



LANDMARK UNIVERSITY, OMU-ARAN

LECTURE NOTE: 1

COLLEGE: COLLEGE OF SCIENCE AND ENGINEERING

DEPARTMENT: MECHANICAL ENGINEERING

PROGRAMME:

ENGR. ALIYU, S.J

Course code: MCE 311

Course title: Applied Thermodynamics

Credit unit: 3 UNITS.

Course status: compulsory

Course Content:–

Fundamentals of thermodynamics of pure gases and vapour, non-reactive mixtures and psychometry. Thermal power cycles. Mode of heat transfer: conduction, convection and radiation. Basic concepts of conduction, basic laws of conduction. Steady-state conduction through solids. Conduction through composite plane slabs and multi-layer composite cylindrical walls. Introduction to the concepts of convection and radiation: simple equations of convection and radiation heat transfer. Combustion reaction. The students should undertake laboratory practical in-line with the topics taught.

Introductory Concepts and Definitions

ENGINEERING CONTEXT: The word thermodynamics stems from the Greek words *therme* (heat) and *dynamis* (force). Although various aspects of what is now known as thermodynamics have been of interest since antiquity, the formal study of thermodynamics began in the early nineteenth century through consideration of the motive power of *heat*: the capacity of hot bodies to produce *work*. Today the scope is larger, dealing generally with *energy* and with relationships among the *properties* of matter. Thermodynamics is both a branch of physics and an engineering science. The scientist is normally interested in gaining a fundamental understanding of the physical and chemical behavior of fixed quantities of matter at rest and uses the principles of thermodynamics to relate the properties of matter. Engineers are generally interested in studying *systems* and how they interact with their *surroundings*. To facilitate this, engineers extend the subject of thermodynamics to the study of systems through which matter flows.

The objective of this course is to introduce you to some of the fundamental concepts and definitions that are used in our study of engineering thermodynamics.

1.1 Using Thermodynamics

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 by Table 1.1, which lists a few of the areas where engineering thermodynamics is important. Engineers seek to achieve

improved designs and better performance, as measured by factors such as an increase in the output of some desired product, a reduced input of a scarce resource, a reduction in total costs, or a lesser environmental impact. The principles of engineering thermodynamics play an important part in achieving these goals.

TABLE 1.1 Selected Areas of Application of Engineering Thermodynamics

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

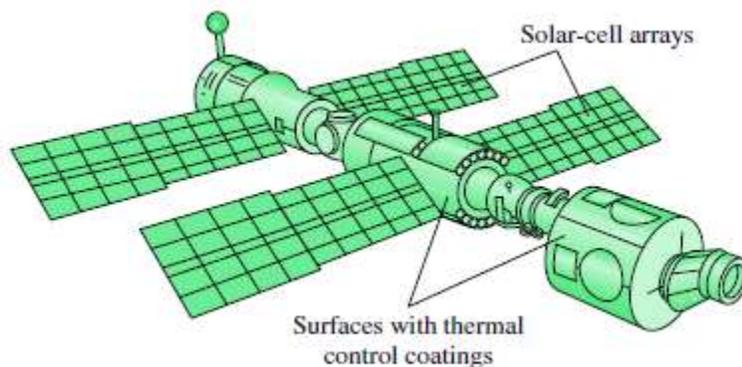
Cooling of electronic equipment

Alternative energy systems

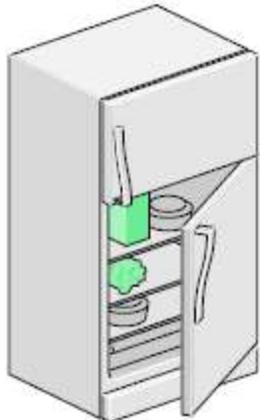
- Fuel cells
- Thermoelectric and thermionic devices
- Magnetohydrodynamic (MHD) converters
- Solar-activated heating, cooling, and power generation
- Geothermal systems
- Ocean thermal, wave, and tidal power generation
- Wind power

Biomedical applications

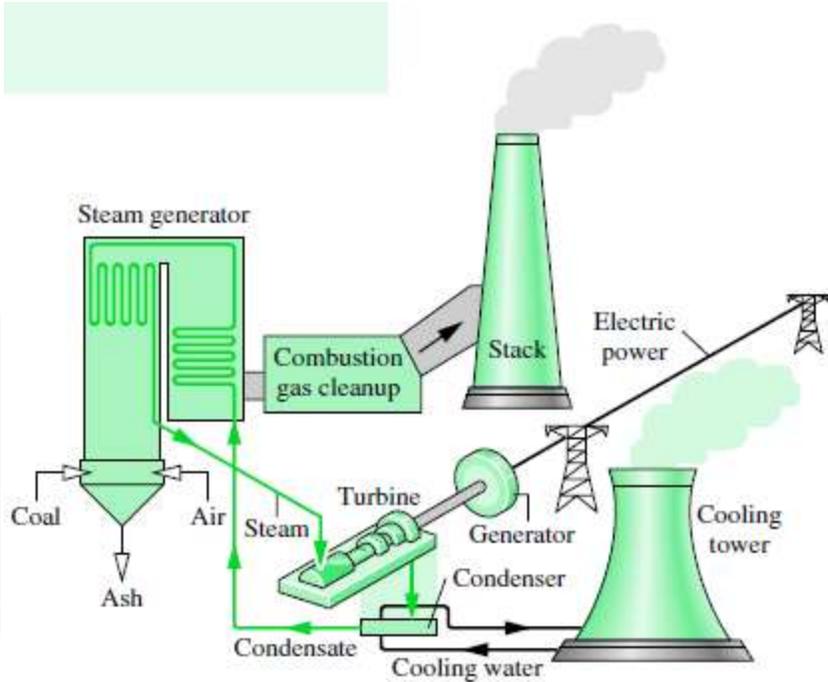
- Life-support systems
- Artificial organs



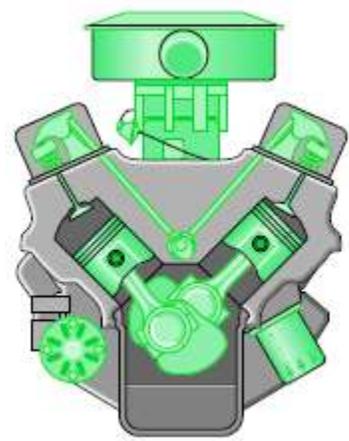
International Space Station



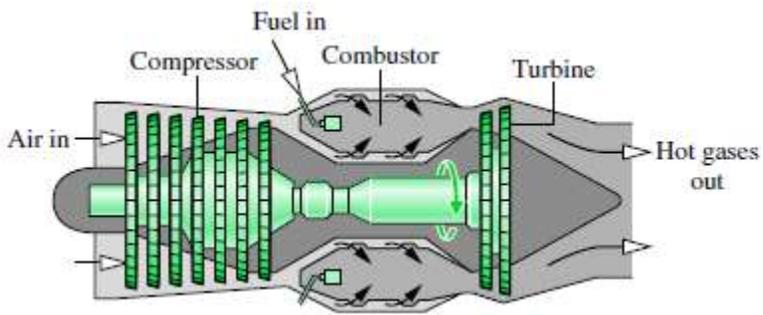
Refrigerator



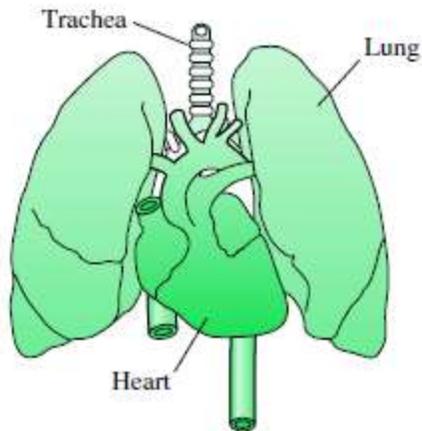
Electrical Power Plant



Automobile Engine



Turbojet Engine



Biomedical applications.

1.2 Defining Systems

An important step in any engineering analysis is to describe precisely what is being studied.

In mechanics, if the motion of a body is to be determined, normally the first step is to define a *free body* and identify all the forces exerted on it by other bodies. Newton's second law of motion is then applied. In thermodynamics the term *system* is used to identify the subject of the analysis. Once the system is defined and the relevant interactions with other systems are identified, one or more physical laws or relations are applied. The *system* is whatever we want to study. It may be as simple as a free body or as complex as an entire chemical refinery. We may want to study a quantity of matter contained within a closed, rigid-walled tank, or we may want to consider something such as a pipeline through which natural gas flows. The composition of the matter inside the system may be fixed or may be changing through chemical or nuclear reactions. The shape or volume of the system being analyzed is not necessarily constant, as when a gas in a cylinder is compressed by a piston or a balloon is inflated. Everything external to the system is considered to be part of the system's *surroundings*.

The system is distinguished from its surroundings by a specified *boundary*, which may be at rest or in motion. You will see that the interactions between a system and its surroundings, which take place across the boundary, play an important part in engineering thermodynamics.

It is essential for the boundary to be delineated carefully before proceeding with any thermodynamic analysis. However, the same physical phenomena often can be analyzed in terms of alternative choices of the system, boundary, and surroundings. The choice of a particular boundary defining a particular system is governed by the convenience it allows in the subsequent analysis.

TYPES OF SYSTEMS

Two basic kinds of systems are distinguished in this course. These are referred to, respectively, as *closed systems* and *control volumes*. A closed system refers to a fixed quantity of matter, whereas a control volume is a region of space through which mass may flow. A *closed system* is defined when a particular quantity of matter is under study. A closed system always contains the same matter. There can be no transfer of mass across its boundary. A special type of closed system that does not interact in any way with its surroundings is called an *isolated system*. Figure 1, shows a gas in a piston–cylinder assembly. When the valves are closed, we can consider the

gas to be a closed system. The boundary lies just inside the piston and cylinder walls, as shown by the dashed lines on the figure.

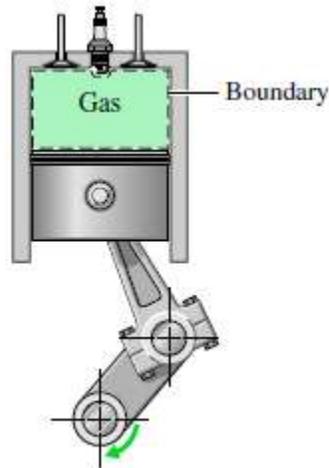


Figure 1. Closed system: A gas in a piston–cylinder assembly.

The portion of the boundary between the gas and the piston moves with the piston. No mass would cross this or any other part of the boundary. In subsequent sections of this book, thermodynamic analyses are made of devices such as turbines and pumps through which mass flows. These analyses can be conducted in principle by studying a particular quantity of matter, a closed system, as it passes through the device. In most cases it is simpler to think instead in terms of a given region of space through which mass flows. With this approach, a *region* within a prescribed boundary is studied. The region is called a *control volume*. Mass may cross the boundary of a control volume. A diagram of an engine is shown in Fig. 2*a*. The dashed line defines a control volume that surrounds the engine. Observe that air, fuel, and exhaust gases cross the boundary. A schematic such as in Fig. 2*b* often suffices for engineering analysis.

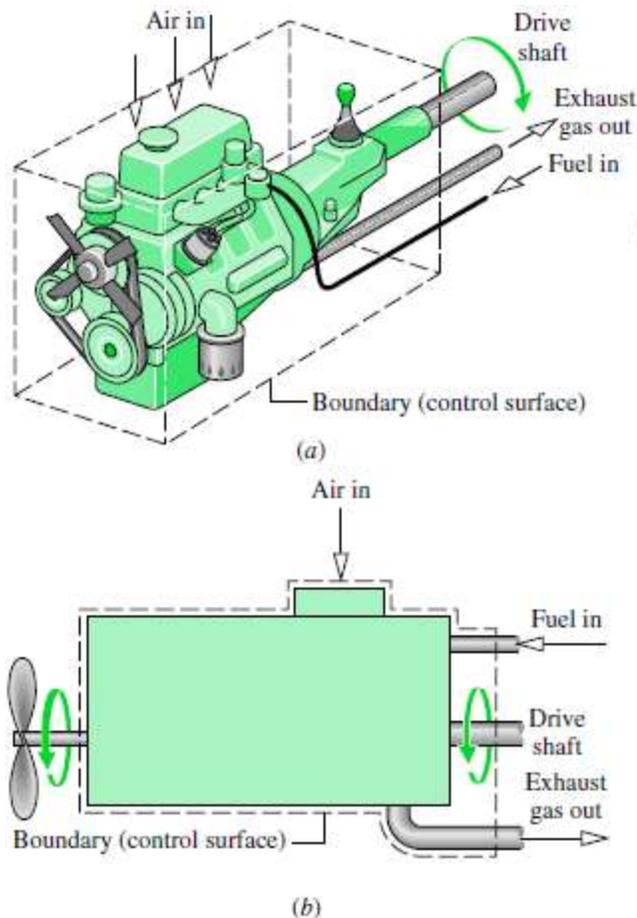


Figure 2. Example of a control volume (open system). An automobile engine.

The term *control mass* is sometimes used in place of closed system, and the term *open system* is used interchangeably with control volume. When the terms control mass and control volume are used, the system boundary is often referred to as a *control surface*. In general, the choice of system boundary is governed by two considerations: (1) what is known about a possible system, particularly at its boundaries, and (2) the objective of the analysis. *for example..* Figure 3 shows a sketch of an air compressor connected to a storage tank. The system boundary shown on the figure encloses the compressor, tank, and all of the piping. This boundary might be selected if the electrical power input were known, and the objective of the analysis were to determine how long the compressor must operate for the pressure in the tank to rise to a specified value. Since mass crosses the boundary, the system would be a control volume. A control volume enclosing only the compressor might be chosen if the condition of the air entering and exiting the compressor were known, and the objective were to determine the electric power input.

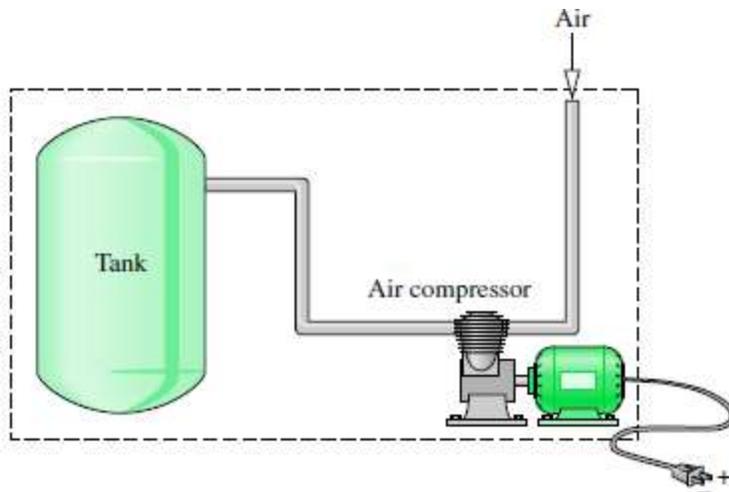


Figure 3: Air compressor and storage tank.

PROPERTY, STATE, AND PROCESS

To describe a system and predict its behavior requires knowledge of its properties and how those properties are related. A *property* is a macroscopic characteristic of a system such as mass, volume, energy, pressure, and temperature to which a numerical value can be assigned at a given time without knowledge of the previous behavior (*history*) of the system. Many other properties are considered during the course of our study of engineering thermodynamics. Thermodynamics also deals with quantities that are not properties, such as mass flow rates and energy transfers by work and heat. 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. When any of the properties of a system change, the state changes and the system is said to have undergone a *process*. A 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. A system is said to be at *steady state* if none of its properties changes with time. A *thermodynamic cycle* is a sequence of processes that begins and ends at the same state. At the conclusion of a cycle all properties have the same values they had at the beginning. Consequently, over the cycle the system experiences no *net* change of state. Cycles that are repeated periodically play prominent roles in many areas of application. For example, steam circulating through an electrical power plant executes a cycle.

At a given state each property has a definite value that can be assigned without knowledge of how the system arrived at that state. Therefore, the change in value of a property as the system is altered from one state to another is determined solely by the two end states and is independent of the particular way the change of state occurred. That is, the change is independent of the details of the process. Conversely, if the value of a quantity is independent of the process between two states, then that quantity is the change in a property. This provides a test for determining whether a quantity is a property: ***A quantity is a property if its change in value between two states is independent of the process.*** It follows that if the value of a particular quantity depends on the details of the process, and not solely on the end states, that quantity cannot be a property.

PHASE AND PURE SUBSTANCE

The term *phase* refers to a quantity of matter that is homogeneous throughout in both chemical composition and physical structure. 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. When more than one phase is present, the phases are separated by *phase boundaries*. Note that gases, say oxygen and nitrogen, can be mixed in any proportion to form a *single* gas phase. Certain liquids, such as alcohol and water, can be mixed to form a *single* liquid phase. But liquids such as oil and water, which are not miscible, form *two* liquid phases.

A *pure substance* is one that is uniform and invariable in chemical composition. A pure substance can exist in more than one phase, but its chemical composition must be the same in each phase. For example, if liquid water and water vapor form a system with two phases, the system can be regarded as a pure substance because each phase has the same composition. A uniform mixture of gases can be regarded as a pure substance provided it remains a gas and does not react chemically. A system consisting of air can be regarded as a pure substance as long as it is a mixture of gases; but if a liquid phase should form on cooling, the liquid would have a different composition from the gas phase, and the system would no longer be considered a pure substance.

EQUILIBRIUM

Classical thermodynamics places primary emphasis on equilibrium states and changes from one equilibrium state to another. Thus, the concept of *equilibrium* is fundamental. In mechanics, equilibrium means a condition of balance maintained by an equality of opposing forces. In thermodynamics, the concept is more far-reaching, including not only a balance of forces but also a balance of other influences. Each kind of influence refers to a particular aspect of thermodynamic, or complete, equilibrium. Accordingly, several types of equilibrium must exist individually to fulfill the condition of complete equilibrium; among these are mechanical, thermal, phase, and chemical equilibrium. Criteria for these four types of equilibrium are considered in subsequent discussions. For the present, we may think of testing to see if a system is in thermodynamic equilibrium by the following procedure: Isolate the system from its surroundings and watch for changes in its observable properties. If there are no changes, we conclude that the system was in equilibrium at the moment it was isolated. The system can be said to be at an *equilibrium state*. When a system is isolated, it does not interact with its surroundings; however, its state can change as a consequence of spontaneous events occurring internally as its intensive properties, such as temperature and pressure, tend toward uniform values. When all such changes cease, the system is in equilibrium. Hence, for a system to be in equilibrium it must be a single phase or consist of a number of phases that have no tendency to change their conditions when the overall system is isolated from its surroundings. At equilibrium, temperature is uniform throughout the system. Also, pressure can be regarded as uniform throughout as long as the effect of gravity is not significant; otherwise a pressure variation can exist, as in a vertical column of liquid.