CBE 30356 Transport II
Problem Set 1
Due via Gradescope, 5 PM 1/26/23

1). Using the Chapman-Enskog relation and the Eucken Formula, calculate the viscosity, thermal conductivity, and Prandtl number for methane at atmospheric pressure from 200°K to 1000°K. Graphically compare the results of your calculation to literature values (put temperature on a log scale for clarity). Values for the data and necessary parameters can be found at the website engineeringtoolbox.com and in tables E.1 and E.2 of BSL.

2). It's cold outside! In this problem we look at the effect of insulation in your attic.

a. Suppose your attic just has a thick drywall (3/4" gypsum board, thermal conductivity of 0.17 W/m°K) separating your living space from the attic, and there is an internal heat transfer coefficient between room air and the ceiling of 10 W/m^2°K and in the attic of 20 W/m^2°K (it's pretty drafty up there). Using this, calculate the overall heat transfer coefficient.

b. If the temperature inside is 72°F and that in the attic is 25°F, the area is 8m x 15m, and the cost of energy is $0.15/kWhr, determine the total cost of this heat loss over a four month period (e.g., the typical winter heating period).

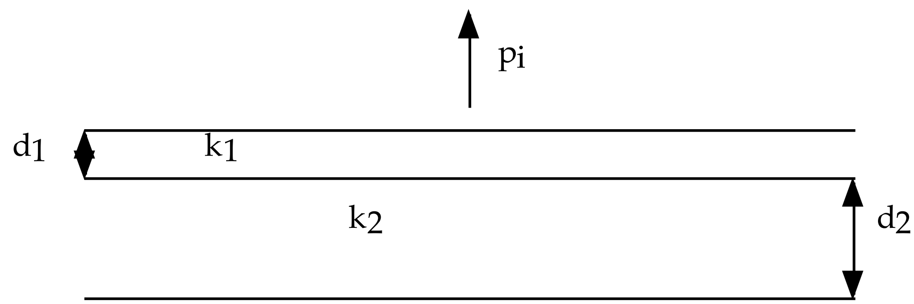
c. Now we add in 6" of fiberglass insulation (conductivity of 0.04 W/m°K). By what fraction is our heat loss reduced and how much does this save in heating costs over our four month winter heating period?

3). In class we talked about the parallel between thermal and electrical conductivity in metals. This is quantified by the Wiedemann-Franz Law which says that k (thermal conductivity) and σ (electrical conductivity, SI units of 1/(Ωm)) are related by:

$$\frac{k}{\sigma} = L\,T$$

where $L = 2.48\times10^{-8}$ $\Omega W/°K^2$ and T is in °K. In this problem I want you to test this law for iron, copper and aluminum over the temperature range [200 800] °K. Use the data from the engineeringtoolbox.com, but note that you will need to use the temperature correction for the electrical conductivity (coefficient provided: add "temperature" into your search to get the right page!). The resistivity of metals is roughly linear in temperature, so use the linear relationship to get the resistivity and invert it to get the electrical conductivity. Plot up the ratio vs. temperature for all three materials on the same graph (use a log-log scale), and include the Wiedemann-Franz Law. Be sure to label your graph clearly!

4). Many materials such as wood have an anisotropic thermal conductivity. This is particularly true of laminates of dissimilar materials. Suppose we have a multilayer laminate of metal and epoxy with a unit cell depicted below (there are lots of these cells stacked up). The director p_i denotes the orientation of the planes.



a. For this material, what is the thermal conductivity in the p_i direction and in the transverse direction (e.g., along the layers). Hint: Remember the analogy with electrical circuits holds, and that for circuits in parallel you add conductances!

b. If layer 1 is 0.5 mm thick epoxy (k = 0.35 W/m°K) and layer 2 is 1 mm thick stainless steel (k = 14.4 W/m°K) what is the ratio of the conductivities in the two directions?

5) Not for credit, but fun to do anyway: What is the full tensorial description of k_{ij} for this material, and what is the thermal conductivity at a 45° angle? Note that this is actually mathematically identical to the problem of a body of revolution settling in a viscous fluid (e.g., zero Re) that we looked at last fall!