RAMA UNIVERSITY

www.ramauniversity.ac.in

FACULTY OF ENGINEERING AND TECHNOLOGY

Department of Mechanical Engineering

BME504:Heat and Mass Transfer

Lecture 2

Instructor:
Aditya Veer Gautam

Fourier's Law

$$\dot{Q}_{\text{cond}} = kA\frac{T_1 - T_2}{\Delta x} = -kA\frac{\Delta T}{\Delta x}$$

- In limiting case of Δx →0

$$\dot{Q}_{\text{cond}} = -kA\frac{dT}{dx}$$

- The negative sign in Eq. ensures that heat transfer in the positive x direction is a positive quantity.
- The heat transfer area A is always normal to the direction of heat transfer
- **k is Thermal Conductivity, Units W/m·K or W/m.°C**

Thermal Conductivity

- ✓ *Thermal conductivity of a material can be defined as the rate of heat transfer through a unit thickness of the material per unit area per unit temperature difference.*
- ✓ The thermal conductivity of a material is a measure of the ability of the material to conduct heat. A high value for thermal conductivity indicates that the material is a good heat conductor, and a low value indicates that the material is a poor heat conductor or insulator. For example, k = 0.608 W/m·°C for water and k = 80.2 W/m·°C for iron at room temperature, which indicates that iron conducts heat more than 100 times faster than Water can.
- ✓ The thermal conductivities of gases such as air vary by a factor of 10^4 from those of pure metals such as copper.

Thermal Conductivity

- ✓ Note that pure crystals and metals have the highest thermal conductivities and gases and conductivities, and gases and insulating materials the lowest.
- ✓ The thermal conductivity of a substance is normally highest in the solid phase and lowest normally highest in the solid phase and lowest in the gas phase.
- ✓ Unlike gases, the thermal conductivities of most liquids **decrease with increasing temperature**, with water being a notable exception

Thermal Conductivity

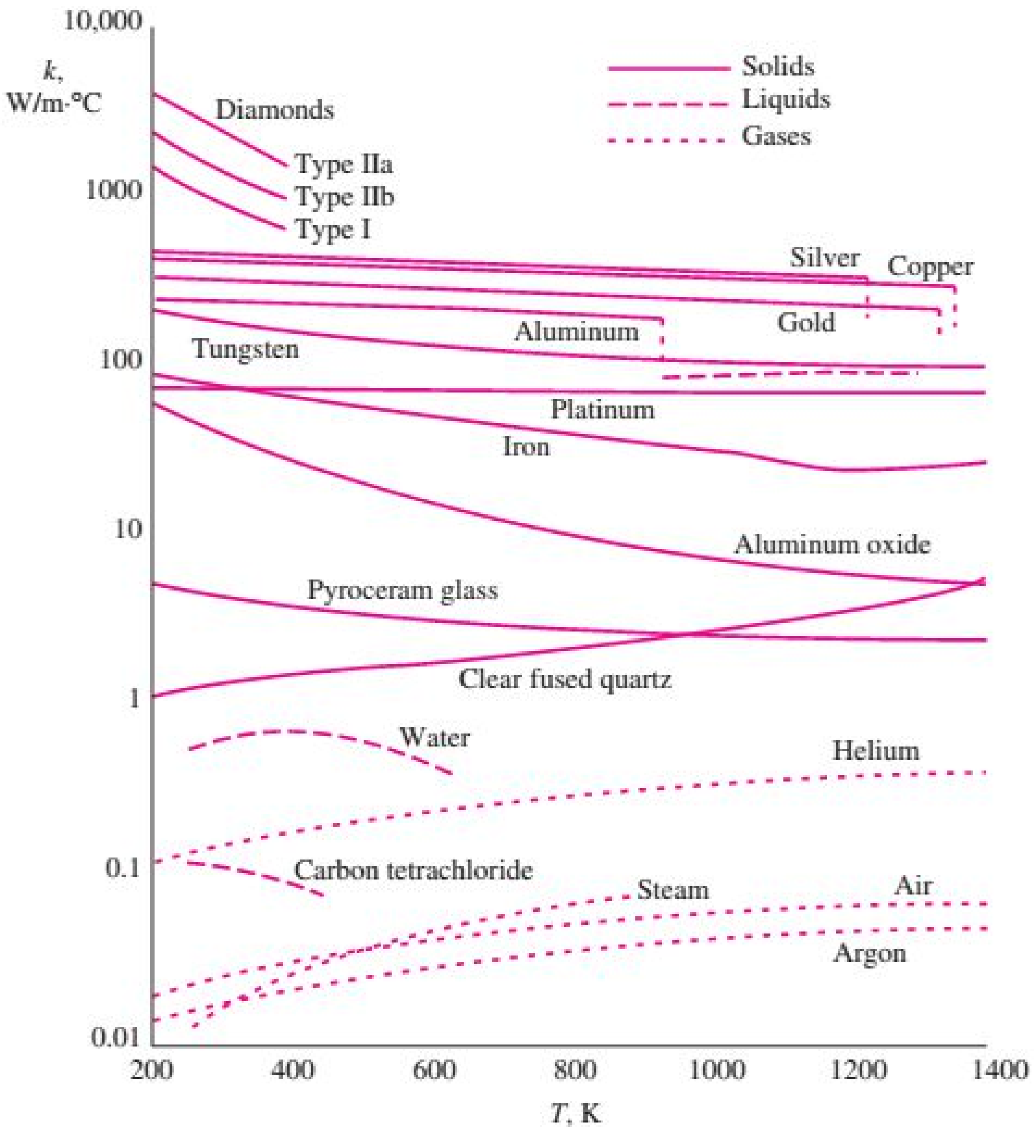
- In solids, heat conduction is due to two effects: the **lattice vibrational** waves induced by the vibrational motions of the molecules positioned at relatively fixed positions in a periodic manner called a lattice, and the energy transported via the free flow of energy transported via the **free flow of electrons** in the solid.
  - The thermal conductivity of a solid is obtained by adding the lattice and electronic components the relatively high thermal conductivities and electronic components. The relatively high thermal conductivities of pure metals are primarily due to the electronic component.

Thermal Conductivity

- ✓The lattice component of thermal conductivity strongly depends on The lattice component of thermal conductivity strongly depends on the way the molecules are arranged

- ✓Unlike metals, which are good electrical and heat conductors, crystalline solids such as diamond and semiconductors such as silicon are good heat conductors but poor electrical conductors. As a result, such materials find widespread use in the electronics industry. Despite their higher price, diamond heat sinks are used in the cooling of sensitive electronic components because of the excellent thermal conductivity of diamond. Silicon oils and gaskets are commonly used in the packaging of electronic components because they provide both good thermal contact and good electrical insulation

Thermal Conductivity



Thermal Diffusivity

- **Thermal Diffusivity:** Material property that appears in the transient heat conduction analysis is the thermal diffusivity, which represents how fast heat diffuses through a material and is defined as

$$\alpha = \frac{\text{Heat conducted}}{\text{Heat stored}} = \frac{k}{\rho C_p}$$

  - The product ρC_p, which is frequently encountered in heat transfer analysis, is called the heat capacity of a material
  - The larger the thermal diffusivity, the faster the propagation of heat into the medium. A small value of thermal diffusivity means that heat is mostly absorbed by the material and a small amount of heat will be conducted further.

Questions

Q1 Two surfaces of a 2-cm-thick plate are maintained at 0°C and 80°C, respectively. If it is determined that heat is transferred through the plate at a rate of 500 W/m2, determine its thermal conductivity

Q2 A 0.3-cm-thick, 12-cm-high, and 18-cm-long circuit board houses 80 closely spaced logic chips on one side, each dissipating 0.06 W. The board is impregnated with copper fillings and has an effective thermal conductivity of 16 W/m · °C. All the heat generated in the chips is conducted across the circuit board and is dissipated from the back side of the board to the ambient air. Determine the temperature difference between the two sides of the circuit board.

Q3 We often turn the fan on in summer to help us cool. Explain how a fan makes us feel cooler in the summer. Also explain why some people use ceiling fans also in winter.

Questions

Q4 Consider a person standing in a room at 23°C. Deter-mine the total rate of heat transfer from this person if the ex-posed surface area and the skin temperature of the person are 1.7 m2 and 32°C, respectively, and the convection heat transfer coefficient is 5 W/m2 · °C. Take the emissivity of the skin and the clothes to be 0.9, and assume the temperature of the inner surfaces of the room to be the same as the air temperature.

Q5 Consider steady heat transfer between two large parallel plates at constant temperatures of T1 = 290 K and T2 = 150 K that are L = 2 cm apart. Assuming the surfaces to be black (emissivity = 1), determine the rate of heat transfer between the plates per unit surface area assuming the gap between the plates is (a) filled with atmospheric air, (b) evacuated, (c) filled with fiberglass insulation, and (d) filled with superinsulation having an apparent thermal conductivity of 0.00015 W/m · °C.