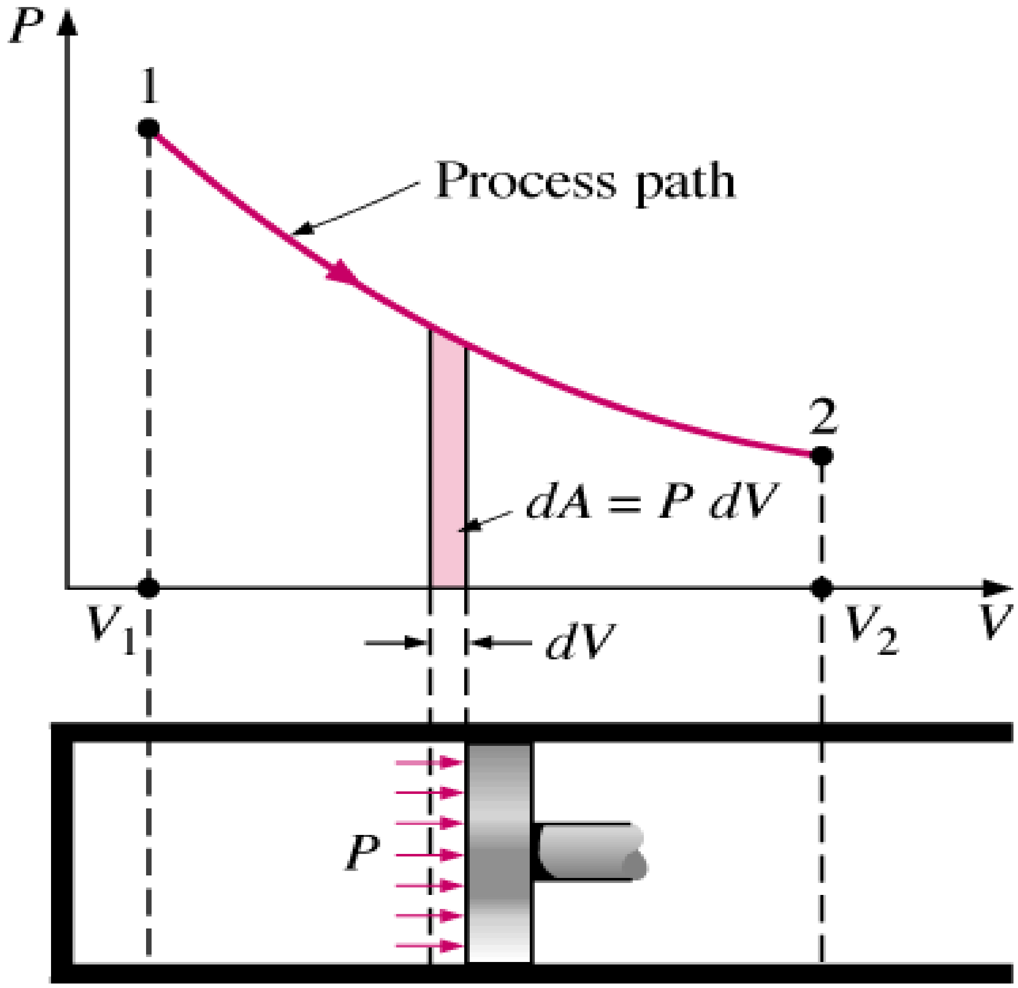
a) Before expansion **b)After expansion**

Expansion work (Boundary work)

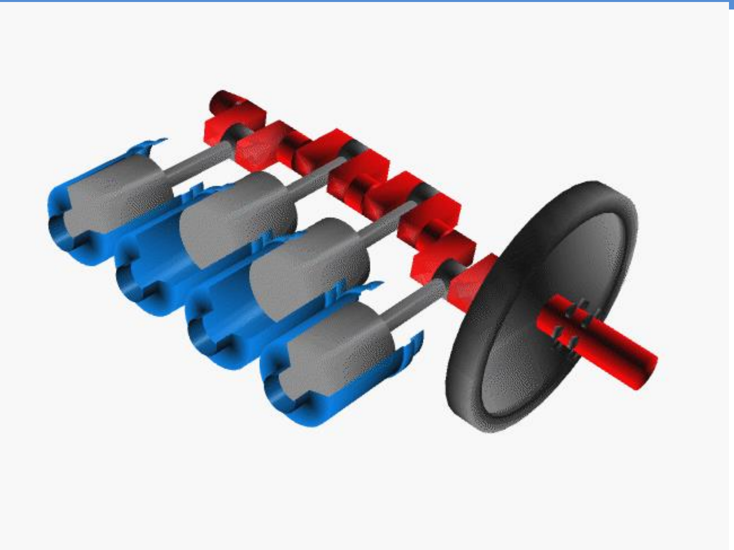
EXPANSION OR COMPRESSION WORK
BOUNDARY WORK

$$
\begin{aligned}
\delta W &= F\,dX \\
&= (P - dP)\,A\,dX \\
&= P\,A\,dX - dP\,A\,dX \\
&= P\,A\,dX \text{ as } dP \to 0 \\
&= P\,dV
\end{aligned}
$$

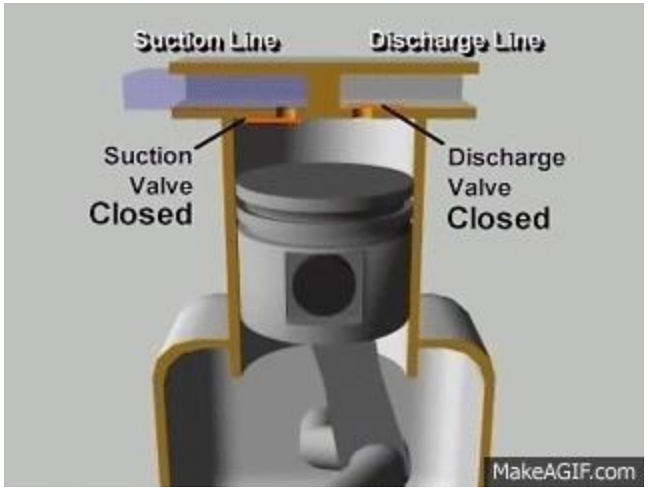
EXPANSION OR COMPRESSION WORK
BOUNDARY WORK



EXPANSION OR COMPRESSION WORK
BOUNDARY WORK



PdV work is commonly encountered in reciprocating devices such as automotive engines and compressors.



ASSIGNMENT 1

A gas in a piston-cylinder assembly is compressed (through a combination of external force on the piston and cooling) in such a manner that the pressure and volume are related by PV^n = constant.

Given an initial state of 100 kPa and 1 m^3 and a final volume of 0.5 m^3.

Evaluate the work transfer if

(a) $n = 0$

(b) $n = 1$

(c) $n = 1.4$

(d) $N = \infty$

Plot a p-V diagram for each process and show the work by shaded areas