Heat Transfer:

Physical process by which thermal energy is exchanged between material bodies or inside the same body as a result of a temperature difference.

- It explains how energy is transferred.
- Also, how fast this exchange is taking place (i.e. it determines the heat-transfer rate).
- It supplements the thermodynamics by providing additional information about the energy transfer under non-equilibrium condition.

Conduction

Energy transfer from the high-temperature region to the lowtemperature region due to thermal diffusion process. It can take place in solids, liquids and gases. The Fourier's law states that the rate at which heat is conducted through a body per unit crosssectional area is proportional negatively to the temperature gradient existing in the body. 1(dQ) = dT

$$\frac{1}{A} \left(\frac{dQ}{dt} \right) = -k \frac{dT}{dx}$$

where k is the thermal conductivity (W m/ °C) and dT/dx is the local temperature gradient, dQ/dt is the rate of heat transfer (W), A is the cross-sectional area (m^2).

Minus sign indicates that the energy flow in the direction of decreasing temperature.



therefore, heat transfer at section 2 is higher than that at section 1.

Temperature Distribution (cont.)

• If there is no heat generation or removal, can the temperature inside the block stays constant? If not, what do you think the temperature at the interface will vary? Increase or decrease?

Energy conservation:

Energy accumulation = energy in -energy out If the energy is flowing out faster than it is flowing in, the total energy inside the block will decrease. Therefore, the energy and, accordingly, the temperature will decrease.

Steady Conduction

• If temperatures at both surfaces of the block are kept constant, what do you think the temperature distribution inside the block will be after a long period of time?

Given time, it is expected that the temperature distribution inside the block will no longer change with time. Based on the previous argument, the energy in and out should exactly balanced.

Therefore, the temperature profile

should have a constant slope, that is, it has a linear distribution.



Convection

This process of heat transfer from a solid surface to a moving liquid or gas is called convection. The motion of the fluid may be natural (driven by the heated or cooled solid) or forced (driven by external means such as a fan or a pump). The empirical equation governing the convective heat rate is often referred to as the Newton's law of cooling:

$$q = \frac{dQ}{dt} = \overline{h}A_s(T_s - T_\infty)$$

where the heat is transferred between a surface at uniform temperature T_s and a fluid with reference temperature of T_{∞} , A_s is the surface area, and is the mean coefficient of convection heat transfer; the unit for is W/(m² ° C).

Convection (cont.)



Isotherm generated by the natural convective flow from a heated cylinder, visualized using Interferometry

Convective process is accomplished in two stages: first, heat transfer from solid to fluid through diffusion process adjacent to the surface. Second, the bulk fluid motion will carry transferred heat away from surface. Therefore, the

conductivity of the fluid plays an important role in heat convection. It is necessary to study fluid mechanics in order to understand fully the flow aspect of heat convection.



 $q_{laminar} < q_{turbulent}$ Turbulent flow is unsteady and random in nature \Rightarrow more mixing \Rightarrow enhanced heat transfer