

Reg No.: _____

Name: _____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SIXTH SEMESTER B.TECH DEGREE EXAMINATION, APRIL 2018

Course Code: ME 302

Course Name: HEAT AND MASS TRANSFER (MA, ME, AU)

Max. Marks: 100

Duration: 3 Hours

(Use of heat and mass transfer data book permitted.)

PART A

Answer any three full questions, each carries 10 marks.

- | | | Marks |
|---|--|-------|
| 1 | a) Derive the general heat conduction equation in cylindrical coordinates. | (6) |
| | b) Explain the significance of critical radius of insulation. | (4) |
| 2 | A hollow aluminium sphere, with an electrical heater in the centre, is used in tests to determine the thermal conductivity of insulating materials. The inner and outer radii of the sphere are 0.15 and 0.18 m, respectively, and testing is done under steady-state conditions with the inner surface of the aluminium maintained at 250°C. In a particular test, a spherical shell of insulation is cast on the outer surface of the sphere to a thickness of 0.12 m. The system is in a room for which the air temperature is 20°C and the convection coefficient at the outer surface of the insulation is 30 W/m ² K. If 80 W are dissipated by the heater under steady-state conditions, what is the thermal conductivity of the insulation? | (10) |
| 3 | a) Discuss the importance of non-dimensional numbers in heat transfer problems. | (3) |
| | b) A square (10 mm x 10 mm) silicon chip is insulated on one side and cooled on the opposite side by atmospheric air in parallel flow at $u_{\infty} = 20$ m/s and $T_{\infty} = 24^{\circ}\text{C}$. When in use, electrical power dissipation within the chip maintains a uniform heat flux at the cooled surface. If the chip temperature may not exceed 80°C at any point on its surface, what is the maximum allowable power?. | (7) |
| 4 | A vertical plate 1m wide and 20 cm high is at a temperature of 100 °C and rests in still air at 1 bar and 20°C. Determine (i) the boundary layer thickness at 10 cm from the leading edge. (ii) the local heat transfer coefficient at 10cm from the leading edge and (iii) the average heat transfer coefficient over the entire length of the plate. | (10) |

PART B

Answer any three full questions, each carries 10 marks.

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|---|--|------|
| 5 | Steel balls 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 $T_{\infty} = 325$ K and heat transfer coefficient, $h = 20$ W/m ² K. Assume the properties of the steel to be the following. Thermal conductivity is 40W/mK, density is 7800 kg/m ³ , and specific heat is 600 J/kg K, estimate the time required for the cooling process. | (10) |
|---|--|------|

- 6 a) Distinguish between fin efficiency and fin effectiveness. (4)
- b) A rectangular aluminium fin of thermal conductivity 200 W/mK, 3mm thick and 7.5 cm long protrudes out from a wall. The fin base is maintained at a temperature of 300°C and the ambient temperature is 50°C with heat transfer coefficient 10W/m²K. The tip of the fin is insulated. Calculate the heat transfer from the fin per unit depth of material. (6)
- 7 a) Derive an equation for the effectiveness of a counter flow heat exchanger. (7)
- b) Explain the terms fouling factor and LMTD correction factor. (3)
- 8 Water at the rate of 4 kg/s is heated from 40°C to 55°C in a shell and tube heat exchanger. On the shell side one pass is used with water as the heating fluid and at a mass flow rate of 2kg/s, and entering the heat exchanger at 95°C. The overall heat transfer coefficient is 1500 W/m²K. and the average water velocity in the 2 cm diameter tubes is 0.5m/s. Because of space limitations, the tube length must not exceed 3 m. Calculate the number of tube passes, the number of tubes per pass and the length of the tubes, keeping in mind the design constraints (10)

PART C

Answer any four full questions, each carries 10 marks.

- 9 Distinguish radiation from other modes of heat transfer. Also describe the laws governing radiation heat transfer (10)
- 10 Explain the term view factor. Derive an expression for view factor for two arbitrarily oriented surfaces. (10)
- 11 Two large plates, one at 800K and other at 600K have emissivities 0.5 and 0.8 respectively. A radiation shield having an emissivity 0.1 on one side and emissivity 0.05 on the other side is placed between the plates. Calculate the heat transfer by radiation per square meter with and without the radiation shield. (10)
- 12 a) Explain equimolar counter diffusion. (4)
- b) Gaseous hydrogen is stored at elevated pressure in a rectangular steel container of 10mm wall thickness. The molar concentration of hydrogen in steel at the inner surface is 2kg mol/m³, while the concentration of hydrogen in steel at the outer surface is 0.5 kgmol/m³. The binary diffusion coefficient for hydrogen in steel is 0.26 x 10⁻¹²m²/s. What is the mass flux of hydrogen through the steel? (6)
- 13 a) Define Schmidt number, Lewis number, Sherwood number and explain their significance. (6)
- b) Discuss Reynolds analogy. (4)
- 14 Air at 35 °C flows over a wet flat plate 50cm long with a velocity of 30 m/s. Calculate the mass transfer coefficient of water vapour in air at the end of the plate. (10)

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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SIXTH SEMESTER B.TECH DEGREE EXAMINATION(R&S), MAY 2019

Course Code: ME302

Course Name: Heat and Mass Transfer

Max. Marks: 100

Duration: 3 Hours

PART A

Answer any three full questions, each carries 10 marks.

Marks

- | | | |
|---|---|------|
| 1 | a) What are the mechanisms of heat transfer? How are they distinguished from each other? (5) | (5) |
| | b) A hollow sphere ($k = 65 \text{ W/mK}$) of 120 mm inner diameter and 350 mm outer diameter is covered 10 mm layer of insulation ($k = 10 \text{ W/mK}$). The inside and outside temperatures are 500°C and 50°C respectively. Calculate the rate of heat flow through this sphere. (5) | (5) |
| 2 | a) Derive the general heat conduction equation in Cartesian coordinates (10) | (10) |
| 3 | a) Explain velocity boundary layer and thermal boundary layer with neat sketches. (5) | (5) |
| | b) Discuss the significance Nusselt number and Prandtl number in convection (5) | (5) |
| 4 | Air at 20°C at atmospheric pressure flows over a flat plate at a velocity of 3 m/s. (10) | (10) |
| | If the plate is 1 m wide and at 80°C , calculate the following at $x = 300 \text{ mm}$. | |
| | i. Hydrodynamic boundary layer thickness | |
| | ii. Thermal boundary layer thickness | |
| | iii. Local friction coefficient | |
| | iv. Average heat transfer coefficient | |
| | v. Heat transfer rate | |

PART B

Answer any three full questions, each carries 10 marks.

- | | | |
|---|---|------|
| 5 | An aluminium alloy fin ($k = 200 \text{ W/mK}$) of 1 m width, 3.5 mm thick, and 2.5 cm long protrudes from a wall. The base is at 420°C , the ambient air temperature is 30°C and the heat transfer coefficient is $11 \text{ W/m}^2\cdot\text{K}$. Find the rate of heat loss and fin efficiency, if the fin tip is insulated. (10) | (10) |
| 6 | Derive equations of temperature distribution and heat dissipation for an infinitely long fin (10) | (10) |
| 7 | Derive an expression for Log Mean Temperature Difference in the case of a counter flow heat exchanger. (10) | (10) |
| 8 | In a double pipe heat exchanger hot water flows at a rate of 14 kg/s and gets (10) | (10) |

cooled from 370K to 340K. At the same time 14 kg/s of cooling water at 303K enters the heat exchanger. The flow conditions are such that overall heat transfer coefficient remains constant at 2270 W/m² K. Determine the effectiveness and the heat transfer area required, assuming two streams are in parallel flow. Assume the specific heat for the both the streams = 4.2 kJ/kg K.

PART C

Answer any four full questions, each carries 10 marks.

- 9 a) Define Irradiation and Radiosity for a grey body. (3)
 b) State and Explain Wein's displacement law (3)
 c) Distinguish between a black body and gray body (4)
- 10 Derive the following relation for the radiant heat exchange between two gray surfaces (10)

$$(Q_{12})_{net} = \frac{A_1 \sigma (T_1^4 - T_2^4)}{\frac{1-\varepsilon_1}{\varepsilon_1} + \frac{1}{F_{1-2}} + \left(\frac{1-\varepsilon_2}{\varepsilon_2}\right) \frac{A_1}{A_2}}$$

- 11 Calculate the heat exchange by radiation between the surfaces of two long cylinders having radii 120 mm and 60 mm respectively. The axes of the cylinders are parallel to each other. The inner cylinder is maintained at a temperature of 130°C and emissivity of 0.6. Outer cylinder is maintained at a temperature of 30°C and emissivity of 0.5. (10)
- 12 a) State and explain the governing law for Diffusion mass transfer? (4)
 b) Discuss the analogy between heat transfer and mass transfer (6)
- 13 a) What are the different modes of mass transfer, give examples for each (6)
 b) Explain the phenomenon of equimolar counter diffusion with an example (4)
- 14 a) Define and explain the physical significance of (4)
 i) Schmidt number
 ii) Sherwood number
- b) Dry air at 30°C and 1 atm flows over a wet flat plate 600 mm long at a velocity of 50 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, $D = 0.26 \times 10^{-4} \text{ m}^2/\text{s}$ (6)

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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SIXTH SEMESTER B.TECH DEGREE EXAMINATION(S), DECEMBER 2019

Course Code: ME302

Course Name: Heat and Mass Transfer

Max. Marks: 100

Duration: 3 Hours

PART A

Answer any three full questions, each carries 10 marks.

Marks

- 1 a) Write down the general heat conduction equation in Cartesian coordinates. (3)
Reduce the equation for steady state one dimensional heat conduction across a plane wall with internal heat generation
- b) With proper figures, derive an equation for steady state temperature distribution (7)
across a plane wall with internal heat generation. Both the surfaces have unequal temperatures (T_1 and T_2) and subjected to convection heat transfer. The surface heat transfer coefficient is h and fluid temperature is T_∞ .
- 2 a) Derive an equation for the thermal resistance across a hollow sphere (4)
- b) A hollow sphere of inside radius 3 cm and outside radius 5 cm is electrically (6)
heated at the inner surface at constant rate of 10^5 W/m^2 . At the outer surface it dissipates heat by convection into a fluid at temperature 100°C with heat transfer coefficient $400 \text{ W/m}^2\text{K}$. The thermal conductivity of the material of sphere is 15 W/mK . Determine inner and outer surface temperatures.
- 3 a) Explain Hydrodynamic Boundary Layer for flow over a flat plate (3)
- b) Air at pressure of 1 atm and temperature 60°C flows over a flat plate which (7)
maintains a surface temperature of 100°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? If the free stream velocity of air is doubled and the pressure is increased to 2.5 atm, what is the rate of heat transfer?
- 4 a) Explain the physical significance of Prandtl No. and Nusselt No. (4)
- b) Atmospheric air at 25°C and velocity of 0.5m/s flows over a 50W incandescent (6)
bulb whose surface temperature is maintained at 140°C . The bulb may be approximated as a sphere of 50 mm diameter. What is the rate of heat loss by convection to air?

PART B

Answer any three full questions, each carries 10 marks.

- 5 a) Explain Lumped system analysis (4)
- b) The temperature of a gas stream is measured with a thermocouple. The junction (6)
may be approximated as a sphere of diameter 1 mm, thermal conductivity
25W/mK, density 8400kg/m³, specific heat 400J/kgK. The heat transfer
coefficient between the junction and the gas stream is 560 W/m²K. How long
will it take for the thermocouple to record 99% of the applied temperature
difference?
- 6 Aluminium fins of triangular profile are connected to a plane wall whose (10)
temperature is 250°C. The fin base thickness is 2 mm and length is 6 mm. The
system is in ambient air at a temperature of 20°C and surface convection
coefficient is 40W/m²K. What are the fin efficiency and effectiveness? What is
the heat dissipated per unit width by a single fin? Properties may be evaluated at
base temperature.
- 7 a) Explain the effectiveness of a heat exchanger (3)
- b) A shell and tube steam condenser is to be constructed of 2.5 cm outer diameter (7)
and 2.2 cm inner diameter single pass horizontal tubes with steam condensing at
54°C outside the tubes. The cooling water enters each tube at 18°C with a flow
rate of 0.7 kg/s and leaves at 36°C. The heat transfer coefficient for the
condensation of steam is 8000W/m²K. Calculate the tube length neglecting wall
thermal resistance.
- 8 a) Illustrate with sketches, the temperature profiles for hot and cold fluids as a (3)
function of distance along the flow path for a counter flow heat exchanger with
 $C_h < C_c$, $C_h = C_c$, $C_h > C_c$. C_h and C_c represent the heat capacities of hot and cold
fluid respectively.
- b) Derive an equation for the effectiveness (ϵ) of a concentric tube counter flow (7)
heat exchanger in terms of NTU and Capacity Ratio (C)

PART C

Answer any four full questions, each carries 10 marks.

- 9 a) Explain the terms-Radiation intensity, Emissive power, Radiosity (5)
- b) What is Wein's Displacement Law? Explain with the help of Planks distribution (5)
- 10 With proper figures, derive an equation for view factor of two arbitrarily oriented (10)
surfaces and arrive at the reciprocity relation
- 11 a) What is a diffuse emitter? For such an emitter, how is the intensity related to the (3)

- total emissive power?
- b) Calculate the radiation exchange per unit area between two parallel plates of temperature 400°C and 25°C . Emissivities of hot and cold plates are 0.9 and 0.7 respectively. Find the percentage reduction in heat transfer of a radiation shield of emissivity 0.25 is placed in between the plates (7)
- 12 a) Discuss Fick's Law of diffusion (4)
- b) Nitrogen gas is maintained at 3.5 bar and 1 bar on opposite sides of a rubber membrane which is 0.25 mm thick. The system temperature is 25°C . What is the molar diffusive flux of nitrogen through the membrane? (6)
- 13 a) Discuss Schmidt No, Lewis No and Sherwood No (5)
- b) Explain steady state equimolar counter diffusion in liquids (5)
- 14 Air at 1 atm and 30°C flows over a vessel full of water at velocity 4m/s. The partial pressure of water vapour present is 0.0070 bar. If water surface is at temperature of 15°C , calculate the evaporation rate of water. Take Diffusion coefficient as $25.83 \times 10^{-6} \text{m}^2/\text{s}$. Saturation pressure of water at 15°C is 0.017 bar. (10)

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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

Sixth semester B.Tech examinations (S), September 2020

Course Code: ME302**Course Name: Heat and Mass Transfer***Use of heat and mass transfer data book permitted*

Max. Marks: 100

Duration: 3 Hours

PART A*Answer any three full questions, each carries 10 marks.*

Marks

- 1 a) Derive the expression for critical thickness of a cylinder. What is the importance of critical thickness of insulation? (4)
- b) A hollow sphere of inner radius 30 mm and outside radius 50 mm is electrically heated at its inner surface at a constant rate of 10^5 W/m^2 . The outer surface is exposed to a fluid at 30°C with $h = 170 \text{ W/m}^2\text{K}$. Thermal conductivity of the material is 20 W/m K . Calculate the inner and outer surface temperatures. (6)
- 2 a) Air at velocity of 3m/s and at 20°C flows over a flat plate along the length. The length, width and thickness of the plate are 100cm , 50cm , 2cm respectively. The top surface of the plate is maintained at 100°C . Calculate the heat lost by the plate and temperature at bottom surface of the plate for steady state conditions. Thermal conductivity of plate material is 23 W/mK . (5)
- b) A vertical plate 15cm high and 10cm wide is maintained at 140°C . Calculate the maximum heat dissipation rate from both sides of the plate in ambient air at 20°C by free convection (5)
- 3 a) Derive the general heat conduction equation in Cartesian coordinates, state the assumptions. (8)
- b) Good electrical conductors usually have the property of high thermal conductivity. Why? (2)
- 4 a) Using Buckingham pi theorem derive the expression for flow through a tube under forced convection. Make suitable assumptions (7)
- b) Explain the importance of hydrodynamic and thermal boundary layers in heat transfer. (3)

PART B

Answer any three full questions, each carries 10 marks.

- 5 a) An aluminium sphere weighing 6kg and initially at temperature of 350°C is suddenly immersed in a fluid at 30°C with $h = 60 \text{ W/m}^2 \text{ C}$. Estimate the time required to cool the sphere to 100°C. (7)
- b) Define fin efficiency and effectiveness (3)
- 6 a) Explain the features of pool boiling process with the curve (5)
- b) Derive an expression for heat flow from a fin with tip insulated (derivation may start from solution of general fin differential equation, $\theta = C_1 e^{mx} + C_2 e^{-mx}$, with clear statement of boundary conditions) (5)
- 7 a) Classify heat exchangers based on flow direction .Explain why a counter flow is superior arrangement. When do we use specifically use parallel flow heat exchangers? (3)
- b) Derive the expression for LMTD of a parallel flow heat exchanger (7)
- 8 The following are the details of a parallel flow heat exchanger - Heat capacity of cold flow entering at 40°C = 20000 W/K, Heat capacity of hot flow entering at 150°C = 10000 W/K, $A = 30 \text{ m}^2$, $U = 500 \text{ W/m}^2 \text{ K}$. Determine heat transfer rate and exit temperatures (10)

PART C

Answer any four full questions, each carries 10 marks.

- 9 a) State and prove Kirchhoff's law of radiation (3)
- b) Two black discs of diameter 50 cm each are placed parallel to each other concentrically at a distance of 1m. Disc temperatures are 727°C and 227°C . Calculate the heat transfer between discs if no other surface is present in between. (7)
- 10 a) What are radiation shields? Mention some of their applications (2)
- b) Two concentric cylinders have inner and outer radius with 5cm and 10cm and length 20cm. Calculate the view factors (8)
- 11 Determine the heat lost by radiation per meter length of 80mm diameter pipe at 300°C, if (i) Located in a large room with red brick walls at temperature of 27°C (ii) Enclosed in a 160 mm diameter red brick conduit at a temperature of 27°C. Emissivities of pipe material and brick 0.79 and 0.93 respectively (10)
- 12 a) State Fick's law of mass diffusion, explaining all the terms (3)
- b) Air at atm temperature 25°C, 18% RH flows through a pipe of 25mm inside dia (7)

with a velocity of 4.5m/s. The inside is constantly wetted with water so as to maintain a water film on the inside the surface. Determine evaporation rate per m^2 of surface area. Kinematic viscosity = $15.6 \times 10^{-6} m^2/s$, $Sc = 0.6$, Diffusion coefficient = $0.26 \times 10^{-4} m^2/s$, density under saturated conditions at $25^\circ C = 0.231 kg/m^3$.

- 13 Derive the expression for mass transfer for the case of isothermal evaporation from the bottom of a small tube through surrounding stagnant gas. (10)
- 14 a) Discuss the analogy between heat transfer and mass transfer (5)
- b) Estimate the diffusion rate of water from bottom of a test tube 1.5cm in diameter and 15cm long into dry atmospheric air at $25^\circ C$. $D = 25.6 \times 10^{-6} m^2/s$ (5)
