Practice Heat-Transfer Problems:

Forced Convection
Free Convection

Practice 1: A wide, deep rectangular oven ($1.0\ ft$ tall) is used for baking loaves of bread. During the baking process the temperature of the air in the oven reaches a stable value of 100^oF. The oven side-wall temperature is measured at this time to be a stable 450^oF. Please estimate the heat flux from the wall per unit width.

Reference: Geankoplis Ex. 4.7-1 page 279

Practice 2: A hydrocarbon oil enters a pipe ($0.0303\ ft$ inner diameter; $15.0\ ft$ long) at a flow rate of $80\ lb_m/h$. Steam condenses on the outside of the pipe, keeping the inside pipe surface at a constant 350^oF. If the temperature of the entering oil is 150^oF, what is temperature of the oil at the outlet of the pipe?

Hydrocarbon oil properties:

Mean heat capacity $= 0.50 \frac{BTU}{lb_m\,^oF}$

Thermal conductivity $= 0.083 \frac{BTU}{h\ ft\ ^oF}$

Viscosity =

$6.50\ cp, 150^oF$
$5.05\ cp\ 200^oF$
$3.80 cp\ 250^oF$
$2.82\ cp\ 300^oF$
$1.95\ cp\ 350^oF$

Reference: Geankoplis Ex. 4.5-5 page 269

Practice 3: Air flows through a tube ($25.4\ mm$ inside diameter, long tube) at $7.62\ m/s$. Steam condenses on the outside of the tube such that the inside surface temperature of the tube is $488.7\ K$. If the air pressure is $206.8\ kPa$ and the mean bulk temperature of the air is $(T_{out}+T_{in})/2 = 477.6\ K$, what is the steady-state heat flux to the air?

Reference: Geankoplis Ex. 4.5-1 page 262

Practice 4: Hard rubber tubing (inside radius $= 5.0mm$; outside radius $= 20.0mm$) is used as a cooling coil in a reaction bath. Cold water is flowing rapidly inside the tubing; the inside wall temperature is $274.9\ K$ and the outside wall temperature is $297.1\ K$. To keep the reaction in the bath under control, the required cooling rate is $14.65\ W$. What is the minimum length of tubing needed to accomplish this cooling rate? What length would be needed if the coil were copper?

Hard rubber properties:

Density $= 1198\frac{kg}{m^3}$

Thermal conductivity $(0^o C) = 0.151\frac{W}{mK}$

Reference: Geankoplis Ex. 4.2-1 page 243, but don't do it his way—follow class methods.

Practice 5: A cold-storage room is constructed of an inner layer of pine (thickness $= 12.7\ mm$), a middle layer of cork board (thickness $= 101.6\ mm$), and an outer layer of concrete (thickness $= 76.2\ mm$). The inside wall surface temperature is $255.4\ K$ and the outside wall surface temperature is $297.1\ K$. What is the heat loss per square meter through the walls and what is the temperature at the interface between the wood and the cork board?

Material properties:

Thermal conductivity pine $= 0.151\frac{W}{mK}$

Thermal conductivity cork board $= 0.0433\frac{W}{mK}$

Thermal conductivity concrete $= 0.762\frac{W}{mK}$

Reference: Geankoplis Ex. 4.3-1 page 245, but don't do it his way—follow class methods.

Practice 6: A thick-walled tube (stainless steel; $0.0254\ m$ inner diameter; $0.0508\ m$ outer diameter; length $0.305\ m$) is covered with a $0.0254\ m$ thickness of insulation. The inside-wall temperature of the pipe is $811.0\ K$ and the outside surface temperature of the insulation is $310.8\ K$. What is the heat loss and the temperature at the interace between the steel and the insulation?

Material properties of stainless steel:

Thermal conductivity $= 21.63\ \frac{W}{mK}$

Density $= 7861\ \frac{kg}{m^3}$

Heat Capacity $= 490\ \frac{J}{kg\ K}$

Material properties of insulation:

Thermal conductivity $= 0.2423\ \frac{W}{mK}$

Reference: Geankoplis Ex. 4.3-2 page 247, but don't do it his way—follow class methods.