1. Introduction

Thermodynamics is a branch of science which deals with energy. Engineering thermodynamics is a modified name of this science when applied to design and analysis of various energy conversion systems. Thermodynamics has basically a few fundamental laws and principles applied to a wide range of problems. This science is core to engineering and allows understanding of the mechanism of energy conversion. It is really very difficult to identify any area where there is no interaction in terms of energy and matter. It is a science having its relevance in every walk of life.

Important Definitions

These are some terms that need to be introduced before we can understand the basics of thermodynamics:

1. System: is defined as a quantity of matter or a region in space chosen for study. The mass or region outside the system is called the surroundings. The real or imaginary surface that separates the system from its surroundings is called the boundary.

2. Working substance: is the matter contained within the boundaries of a system. All the thermodynamics systems require some working substance in order to perform various operations.

3. Phase: when a substance is in the same nature through its mass, then it is said to be in phase.

4. State: the thermodynamic state of a system is defined completely by the knowledge of two independent and intensive properties such as (pressure, specific volume, temperature).

5. Process: when the state of substance is changed by means of an operation carried out on the substance, then the substance is said to be undergone a process.

6. Cycle: if processes are carried out on a working substance so that, at the end, the substance is returned to its original state, then the substance is said to have been taken through a cycle.

Dimensions and Units

Dimension refers to certain fundamental physical concepts that are involved in the process of nature and are more or less directly evident to our physical senses, thus dimension is used for characterizing any physical quantity. Dimensions can be broadly classified as **primary dimensions** and **secondary or derived dimensions**. Basic dimensions such as mass, length, time and temperature are called primary dimensions, while quantities which are described using primary dimensions are called secondary dimensions such as for energy, velocity, force and volume. Units are the magnitudes assigned to the dimensions. Units assigned to primary dimensions are called **basic units** whereas units assigned to secondary dimensions are called **derived units**. The following table contains some important dimensions in thermodynamics as well as their units in different systems:

Dimensions	SI Units	English Units
Basic units		
Length	Meter (m)	Inch (in) & Foot (ft) (1 ft = 12 in)
Mass	Kilogram (kg)	Pound (lb)
Amount of matter	Mole (mol)	Mole (mol)
Time	Second (s)	Second (s)
Temperature	Centigrade (°C)	Fahrenheit (°F)
Derived units		
Force	Newton (N)	(Pound force) lbf
Energy	Joule (J)	(Foot-pound force) ft.lbf
Power	Watt (W)	(Foot-pound force/second) ft.lbf/s
Pressure	Pascal (Pa)	(Pound-force per square inch) psi

The following table contains the conversion factors for units:

Prefix	Factor	Symbol	Prefix	Factor	Symbol
deca	10	da	deci	10^{-1}	d
hecto	10^{2}	h	centi	10^{-2}	c
kilo	10^{3}	k	milli	10^{-3}	m
mega	10^{6}	M	micro	10^{-6}	μ
giga	10^{9}	G	nano	10^{-9}	n
tera	10^{12}	T	pico	10^{-12}	p
peta	10^{15}	P	femto	10^{-15}	f
exa	10^{18}	E	atto	10^{-18}	a

Thermodynamic Properties

For defining any system certain parameters are needed. Properties are those observable characteristics of the system which can be used for defining it. Thermodynamic properties are observable characteristics of the thermodynamic system. Pressure, temperature, volume, viscosity, etc. are examples of properties. These properties are sometimes observable directly **independent properties** and sometimes indirectly **dependent properties**. Properties can be further classified as **intensive properties** and **extensive properties**. The following are some of the most important thermodynamic properties:

1. Temperature (*T*): is a physical quantity expressing hot and cold. It is a proportional measure of the average kinetic energy of the random motions of the constituent particles of matter (such as atoms and molecules) in a system.

2. Pressure (*P*): is the force applied perpendicular to the surface of an object per unit area over which that force is distributed. Pressure is an independent property.

3. Volume (*V*): is the quantity of three-dimensional space enclosed by a closed surface, for example: the space that a substance (solid, liquid, gas or plasma) occupies or contains. Volume is an independent property.

4. Internal energy (*U*): is a property consisting of the combined molecular kinetic and potential energies. This property is derived from the first law of thermodynamics. Internal energy is a dependent property.

5. Enthalpy (*H*): is a thermodynamic quantity equivalent to the total heat content of a system. It is equal to the internal energy of the system plus the product of pressure and volume. Enthalpy is a dependent property.

6. Entropy (*S*): is a thermodynamic quantity representing the unavailability of a system's thermal energy for conversion into mechanical work, often interpreted as the degree of disorder or randomness in the system. This property is derived from the second law of thermodynamics. Entropy is a dependent property.

Intensive and Extensive Properties

An intensive property is a bulk property, meaning that it is a physical property of a system that does not depend on the system size or the amount of material in the system. Examples of intensive properties include (temperature, pressure and density). By contrast, an extensive property is additive for subsystems. This means the system could be divided into any number of subsystems. Examples of extensive properties include (volume, internal energy, enthalpy and entropy). Extensive properties have two values (Total and Specific), total values have the usual units of that property while specific values have the same units divided by the units of mass. For example: Volume (*V*) has the units (m^3) in SI system, while specific volume (*v*) has the units (m^3/kg). So that:

$$\text{Specific value of a property} = \frac{\text{Total value}}{\text{Mass}}$$

System

All physical things in nature have some form of boundary whose shape in general identifies it. Inside its boundary, there are certain things with particular functions to carry out. This inside arrangement is called system. In thermodynamics there are three types of systems:

1. Closed system: inside this system, the mass of a substance remains constant (i.e. no mass transfer through the system boundary).

2. Opened system: if the mass of a substance in a system changes or is changing (i.e. mass is crossing the system boundary), the system is said to be an opened system.

3. Isolated system: in this type of a system mass and energy cannot be transferred to or from the surroundings.

Thermodynamic Processes

There are two types of processes in thermodynamics:

1. Non-flow process: a fixed mass of fluid undergoes a change of state with no mass transfer across the boundaries.

2. Flow process: a uniform mass flow rate from one state to another where the mass must cross the control surface (boundary) at inlet and exit.

Pressure

It is defined as a normal force exerted by a fluid per unit area. We speak of pressure only when we deal with a gas or a liquid. The counterpart of pressure in solids is normal stress. Since pressure is defined as force per unit area, it has the unit of newton per square meter (N/m^2), which is called a Pascal (Pa). That is:

$1\ Pa = 1\ N/m^2$

The pressure unit Pascal is too small for pressures encountered in practice. Therefore, its multiples kilo Pascal ($1\ kPa = 10^3\ Pa$) and mega Pascal ($1\ MPa = 10^6\ Pa$) are commonly used. Three other pressure units commonly used in practice which are: bar, standard atmosphere (atm) and pound-force per square inch (psi). The relationships between these units are:

$1\ bar = 10^5\ Pa$

1 atm = 101325 Pa = 14.696 psi