Quiz IV

This is a 50 minute closed-book exam; no notes. Please put your name on the top sheet. Answer all three questions. Explain your working and state any assumptions you have made.

1 (3 points) Circle the correct answer.

1. The design equation for double-pipe heat exchangers
   - is independent of the area of the heat exchanger.
   - involves the log-mean temperature difference.
   - is used in the (ε,NTU) method.
   - has a correction factor $F = 0.5$.
   - comes from solving the Navier–Stokes equations.
2. The overall heat transfer coefficient U
   - only depends on conduction.
   - is not used in double-pipe heat exchangers.
   - is always determined by experiment.
   - is obtained by adding in series convective and conductive resistances.
   - is independent of Prandtl number.
3. Heat exchanger effectiveness ε
   - is the same as taking $F = 1$.
   - cannot be used to find tube pass lengths.
   - only applies to laminar flows.
   - involves the maximum possible heat transfer in the denominator.
   - is independent of T_h at the hot inlet.

2 (7 points) Water ($C_p = 1$ kJ/kg·K) at 80°C flows through a cross-flow exchanger of area 10 m^2 at a rate of 900 kg/h. Cooling water at 15°C is available. If the water flow rate is 450 kg/h, find the exit temperatures. Take $U = 200$ W/m^2·K.

3 (10 points) Show that for a cylindrical pipe of conductivity k with inner and outer radii r_1, r_2, the overall heat transfer coefficient U based on the outer area is

$$U = \left[\frac{1}{h_2} + \frac{r_2}{k} \ln\left(r_2/r_1\right) + \frac{r_2}{r_1}\frac{1}{h_1} \right]^{-1},$$

where h_1 and h_2 are the heat transfer coefficients at the inner and outer surfaces.
Carbon tetrachloride (boiling point at 1 atm: 76.7°C; heat capacity on a molar basis: $c_p = 131.3$ J/mol·K; atomic weights of carbon and chlorine 12 and 35.45 g/mol respectively) is cooled from its boiling point as it flows through a cocurrent heat double-pipe heat exchanger. The pipe is made of stainless steel ($k = 16$ W/m·K) with inner and outer diameters 1.2 and 1.3 cm respectively. Water ($C_p = 1$ kJ/kg·K) at a flow rate of 200 kg/s enters at 25°C and leaves at 40°C. The heat transfer coefficients of the inner and outer surfaces are both 800 W/m^2·K and the length of the pipe is 4 m. Calculate the flow rate of carbon tetrachloride and its outlet temperature.

Effectiveness versus number of transfer units: