Name: **Enrolment No:**	UPES UNIVERSITY OF TOMORROW

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, December 2023

Programme Name: B. Tech. in Chemical Engineering **Semester : III**
Course Name : Process Heat Transfer **Time : 3 hrs**
Course Code : CHCE 2021 **Max. Marks : 100**
Nos. of page(s) : 2
Instructions : Attempt all questions. Assume any missing data with proper justification.

S. No.		Marks	CO
	Section A		
Q 1	Discuss heat transfer via natural convection using a suitable example. Draw a temperature profile and velocity profile for a vertical plate having higher temperature than surrounding temperature in natural convection.	**10**	**CO1**
Q 2	Discuss the filmwise condensation and dropwise condensation. How does the presence of non-condensable gas affect the rate of condensation of a vapor.	**10**	**CO1**
Q 3	A stainless steel ball (ρ = 8055 kg/m3, C_p = 480 J/kg .°C) of diameter D =15 cm is removed from the oven at a uniform temperature of 350 °C. The ball is then subjected to the flow of air at 1 atm pressure and 30 °C with a velocity of 6 m/s. The surface temperature of the ball eventually drops to 250 °C. Determine the average convection heat transfer coefficient during this cooling process and estimate how long this process has taken. The properties of air at 1 atm and free stream temperature are k=0.02588 W/m. ºC, $\upsilon = 1.608 \times 10^{-5}$ m^2/s, Pr = 0.7282, $\mu_\infty = 1.872 \times 10^{-5}$ kg/m.s $\mu_{s@300\,^oC} = 2.934 \times 10^{-5}$ kg/m.s The heat transfer coefficient is calculated by the following correlation: $$Nu = 2 + [0.4\,Re^{0.5} + 0.06\,Re^{2/3}]Pr^{0.4}\left(\frac{\mu_\infty}{\mu_{s@300^oC}}\right)^{0.25}$$	**10**	**CO2**
Q.4	Two very long concentric cylinders of diameters D_1= 0.2 m and D_2= 0.5 m are maintained at uniform temperatures of T_1 = 950 K and T_2 = 500 K and have emissivities ε_1 = 1 and ε_2 = 0.7, respectively. Determine the net rate of radiation heat transfer between the two cylinders per unit length of the cylinders.	**10**	**CO2**
Q.5	Exhaust gases at 1 atm and 300ºC are used to preheat water in an industrial facility by passing them over a bank of tubes through which water is flowing at a rate of 6 kg/s. The mean tube wall temperature is 80ºC. Exhaust gases approach the tube bank in normal direction at 4.5 m/s. The outer diameter of the tubes is 2.1 cm, and the tubes	**10**	**CO3**

	are arranged in-line with longitudinal and transverse pitches of SL 8 cm. There are 16 rows in the flow direction with eight tubes in each row. Using the properties of air for exhaust gases, determine (a) the rate of heat transfer per unit length of tubes the temperature rise of water flowing through the tubes per unit length of tubes. Data: $k = 0.04104\ W/_{m.K}$; $\rho = 0.6746\frac{kg}{m^3}$; $C_p = 1.033\frac{kJ}{Kg-K}$; Pr = 0.6946 $Pr_{@T_s} = 0.7154$; $\mu = 2.76\ \times 10^{-5}\ kg/m-s$ $$Nu_D = 0.27\ Re_D^{0.63}\ Pr^{0.36}\left(\frac{Pr}{Pr_{@T_s}}\right)^{0.25}$$		
Q.6	Suppose you have designed an experiment in heat transfer lab to validate the Dittus–Boelter equation. In this experiment, the water temperature is raised from 15 °C to 65 °C by flowing through it through a 3 cm internal diameter 5 m long tube wrapped with electric resistance heater. The outer surface of the heater is insulated so that all the heat generated is transferred to water only. The water flow rate is 10 L/min. The power rating of the heater is 35 kW and surface temperature of the pipe measured at exit is 120 °C. Estimate the heat transfer coefficient using this experimental data and comment on validity of Dittus–Boelter equation. If one of your friends suggested the flow rate at a value of 1 L/min, would you conduct the experiment at this flow rate. Justify your answer.	**10**	**CO3**
	Section B		
Q.7	Steam in a heating system flows through tubes whose outer diameter is 5 cm and whose walls are maintained at a temperature of 180°C. Circular aluminium alloy 2024-T6 fins (*k* =186 W/m.°C) of outer diameter 6 cm and constant thickness 1 mm are attached to the tube. The space between the fins is 3 mm, and thus there are 250 fins per meter length of the tube. Heat is transferred to the surrounding air at $T\infty$ = 25°C, with a heat transfer coefficient of 40 W/m^2. °C. Determine the increase in heat transfer from the tube per meter of its length as a result of adding fins.	**20**	**CO4**
Q.8	Consider a water-to-water counter-flow heat exchanger with these specifications. Hot water enters at 95°C while cold water enters at 20°C. The exit temperature of hot water is 15°C greater than that of cold water, and the mass flow rate of hot water is 50 percent greater than that of cold water. The product of heat transfer surface area and the overall heat transfer coefficient is 1400 W/m^2. °C. Taking the specific heat of both cold and hot water to be C_p = 4180 J/kg · °C, determine (*a*) the outlet temperature of the cold water, (*b*) the effectiveness of the heat exchanger, (*c*) the mass flow rate of the cold water, and (*d*) the heat transfer rate.	**20**	**CO4**