Dr. Mustafa B. Al-hadithi

First Lecture

Introduction to Heat Transfer

1- What is Heat Transfer?

"Energy in transit due to temperature difference."

Thermodynamics tells us:

- How much heat is transferred (δQ)
- How much work is done (δW)
- Final state of the system

Heat transfer tells us:

- How (with what modes) δQ is transferred
- At what rate δQ is transferred
- Temperature distribution inside the body

Heat transfer ⟷ complementary ⟷ Thermodynamics

2- Heat transfer Modes.

✓ Conduction
- needs matter
- molecular phenomenon (diffusion process)
- without bulk motion of matter

✓ Convection
- heat carried away by bulk motion of fluid
- needs fluid matter

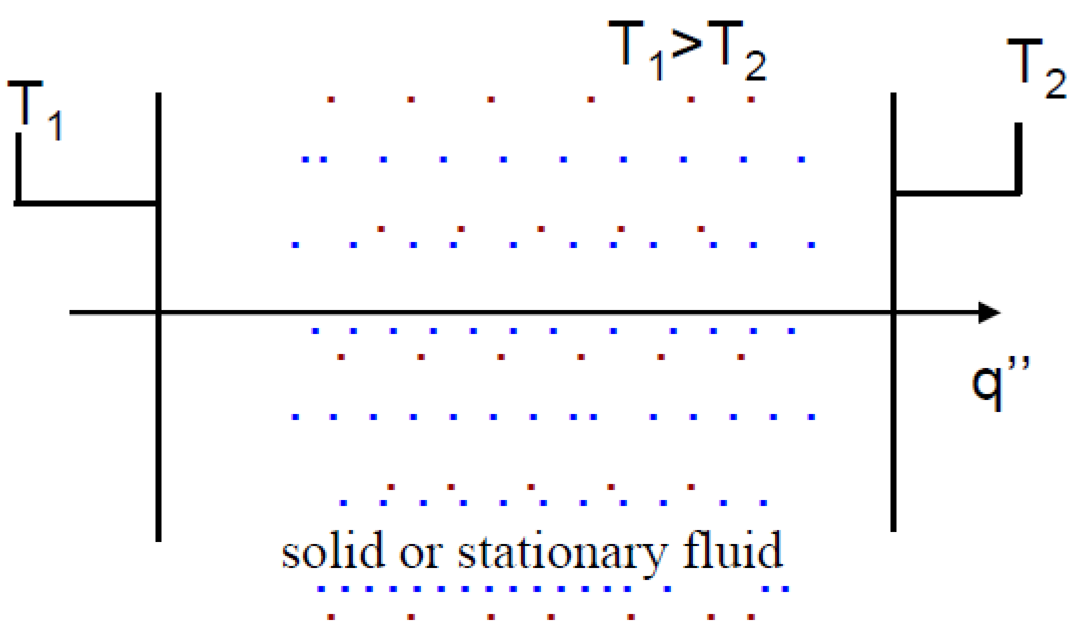
✓ Radiation
- does not needs matter
- transmission of energy by electromagnetic waves

3- Applications of Heat Transfer.

- ✓ Energy production and conversion
  - steam power plant, solar energy conversion etc.
- ✓ Refrigeration and air-conditioning
- ✓ Domestic applications
  - ovens, stoves, toaster
- ✓ Cooling of electronic equipment
- ✓ Manufacturing / materials processing
  - welding,casting, soldering, laser machining
- ✓ Automobiles / aircraft design
- ✓ Nature (weather, climate etc)

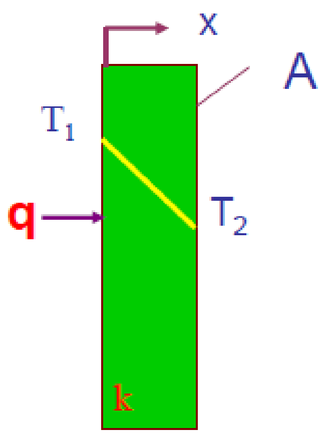
4- Heat Transfer by Conduction Mode.

In this mode type of heat transfer required (**Medium and Temperature Gradient**)



RATE:

q(W) or (J/s)   (heat flow per unit time)



Rate equations (1D conduction):

- Differential Form

  $q = - k\,A\,dT/dx$, W

  k = Thermal Conductivity, W/mK

  A = Cross-sectional Area, m^2

  T = Temperature, K or °C

  x = Heat flow path, m

- Difference Form

  $q = k\,A\,(T_1 - T_2) / (x_1 - x_2)$

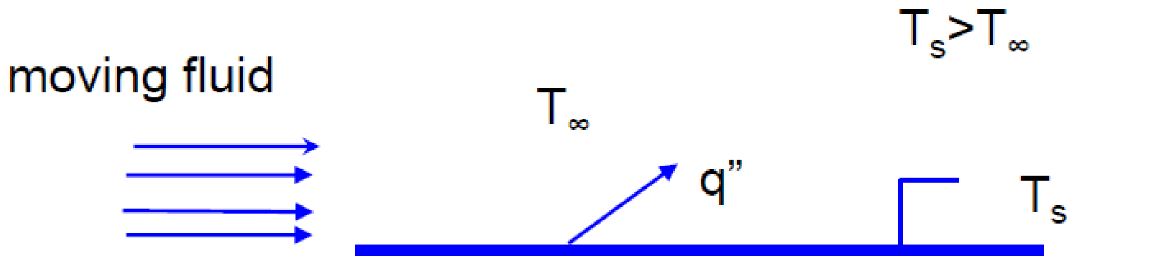
Heat flux: $q'' = q / A = - k\,dT/dx$ (W/m^2)

(negative sign denotes heat transfer in the direction of decreasing temperature)

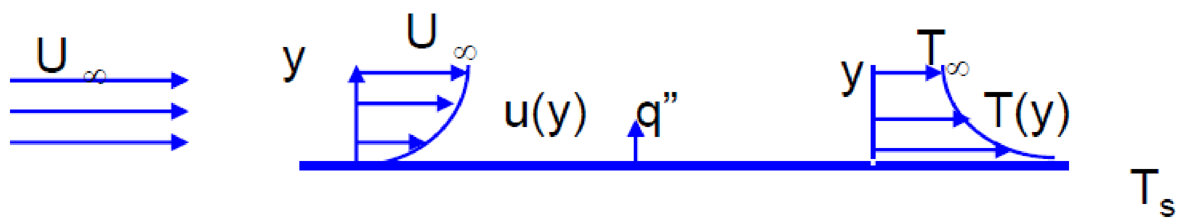
- Example:

The wall of an industrial furnace is constructed from 0.15 m thick fireclay brick having a thermal conductivity of 1.7 W/mK. Measurements made during steady state operation reveal temperatures of 1400 and 1150 K at the inner and outer surfaces, respectively. What is the rate of heat loss through a wall which is 0.5 m by 3 m on a side ?

5- Heat Transfer by Convection Mode.



❖ Energy transferred by diffusion + bulk motion of fluid

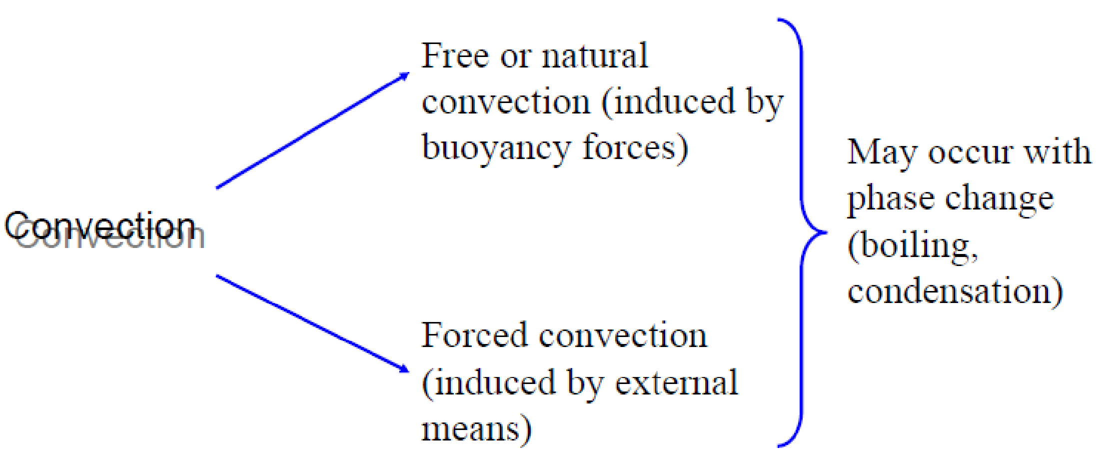


Heat transfer rate $q = hA(T_s - T_\infty)$ W

Heat flux $q'' = h(T_s - T_\infty)$ W / m^2

h=heat transfer co-efficient (W /m^{2}K)

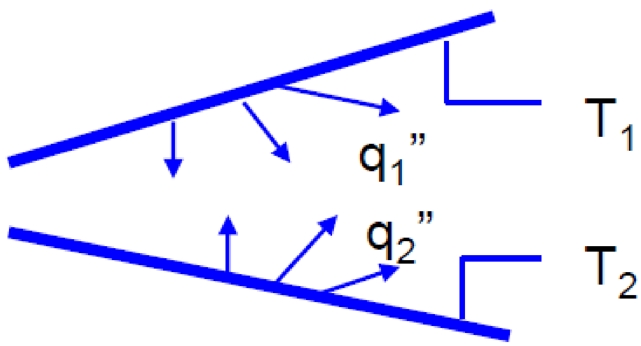
The properties depends on geometry, nature of flow, thermodynamics properties etc.



Typical values of h (W/m^2K)

Free convection	gases: 2 - 25
	liquid: 50 - 100
Forced convection	gases: 25 - 250
	liquid: 50 - 20,000
Boiling/Condensation	2500 -100,000

6- Heat Transfer by Radiation Mode.



RATE:

q(W) or (J/s) Heat flow per unit time.

Flux : q'' (W/m^2)

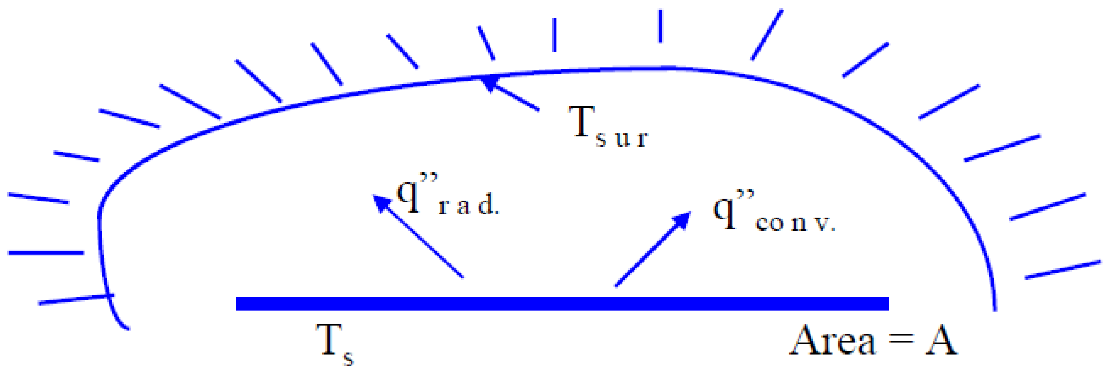
Heat Transfer by electro-magnetic waves or photons(no medium required.)

Emissive power of a surface (energy released per unit area):

$$E=\varepsilon\sigma T_s^4 \ (W/\ m^2)$$

ε= emissivity (property)………

σ=Stefan-Boltzmann constant



Radiation exchange between a large surface and surrounding

$$Q''_{rad} = \varepsilon\sigma(T_s^4 - T_{sur}^4)\ W/\ m^2$$

- **Example:**

An uninsulated steam pipe passes through a room in which the air and walls are at 25 °C. The outside diameter of pipe is 70 mm, and its surface temperature and emissivity are 200 °C and 0.8, respectively. If the coefficient associated with free convection heat transfer from the surface to the air is 5 W/m²K, what is the rate of heat loss from the surface per unit length of pipe ?