

Chapter 1

Getting Started

Introductory Concepts and Definitions

Learning Outcomes

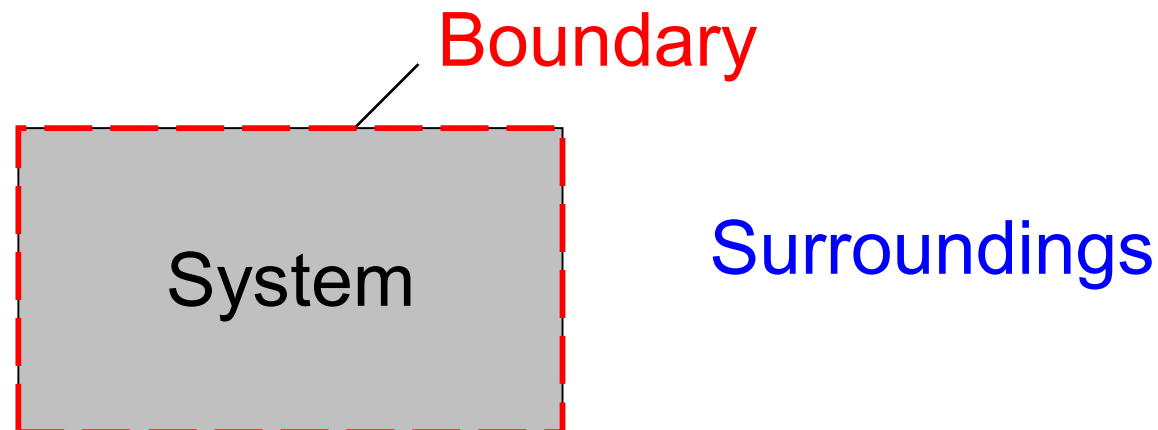
- ▶ Demonstrate understanding of several fundamental concepts used throughout this book . . . Including closed system, control volume, boundary and surroundings, property, state, process, the distinction between extensive and intensive properties, and equilibrium.

Learning Outcomes, cont.

- ▶ **Apply** SI Engineering units, including units for specific volume, pressure, and temperature.
- ▶ **Work** with the Kelvin and Celsius temperature scales.
- ▶ **Apply** the problem-solving methodology used in this book.

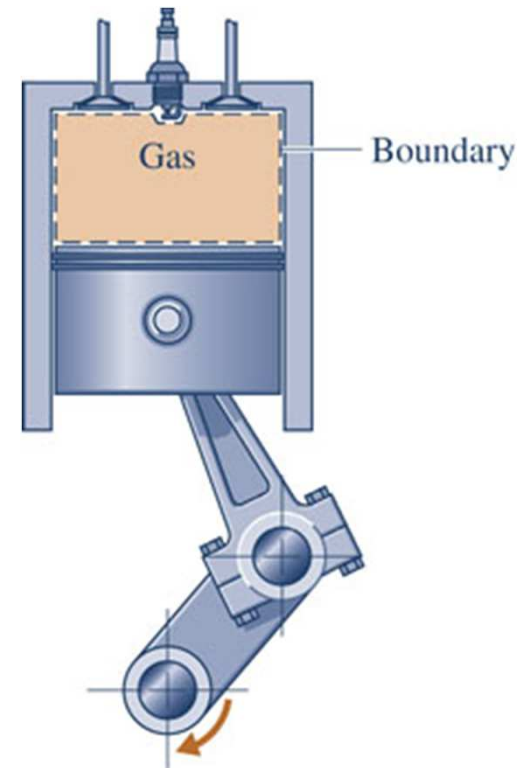
Defining Systems

- ▶ **System**: whatever we want to study.
- ▶ **Surroundings**: everything external to the system.
- ▶ **Boundary**: distinguishes system from its surroundings.



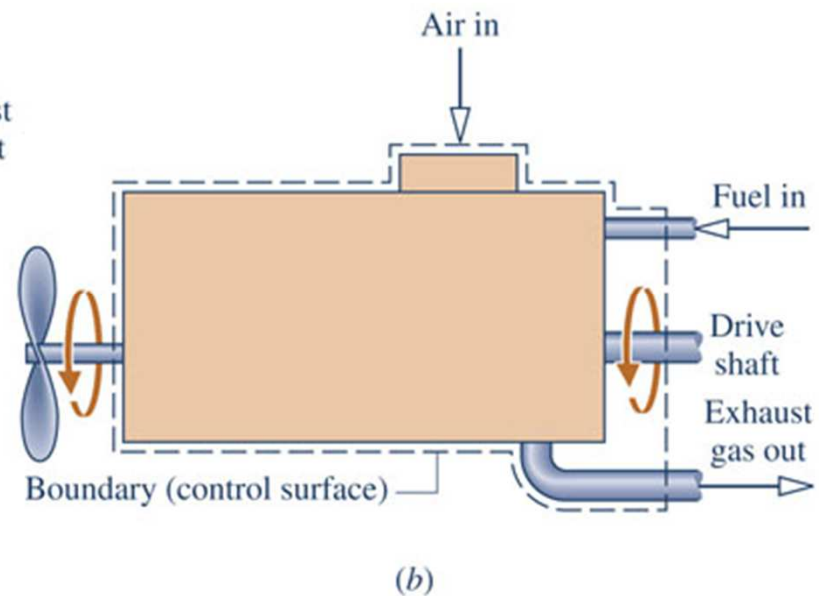
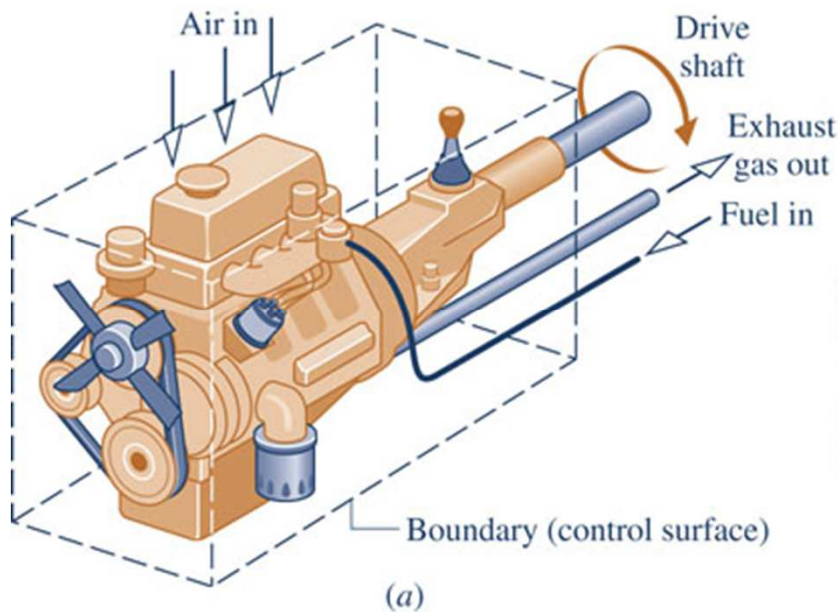
Closed System

- ▶ A system that **always contains the same matter**.
- ▶ **No transfer of mass across its boundary** can occur.
- ▶ **Isolated system**: special type of closed system that does not interact in any way with its surroundings.



Control Volume

- ▶ A **given region of space** through which mass flows.
- ▶ **Mass may cross the boundary** of a control volume.



Macroscopic and Microscopic Views

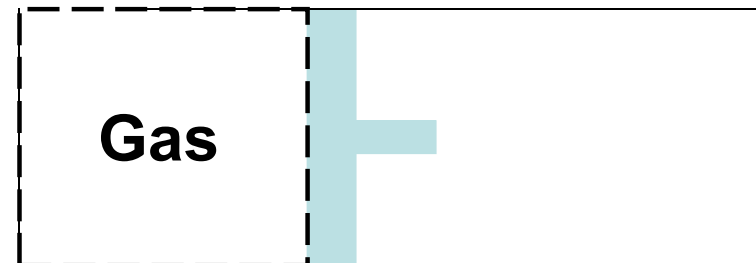
- ▶ Systems can be described from the macroscopic and microscopic points of view.
- ▶ The **microscopic approach** aims to characterize by **statistical means** the average behavior of the particles making up a system and use this information to describe the overall behavior of the system.
- ▶ The **macroscopic approach** describes system behavior in terms of the **gross effects** of the particles making up the system – specifically, effects that can be measured by instruments such as pressure gauges and thermometers.
- ▶ Engineering thermodynamics predominately uses the macroscopic approach.

Property

▶ A macroscopic **characteristic of a system** to which a **numerical value can be assigned** at a given time without knowledge of the previous behavior of the system.

▶ For the system shown, examples include:

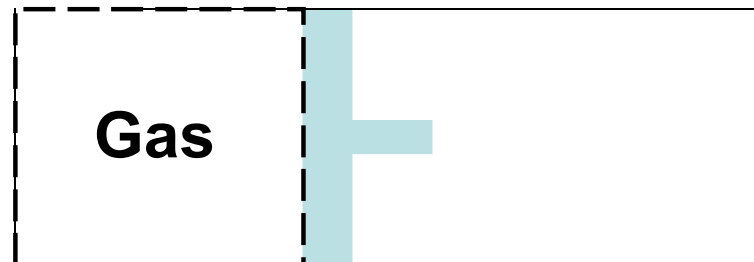
- ▶ **Mass**
- ▶ **Volume**
- ▶ **Energy**
- ▶ **Pressure**
- ▶ **Temperature**



State

- ▶ The **condition of a system** as described by its properties.
- ▶ **Example:** The state of the system shown is described by p, V, T, \dots
- ▶ The **state** often can be **specified by** providing the **values of a subset of its properties**. All other properties can be determined in terms of these few.

State: p, V, T, \dots

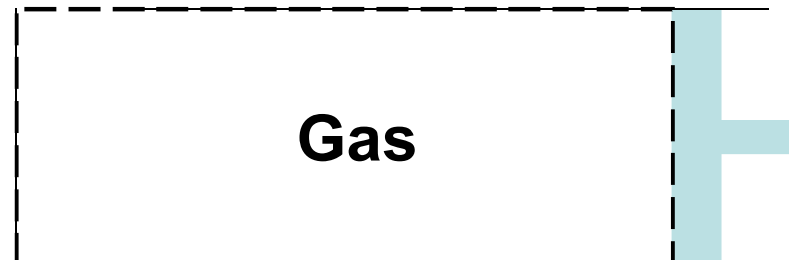
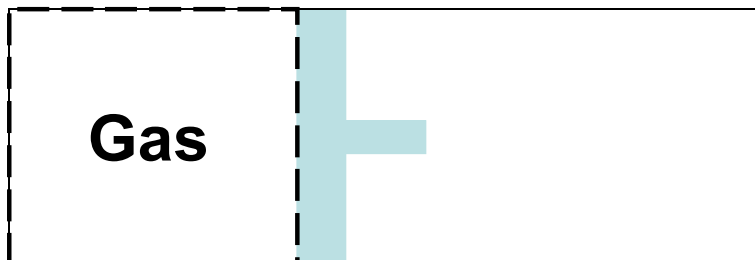


Process

- ▶ A transformation from one state to another.
- ▶ When any of the properties of a system changes, the state changes, and the system is said to have undergone a process.
- ▶ **Example:** Since $V_2 > V_1$, at least one property value changed, and the gas has undergone a process from State 1 to State 2.

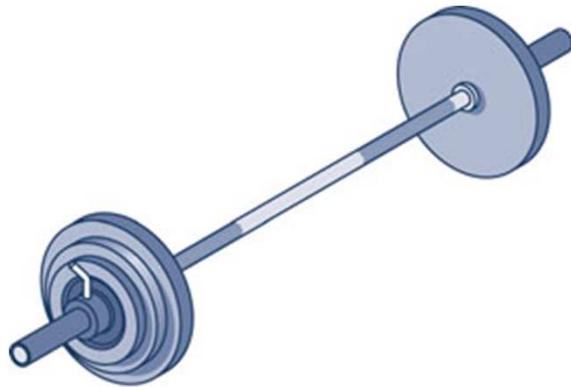
State 1: p_1, V_1, T_1, \dots

State 2: p_2, V_2, T_2, \dots

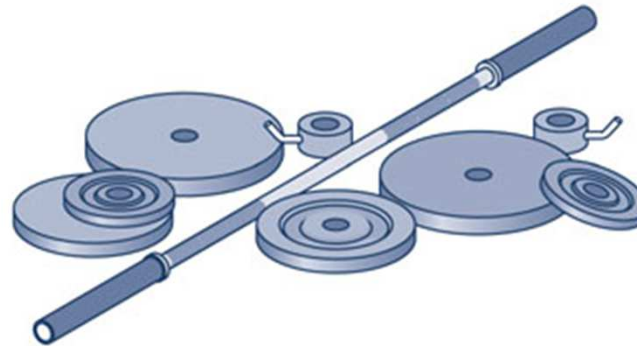


Extensive Property

- ▶ Depends on the **size** or **extent** of a **system**.
- ▶ **Examples**: mass, volume, energy.
- ▶ Its value for an overall system is the **sum of its values for the parts** into which the system is divided.



(a)



(b)

- ▶ Its **value may vary with time** but **not position**.

Intensive Property

- ▶ Independent of the size or extent of a system.
- ▶ Examples: pressure, temperature.
- ▶ Its value is not additive as for extensive properties.
- ▶ May vary from place to place within the system at any moment – function of both position and time.

Equilibrium

▶ 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 at an **equilibrium state**.

▶ **Equilibrium states** and **processes** from one equilibrium state to another equilibrium state play important roles in thermodynamic analysis.

Units

- ▶ A unit is any specified amount of a quantity by comparison with which any other quantity of the same kind is measured (e.g., meter, kilometers, feet, and miles are all *units of length*).
- ▶ Two systems of units:
 - ▶ SI (Système International d'Unités)
 - ▶ English Engineering units.

Units

Units for Mass, Length, Time, and Force

SI		
Quantity	Unit	Symbol
mass	kilogram	kg
length	meter	m
time	second	s
force	newton (= 1 kg · m/s ²)	N

In these unit systems, mass, length, and time are **base units** and force has a unit **derived** from them using,

$$F = ma \quad (\text{Eq. 1.1})$$

$$\text{SI: } 1 \text{ N} = (1 \text{ kg})(1 \text{ m/s}^2) = 1 \text{ kg}\cdot\text{m/s}^2 \quad (\text{Eq. 1.2})$$

English:

$$1 \text{ lbf} = (1 \text{ lb})(32.1740 \text{ ft/s}^2) = 32.1740 \text{ lb}\cdot\text{ft/s}^2 \quad (\text{Eq. 1.5})$$

Density (ρ) and Specific Volume (v)

- ▶ From a macroscopic perspective, description of **matter** is simplified by considering it to be **distributed continuously** throughout a region.
- ▶ When substances are treated as continua, it is possible to speak of their **intensive thermodynamic properties** “**at a point.**”
- ▶ At any instant the density (ρ) at a point is defined as

$$\rho = \lim_{V \rightarrow V'} \left(\frac{m}{V} \right) \quad \text{(Eq. 1.6)}$$

where V' is the smallest volume for which a definite value of the ratio exists.

Density (ρ) and Specific Volume (v)

- ▶ Density is mass per unit volume.
- ▶ Density is an **intensive property** that may vary from point to point.
- ▶ SI units are (**kg/m³**).
- ▶ English units are (**lb/ft³**).

Density (ρ) and Specific Volume (v)

- ▶ Specific volume is the **reciprocal of density**: $v = 1/\rho$.
- ▶ Specific volume is volume per unit mass.
- ▶ Specific volume is an **intensive property** that may vary from point to point.
- ▶ SI units are (**m³/kg**).
- ▶ English units are (**ft³/lb**).

Specific volume is usually preferred for thermodynamic analysis when working with gases that typically have small density values.

Pressure (p)

- ▶ Consider a small area A passing through a point in a **fluid at rest**.
- ▶ The fluid on one side of the area exerts a compressive force that is normal to the area, F_{normal} . An equal but oppositely directed force is exerted on the area by the fluid on the other side.
- ▶ The pressure (p) at the specified point is defined as the limit

$$p = \lim_{A \rightarrow A'} \left(\frac{F_{\text{normal}}}{A} \right)$$

(Eq. 1.10)

where A' is the area at the “point” in the same limiting sense as used in the definition of density.

Pressure Units

- ▶ SI unit of pressure is the **pascal**:

$$1 \text{ pascal} = 1 \text{ N/m}^2$$

- ▶ Multiples of the pascal are frequently used:

- ▶ 1 kPa = 10^3 N/m²

- ▶ 1 bar = 10^5 N/m²

- ▶ 1 MPa = 10^6 N/m²

- ▶ English units for pressure are:

- ▶ pounds force per square foot, **lbf/ft²**

- ▶ pounds force per square inch, **lbf/in.²**

Absolute Pressure

- ▶ **Absolute pressure**: Pressure with respect to the zero pressure of a complete vacuum.
- ▶ **Absolute pressure** *must* be used in thermodynamic relations.
- ▶ **Pressure-measuring devices** often indicate the *difference* between the absolute pressure of a system and the absolute pressure of the atmosphere outside the measuring device.

Gage and Vacuum Pressure

► When system pressure is greater than atmospheric pressure, the term **gage pressure** is used.

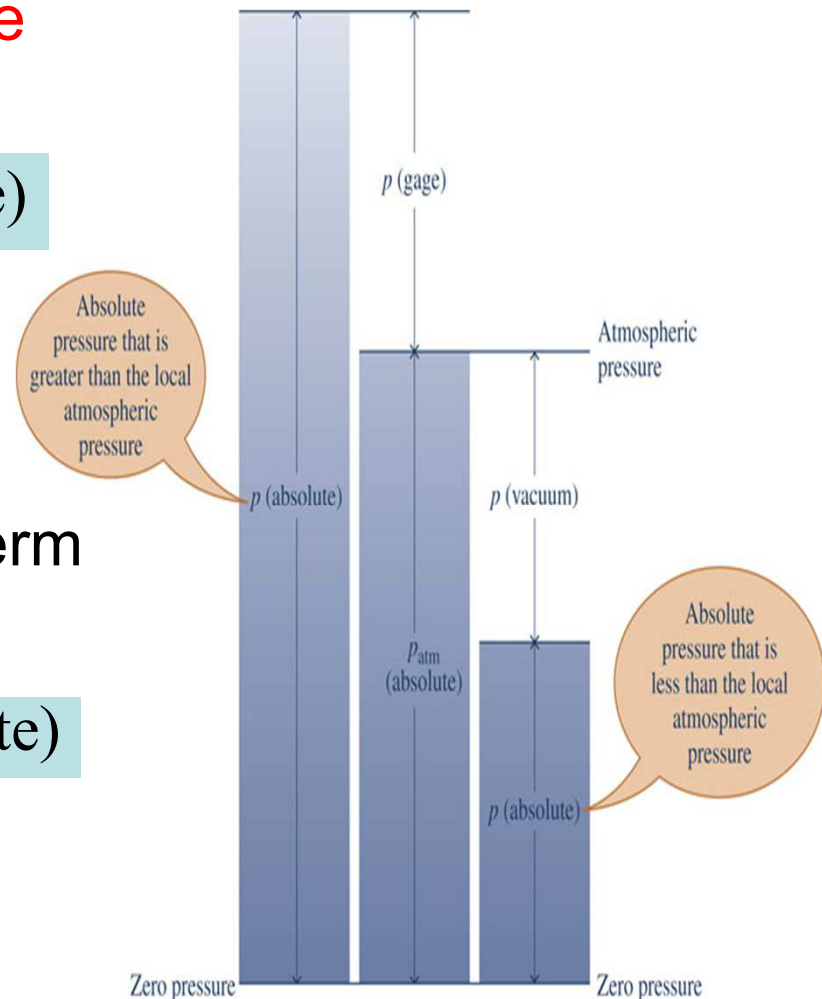
$$p(\text{gage}) = p(\text{absolute}) - p_{\text{atm}}(\text{absolute})$$

(Eq. 1.14)

► When atmospheric pressure is greater than system pressure, the term **vacuum pressure** is used.

$$p(\text{vacuum}) = p_{\text{atm}}(\text{absolute}) - p(\text{absolute})$$

(Eq. 1.15)



Temperature (T)

- ▶ If two blocks (one warmer than the other) are brought into contact and isolated from their surroundings, they would **interact thermally** with changes in observable properties.
- ▶ When all changes in observable properties cease, the two blocks are in **thermal equilibrium**.
- ▶ **Temperature** is a physical property that determines whether the two objects are in thermal equilibrium.

Thermometers

- ▶ Any object with at least one measurable property that changes as its temperature changes can be used as a **thermometer**.
- ▶ Such a property is called a **thermometric property**.
- ▶ The substance that exhibits changes in the thermometric property is known as a **thermometric substance**.

Thermometers

▶ **Example:** Liquid-in-glass thermometer

▶ Consists of glass capillary tube connected to a bulb filled with liquid and sealed at the other end. Space above liquid is occupied by vapor of liquid or an inert gas.

▶ As temperature increases, liquid expands in volume and rises in the capillary. The length (L) of the liquid in the capillary depends on the temperature.

▶ The **liquid** is the **thermometric substance**.

▶ L is the **thermometric property**.

▶ Other types of thermometers:

▶ Thermocouples

▶ Thermistors

▶ Radiation thermometers and optical pyrometers

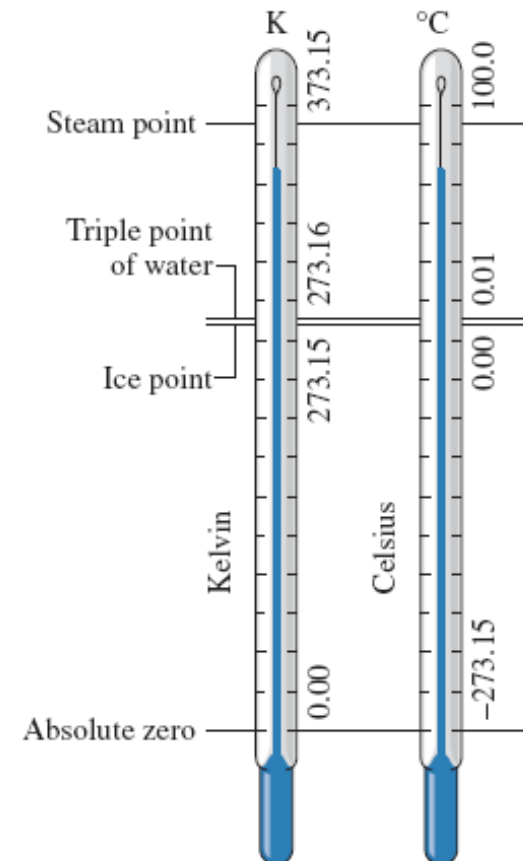


Temperature Scales

▶ **Kelvin scale:** An absolute thermodynamic temperature scale whose unit of temperature is the kelvin (K); an SI base unit for temperature.

▶ **Celsius scale (°C):**

$$T(^{\circ}\text{C}) = T(\text{K}) - 273.15 \quad (\text{Eq. 1.16})$$



Problem-Solving Methodology

- ▶ **Known:** Read the problem, think about it, and identify what is known.
- ▶ **Find:** State what is to be determined.
- ▶ **Schematic and Given Data:** Draw a sketch of system and label with all relevant information/data.
- ▶ **Engineering Model:** List all simplifying assumptions and idealizations made.
- ▶ **Analysis:** Reduce appropriate governing equations and relationships to forms that will produce the desired results.