Heat Transfer

CHAPTER 1: INTRODUCTION

Heat transfer

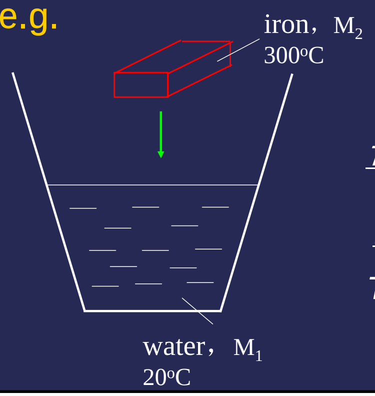
Thermal energy (heat): refers to the energy transported from one system to another as a result of temperature difference (ΔT)

- It is a dynamic transport process.
- Quantity= driving force/ resistance
- Driving force for heat transfer is the temperature difference.
- Heat is transferred in the direction of decreasing temperature. (from hot to cold)

The Second Law of Thermodynamics

1.1 Thermodynamics and Heat Transfer

e.g.



Thermodynamics: T_m, Q

Heat tranfer: rate

$$T = f(x, y, z, t); \quad Q = f(t)$$

- subjects:

Thermodynamics : energy form, energy transformation, the amount of heat transfer (how much)

Heat transfer: heat transfer rate, temperature variation/distribution, cooling/heating time (how long)

- time

Thermodynamics: gives no consideration of the time the heat transfer process will take.

Heat transfer: time is important

- states

Thermodynamics : **Equilibrium**

Heat transfer : **Non-equilibrium (process)**

1.2 Application of Heat Transfer

Heat transfer is commonly encountered in *daily life* and *engineering systems*.

Examples:

- Nature: Aerosphere (CO_2+H_2O)-green house
- Daily life: Human comfort (cloth-summer/winter)
  Household application (refrigerator, iron)
- Engineering application:
  Radiator, solar collector, steam pipe
  Electronic equipment
  Spacecraft
  Metallurge ...

Engineering application areas

Power, mechanical manufacture, chemical industry, refrigeration, architecture, environment, new energy source, micro-electronics, nuclear energy, aerospace, MEMS, new material, military science and technology, life science and biology technology

1.3 Heat and Energy Transfer

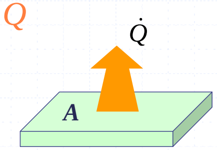
- Energy can be transferred to or from a given object or system by two mechanisms:
  Energy Transfer as Work (W)
  Energy Transfer as Heat (Q)
- Heat transfer= heat flow
  Heat addition, heat absorption, heat gain
  Heat rejection, heat loss
  Heat generation, heat source, heat sink
  Heat storage, body heat

Heat flux, heat transfer rate, total heat transfer

1) heat flux (热流密度) $\dot{q}$

$$\dot{q} = \frac{dQ}{dtdA} \qquad (\mathrm{W/m^2})$$

2) heat transfer rate (热流量) $\dot{Q}$



$$\dot{Q} = \frac{dQ}{dt} = \int_A \dot{q} dA \qquad (\mathrm{W})$$

$$If \quad \dot{q} = \dot{q}_o \,, \quad then \quad \dot{Q} = \dot{q}_o A \quad (\mathrm{W})$$

3) total amount of heat transfer (总热量) Q

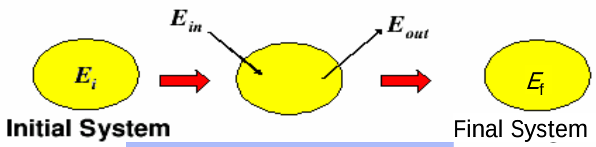
$$Q = \int_0^t \dot{Q} dt = \int_0^t \int_A \dot{q} dA\, dt \qquad (\mathrm{J})$$

1.4 The 1st Law of Thermodynamics

- Conservation of Energy (Energy Balance):

Energy can be neither created nor destroyed, but can only be transformed and transferred

The difference between the total energy entering a system and the total energy leaving it is equal to the energy accumulated in that system.



$$E_{in} - E_{out} = \Delta E_{system}$$

where $\Delta E_{system} = E_f - E_i$

Heat Balance

- Heat Balance:

$$Q_{in} - Q_{out} + E_{gen} = \Delta E_{thermal,system} = \Delta U$$

Steady state: ΔU =0

$$Q_{in} - Q_{out} + E_{gen} = 0$$

No heat generation: E_{gen}=0

$$Q_{in} - Q_{out} = 0 \quad i.e. \quad Q_{in} = Q_{out}$$

Heat balance for closed and open system

$$Q_{in} - Q_{out} + E_{gen} = \Delta U$$

- Heat balance for closed systems:

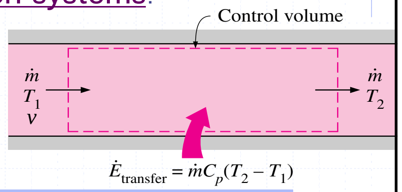
No heat generation $\qquad Q_{in} - Q_{out} = mC_v \Delta T$

Heat balance for closed and open system

- Heat balance for open systems:

steady-flow system

$\dot{m} = \text{const}$



$$\dot{Q}_{in} - \dot{Q}_{out} = \dot{m}C_p\Delta T = (\rho v A_c)C_p(T_2 - T_1)$$

Where mass flow rate ($\dot{m}$ kg/s) is the amount of mass flowing through a pipe or duct per unit time.