Name: **Enrolment No:**	UPES UNIVERSITY OF TOMORROW

UPES
End Semester Examination, May 2025

Programme Name: B. Tech Aerospace **Semester : IV**
Course Name : Heat Transfer for aerospace applications **Time : 03 hrs**
Course Code : ASEG2024 **Max. Marks : 100**
Instructions:

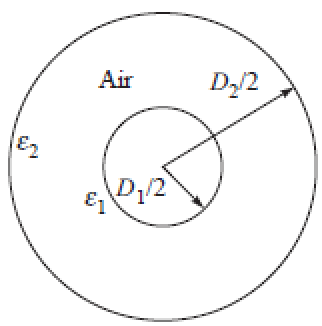
- Section A constitutes of 20 Marks (5 questions x 4 marks); Attempt All.
- Section B constitutes of 40 Marks (4 questions x 10 marks). Attempt All (One choice question).
- Section C constitutes of 40 Marks (2 questions x 20 marks). Attempt All (One choice question).
- Question #8 and Question#10 have options. Please answer only one of the options.

SECTION A

SN		Marks	CO
Q1	*Ramnath*, a roadside blacksmith takes an iron piece and immerses in a hot flame at $t_1 = 0$ and keeps it inside the flame till $t_2 = 10$ minutes. He reports that he did observe that the color of the metallic piece changes. What color changes is expected to be observed? Explain by drawing the wavelength spectra at time intervals t_1 and t_2. Will the metal ever appear blue? Justify.	**4**	**CO1**
Q 2	You are tasked with designing a thermal protection system (TPS) for a reusable hypersonic vehicle that faces prolonged high heat flux during cruise and intense thermal spikes during re-entry. Which combination of thermal management methods would you choose and why? Discuss by evaluating the suitability of passive, semi-passive, and active cooling strategies with examples.	**4**	**CO1**
Q 3	a) What are rotary enthalpy wheels and how is the heat exchange effected in them? b) Is the heat pipe a biomimetic design? Comment.	**4**	**CO1**
Q 4	A plane wall of thickness 2L, has a volumetric heat source q (W/m^3). It is exposed to local ambient temperature $T\infty$ at both the (x= ±L). Derive an expression for the surface temperature Ts of the wall under steady state condition (where h and q carry their usual meaning).	**4**	**CO2**
Q5	Two cylinders of radius r_1 and r_2 and length L are placed concentrically. The outer surface of inner cylinder is marked as 1 whereas the inner surface of the outer cylinder is marked as 2. Determine all four view factors F_{ij} for i,j = 1,2.	**4**	**CO3**

SECTION B

Q 6	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	**10**	**CO1**

	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 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.		
Q 7	Two concentric spheres of diameters *D*1 = 0. 5 m and *D*2 = 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?	**10**	**CO2**
Q 8	A solid iron sphere with surface temperature T_s is suspended in a room with ambient temperature T_o a. For $T_s > T_o$ *and* $T_s < T_o$, show the boundary layer development for both cases. 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.	**10**	**CO2**
Q 9	A composite hollow cylinder with steady internal heating is made of two layers of materials of equal thickness with thermal conductivities in the ratio of 1:2 for inner to outer layers. Ratio of inside to outside diameter is 0.8. What is the ratio of temperature drop across the inner and outer layers?	**10**	**CO4**

SECTION C

Q 10	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 11	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: Water 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	$\varepsilon = \dfrac{1-\exp[-\text{NTU}(1+C)]}{1+C}$
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 $C = 0$	$\text{NTU} = -\ln(1-\varepsilon)$

Other fluid properties may be provided during the exam or assume approximate values.

Heat Transfer (MECH3008) End-sem Exam

Formula Sheet

For forced convection, Nu = C $Re^m Pr^n$ and for free convection, Nu = C Ra^m. The values of constants are given below.

Mode	Geometry	Condition	Constants (C,m,n)
Forced Convection	Circular cross-section cylinder	0.4-4 (Range of Re) 4-40 40-4000 4000-40000	0.989,0.330,0.33 0.911,0.385,0.33 0.683,0.466,0.33 0.193,0.618,0.33
Forced Convection	Ellipse cross-section cylinder	2500-15000 (Range of Re)	0.248,0.612,0.33
Forced Convection	Square cross-section cylinder	5000 – 100000 (Range of Re)	0.102,0.675,0.33
Forced Convection	Vertical plate Cross-section cylinder	4000-15000 (Range of Re)	0.228,0.731,0.33
Free Convection	Vertical Plate	10^4-10^9 10^9-10^{13} (Range of Ra)	0.59,0.25 0.1,0.33
Free Convection	Horizontal plate (upper surface of a hot plate or lower surface of a cold plate)	10^4-10^7 10^7-10^{11} (Range of Ra)	0.54,0.25 0.15,0.33
Free Convection	Horizontal plate (upper surface of a cold plate or lower surface of a hot plate)	10^5-10^{11} (Range of Ra)	0.27,0.25
Forced Convection	Flat Plate Laminar Isothermal Plate Local	Pr>0.6	0.332,0.5,0.33
Forced Convection	Flat Plate Laminar Isoflux Plate Local		0.453,0.5,0.33
Forced Convection	Flat Plate Laminar Isothermal Plate Averaged	Pr>0.6	0.664,0.5,0.33
Forced Convection	Flat Plate Laminar Isoflux Plate Averaged		0.906,0.5,0.33
Forced Convection	Flat Plate Turbulent Isothermal Plate Local	60>Pr>0.6	0.0296,0.8,0.33
Forced Convection	Flat Plate Turbulent Isoflux Plate Local		0.0308,0.8,0.33
Forced Convection	Flat Plate Turbulent Isothermal Plate Averaged	60>Pr>0.6	0.037,0.8,0.33
Forced Convection	Flat Plate Turbulent Isoflux Plate Averaged		0.0385,0.8,0.33

Fluid Properties at different temperatures in SI units at a pressure of 1 bar.

Fluid	Temp. (^{o}C)	Kinematic viscosity*10^5	Thermal conductivity	Specific heat	Dynamic Viscosity*10^5	Density
Air	18	1.508	0.03	1006.84	1.806	1.20
Air	-3	1.318	0.02	1006.47	1.701	1.29
Air	8	1.416	0.02	1006.66	1.756	1.24
Air	30	1.623	0.03	1007.09	1.864	1.15
Air	150	2.882	0.04	1017.65	2.395	0.83
Air	90	2.240	0.03	1009.97	2.141	0.96
Air	100	2.347	0.03	1010.86	2.185	0.93
Air	25	1.575	0.03	1006.98	1.840	1.17
Air	20	1.527	0.03	1006.88	1.816	1.19
Water	10	0.1272	0.59	4090.03	127.2	999.59
Water	20	0.09829	0.60	4076.58	98.08	997.82
Water	30	0.07836	0.62	4070.25	77.98	995.23
Water	40	0.06425	0.63	4067.33	63.72	991.86
Water	50	0.05398	0.64	4066.03	53.32	987.75
Water	60	0.04629	0.65	4065.79	45.50	982.94
Water	70	0.04037	0.66	4066.80	39.46	977.44
Water	100	0.02875	0.68	4082.08	27.52	957.20