Heat Transfer - 2

You are asked to re-design a heat exchanger. The initial design is one pipe that has a length of L_1 = 10 m and diameter of D_1 = 0.05 m. The pipe wall temperature is a constant 320 K. The fluid has a mass flow rate of 2 kg/s with an inlet temperature of 280 K and an outlet temperature of 300 K. The fluid specific heat is 4200 J/kg-K. This gives a Reynolds number of Re_1 = 50,000. Because the pipe for the current design is too long, it is desired to split it into four pipe segments in parallel with the same total mass flow rate. You are to evaluate two cases which are being considered to provide the **same** total mass flow rate, heat transfer, and temperature change of the fluid.

Case A: The four parallel pipes are the same diameter as the original design $D_A = D_1$ = 0.05 m.

Case B: The four parallel pipes are one-half the original diameter, $D_B = D_1/2$ = 0.025 m.

Assume that all of the fluid properties remain the same. The heat transfer coefficient is assumed to follow the typical correlation for turbulent flow

$$Nu = \frac{hD}{k} = CRe^{0.8} \quad \text{where} \quad Re = \frac{\bar{u}D}{\nu}$$

h is the heat transfer coefficient between the pipe and the fluid, $\bar{u}$ is the average velocity, C is a constant, k is the thermal conductivity and ν is the kinematic viscosity of the fluid. Determine the following with both symbolic and numeric solutions (Hint: Use ratios):

1) (**15 points**) the total heat transfer (same for all three cases), q =

2) (**15 points**) the log-mean temperature difference (same for all three cases), $\Delta T_{\ell m}$ =

3) (**30 points**) the length of the four pipes required for case A, L_A =

4) (**30 points**) the length of the four pipes required for Case B, L_B =

5) (**5 points**) Which case is the most advantageous in amount of pipe used?

6) (**5 points**) Which case is the most advantageous in pumping power required? Assume the pressure drop is proportional to the velocity squared and L/D.