CHC-201, Heat Transfer

Department of Chemical Engineering (IIT-R)

Tutorial-4

1. In the final stages of production, a pharmaceutical is sterilized by heating it from 20 to 80ºC as it moves at 0.15 m/s through a straight thin-walled stainless steel tube of 12.7-mm diameter. A uniform heat flux is maintained by an electric resistance heater wrapped around the outer surface of the tube. If the tube is 12 m long, what is the required heat flux? Also, calculate the surface temperature at the tube exit? Fluid properties may be approximated as ρ=1000 kg/m^3 , C_p=4000 J/kgK, μ= 2×10^{-3} kg/ms, k=0.8 W/mK, and Pr=1.3.

2. Air at P=1 atm enters a thin-walled (D=6-mm diameter) long tube (L=2.5 m) at an inlet temperature of 90ºC. A constant heat flux is applied to the air from the tube surface. The air mass flow rate is 135×10^{-6} kg/s. If the tube surface temperature at the exit is 150ºC, Determine the rate of heat transfer to the fluid.

3. Water at 60°C enters a tube of 2.54 cm diameter at a mean flow velocity of 2 cm/s. Calculate the exit water temperature if the tube is 3.0 m long and the wall temperature is constant at 80°C.

$$\mu = 4.71\times10^{-4}\ kg/m.s \quad \rho = 985 kg/m^3 \quad c_p = 4.18 kJ/kg.°C \quad \mathrm{Pr} = 3.02 \quad k = 0.651\frac{w}{m.°C}$$

4. Hot air at atmospheric pressure and 75°C enters a 10-m-long uninsulated square duct of cross section 0.20 m x 0.20 m. The volume flow rate of air through the duct is 0.15 m^3/s. The duct is observed to be nearly isothermal at 60°C. Determine the exit temperature of the air.

5. Consider the flow of oil at 10 °C in an 80 cm diameter pipeline at an average velocity of 0.8 m/s. A 400 m long section of the pipeline passes through icy water of the lake at 0°C. The surface temperature of the pipe is nearly 0°C. Neglect thermal resistance of the pipe, determine a) the temperature of the oil when the pipe leaves the lake , b) the rate of heat transfer from the oil. Properties of oil ρ = 893.5 kg/m^3, k = 0.146 W/m °C, μ = 2.325 kg/m.s, ν = 2594 x 10^{-6}, C_p= 1838 J/kg°C, Pr = 28750.

6. Hot exhaust gases leaving a stationary diesel engine at 450 °C enters a 20 cm diameter at an average velocity of 5 m/s. The surface temperature of the pipe is 180°C. Determine the length of the pipe if the exhaust gases are to leave the pipe at 250 °C after transferring heat to water in a heat recovery unit. Use properties of air for exhaust gases.

Properties of air at 1 atm pressure

Temp. T, °C	Density ρ, kg/m^3	Specific Heat c_p J/kg·K	Thermal Conductivity k, W/m·K	Thermal Diffusivity α, m^2/s	Dynamic Viscosity μ, kg/m·s	Kinematic Viscosity ν, m^2/s
−150	2.866	983	0.01171	4.158×10^{-6}	8.636×10^{-6}	3.013×10^{-6}
−100	2.038	966	0.01582	8.036×10^{-6}	1.189×10^{-6}	5.837×10^{-6}
−50	1.582	999	0.01979	1.252×10^{-5}	1.474×10^{-5}	9.319×10^{-6}
−40	1.514	1002	0.02057	1.356×10^{-5}	1.527×10^{-5}	1.008×10^{-5}
−30	1.451	1004	0.02134	1.465×10^{-5}	1.579×10^{-5}	1.087×10^{-5}
−20	1.394	1005	0.02211	1.578×10^{-5}	1.630×10^{-5}	1.169×10^{-5}
−10	1.341	1006	0.02288	1.696×10^{-5}	1.680×10^{-5}	1.252×10^{-5}
0	1.292	1006	0.02364	1.818×10^{-5}	1.729×10^{-5}	1.338×10^{-5}
5	1.269	1006	0.02401	1.880×10^{-5}	1.754×10^{-5}	1.382×10^{-5}
10	1.246	1006	0.02439	1.944×10^{-5}	1.778×10^{-5}	1.426×10^{-5}
15	1.225	1007	0.02476	2.009×10^{-5}	1.802×10^{-5}	1.470×10^{-5}
20	1.204	1007	0.02514	2.074×10^{-5}	1.825×10^{-5}	1.516×10^{-5}
25	1.184	1007	0.02551	2.141×10^{-5}	1.849×10^{-5}	1.562×10^{-5}
30	1.164	1007	0.02588	2.208×10^{-5}	1.872×10^{-5}	1.608×10^{-5}
35	1.145	1007	0.02625	2.277×10^{-5}	1.895×10^{-5}	1.655×10^{-5}
40	1.127	1007	0.02662	2.346×10^{-5}	1.918×10^{-5}	1.702×10^{-5}
45	1.109	1007	0.02699	2.416×10^{-5}	1.941×10^{-5}	1.750×10^{-5}
50	1.092	1007	0.02735	2.487×10^{-5}	1.963×10^{-5}	1.798×10^{-5}
60	1.059	1007	0.02808	2.632×10^{-5}	2.008×10^{-5}	1.896×10^{-5}
70	1.028	1007	0.02881	2.780×10^{-5}	2.052×10^{-5}	1.995×10^{-5}
80	0.9994	1008	0.02953	2.931×10^{-5}	2.096×10^{-5}	2.097×10^{-5}
90	0.9718	1008	0.03024	3.086×10^{-5}	2.139×10^{-5}	2.201×10^{-5}
100	0.9458	1009	0.03095	3.243×10^{-5}	2.181×10^{-5}	2.306×10^{-5}
120	0.8977	1011	0.03235	3.565×10^{-5}	2.264×10^{-5}	2.522×10^{-5}
140	0.8542	1013	0.03374	3.898×10^{-5}	2.345×10^{-5}	2.745×10^{-5}