Reg No.:_______________ Name:___________________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

B.Tech Degree S6 (S,FE) (FT/WP/S4 PT) Examination December 2025 (2019 Scheme)

Course Code: MET302

Course Name: HEAT AND MASS TRANSFER

Max. Marks: 100 **Duration: 3 Hours**

Use of Heat and Mass Transfer data book is permitted.

PART A

Answer all questions, each carries 3 marks.

Marks

1	Define thermal diffusivity and explain its physical significance	(3)
2	What is the fin effectiveness? Under what conditions are fins most effective?	(3)
3	Explain the physical significance of the Nusselt number? What does a Nusselt number of 1 indicate for a plain fluid layer?	(3)
4	For a hot horizontal plate in quiescent air, do you expect heat transfer to be larger for the top or bottom surface? Why?	(3)
5	What are the common causes of fouling in a heat exchanger? How does fouling affect heat transfer and pressure drop?	(3)
6	Why is the maximum possible heat rate for a heat exchanger not equal to $C_{max}(T_{h,inlet} - T_{c,inlet})$, where C_{max} is the higher heat capacity among the hot and cold fluids, $T_{h,inlet}$ and $T_{c,inlet}$ being the inlet temperatures of the hot and cold fluids respectively.	(3)
7	What are the characteristics of a blackbody? Does such a thing actually exist in nature? What is the principal role of blackbody behavior in radiation analysis?	(3)
8	What are the surface and space resistances in radiation? How are they expressed? For what kind of surfaces is the radiation surface resistance zero?	(3)
9	State Fick's law of mass diffusion. How is it mathematically expressed?	(3)
10	What is the difference between mass concentration and molar concentration?	(3)

PART B

Answer any one full question from each module, each carries 14 marks.

Module I

11	a)	The walls of a refrigerator are typically constructed by sandwiching a layer of insulation between sheet metal panels. Consider a wall made from fiberglass insulation of thermal conductivity k_i =0.046 W/mK and thickness L_i= 50 mm and steel panels, each of thermal conductivity k_p =60 W/mK and thickness L_p=3 mm. If the wall separates refrigerated air at $T_{\infty,i}$ =4 °C from ambient air at $T_{\infty,o}$ =25 °C, what is the heat gain per unit surface area? Heat transfer coefficients associated with natural convection at the inner and outer surfaces may be approximated as h_i=h_o=5 W/m^{2}K.	(10)
	b)	In a nuclear reactor, 1-cm-diameter cylindrical uranium rods cooled by water from outside serve as the fuel. Heat is generated uniformly in the rods (k=29.5	(4)

W/m·°C) at a rate of 7×10^7 W/m^3. If the outer surface temperature of rods is 175°C, determine the temperature at their center.

OR

12 a) Carbon steel balls (ρ=7833kg/m^3, k=54W/m.°C, c_p=465J/kg.°C and α=1.474×10^{-6} m^2/s) 8mm in diameter are annealed after heating them first to 900 °C in a furnace and then allowing them to cool slowly to 100 °C in ambient air at 35 °C. If the average heat transfer coefficient is 75 W/m^2. °C, determine how long the annealing process will take. (6)

b) Consider a very long rectangular fin attached to flat surface such that the temperature at the end of the fin is essentially that of the surrounding air at 20 °C. Its width is 5cm; thickness is 1mm; thermal conductivity is 200 W/m. °C; and base temperature is 40 °C. The heat transfer coefficient is 20W/m^2. °C. Estimate the fin temperature at 5cm from the base and the rate of heat loss from the entire fin. (8)

Module II

13 (a) A rectangular plate is 120 cm long in the direction of flow and 200cm wide. The plate is maintained at 80°C when placed in nitrogen that has a velocity of 2.5m/s and a temperature of 0°C. Determine a) the average heat transfer coefficient and b) the total heat transfer from the plate. The properties of nitrogen at film temperature (40°C) are ρ=1.142 kg/m^3, (8)

c_p=1.04 kJ/kg K,

ν=15.63×10^{-6} m^2/s and

k=0.0262 W/m K., Pr=0.7085

(b) Explain velocity boundary layer and thermal boundary layer for flow through pipes with neat sketches. (6)

OR

14 (a) Consider a vertical plate of dimension 0.25 m×0.50 m, maintained at T_s=100 °C, in quiescent air (air at rest) at T_∞= 20°C. In the interest of minimizing heat transfer from the plate, which orientation, (A – the 0.25m side kept vertical) or (B – the 0.5m side kept vertical), is preferred? What is the convection heat transfer from the front surface of the plate when it is in the preferred orientation? (10)

(b) Explain the physical significance of Grashoff number and Prandtl number in convection. (4)

Module III

15 a) Draw the pool boiling curve and identify the different boiling regimes. Also, explain the characteristics of each regime. (6)

b) A double-pipe parallel-flow heat exchanger is to heat water (c_p=4180 J/kg·°C) from 25°C to 60°C at a rate of 0.2 kg/s. The heating is to be accomplished by geothermal water (c_p=4310 J/kg·°C) available at 140°C at a mass flow rate of 0.3 kg/s. The inner tube is thin-walled and has a diameter of 0.8 cm. If the overall heat transfer coefficient of the heat exchanger is 550 W/m^2 °C, determine the length of the heat exchanger required to achieve the desired heating. (8)

OR

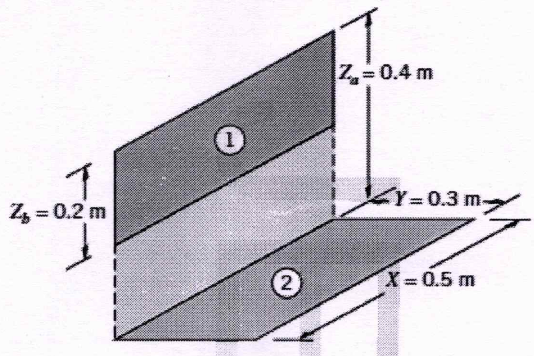
16 a) Derive an expression for the LMTD of a parallel flow double pipe heat exchanger. (6)

b) Hot oil (c_p =2200 J/kg · °C) is to be cooled by water (c_p = 4180 J/kg · °C) in a 2-shell-pass and 12-tube-pass heat exchanger. The tubes are thin-walled and are made of copper with a diameter of 1.8 cm. The length of each tube pass in the heat exchanger is 3 m, and the overall heat transfer coefficient is 340 W/m^2 · °C. Water flows through the tubes at a total rate of 0.1 kg/s, and the oil through the shell at a rate of 0.2 kg/s. The water and the oil enter at temperatures 18°C and 160°C, respectively. Determine the rate of heat transfer in the heat exchanger and the outlet temperatures of the water and the oil. (8)

Module IV

17 a) What is meant by view factor in radiation? When is the view factor from a surface to itself not zero? Consider an enclosure consisting of five surfaces. How many view factors does this geometry involve? How many of these view factors can be determined by the application of the reciprocity and summation rules? (6)

b) Consider the perpendicular rectangles shown schematically. (8)



Determine the shape factor F_{12}.

OR

18 a) What is a radiation shield? Why is it used? (3)

b) Two very large parallel plates are maintained at uniform temperatures of T_1=1000 K and T_2=800 K and have emissivities of ε_1=ε_2=0.2, respectively. It is desired to reduce the net rate of radiation heat transfer between the two plates to one-fifth by placing thin aluminum sheets with an emissivity of 0.15 on both sides between the plates. Determine the number of sheets that need to be inserted. (11)

Module V

19 a) A gas mixture consists of 8 kmol of H_2 and 2 kmol of N_2. Determine the mass of each gas and the apparent gas constant of the mixture. How does the mass diffusivity of a gas mixture change with (*a*) temperature and (*b*) pressure? (6)

b) Helium gas is stored at 293 K in a 3-m-outer-diameter spherical container made of 5-cm-thick Pyrex. The molar concentration of helium in the Pyrex is 0.00073 kmol/m^3 at the inner surface and negligible at the outer surface. Determine the (8) mass flow rate of helium by diffusion through the Pyrex container. The binary diffusion coefficient of helium in the Pyrex at the specified temperature is 4.5×10^{-15} m^2/s. The molar mass of helium is M = 4 kg/kmol.

OR

20 a) Heat convection is expressed by Newton's law of cooling as $Q=hA(T_s - T_\infty)$. Express mass convection in an analogous manner on a mass basis, and identify all the quantities in the expression and state their units. (2)

b) Consider a 15-cm-internal-diameter, 10-m-long circular duct whose interior surface is wet. The duct is to be dried by forcing dry air at 1 atm and 15°C through it at an average velocity of 3 m/s. The duct passes through a chilled room, and it always remains at an average temperature of 15°C. Determine the mass transfer coefficient in the duct. (12)

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