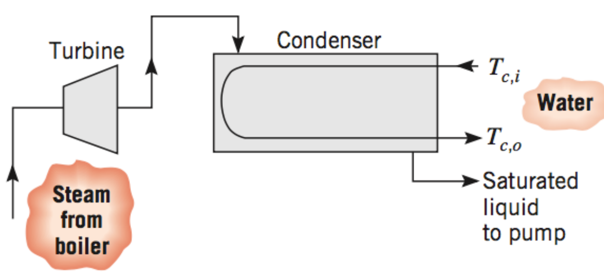
ME 331 Homework Assignment #6

Due Monday May 15, by 5 pm in MEB main office

1. Water at 30°C flows through a long 1.85 cm diameter tube at a mass flow rate of 0.020 kg/s. Find the mean velocity, maximum velocity, and the pressure difference between two sections 150 m apart in the tube.
2. You want to heat water from 12°C to 70°C as it flows through a 2.0 cm internal diameter, 7.0 m long tube. The tube is equipped with an electric resistance heater, which provides uniform heating at the outer surface of the tube. The heater is well insulated, so that in steady operation all the thermal energy generated in the heater is transferred to the water in the tube. You want the system to provide hot water at a rate of 8.0 L/min. What is the power rating that you need for the resistance heater? Also, estimate the inner surface temperature of the tube at the exit.
3. A typical automotive exhaust pipe carries exhaust gas at a mean velocity of 6.0 m/s. If the gas leaves the manifold at a temperature of 450°C and the muffler is located 2.6 m away, estimate the temperature of the gas as it enters the muffler. Assume an ambient air temperature of 40°C and a heat transfer coefficient of 12 W / m^2 K for the outside surface of the exhaust pipe. The exhaust pipe is thin walled and has a diameter of 10 cm. ε = 0.020 mm.
4. A blood purification system removes blood from a patient through a 3.0 mm diameter tube at a mass flow rate of 0.090 kg/min. The blood exits the patient at 37°C and cools to 33°C just prior to entering a filter and heat exchanger that raises the blood temperature back to 37°C. Approximating the properties of blood with those of water, estimate the heat transfer from the blood and the heat transfer coefficient, assuming fully developed flow.
5. The condenser of a steam power plant contains N = 1000 brass tubes (k_t = 110 W/m-K), each of inner and outer diameters, D_i = 25 mm and D_o = 28 mm, respectively. Steam condensation on the outer surfaces of the tube is characterized by a convection coefficient of h_o = 10,000 W/m^2-K.



   (a) If cooling water from a large lake is pumped through the condenser tubes at $\dot{m}_c$ = 400 kg/s, what is the overall heat transfer coefficient U_o based on the outer surface area of a tube? Water properties may be approximated as μ = 9.60 x 10^{-4} N-s/m^2, k = 0.60 W/m-K, and Pr = 6.6.
   (b) If after extended operation, fouling provides a resistance of $R''_{f,I}$ = 10^{-4} m^2-K/W, at the inner surface, what is the value of U_o?
   (c) If water is extracted from the lake at 15°C and 10 kg/s of steam at 0.0622 bars are to be condensed, what is the corresponding temperature of the water leaving the condenser? The specific heat of the water is 4180 J/kg-K.
6. In a Rankine power system, 1.5 kg/s of steam leaves the turbine as saturated vapor at 0.51 bar. The steam is condensed to saturated liquid by passing it over the tubes of a shell-and-tube heat exchanger, while liquid water, having an inlet temperature of $T_{c,I}$ = 280 K, is passed through the tubes. The condenser contains 100 thin-walled tubes, each of 10 mm diameter, and the total water flow rate through the tubes is 15 kg/s. The average convection coefficient associated with condensation on the outer surface of the tubes may be approximated as $\bar{h}_o$ = 5000 W/m^2-K. Appropriate property values for the liquid water are c_p = 4178 J/kg-K, μ = 700 x 10^{-6} kg/s-m, k = 0.628 W/m-K, and Pr = 4.6.
   (a) What is the water outlet temperature?
   (b) What is the required tube length (per tube)?
   (c) After extended use, deposits accumulating on the inner and outer tube surfaces provide a cumulative fouling factor of 0.0003 m^2-K/W. For the prescribed inlet conditions and the computed tube length, what mass fraction of the vapor is condensed?