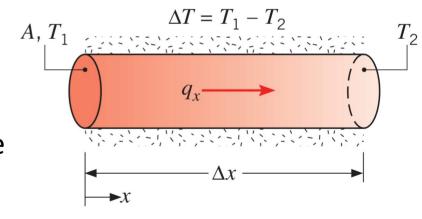
Conduction Introduction

Fourier's Law

- Describes how heat transfer due to conduction behaves
- Named after <u>Jean-Baptiste Joseph Fourier</u>
- Is phenomenological; Developed from observed phenomena rather than derived
- Fourier found that $\dot{Q} \propto A \frac{\Delta T}{\Delta x}$
- Varied area, temperature, and distance
- Found that the material made a difference



Fourier's Law

 Since material affected the performance, Fourier created a property called thermal conductivity and said

$$\dot{Q} = k A \frac{\Delta T}{\Delta x}$$

• If the change in length is allowed to approach zero, we get

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

- The negative sign is there because heat is transferred in the direction of decreasing temperature
- Thermal conductivity has units of $k = \frac{\dot{Q}}{A \frac{dT}{dx}} [=] \frac{W}{m^2 \frac{K}{m}} [=] \frac{W}{mK}$

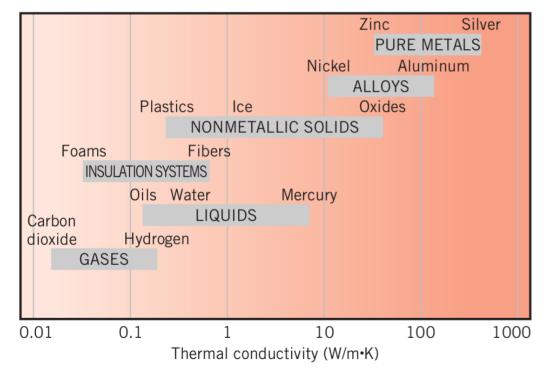
Fourier's Law

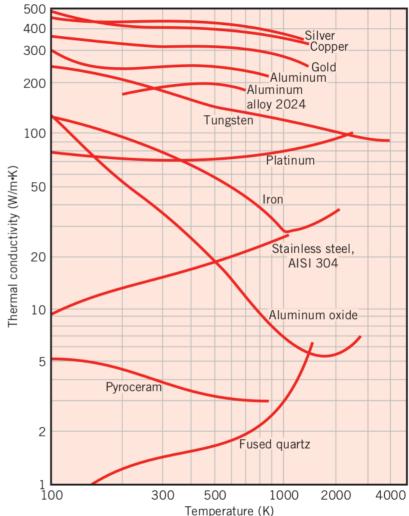
The expression may be expanded to 3D

$$\hat{q}'' = -k_x \frac{\partial T}{\partial x} \hat{i} - k_y \frac{\partial T}{\partial y} \hat{j} - k_z \frac{\partial T}{\partial z} \hat{k}$$

- Notice the thermal conductivity is different in the 3 directions
- If $k_x = k_y = k_z$, known as an isotropic material
- The thermal conductivity is dependent on many things such as material, material state, temperature, etc.

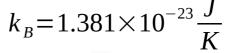
Thermal Conductivity



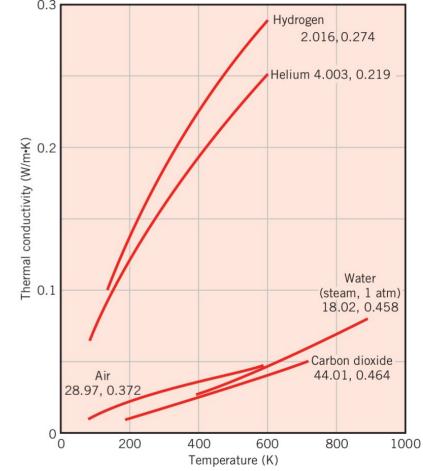


Thermal Conductivity

- For gases, $k = \frac{9 \gamma 5}{4} \frac{c_v}{\pi d^2} \sqrt{\frac{M_w k_B T}{N_A \pi}}$
 - y is specific heat ratio
 - c_{y} is specific heat at constant volume
 - d is diameter of gas molecule
 - M_{ω} is molecular weight
 - $k_{\scriptscriptstyle R}$ is Boltzmann's constant
 - T is temperature
 - N_{Δ} is Avogadro's number



$$N_A = 6.022 \times 10^{23}$$



Note: 1^{st} number is M_{st} , and

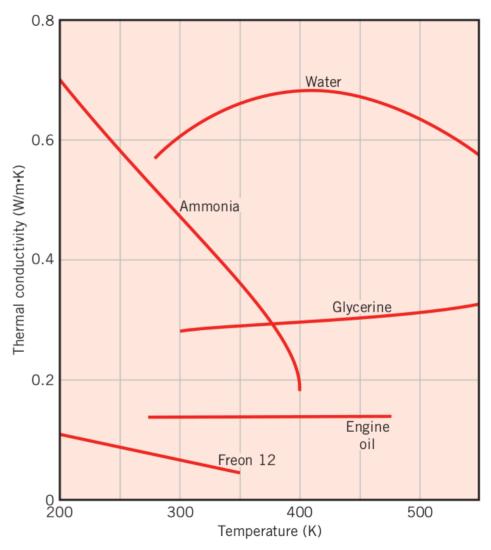
Example 1

Use the thermal conductivity expression for gases to determine the specific heat ratio for the following gases at the given temperatures.

- (a) Air, 550 K
- (b) Carbon dioxide, 800 K
- (c) Hydrogen, *375 K*

Thermal Conductivity

 Shows temperature dependence of selected nonmetal liquids under saturated conditions



Thermal Diffusivity

Ratio of the thermal conductivity to heat capacity

$$\alpha = \frac{k}{\rho c_{\mu}}$$

- Describes a materials ability to conduct energy relative to its ability to store thermal energy
- Looking at the units

$$\alpha = \frac{k}{\rho c_p} [=] \frac{\frac{W}{mK}}{\frac{kg}{m^3} \frac{J}{kgK}} [=] \frac{\frac{W}{mK}}{\frac{J}{m^3K}} [=] \frac{W m^3 K}{mKJ} [=] \frac{m^2}{s}$$

Example 2

Using appropriate values of k, ρ , and c_p from Appendix A, calculate α for the following materials at the prescribed temperatures:

- (a) pure aluminum, 300 and 700 K
- (b) silicon carbide, 1000 K
- (c) paraffin, 300 K

Example 3

The thermal conductivity of a sheet of rigid, extruded insulation is reported to be $k = 0.029 \ W/mK$. The measured temperature difference across a $20 \ mm$ thick sheet of material is $T_1 - T_2 = 10^{\circ}C$.

- (a) What is the heat flux through $2m \times 2m$ sheet of insulation?
- (b) What is the rate of heat transfer through the sheet of insulation?