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| **Name:**<br><br>**Enrolment No:** | UPES |

**UNIVERSITY OF PETROLEUM AND ENERGY STUDIES**
**End Semester Examination, April/May 2018**

**Course: Heat Transfer Processes (GNEG 356)** **Semester: VI**
**Program: B. Tech Mechanical Engineering**
**Time: 03 hrs.** **Max. Marks: 100**

**Instructions:**
**Section A** constitutes of **30 Marks** (6 questions x 5 marks); Attempt All. ***Give answers in few lines, definitely not more than half a page.***
**Section B** constitutes of 45 Marks (each carrying 15 marks)**.** Attempt three.
**Section C** constitutes of 25 Marks (one question worth 25 marks)**.** Attempt either of two.
***Please answer the sub-parts of a question together.***

## SECTION A

| S. No. | | Marks | CO |
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| Q 1 | A solid iron sphere with surface temperature $T_s$ is suspended in a room with ambient temperature $T_o$<br>a) For $T_s > T_o$ and $T_s < T_o$, show the boundary layer development for both cases.<br>b) Plot the variation of $Nu$ with respect to the angle from the horizontal (angle increasing counterclockwise) for both the cases on the same axis. | **[5]** | **CO2** |
| Q2) | An analysis of the comparison between diurnal and nocturnal temperatures at India's biggest metros – Delhi and Mumbai reveals an interesting trend. The temperature swings are much larger in Delhi as compared to Mumbai. What is ONE SINGLE most important reason behind this? Explain. | **[5]** | **CO3** |
| Q3) | Liquid metals like mercury are used for coolants in applications where extremely high heat transfer rates are needed. By drawing and comparing the hydrodynamic and thermal boundary layers on a horizontal flat plate, explain why is mercury a right choice. | **[5]** | **CO2** |
| Q4) | Mr. Gopal Das Banarasilal wants to setup a small industry with a great business idea, which has promising potential for consistent high profits. But, he is short of funds in trying to procure all the heat exchangers required for his factory. With appropriate mathematics, convince this businessman what approach he should take in selecting the right heat exchangers. | **[5]** | **CO4** |
| Q5) | Boiling is effected at the base of a bubble column by heating a hot plate and bubbles are being generated at the base. Assuming vertically upward direction as the +ve x-axis, draw curves for the bubble size as a function of $x$ for the case of | **[5]** | **CO2** |

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| | a) subcooled boiling.<br>b) Saturated boiling<br>Explain your plots as well. | | |
| Q6) | Figure below shows a multiple effect evaporator with five effects<br><br>How do these compare (increasing, decreasing or equal) in the different effects<br>a) The temperature of the inlet vapors. Explain.<br>b) The pressure maintained in these different effects. Explain. | **[5]** | **CO5** |
| | **<u>Section-B</u>** | | |
| Q7) | In a production facility, thin vertical square plates 2m x 2m in size coming out of the oven at 270 deg C are cooled by blowing ambient air at 30 deg C.<br>(a) Determine the air velocity above which the natural convection effects on heat transfer are less than 10% and thus are negligible, if air is blown horizontally parallel to their surfaces<br>(b) Considering the air is blowing at this velocity (found in the above question) and assuming both free and forced convection are happening, estimate the heat transfer rate if air is blown vertically in the downward direction.<br>**OR**<br>The evaporator section of a refrigeration unit consists of thin-walled, 10-mm-diameter tubes through which refrigerant passes at a temperature of -18°C. Air is cooled as it flows over the tubes, maintaining a surface convection coefficient of 100 W/$m^2$K, and is subsequently routed to the refrigerator compartment. For the foregoing conditions and an air temperature of -3°C, what is the rate at which heat is extracted from the air per unit tube length? | **[15]** | **CO1** |
| Q8) | In a typical coquette flow situation (flow of water between two large isothermal parallel plates with the top plate moving at a velocity of $U$, and the bottom plate stationary), the distance between the plates is $L$. Obtain expressions for velocity and temperature distributions in the pipe and the heat flux from liquid to each plate, when the temperatures of top and bottom plate are $T_1$ and $T_2$, respectively. | **[15]** | **CO2** |

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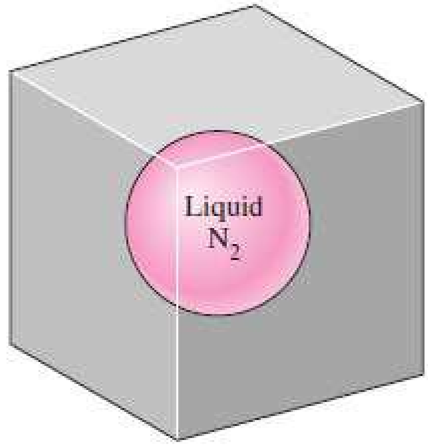
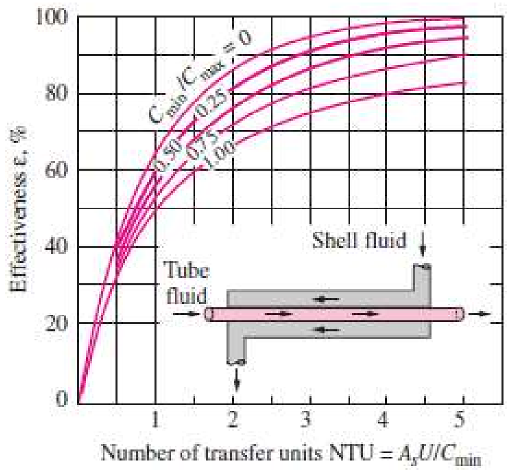
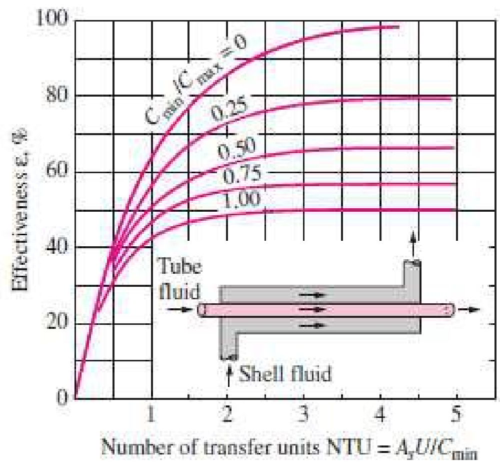
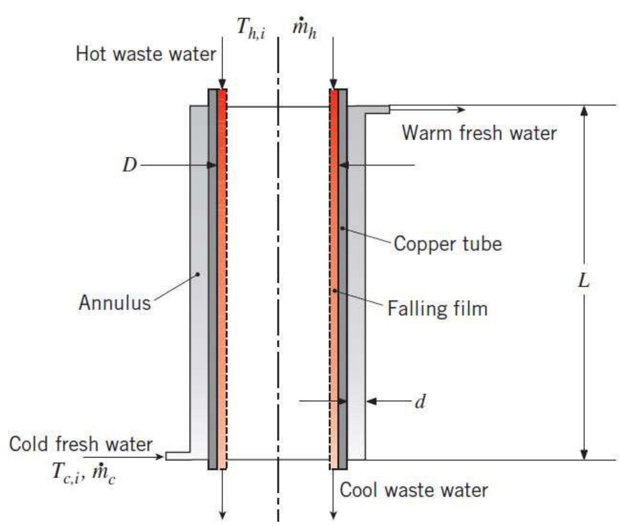
| Q9) | <br><br>A spherical tank of diameter, $D$ = 2 m that is filled with liquid nitrogen at 100 K is kept in an evacuated cubic enclosure whose sides are 3 m long. The emissivities of the spherical tank and the enclosure are 0.1 and 0.8, respectively. If the temperature of the cubic enclosure is measured to be 240 K,<br>(a) determine the net radiation of heat transfer to the liquid nitrogen, assuming the enclosure to be a real surface (as described earlier).<br>(b) determine the net radiation of heat transfer to the liquid nitrogen assuming it to be a blackbody. | **15** | **CO3** |
| | **SECTION-C** | | |
| Q 10 | Water ($C_p$ = 4180 J/kg · °C) enters the 2.5-cm internal-diameter tube of a double-pipe counter-flow heat exchanger at 17°C at a rate of 3 kg/s. Water is heated by steam condensing at 120°C ($h_{fg}$ = 2203 kJ/kg) in the shell. If the overall heat transfer coefficient of the heat exchanger is 900 W/m$^2$ °C, determine the length of the tube required in order to heat the water to 80°C using<br>(a) the LMTD method and<br>(b) the ε–NTU method.<br>(c) Draw the velocity profiles, beginning from the pipe entrance to the point flow has become fully developed. Also, draw the temperature profiles, beginning from the pipe entrance to the point flow has become fully developed. For drawing these profiles, assume that the milk at the cow-body temperature enters the pipe which is at a temperature significantly lower than the cow-body.<br>(d) If instead of steam condensing on the water tube, the same water was heated using an electric resistance heater that provides uniform heating throughout the tube surface. The outer surface of the heater is well insulated so that in steady operation all the heat generated in the heater is transferred to the tube. Determine the power rating of the resistance heater.<br>(e) For the part (d) above, estimate the inner surface temperature of the pipe at the exit. | **[25]** | **CO4** |




# OR

The chief engineer at a university that is constructing a large number of new student dormitories decides to install a counterflow concentric tube heat exchanger on each of the dormitory shower drains. The thin-walled copper drains are of diameter $D_i$ = 50mm. Wastewater from the shower enters the heat exchanger at $T_{h,i}$ = 38°C while fresh water enters the dormitory at $T_{c,i}$ =10°C. The wastewater flows down the vertical wall of the drain in a thin, falling film , providing $h_h$ =10,000W/$m^2$K.




If the annular gap is d = 10mm, the heat exchanger length is L = 1m, and the water flow rate is , determine the **(a)** heat transfer rate and the outlet temperature of the warmed fresh water. **(b)** If a helical spring is installed in the annular gap so the fresh water is forced to follow a spiral path from the inlet to the fresh water outlet, resulting in $h_c$ = 9050W/$m^2$K, determine the heat transfer rate and the outlet temperature of the fresh water. **(c)** Based on the result for part (b), calculate the daily savings if 15,000 students each take a 10-minute shower per day and the cost of water heating is Rs. 7/kWh.