Closed Book

Birla Institute of Technology & Science, Pilani

Pilani Campus

I Semester / II Semester / Summer Term 20___- 20___

Comprehensive Examination (Regular/Make-Up)

ID No. ____________________ Name ____________________________________

Course No. ________________ Course Title _______________Section No._______

Instructor's Name ___________ Room No. ______________________ Date_______

Verified:
Signature of Invigilator:

INSTRUCTIONS

1. Enter all the required details on the cover of every answer booklet.
2. Write on both sides of the sheet in the answer book. Rough work, if any should be done at the bottom of the page. Finally cross out the rough work and draw a horizontal line to separate it from the rest of the material on the page. Also, cross out all blank pages in the answer booklet.
3. Any answer crossed out by the student will not be examined by the examiner.
4. No sheet should be torn from the answer booklet.
5. Mobile phones or any electronic communication/storage device of any kind is prohibited in the examination hall.
6. Use of any unfair means will make the candidate liable to disciplinary action.
7. Student should not leave the examination hall without submitting the answer booklet to invigilator on duty.
8. Student must abide by all the instructions given by the invigilator(s) on duty.

I have carefully read and understood all the instructions.

I do understand that any attempt to use unfair means of any kind in an examination is a serious and punishable offence.

I hereby declare that I will not attempt to do any malpractice in the examination.

Signature of the student

BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI, PILANI CAMPUS
DEPARTMENT OF CHEMICAL ENGINEERING
Second Semester 2022-23
Course Title: Heat Transfer (CHE F241)
Comprehensive Examination (Closed Book)

Marks: 60 **Date: 11/05/23** **Time: 1 h 30 min**

Note: Questions 1 - 15 (4 Marks each). Write the final answers (upto two decimals in prescribed units) in the space provided at end of this question paper.

1. Consider two walls, 1 and 2, both have the same surface area and the same temperature drop across their thickness. The ratio of the thermal conductivity between two walls is given as $k_1/k_2 = 2$. The thickness ratio between the two walls is given as $L_1/L_2 = 4$. Then what is the **ratio of the heat transfer between the two walls Q_1/Q_2**?
2. A hot fluid is flowing through a long pipe of 4 cm outer diameter and covered with 2 cm thick insulation. It is proposed to reduce the conduction heat loss to the surroundings to one-third of the present rate by increasing the same insulation thickness. What will the **additional thickness of insulation** require in **cm**?
3. A circumferential aluminum fin (k = 222 W/m.K) of rectangular profile is attached to a copper tube having an outside radius of 0.04 m. The length of the fin is 0.04 m and the thickness is 2 mm. The outside wall or tube base is at 523 K and the external surrounding air at 343 K has a convective coefficient of 30 W/m^2.K. If the fin efficiency is 0.89 then, **estimate the rate of heat loss from the fin in W**.
4. A small metal spherical bead (radius 0.5 mm), initially at 100 °C, when placed in a stream of fluid at 20 °C, attains a temperature of 28 °C in 4.35 seconds. The density and specific heat of the metal are 8500 kg/m^3 and 400 J/kg.K, respectively. If the bead is considered as lumped system, **estimate the convective heat transfer coefficient (in W/m^2.K)** between the metal bead and the fluid stream.
5. A small solid copper ball of mass 500 grams, when quenched in a water bath at 30 °C cools from 530 °C to 430 °C in 10 seconds. What will be the **temperature (in ^{o}C) of the ball after the next 10 seconds**?
6. Consider the flow of a gas with density = 1 kg/m^3, viscosity = 1.5×10^{-5} kg/m.s, specific heat = 846 J/kg.K and thermal conductivity = 0.017 W/m.K, in a pipe of diameter = 0.01 m and length = 1 m, and assume the viscosity does not change with temperature. The Nusselt number for a pipe with L/D ratio greater than 10 and Reynolds number greater than 20000 is given by $Nu = 0.026\, Re^{0.8} Pr^{1/3}$. While the Nusselt number for a laminar flow for Reynolds number less than 2100 and (RePrD/L) < 10 is $Nu = 1.86[RePr(D/L)]^{1/3}$. If the gas flows through the pipe with an average velocity of 0.1 m/s, then **estimate the heat transfer coefficient (in W/m^2.K)**.
7. Air is flowing over a hot plate at a temperature of 120 °C. If at a point Reynold number is increased by 4 times and Nusselt number is increased by 2 times, then the **new value of Prandtl number will be how many times the previous one**? Consider laminar flow (For constant temperature boundary condition, $Nu = 0.332 Re^{1/2} Pr^{1/3}$ and for constant heat flux boundary condition, $Nu = 0.453 Re^{1/2} Pr^{1/3}$).
8. A solid sphere of radius r_1 = 20 mm is placed concentrically inside a hollow sphere of radius r_2 = 30 mm. The exchange of radiation (uniform in all directions) occurs only between the outer surface of the smaller sphere (surface 1) and the inner surface of the larger hollow sphere (surface 2). Calculate the **view factor F_{21} for radiation heat transfer**.

9. Determine the **net radiant heat exchange (W/m^2)** for two infinite parallel plates held at temperatures of 800 K and 500 K. Take emissivity as 0.6 for the hot plate and 0.4 for the cold plate. (Stefan-Boltzmann's costant = 5.669×10^{-8} $W/m^2.K^4$)
10. In a heat exchanger, the inner diameter of a tube is 25 mm and the thickness of the pipe wall is 2.5 mm. The overall heat transfer coefficient based on the inner area is 360 $W/m^2.^{\circ}C$. Then, calculate the **overall heat transfer coefficient based on the outer area in $W/m^2.^{\circ}C$**.
11. It is desired to concentrate a 20 wt% salt solution to a 30 wt% salt solution in an evaporator. Consider a feed of 300 kg/min at 30 ^oC. The boiling point of the solution is 110 ^oC, the latent heat of vaporization is 2100 kJ/kg, and the specific heat of the solution is 4 kJ/kg.K. **Estimate the rate at which total heat has to be supplied (in kJ/min) to the evaporator**.
12. In a double-pipe heat exchanger, the cold fluid is water with inlet temperature of 20^{o}C and mass flow rate of 20 kg/s, and the hot fluid which is also water has inlet temperature of 80^{o}C and mass flow rate of 10 kg/s. For water c_p = 4.2 kJ/kg.^{o}C. What is the **maximum temperature to which the cold fluid** can be heated in a counterflow heat exchanger?
13. Consider a counterflow heat exchanger with the inlet temperatures of two fluids (1 and 2) being $T_{1,in}$ =300K and $T_{2,in}$ =350K. The heat capacity rates of the two fluids are $(mc_p)_1$ = 1000 W/K and $(mc_p)_2$ = 400 W/K, and the effectiveness of the heat exchanger is 0.5. **Calculate the actual heat transfer in W**.
14. In a counter-flow heat exchanger, the hot fluid is cooled from 100 °C to 70 °C by a cold fluid which gets heated from 25 °C to 55 °C. **Calculate the LMTD (in ^{o}C) for the heat exchanger**.
15. Steam at 100 °C is condensing on a vertical steel plate. The condensate flow is laminar. The average Nusselt numbers are Nu_1 and Nu_2, when the plate temperatures are 10 °C and 55 °C, respectively. Assume the physical properties of the fluid and steel to remain constant within the temperature range of interest. Using Nusselt equations for film-type condensation, **what is the value of the ratio Nu_2/Nu_1**?

$$\bar{h} = 1.13 \left[\frac{\rho(\rho - \rho_v) g h_{fg} k^3}{L\mu(T_g - T_w)} \right]^{1/4}$$

Solutions (Closed Book)

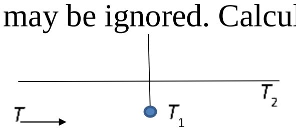
Q No.	**Answer**	**Q No.**	**Answer**
1		**9**	
2		**10**	
3		**11**	
4		**12**	
5		**13**	
6		**14**	
7		**15**	
8			

BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI, PILANI CAMPUS
DEPARTMENT OF CHEMICAL ENGINEERING
Second Semester 2021-22
Course Title: Heat Transfer (CHE F241)
Comprehensive Examination (Open Book)

Marks: 75 **Date: 11/05/23** **Time: 1 h 30 min**

Note: Write all assumptions and steps clearly.

1. **(15 Marks)**
   Water at atmospheric pressure condenses on a strip 30 cm in height that is held at 90 ^oC. Calculate the overall heat transfer per meter, the film thickness at the bottom, and the mass rate of condensation per meter. Latent heat of condensation of the vapor = 2257 kJ/kg.
2. **(15 Marks)**
   What maximum heat removal flux can be achieved at the surface of a horizontal 0.01 mm diameter electrical resistance wire in still 27 ^oC air if its melting point is 927 ^oC? Neglect radiation.
3. **(15 Marks)**
   A flow rate of 1.4 kg/s of water (c_p = 4190 J/kg.^oC) enters the tubes of a two-shell-pass, four-tube-pass heat exchanger at 7 ^oC. A flow rate of 0.6 kg/s of liquid ammonia (c_p = 5189 J/kg.^oC) at 100 ^oC is to be cooled to 30 ^oC on the shell side; U = 573 W/m^2 K. **Use NTU method** to determine the following:
   (a) How large (area) must the heat exchanger be?
   (b) How large must it be if, after some months, a fouling of 0.0015 m^2.K/W will build up in the tubes, and we still want to deliver ammonia at 30 ^oC?
   (c) If we make it large enough to accommodate fouling, to what temperature will it cool the ammonia when it is new?
   (d) At what temperature does water leave the new, enlarged exchanger?
4. **(15 Marks)**
   A feed of 4535 kg/h of a 2 wt% salt solution at 311 K enters continuously a single-effect evaporator and is concentrated to 3.0 wt%. The evaporation is at atmospheric pressure and the area of the evaporator is 69.7 m^2. Saturated steam at 383 K is supplied for heating. Since the solution is dilute, it can be assumed to have the same boiling point as water. The heat capacity of the feed can be taken as 4.10 kJ/kg K. Calculate the amounts of vapor and liquid product and the overall heat-transfer coefficient U. Saturated water vapor enthalpy at 100 ^oC and 110 ^oC is 2676.1 and 2691.5 kJ/kg, respectively. Saturated water enthalpy at 100 ^oC and 110 ^oC is 419.04 and 461.3 kJ/kg, respectively.
5. **(15 Marks)**
   A pyrometer inserted in a duct through which hot air is flowing reads 480 ^oC and the walls of the duct are at 475 ^oC. The heat transfer coefficient by convection is 28.38 W/m^2 ^oC and the emissivities of all materials are to be taken as 0.75 in the system. The thermal conductivities may be ignored. Calculate the true temperature of air.



ALL THE BEST