Y/K/TY

Reg. No: 23BMM0065

Final Assessment Test – November 2025

Vellore Institute of Technology

Course: BMEE402L - Heat and Mass Transfer

Class NBR(s): 2200 / 2201 / 2326 / 3826 Slot: D1+TD1

Time: Three Hours Max. Marks: 100

- **KEEPING MOBILE PHONE/ANY ELECTRONIC GADGETS, EVEN IN 'OFF' POSITION IS TREATED AS EXAM MALPRACTICE**
- **DON'T WRITE ANYTHING ON THE QUESTION PAPER**

General Instruction: Standard Heat and Mass Transfer Data Book is permitted

COs	CO Statements
CO1	Solve the steady and unsteady heat conduction problems for simple geometries
CO2	Analyse the natural and forced convective heat transfer processes
CO3	Design the heat exchangers using the LMTD and effectiveness-NTU methods
CO4	Solve the radiation heat transfer problems
CO5	Analyse the various mass transfer processes

BL – Blooms Taxonomy Level (1 – Remember, 2 – Understand, 3 – Apply, 4 – Analyse, 5 – Evaluate, 6 – Create)

Answer ALL Questions
(10 X 10 = 100 Marks)

1. A furnace wall is of three layers, first layer of insulation brick of 15 cm thickness of conductivity 0.5 W/mK. The face is exposed to gases at 970°C with a convection coefficient of 140 W/m^{2}K. This layer is backed by a 12 cm layer of fire brick of conductivity 0.8 W/mK. There is a contact resistance between the layers of 2.56×10^{-4} m^2 K/W. The third layer is the plate backing of 12 mm thickness of conductivity 50 W/mK. The contact resistance between the second and third layers is 1.5×10^{-4} m^2 K/W. The plate is exposed to air at 30°C with a convection coefficient of 15 W/m^{2}K. Determine the heat flow, the surface temperatures and the overall heat transfer coefficient. CO1 BL3

2. An iron sphere of diameter 20 cm is originally at a uniform temperature of 300 °C. The surface of the sphere is suddenly exposed to the ambient at 30 °C with a convective heat transfer coefficient of 600 W/m^{2}K. The thermophysical properties of iron can be taken as k=60 W/mK, c=460 J/kg K, ρ=7850 kg/m^3, respectively. Using a suitable analysis, calculate the following after 2 minutes. CO1 BL5
   (i) The center temperature of the sphere.
   (ii) The temperature of the sphere at a depth of 1 cm from its surface.
   (iii) Amount of energy absorbed/removed from the sphere.

3. An average person generates heat at a rate of 100 W while resting. Assuming one-quarter of this heat is lost from the head and disregarding radiation, determine the average surface temperature of the head when it is not covered and is subjected to winds at 10 °C and 30 km/h. The head can be approximated as a 30 cm diameter sphere. CO2 BL5

4. The air conditioning ducts are very popular in large auditoriums. Hot air at atmospheric pressure, 70 °C, enters a 10 m long, uninsulated square duct of cross section 0.2 m × 0.2 m that passes through the lower wall of a house at a rate of 0.2 m^3/s. The duct is observed to be nearly isothermal at 50°C. Assuming fully developed flow, determine the following. CO2 BL5

(i) The exit temperature of the air.
(ii) The rate of heat loss from the duct to the wall.

5. Estimate the coefficient of heat transfer from a vertical plate (made of copper) of size 1.5 m x 1.5 m exposed to the surrounding air at 25 °C. The plate is maintained at a temperature of 155 °C. Also, calculate the rate of heat transfer from the plate. Assume a suitable correlation for the analysis. CO2 BL4

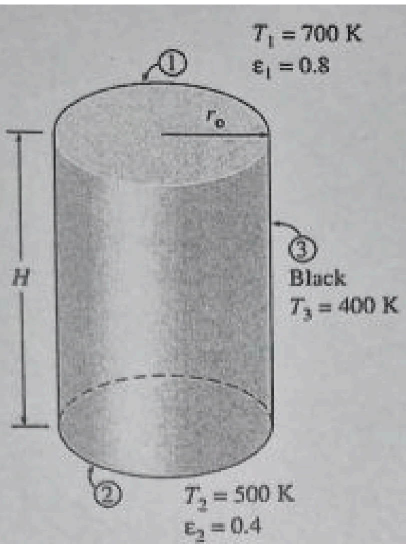
6. A hot plate kept vertical in the air develops a boundary layer by free convection. The thickness of the boundary layer at a distance of 0.4 m was 19 mm. (i) Estimate the location where it will be 22.5 mm, (ii) If the gas was carbon dioxide with a kinematic viscosity of $12.6 \times 10^{-6}\ m^2/s$ as compared to air with $23.13 \times 10^{-6}\ m^2/s$, determine the boundary layer thickness at 0.4 m. Assume that the Prandtl number is nearly the same and all other conditions remain unchanged. CO2 BL4

7. Hot oil is to be cooled by water in a 2-shell-pass and 8-tube-pass heat exchanger. The tubes are thin-walled and are made of copper with an internal diameter of 2 cm. The length of each tube pass in the heat exchanger is 6 m, and the overall heat transfer coefficient is 320 W/m^2K. Water flows through the tubes at a rate of 0.2 kg/s, and oil through the shell at a rate of 0.3 kg/s. The water and the oil enter the heat exchanger at temperatures of 30 °C and 150 °C, respectively. The specific heat of oil and water is 2100 J/kgK and 4180 J/kgK, respectively. Determine the following. CO3 BL5

(i) Rate of heat transfer in the heat exchanger.
(ii) Outlet temperature of the water.

8. A counter-flow double-pipe heat exchanger is to heat water from 20°C to 80°C at a rate of 1.2 kg/s. The heating is to be accomplished by geothermal water available at 160°C at a mass flow rate of 2 kg/s. The inner tube has a diameter of 1.5 cm. If the overall heat transfer coefficient of the heat exchanger is 640 W/m^2K determine the length of the heat exchanger required to achieve the desired heating. CO3 BL5

9.a) Consider a cylindrical furnace with radius (r_o) = height (H) = 2 m, as shown in the Figure below. The top (surface 1) and the base (surface 2) of the furnace have emissivities of 0.8 and 0.4, respectively, and are maintained at uniform temperatures of 700 K and 500 K, respectively. The side (surface 3) of the furnace closely approximates a blackbody and is maintained at a temperature of 400 K. Determine the net rate of radiation heat transfer from each surface during the steady-state operation. 6 CO4 BL5



OR

9.b)	Two large parallel plates are maintained at temperatures of 1000 K and 600 K, respectively. Determine the heat exchange per unit area of the plates for the following cases. (i) The surfaces are black. (ii) The emissivity of hot and cold surfaces is 0.8 and 0.5, respectively. (iii) A large plate of emissivity 0.2 is inserted between these two plates.	CO4	BL5
10.a)	Dry air at 30 °C and 6 m/s flows over a plate (which is maintained at 50 °C) of 1 m long with the plate surface constantly covered with a water film. Determine the following. (i) Average convective mass transfer coefficient. (ii) Mass of water evaporated per second.	CO5	BL3
	OR		
10.b)	Give the fundamental difference between heat and mass transfer. Define molecular diffusion and state Fick's law of diffusion. Highlight the effect of temperature and pressure on the diffusivity of the gases.	CO5	BL3

⇔⇔⇔ Y/K/TY ⇔⇔⇔