Name:

Enrolment No:

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, May 2019

Programme Name: B. Tech. CERP and APE (Gas) **Semester : IV**
Course Name : Heat Transfer **Time : 03 hrs**
Course Code : CHCE 2009 **Max. Marks : 100**
Nos. of page(s) : 04

Instructions:

The question paper consists of three sections. Answer the questions section wise in the answer booklet.

Assume suitable data wherever necessary. The notations used here have the usual meanings.

SECTION A ($10 \times 2 = 20$ Marks)

S. No.		Marks	CO
1.	The outside of a copper wire having a diameter of 2 mm is exposed to a convection environment with h = 5000 W/m^2-^{0}C and T_∞ =100 ^{0}C. What current must be passed through the wire to produce a center temperature of 150 ^{0}C? The resistivity of copper is 1.67 $\mu\Omega$-cm.	**10**	**CO1**
2.	Derive the relationship for the temperature profile of a steady state laminar flow of an incompressible fluid in the fully developed region of a tube having constant heat flux.	**10**	**CO3**

SECTION B ($12 \times 5 = 60$ Marks)

S. No.		Marks	CO
3.(a)	Define Kirchoff's law and Wien's displacement law.	**2+10**	**CO1**
(b)	Three hollow cylinders of thin wall 10cm, 20cm and 30cm in diameter are arranged concentrically. The temperature of the surface of the 10 cm diameter cylinder and 20cm diameter cylinder are maintained at -173 ^{0}C and 27 ^{0}C, respectively. Assuming the vacuum between the annular spaces, find the steady state temperature attained by the surface of the cylinder whose diameter is 20 cm. Take $\varepsilon_1 = \varepsilon_2 = \varepsilon_3$ =0.05. Also, find the heat loss per meter length of the composite cylinder and the convective heat transfer coefficient, if the surrounding air temperature is 10 ^{0}C.		
4.	Consider a 2-ft × 2-ft thin square plate in a room at 75 ^{0}F. One side of the plate is maintained at a temperature of 130 ^{0}F, while the other side is insulated. Determine the rate of heat transfer from the plate by natural convection if the plate is	**12**	**CO3**

	(*a*) vertical, (*b*) horizontal with hot surface facing up, and (*c*) horizontal with hot surface facing down. The properties of air at 1 atm and the film temperature of 102.5 ^{0}F are: k = 0.01535 Btu/ft-h-^{0}F, υ = 0.1823 × 10^{-3} ft^2/s, Pr = 0.7256 Relation of Nusselt Number for vertical surface: $Nu = \left\{ 0.825 + \frac{0.387\, Ra^{1/6}}{\left[1 + \left(\frac{0.492}{Pr} \right)^{9/16} \right]^{8/27}} \right\}^2$ Relation of Nusselt Number for hot surface facing up: $Nu = 0.59\, Ra^{1/4}$ Relation of Nusselt Number for hot surface facing down: $Nu = 0.27\, Ra^{1/4}$		
5.(a) (b)	What is condensation? What are the types of condensation and which is a more effective mechanism of heat transfer? A 40 cm × 40 cm plate is inclined at an angle of 30° with the vertical and exposed to water vapor at 1 atm. The plate is maintained at 98 ^{0}C. Calculate the heat-transfer and mass-flow rate of condensate. The properties of the condensate at 99 ^{0}C are: ρ = 960 kg/m^3, k =0.68 W/m-K, μ = 282 ×10^{-6} kg/m-s and latent heat of vaporization at 100 ^{0}C is 2255 kJ/kg.	**4+8**	**CO4**
6.	A counter flow heat exchanger consists of a bundle of 20 mm diameter tubes contained in a shell. Oil flowing in the tubes is cooled by water flowing in the shell. The total flow area with in the tubes is 4.4 × 10^{-3} m^2. The flow rate of oil is 2.5 kg/s. It enters at 65 ^{0}C and leaves at 48 ^{0}C. Water enters the shell at the rate of 20 kg/sec and at 15 ^{0}C. Calculate the heat transfer area and effectiveness of the exchanger. For oil in the tubes, the properties are: ρ = 880 kg/m^3, μ = 2.2 x 10^{-5} Pa.s, C_p = 2.15 kJ/kg-K, k = 190 × 10^{-6} kW/m-K For water, C_p = 4.19 kJ/kg-K , h = 1.2 kW/m^2-K.	**12**	**CO5**
7.	Calculate the amount of steam required for concentrating the solution of caustic soda from 28% W of solids to 40% W of solids in a single effect evaporator. The feed rate is 25000 kg/hr and its temperature is 60 ^{0}C. The absolute pressure in the evaporator is	**12**	**CO5**

	0.2 kg/cm^2 (Boiling point 60 ^0C). Saturated steam at 1.4 kg/cm^2 (108.7 ^0C) is to be used as heating medium. The elevation in boiling point is 25 ^0C. If the overall heat transfer coefficient is 670 kcal/h-m^2-^0C, calculate the heating surface required. The enthalpy data for various streams are as follows: Vapor at 0.2 kg/ cm^2 =623 kcal/kg 28% NaOH at 60 ^0C =50 kcal/kg 40% NaOH at 85 ^0C= 90 kcal/kg Latent heat of steam at 1.4 kg/cm^2 = 534 kcal/kg.		
SECTION - C (20 × 1 = 20 Marks)			
8.(a)	Derive a relationship for the LMTD (log mean temperature difference) between the two fluids considering the counter-flow configuration in a double pipe heat exchanger. List the assumptions, also.	**10**	**CO5**
(b)	Water is heated from 15 ^0C to 65 ^0C as it flows through a 3 cm internal diameter and 5 m long tube. The tube is equipped with an electric resistance heater, which provides uniform heating throughout the surface of the tube. The outer surface of the heater is perfectly insulated so that the whole generated heat is given to the water in the tube. The water flow rate is 10 litre/minute. Determine the power rating of the heater. Also, find the inner surface temperature of the pipe at the exit. Take the following properties of air at mean film temperature of 40 ^0C: ρ = 994 kg/m^3, k = 0.62860 W/m-K, C_p = 4.178 kJ/kg-K, $\upsilon = 0.66 \times 10^{-6}\ m^2/s$	**10**	**CO3**
OR			
8.(a)	Air at 207 kPa and 200 ^0C enters a 2.5 cm inside diameter tube at 6 m/s. The tube is constructed of copper with a thickness of 0.8 mm and a length of 3 m. Atmospheric air at 1 atm and 20 ^0C flows normal to the outside of the tube with a free-stream velocity of 12 m/s. Calculate the air temperature at exit from the tube. What would be the effect of reducing the hot air flow in half? The properties of air at mean bulk temperature are: $\mu = 2.58 \times 10^{-5}$ kg/m-s, ρ = 1.525 kg/m^3, k=0.0385 W/m-K and C_p = 1.03 kJ/kg-K. The properties of air at mean film temperature are: $\upsilon = 25.15 \times 10^{-6}\ m^2/s$, k=0.0324 W/m-K and Pr =0.69. Nusselt Number for flow outside the tube is given by:	**10**	**CO5**

	$Nu = 0.193\,\Re^{0.618}\,Pr^{\frac{1}{3}}$		
(b)	A 3 m internal diameter spherical tank made of 1 cm thick stainless steel (k = 15 W/m-^{0}C) is used to store iced water at 0 ^{0}C. The tank is located outdoors at 30 ^{0}C and is subjected to winds at 25 km/h. Assuming the entire steel tank to be at 0 ^{0}C and thus its thermal resistance to be negligible, determine (a) the rate of heat transfer to the iced water in the tank and (b) the amount of ice at 0 ^{0}C that melts during a 24 h period. The heat of fusion of water at atmospheric pressure is h_{fg} = 333.7 kJ/kg. Disregard any heat transfer by radiation. The properties of air at 30 ^{0}C and 1 atm pressure are: k = 0.02588 W/m-K, $\upsilon = 1.608 \times 10^{-5}$ m^2/s, $\mu_\infty = 1.872 \times 10^{-5}$ kg/m-s, Pr = 0.7282 The dynamic viscosity of air at 0 ^{0}C is 1.729×10^{-5} kg/m-s. The Nusselt Number is given by: $Nu = 2 + \left[0.4\,\Re^{0.5} + 0.06\,\Re^{2/3}\right] Pr^{0.4} \left(\frac{\mu_\infty}{\mu_s}\right)^{1/4}$	**10**	**CO3**

Name:	
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Course Name : Heat Transfer **Time : 03 hrs**
Course Code : CHCE 2009 **Max. Marks : 100**
Nos. of page(s) : 03
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SECTION A (10 × 2 = 20 Marks)

S. No.		Marks	CO
1.	A long solid cylinder rod of 10 cm radius is made of a material (k=1 W/m.K) generating 24×10^3 W/m^3 uniformly throughout its volume. This rod is tightly encapsulated within a long hollow cylinder (k=14 W/m.K), whose inner radius is 10 cm and outer radius is 20 cm. The outer surface is surrounded by a fluid at 200°C and the convective heat transfer coefficient between the surface and the fluid is 120 W/m^2.K. What is the temperature at the outer surface of the outer cylinder and the temperature at the interface between the two cylinders?	10	CO1
2.(a)	How is natural convection different from forced convection?	2	CO3
(b)	In which mode of heat transfer will the convection heat-transfer coefficient usually be higher, and why?	2	
(c)	Enumerate some examples of free convection flow?	2	
(d)	What does the Grashof number represent and how is it different from the Reynolds number?	2	
(e)	Define Hydraulic diameter? What is it equal to for a circular tube of diameter D?	2	

SECTION B (12 × 5 = 60 Marks)

S. No.		Marks	CO
3.(a)	Define Planck's Law.	2+10	CO1
(b)	Two long concentric cylinders have diameters of 4 and 8 cm, respectively. The inside cylinder is at 800 ^{0}C and the outer cylinder is at 100 ^{0}C. The inside and outside emissivities are 0.8 and 0.4, respectively. Calculate the percent reduction in heat transfer if a cylindrical radiation shield having a diameter of 6 cm and emissivity of 0.3 is placed between the two		

	cylinders.		
4.	A 1.5 m diameter, 5 m long cylindrical propane tank is initially filled with liquid propane, whose density is 581 kg/m^3. The tank is exposed to the ambient air at 25°C in calm weather. The outer surface of the tank is polished so that the radiation heat transfer is negligible. Now a crack develops at the top of the tank, and the pressure inside drops to 1 atm while the temperature drops to -42 °C, which is the boiling temperature of propane at 1 atm. The heat of vaporization of propane at 1 atm is 425 kJ/kg. The propane is slowly vaporized as a result of the heat transfer from the ambient air into the tank, and the propane vapor escapes the tank at -42°C through the crack. Assuming the propane tank to be at about the same temperature as the propane inside at all times, determine how long it will take for the tank to empty if it is not insulated. The properties of air are: k = 0.02401 W/m-K, $\upsilon = 1.382 \times 10^{-5}$ m^2/s, Pr = 0.7350 Relation of Nusselt Number is given by: $Nu=\left\{0.6+\frac{0.387\,Ra^{1/6}}{\left[1+\left(\frac{0.599}{Pr}\right)^{9/16}\right]^{8/27}}\right\}^2$	12	CO3
5.(a)	Explain the effect of presence of non-condensables on rate of condensation of condensable vapors?	4+8	CO4
(b)	Saturated air-free steam at 85 ^{0}C condenses on the outer surface of 225 horizontal tubes of 12.7 mm outer diameter arranged in a 15 × 15 array. Tube surfaces are maintained at 75 ^{0}C. Calculate the total condensation per metre length of the tube bundle. Properties of air are: $\rho = 971.8$ kg/m^3, $\mu = 360.7 \times 10^{-6}$ kg/m-s, $h_{fg} = 2257$ kJ/kg, k = 0.67 W/m-K.		
6.	Hot water at 90 ^{0}C flows on the inside of a 2.5 cm ID steel tube with 0.8 mm wall thickness at a velocity of 4 m/s. This tube forms the inside of a double-pipe heat exchanger. The outer pipe has a 3.75 cm ID, and engine oil at 20 ^{0}C flows in the annular space at a velocity of 7 m/s. Calculate the overall heat-transfer coefficient for this arrangement. The tube length is 6.0 m. For water at 90 ^{0}C: ρ =965 kg/m^3, $\mu = 3.16 \times 10^{-6}$ kg/m-s, k = 0.676 W/m-K, Pr = 1.96 For Engine oil: $\upsilon = 0.0009$ m^2/s, k = 0.145 W/m-K, Pr = 10400, $\upsilon_w = 0.289 \times 10^{-4}$ m^2/s, and Nusselt Number is given by $Nu_d = 1.86(\Re_d Pr)^{1/3}\left(\frac{d}{l}\right)^{1/3}\left(\frac{\mu}{\mu_w}\right)^{1/3}$	12	CO5
7.	A single effect vertical short tube evaporator is used to concentrate a syrup from 10% to 40% solids at the rate of 2000 kg of feed per hour. The feed enters at 30 ^{o}C and a reduced pressure of 0.33 kg/cm^2 is maintained in the vapour space. At this pressure, the liquor boils	12	CO5

	at 75°C. Saturated steam at 115°C is supplied to the steam chest. No sub cooling of the condensate occurs. Calculate the steam requirement and the number of tubes if the height of the calandria is 1.5 m. Specific heat of liquor =0.946 kcal/kg °C. Latent heat of steam at 0.33 kg/cm^2 =556.5 kcal/kg, boiling point of water at this pressure=345 K. the overall heat transfer coefficient =2150 kcal/ h m^2 °C.		
SECTION - C (20 × 1 = 20 Marks)			
8.(a)	Discuss the common causes of fouling in a heat exchanger. How does fouling affect its performance? What is the effect of fluid velocity and temperature on fouling?	**10**	**CO5**
(b)	Blood at 32°C enters a 2.5 mm inside diameter steel tube with a volumetric flow rate of 15 mL/s. The tube surface is electrically heated to impart a uniform heat flux. The tube wall temperature must not exceed 44°C to avoid damage to the blood. Calculate the minimum length of the tube required to warm the blood to 37°C. Blood properties may be approximated as those of water. Properties of water at the bulk mean temperature of 34.5°C are ρ = 994.0 kg/m^3 , μ = 7.32 ×10^{-4} N-s/m^2, k = 0.624 W/m-K, Pr =4.91, C_p= 4.178 kJ/kg-K	**10**	**CO3**
OR			
8.(a)	A single pass steam condenser contains 100 thin walled tubes of 25 mm nominal diameter and 2 m length. Cooling water enters at a temperature of 10°C leaves at 50°C and flows through the tubes at a velocity of 2 m/s. The condenser pressure is 0.5 bar and the heat transfer coefficient is 5000 W/m^2 K. Determine the condensate flow rate. The following properties of water are used: ρ =995.8 kg/m^3, μ=801×10^{-6} kg/ m.s , C_p = 4.178 kJ/kg K, k=0.617 W/ m K	**10**	**CO5**
(b)	The hot water needs of a household are to be met by heating water at 55°F to 200°F by a parabolic solar collector at a rate of 4 lbm/s. Water flows through a 1.25-in.-diameter thin aluminium tube whose outer surface is black anodized in order to maximize its solar absorption ability. The centerline of the tube coincides with the focal line of the collector, and a glass sleeve is placed outside the tube to minimize the heat losses. If solar energy is transferred to water at a net rate of 350 Btu/h per ft length of the tube, **estimate** the required length of the parabolic collector to meet the hot water requirements of this house. Also, determine the surface temperature of the tube at the exit. The properties of water at the average temperature of 127.5°C are: ρ = 61.59 lb_m/ft^3, υ = 0.5683 × 10^{-5} ft^2/ s , C_p = 0.999 Btu/lbm °F, k=0.374 Btu/ft °F, Pr=3.368.	**10**	**CO3**