Energy: The ability to cause changes. thermodynamics stems from therme (heat) and dynamis (power).

Thermodynamics: The science of energy.

Conservation of energy principle: During an interaction, energy can change from one form to another (transform) but the total amount of energy remains constant.
   Energy cannot be created or destroyed.
IMPORTANCE OF DIMENSIONS AND UNITS

• Any physical quantity can be characterized by **dimensions**.

• **Primary** or **fundamental dimensions**
  Basic dimensions, such as
  - mass \( m \),
  - length \( L \),
  - time \( t \),
  - temperature \( T \)

• **secondary** or **derived dimensions**
  such as
  - velocity \( V \),
  - energy \( E \),
  - volume \( V \)

  are expressed in terms of the primary dimensions.

• The magnitudes assigned to the dimensions are called **units**.
UNITS

- **Metric SI system:** A simple and logical system based on a decimal relationship between the various units.

  mass: \( m = 1 \text{ kg} = 10^3 \text{ g} \)

  volume: \( V = 200 \text{ mL} = 0.2 \text{ L} = 200 \text{ cm}^3 \)

- **English system:** It has no apparent systematic numerical base, and various units in this system are related to each other rather arbitrarily.

<table>
<thead>
<tr>
<th>TABLE 1–1</th>
</tr>
</thead>
<tbody>
<tr>
<td>The seven fundamental (or primary) dimensions and their units in SI</td>
</tr>
<tr>
<td>Dimension</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Length</td>
</tr>
<tr>
<td>Mass</td>
</tr>
<tr>
<td>Time</td>
</tr>
<tr>
<td>Temperature</td>
</tr>
<tr>
<td>Electric current</td>
</tr>
<tr>
<td>Amount of light</td>
</tr>
<tr>
<td>Amount of matter</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 1–2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard prefixes in SI units</td>
</tr>
<tr>
<td>Multiple</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>(10^{12})</td>
</tr>
<tr>
<td>(10^9)</td>
</tr>
<tr>
<td>(10^6)</td>
</tr>
<tr>
<td>(10^3)</td>
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<td>(10^2)</td>
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<td>(10^{-1})</td>
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<td>(10^{-2})</td>
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<tr>
<td>(10^{-3})</td>
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<tr>
<td>(10^{-6})</td>
</tr>
<tr>
<td>(10^{-9})</td>
</tr>
<tr>
<td>(10^{-12})</td>
</tr>
</tbody>
</table>
Some SI and English Units

1 lbm = 0.45359 kg
1 ft = 0.3048 m

Force

Force = (Mass)(Acceleration)

\[ F = ma \]

1 N = 1 kg \cdot m/s^2
1 lbf = 32.174 lbm \cdot ft/s^2

Work, Energy

Work = Force \times Distance

1 J = 1 N \cdot m
1 cal = 4.1868 J
1 Btu = 1.0551 kJ
Dimensional homogeneity

All equations must be dimensionally homogeneous.

• Every term in an equation must have the same unit.

Unity Conversion Ratios

\[
\frac{N}{\text{kg} \cdot \text{m/s}^2} = 1 \quad \text{and} \quad \frac{\text{lbf}}{32.174 \text{ lbm} \cdot \text{ft/s}^2} = 1
\]

Unity conversion ratios are identically equal to 1 and are unitless, and thus such ratios (or their inverses) can be inserted conveniently into any calculation to properly convert units.
1-3 SYSTEMS AND CONTROL VOLUMES

- **System**: A quantity of matter or a region in space chosen for study.
- **Surroundings**: The region outside the system.
- **Boundary**: The real or imaginary surface that separates the system from its surroundings.
  - *fixed* or
  - *movable*.

- **Systems** may be considered to be
  - *closed* or
  - *open*.

**Closed System (control mass):**
- ✔ Fixed amount of mass
- ✔ No mass can cross its boundary
- ✔ No mass + No energy = **isolated system**.
**Open System** (control volume):

- Encloses a device that involves mass flow
  - such as compressor, turbine, or nozzle.
- Both mass and energy can cross the boundary of a control volume.
- **Control surface (-----)**: The boundaries of a control volume. It can be real or imaginary.

![Diagram](image-url)
1-4 PROPERTIES OF A SYSTEM

- **Property:** Any characteristic of a system, such as
  - pressure $P$, temperature $T$, volume $V$, and mass $m$, etc.
  - Properties are considered to be either *intensive* or *extensive*.

  ✓ **Intensive properties:** Values independent of the mass of a system,
    - temperature, pressure, and density, etc

  ✓ **Extensive properties:** Values depend on the size or extent of the system.
    - mass and volume

  ✓ **Specific properties:** Extensive properties per unit mass.
1-5 DENSITY AND SPECIFIC GRAVITY

Density
\[ \rho = \frac{m}{V} \quad (\text{kg/m}^3) \]

Specific volume
\[ V = \frac{\rho}{m} = \frac{1}{\rho} \]

Specific weight: The weight of a unit volume of a substance.
\[ \gamma_s = \rho g \quad (\text{N/m}^3) \]

Specific gravity (SG): The ratio of the density of a substance to the density of water at 4°C.
\[ SG = \frac{\rho}{\rho_{\text{H}_2\text{O}}} \]

<table>
<thead>
<tr>
<th>Substance</th>
<th>SG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1.0</td>
</tr>
<tr>
<td>Blood</td>
<td>1.05</td>
</tr>
<tr>
<td>Seawater</td>
<td>1.025</td>
</tr>
<tr>
<td>Gasoline</td>
<td>0.7</td>
</tr>
<tr>
<td>Ethyl alcohol</td>
<td>0.79</td>
</tr>
<tr>
<td>Mercury</td>
<td>13.6</td>
</tr>
<tr>
<td>Wood</td>
<td>0.3–0.9</td>
</tr>
<tr>
<td>Gold</td>
<td>19.2</td>
</tr>
<tr>
<td>Bones</td>
<td>1.7–2.0</td>
</tr>
<tr>
<td>Ice</td>
<td>0.92</td>
</tr>
<tr>
<td>Air (at 1 atm)</td>
<td>0.0013</td>
</tr>
</tbody>
</table>
**1-7 PROCESSES AND CYCLES**

**Process**: Any change that a system undergoes from one equilibrium state to another.

**Path**: The series of states through which a system passes during a process.
- A process: initial state, final states, as well as the path it follows, and the interactions with the surroundings.

---

**Process Diagram**

**Property A**

- **State 1**
- **State 2**
- **Process path**

**Property B**

- **(a) State 1**: $m = 2 \text{ kg}$, $T_1 = 20^\circ C$, $V_1 = 1.5 \text{ m}^3$
- **(b) State 2**: $m = 2 \text{ kg}$, $T_2 = 20^\circ C$, $V_2 = 2.5 \text{ m}^3$

---

**Quasistatic or quasi-equilibrium process:**

A process proceeds in such a manner that the system remains infinitesimally close to an equilibrium state at all times.
Temperature Scales

- All temperature scales are based on some easily reproducible states such as the freezing and boiling points of water: the *ice point* and the *steam point*.
- **Ice point**: A mixture of ice and water that is in equilibrium with air saturated with vapor at 1 atm pressure (0°C or 32°F).
- **Steam point**: A mixture of liquid water and water vapor (with no air) in equilibrium at 1 atm pressure (100°C or 212°F).

- **Celsius scale**: in SI unit system
- **Fahrenheit scale**: in English unit system
- **Thermodynamic temperature scale**: A temperature scale that is independent of the properties of any substance.
  - ✓ Kelvin scale (SI)
  - ✓ Rankine scale (E)

A constant-volume gas thermometer would read -273.15°C, or 0 K, at absolute zero pressure.
\[ \Delta T(K) = \Delta T(\degree C) \]

\[ \Delta T(R) = \Delta T(\degree F) \]

\[
\begin{array}{c|c|c|c}
1 \text{ K} & 1 \text{ C} & 1.8 \text{ R} & 1.8 \text{ F} \\
\end{array}
\]

\[ T(K) = T(\degree C) + 273.15 \]

\[ T(R) = T(\degree F) + 459.67 \]

\[ T(R) = 1.8T(K) \]

\[ T(\degree F) = 1.8T(\degree C) + 32 \]
1-9 PRESSURE

Pressure: A normal force exerted by a fluid per unit area

\[ 1 \text{ Pa} = 1 \text{ N/m}^2 \]

\[ 1 \text{ bar} = 10^5 \text{ Pa} = 0.1 \text{ MPa} = 100 \text{ kPa} \]

\[ 1 \text{ atm} = 101,325 \text{ Pa} = 101.325 \text{ kPa} = 1.01325 \text{ bars} \]

\[ 1 \text{ kgf/cm}^2 = 9.807 \text{ N/cm}^2 = 9.807 \times 10^4 \text{ N/m}^2 = 9.807 \times 10^4 \text{ Pa} \]

\[ = 0.9807 \text{ bar} \]

\[ = 0.9679 \text{ atm} \]
• **Absolute pressure**: The actual pressure (relative to absolute vacuum)

• **Gage pressure**: The difference between the absolute pressure and the local atmospheric pressure.
  – Most pressure-measuring devices are calibrated to read zero in the atmosphere, and so they indicate gage pressure.

• **Vacuum pressures**: Pressures below atmospheric pressure.

\[
P_{\text{gage}} = P_{\text{abs}} - P_{\text{atm}}
\]

\[
P_{\text{vac}} = P_{\text{atm}} - P_{\text{abs}}
\]
Atmospheric pressure is measured by a device called a barometer; thus, the atmospheric pressure is often referred to as the barometric pressure.

**standard atmosphere**: Pressure produced by a column of mercury 760 mm (= $h$) in height at 0°C ($\rho_{\text{Hg}} = 13,595 \text{ kg/m}^3$) under standard gravitational acceleration ($g = 9.807 \text{ m/s}^2$).