RAMA UNIVERSITY

www.ramauniversity.ac.in

FACULTY OF ENGINEERING AND TECHNOLOGY

Department of Mechanical Engineering

BME504:Heat and Mass Transfer

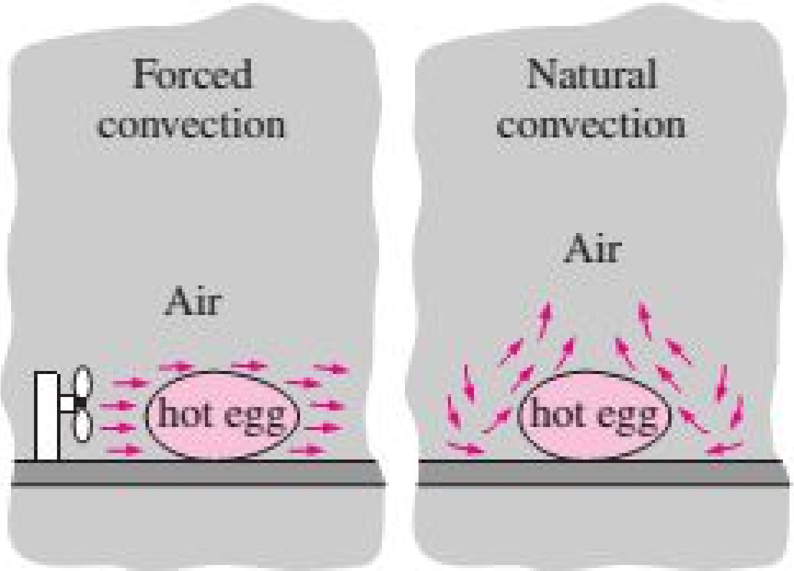
Lecture 3

Instructor:

Aditya Veer Gautam

CONVECTION

- Convection heat transfer involves both energy transfer due to random molecular motions and by bulk motion of the fluid molecular motions and by bulk motion of the fluid
  - Convection heat transfer includes both forced convection and natural convection



CONVECTION

- The rate of convection heat transfer is observed to be proportional to the temperature difference, and is conveniently expressed by **Newton's law of cooling** as $\dot{Q}_{conv} = hA_s(T_s - T_\infty)$

- Where ***h*** is the convection heat transfer coefficient in ***A*** is the surface area through which convection heat transfer takes place, $\boldsymbol{T_s}$ is the surface temperature, and $\boldsymbol{T_\infty}$ is the temperature of the fluid sufficiently far from the surface. Note that at the surface, the fluid temperature equals the surface temperature of the solid

- The convection heat transfer coefficient h is not a property of the fluid

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.
  - Does not require the presence of an intervening medium.
  - Fastest (at the speed of light)
  - No attenuation in a vacuum
  - Volumetric phenomenon, but considered to be a surface phenomenon for solids that are opaque
  - **Stefan–Boltzmann law**

$$\dot{Q}_{\text{emit, max}} = \sigma A_s T_s^4$$

  - Where σ = 5.67×10^{-8} W/m^2K^4 is called Stefan–Boltzmann constant.

SIMULTANEOUS HEAT TRANSFER MECHANISMS

- Three mechanisms of heat transfer, but not all three can exist simultaneously in a medium.
  - Opaque solids – only conduction
  - Semitransparent solid – conduction + radiation
  - Still fluid – conduction + radiation
  - Flowing Fluid – convection + radiation
  - Vacuum – only radiation

Questions

Q1 The hot water needs of a household are met by an electric 60-L hot water tank equipped with a 1.6-kW heating element. The tank is initially filled with hot water at 80°C, and the cold water temperature is 20°C. Someone takes a shower by mixing constant flow rates of hot and cold waters. After a showering period of 8 minutes, the average water temperature in the tank is measured to be 60°C. The heater is kept on during the shower and hot water is replaced by cold water. If the cold water is mixed with the hot water stream at a rate of 0.06 kg/s, determine the flow rate of hot water and the average temperature of mixed water used during the shower.

Q2 Engine valves (Cp 440 J/kg °C and 7840 kg/m3) are to be heated from 40°C to 800°C in 5 minutes in the heat treatment section of a valve manufacturing facility. The valves have a cylindrical stem with a diameter of 8 mm and a length of 10 cm. The valve head and the stem may be assumed to be of equal surface area, with a total mass of 0.0788 kg. For a single valve, determine (a) the amount of heat transfer, (b) the average rate of heat transfer, and (c) the average heat flux, (d) the number of valves that can be heat treated per day if the heating section can hold 25 valves, and it is used 10 hours per day.

Questions

Q3 Consider a 3-m X 3-m X 3-m cubical furnace whose top and side surfaces closely approximate black surfaces at a temperature of 1200 K. The base surface has an emissivity of $\epsilon = 0.7$, and is maintained at 800 K. Determine the net rate of radiation heat transfer to the base surface from the top and side surfaces.

Q4 A 4-m x 5-m x 6-m room is to be heated by one ton (1000 kg) of liquid water contained in a tank placed in the room. The room is losing heat to the outside at an average rate of 10,000 kJ/h. The room is initially at 20°C and 100 kPa, and is maintained at an average temperature of 20°C at all times. If the hot water is to meet the heating requirements of this room for a 24-hour period, determine the minimum temperature of the water when it is first brought into the room. Assume constant specific heats for both air and water at room temperature.

Questions

Q5 A passive solar house that is losing heat to the out-doors at an average rate of 50,000 kJ/h is maintained at 22°C at all times during a winter night for 10 hours. The house is to be heated by 50 glass containers each containing 20 L of water heated to 80°C during the day by absorbing solar energy. A thermostat-controlled 15-kW back-up electric resistance heater turns on whenever necessary to keep the house at 22°C. (a) How long did the electric heating system run that night? (b) How long would the electric heater have run that night if the house incorporated no solar heating?