Name: Enrolment No:	UPES

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

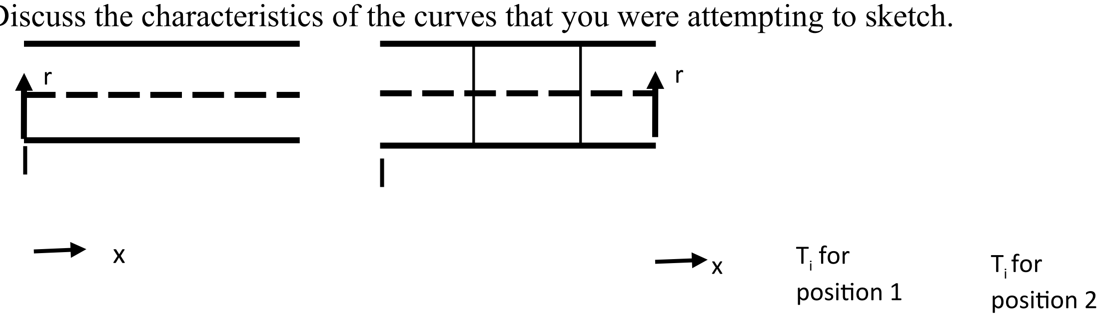
End Semester Examination, December 2020

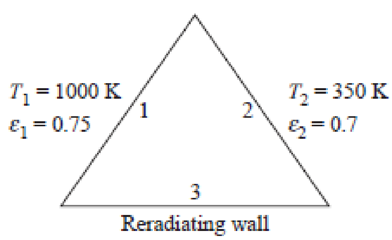
Programme Name: B.Tech Mechanical **Semester: V**
Course Name: Heat Transfer **Time: 03 hrs**
Course Code: MECH3003 **Max. Marks: 100**

Instructions:

- Section A constitutes of 30 Marks (6 questions x 5 marks); Attempt All.
- Section B constitutes of 50 Marks (5 questions x 10 marks). Attempt All (One choice question).
- Section C constitutes of 20 Marks (1 questions x 20 marks). Attempt All (One choice question).
- Question #5 of section-B and Question#1 of Section-C have options. Please answer only one of the options.

SECTION A

SN		Marks	CO
Q1	For a fully-developed laminar flow in a round pipe experiencing heating of the flow with a uniform surface heat flux and no significant property variations, sketch velocity and temperature profiles *u*(r) and *T*(r) for two stream wise positions. Use the subscripts s (surface), b (bulk) and c (center), as needed. The temperatures are to be plotted relative to the tube uniform entrance temperature, T_i, which is a constant. Thus, plot $T(r) - T_i$? Discuss the characteristics of the curves that you were attempting to sketch. 	5	CO1
Q 2	If heat transfer is directly proportional to temperature difference, and since it is known that film boiling occurs at a larger temperature difference between fluid and the solid surface, why is it that under some cases, the heat transfer in film boiling may be less than that of Nucleate boiling? Explain.	5	CO1
Q 3	Mr. Hari Prasad and Dr. Nandkishore had a severe debate on how the clouds affect our climate. One of them asserts that the clouds have a cooling effect on our climate, whereas Dr. Nandkishore tends to believe that the clouds warm our climate. First, explain the thought process of both Mr. Hari and Nandkishore and then give your own assessment.	5	CO1
Q 4	Draw temperature profiles in the developing region of a circular duct for the following cases: a) Isoflux plate: Cooling the Fluid case. b) Isothermal plate: Heating the Fluid case. **Be legible in your drawing, and indicate what you wish to show by arrows.**	5	CO1
Q 5	Dr. Mohan is a safety engineer at Thermal Systems Inc. In one of the job requirements,	5	CO1

	he is expected to insulate a metallic pipe carrying hot liquid at 100 degree C. He wants to use the hot water for a heat exchange operation. Briefly describe what are two most important considerations that Dr. Mohan should consider in the design of this insulation system		
Q 6	For a multiple effect evaporator with five effects: how do these compare (increasing, decreasing or equal) in the different effects. a) The temperature of the inlet vapors. Explain. b) The pressure maintained in these different effects. Explain	**5**	**CO2**
	SECTION B		
Q 1	A pressure vessel for a nuclear reactor is approximated as a large flat plate of thickness *L*. The inside surface of the plate at $x = 0$ is insulated, the outside surface at $x = L$ is maintained at a uniform temperature Tw. The gamma-ray heating of the plate can be represented as a generation of thermal energy within the plate in the form $$q_G = q_0 e^{-\beta x} \text{ W/m}^3$$ where q_0 and β are constants and x is measured from the insulated inner surface. Develop expressions for: (a) The temperature distribution in the plate. (b) The temperature at the insulated surface ($x = 0$) of the plate. (c) The heat flux at the outer surface ($x = L$).	**10**	**CO2**
Q 2	The configuration of a furnace can be approximated as an equilateral triangular duct which is sufficiently long so that the end effects are negligible. The hot wall is maintained at 1000 K and has an emissivity of $\varepsilon_1 = 0.75$. The cold wall is at 350 K and has an emissivity of $\varepsilon_2 = 0.7$. The third wall is a reradiating zone for which $Q3 = 0$. Determine the radiation heat flux leaving the hot wall. 	**10**	**CO2**
Q 3	Two parallel infinite plane surfaces are maintained at 200°C and 300°C. Determine the net rate of radiation heat transfer per unit area when (a) the two surfaces are gray having emissivity of 0.7 (b) the two surfaces are black.	**10**	**CO4**
Q 4	The temperature distribution in a cylindrical stainless fin (thermal conductivity 0.17 W/cm-°C) of constant cross-sectional area of 2 cm2 and length of 1 cm, exposed to an ambient of 40°C (with a surface heat transfer coefficient of 0.0025 W/cm°C) is given by $$T - T\infty = 3x2 - 5x + 60$$ where T is in °C and x (distance from the fin base) in in cm. If the base temperature is 100°C, then find the heat dissipated by the fin surface. Calculate Fin efficiency and fin	**10**	**CO4**

	effectiveness.		
Q 5	In the final stages of production, a pharmaceutical is sterilized by heating it from 25 to 75 ºC as it moves at 0.2 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 10 m long, what is the required heat flux? If fluid enters the tube with a fully developed velocity profile and a uniform temperature profile, what is the surface temperature at the tube exit and at a distance of 0.5 m from the entrance? Fluid properties may be approximated as C_p = 4000 J/kg K, $\mu = 2\text{x}10^{-3}$ kg/m-s, $\boldsymbol{\rho}$ =¿1000 kg/m^3, k = 0.8 W/mK. OR Cooling water flows through the 25.4-mm-diameter thin-walled tubes of a steam condenser at 1 m/s, and a surface temperature of 350 K is maintained by the condensing steam. The water inlet temperature is 290 K, and the tubes are 5 m long. (a) What is the water outlet temperature? Evaluate water properties at an assumed average mean temperature. Was the assumed value reasonable? Comment. (b) A range of tube lengths from 4 to 7 m is available to the engineer designing this condenser. Generate a **rough** plot to show what coolant mean velocities are possible if the water outlet temperature is to remain at the value found for part (a). All other conditions remain the same.	**10**	**CO3**
	SECTION C		
Q 1	We know this about our heat exchanger: Fluid A: Air at 1.0 atmosphere $\dot{m}$ = 0.1 kg/sec $T_{A,in}$ = 20ºC Fluid B: Water at 1.0 atmosphere pressure $\dot{m}$ = 0.1 kg/sec $T_{A,in}$ = 100ºC The arrangement is cross-flow, both fluids are unmixed, U_0A_0 for the exchanger is 400 W/K. What are the exit temperatures [ºC]? Assume constant properties taken at the respective inlet temperatures of each of the two fluids. OR Suppose we have air at 1.0 atmosphere pressure on the shell side of a shell and tube heat exchanger (single pass for the fluid on this shell side). On the tube side, which has two passes, we have water entering at 50ºC. The overall heat transfer coefficient, U_0, is 100 W/m^{2}K (U_0, based on the tube outside area). What is the total tube length? The air is flowing at 0.1 kg/sec and is being heated from 10ºC to 40ºC. The water flow rate is 0.1 kg/sec. What is the heat exchanger size, given as A_0, the tube total outside area?	**20**	**CO4**

Appendix

Heat exchanger type	*Effectiveness relation*
1 *Double pipe:*	
Parallel flow	$\varepsilon = \dfrac{1-\exp[-\text{NTU}(1+C)]}{1+C}$
Counterflow	$\varepsilon = \dfrac{1-\exp[-\text{NTU}(1-C)]}{1-C\exp[-\text{NTU}(1-C)]}$
2 *Shell and tube:* One-shall pass 2, 4,... tube passes	$\varepsilon = 2\left\{1+C+\sqrt{1+C^2}\,\dfrac{1+\exp[-\text{NTU}\sqrt{1+C^2}]}{1-C\exp[-\text{NTU}\sqrt{1+C^2}]}\right\}^{-1}$
3 *Cross-flow:* (*single-pass*)	
Both fluids unmixed	$\varepsilon = 1-\exp\left\{\dfrac{\text{NTU}^{0.22}}{C}[\exp(-C\,\text{NTU}^{0.78})-1]\right\}$
C_{max} mixed, C_{min} unmixed	$\varepsilon = \dfrac{1}{C}(1-\exp\{1-C[1-\exp(-\text{NTU})]\})$
C_{min} mixed, C_{max} unmixed	$\varepsilon = 1-\exp\left\{-\dfrac{1}{C}[1-\exp(-C\,\text{NTU})]\right\}$
4 All heat exchangers with $C = 0$	$\varepsilon = 1-\exp(-\text{NTU})$

Heat exchanger type	NTU *relation*
1 *Double pipe:*	
Parallel flow	$\text{NTU} = -\dfrac{\ln[1-\varepsilon(1+C)]}{1+C}$
Counterflow	$\text{NTU} = \dfrac{1}{C-1}\ln\left(\dfrac{\varepsilon-1}{\varepsilon C-1}\right)$
2 *Shell and tube:* One-shall pass 2, 4,... tube passes	$\text{NTU} = -\dfrac{1}{\sqrt{1+C^2}}\ln\left(\dfrac{2/\varepsilon-1-C-\sqrt{1+C^2}}{2/\varepsilon-1-C+\sqrt{1+C^2}}\right)$
3 *Cross-flow:* (*single-pass*)	
C_{max} mixed, C_{min} unmixed	$\text{NTU} = -\ln\left[1+\dfrac{\ln(1-\varepsilon C)}{C}\right]$
C_{min} mixed, C_{max} unmixed	$\text{NTU} = -\dfrac{\ln(C\ln(1-\varepsilon)+1)}{C}$
4 All heat exchangers with $C = 0$	$\text{NTU} = -\ln(1-\varepsilon)$

Water Properties				
Temperature	Dynamic Viscosity (Pa s) μ	Density (kg/m^3) ρ	Kinematic viscosity (m^2/s) ν	Specific heat J/(kg K) C_p
20 degree	**9.808E-04**	**997.82**	**9.829E-07**	**4076.58**
25 degree	**8.714E-04**	**996.62**	**8.743E-07**	**4072.80**
30 degree	**7.798E-04**	**995.23**	**7.836E-07**	**4070.25**
50 degree	**5.332E-04**	**987.75**	**5.398E-07**	**4066.03**
90 degree	**3.076E-04**	**964.55**	**3.189E-07**	**4074.59**

Air Properties				
Temperature	Dynamic Viscosity (Pa s) μ	Density (kg/m^3) ρ	Kinematic viscosity (m^2/s) ν	Specific heat J/(kg K) C_p
20 degree	**1.816E-05**	**1.19**	**9.829E-07**	**4076.58**
47 degree	**1.945E-05**	**1.09**	**1.791E-05**	**1007.57**
50 degree	**1.959E-05**	**1.08**	**1.821E-05**	**1007.67**
100 degree	**2.185E-05**	**0.93**	**2.347E-05**	**1010.86**
150 degree	**2.395E-05**	**0.83**	**2.882E-05**	**1017.65**