Al- Furat Al- Awsat Technical University
Engineering Technical College/ Najaf

1^{ST} Class
Thermodynamics

Asst. Prof. Dr. Qahtan A Abed
qahtan.abed@etcn.edu.iq

Chapter One: Introduction

Objectives

1. Identify the unique vocabulary associated with thermodynamics.
2. Review the metric SI and the English unit systems that will be used throughout the text.
3. Explain the basic concepts of thermodynamics such as system, state, equilibrium, process, and cycle.
4. Discuss properties of a system and define density, specific gravity, and specific weight.
5. Review concepts of temperature, temperature scales, pressure, and absolute and gage pressure.

The name thermodynamics stems from the Greek words thermo (heat) and dynamics (power), which is most descriptive of the early efforts to convert heat into power. Today the same name is broadly interpreted to include all aspects of energy and energy transformations, including power generation, refrigeration, and relationships among the properties of matter.

1.1 Definitions

- **Thermodynamics** It is the science of energy and entropy and it is the science that deals with heat and work and those properties of substances that bear a relation between eat and work.
- **Working substance.** All the thermodynamic systems require, some working substance in order to perform various operations.
- **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.
- **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. All other properties can be determined in terms of these few.
- **Phase:** It is defined as a quantity of matter in homogeneous throughout. When more than one phase is present the phases are separated from each other by the phase boundary. 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.
- **Cycle.** When a system in a given initial state goes through a number of different change of states or processes and finally returns to its initial state, the system has undergone a cycle. Also it can be defined as system

is said to have undergone a cycle if it returns to its initial state at the end of the process. That is, for a cycle, the initial and the final states are identical.

1.2 Thermodynamic System:

It is defined as a quantity of fixed mass and identity upon which attention is focused for study. Every thing external to the system is the ***surrounding***, and the system is separated from surrounding by the system ***boundaries***. These boundaries may be either movable or fixed. Mathematically, the boundary has zero thickness, no mass, and no volume.

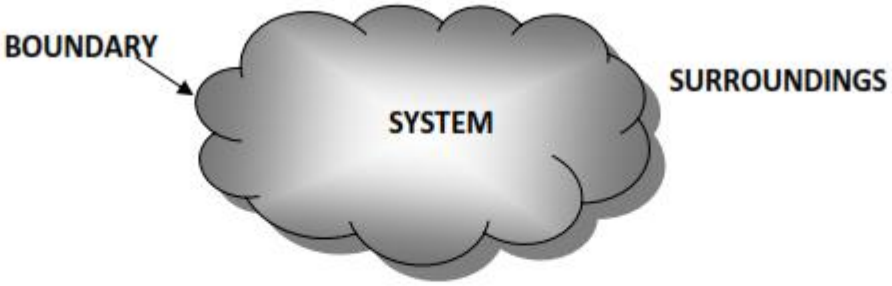

Figure1 . System, Surrounding and Boundary.

Engineers use principles drawn from thermodynamics and other engineering sciences, such as fluid mechanics and heat and mass transfer, to analyze and design things intended to meet human needs. The wide realm of application of these principles is suggested bellow:

- Automobile engines.
- Turbines.
- Compressors, pumps.
- Fossil- and nuclear-fueled power stations.
- Propulsion systems for aircraft and rockets.
- Combustion systems.
- Cryogenic systems, gas separation, and liquefaction.
- Heating, ventilating, and air-conditioning systems.
- Vapor compression and absorption refrigeration.
- Heat pumps.
- Fuel cells.
- Thermoelectric and thermionic devices.
- Magneto hydrodynamic (MHD) converters.
- Solar-activated heating, cooling, and power generation.
- Geothermal systems.
- Ocean thermal, wave, and tidal power generation.

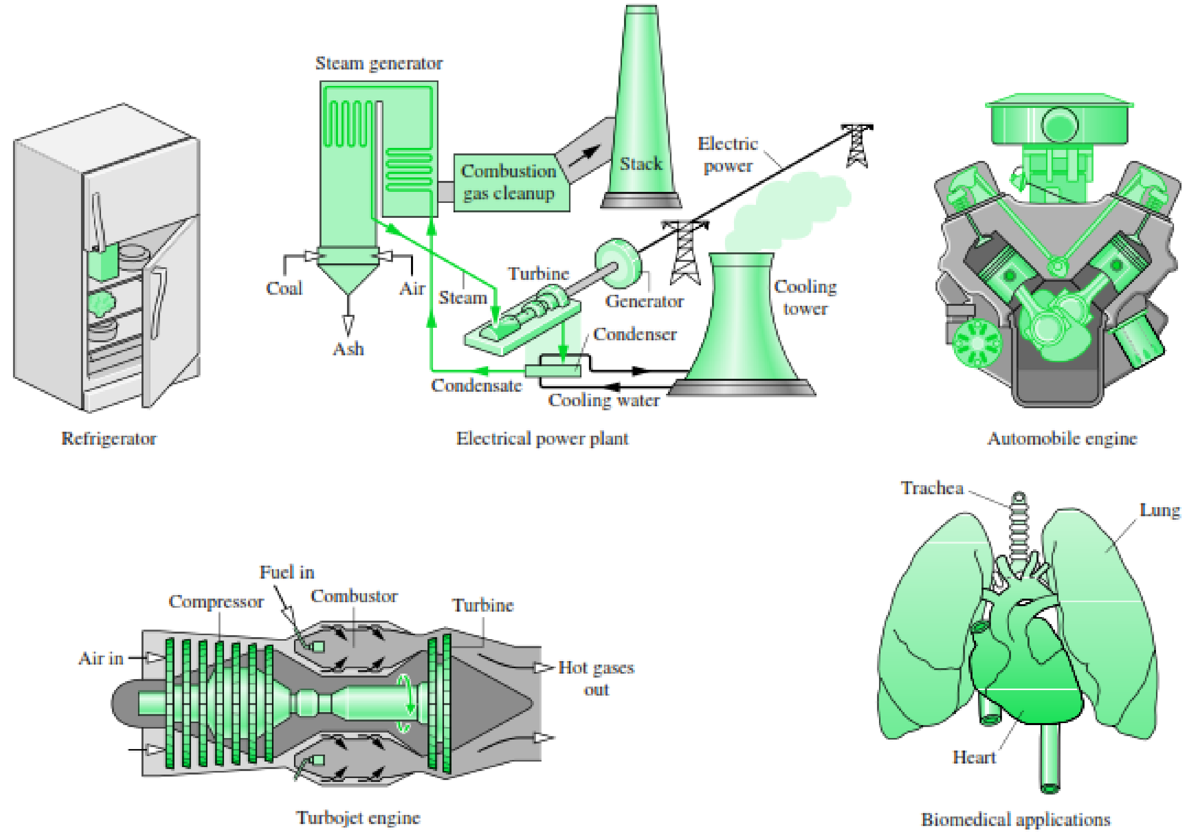

Figure2 . Some applications of engineering thermodynamics

1.3 Classification of thermodynamics system

The system may be closed or open depending on whether a fixed mass or a fixed volume in space is chosen for study.

- **Closed system:** (also known as a **control mass**) consists of a fixed amount of mass, and no mass can cross its boundary. That is, no mass can enter or leave a closed system, as shown in Fig. 3a. But energy, in the form of heat or work, can cross the boundary; and the volume of a closed system does not have to be fixed.
- **Open system:** (also known as a **control volume**) is a properly selected region in space. It usually encloses a device that involves mass flow as shown in Fig. 3b, such as a compressor, turbine, or nozzle. Flow through these devices is best studied by selecting the region within the device as the control volume. Both mass and energy can cross the boundary of a control volume.
- **Isolated system:** A special type of closed system that does not interact in any way with its surroundings.

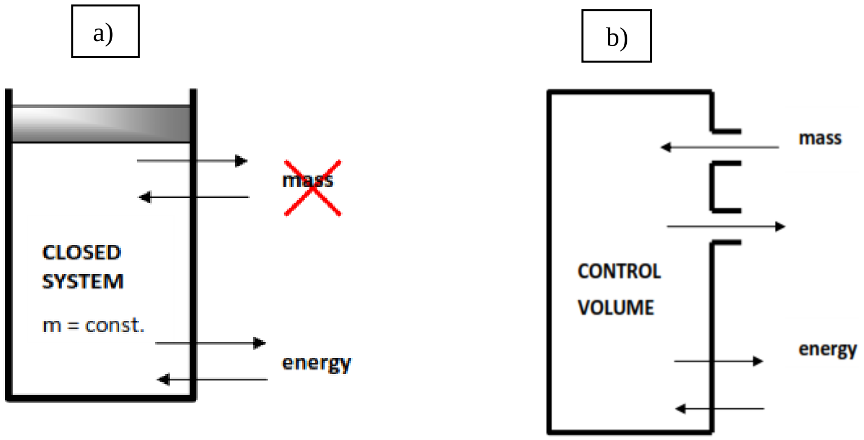

Figure3 . The system:

a) Closed system, mass cannot cross the boundaries, but energy can (control mass).
b) Control volume, both mass and energy can cross the boundaries.

In the closed system, the energy crosses the boundary but the substance does not. In the open system, the energy and substance cross the boundary.

Closed system (Control mass)	Open system (Control volume
Fixed amount of mass	A device that involves mass flow such a compressor, water heater or nozzle
No mass can cross its boundary.	Mass can cross its boundary
Energy can cross (heat or work).	Energy can cross (heat or work).
Volume can change.	Volume can change but it is often fixed

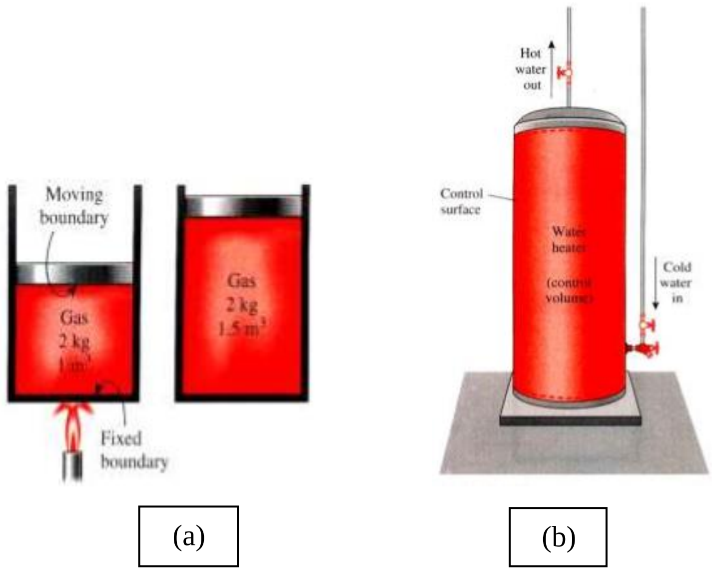

Figure 4. A closed system with moving boundary

a) An open system (control volume) with one inlet and on exit.

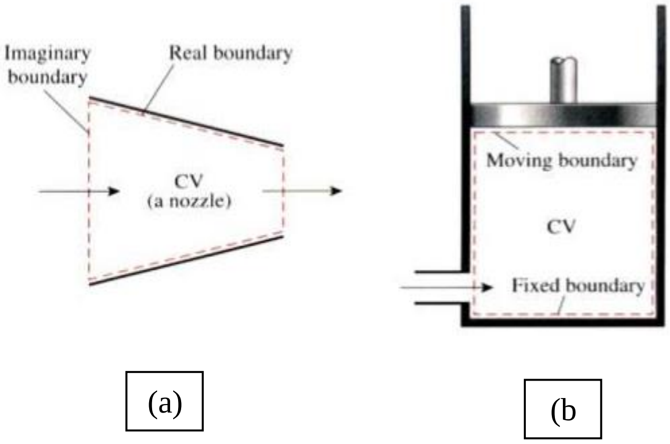

Figure 5. A control volume with real and imaginary boundaries.
a) A control volume with fixed and moving boundaries.

1.4 Processes and Cycles

Any change that a system undergoes from one equilibrium state to another is called a **process**, and the series of states through which a system passes during a process is called the **path** of the process (Fig. 6). To describe a process completely, one should specify the initial and final states of the process, as well as the path it follows, and the interactions with the surroundings.

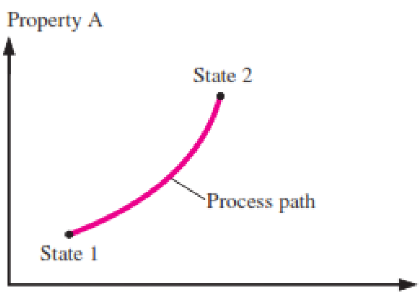

Figure6 . A process between states 1 and 2 and the process path.

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.

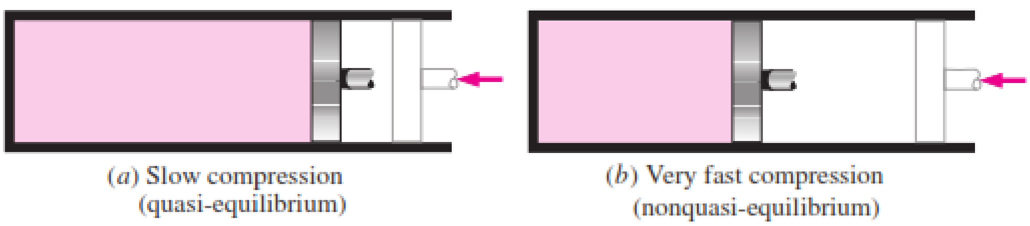

Figure7 . Quasi-equilibrium and nonquasi- equilibrium compression processes.

1.5 Dimensions and Units

Any physical quantity can be characterized by dimensions. The magnitudes assigned to the dimensions are called units. Some basic dimensions such as mass ***m***, length ***L***, time ***t***, and temperature ***T*** are selected as primary or fundamental dimensions.

Table 1. The fundamental dimensions and their units

Dimension	Unit
Length	meter (m)
Mass	kilogram (kg)
Time	second (s)
Temperature	kelvin (K)
Electric current	Ampere (A)
Amount of light	candela (cd)
Amount of matter	mole (mol)

A number of unit systems have been developed over the years. Despite strong efforts in the scientific and engineering community to unify the world with a single unit system, two sets of units are still in common use today: The **English system**, which is also known as the United States Customary System (USCS), and the metric SI, which is also known as the **International System**.

The prefixes used to express the multiples of the various units are listed in Table 2, they are standard for all units.

Table 2. SI Unite Prefixes

Factor	prefix	symple
10^{12}	Tera	T
10^{9}	Giga	G
10^{6}	Mega	M
10^{3}	kilo	k
10^{-3}	milli	m
10^{-6}	Micro	µ
10^{-9}	Nano	N
10^{-12}	Pico	P

The basic units of mass, length and time is kg, meter and second respectively. These units are used to find the other units that called the secondary units like force, work, energy, power, torque, and acceleration.

Acceleration =α =[m/sec^2]

Force =F =Newton[N]

The force is defined as product of acceleration and mass

$$F = \alpha \times m \qquad N = [m/\sec^2] \times [kg]$$

The torque can be defined as the force multiply by length

$$T = F \times L \qquad J = N \times m = kg.m^2/\sec^2$$

The work also defined as force into distance so the unit of work is Joule [J].

The power is the rate of doing work, the unit of power is Watt [W].

$$P = W / t \qquad\qquad W = J/\sec = kg.m^2/\sec^3$$

Example 1.1

A school is paying $0.12/kWh for electric power. To reduce its power bill, the school installs a wind turbine (Fig. 8) with a rated power of 30 kW. If the turbine operates 2200 hours per year at the rated power, determine the amount of electric power generated by the wind turbine and the money saved by the school per year.

Solution: given; Unit cost of energy= $0.12/kWh, Energy per unit time= 30 kW =30 KJ/sec, Time interval= 2200h.

Total energy = (Energy per unit time) *(Time interval)
= (30 kW) * (2200 h)
= 66,000 kWh

The money saved per year is the monetary value of this energy determined as

Money saved = (Total energy) * (Unit cost of energy)
= (66,000 kWh) * ($0.12/kWh) = $7920

Note; The annual electric energy production also could be determined in kJ by unit manipulations as

$$\text{Total energy} = (30\text{ kW})\ (2200\text{ h})\left(\frac{1\,kJ/s}{1\,kW}\right)\left(\frac{3600\,s}{1\,h}\right) = 2.38 * 10^8\text{ kJ}$$

Figure 8. wind turbine