BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(END SEMESTER EXAMINATION)

CLASS: BTECH | **SEMESTER: V**
BRANCH: MECHANICAL ENGINEERING | **SESSION: MO/2024**

SUBJECT: ME315 HEAT AND MASS TRANSFER

TIME: 3 Hours | **FULL MARKS: 50**

INSTRUCTIONS:
1. The question paper contains 5 questions each of 10 marks and total 50 marks.
2. Attempt all questions.
3. The missing data, if any, may be assumed suitably.
4. Before attempting the question paper, be sure that you have got the correct question paper.
5. All symbols have their usual meanings.

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Q.1(a)	A 2-mm-diameter electrical wire is insulated by a 2-mm thick rubberized sheath (k = 0.13 W/m · K). The convection heat transfer coefficient at the outer surface of the sheath is 10 $W/m^2 \cdot K$, and the temperature of the ambient air is 20 ^oC. If the temperature of the insulation may not exceed 50 ^oC, what is the maximum allowable electrical power that may be dissipated per unit length of the conductor? Can the electrical power through the wire be increased further by increasing the radius of the insulation?	[5]	1-3	1-4
Q.1(b)	The temperature of a gas stream is to be measured by a thermocouple whose junction can be approximated as a 1-mm-diameter sphere. The properties of the junction are k = 35 W/m °C, ρ = 8500 kg/m^3, and C_p = 320 J/kg °C, and the convection heat transfer coefficient between the junction and the gas is h = 210 W/m^2 °C. Determine the response time of the thermocouple, i.e., the time to read 99 percent of the initial temperature difference. Is lumped system analysis valid for this thermocouple junction?	[5]	1-4	1-3
Q.2(a)	A long, slender and circular shaped steel rod is attached at one end to a heated wall and transfers heat by convection to a cold fluid. If the diameter of the rod is tripled, how will the rate of heat removal change and by what factor? If a copper rod of the same diameter is used in place of the steel rod, how will the rate of heat removal change qualitatively?	[2]	1-2	1-4
Q.2(b)	State few characteristics of a blackbody. How does the radiative properties of a real body differ from a blackbody? Illustrate this citing few essential radiative properties of a real body, and the parameters upon which they depend.	[3]	1	1-2
Q.2(c)	Two large parallel planes having emissivities at 0.3 and 0.5 are maintained at temperatures of 800 ^oC and 300 ^oC respectively. Calculate the radiative heat flux exchange between them. If a radiation shield having an emissivity of 0.05 on both sides is placed between them, what is the resultant heat exchange? Also calculate the temperature of the shield in this case.	[5]	1-3	1-4
Q.3(a)	State any 2 non-dimensional numbers and define their significance in the study of forced convection heat transfer. Define and state the importance of hydrodynamic and thermal boundary layers. What is the importance of Reynold's and Colburn analogies in the context of convective heat transfer?	[5]	1	1-2
Q.3(b)	Engine oil at 60°C flows over the upper surface of a 5 m long flat plate whose temperature is 20°C with a velocity of 2 m/s. Determine the total drag force and the rate of heat transfer per unit width of the entire plate. Take the properties of engine oil as: k = 0.144 W/m °C, ρ = 876 kg/m^3, Pr = 2870, v = 242 x 10^{-6} m^2/s. Use the following correlations as per suitability: For laminar flow, $C_f = 1.328 \cdot Re_L^{-0.5}$, $Nu_L = 0.664 \cdot Re_L^{0.5} \cdot Pr^{1/3}$ and for turbulent flow, $C_f = 0.074 \cdot Re_L^{-0.2}$, $Nu_L = 0.037 \cdot Re_L^{0.8} \cdot Pr^{1/3}$.	[5]	1-3	1-3

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Q.4(a)	Airflow through a long, 0.2-m-square air conditioning duct maintains the outer duct surface temperature at 10 °C. If the horizontal duct is uninsulated and exposed to air at 35 °C outside the air-conditioned room, what is the heat gain per unit length of the duct? Consider free convection on all 4 outer surfaces of the horizontal square duct. Take the properties of air as: *k* = 0.0263 W/m °C, α = 22.5 x 10^{-6} m^2/s, *Pr* = 0.707, ν = 15.89 x 10^{-6} m^2/s. Consider the following correlations for use as necessary. For laminar flow over a horizontal plate with hot face facing upward and facing down, $Nu = 0.54 \cdot Ra_L^{1/4}$ and $Nu = 0.52 \cdot Ra_L^{1/5}$ respectively, and for laminar flow across a vertical plate, the Nusselt No. may be calculated by the relation given below, where the Rayleigh No. is $Ra_L = Gr \cdot Pr$ $$\overline{Nu}_L = 0.68 + \frac{0.670\, Ra_L^{1/4}}{\left[1 + (0.492/Pr)^{9/16}\right]^{4/9}}$$	[5]	1-4	1-3
Q.4(b)	Describe the various regimes of saturated pool boiling heat transfer along with a neat sketch, clearly labelling the heat transfer rate vs excess temperature plot for water boiling.	[5]	1	1-2
Q.5(a)	Briefly define the importance of heat exchangers and classify them. What are some of the ways used to increase the heat transfer between the two fluids in shell and tube type heat exchangers? What is the phenomena of fouling in heat exchangers?	[5]	1, 4	1-2
Q.5(b)	A counter-flow double-pipe heat exchanger is to heat water from 20°C to 80°C at a rate of 1.2 kg/s. The heating is to be accomplished by geothermal water available at 160°C at a mass flow rate of 2 kg/s. The cylindrical inner tube is thin-walled and has a diameter of 1.5 cm. If the overall heat transfer coefficient of the heat exchanger is 640 W/m^2 °C, determine the length of the heat exchanger required to achieve the desired heating.	[5]	1-4	1-3

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