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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

B.Tech Degree S6 (R,S) / (WP), S4 (PT) Exam April 2025 (2019 Scheme)

Course Code: MET302

Course Name: HEAT AND MASS TRANSFER

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

Use of Steam Table & Heat and Mass Transfer Data Book Permitted

PART A

Answer all questions, each carries 3 marks. Marks

1	Explain how a hot cup of coffee loses heat.	(3)
2	Describe the role of fins in electronic cooling systems.	(3)
3	Describe the concept of a hydrodynamic boundary layer with a sketch.	(3)
4	List three real-life examples of natural convection heat transfer.	(3)
5	Describe the differences between pool boiling and flow boiling.	(3)
6	Identify the main types of heat exchangers based on flow arrangement.	(3)
7	Explain Wien's displacement law and its importance.	(3)
8	Define radiation shape factor and its role in heat exchange calculations.	(3)
9	State Fick's first law of diffusion and its mathematical expression.	(3)
10	Differentiate stagnant diffusion and counter diffusion with examples	(3)

PART B

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

Module I

11 a) A composite cylindrical pipe consists of three concentric layers made of different materials. The inner and outer radii of the first layer are 0.05 m and 0.08 m, respectively, with a thermal conductivity of 20 W/m·K. The second layer has an outer radius of 0.12 m and a thermal conductivity of 5 W/m·K, while the third layer extends to an outer radius of 0.18 m and has a thermal conductivity of 2 W/m·K. The inner surface temperature is maintained at 300°C, while the outer surface temperature is 100°C. Assuming steady-state one-dimensional radial heat conduction and neglecting contact resistance, determine the total thermal resistance, the heat transfer rate per meter length of the pipe, and the interface temperatures at r=0.08m and r=0.12m. (9)

b) Derive the expression for the critical radius of insulation for a cylindrical system. (5)

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OR

12 a) Derive the general three-dimensional heat conduction equation in Cartesian coordinates. (9)

b) A solid sphere made of copper (thermal conductivity k=400 W/m·K, density ρ=8933 kg/m³, specific heat c_p=385 J/kg·K) with a diameter of 5 cm is initially at 200°C. It is suddenly immersed in a large water bath maintained at 30°C. The convective heat transfer coefficient between the sphere and water is 120 W/m²·K. Using the lumped capacitance method, determine: (i) The time required for the sphere's temperature to drop to 90°C. (5)

Module II

13 a) Air at 30°C flows over a 1-meter-long flat plate with a velocity of 2 m/s. The plate is maintained at a surface temperature of 90°C. Assume that the flow is laminar over the entire plate. Given the properties of air at the film temperature: Thermal conductivity, k=0.026W/m· K, Kinematic viscosity, $\nu=1.5\times10^{-5}$, Prandtl number, Pr = 0.7, Density, ρ = 1.2 kg/m³. Determine: (i) The boundary layer thickness at the end of the plate. (ii) The total drag force exerted by the air on the plate per unit width. (iii) The total heat transfer rate from the plate per unit width. (9)

b) Explain the significance of the Prandtl number in convection heat transfer. (5)

OR

14 a) A 1-meter-high vertical plate with a surface temperature of 150°C is exposed to air at 50°C under natural convection. Given: Thermal conductivity of air, k= 0.03 W/m·K, Kinematic viscosity, $\nu=2.0\times10^{-5}$ m²/s, Prandtl number, Pr=0.72, Density, ρ=1.1 kg/m³. Determine: (i) The Rayleigh number, (ii) The average convective heat transfer coefficient. (iii) The total heat transfer rate from the plate per unit width. (9)

b) Discuss the role of Grashof number in natural convection heat transfer. (5)

Module III

15 a) Hot water enters a parallel flow heat exchanger at 90°C and exits at 60°C. Cold water enters at 30°C and exits at 50°C. The specific heat capacity of water is 4.18 kJ/kg·K, and the mass flow rate of both fluids is 2 kg/s. Determine: (i) The LMTD for the heat exchanger, (ii) The total heat transfer rate, (iii) The required heat exchanger area if the overall heat transfer coefficient is 300 W/m²·K. (9)

b) Differentiate between filmwise condensation and dropwise condensation. (5)

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OR

16 a) Hot oil enters a counter flow heat exchanger at 150°C, while cold water enters at 30°C. The mass flow rate of hot oil is 3 kg/s, and that of cold water is 5 kg/s. The specific heat capacities are: Hot oil: $c_{p,h}$=2100 J/kg·K, Cold water: $c_{p,c}$==4180 J/kg·K, The overall heat transfer coefficient is 250 W/m²·K, and the heat exchanger area is 8 m². Determine: (i) The Number of Transfer Units (NTU), (ii) The effectiveness of the heat exchanger, (iii) The heat transfer rate. (9)

b) Explain the different regimes of the boiling curve with a labeled diagram. (5)

Module IV

17 a) A black body at 3000 K emits radiation. Calculate the following: i) Monochromatic emissive power at 7 μm wave length. ii) Wave length at which emission is maximum. iii) Emissive power at maximum wavelength iv) Total emissive power, v) Calculate the total emissive of the furnace if it is assumed as a real surface having emissivity equal to 0.85. (9)

b) Describe the use of radiation shields to reduce heat loss. (5)

OR

18 a) Two infinite parallel plates with emissivities $\varepsilon_1 = 0.7$ and $\varepsilon_2 = 0.5$ are maintained at temperatures $T_1 = 800$ K and $T_2 = 400$ K, respectively. The plates are separated by a vacuum and behave as gray surfaces. Determine: (i) The net radiation heat transfer per unit area between the plates, (ii) The % reduction in radiation heat flux if a radiation shield with $\varepsilon = 0.3$ is placed between them. Take Stefan-Boltzmann constant: $\sigma = 5.67\times10^{-8}$ W/m²K⁴ (9)

b) Explain Kirchhoff's law of thermal radiation with examples. (5)

Module V

19 a) A liquid layer of 8 mm thickness contains acetic acid diffusing through water at steady-state equimolar counter-diffusion conditions at 20°C. The concentration of acetic acid at one side of the layer is 2.5 kmol/m³, and at the other side, it is 0.5 kmol/m³. The diffusion coefficient of acetic acid in water is 1.3×10^{-9} m²/s. Find: (i) The molar flux of acetic acid in kmol/m²·s, (ii) The molar flux of water, (iii) The total volume (in liters) of acetic acid diffused in 8 hours, assuming a 1 m² area and that acetic acid has a density of 1.049 kg/L. (9)

b) Describe the differences between molecular diffusion and convective mass transfer. (5)

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151

OR

20 a) A wet paper sheet of 1.2 m^2 area is placed in an airflow at 20°C and 1 atm pressure. The mass transfer coefficient for water vapor in air is 0.03 m/s, and the saturation vapor pressure of water at 20°C is 2.34 kPa. The air has a humidity of 40%. Determine: (i) The rate of water evaporation in $kg/m^2 \cdot s$, (ii) The total amount of water evaporated in 2 hours. (9)

b) Describe the physical significance of Sherwood number in convective mass transfer. (5)

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152

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Reg No.:_______________ Name:________________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

Sixth Semester B.Tech Degree Examination June 2022 (2019 Scheme)

Course Code: MET302

Course Name: Heat and Mass Transfer

(Use of heat and mass transfer data book permitted)

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

PART A

Answer all questions, each carry 3 marks. Marks

1	What is critical radius of insulation? Explain its importance.	(3)
2	Explain Lumped system analysis.	(3)
3	Explain the physical significance of Prandtl No. and Nusselt No.in convection.	(3)
4	What is Grashof number? Explain its significance.	(3)
5	Why drop-wise condensation is better than film wise condensation? What are the methods to achieve drop wise condensation?	(3)
6	What is fouling factor? How fouling factor is accounted in heat exchanger analysis?	(3)
7	What is view factor? State summation rule of view factor.	(3)
8	Explain perfect black body concept.	(3)
9	What are the three modes of mass transfer?	(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)	Derive general conduction equation in Cartesian coordinate with necessary sketch. Reduce the equation for steady state one dimensional heat conduction across a plane wall without internal heat generation	(7)
	b)	A rectangular aluminum fin of cross section 8 x 3 cm^2 and 1 m long is protrudes out from a wall of thermal conductivity 250 W/mK. The fin base is maintained at a temperature of 400°C and the ambient temperature is 30°C with heat transfer coefficient 10W/m^2K. The tip of the fin is insulated. Calculate the heat transfer from the fin.	(7)

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OR

12 a) An electric cable of 10 mm diameter is to be insulated by a rubber (k=0.14W/mK). Assume cable surface temperature is 70°C. The surrounding air temperature is 30°C and convective heat transfer coefficient is 10 W/m^2K in both bare and insulated cases. Find critical thickness of the insulation and compare the heat transfer for with and without insulation. (7)

b) The interior temperature of a refrigerator is maintained at 5°C. The walls are constructed with two mild steel sheets 3 mm thick with 5 cm of glass wool insulation between them. The heat transfer coefficients on inner and outer surface of refrigerator are 10 W/m^2°C and 12.5 W/m^2 °C respectively. The temperature in kitchen room is 35°C.Take k (mild steel) =40 W/m-°C and k (glass wool) = 0.04 W/m-°C. Sketch the electric analog of the system. Find the rate of heat leaked to the refrigerator in watts per unit area when it is kept in a kitchen room. Also find interface wall temperatures. (7)

Module II

13 a) Air at pressure of 1 atm and temperature 70°C flows over a flat plate which maintains a surface temperature of 90°C. The plate has a length of 0.2m (in the flow direction) and width of 0.1m. The Reynolds number based on the plate length is 40000. What is the rate of heat transfer from plate to air? (9)

If the free stream velocity of air is doubled and the pressure is increased to 3 atm, what is the rate of heat transfer?

b) Explain hydrodynamic and thermal boundary layer for flow through tubes with the help of neat sketches. (5)

OR

14 a) A hot square plate 40 cm x 40 cm at 90°C is exposed to atmospheric air at 30°C. Make calculations for the heat loss from both surfaces of the plate, if (a) the plate is kept vertical (b) the plate is kept horizontal. The following empirical correlations have been suggested: (8)

$Nu = 0.125\,(Gr\,Pr)^{0.33}$ for vertical position of plate, and

$Nu = 0.72\,(Gr\,Pr)^{0.25}$ for upper surface (horizontal position)

$= 0.35\,(Gr\,Pr)^{0.25}$ for lower surface (horizontal position)

where the air properties are evaluated at the mean temperature.

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b) An incandescent bulb can be considered as a sphere of 0.06 m dia. The bulb surface is at 130°C. Air at 30°C flows over it with a velocity of 0.6 m/s. Determine the heat loss from the bulb surface. (6)

Module III

15 a) Explain boiling (pool boiling) curve for water with the help of a neat sketch. (7)

b) In an open-heart surgery under hypothermic conditions, the patient's blood is cooled before the surgery and re-warmed afterwards. It is proposed that a concentric tube counter flow heat exchanger of length 0.5 m is to be used for this purpose, with a thin-walled inner tube having a diameter of 55 mm. If water at 60° C and 0.1 kg/s is used to heat blood entering the exchanger at 18°C and 0.05 kg/s, what is the temperature of the blood leaving the exchanger and the heat flow rate. Take U_0 = 500 W/m^2 K, c_p of blood = 3.5 kJ/kg K and c_p of water = 4.183 kJ/kg K. (7)

OR

16 a) Derive an expression for effectiveness of parallel flow heat exchanger using NTU method. (10)

b) What are compact heat exchangers? Explain with suitable examples. (4)

Module IV

17 a) Derive an expression for the net radiation exchange between two black bodies. (7)

b) What is Wien's Displacement Law? Explain with the help of Planks distribution. (7)

OR

18 a) Calculate the radiation exchange per unit area between two parallel plates of temperature 500^{0}C and 50^{0}C. Emissivity of hot and cold plates are 0.9 and 0.7 respectively. Find the percentage reduction in heat transfer, if a radiation shield of emissivity 0.25 on both surface is placed in between the plates. (7)

b) State and prove Kirchhoff's law of radiation. (7)

Module V

19 a) State and explain Fick's law of molecular diffusion. Write its analogy with Fourier law. (7)

b) Dry air at 30°C and 1 atm flows over a wet flat plate 700 mm long at a velocity of 60 m/s. Calculate the mass transfer co-efficient of water vapour in air at the end of the plate. Take the diffusion co-efficient of water vapour in air, D = 0.26 x 10-^{4} m^2/s (7)

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OR

20 a) Air at 20° C, 40% RH, flows over a water surface at a velocity of 1.2 m/s, the length parallel to flow is 200 mm and width is 300mm. If average surface temperature is 16°C, calculate the amount of water evaporated in kg/sec from the surface? (7)

Assume the following properties:

Partial pressure of water vapor at 20° and 40% RH, P_{wa} = 0.011 bar,

The saturated vapor pressure at 16°C, P_{ws} = 0.017 bar,

Kinematic Viscosity of air, υ = 16.38 x 10 m^2/s,

Density of air ρ = 1.22 kg/m^3,

Diffusion coefficient; D = 0.256 x 10^{-4} m^2/s,

Gas constant of water=461.9 J/kg K

b) What is equimolar counter diffusion? Obtain an expression for molar diffusion rate in terms of partial pressures (7)

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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

B.Tech Degree S6 (R, S) / S4 (PT) (R,S) Examination June 2023 (2019 Scheme)

JYOTHI ENGG. COLLEGE LIBRARY THRISSUR EDUCATIONAL CHERUTHURUTHY 26/7/23

Course Code: MET302

Course Name: HEAT AND MASS TRANSFER

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

PART A

Answer all questions, each carries 3 marks. Marks

1	Distinguish between (i) steady and unsteady conduction (ii) 1-D and 2-D conduction.	(3)
2	Write the assumptions used for Fourier's law of heat conduction	(3)
3	Discuss the differences between natural and forced convection?	(3)
4	Explain the significance of Reynolds number	(3)
5	Discuss "correction factor" in heat exchanger analysis?	(3)
6	Illustrate cross flow heat exchanger	(3)
7	State and explain Kirchhoff's law of thermal radiation	(3)
8	List and explain the factors affecting the rate of emission of radiation by a body	(3)
9	Discuss the three modes of mass transfer	(3)
10	What is convective mass transfer coefficient? What is its dimension?	(3)

PART B

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

Module I

11 a) A 5 mm diameter and 2 m long electric wire is insulated with a 2 mm thick layer of fibrous cotton (k=0.8W/mK) followed by plastic layer(k=0.15 W/mK) of 3mm thickness. Electrical measurements indicate that a current of 20 A passes through the wire and there is a voltage drop of 25 V along the wire. If the insulated wire is exposed to air at $T_\infty = 30°C$ with a convection heat transfer coefficient of h = 12 W/m^2-K, determine the temperature at the interface of the wire and the fibrous cotton cover in steady operation. (7)

b) Explain critical thickness of insulation of a cylinder and derive an expression for the same. (7)

OR

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12 a) Calculate the rate of heat loss through the vertical walls of a boiler furnace of size 4 m × 3 m and 3 m high. The walls are constructed from an inner fire brick wall 25 cm thick of thermal conductivity 0.4 W/mK , a layer of ceramic blanket insulation of thermal conductivity 0.2 W/mK and 8 cm thick , and a steel protective layer of thermal conductivity 55 W/mK and 2 mm thick. The inside temperature of the fire brick layer was measured at 600 ^{0}C and the temperature of the outside of the insulation 60^0 C. Also find the interface temperature of layers. (7)

b) A steam pipe of 10 cm inner diameter and 11 cm outer diameter is covered with an insulating substance k = 1 W/mK. The steam temperature is 200^0 C and ambient temperature is 20^0 C. If the convective heat transfer coefficient between insulating surface and air is 8 W/m^{2}K, find the critical radius of insulation and for this value of r_c, calculate the heat loss per m of pipe and the outer surface temperature. Neglect the resistance of the pipe material. (7)

Module II

13 a) When 0.6 kg of water per minute is passed through a tube of 2 cm diameter, it is found to be heated from 20°C to 60°C. The heating is achieved by condensing steam on the surface of the tube and subsequently the surface temperature of the tube is maintained at 90° C. Determine the length of the tube required for fully developed flow. (9)

b) State and explain Newtons law of cooling. (5)

OR

14 a) A vertical pipe 80 mm diameter and 2 m height is maintained at a constant temperature of 120°C. The pipe is surrounded by still atmospheric air at 30° C. Find heat loss by natural convection. (10)

b) Illustrate thermal boundary layer over a flat plate when the plate surface is hotter than fluid. (4)

Module III

15 a) Explain the classification of heat exchanger by the 'nature of heat exchange' with the help of diagrams. (7)

b) Derive the expression for log mean temperature difference in parallel flow heat exchanger (7)

OR

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16 a) A chemical having specific heat of 3.3 kJ/kgK enters a parallel flow heat exchanger at 120 ^{0}C with a mass flow rate of 20000 kg/h. The flow rate of cooling water is 50000 kg/h with an inlet temperature of 20 ^{0}C. The heat transfer area is 10 m^2 and overall heat transfer coefficient is 1050 W/m^2K. Find the outlet temperature of water and chemical. (Take C_P of water =4.18kJ/kgK) (10)

b) State the causes of fouling in heat exchanger. How fouling is accounted in heat exchanger analysis? (4)

Module IV

17 a) Compare white body with grey body (5)

b) A boiler furnace, whose surfaces closely approximate black surface, is made in the shape of a cylinder of height 2.4 m and diameter 6 m. The base, top and curved surfaces are maintained at 800K, 1500K and 600K respectively. Determine net radiation heat transfer between top and curved surfaces. (9)

OR

18 a) Two large plates are maintained at a temperature of 900 K and 500 K respectively. Each plate has area of 6m^2. Compare the net heat exchange between the plates for the following cases. i) Both plates are black and ii) Plates have an emissivity of 0.5 (8)

b) The filament of a 75 W light bulb may be considered as a black body radiating into a black enclosure at 70^0 C. Considering the radiation, determine the filament temperature, if the filament diameter is 0.10 mm and length is 5 cm. (6)

Module V

19 a) State and explain governing law of diffusion mass transfer. (6)

b) Explain steady state diffusion through a plane membrane (8)

OR

20 a) Air at 50 ^{0}C and 1 atm. flow over the surface of a water reservoir at an average velocity of 2.3 m/s. The water surface is 0.65 m long and 0.65 m wide. The water surface temperature is estimated to be 30^{0}C. The relative humidity of air is 40%. The density of air is 1.105kg/m^3 and its kinematic viscosity is 17.58×10^{-6} m^2/s. Calculate the amount of water vapour evaporates per hour per square meter of water surface in kg/m^2h. Diffusion coefficient= $0.256 \times 10^{-4}\ m^2/s$. (14)

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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

B.Tech Degree S6 (R, S) / S4 (PT) (R, S) Examination May 2024 (2019 Scheme)

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Course Code: MET302

Course Name: HEAT & MASS TRANSFER

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

PART A

Answer all questions, each carries 3 marks. Marks

1	Define thermal diffusivity and give its physical explanation.	(3)
2	What is meant by lumped heat capacity analysis? What is the criterion to decide whether heat transfer problem can be analysed using Lumped heat capacity model?	(3)
3	Show that Nusselt number represents the enhancement of heat transfer in convection relative to that in conduction by the fluid.	(3)
4	Sketch the velocity boundary layer that forms in flow over a flat plate and mark important flow regions in it.	(3)
5	When do we prefer Effectiveness-NTU method over LMTD method in heat exchanger analysis?	(3)
6	What is the relevance of Critical Heat Flux in boiling heat transfer?	(3)
7	How do we see colour of things? Explain it with basic concepts of radiation.	(3)
8	What is Kirchhoff's law of radiation? How the concept of grey surface is relevant in the context of it?	(3)
9	Which are the nondimensional numbers in mass transfer, which are analogous to Prandtl number and Nusselt numbers in heat transfer?	(3)
10	What is Fick's law of diffusion? How does the nature of diffusion coefficient of gases differ from that of liquids and solids?	(3)

PART B

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

Module I

11 a) A spherical tank of 3 m diameter contains LPG at -60°C. Insulation with thermal conductivity of 0.06 W/m.K and thickness 250 mm is applied to the tank to reduce heat gain. Ambient air temperature is 20°C and the convection coefficient on the (7)

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outer surface is 6 $W/m^2.K$. Determine the radial position in the insulation layer at which the temperature is 0°C.

b) Steel balls of 12 mm in diameter are annealed by heating to 1150 K and then slowly cooling to 400 K in an air environment for which temperature T_∞ = 325 K and heat transfer coefficient, h =20 W/m^2 K. Assume the properties of the steel to be the following: Thermal conductivity is 40 W/mK, density is 7800 kg/m^3, and specific heat is 600 J/kg K. Estimate the time required for the cooling process. (7)

OR

12 a) Steam at 230°C is flowing through a steel pipe (k=15.1 W/m°C) whose inner and outer diameters are 9 cm and 10 cm, respectively. The pipe is insulated with a 5 cm thick fibre glass insulation (k=0.035 W/m °C). Outside temperature is 13°C. If heat transfer coefficients on the inside and outside of the pipe are 170 W/m^2 °C and 30 W/m^2 °C, respectively, find the heat loss per meter length of the pipe. (7)

b) A 1 mm diameter wire is maintained at a temperature of 400°C and exposed to a convection environment at 40°C, with heat transfer coefficient of 120 W/m^2K. Calculate the thermal conductivity which will just cause an insulation thickness of 0.2 mm to make a critical radius. How much of this insulation must be added to reduce the heat transfer by 75% from that which would be experienced by the bare wire? (7)

Module II

13 a) Atmospheric air at 60°C flows over a flat square plate of size $0.5\,m \times 0.5\,m$, maintained at 10°C. What must be the velocity of the air so that the total convective heat transfer from the air to plate is 215 W? (7)

b) A 3 m long circular cylinder with a diameter of 4 cm is exposed to the crossflow of 20°C atmospheric air at a velocity of 6m/s. If the surface temperature of the cylinder is 85°C, find the convective heat transfer from the cylinder. (7)

OR

14 a) A horizontal plate, with top view as shown in figure, has a surface temperature of 200°C and it is exposed to atmospheric air at 20°C. Its bottom side is insulated. Find the convective heat transfer from the plate. (7)

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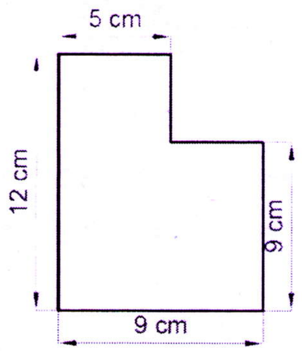

b) Water at 25°C flows through a tube of 50 mm diameter. The flow rate is 0.0575 kg/s. The tube is provided with a nichrome heating element on its internal surface and it provides a constant heat flux of 800 W per metre length of the tube. Determine the average heat transfer coefficient between the tube and water. Also, determine the length of the tube required for the rise of bulk water temperature to 50°C. (7)

Module III

15 a) In a parallel flow heat exchanger, hot fluid enters the heat exchanger at a temperature of 150 °C and a mass flow rate of 3 kg/s. The cooling medium enters the heat exchanger at 30^0C with a mass flow rate of 0.5 kg/s and leaves at a temperature of 70 °C. The specific heat capacities of hot and cold fluid are 1150 J/kg.K and 4180 J/kg. K, respectively. The convection heat transfer coefficients on the inner and outer side of the tube are 300 W/m^2 K and 800 W/m^2 K, respectively. For fouling factors of 0.0003 m^2 K/W inside the tube and 0.0001 m^2K/W on the outer surface of the tube, determine a) The overall heat transfer coefficient b) The exit temperature of hot fluid c) Surface area of the heat exchanger. (10)

b) With simple sketches, explain Dropwise condensation and Film wise condensation on a vertical surface. Which among them has the better heat transfer coefficient and why? (4)

OR

16 a) Water enters a counter flow, double pipe heat exchanger at 15°C, flowing at the rate of 1300kg/h. It is heated by oil (c_p=2000 J/kgK) flowing at the rate of 550 kg/h, with an inlet temperature of 94°C. For an area of 1 m^2 and for an overall heat transfer coefficient of 1075W/m^2K, determine the total heat transfer and the outlet temperature of water and oil. (9)

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b) Give a description on the classification of heat exchanger on the basis of flow arrangement and construction. (5)

Module IV

17 a) Two circular discs of diameters 20 cm each are placed 2 m apart. Calculate the net heat exchange between these plates, if they are maintained at 800°C and 300°C, respectively. Their corresponding emissivity are 0.3 and 0.5. (7)

b) A hemispherical furnace of radius 1m has the inner surface (emissivity =1) of its roof maintained at 800 K, while its floor (emissivity=0.5) is kept at 600 K. Calculate the net heat transfer from the roof to the floor. (7)

OR

18 a) A hollow enclosure is formed between two infinitely long concentric cylinders of radii 1 m and 2 m, respectively. Radiative heat transfer takes place between inner surface of the larger cylinder (*surface 2*) and the outer surface of the smaller cylinder (surface *1*) The radiating surfaces are diffuse and the medium present in between is non-participating. Calculate the fraction of the thermal radiation leaving the larger surface and striking itself. (10)

b) Explain Wein's displacement law. (4)

Module V

19 a) Oxygen gas at 25°C and a pressure of 2 bar is flowing through a rubber pipe of inside diameter 25 mm and wall thickness of 2.5 mm. The diffusivity of oxygen through rubber is 0.21×10^{-2} m^2/s and the solubility of oxygen in rubber is 3.12×10^{-3} kmol/m^{3}bar. Find the rate of loss of oxygen by diffusion per metre length of the pipe. (10)

b) Explain the phenomenon of equimolar counter diffusion. (4)

OR

20 a) CO_2 and air experience equimolar counter diffusion in a circular tube, whose diameter and length are 1 m and 50 ~~mm~~, respectively. The system is at a total pressure of 1 atm and a temperature of 25°C. The ends of the tubes are connected to large chambers, where the species concentrations are kept at fixed values. The partial pressure of CO_2 at one end of the tube is 190 mm of Hg, while that at the other end is 95 mm of Hg. The diffusion coefficient for CO_2-air combination is $D_{AB}=0.16\times 10^{-4}$ m^2/S. Estimate the mass transfer of CO_2 and air through the tube. (10)

b) Give a briefing on different modes of mass transfer. (4)

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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

Sixth Semester B.Tech Degree Supplementary Examination May 2023 (2019 Scheme)

Course Code: MET302

Course Name: HEAT &MASS TRANSFER

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

(Use of Heat and Mass Transfer Data Book permitted)

PART A

Answer all questions, each carries 3 marks. Marks

1	Define thermal diffusivity and explain its physical significance	(3)
2	Discuss the effect of contact resistance on heat transfer and temperature distribution.	(3)
3	Explain the significance of Nusselt number and Prandtl number in convection	(3)
4	Explain why the heat transfer coefficient for natural convection is much less than that for forced convection?	(3)
5	List and explain any three classification of heat exchangers.	(3)
6	Discuss the advantage of NTU method over the LMTD method.	(3)
7	Distinguish between absorptivity and emissivity of a surface	(3)
8	State and Explain Kirchhoff's law	(3)
9	Explain diffusion mass transfer and convective mass transfer by giving example	(3)
10	Define diffusion resistance in mass transfer	(3)

PART B

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

Module I

11 a) Derive an equation for steady state temperature distribution across a plane wall with internal heat generation. Both the surfaces have equal temperatures and subjected to convection heat transfer. The surface heat transfer coefficient is h and fluid temperature is T_∞ (7)

b) A steam pipe of 5 cm inside diameter and 6.5 cm outside diameter is covered with a 2.75 cm radial thickness of high temperature insulation (k = 1.1 W/m.K). The surface heat transfer coefficient for inside and outside surfaces are 4650 W/m^2.K and 11.5 W/m^2.K, respectively. The thermal conductivity of the pipe material is (7)

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45 W/m.K. If the steam temperature is 200°C and ambient air temperature is 25°C, determine:

(i) Heat loss per metre length of pipe.

(ii) Overall heat transfer coefficient based on outer radius

OR

12 a) Derive three-dimensional unsteady state heat conduction equation with heat generation, in Cartesian co-ordinate system for anisotropic material. (7)

b) A furnace wall is made of three layers. First layer is of insulation (k = 0.6 W/m.K), 12 cm thick. Its face is exposed to gases at 870°C with convection coefficient of 110 $W/m^2.K$. It is covered with (backed with), a 10 cm thick layer of fire brick (k = 0.8 W/m.K) with a contact resistance of 2.6×10^{-4} $m^2.K/W$ between first and second layer. The third layer is a plate of 10 cm thickness (k = 4 W/m.K) with a contact resistance between second and third layer of 1.5×10^{-4} $m^2.K/W$. The plate is exposed to air at 30°C with convection coefficient of 15 $W/m^2.K$. Determine the heat flow rate and overall heat transfer coefficient. (7)

Module II

13 a) Water at 20°C enters a 20mm diameter tube with a velocity of 1.5 m/s. The tube is maintained at 100°C. Find the tube length required to heat the water to a temperature of 60°C (7)

b) Estimate the heat transfer rate from a 100 W incandescent bulb at 140°C to an ambient at 24°C. Approximate the bulb as 60 cm diameter sphere. Calculate the percentage of power lost by natural convection. (7)

OR

14 a) Explain with neat sketches the evolution of hydrodynamic and thermal boundary layer when a heated fluid flows over a flat plate (7)

b) A motor cycle travels at 100 km/hr. On the engine head a fin of 0.16 m length and 0.04 m width is exposed to convection on both sides. The fin surface is at 300°C and air is at 20°C. Determine the rate of heat removal from the fin assuming turbulent flow prevails all through. (7)

Module III

15 a) Derive an expression for Log Mean Temperature Difference in the case of a counter flow heat exchanger. (7)

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b) A counter flow heat exchanger consists of two concentric flow passages is used for heating 1110 kg/hr of oil (sp. heat = 2.1 kJ/kg.K) from a temperature of 27°C to 49°C. The oil flows through the inner pipe made of copper (Outside Diameter = 2.86 cm, Inside Diameter = 2.54 cm) and the surface heat transfer coefficient on the oil side is 635 $W/m^2.K$. The oil is heated by hot water supplied at the rate of 390 kg/hr and at an inlet temperature of 93°C. The water side heat transfer coefficient is 1270 $W/m^2.K$. If the thermal conductivity of copper is 350 W/m.K and the fouling factors on the oil and water sides to be 0.0001 and 0.0004$m^2.K/W$, calculate the length of the heat exchanger (7)

OR

16 a) Derive an equation for the effectiveness (ε) of a concentric tube parallel flow heat exchanger in terms of NTU and Capacity Ratio (C) (7)

b) In an open-heart surgery, under hypothermic conditions, the patient blood is cooled before the surgery and rewarmed afterwards. It is proposed that a concentric tube, counter flow heat exchanger of length 0.5 m be used for this purpose with the thin-walled inner tube having a diameter of 55 mm. If the water at 60°C and 0.10 kg/s is used to heat the blood entering the exchanger at 18°C and 0.05 kg/s, what is the temperature of blood leaving the exchanger? The overall heat transfer coefficient is 500 $W/m^2.K$ and specific heat of the blood is 3500 J/kg.K. (7)

Module IV

17 a) Define Intensity of radiation. Show that the emissive power of a black body is π-times the intensity of emitted radiation (7)

b) A black body emits radiation at 1727 ^{0}C. Calculate (i) the monochromatic emissive power at 1μm wavelength, (ii) wavelength at which the emission is maximum, and (iii) the maximum emissive power. (7)

OR

18 a) Explain the "surface resistance" and "space resistance". Construct a radiation network for two grey surfaces exchanging radiant energy. (7)

b) A room 4 m × 4 m × 4 m is heated through the ceiling by maintaining it at uniform temperature of 77 ^{0}C, while walls and the floor are at 27 ^{0}C. If all surfaces have an emissivity of 0.8, determine the rate of heat loss from ceiling by radiation. (7)

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Module V

19 a) Explain the significance of Reynolds number, Schmidt number, Sherwood number and Lewis number. (7)

b) A tank contains a mixture of CO_2 and N_2 in the mole proportions of 0.2 and 0.8 at 1 bar and 17^0C. It is connected by a duct of sectional area 0.1 m^2 and 0.5 m long, to another tank containing a mixture of CO_2 and N_2 in the molar proportion of 0.8 and 0.2 respectively. Determine the diffusion of rates CO_2 and N_2. Assume Diffusion coefficient, $D = 0.16 \times 10^{-4}\ m^2/s$. (7)

OR

20 a) Discuss the following (7)

(i) Analogy between heat and mass transfer.

(ii) Equimolar counter diffusion

b) The water in a 5 m × 15 m outdoor swimming pool is maintained at a temperature of 27°C. The average ambient temperature and relative humidity are 27°C and 40%, respectively. Assuming a wind speed of 2 m/s in the direction of long side of the pool, estimate the mass transfer coefficient for the evaporation of water from the pool surface (7)

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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

B.Tech Degree S6 (S, FE) / S4 (PT) (S) Examination January 2024 (2019 Scheme)

Course Code: MET 302

Course Name: HEAT AND MASS TRANSFER

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

Use of steam table & Heat and mass transfer data book permitted

PART A

Answer all questions, each carries 3 marks. Marks

1	Discuss the differences between Thermodynamics and Heat transfer	(3)
2	Give any three boundary conditions in heat conduction analysis.	(3)
3	What are the characteristics of thermal and hydrodynamic boundary layers?	(3)
4	Explain the significance of Prandtl number?	(3)
5	Classify recuperative heat exchangers according to construction and flow arrangement	(3)
6	Explain the effectiveness of a heat exchanger.	(3)
7	Distinguish between emissive power and emissivity.	(3)
8	Explain Wein's displacement law.	(3)
9	Distinguish between diffusion and convection mass transfer	(3)
10	Define diffusion resistance. What is its dimension?	(3)

PART B

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

Module I

11 a) Derive the general heat conduction equation in cylindrical co-ordinates. (7)

b) Compare fin efficiency and fin effectiveness. What are the factors to be considered while providing fins? (7)

OR

12 a) A metallic sphere of 15 mm diameter (k = 43 W/m°C, ρ = 7850 kg/m^3, C = 474 J/kg°C) initially at 625^{0}C is cooled by exposing to air at 25°C with a convective heat transfer coefficient of 120 W/m^2 °C. Find (7)

(i) Time required to cool the sphere to 100°C.

(ii) Initial Rate of cooling in ^{0}C/s

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b) Explain critical radius of insulation. Derive an expression for critical radius of insulation for cylindrical surface. (7)

Module II

13 a) Atmospheric air at 20^0C flows over a flat plate with a velocity of 15 m/s. The plate has a length of 2 m (in the flow direction) and a width of 0.5 m. If the plate is maintained at 80^0C, calculate the following quantities. (10)

(i) Average heat transfer coefficient over the region of laminar boundary layer

(ii) Total heat transfer rate from the plate

b) What is natural convection? Draw velocity and temperature profiles for natural convection flow over a hot vertical plate. (4)

OR

14 a) With neat sketch, explain thermal entrance region in internal flow for forced convection. (5)

b) Water at 20 ^{0}C enters 2 cm diameter tube with a velocity of 1.5 m/s. The tube wall is maintained at 100^0C. Find the tube length required to heat the water to a temperature of 60 ^{0}C. (9)

Module III

15 a) A 2-shell pass and 4-tube passes heat exchanger is used to heat glycerine from 20 ^{0}C to 50 ^{0}C by hot water, which enters thin walled 2 cm diameter tube at 80^0C and leaves at 40^0C. The total length of the tube in the heat exchanger is 60m. The convection heat transfer coefficient on shell side is 25 W/m^2K and that on water side is 160 W/m^2K. Using LMTD method, determine the rate of heat transfer in the heat exchanger after fouling with fouling factor of 0.0006 m^2K/W on outer surface of tube. (10)

b) Discuss the factors to be considered in the design of heat exchangers. (4)

OR

16 a) Water flows at the rate of 65 kg/min through a double pipe counter flow heat exchanger. Water is heated from 50° C to 75°C by an oil flowing through the tube. The specific heat of the oil is 1.780 kJ/kg.K. The oil enters at 115°C and leaves at 70°C. The overall heat transfer co-efficient is 340 W/m^2K.Calculate the heat exchanger area and the rate of heat transfer. (10)

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b) What is the difference between film and dropwise condensation? Which is more effective mechanism of heat transfer? (4)

Module IV

17 a) A glass plate 30 cm square is used to view radiation from a furnace. The transmissivity of the glass is 0.5 from 0.2 to 3.5μm. The emissivity may be assumed to be 0.3 up to 3.5μm and 0.9 above that. The transmissivity of the glass is zero, except in the range from 0.2 to 3.5 μm. Assuming that furnace is a black body at 2000 ^{0}C, calculate the energy absorbed in the glass and the energy transmitted. (10)

b) Explain Planck's distribution law (4)

OR

18 a) Two very large parallel plates at temperatures 1000K and 600K, both having emissivity 0.5, exchange heat. A polished-aluminium shield having emissivity 0.1 on both sides is placed between them. Find (7)

(i) Net radiation heat exchange between the plates.

(ii) Temperature of the shield at thermal equilibrium.

b) Define radiation shape factor. Discuss any five properties of radiation shape factor. (7)

Module V

19 a) Explain the dimensionless numbers for forced convection mass transfer (7)

b) A well is 40 m deep and 9 m in diameter is exposed to atmosphere at 25 ^{0}C. The air at the top has relative humidity of 50%. Calculate the diffusion rate of water into atmosphere. Take diffusion coefficient as 2.58×10^{-5} m^2/s. (7)

OR

20 a) Derive the general mass diffusion equation in stationary media (8)

b) List any six examples of mass transfer (6)

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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)

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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 $\alpha=1.474\times10^{-6}$ 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,
$\nu=15.63\times10^{-6}$ 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)

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OR

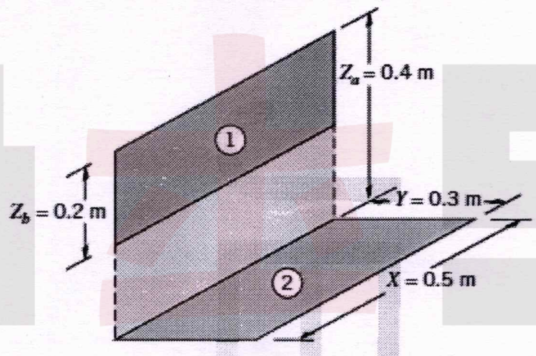
16 a) Derive an expression for the LMTD of a parallel flow double pipe heat exchanger. (6)

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)

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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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