ME453- HEAT EXCHANGER DESIGN – HOMEWORK

PROBLEM 1:
In order to cool a mass flow rate of 9.4 kg/h of air from 616°C to 232°C, it is passed through the inner tube of double-pipe heat exchanger with counterflow, which is 1.5 m long with an outer diameter of the inner tube of 2 cm.
a. Calculate the heat transfer rate. For air, $c_{p,h}$ = 1060 J/kg·K.
b. The cooling water enters the annular side at 16°C with a volume flow rate of 0.3 L/min. Calculate the exit temperature of the water. For water, $c_{p,c}$ = 4,180 J/kg·K.
c. Determine the effectiveness of this heat exchanger and then determine NTU.
d. The overall heat transfer coefficient based on the outside heat transfer surface area is 38.5 W/m^2·K. Calculate the surface area of the heat exchanger and the number of hairpins.

PROBLEM 2:
In an oil cooler, oil flows through the heat exchanger with a mass flow rate of 8 kg/s and inlet temperature of 70°C. The specific heat of oil is 2 kJ/kg·K. The cooling stream is treated cooling water that has a specific heat capacity of 4.2 kJ/kg·K, a flow rate of 20 kg/s, and an inlet temperature of 15°C. Assuming a total heat exchanger surface area of 150 m^2 and an overall heat transfer coefficient of 150 W/m^2·K, calculate the outlet temperature for a heat exchanger with two-shell passes and four-tube passes and a heat exchanger with unmixed–unmixed crossflow, respectively. Estimate the respective F-correction factors.

PROBLEM 3:
Air at 1.5 atm and 40°C flows through a 10 m rectangular duct of 40 cm by 25 cm with a velocity of 5 m/s. The surface temperature of the duct is maintained at 120°C, and the average air temperature at exit is 80°C. Calculate the total heat transfer using Gnielinski's correlation and check your result by energy balance.

PROBLEM 4:
A shell-and-tube type condenser is to be made with 3/4 in. outer diameter (0.654 in. inner diameter) brass tubes, and the length of the tubes between tube plates is 3 m. Under the worst conditions, cooling water is available at 21°C and the outlet temperature is 31°C. Water velocity inside the tubes is approximately 2 m/s. The vapor side film coefficient can be taken as 10,000 W/ m^2·K. Calculate the overall heat transfer coefficient for this heat exchanger.

PROBLEM 5:
A double-pipe heat exchanger is used to condense steam at 40°C saturation temperature. Water at an average bulk temperature of 20°C flows at 2 m/s through the inner tube (copper, 2.54 cm ID, 3.05 cm OD). Steam at its saturation temperature flows in the annulus formed between the outer surface of the inner tube and outer tube of 6 cm ID. The average heat transfer coefficient of the condensing steam is 6,000 W/m^2·K, and the thermal resistance of a surface scale on the outer surface of the copper pipe is 0.000176 m^2·K/W.
a. Determine the overall heat transfer coefficient between the steam and the water based on the outer area of the copper tube.
b. Evaluate the temperature at the inner surface of the tube.