Lecture one: Introduction to Thermodynamics , Basic Concepts and Units

by: Asst. lect. Karrar Al-Mansoori

1.1 Introduction to Thermodynamic

- ***Thermodynamics*** is a branch of science which deals with energy. including power generation, refrigeration, and relationships among the properties of matter . The conversion of heat into work, or chemical energy into electrical energy, both of these are energy transformations, and thermodynamics is the science that provides the tools to analyze them. Or:

- ***Thermodynamics*** is the branch of physical science that deals with the various phenomena of energy and related properties of matter, especially of the laws of transformations of heat into otherforms of energy and vice-versa.

- The name *thermodynamics* stems from the Greek words *Therme* (heat) and *dynamis* (power).

Thermodynamics = *Therme* + *Dynamis*
(Heat) *(Power)*

Internal combustion engines employed in automobiles are a good example of the energy conversion equipments where fuel is being burnt inside the piston cylinder arrangement and chemical energy. Thermodynamics lets one know the answer for the questions as, what shall be the amount of work available from engine?, what shall be the efficiency of engine?, etc.

For analysing any system there are basically two approaches available in engineering thermodynamics. Approach of thermodynamic analysis means how the analyser considers the system.

Macroscopic approach is the one in which complete system as a whole is considered and studied without caring for what is there constituting the system at microscopic level.

Contrary to this the microscopic approach is one having fragmented the system under consideration upto microscopic level and analysing the different constituent subsystems/microsystems. In this approach study is made at the microscopic level. For studying the system the microlevel studies are put together to see the influences on overall system. Thus, the statistical techniques are used for integrating the studies made at microscopic level. This is how the studies are taken up in statistical thermodynamics. In general it can be said that, Macroscopic approach analysis = Σ (Microscopic approach analysis).

The objectives of this course are to study the fundamentals of thermodynamics and to apply them to the solution of engineering problems, So we will develop a thorough understanding of the properties of thermodynamic systems and the laws of thermodynamics.

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مقدمة عامة :

توجد أنواع كثيرة من الطاقة مثل الطاقة الحرارية، الطاقة الكهربائية، الطاقة الميكانيكية، الطاقة الكيميائية، الطاقة المغناطيسية، الطاقة الحرارية وغير ذلك وتحت ظروف معينة يمكن لهذه الانواع من الطاقة أن تتحول الى بعضها البعض. تهتم الديناميكا الحرارية بالبحث عن العلاقة بين هذه الانواع المختلفة من الطاقة كما تهتم بانتقال الحرارة وكذلك الشغل المصاحب لبعض العمليات الكيميائية والفيزيائية. ، **وبالتالي فإن :**

الديناميكا الحرارية (الثيرموداينمك) : هو العلم الذي يهتم بدراسة جميع اشكال الطاقة وتحولاتها وبكل الظواهر التي تظهر أو تتعلق بهذه الطاقة مثل عمليات انتقال الحرارة من جسم لآخر أو كيفية تخزين هذه الطاقة أو توليدها.

بحيث يعتبر علم الديناميكا الحرارية العلم الأساسي الذي يهتم بتحويل أكبر مقدار من الطاقة الحرارية الناتجة من احتراق الوقود الى طاقة ميكانيكية، بمعنى آخر : تحسين كفاءة المحرك. وبني هذا العلم على أساس التجربة الإنسانية الكبرى التي تثبت وجود الطاقة ، و التي لا يمكن خلقها أو فناؤها. ومن هذه الحقيقة أمكن استنباط علاقات رياضية مختلفة بين خواص المادة.

فوائد الديناميكا الحرارية:

يجيب علم الثيرموديناميك على أسئلة مهمة مثل:

- لماذا تحدث التفاعلات الكيميائية؟
- لماذا تحدث بعض التفاعلات تلقائياً حتى اكتمالها، والبعض الآخر تتم جزئياً، وتفاعلات أخرى لا تحدث أبداً عند نفس الظروف؟
- ما هي تغيرات الطاقة المصاحبة للتفاعلات الكيميائية سواءً في التفاعلات نفسها أو في الوسط المحيط بها؟

1.2 Application of Thermodynamics

Thermodynamics has very wide applications as basis of thermal engineering. Almost all process and engineering industries, agriculture, transport, commercial and domestic activities use thermal engineering, Fig. (1-1) shown some application of thermodynamics.

For example:

(i) Central thermal power plants, captive power plants based on coal.
(ii) Nuclear power plants.
(iii) Gas turbine power plants.
(iv) Engines for automobiles, ships, airways, spacecrafts.
(v) Direct energy conversion devices: Fuel cells, thermoelectric engines.
(vi) Air conditioning, heating, cooling, ventilation plants.
(vii) Domestic, commercial and industrial lighting.
(viii) Agricultural, transport and industrial machines.

All the above engines and power consuming plants are designed using laws of thermodynamics.

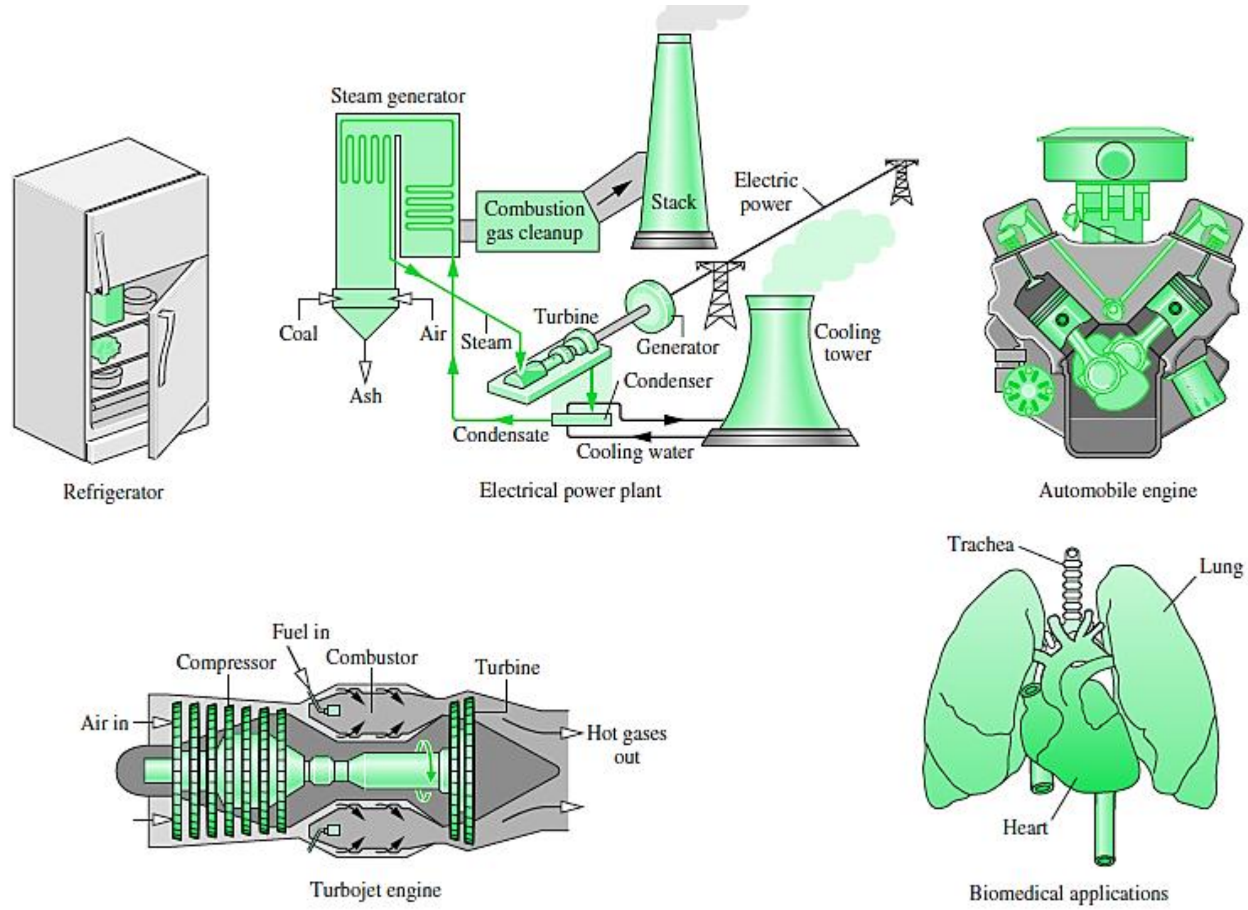


Figure (1-1) Some application of thermodynamics.

1.3 Basic Concepts

- *1.3.1* ***Force (F):*** The ability of accelerated a body of a given mass, the unit of the force is the Newton(N).
- *1.3.2* ***Newton(N)*****:** The force required to give a mass of I kg an acceleration of 1 m/s^2.
- *1.3.3* ***pressure (P)*** : Pressure is defined as the normal force per unit area. Where Pressure = F/A . The unit of pressure is N/m^2 and is called the Pascal (Pa).
- *1.3.4* ***Heat :*** is a form of energy which transferred from one body to another body at a lower temperature, by virtue of the temperature difference between the bodies.

When the temperature of the bodies are equal no heat transfer takes place between them.

- *1.3.5* ***Heat Engine*** **:** Any type of engine or machine which derives heat energy from the combustion of fuel or any other source and converts this energy into mechanical work is termed as a heat engine.
- *1.3.6* ***Work :*** is usually defined as a force F acting through a displacement x, where the displacement is in the direction of the force.

Already noted, work done by a system, such as that done by a gas expanding against a piston, is ***positive***, and work done on a system, such as that done by a piston compressing a gas, ***is negative***. In othe form , positive work means that energy leaves the system, and negative work means that energy is added to the system. The product of unit force (one newton) acting through a unit distance (one meter). This unit for work in SI units is called the joule (J). 1 J = 1N.m

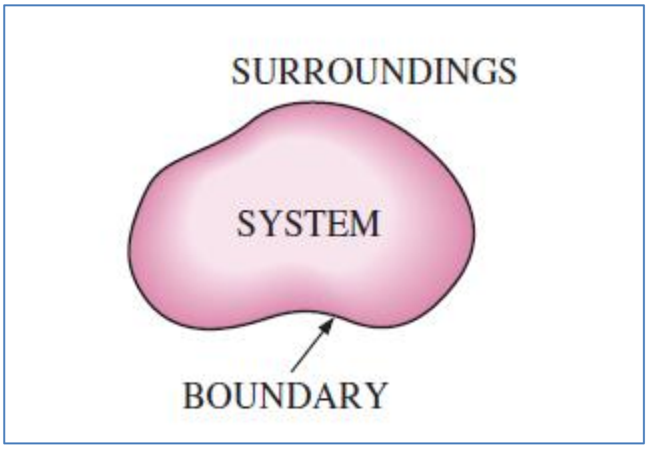
- *1.3.7* ***Power*** : The work done per unit time, the unit of the power is Watt (J/s)

1.4 Systems And Control Volumes

- *1.4.1* ***System :*** A system is defined as a *quantity of matter or a region in space chosen for study*.
- *1.4.2* ***Surroundings :*** The mass or region outside the system is called the surroundings. (Everything external to the system).
- *1.4.3* ***Boundary :*** The real or imaginary surface that separates the system from its surroundings is called the boundary**.**

These terms are illustrated in Fig. (1-2) The boundary of a system can be *fixed* or *movable*.

Figure (1-2): System, surroundings, and boundary



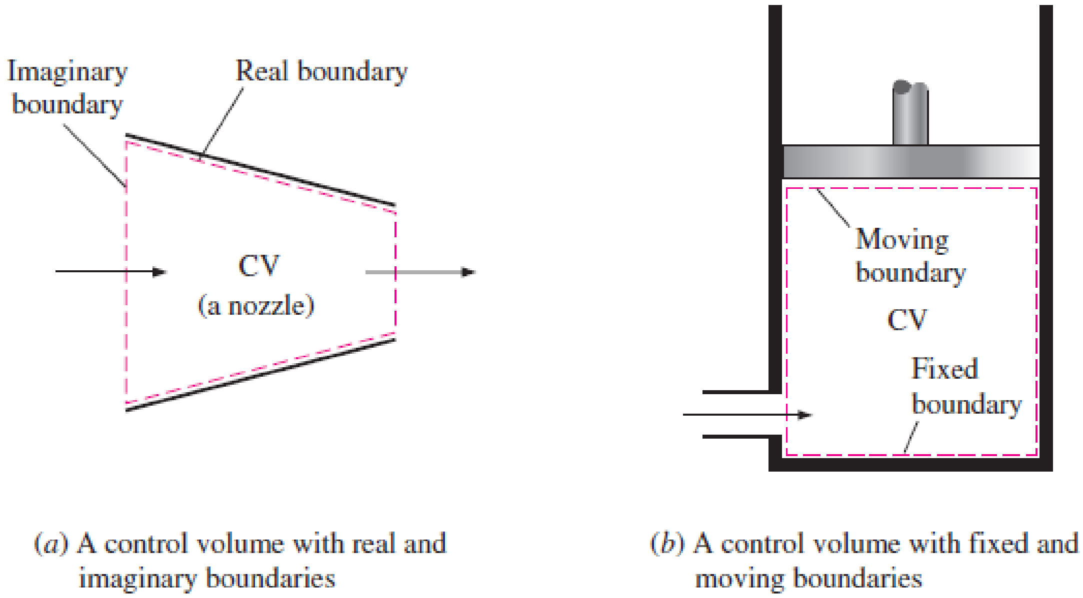


Figure (1-3): A control volume can involve fixed, moving, real, and imaginary boundaries.

1.5 Types of systems

Two basic kinds of systems are distinguished in this lecture. These are referred to, respectively, as ***closed systems*** and ***control volumes.*** A closed system refers to a fixed quantity of matter, where as a control volume is a region of space through which mass may flow.

- 1.5.1 ***Closed System*** **:** The system, which can exchange energy with their surrounding but not the mass. The quantity of matter thus remains fixed, and the system is described as control mass system, as shown in Fig.(1-4) The physical nature and chemical composition of the mass of the system may change. Water may evaporate into steam or steam may condense into water. A chemical reaction may occur between two or more components of the closed system.

A special type of closed system that does not interact in any way with its surroundings is called an **isolated system**

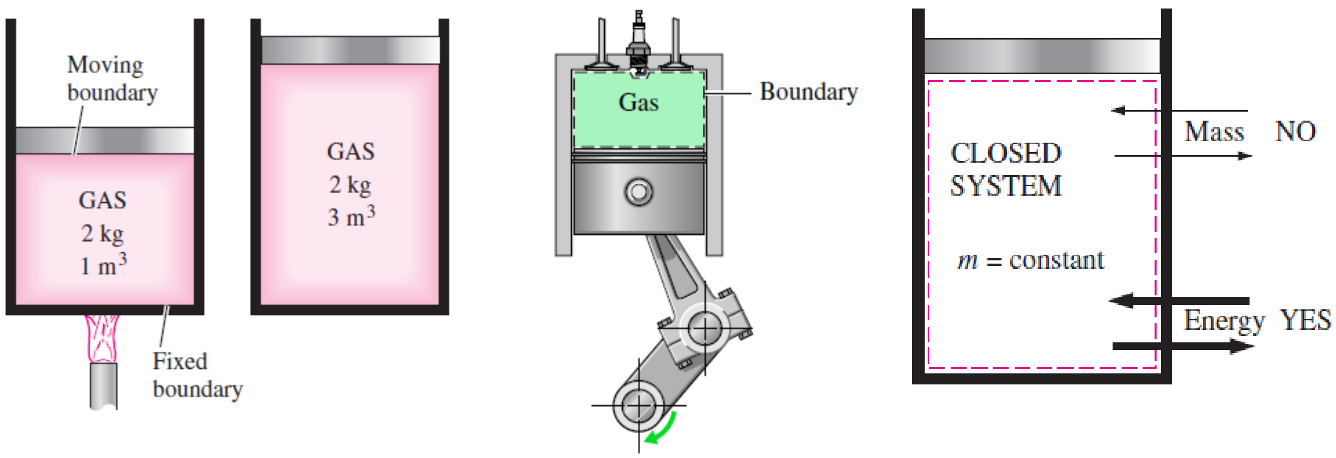
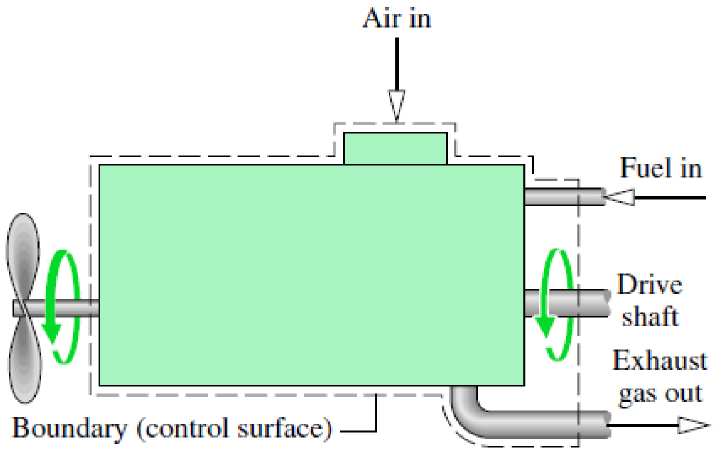
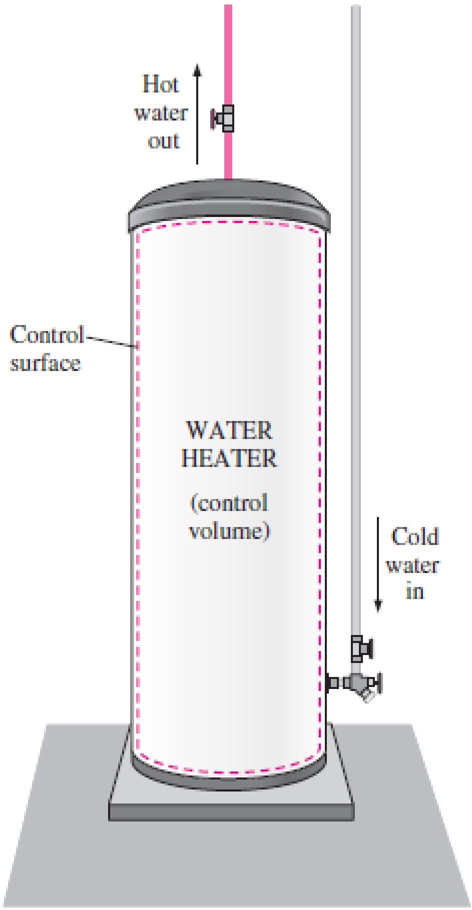


Figure (1-4) : A closed system with a fixed and a moving boundary, So the mass cannot cross the boundaries of a closed system, but energy can.

- *1.5.2* ***open system :*** **(control volume)** The system which can exchange both the mass and energy (Heat and work) with its surrounding. The mass within the system may not be constant. The nature of the processes occurring in such system is flow type.

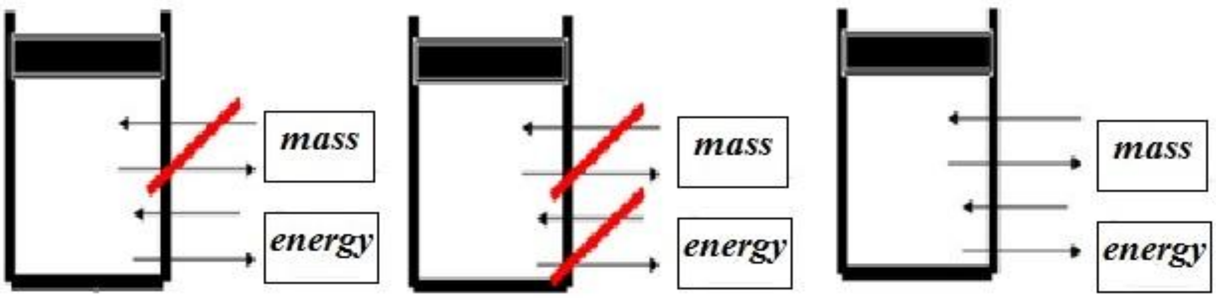


(a)



(b)

Figure (1-5) : Example of a control volume (open system).



Closed System	***Isolated System***	***Open System***

Figure (1-6) : Type of system

1.6 Properties of A system

Any characteristic of a system is called a **property.** Some familiar properties are pressure *P*, temperature *T*, volume *V*, and mass *m*. The list can be extended to include less familiar ones such as viscosity, thermal conductivity, modulus of elasticity, thermal expansion coefficient, electric resistivity, and even velocity and elevation. Properties are considered to be either *intensive* or *extensive*.

- *1.6.1* ***Intensive properties*** are those that are independent of the mass of a system, such as temperature, pressure, and density.
- *1.6.2* ***Extensive properties :*** are those whose values depend on the size—or extent—of the system. Total mass, total volume, and total momentum are some examples of extensive properties. An easy way to determine whether a property is intensive or extensive is to divide the system into two equal parts with an imaginary partition, as shown in Fig. (1-7)

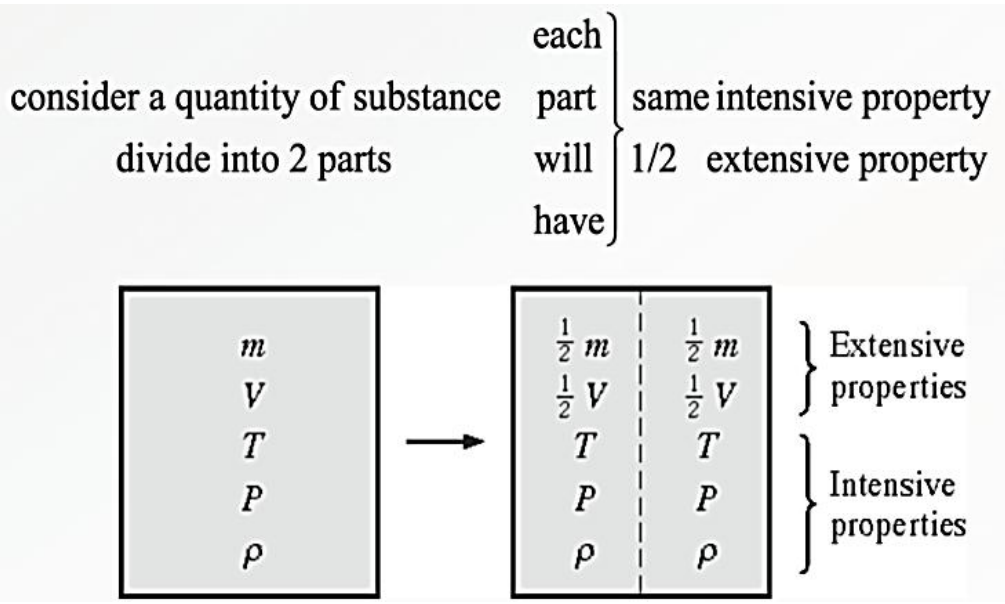


Figure (1-7): Extensive and Intensive properties

1.7 Importance of 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,** while others such as velocity *V*, energy *E*, and volume *V* are expressed in terms of the primary dimensions and are called **secondary dimensions,** or **derived dimensions.**

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** (from *Le system International Unités*), which is also known as the *International System*. The **SI** System is a simple and logical system based on a decimal relationship between the various units, and it is being used for scientific and engineering work.

The fundamental (or primary) dimensions and their units in SI are illustrated in the following table (1-1).

Table (1-1): The fundamental (or primary) dimensions and their units in SI

Dimensions	Units
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)

The prefixes used to express the multiples of the various units are listed in Table (1-2).

Table (1-2): Standard prefixes in SI units.

Multiple	Prefix
10^{12}	tera, T
10^{9}	giga, G
10^{6}	mega, M
10^{3}	kilo, k
10^{2}	hecto, h
10^{1}	deka, da
10^{-1}	deci, d
10^{-2}	centi, c
10^{-3}	milli, m
10^{-6}	micro, m
10^{-9}	nano, n