CHAPTER-1 / Introduction

From thermodynamics you have gained the knowledge that there could be energy exchange between the system and the surroundings.

These energy exchanges are "work" and "heat".

Work → shaft work : closed & open systems : energy transferred across the boundary by a rotating shaft.
PV work : closed & open systems : occurs when the V of a system changes
flow work : open systems : work required to push the liquid/gas (fluid) into or out of the boundaries of a system.
electrical work

Before we begin heat transfer, there are 3 key questions to answer,

- What is heat transfer?
- How is heat transferred?
- Why is it important?

] Today we are gonna have answer to these 3 fundamental questions.

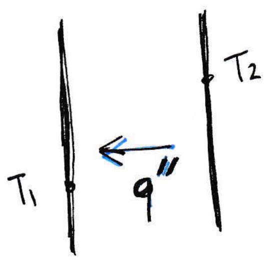
Heat transfer is the thermal energy transit due to a spatial (uzaysal) temperature difference. ΔT / temperature gradient

When there is a T difference between the system and the surroundings or at any two points within the system] Heat transfer will occur.

Modes of heat transfer

Conduction

When ΔT exists in a stationary medium which may be either solid or fluid (but not a gas) → molecular motion

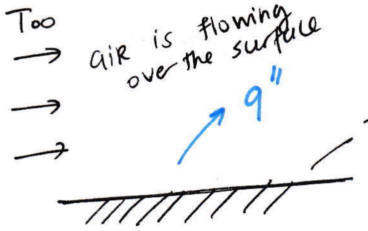


$$q'' = -k\frac{dT}{dx}$$

Convection

When ΔT exists in a moving fluid → bulk motion, macroscopic motion

$T_s > T_\infty$



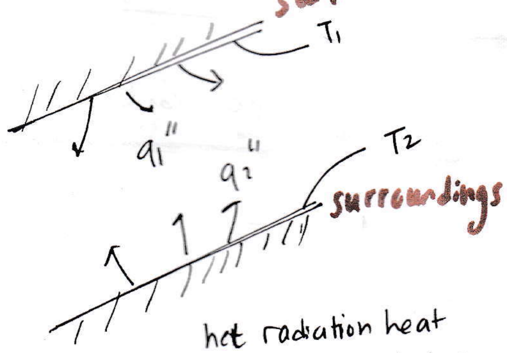
$$q'' = h(T_s - T_\infty)$$

↙ Natural convection: Flow is caused by ρ difference

↘ Forced convection: by external means, by a fan, pump, atmospheric winds

Radiation (thermal radiation)

all surfaces at finite temperature emit energy in the form of electromagnetic waves.



net radiation heat exchange between two surfaces.

Even in vacuum, there is thermal radiation.

$$q''_{rad} = \varepsilon\sigma(T_s^4 - T_{surr}^4)$$

Some common symbols used in heat transfer.

q : Heat transfer rate ($J/s \rightarrow W$)

q'' : Heat transfer rate per unit area (W/m^2)
↳ the area that is perpendicular to the direction of heat transfer.

q' : Heat transfer rate per unit length (W/m)

- There are some certain equations that are used to determine q'' for each mode of heat transfer

Conduction ⇒ $q''_{cond,x} = -k \dfrac{dT}{dx}$

$\dfrac{dT}{dx}$: temperature gradient in x-direction

(Heat transfer rate per unit area is proportional to the negative gradient of temperature)

k : thermal conductivity / conductivity of a material

How can these put in order?

$k_{solid} > k_{liquids} > k_{gases}$

- This is due to the difference in intermolecular spacing for the states of matter.

- a material that readily transfers energy by conduction is a good thermal conductor and has a high k.

- For most solids and liquids $k = f(T)$

k is a characteristic property of material (physical)

$$q_{cond,x} = -kA \frac{dT}{dx}$$

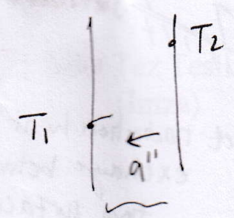
A: area perpendicular to the direction of heat transfer.

k ($W/m.K$)

The reason that we have a (−) sign is that heat transfer occurs in the direction of decreasing temperature.

Under steady-state conditions (accumulation = 0) (heat gen = 0), in which T distribution is linear with x-direction

$T_2 > T_1$



$$T = ax + b \qquad \frac{dT}{dx} \Longrightarrow \frac{T_1 - T_2}{L}$$

$$q''_x = -k \frac{T_1 - T_2}{L} = k \frac{T_2 - T_1}{L} = k \frac{\Delta T}{L}$$

$$\boxed{q''_x = k \frac{\Delta T}{L}}$$

Transfer Relation to Thermodynamics

The basic thing that you perform for thermodynamic problems is to establish energy balances ⇒ apply the 1st Law of thermodynamics for the system.

1st law provides a useful, often essential starting point for the solution of heat transfer problems.

Closed system: $\Delta U = Q + W_c$ (ΔU: accumulation; W_c: work exchange by volume variation.)

Open system: $\Delta \dot{H} = \dot{Q} + \dot{W}_s$ (at steady-state)

$$\dot{E}_{stored} = \dot{E}_{in} - \dot{E}_{out} + \dot{E}_g \quad \text{(For an open system)}$$

$$\dot{E}_{st} = \dot{Q} - W \quad \text{(For a closed system)}$$

$\dot{E}_{st}$: stored mechanical or thermal energy

E_g: generated " " "

E_{in}, E_{out}: mechanical / thermal energy that transports across the control surfaces.

Advice: Last but not the least, I want to recommend you to follow the book. Because reading a technical book in English is not just there on the lectures. extremely important for your engineering education.

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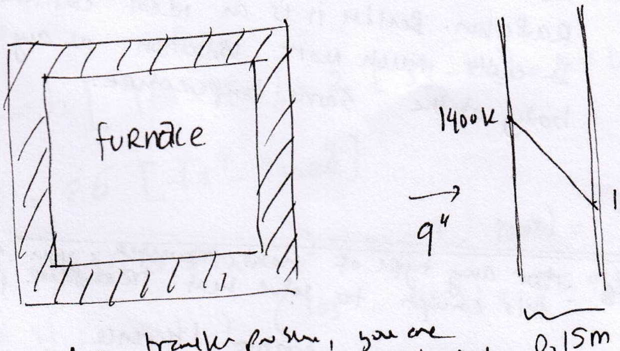
(1)

ex-1.1 from the book



$k = 1.7\ W/m \cdot K$

$q = ?$

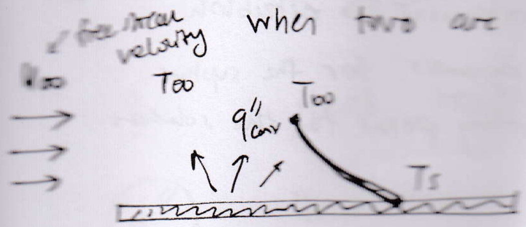
Wall has $0.5m \times 1.2m$ dimensions

to each heat transfer problem, you are required to start with the (assumptions)

↳

Convection occurs between a fluid in motion and a boundary surface when two are at different temperature

Convection is both sustain[ed by] random molecular motion an[d bulk] motion



$T_s > T_\infty$

Colder fluid approaches to a heated surface.

$$q''_{conv} = h\,[T_s - T_\infty] \quad \text{(Newton's law of cooling)}$$

h : Convective heat transfer coefficient. $h\ [W/m^2.K]$

physical feature of matter.

Unlike k, h is dependent on a few more factors.

Since fluid dynamics play a vital role in the analysis of convection:

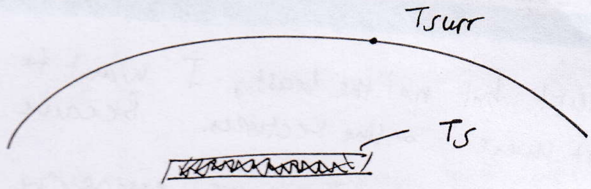
you may expect (h) being influenced by the surface geometry, nature of the fluid motion and fluid thermodynamic and transport properties.

Radiation (Thermal radiation)

emitted by matter at non-zero temperature.

the most effective medium for radiation is vacuum.

$$q''_{rad} = \varepsilon\, \sigma\, (T_s^4 - T_{surr}^4)$$



ε : emissivity : radiative property of the surface

$0 < \varepsilon \leq 1$

this property provides a measure of how efficiently a surface emits energy relative to a Blackbody.

Blackbody is an ideal radiator

σ : stefan - boltzman constant

$\sigma = 5.67 \times 10^{-8}\ W/m^2 K^4$

A blackbody is an idealized physical body that absorbs all incident electromagnetic Radiation. Besides it is an ideal emitter. It emits much more radiation as any other body at the same temperature.

The Concept of Resistances : for any type of heat transfer, you can use this concept to solve heat transfer problems.

$$q = q'' A \quad \frac{\Delta T}{R_T}$$

ΔT = is relevant temperature difference.

A : area normal [perpendicular] to the direction of heat transfer.

For conduction $q'' = k\,\dfrac{\Delta T}{L} \rightarrow q'' = \dfrac{\Delta T}{L/k}$

this is our equation for a linear T variation

$\dfrac{L}{k} = R_T$: resistance associated with the conduction

as $L \uparrow$ $R_T \uparrow$ → less heat transfer you will obtain

$k \uparrow$ $R_T \downarrow$ → more heat transfer you will obtain.