Welcome to ME 516: Macroscale Heat Transfer

→ Open Website & Read intro

→ Open Syllabus & Read

☆ So what is Heat Transfer besides redundant?

<u>Heat</u>: is the transfer of energy due to a temperature gradient.

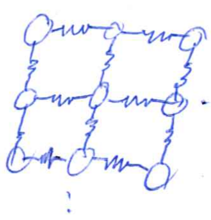
→ <u>Conduction</u>: occurs due to the interaction of micro-scale energy carriers

→ <u>Convection</u>: occurs when conduction happens to a medium that is flowing or free to move.

→ <u>Radiation</u>: occurs when electromagnetic waves (e.g. light) transfers

Principle Microscale Energy Carriers

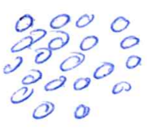
<u>Solid</u>



<u>Mechanisms</u>

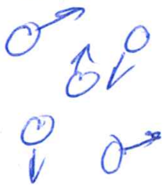
1) Electron/Hole transport (Thermo-electric generators)
2) Phonon (Lattice Vibrations)
3) Radiation (EM waves/photons)

<u>Liquid</u>



4) Fluid particle translation, vibration, rotation, electron
5) Random Collisions

<u>Gas</u>



☆ When the distance between microscale carrier interaction (L_{mfp}) is much less than the length scale (L) that matters

$K_n = \frac{L_{mfp}}{L} << 1$ then we can lump these interactions into 1 property.

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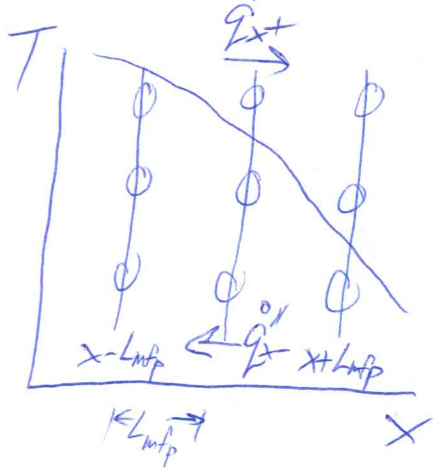
Thermal Conductivity $k\left(\frac{W}{m\text{-}k}\right)$ is used to calculate heat transfer via Fourier's Law: $\dot{q}'' = -k\frac{\partial T}{\partial x}$ where $\dot{q}''$ is heat flux in x direction $\left(\frac{W}{m^2}\right)$

$\frac{\partial T}{\partial x}$ is the temperature gradient in x



n_{ms} = # density of the energy carriers $\left(\frac{\#}{m^2}\right)$

v_{ms} = velocity of the energy carriers (m/s)

$L_{mfp} \simeq L_{ms}$ = average distance between interactions (m)

C_{ms} = ratio of the energy of it's carrier to its temperature $\left(\frac{J}{K}\right)$

Left to right

$$\dot{q}''_{x+} \simeq \underbrace{n_{ms} v_{ms}}_{\frac{\#\text{ of carries}}{\text{area-time}}} \underbrace{C_{ms} T_{x-L_{mfp}}}_{\frac{\text{energy}}{\text{carries}}}$$

Right to Left

$$\dot{q}''_{x-} \simeq n_{ms} v_{ms} C_{ms} T_{x+L_{ms}}$$

Net energy Transfer

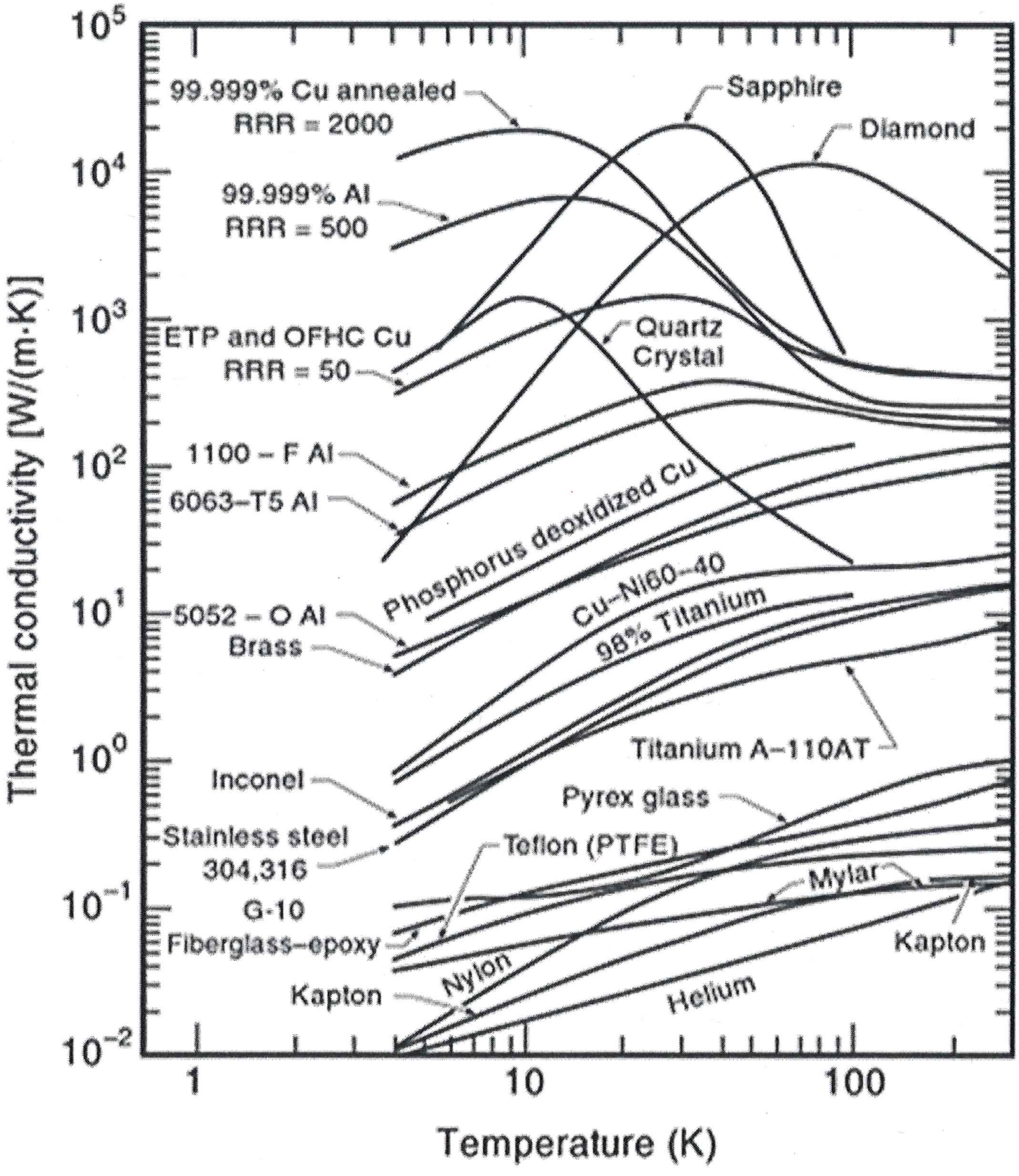
$$\dot{q}'' \simeq n_{ms} v_{ms} C_{ms} \left(T_{x-L_{mfp}} - T_{x+L_{mfp}}\right)\left(\frac{2L_{ms}}{2L_{ms}}\right) \Rightarrow$$

$$\Rightarrow \dot{q}'' \simeq \underbrace{-n_{ms} v_{ms} C_{ms} 2L_{ms}}_{k} \underbrace{\frac{\left(T_{x+L_{ms}} - T_{x-L_{ms}}\right)}{2L_{ms}}}_{\frac{\partial T}{\partial x}} \Rightarrow \dot{q}'' = -k\frac{\partial T}{\partial x}$$

\# Show Plot from Ekin

LMME576F19 1.3

→ What causes the features & trends observed in this graph?
→ List as many mechanisms as you can think of.



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→ It is often more convenient & desirable to calculate the total heat transfer $\dot{q}$ instead of the heat flux. This allows us to transform thermal conductivity into a convenient resistance value:

$$R\left(\frac{K}{W}\right) = \frac{\text{temperature differential}}{\text{heat transfer rate}} = \frac{(T_H - T_C)}{\dot{q}} \Rightarrow \dot{q} = \frac{(T_H - T_C)}{R}$$

However, the thermal resistance not only depends on thermal conductivity but on the particular geometry of the problem. ~~See~~ Show table 1-2 pg. 17

By quickly estimating the relative size of thermal resistances for a problem, you can quickly determine what physics & features are relevant to an analysis. This is similar ~~to~~ to & a type of ~~###~~ comparison known as a sensitivity study → if convective & radiative resistances are orders of magnitude less than conduction ~~the~~ you can often assume these forms are negligible in your analysis.

★ Next time we'll begin to create a process that will help us focus our efforts on 1-D conduction problems.