FDE 208 HEAT TRANSFER AND THERMAL PROCESSES

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HEAT TRANSFER BY CONDUCTION

- Conduction is the transfer of heat through the adjacent molecules from the more energetic to the less energetic particles of a substance.
- When the medium is stationary , conduction is the valid form of heat transfer.
  - Mostly valid for solids but it also occurs in liquids and gases.

Conduction is the transfer of heat within a substance, molecule by molecule. If you put one end of a metal rod over a fire, that end will absorb the energy from the flame. The molecules at this end of the rod will gain energy and begin to vibrate faster. As they do their temperature increases and they begin to bump into the molecules next to them. The heat is being transferred from the warm end to the cold end.

FOURIER'S LAW OF HEAT CONDUCTION

- As mentioned in fluid mechanics course, the rate of a transfer process (momentum transfer, heat transfer and mass transfer) is shown by the same general type of equation

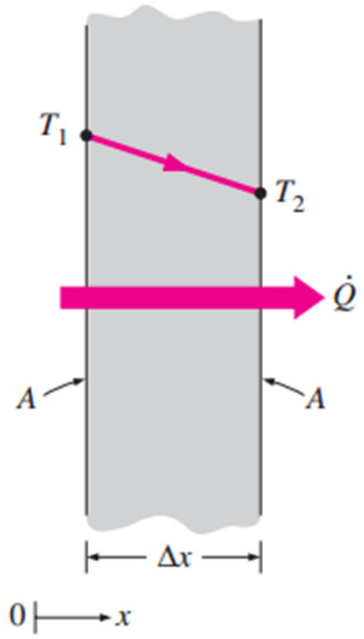
- The basic equation:

$$RATE = \frac{Driving\ Force}{Resistance}$$

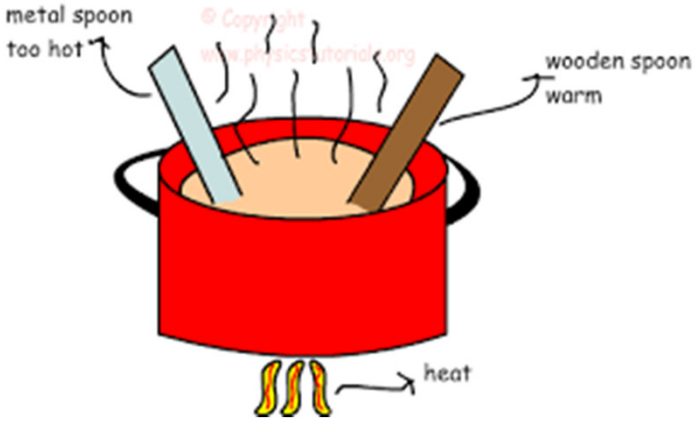
- In order to transfer a property (momentum, heat or mass) we need a driving force to overcome a resistance.
- In heat transfer the driving force is the temperature difference.

FOURIER'S LAW OF HEAT CONDUCTION

- Consider steady-state heat transfer through a large wall.
  - Temperature difference on the left and right hand side of the wall.
  - Driving force = T2-T1=ΔT
  - Wall thickness will pose a resistance to heat transfer.
  - Increasing surface area will decrease the heat transfer resistance.
  - Thermal conductivity (k) of the wall will also affect the heat transfer rate.



- Thermal conductivity (k) is a physical property related to the ability of a material to conduct heat.
- If thermal conductivty is high, material is a good conductor, if it is low, the material is a good insulator.
  - Wooden spoon is better choice than metal spoon for stirring hot soup, since wood is not a good conductor of heat.



- If Thermal conductivity increases, resistance to heat transfer will decrease.

- $RESISTANCE = \frac{\Delta x}{kA}$

- $RATE = \frac{DRIVING\ FORCE}{RESISTANCE}$

If the heat transfer rate is positive, heat is flowing in the positive x-direction

- $RATEOF\ HEAT\ TRANSFER\ (\dot{Q}) \dot{=} -\frac{\Delta T}{\frac{\Delta x}{kA}} = -kA\frac{\Delta T}{\Delta x}$

Q: rate of heat transfer (W) or (J/s)
K: thermal conductivity (W/mK)
A: area perpendicular to heat flow (m2)
ΔT: temperature difference (K)
Δx: thickness of the wall (m)

- Flux: Rate/ Area
- Heat flux: $\dot{q} = -k\frac{\Delta T}{\Delta x}$
- In differential form: $\dot{q} = -k\frac{dT}{dx}$ (Fourier's Law of Heat Conduction)

- Example 13.3

Let's say you are in the hut in an island in a rather cold climate. The hut is 2X2X2 m in geometry. The walls are made of wood of thickness 2 cm. The temperature at the inner and outer surface of the wall are kept at 18 and 5 °C, respectively. The thermal conductivity of the wood may be assumed constant as 0.16 W/mK

a) Rate of heat loss through the walls?

b) How much energy will be lost from the walls of the hut for a period of 10h?

THERMAL CONDUCTIVITY

- Ability to conduct heat (W/mK)
- k (solids)>k (liquids)>k (gases)
- For gases:
  - $k \propto \sqrt{T}$ (Thermal conductivity increases with temperature and is independent of pressure up to a few atm.
- For liquids:
  - $k = a + bT$ (The thermal conductivity of liquids varies moderately with temperature and often can be expressed as a linear variation.)(a and b are constants)(k is independent of pressure for liquids.)
- For solids:
  - Varies quite widely.
  - copper and silver that are good electric conductors are also good heat conductors, and have high values of thermal conductivity.
  - Materials such as rubber, wood, and Styrofoam are poor conductors of heat and have low conductivity values.

THERMAL CONDUCTIVITY

The thermal conductivities of some materials at room temperature

Material	k, W/m · °C*
Diamond	2300
Silver	429
Copper	401
Gold	317
Aluminum	237
Iron	80.2
Mercury (l)	8.54
Glass	0.78
Brick	0.72
Water (l)	0.607
Human skin	0.37
Wood (oak)	0.17