1.1 Thermodynamics and Energy

- Thermodynamics can be defined as the science of Energy.
- The conservation of energy
  - Energy cannot be created or destroyed; it can only change forms (the first law)
  - Energy is a thermodynamic property.
- Energy has quality as well as quantity, and actual processes occur in the direction of decreasing quality of energy. (the second law)

Classical thermodynamics: The macroscopic approach to study of thermodynamics that does not required a knowledge of the behavior of individual particles.

Statistical thermodynamics: A more elaborate approach, based on the average behavior of large groups of individual particles.
熱力學與能量

圖 1-3 熱往減低溫度的方向流動。
(the second law)

圖 1-4 很多工程系統的設計均涉及熱力學，例如
圖中所示之太陽能熱水系統。

1.2 Dimensions and Units (因次與單位)

- Dimension: Any physical quantity
- Primary or fundamental dimension: mass m, length L, time t, temperature T, etc
- Second or derived dimension: velocity v, energy E, volume V, force F, etc.
- Units: The arbitrary magnitudes assigned to the dimensions
1.2 Dimensions and Units

**SI units: (system international)**
- Length m;
- Electric current A (Ampere);
- Mass kg; Amount of light cd (candelas);
- Time s; Amount of matter mole;
- Temperature K (Kelvin) or °C (Celsius).

**EI units: (English units)**
- Length ft;
- Pound mass lbm;
- Time s;
- Temperature °R (Rankine) or °F (Fahrenheit).

```
texa giga mega kilo centi milli micro nano pico
```

1.2 Dimensions and Units

**Energy: Cal; Btu**

*Calorie (Cal):*
The amount of energy needed to raise the temperature of 1g of water at 15 °C by 1 °C.

*British thermal unit (Btu):*
The energy required to raise the temperature of 1 lbm of water at 68 °F by 1 °F.

**Dimensional Homogeneity:**
All the terms in an equation must have the same unit.
1.2 因次與單位

重量(力) = 質量 x 異地引力 \( g \) (gravity)

1 kgf = 1 kg \( \times 9.807 \text{ m/s}^2 \)
1 lbf = 1 lbm \( \times 32.174 \text{ ft/s}^2 \)

![圖1-9 在地球上150磅的體重在月球上僅重25磅。](image)

重量 \( W \) 由下式表示：

\[
W = mg
\]

其中，

- \( m \) 是質量，
- \( g \) 是當地的重力加速度。

1 J (joule) = 1 N \( \times 1 \text{ m} \)

1 N \( \equiv \) newton

1 kgf \( \equiv \) kilogram-force

因次與單位

**Dimensional Homogeneity:**

All the terms in an equation must have the same unit

**Ex 1:**

\[
\rho \frac{N}{m^2} \times V(m^3) = m(kg) \times R(8.31434 kJ/kmol K) \times \frac{kJ}{kmol K} = \frac{M}{kg} \times \frac{T(K)}{}
\]

**Ex 2:** 聲速

\[
a = \sqrt{\frac{m}{M}} \times \frac{N}{kmol K} \times \frac{kJ}{kmol K} \times \frac{1}{N} \times \frac{1}{m^2}
\]

1 J = 1 N \( \times 1 \text{ m} \)

1 N \( \equiv \) newton

1 kgf \( \equiv \) kilogram-force

1 J \( \equiv \) joule

系統

- **System (系統):**
  A quantity of matter or a region in space chosen for study

- **Surrounding or Environment (外界):**
  Everything external to the system

- **Boundary (邊界):**
  The real or imaginary surfaces that separate the system from its surroundings.
### The definition of “systems”

- A fixed quantity of mass (control mass) or
- Closed system (a specified amount of mass, no flow of matter) and

- A control volume
- Open system (a specified region in space, open to the flow of matter)

* Isolated system (one that is not influenced in any way by surroundings)
* Adiabatic system (one that is without heat transfer by surroundings)
1.3 Open (Control) System

1.4 Properties of a System

- **Property**: Any observable characteristic of a system
  - properties (Characteristics)
    - \( P, T, V \) (measurable) viscosity, thermal conductivity, ...
    - \( U, S, H \) (un-measurable)
  - **Extensive Properties**: depend on mass, size (i.e. volume, mass, energy, S, Availability)
  - **Intensive Properties**: independent of the size of a system (i.e. \( T, P \), density, height)
  - **Specific properties**: extensive properties/total mass or moles (i.e. specific volume, specific energy, specific entropy)

- **Continuum**:
  - Matter is made up of atoms, view it as a continuous, homogeneous matter with no holes
  - to treat properties as point function, and to assume the properties to vary continually in space with no jump discontinuities.
1.5 Density and Specific Gravity

- **Density**: mass per unit volume, \( \rho = \frac{m}{V} \)
- **Specific volume**: volume per unit mass
  \[ \text{Specific volume} = \frac{V}{M} \]
- **Specific gravity**: The ratio of the density of a substance to the density of some standard substance at a specified temperature (Usually water at 4°C, for which \( \rho_{H2O} = 1000 \) kg/m\(^3\)).
  \[ \text{SG} = \frac{\rho}{\rho_{H2O}} \]
- **Specific weight**: The weight of a unit volume of a substance.
  \[ \gamma_s = \rho g \]

1.6 State and Equilibrium (狀態與平衡)

- **State** (狀態):
  The state of a system is described by its properties, a description of the system.
  - For a simple compressible system:
    The “state postulate” requires - the state of a simple compressible system is completely specified by two independent, intensive properties.
    or - two properties be specified independent to fix the state
- **Equilibrium** (平衡):
  A state of balance in
  - thermal equilibrium: \( T \)
  - mechanical equilibrium: \( P \)
  - phase equilibrium: \( m \)
  - chemical equilibrium: \( t \)
1.6 狀態與平衡

系統在兩個不同的狀態。

(a) 狀態1

(b) 狀態2

圖1-27 系統在兩個不同的狀態。

(a) 之前

(b) 之後

圖1-28 密閉系統達到熱平衡。

狀態假說(State Postulate):

兩個獨立的內函性質即可確定物質的狀態

圖1-29 系統內氧的狀態由兩個獨立的
內函性質 (T and v) 確定。

Phase Rule (no chemical reaction)

- \( F = C - P + 2 \)
  - \( F \): # of intensive (internal) properties need to fix the state of the system
  - \( C \): # of components
  - \( P \): # of phases

Nitrogen gas \( F = 2 \) (\( C = 1, P = 1 \))

Un-saturated water \( F = 1 \) (\( C = 1, P = 2 \))

1.7 Processes and Cycles (過程與循環)

- **Process:** The sequence of states which a system passes in going from one equilibrium state to another
- **Path:** A system passes during a process
- **Quasi-state process:**
  - The system remains infinitesimally close to an equilibrium state at all times
- **Cycle:** Process in which the final state is identical to the initial value
1.7 Processes and Cycles

- **Some Special Processes:**
  - Isothermal Process: \( T \) is constant
  - Isobaric Process: \( P \) is constant
  - Isochoric or isometric Process:
    - specific volume is constant
  - Steady-flow Process (for open system only):
    A process during which a fluid flows through a control volume steadily (time independent).
1.8 Temperature and the Zeroth Law

溫度與熱力學第零定律

- **Temperature:**
  A measure of hotness or coldness

- **Thermodynamic Temperature Scale:**
  - Celsius scale, C
  - Fahrenheit scale, F
  - Kelvin scale, K
  - Rankine scale, R
  - Ideal gas temperature scale, K

- **Constant-volume gas thermometer**
  At low pressure, the temperature of a gas is proportional to its pressure at constant volume.
1.8 Temperature and Thermodynamics

- Zeroth Law
  - The internal properties of a system are functionally related.
  - If two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other.
  - \( T_1 = T_2, T_2 = T_3 \), we have \( T_1 = T_3 \)
  - In 1931, by R. H. Fowler

1.9 Pressure (壓力)

- Is defined as the force exerted by a fluid per unit area, \( F/A \).
- Units:
  - 1 pascal (Pa) = 1 N/m²
  - 1 bar = 100 kPa
  - 1 psi = 1 lb/in²
  - 1 atm = 76 in-Hg (standard atmospheric pressure)
  - 1 atm = 101,325 Pa = 1.01325 bar
  - 1 kgf/cm² (kg/cm²) = 0.96788 atm = 14.223 psi
  - 1 atm = 14.696 psi
1.9 Pressure

- **Absolute Pressure:**
  The actual pressure at a given position and it is measured relative to absolute vacuum

- **Gage Pressure:**
  The difference between the absolute pressure and the local atmospheric pressure (measured)
  \[ P_{gage} = P_{abs} - P_{atm} \] (P above P\textsubscript{atm})

- **Vacuum Pressure:**
  Pressure below atmospheric pressure
  \[ P_{vac} = P_{atm} - P_{abs} \] (P below P\textsubscript{atm})

- **Variation of pressure with depth,**
  or \( P = P_{atm} + \rho gh; \) \( \rho \): liquid density
1.9 Pressure

- Pascal’s principle:
The pressure applied to a confined fluid increases the pressure throughout by the same amount,
\[ P_1 = P_2 \text{; and } F_1/A_1 = F_2/A_2 \]

For a constant \( p \)
\[ \Delta P = P_2 - P_1 = \rho g dz \]

1.9 壓力

\[ \int \rho g dz = \int \Delta P \]

\[ \Delta P = P_2 - P_1 = \rho g \Delta z = \gamma \Delta z \]

\[ \int \Delta P = \int \rho g \Delta z = \int \gamma \Delta z \]

\[ P_{\text{顶}} = 1 \text{ atm} \]

空氣
(5 m 高的空間）

\[ P_{\text{底}} = 1.006 \text{ atm} \]

\[ P = P_2 \text{; a small height difference is negligible at high pressure} \]

應用巴斯卡原理以小的力量舉高重物。
1.10 The Manometer (液體壓力計)

- Manometer:
  A fluid column can be used to measure pressure
  Pressure variations (as shown in previous)
  - The pressure change across a fluid column of height is $\Delta P = \rho gh$
  - Pressure increases downward in a given fluid and decreases upward. $P_{bottom} > P_{top}$
  - Two points at the same elevation in a continuous fluid at rest are at the same pressure.
1.10 Other pressure measurement devices

- **Bourdon tube:**
  It consists of a hollow metal tube bent like a hook whose end is closed and connected to a dial indicator needle.

- **Pressure transducer:**
  It is made of semiconductor materials such as silicon and converts the pressure effect to an electrical effect such as a change in voltage, resistance, or capacitance.

- **Gage pressure transducer:**
  The atmospheric pressure as a reference

- **Absolute pressure transducer:**
  It is calibrated to have a zero signal output at full vacuum.

- **Differential pressure transducer:**
  Measure the pressure difference between two locations directly instead of using two pressure transducers and taking their difference.

- **Piezoelectric effect:**
  The emergence of an electric potential in a crystalline substance when subjected to mechanical pressure.

- **Strain-gage pressure transducer:**
  The sensors of such transducers are made of thin metal wires or foil whose electrical resistance changes when strained under the influence of fluid pressure.

1.11 Barometer and Atmospheric Pressure

- **Barometer:**
  A device is used to measure the atmospheric pressure
  - $P_{atm} = \rho gh$; $\rho$: density
  - Torr: The unit mmHg
  - 1 atm = 760 torr; and 1 torr = 133.3 Pa

- **Atmospheric Pressure**
  The atmospheric pressure changes not only with elevation but also with weather conditions.
1.11 大氣壓力計

1.12 Problem-solving technique

- Step 1: Problem statement
- Step 2: Schematic
- Step 3: Assumptions
- Step 4: Physics laws
- Step 5: Properties
- Step 6: Calculation
- Step 7: Reasoning, verification, and discussion
### 1.12 解題技巧

解題技巧圖1-62解答工程問題時所作的假設必須是合理的、可以解釋的。

解題技巧圖1-63工程分析得到的結果必須檢查是否合理。

### 1.12 解題技巧

解題技巧圖1-67有效數字。

### 第一章習題

10, 15, 28, 40, 49, 54, 63, 74, 82, 92, 104, 110