

VTU B.E/B.TECH QUESTION PAPER SET

CBCS SEMESTER V

HEAT AND MASS TRANSFER

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15AE53

Fifth Semester B.E. Degree Examination, Dec.2017/Jan.2018

Heat and Mass Transfer

Time: 3 hrs.

Max. Marks: 80

- Note: 1. Answer any FIVE full questions, choosing one full question from each module.
2. Use of heat transfer and data handbook is permitted.*

Module-1

- 1 a. Explain Fourier's law of conduction. (06 Marks)
b. Explain types of mass transfer with examples. (06 Marks)
c. Briefly explain Fick's law of diffusion. (04 Marks)

OR

- 2 a. Explain Newton's law of cooling and derive the governing equation for convective heat transfer. (06 Marks)
b. Briefly explain Stefan Boltzmann law. (04 Marks)
c. Explain combined heat transfer mechanism. (06 Marks)

Module-2

- 3 a. One end of a long rod is inserted into furnace, while the other end projects into ambient air. Under steady state, the temperature of the rod is measured at two points, 75 mm apart and found to be 125°C and 88.5°C, while the ambient temperature is 20°C. If the rod is 25 mm in diameter and h is 23.36 W/m²K, determine the thermal conductivity of the rod material. (06 Marks)
b. Derive the three dimensional general heat conduction equation in Cartesian coordinates. (04 Marks)
c. Derive an expression for instantaneous heat transfer and total heat transfer using lumped heat analysis for unsteady state heat transfer to a body from the surroundings. (06 Marks)

OR

- 4 a. Derive an expression for temperature distribution and heat flow through a fin of uniform cross section with the end insulated. (06 Marks)
b. A rod ($K = 200$ W/m.K), 5 mm in diameter and 5 cm long has its one end maintained at 100°C. The surface of the rod is exposed to ambient air at 25°C with convection heat transfer coefficient of 100 W/m²K. Assuming other end is insulated, determine:
i) The temperature of rod at 20 mm distance from the end at 100°C
ii) Heat dissipation rate from the surface of the rod
iii) Effectiveness. (06 Marks)
c. Derive the three dimensional general heat conduction equation in cylindrical coordinates. (04 Marks)

Module-3

- 5 a. Obtain an empirical expression in terms of dimensionless numbers for heat transfer coefficient in the case of forced convection heat transfer. (08 Marks)
b. Dry air at atmospheric pressure and 20°C is flowing with a velocity of 3 m/s along the length of a long flat plate, 0.3 m wide, maintained at 100°C. Calculate the following quantities at $x = 0.3$ m.
i) Boundary layer thickness
ii) Average friction coefficient
iii) Thickness of thermal boundary layer
iv) Rate of heat transfer from the plate between $x = 0$ and $x = x$ by convection. (08 Marks)

1 of 2

Important Note - 1 On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.

OR

- 6 a. Explain the following:
 i) Velocity boundary layer
 ii) Thermal boundary layer (06 Marks)
- b. Explain the significance of following:
 i) Grashoff Number
 ii) Nusselt number
 iii) Prandtl number (06 Marks)
- c. A horizontal plate $1\text{m} \times 0.8\text{m}$ is kept in a water tank with the water surface at 60°C providing heat to warm stagnant water at 20°C . Determine the value of convection heat transfer coefficient. (04 Marks)

Module-4

- 7 a. With assumptions, derive an expression for LMTD for a parallel flow heat exchanger. (08 Marks)
- b. What is fouling factor in heat exchanger and what is the effect of it on heat exchanger? (02 Marks)
- c. An oil cooler consists of straight tube of 2 cm outer diameter and 1.5 cm inner diameter, enclosed within a pipe and concentric with it. The external pipe is well insulated. The oil flows through the tube at 0.05 kg/s ($C_p = 2\text{ kJ/kg.K}$) and cooling fluid flows in the annulus in the opposite direction at the rate of 0.1 kg/s ($C_p = 4.2\text{ kJ/kg.K}$). The oil enters the cooler at 180°C and leaves at 80°C , while cooling liquid enter the cooler at 30°C . Calculate the length of the pipe required if heat transfer coefficient from oil to the surface is $1720\text{ W/m}^2\text{K}$ and from metal surface to coolant is $3450\text{ W/m}^2\text{K}$. Neglect the resistance of the tube wall. (06 Marks)

OR

- 8 a. Explain : i) Stefan Boltzman law, ii) Black body. (04 Marks)
- b. Obtain an expression for the rate of heat transfer when radiation shield is introduced between two parallel plates. (06 Marks)
- c. Consider two large parallel plates, one at 1000 K with emissivity 0.8 and other is at 300 K having emissivity 0.6 . A radiation shield is placed between them, The shield has emissivity 0.1 on the side facing hot plate and 0.3 on the side facing cold plate. Calculate percentage reduction in radiation heat transfer as a result of radiation shield. (06 Marks)

Module-5

- 9 a. Write a short note on Aerodynamic heating. (08 Marks)
- b. The flow rate of hot and cold fluids running through a parallel flow heat exchanger are 0.2 and 0.5 kg/s respectively. The inlet temperature on the hot and cold sides are 75°C and 20°C respectively. The exit temperature of hot water is 45°C . If the individual heat transfer coefficient on both sides are $650\text{ W/m}^2\text{K}$, calculate the area of heat transfer (for hot and cold fluid, $C_p = 4.2\text{ kJ/kg.K}$) (08 Marks)

OR

- 10 a. Explain diffusive mass transfer with neat diagram. (08 Marks)
- b. Write a short note on Ablative heat transfer. (08 Marks)

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15AE53

Fifth Semester B.E. Degree Examination, June/July 2018

Heat and Mass Transfer

Time: 3 hrs.

Max. Marks: 80

Note: 1. Answer any FIVE full questions, choosing one full question from each module.
2. Use of heat and mass transfer data handbook is permitted.

Module-1

- 1 a. Explain types of mass transfer with example. (06 Marks)
b. Briefly explain Fick's law of diffusion. (04 Marks)
c. State the laws governing three basic modes of heat transfer. (06 Marks)

OR

- 2 a. Briefly explain Stefan Boltzmann law. (06 Marks)
b. A 0.8m height and 1.5m wide double – plane window consists of two thick layers of glass ($K = 78 \text{ W/mK}$) separated by a 10mm wide stagnant air space ($K = 0.026 \text{ W/mK}$). Determine the rate of heat transfer through this window and the temperature of the inside surface when the room is maintained at 20°C and the outside air is at -10°C , take the convection heat transfer co-efficients on the inside and the outside surfaces of the window as $10 \text{ W/m}^2\text{-K}$ and $40 \text{ W/m}^2\text{-K}$. (10 Marks)

Module-2

- 3 a. A $40 \times 40 \text{ cm}$ copper slab 5mm thick at a uniform temperature of 250°C , suddenly has its surface temperature lowered to 30°C . Find the time which the slab temperature becomes 90°C , $\rho = 900 \text{ kg/m}^3$, specific heat (c) = 0.38 kJ/kg-K , $K = 370 \text{ W/m-K}$ and convective heat transfer co-efficient (h) = $90 \text{ W/m}^2\text{-K}$. (08 Marks)
b. Derive the general three dimensional conduction equation in Cartesian Co – ordinates and state the assumption made. (08 Marks)

OR

- 4 a. A stainless steel rod of outer diameter 1 cm originally at a temperature of 320°C is suddenly immersed in a liquid at 120°C for which the convective heat transfer co-efficient is $100 \text{ W/m}^2\text{-K}$. Determine the time required for the rod to reach a temperature of 200°C . (08 Marks)
b. Derive an expression for instantaneous heat transfer and total heat transfer for lumped heat analysis treatment of heat conduction problem. (08 Marks)

Module-3

- 5 a. Dry air at atmospheric pressure and 20°C is flowing with a velocity of 3m/s along the length of a long flat plate, 0.3m wide, maintained at 100°C . Calculate the following quantities at $x = 0.3 \text{ m}$: i) Boundary layer thickness ii) Average friction co-efficient iii) Thickness of thermal boundary layer iv) Rate of heat transfer from the plate between $x = 0$ and $x = x$ by convection. (08 Marks)
b. Define clearly and give expression for : i) Reynolds number ii) Prandtl number iii) Nusselt number iv) Stanton number. (08 Marks)

OR

- 6 a. Obtain an empirical expression in terms of dimensionless numbers for heat transfer coefficient in the case of forced convection heat transfer. (08 Marks)
- b. Explain the following : i) Velocity boundary layer ii) Thermal boundary layer
iii) Thermal entry. (08 Marks)

Module-4

- 7 a. With assumptions, derive an expression for LMTD for a Parallel flow heat exchanger. (08 Marks)
- b. An oil cooler consists of straight tube of 2cm outer diameter and 1.5cm inner diameter enclosed within a pipe and concentric with it. The external pipe is well insulated. The oil flow through the tube at 0.05kg/s ($C_p = 2\text{kJ/kg K}$) and cooling fluid flows in the annulus in the opposite direction at the rate of 0.1 kg/s [$C_p = 4.2\text{kJ/kg K}$]. The oil enters the cooler at 180°C and leaves at 80°C , while cooling liquid enter the cooler at 30°C . Calculate the length of the pipe required if heat transfer co-efficient from oil to the surface is $1720\text{W/m}^2\text{ K}$ and from metal surface to coolant is $3450\text{W/m}^2\text{ K}$. Neglect the resistance of the tube wall. (08 Marks)

OR

- 8 a. Obtain an expression for the rate of heat transfer when radiation shield is introduced between two parallel plates. (08 Marks)
- b. Consider two large parallel plates, one at 1000K with emissivity 0.8 and other is at 300K having emissivity 0.6. A radiation shield is placed between them. The shield has emissivity 0.1 on the side facing hot plate and 0.3 on the side facing cold plate. Calculate percentage reduction in radiation heat transfer as a result of radiation shield. (08 Marks)

Module-5

- 9 a. Write a short note on Aerodynamic heating. (08 Marks)
- b. The flow rate of hot and cold fluids running through a parallel flow heat exchanger are 0.2 and 0.5kg/s respectively. The inlet temperature on the hot and cold sides are 75°C and 20°C respectively. The exit temperature of hot water is 45°C . If the individual heat transfer co-efficient on both sides are $650\text{W/m}^2\text{ K}$. Calculate the area of heat transfer [for hot and cold fluid, $C_p = 4.2\text{ kJ/kg K}$]. (08 Marks)

OR

- 10 a. Explain the heat transfer concept for the following : (08 Marks)
- i) Rocket thrust chamber ii) Gas turbine combustion chamber.
- b. Explain the concept of ablative heat transfer with its application. (08 Marks)

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15AE53

Fifth Semester B.E. Degree Examination, Dec.2018/Jan.2019

Heat and Mass Transfer

Time: 3 hrs.

Max. Marks: 80

- Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. Use of Heat Transfer data hand book is permitted.*

Module-1

- 1 a. Derive an equation for heat transfer through convection. (08 Marks)
b. Explain the types of mass transfer with examples. (08 Marks)

OR

- 2 a. Derive an equation for heat transfer through radiation. (08 Marks)
b. Derive an equation for radiation exchange between two bodies. (08 Marks)

Module-2

- 3 a. Derive the three dimensional general heat conduction equation in cylindrical coordinate system. (08 Marks)
b. Explain the effect of variable thermal conductivity on heat transfer in solids. (08 Marks)

OR

- 4 a. Explain the types of fins with applications. (08 Marks)
b. Derive an equation for an infinitely long fin of uniform cross section along the length. (08 Marks)

Module-3

- 5 a. Dry air at atmospheric pressure and 20°C is flowing with a velocity of 3m/s along the length of a long flat plate, 0.3m wide, maintained at 100°C. Calculate the following quantities at $x = 0.3m$.
i) Boundary layer thickness
ii) Average friction coefficient
iii) Thickness of thermal boundary layer
iv) Rate of heat transfer from the plate between $x = 0$ and $x = x$ by convection. (08 Marks)
b. Define fin efficiency. Derive an equation for the efficiency of,
i) infinitely long fin ii) fin with insulated tip. (08 Marks)

OR

- 6 a. Three 10mm diameter rods A, B and C protrude from a steam bath at 100°C to a length of 25cm into the atmosphere at 20°C. The temperature at the other ends are found to be 26.27°C for A, 32°C for B and 36.96°C for C. Neglecting the effect of radiation and assuming a surface heat transfer coefficient as 23W/m² K, evaluate their thermal conductivity. (08 Marks)

1 of 2

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and/or equations written eg. 42+8 = 50, will be treated as malpractice.

- b. In a thermal conductivity measuring experiment, 2 identical long rods are used. One rod is made of aluminum with $K = 200 \text{ W/m-k}$. The other rod is a specimen. One end of both the rod is fixed to a wall at 100°C , while the other end is suspended in air at 25°C . The steady temperature at the same distance along the rods were measured and found to be 75°C on aluminum, and 60°C on the specimen rod. Find the thermal conductivity for the specimen. Assume that the fin is insulated at the tip. (08 Marks)

Module-4

- 7 a. With assumption, derive an expression for LMTD for a counter flow heat exchanger. (08 Marks)
- b. 8000 kg/hr of air at 105°C is cooled by passing it through a counter flow heat exchanger. Find the exit temperature of air, if water enters at 15°C and flows at a rate of 7500 kg/hr. The heat exchanger has heat transfer area of 20m^2 and overall heat transfer coefficient corresponding to this area is $145 \text{ W/m}^2 \text{ K}$. Take C_p of air as 1kJ/kg K and that of water as 4.18 kJ/kg K . (08 Marks)

OR

- 8 a. Derive an expression for E-NTU relation for a counter flow heat exchanger. (08 Marks)
- b. Obtain an expression for the rate of heat transfer when radiation shield is introduced between two parallel plates (08 Marks)

Module-5

- 9 a. With a neat diagram, explain diffusive mass transfer. (08 Marks)
- b. What is Aerodynamic heating, explain. (08 Marks)
- OR**
- 10 a. Explain ablative heat transfer. (08 Marks)
- b. A circular plate of 25cm diameter with both surfaces maintained at a uniform temperature of 100°C is suspended horizontally in atmospheric air at 20°C . Determine the heat transfer from the plate. (08 Marks)

- b. A hot square plate $50 \text{ cm} \times 50 \text{ cm}$ at 100°C is exposed to atmosphere air at 20°C . Find the heat loss from both surfaces of the plate, if (i) Plate is kept vertical (ii) Plate is kept horizontal. Use the following relations:
- $N_u = 0.13 (\text{GrPr})^{1/3}$ vertical position
 - $N_u = 0.71 (\text{GrPr})^{1/4}$ for upper surface
 - $N_u = 0.35 (\text{GrPr})^{1/4}$ for lower surface

(08 Marks)

OR

- 6 a. Explain the following:
- Velocity boundary layer
 - Thermal boundary layer
 - Thermal entry
- b. Using Buckingham's Pi theorem, obtain a relationship between Nu , Pr and Gr for free convection heat transfer.

(08 Marks)

(08 Marks)

Module-4

- 7 a. Obtain an expression for the rate of heat transfer when radiation shield is introduced between two parallel plates. (10 Marks)
- b. A boiler furnace lagged with plate steel is lined with five clay bricks on the inside. The temperature of the outer side of the brick setting is 127°C and the temperature of the inside of the steel plate is 50°C . Assuming the gap between plate steel and fire clay bricks to be small compared with the size of the furnace, calculate the loss of heat per unit area by radiation between the lagging and setting (ϵ for steel = 0.6, ϵ for fire clay = 0.8). (06 Marks)

OR

- 8 a. Derive an expression for LMTD of a counter flow heat exchanger, state the assumption made. (08 Marks)
- b. Hot oil is to be cooled by water in a 1-shell-pass and 8-tube-passes heat exchanger. The tubes are thin walled and are made of copper with an inner diameter of 1.4 cm. The length of each tube pass in the heat exchanger is 5m, and the overall heat transfer coefficient is $310 \text{ W/m}^2\text{C}$ water flows through the tubes at a rate of 0.2 kg/s and the oil through the shell at a rate of 0.3 kg/s. The water and the oil enters at the temperature of 20°C and 150°C respectively. Determine the rate of heat transfer in the heat exchanger and the outlet temperatures of the water and oil. (08 Marks)

Module-5

- 9 a. Explain the heat transfer concept for the following:
- Rocket thrust chamber
 - Gas turbine combustion chamber
- b. Explain the concept of ablative heat transfer.

(08 Marks)

(08 Marks)

OR

- 10 a. A mixture of O_2 and N_2 with their partial pressure in the ratio 0.21 to 0.79 in a container at 25°C . Calculate the molar concentration, the mass density, the mole fraction, and the mass fraction of each species for a total pressure of 1 bar. (04 Marks)
- b. Derive an expression for species conservation equation. (12 Marks)

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15AE53

Fifth Semester B.E. Degree Examination, Dec.2019/Jan.2020
Heat and Mass Transfer

Time: 3 hrs.

Max. Marks: 80

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

- 1 a. Explain the modes of heat transfer with their corresponding basic equations. (06 Marks)
 b. Define the term thermal diffusivity. (02 Marks)
 c. Explain combined heat transfer mechanism. (04 Marks)
 d. Briefly explain the boundary conditions of 1st, 2nd and 3rd kind. (04 Marks)

OR

- 2 a. Explain mass transfer and modes of mass transfer. (08 Marks)
 b. Explain:
 i) Convective heat transfer coefficient
 ii) Radiation heat transfer coefficient
 iii) Combined heat transfer coefficient
 iv) Mass and Molar concentration. (08 Marks)

Module-2

- 3 a. State the assumptions and derive the general three dimensional conduction equation Cartesian coordinates. (08 Marks)
 b. One end of a long rod is inserted into furnace, while the other end projects, into ambient air under steady state, the temperature of the rod is measured at two points, 75mm apart and found to be 125°C and 88.5°C, while the ambient temperature is 20°C. If the rod is 25mm in diameter and h is 23.36W/m²K. Determine the thermal conductivity of the rod material. (08 Marks)

OR

- 4 a. Derive an expression for temperature distribution and heat flow through a fin of uniform cross section with end insulated. (08 Marks)
 b. A 50cm × 50cm copper slab 6.25mm thick has a uniform temperature of 300°C. Its temperature is suddenly lowered to 36°C. Calculate the time required for the plate to reach the temperature of 108°C. Assume $\rho = 9000\text{kg/m}^3$, $c = 0.38\text{kJ/kg}^\circ\text{C}$. Take $K = 370\text{W/m}^\circ\text{C}$, $h = 90\text{W/m}^2\text{C}$. (08 Marks)

Module-3

- 5 a. Explain briefly boundary layer concept for flow along a flat plate. (08 Marks)
 b. Calculate the convection heat loss from a radiator 0.5m wide and 1m high maintained at a temperature of 84°C in a room at 20°C. Treat the radiator as a vertical plate. (08 Marks)

OR

- 6 a. What do you mean by velocity boundary layer thermal boundary layer? (05 Marks)
 b. Explain the significance of following:
 i) Grashoff Number
 ii) Nusselt Number
 iii) Prandtl Number. (06 Marks)

1 of 2

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
 2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

- c. A plate of length 750mm and width 250mm has been placed longitudinally in a stream of crude oil which flows with a velocity of 5m/s. If the oil has a specific gravity of 0.8 and kinematic viscosity of 1 stroke. Calculate:
- Boundary layer thickness at the middle of plate
 - Shear stress at the middle of plate
 - Friction drag on one side of the plate.

(05 Marks)

Module-4

- 7 a. Explain the concept of black and gray bodies. (04 Marks)
- b. State and explain
- Kirchoff's law
 - Stefan-Boltzman's law
 - Planck's law. (06 Marks)
- c. Two large parallel plates with emissivity of 0.5 are maintained at different temperature and exchange heat only by radiation. Two equally large radiation shields with surface emissivity 0.05 are introduced in parallel to the plates. Find the percentage reduction in net radiative heat transfer. (06 Marks)

OR

- 8 a. With assumptions, derive an expression for LMTD for a parallel flow heat exchanger. (08 Marks)
- b. Exhaust gases ($C_p = 1.12 \text{ kJ/kg K}$) flowing through a tubular heat exchanger at the rate of 1200 kg/hr is cooled from 400°C to 120°C . The cooling is affected by water ($C_p = 4.2 \text{ kJ/kg K}$) that enters the system at 10°C at the rate of 1500kg/hr. If the overall heat transfer coefficient is $500 \text{ kJ/m}^2 \text{ hr}^\circ\text{C}$, what heat exchange area is required to handle the load for parallel flow and counter flow arrangement? (08 Marks)

Module-5

- 9 a. Explain diffusive mass transfer with neat diagram. (05 Marks)
- b. Write a short note on aerodynamic heating. (05 Marks)
- c. The flow rate of hot and cold fluids running through a parallel flow heat exchanger are 0.2 and 0.5 kg/s respectively. The inlet temperature on the hot and cold sides are 75°C and 20°C respectively. The exit temperature of hot water is 45°C . If the individual heat transfer coefficient on both sides are $650 \text{ W/m}^2\text{K}$. Calculate the area of heat transfer (for hot and cold fluid, $C_p = 4.2 \text{ kJ/kg K}$). (06 Marks)

OR

- 10 a. State and explain Fick's law of diffusion. (05 Marks)
- b. Briefly explain the species conservation equation. (05 Marks)
- c. Write a short note on Ablative heat transfer and the principle of Rocket propulsion. (06 Marks)

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17AE53

Fifth Semester B.E. Degree Examination, Dec.2019/Jan.2020
Heat and Mass Transfer

Time: 3 hrs.

Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

- 1 a. Explain different modes of heat transfer. (12 Marks)
 b. Define the following terms used in mass transfer.
 i) Mass concentration
 ii) Mole concentration
 iii) Mass fraction
 iv) Mole fraction. (08 Marks)

OR

- 2 a. Explain different modes of mass transfer. (08 Marks)
 b. Explain Ficks law of diffusion. (08 Marks)
 c. Explain significance of Sherwood and Lewis number in mass transfer analogy. (04 Marks)

Module-2

- 3 a. The metallic steel pipe ($k = 45 \text{ w/mk}$) 5cm inner diameter and 6.5cm outer diameter is lagged with 2.75cm radial thickness of high temperature insulation having thermal conductivity of 1.1 w/mk . The surface heat transfer co-efficient at inside and outside can be taken as $4650 \text{ w/m}^2\text{k}$ and $11.5 \text{ w/m}^2\text{k}$ respectively. If the steam temperature is 200°C and ambient temperature is 25°C . Determine :
 i) Heat loss per meter length of pipe
 ii) Temperature at interfaces. (10 Marks)
 b. Obtain temperature distribution equation for system with negligible internal resistance and hence obtain expression for total heat transfer through it in terms of Biot and Fourier number. (10 Marks)

OR

- 4 a. A long steel cylinder 12cm in diameter and initially at 20°C is placed into a furnace at 820°C with the local heat transfer coefficient $h = 140 \text{ w/m}^2\text{k}$. Calculate the time required for axis temperature to reach 800°C . Also calculate the corresponding temperature at a radius of 5.4cm at that time. Take $\alpha = 6.11 \times 10^{-6} \text{ m}^2/\text{s}$ and $k = 21 \text{ w/mk}$. (08 Marks)
 b. Explain the concept of variable thermal conducting. (04 Marks)
 c. A large slab of aluminium at a uniform temperature of 250°C is suddenly exposed to a concrete environment at 50°C with a heat transfer coefficient of $500 \text{ w/m}^2\text{k}$. Estimate the temperature at a depth of 5cm after 1 hour. The thermal diffusivity and thermal conductivity of aluminium are $8.4 \times 10^{-5} \text{ m}^2/\text{s}$ and 215 w/mk respectively. (08 Marks)

Module-3

- 5 a. Obtain dimensionless numbers for natural convection using Buckingham's Pi theorem with usual notations. (10 Marks)
 b. Water at 50°C enters a 1.5cm diameter and 3m long tube with a velocity of 60m/min. The tube wall is maintained at a constant temperature of 90°C . Calculate the total heat transferred if exit temperature is 64°C . (10 Marks)

1 of 2

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
 2. Any revealing of identification, appeal to evaluator and/or equations written eg, $42+8=50$, will be treated as malpractice.

OR

- 6 a. Explain hydrodynamic boundary layer theory and thermal boundary layer theory with suitable figures. (08 Marks)
- b. Air flows through a long rectangular (30cm height \times 60cm width) air conditioning duct maintains the outer duct surface temperature at 15°C. If the duct is uninsulated and exposed to air at 25°C, calculate the heat gained by the duct per meter length, assuming it to be horizontal. (12 Marks)

Module-4

- 7 a. Explain following :
- Specular reflection and diffuse reflection
 - Kirchoff's law
 - Lambert's cosine law
 - Black body. (08 Marks)
- b. Emissivities of two large parallel plates maintained at 800°C and 300°C are 0.3 and 0.5 respectively. Find the net radiant heat exchange per square meter for these plates. (04 Marks)
- c. The net radiation from the surfaces of two parallel plates maintained at temperature T_1 and T_2 is to be reduced by 79 times. Calculate the number of screens to be placed between the two surfaces to achieve this reduction in heat exchange, assuming the emissivity of the screen as 0.05 and that of the surfaces as 0.8. (08 Marks)

OR

- 8 a. Obtain expression for LMTD of counter flow heat exchanger. (08 Marks)
- b. Water enters a cross flow heat exchanger (both fluids unmixed) at 5°C and flows at the rate of 4600kg/n to cool 4000kg/n of air that is initially at 40°C. Assume overall heat transfer coefficient to be 150w/m²K and area of 25m², calculate the exit temperature of air and water. Take $C_{pw} = 4.18$ kJ/kg k and $C_{pair} = 1.01$ kJ/kgk. (08 Marks)
- c. A counter flow concentric flow heat exchanger is used to cool the engine oil [$C_p = 2130$ J/kgk] from 160°C to 60°C with water available at 25°C as the cooling medium. The flow rate at the cooling water of inner diameter of 0.5m is 2 kg/s, while flow rate of oil through outer annulus of diameter 0.7m is also 2kg/s. IF $U = 300$ w/m²k, How long must be the heat exchanger to meet cooling requirement. (04 Marks)

Module-5

- 9 a. Explain heat distribution in rocket thrust chamber. (08 Marks)
- b. Explain ablative heat transfer. (08 Marks)
- c. Explain aerodynamic heating in Aerospace engineering. (04 Marks)

OR

- 10 a. Obtain species conservation equation using conventional notations. (10 Marks)
- b. Ambient air at 20°C, flows past a flat plate with a sharp leading edge at 3m/sec. The plate is heated uniformly throughout its entire length and it is maintained at a surface temperature of 40°C. Calculate the distance from leading edge at which the flow in the boundary layer changes from laminar to turbulent. Assume transition occurs at a critical Reynolds number of 5×10^5 . Determine :
- Thickness of hydrodynamic and thermal boundary layer at transition point
 - Local and average heat transfer coefficient
 - Total drag per unit width on one side of plate
 - Convective heat flow from plate to ambient air considering unit width of the plate. (10 Marks)

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17AE53

Fifth Semester B.E. Degree Examination, Aug./Sept.2020
Heat and Mass Transfer

Time: 3 hrs.

Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

- 1 a. Explain heat transfer and its modes with examples. (10 Marks)
 b. Explain boundary layer characteristics and its types. (06 Marks)
 c. Briefly explain Fourier's law of conduction. (04 Marks)

OR

- 2 a. Briefly explain Stefan Boltzmann law. (08 Marks)
 b. Explain combined heat transfer mechanism. (04 Marks)
 c. Define the term:
 (i) Mass concentration
 (ii) Molar concentration
 (iii) Mass fraction
 (iv) Mole fraction (08 Marks)

Module-2

- 3 a. State the assumptions and derive the general heat conduction equation in Cartesian coordinates for rectangular element. (10 Marks)
 b. A square plate heater (size 15 cm × 15 cm) is inserted between two slab. Slab A is 2 cm thick ($K = 50 \text{ W/m}^\circ\text{C}$) and slab B is 1 cm thick ($K = 0.2 \text{ W/m}^\circ\text{C}$). The outside heat transfer coefficients on both sides of A and B are 200 and 50 $\text{W/m}^2\text{C}$ respectively. Temperature of surroundings air is 25°C. If the rating of heater is 1 KW. Find:
 (i) Maximum temperature in the system
 (ii) Outer surface temperature of two slab (10 Marks)

OR

- 4 a. Derive an expression for heat flow through a fin of uniform cross section with infinitely long fin. (10 Marks)
 b. A 50 cm × 50 cm copper slab 6.25 mm thick has a uniform temperature of 300°C. Its temperature is suddenly lowered to 36°C. Calculate the time required for the plate to reach the temperature of 108°C. Assume $\rho = 9000 \text{ kg/m}^3$, $c = 0.38 \text{ kJ/kg}^\circ\text{C}$. Take $K = 370 \text{ W/m}^\circ\text{C}$, $h = 90 \text{ W/m}^2\text{C}$. (10 Marks)

Module-3

- 5 a. Obtain an empirical expression in terms of dimensionless numbers for heat transfer coefficient in the case of forced convection heat transfer. (10 Marks)
 b. Air at 10°C and at a pressure of 100 kPa is flowing over a plate at a velocity of 3 m/s. If the plate is 30 cm wide and at a temp of 60°C. Calculate the following at $x = 0.3 \text{ m}$.
 (i) Boundary layer thickness (ii) Local friction coefficient
 (iii) Local shearing stress (iv) Total drag force
 (v) Thermal boundary layer thickness (vi) Local convection heat transfer coefficient
 (vii) Heat transfer from the plate (10 Marks)

1 of 2

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
 2. Any revealing of identification, appeal to evaluator and/or equations written eg. 42-8-50, will be treated as malpractice.

OR

- 6 a. Explain the significance of following:
(i) Grashoff number
(ii) Nusselt number
(iii) Prandtl number (06 Marks)
- b. Explain the following:
(i) Thermal boundary layer
(ii) Velocity boundary later (08 Marks)
- c. Calculate the convection heat loss from a radiator 0.5 m wide and 1m high maintains at a temperature of 84°C in a room at 20°C. Treat the radiator as a vertical plate. (06 Marks)

Module-4

- 7 a. Derive an expression for radiation heat exchanger between two parallel infinite gray surface. (10 Marks)
- b. Two parallel large plates with emissivity (ϵ) = 0.5 each, are maintained at different temperature and are exchanging heat only by radiation. Two equally large radiations shields with surface emissivity 0.05 are introduced in parallel to the plates. Find the percentage of reduction in net radiative heat transfer. (10 Marks)

OR

- 8 a. With assumptions, derive an expression for LMTD for a parallel flow heat exchanger. (10 Marks)
- b. In a counter flow double pipe heat exchanger from 25°C to 65°C by an oil with a specific heat of 1.45 kJ/kgK and mass flow rate of 0.9 kg/s. the oil is cooled from 230°C to 160°C. If the overall heat transfer coefficient is 420 W/m²C. Calculate the following:
(i) The rate of heat transfer
(ii) Mass flow rate of water
(iii) The surface area of heat exchanger (10 Marks)

Module-5

- 9 Write short notes on:
a. Aerodynamic heating
b. Ablative heat transfer
c. Principle of rocket propulsion
d. Gas turbine combustion chamber (20 Marks)

OR

- 10 a. Explain mass transfer and modes of mass transfer. (10 Marks)
b. Briefly explain the species conservation equation. (06 Marks)
c. Explain briefly Fick's law of diffusion. (04 Marks)
