Name:	UPES
Enrolment No:	

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, December 2019

Programme Name: B.Tech Mechanical **Semester : V**
Course Name : Heat and Mass Transfer **Time : 03 hrs**
Course Code : MECH3008 **Max. Marks : 100**

Instructions:

- Section A constitutes of 20 Marks (4 questions x 5 marks); Attempt All.
- Section B constitutes of 40 Marks (4 questions x 10 marks). Attempt All (One choice question).
- Section C constitutes of 40 Marks (2 questions x 20 marks). Attempt All (One choice question).
- Question #5 and Question#10 have options. Please answer only one of the options.

Please answer the sub-parts of a question together. Highlight the numerical answers**.**

SECTION A

S. No.		Marks	CO
Q 1	Mr. Vasudeva Ghosh has proposed to install "Roof-ponds" as a green building concept in many tall buildings in New Delhi. He claims that such Roof ponds will save energy and costs. However, Dr. Devakinandana Chattopadhyay, the chief engineer wantsMr. Vasudeva to present an analysis of the working and operation of such Roof-ponds over different weather and dirunal/nocturnal conditions. Prepare a small note for Mr. Vasudeva.	**5**	**CO1**
Q 2	Mr. Murari Dasgupta has claimed in a recent newspaper article that he has discovered a red-stone artifact which is a blackbody? Is the statement of Mr. Murari contradictory? Explain in detail.	**5**	**CO1**
Q 3	Draw temperature profiles of **liquid as well as tube surface** in the fuly developed region of an a) Isothermal tube b) Isoflux tube Explain the trends and state your assumptions.	**5**	**CO1**
Q 4	Trombe walls are an interesting way of passive solar heating in many cold countries. Explain thoroughly what enables a trombe wall to cause heating inside a building.	**5**	**CO1**

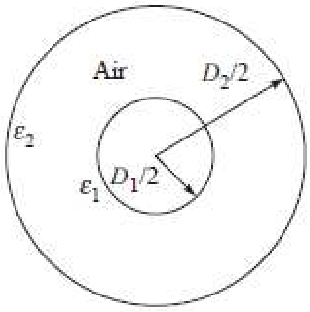
SECTION B

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, μ = 2x10^3 kg/m-s, ρ = 1000 kg/m^3, k = 0.8 W/mK. OR	**10**	**CO2**

<table>
<tr><td></td><td>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.

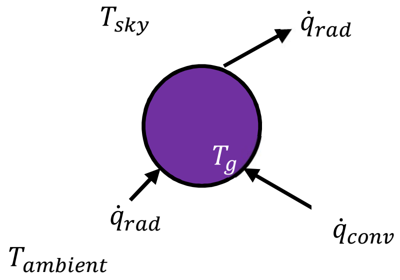
(a) What is the water outlet temperature? Evaluate water properties at an assumed average mean temperature. Was the assumed value reasonable? Comment.

(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.</td><td></td><td></td></tr>
<tr><td>Q 6</td><td>Two concentric spheres of diameters $D1 = 0.5$ m and $D2 = 1$ m are separated by an air space as shown in Figure below and have surface temperatures of 400 K and 300 K respectively.



(a) If the surfaces are black, what is the net rate of radiation exchange between the spheres?
(b) What is the net rate of radiation exchange between the surfaces if they are diffuse and gray with $\epsilon 1 = 0.5$ and $\epsilon 2 = 0.5$?
(c) What error would be introduced by assuming blackbody behaviour for the outer surface ($\epsilon 2 = 1$) with all other conditions remaining the same?</td><td>10</td><td>CO2</td></tr>
<tr><td>Q 7</td><td>

An ice rink is a public skating place typically meant for recreation. A square ice rink of 500 m^2 in surface area has a surface temperature of -3ºC. The ambient air temperature in the rink is 18ºC. Determine the cooling load on the refrigeration system holding the ice rink to its steady state condition. Neglect radiation. Assume that there are no sideboards. Use the properties for air below.</td><td>10</td><td>CO3</td></tr>
</table>

Q 8	 A grape of diameter ***d*** is heated by a mild breeze of ambient air and by radiation from its near surroundings at the ambient temperature (assume that this is over the grape lower hemisphere and from that surface, the view factor is 1). The grape is cooled by radiation to a cloudless night sky (assume that this is over the grape upper hemisphere and from that surface, the view factor is 1). Assume: The grape temperature is uniform. Known about the grape are the values of k, ρ, c and α. Also known are the convective heat transfer coefficient, h, and the temperatures T_{sky}, and $T_{ambient}$. Develop an equation that gives the grape steady state temperature T_g. Note that T_g should remain as the only undefined term, written in terms of the problem values given herein.	**10**	**CO4**
	SECTION C		
Q 9	Air is forced through a long tube of 0.1 m diameter at a bulk velocity of 6 cm/s. The inlet temperature is 30°C and the wall temperature is 150°C. Begin by basing the fluid properties on 30°C temperature and 2.0 atmospheres pressure. a) After the flow has become fully-developed, hydrodynamically and thermally, and the bulk temperature has reached 100°C, what is the value of dT_b/dx at this point? Note, T_b is the bulk temperature and x is distance in the streamwise direction. Begin by establishing whether the flow is laminar or turbulent. **Justify your answer.** b) What length of tube from the entrance is needed to establish fully-developed conditions?	**20**	**CO3**
Q 10	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 50°C. 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 10°C to 40°C. The water flow rate is 0.1 kg/sec. What is the heat exchanger size, given as A_0, the tube total outside area? **OR** We know this about our heat exchanger: Fluid A: Air at 1.0 atmosphere $\dot{m} = 0.1$ kg/sec $T_{A,in} = 20$°C Fluid B: CO_2 at 1.0 atmosphere pressure $\dot{m} = 0.1$ kg/sec $T_{A,in} = 100$°C The arrangement is cross-flow, both fluids are unmixed, U_0A_0 for the exchanger is 400 W/K. What are the exit temperatures [°C]? Assume constant properties taken at the respective inlet temperatures of each of the two fluids.	**20**	**CO4**

Appendix

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

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