HEAT and MASS TRANSFER

Introductory Concepts and Definitions

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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

MODES:

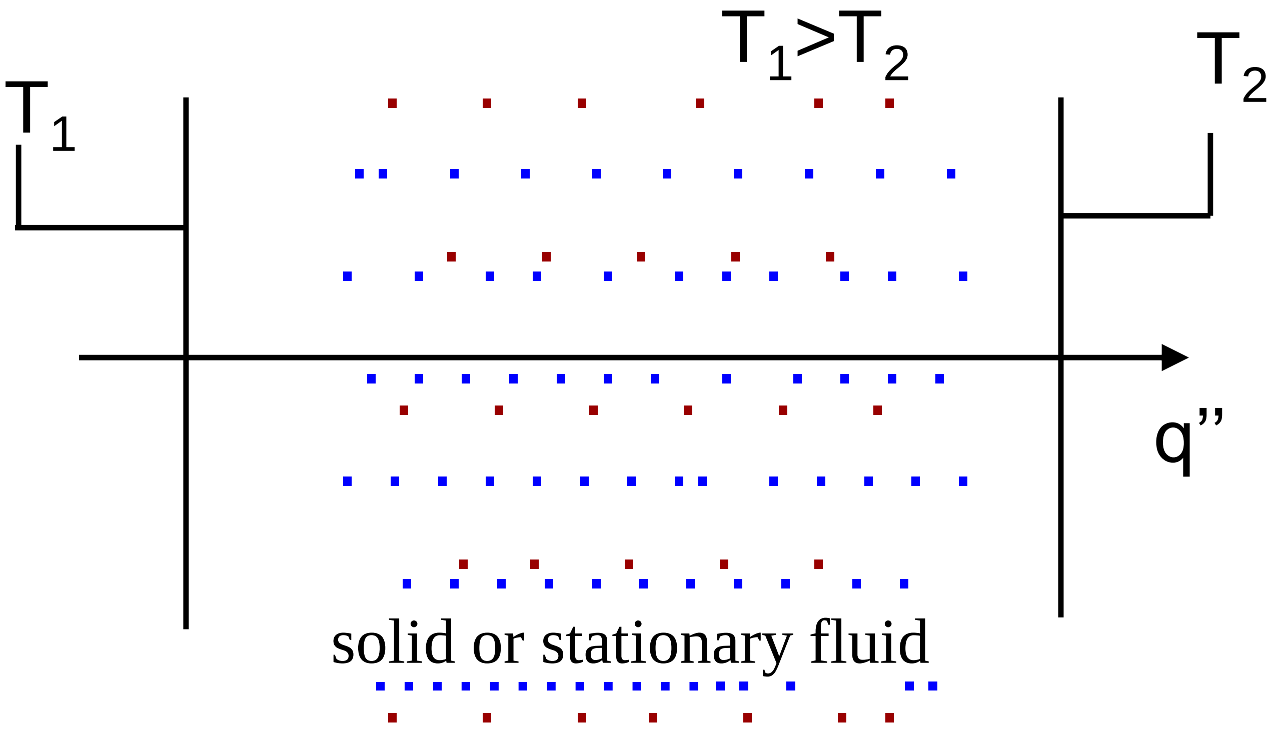
- ✓ Conduction
  - needs matter
  - molecular phenomenon (diffusion process)
  - without bulk motion of matter
- ✓Convection
  - heat carried away by bulk motion of fluid
  - needs fluid matter
- ✓Radiation
  - does not needs matter
  - transmission of energy by electromagnetic waves

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)

CONDUCTION

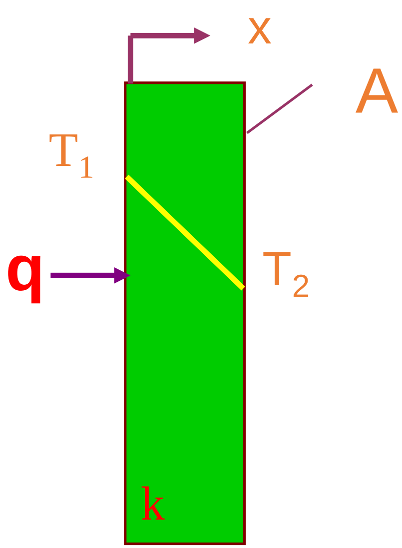
(Needs medium, Temperature gradient)



RATE:

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

Conduction (contd…)



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 ^oC

  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)

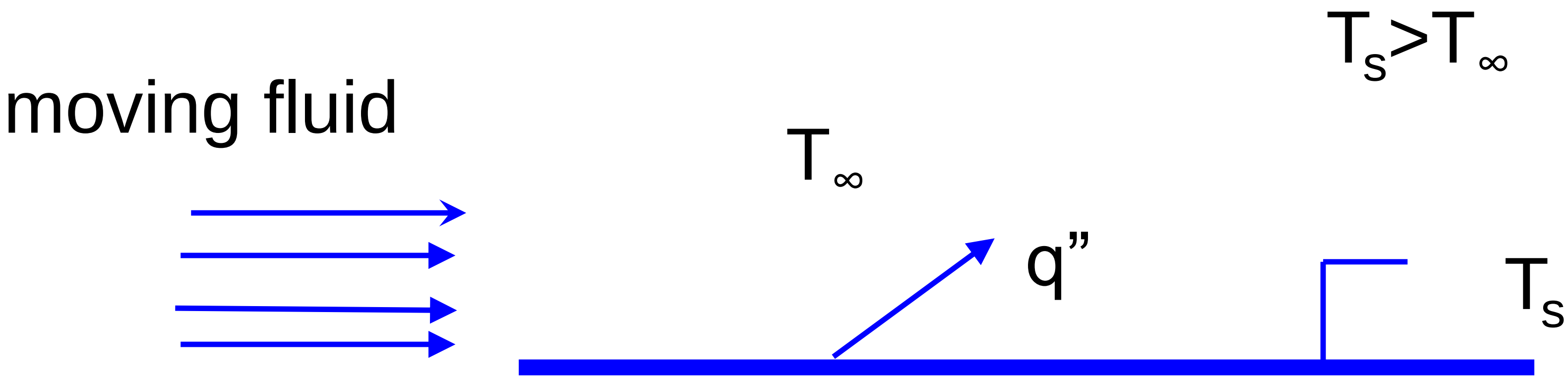
(negative sign denotes heat transfer in the direction of decreasing temperature)

Conduction (contd…)

- Example:

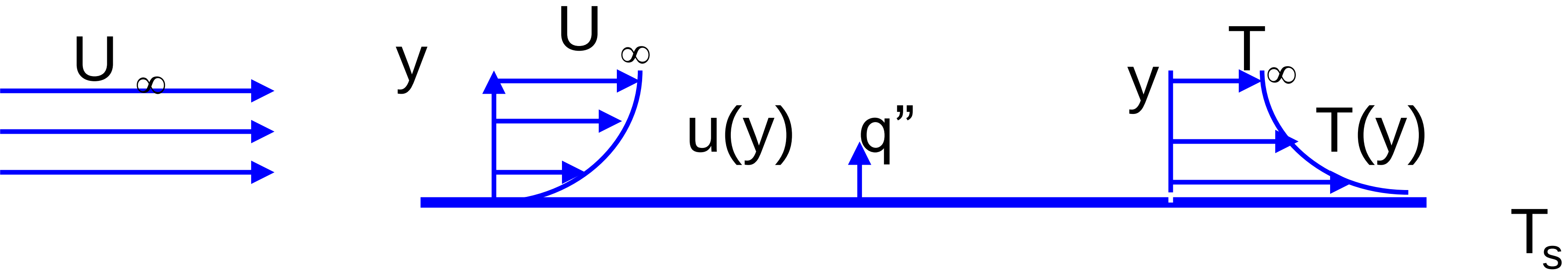
The wall of an industrial furnace is constructed from 0.2 m thick fireclay brick having a thermal conductivity of 2.0 W/mK. Measurements made during steady state operation reveal temperatures of 1500 and 1250 K at the inner and outer surfaces, respectively. What is the rate of heat loss through a wall which is 0.5 m by 4 m on a side ?

CONVECTION



❖ Energy transferred by diffusion + bulk motion of fluid

Rate equation (convection)



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^2K)

(not a property) depends on geometry ,nature of flow, thermodynamics properties etc.

Convection (contd…)

Convection

- Free or natural convection (induced by buoyancy forces)
- Forced convection (induced by external means)

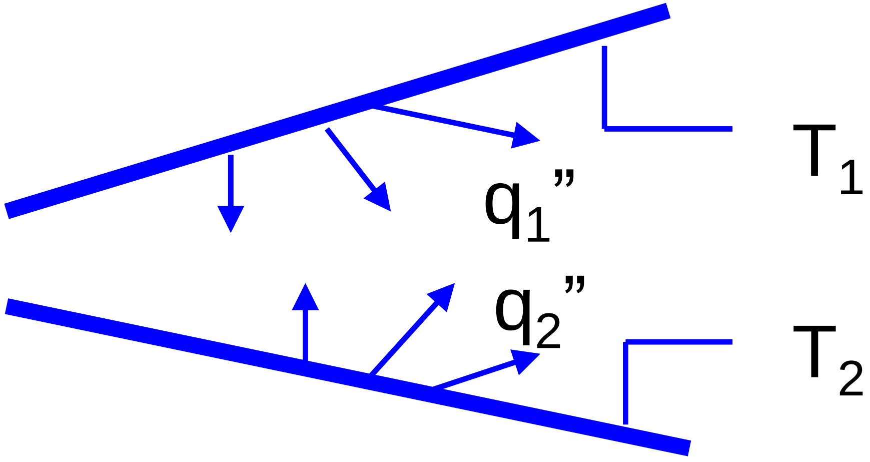
May occur with phase change (boiling, condensation)

Convection (contd…)

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

RADIATION



RATE:

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

Flux : q" (W/m^2)

Rate equations (Radiation)

RADIATION:

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

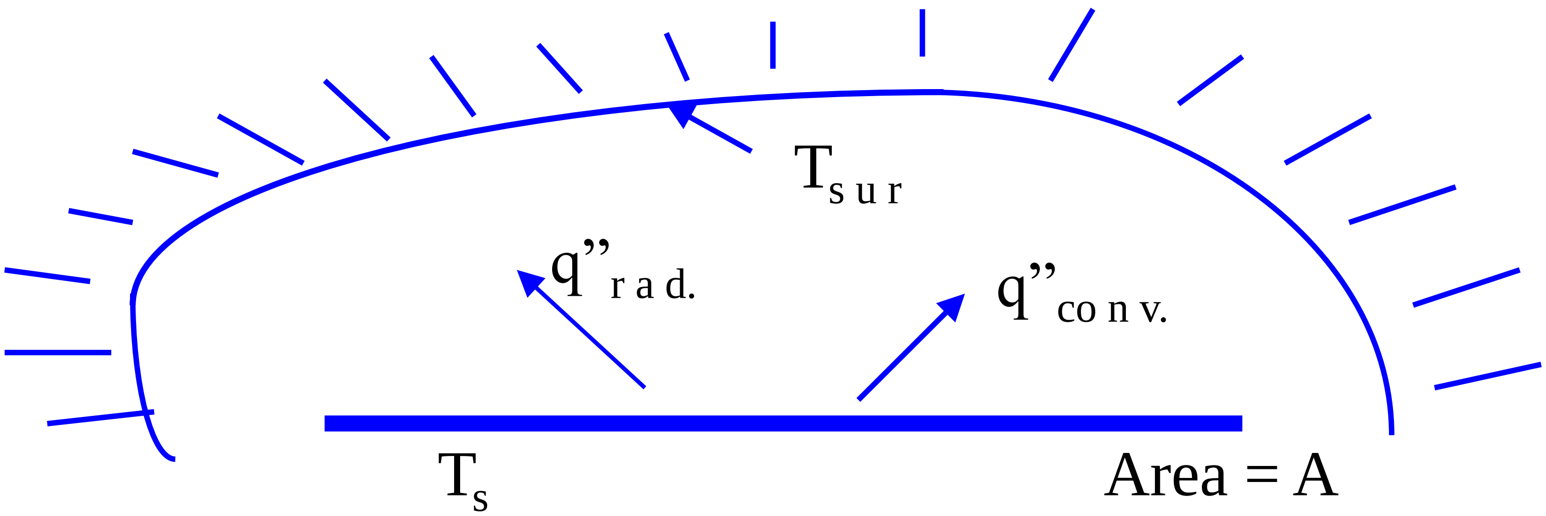
Emissive power of a surface (energy released per unit area):

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

ε= emissivity (property)………

σ=Stefan-Boltzmann constant

Rate equations (Contd….)



Radiation exchange between a large surface and surrounding

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

Radiation (contd…)

❑ **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 80 mm, and its surface temperature and emissivity are 180°C and 0.85, respectively. If the free convection coefficient from the surface to the air is 6 W/m^2K, what is the rate of heat loss from the surface per unit length of pipe ?