CHAPTER SIXTEEN

MECHANISMS OF HEAT TRANSFER

Heat
The form of energy that can be transferred from one system to another as a result of temperature difference

Difference Between Thermodynamics and Heat Transfer
- Thermodynamic analysis is concerned with the amount of heat transfer as a system undergoes a process from one equilibrium state to another
- Heat transfer deals with the determination of the rate of energy transfer

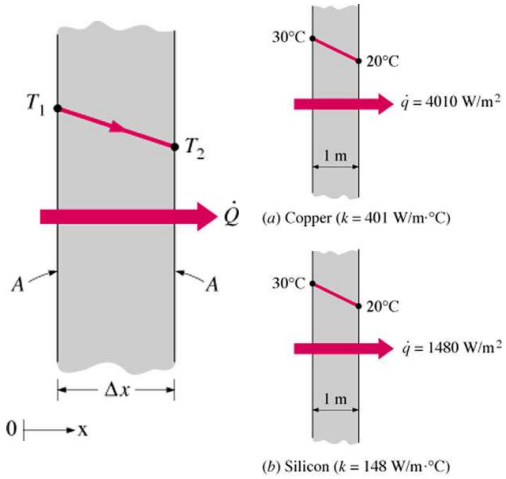
Modes of Heat Transfer
- Conduction
- Convection
- Radiation

Conduction
- It is the transfer of energy from the more energetic particles of a substance to the adjacent less energetic ones as a result of interactions between the particles
- Rate of heat conduction $\propto \dfrac{(\text{Area})(\text{Temperature difference})}{\text{Thickness}}$

  or

  $\dot{Q}_{\text{cond}} = kA\dfrac{\Delta T}{\Delta x}$, $\dot{Q}_{\text{cond}} = -kA\dfrac{dT}{dx}$, where k is the thermal conductivity

  This is called the **Fourier's law of heat conduction**.

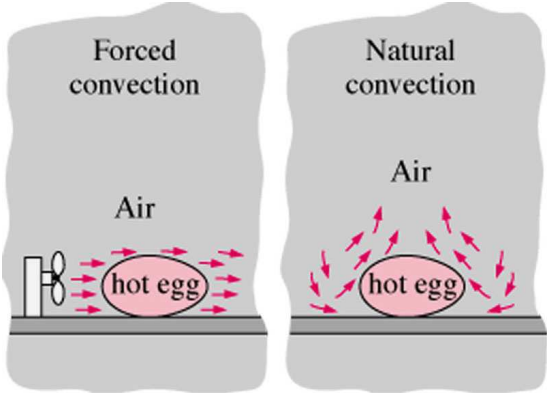


Thermal Conductivity (k)
- It is a measure of a material's ability to conduct heat

Convection
- Convection is the mode of energy transfer between a solid surface and the adjacent liquid or gas
- The faster the fluid motion, the greater the convection heat transfer
- Without any motion, convection disappears

Forced Convection
When the fluid is forced to flow over the surface by external means (e.g. pump, fan, wind)

Natural (Free) Convection
When the fluid motion is caused by buoyancy forces that are induced by density differences due to the variation of temperature in the fluid



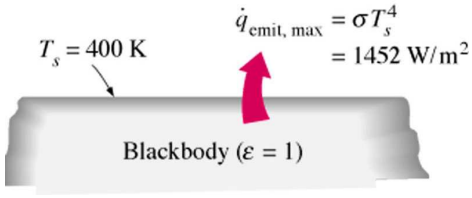
Newton's Law of Cooling

$$\dot{Q}_{\text{conv}} = hA(T_s - T_\infty)$$

where h is the convection heat transfer coefficient, T_s is the surface temperature, and T_∞ is the temperature of the fluid sufficiently far from the surface

Radiation

- Radiation is the energy emitted by matter in the form of electromagnetic waves (or photons) as a result of the changes in the electronic configurations of the atoms or molecules
- Transfer of heat by radiation does not require a medium
- The **maximum** rate of radiation that can be emitted from a surface at an absolute pressure T_s is given by the **Stefan-Boltzmann law** as:
  $\dot{Q}_{\text{emit,max}} = \sigma A T_s^4$
  where σ is called the Stefan-Boltzmann constant
- A surface that can emit this amount of radiation is called a **blackbody**
- The radiation emitted by all real surfaces is less than blackbody radiation and is expressed as:
  $\dot{Q}_{\text{emit}} = \varepsilon\sigma A T_s^4$
  where ε is called **emissivity**



Radiation Heat Transfer Between a Surface and the Surrounding Surfaces

When a surface of emissivity ε and the surface area A at an absolute temperature T_s is completely enclosed by a gas that does not intervene with radiation, the net rate of radiation heat transfer between those two surfaces is given by:

$$\dot{Q}_{\text{rad}} = \varepsilon\sigma A(T_s^4 - T_{\text{surr}}^4)$$