OCT. 17/17

Thermal

$$Q - W = m\left[(h_2 - h_1) + \left(\frac{V_2^2 - V_1^2}{2}\right) + g(z_2 - z_1)\right]$$

$$q - w = h_2 - h_1 + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)$$

Throttling Valves:

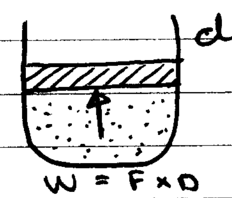
$q \simeq 0$, $w \simeq 0$, $\Delta Pe \simeq 0$, $\Delta Ke \simeq 0$

$0 = h_2 - h_1 + 0 + 0$

$\therefore h_1 = h_2 \rightarrow$ isenthalpic

$U_1 + P_1 V_1 = U_2 + P_2 V_2$

Mixing Chamber:



$q \simeq 0$, $w \simeq 0$

$\Delta Ke \simeq 0$, $\Delta Pe \simeq 0$

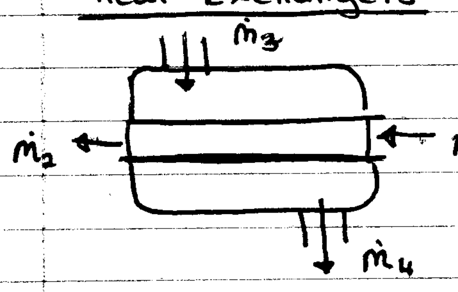
$\therefore h_1 = h_2$

$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3$

(cold, hot, warm)

$h_1 + h_2 = h_3$

Heat Exchangers



$\dot{m}_1 = \dot{m}_2$

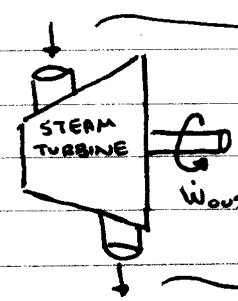
$\dot{m}_3 = \dot{m}_4$

$\dot{E}_1 = \dot{E}_2$

$\dot{m}_1 + \dot{m}_3 = \dot{m}_2 + \dot{m}_4$

$\dot{m}_1 h_1 + \dot{m}_3 h_3 = \dot{m}_2 h_2 + \dot{m}_4 h_4$

Example: 5-7 (From textbook)



$P_1 = 2\,MPa$ $V_1 = 50\,m/s$

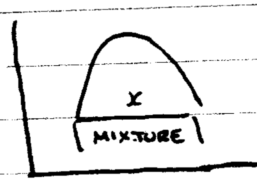
$T_1 = 400°C$ $Z_1 = 10\,m$

$\dot{W}_{out} = 5\,MW$

$P_2 = 15\,kPa$ $V_2 = 180\,m/s$

$x_2 = 0.90$ $Z_2 = 6\,m$

Cont'd :



@ 2MPa , $T_{sat} = 212°C$

$P_1 = 2MPa$
$T_1 = 400°C$ } Table A-6

$h_1 = 3248.4 \text{ kJ/kg}$

$h_2 = h_f + x_2 h_{fg}$

$= 225.94 + (0.9)(2372.3)$

$\therefore h_2 = 2361. \sim \text{ kJ/kg}$

$\Delta h = h_2 - h_1$

$= 2361 - 3248.4$

$= -887.4 \text{ kJ/kg}$

$\Delta ke = \frac{V_2^2}{2} - \frac{V_1^2}{2}$

$= \frac{(180)^2 - 50^2}{2 \times 1000}$

$= 14.95 \text{ kJ/kg}$

$\Delta Pe = g(z_2 - z_1)$

$= \frac{(9.81)(6-10)}{1000}$

$= -0.04 \text{ kJ/kg}$

→ $\dot{Q}_{in} + \dot{W}_{in} + \dot{m}(h_1 + V_1^2/2 + gz_1) = \dot{Q}_{out} + \dot{W}_{out} + \dot{m}(h_2 + V_2^2/2 + gz_2)$

$W_{out} = -\left[(h_2 - h_1) + \left(\frac{V_2^2 - V_1^2}{2}\right) + g(z_2 - z_1)\right]$

$\therefore W_{out} = 872.48 \text{ kJ/kg}$

$\dot{W}_{out} = \dot{m} W_{out}$

$\therefore \dot{m} = \frac{\dot{W}_{out}}{W_{out}} = \frac{5 \times 1000}{872.48 \text{ kJ/kg}}$

$\therefore \dot{m} = 5.73 \text{ kg/s}$

Midterm Review

75 minutes

two sections

A - theory

1-15 Multiple choice, T/F, short answers

B - Problem section

4-5 Problems

Practice

- ASSIGNMENT PROBS
- CLASS PROBLEMS
- PRACTICE PROBLEMS

Oct. 19/17
THERMAL SCI.

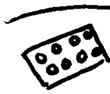
HEAT TRANSFER

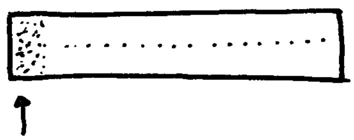
Chapter 1: Intro and Basic Concepts

Obj: 1) Understand basic mechanisms of heat transfer
2) Understand different laws of heat transfer
- i) conduction
- ii) convection
- iii) Radiation

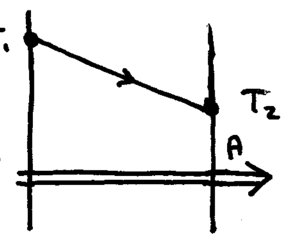
laws: Conduction: Fourier's Law
convection: Newton's Law of cool.
radiation: Stefan-Boltzman law

Conduction: → In solid, liquid, gas





Fourier's Law of Heat Conduction



1. $Q \propto$ Area
2. $\dot{Q} \propto (T_2 - T_1)$
3. $\dot{Q} \propto (1/\Delta x)$

$$\dot{Q} \propto \frac{A(T_1 - T_2)}{\Delta x} \Rightarrow \boxed{\dot{Q} = \frac{K A (T_1 - T_2)}{\Delta x}}$$

(in WATT)

$$\dot{Q}_{COND} = -KA\left(\Delta T/\Delta x\right) \qquad (\Delta T = T_2 - T_1)$$

$$\dot{Q}_{COND} = -KA\left(dT/dx\right)$$

$\text{Watt} = (K) \cdot \frac{m^2 \cdot \text{kel}}{m}$

Thermal conductivity
$K = W/m.K$

K_{H_2O} = 0.607 W/m.K

K_{IRON} = 80.2 W/m.K

0°K → 20000 W/m.K

Table 1-1

$K_{DIAMOND}$ = 2300 W/m.K (=) W/m°C

K_{COPPER} = 401 W/m.K → @20°C

K_{WATER} = 0.601 W/m.K

K_{AIR} = 0.026 W/m.K

$k \rightarrow$ high to low

1) Non-metal crystals
2) Pure metals
3) Metal alloys
4) Non-metallic solids
5) Liquids
6) Insulators
7) Gases

Pure metalic alloy (k)

Copper - 401

Aluminum - 237

Bronze - 52 (P. 899)

(90% Cu + 10% Al)

Thermal Diffusivity: $\longrightarrow$ $\alpha = \dfrac{\text{Thermal Conductivity } (k)}{\text{Heat Storage}}$

$C_p \rightarrow$ sp. heat

$(C_p)_{H_2O} = 4.18$ kJ/kg°c

$(C_p)_{IRON} = 0.45$ kJ/kg°c

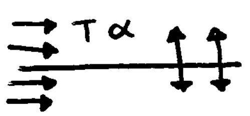
ρC_p = per unit volume

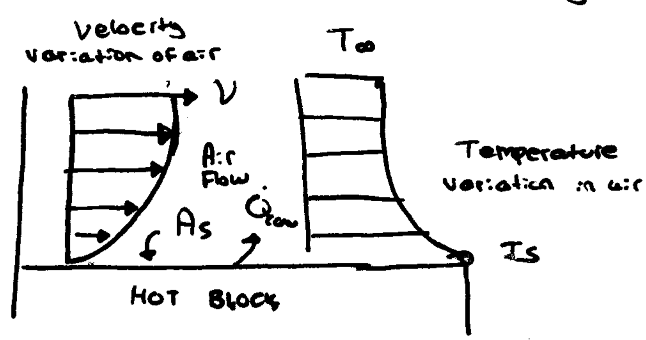
$= \dfrac{k}{\rho C_p}$ (m^2/s)

$= W/m \cdot K \times m^3/kg \times kJ \times kg K$

Convection:

$T_s > T_\alpha$





Newton's Law of Cooling

$$\boxed{\dot{Q}_{conv} = h A_s (T_s - T_\alpha)}$$

h → convective coefficient

$\dot{Q}_{conv.} \propto A_s$

$\dot{Q}_{conv.} \propto T_s - T_\alpha$

$h = W/m^2 \cdot K$ $W/m^2 \cdot K$

Free conv. of gases: 2-25

Free conv. of liquids: 10-1000

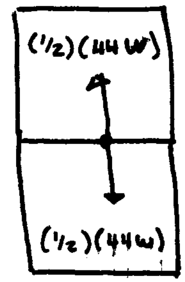
Forced conv. of gases: 25-250

Forced conv. of liquids: 50-20000

Boiling and Condensation: 2500 - 100000

Example 1-6 (From textbook):

$\dot{W}_{e,in} = \dot{Q}_{total} = VI$
$= (110\,V)(0.4\,A)$
$= 44\,W$



$\dot{Q} = 22\,W$

$$\dot{Q} = \frac{kA(T_1 - T_2)}{L}$$

$$\therefore\ k = \frac{\dot{Q} \times L}{A(T_1 - T_2)} \Rightarrow \frac{(22)(0.03)}{(\pi D^2/4)(15)} \qquad \therefore\ k = 22.4\ W/m\cdot K$$

$\Rightarrow D = 5\,cm = 0.05\,m$

Example 1-8 (From textbook):

$\dot{W}_e = \dot{Q} = VI$
$= (60\,V)(1.5\,A)$
$= 90\,W$

A_s (cylinder)
$2\pi r L$ or $\pi d L$
$\Rightarrow A_s = \pi(0.003)(2)$

$$\dot{Q}_{conv} = h A_s (T_s - T_\infty)$$

$$h = \frac{\dot{Q}_{conv}}{A_s(T_s - T_\infty)} \Rightarrow \frac{(90)}{(A_s)(152-15)} \Rightarrow 34.9\ W/m^2\,^\circ C$$

$\therefore$ ↓