1. (50 points) Oil (thermal conductivity = 0.185 W/m K, mean heat capacity = 7.43 kJ/kg K, viscosity = 132 cP) is heated from 25°C to 65°C by liquid water in a counter-current, double-pipe heat exchanger. The inlet water temperature is 95°C and the outlet water temperature is 85°C (for water thermal conductivity = 0.68W/m K, mean heat capacity = 4.2kJ/kg K, viscosity = 1.000cP, and latent heat of vaporization of water is 2270.14 kJ/kg at 95°C and 2296.00 kJ/kg at 85°C). The area for heat transfer is 6.91m² and the overall heat transfer coefficient for this apparatus is 1200 W/m²K. If the heat exchanger is adiabatic (no overall heat loss), what is the flow rate (in kg/s) of the water stream?

2. (50 points) An oven wall made of material with thermal conductivity $k_1=0.151 \text{ W/mK}$ is insulated with a material of thermal conductivity $k_2=0.0433 \text{ W/mK}$. The temperature of the left face of the wall is held at 100.0°C. The right face of the wall is measured to be 98°C, see figure below. The wall is 1.0 cm thick. What is the thickness in cm of the insulation needed if the outside surface temperature should be no more than 85°C?

![Diagram of oven wall with temperatures and insulation]
3. **Fluid mechanics bonus problem (12 points):** Calculate the velocity profile $v_x$ for steady, pressure-driven flow in a long, wide, tilted slit of an incompressible, Newtonian fluid (see figure below). The pressure at the inlet is $p_0$ and the pressure at the outlet, which is a distance $L$ away, is $p_L$. The gap between the plates is $H$ and the slit is tilted at an angle $\beta$. You must derive your solution in the coordinate system shown. Please indicate all of your assumptions. Detailed work is required for partial credit.