TRANSPORT PHENOMENA
(CHEN 2202)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) Momentum flux for i=j is given by ________
(a) $\phi_{ij} = p + \rho u_i u_j$ (b) $\phi_{ij} = p + \tau_{ij} + \rho u_i u_j$
(c) $\phi_{ij} = \delta_{ij} p + \tau_{ij} + \rho u_i u_j$ (d) $\phi_{ij} = \tau_{ij} + \rho u_i u_j$

(ii) Comparing the non-dimensional form of the Navier-Stokes' equation with its dimensional one momentum diffusivity can be said as equivalent to ________.
(a) Reynold's number
(b) Product of Reynold's number and apparent viscosity
(c) Inverse of the Reynold's number
(d) Product of inverse of the Reynold's number and apparent viscosity

(iii) The Prandlt number is defined as
(a) $\mu/\rho C_p$ (b) $\rho/C_p k$ (c) $\mu C_p/k$ (d) $k/\rho C_p$

(iv) If the film thickness of flowing Newtonian fluid over a flat plate is δ, then the velocity profile is given by ________
(a) $u = u_{max}\left[1+\left(\frac{x}{\delta}\right)^2\right]$ (b) $u = u_{max}\left[1-\left(\frac{x}{\delta}\right)^2\right]$
(c) $u = u_{max}\left(\frac{x}{\delta}\right)^2$ (d) $u = u_{max} / \left(\frac{x}{\delta}\right)^2$

(v) The three-dimensional form of Fourier's law of conduction in an isotropic material is equal to ________
(a) –Kδt (b) $k/\rho C_p$ (c) -k dT/dx (d) hAΔT

(vi) Reynolds' Analogy is defined as
(a) St = f/2 (b) St = Re.Pr (c)St .Pr = f/3 (d) $Sc = Pr^{1/3}$

(vii) Using Von-Karman integral method the thickness of momentum boundary layer is equal to ________

(a) $\frac{4.64}{\sqrt{Re_x}}$ (b) $\frac{2.32}{\sqrt{Re_x}}$ (c) $\frac{1}{\sqrt{Re_x}}$ (d) $\frac{9.28}{\sqrt{Re_x}}$

(viii) For a heterogeneous reaction the Thiele modulus is ________ for a pore diffusion controlled reaction.

(a) more than 1 (b) less than 1 (c) equal to 1 (d) either (a) or (c)

(ix) Dimensional analysis of equation of energy (Heat transfer) results in generating
(a) Prandlt number and Reynolds number
(b) Prandlt number and Biot number
(c) Biot number and Reynolds number
(d) Biot number and Courant number.

(x) The unit of diffusivity is
(a) Length^2/time^2 (b) Length/time^2
(c) Time/length^2 (d) Length^2/time.

Group - B

2. (a) What is difference between molecular stress tensor and momentum flux? – Elaborate with mathematical expression. [(CO2)(Remember/LOCQ)]

(b) For $v_x = -\frac{1}{2}bx, v_y = -\frac{1}{2}by$ and $v_z = 0$ velocity distributions, draw a meaningful sketch showing the flow pattern. Then find all the components of **τ** and **ρvv** for the Newtonian fluid. The parameter b is a constant. [(CO2)(Apply/IOCQ)]

(c) Shear stress is given by $\tau_{ij} = -\mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)$. Explain, both the force and momentum flux directions are included in τ_{ij} to calculate velocity gradient.
[(CO2)(Evaluate/HOCQ)]

2 + 6 + 4 = 12

3. (a) What is the role of Kronecker delta in molecular stress tensor?
[(CO2)(Remember/LOCQ)]

(b) Estimate the viscosity of the following gas mixture at 1 atm and 293 K from the given data on the pure components at the same pressure and temperature.

Species	Mole fraction	Molecular weight	Viscosity (Pa.s)
CO_2	0.133	44	14.62×10^{-6}
O_2	0.039	32	20.31×10^{-6}
N_2	0.828	28	17.54×10^{-6}

[(CO2) (Apply/IOCQ)]

(c) Mathematically justify, that at the condition, when collision diameter and intermolecular distance will be equal the Lennard-Jones potential energy becomes zero. [(CO2)(Evaluate/HOCQ)]

2 + 6 + 4 = 12

Group - C

4. (a) Cite one practical example for each of Coutte and Creeping flow. [(CO2)(Remember/LOCQ)]

(b) Show that the average velocity across a cross section of a falling film flowing over a flat plate (making angle θ with the vertical) of length 'L unit' is two-third of the maximum velocity over the plate. [(CO2)(Create/HOCQ)]

(c) An oil has a kinematic viscosity of 2×10^{-4} m^2/s and a density of 0.8×10^3 kg/m3. If we want to have a falling film of thickness of 2.5 mm on a vertical wall, what should the mass rate of flow the liquid be? [(CO2)(Apply/IOCQ)]

2 + 6 + 4 = 12

5. (a) How the Reynold's stress terms differ from molecular stress? [(CO2)(Understand/LOCQ)]

(b) Using shell momentum balance, develop the differential equation to obtain the velocity profile within the fluid medium (fig. 2). ω is the rotational speed of the stirrer arrangement. R_1 is the stirrer radius and R_2 is the cylinder radius. $R_2 >> R_1$. Assume the fluid is the Newtonian fluid. [(CO2) (Create/HOCQ)]

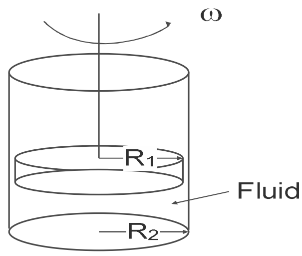

Fig. 2

(c) "No slip condition assumption is purely dependent on the geometry of the control volume" – Justify the appropriateness of the statement. [(CO2)(Evaluate/HOCQ)]

3 + 6 + 3 = 12

Group - D

6. (a) For a hot flowing fluid (T_b) inside a circular pipe (of radiation R) attach to circular fins (Length L), Find out the temperature profile along the fins. Assume ambient temperature Tα. [(CO4)(Apply/IOCQ)]

(b) Derive the conduction resistances for a composite wall. Thermal conductivity of wall material is K. [(CO4)(Remember/LOCQ)]

8 + 4 = 12

7. (a) Derive the velocity profile and the temperature profile for a flowing Newtonian incompressible fluid between two parallel plates separated by a distance L. Assume the flow in laminar. [(CO4)(Create/HOCQ)]

(b) Explain why the Grashof number is significant for free convection while the Nusselt number is significant to forced convection? [(CO5)(Analysis/IOCQ]

10 + 2 = 12

Group - E

8. (a) In case with component flux determination during mass transfer, why one requires to understand the advective mass transfer along with the molecular mass transfer? Explain mathematically. [(CO3)(Evaluate/HOCQ)]

(b) What is the purpose of calculating mass transfer average velocity in two different ways – one is the mass average velocity and the other one is the molar average velocity? [(CO3)(Understand/LOCQ)]

(c) A droplet of liquid A, of radius r_1 is suspended in a stream of gas B. We postulate that there is a spherical stagnant gas film of radius r_2 surrounding the droplet. The concentration of A in the gas phase is x_{A1} at $r = r_1$ and X_{A2} at the outer edge of the film, $r = r_2$. By a shell balance, show that for steady-state diffusion r^2N_{Ar} is a constant within the gas film, and set the constant equal to $r_1^2N_{Ar1}$ at the droplet surface also show that the result leads to the following equation for x_A, $r_1^2N_{Ar1} = -\frac{cD_{AB}}{1-x_A}r^2\frac{dx_A}{dr}$. [(CO3)(Apply/IOCQ)]

3 + 3 + 6 = 12

9. (a) Write down the von Kármán mass balance equation. Why this integral method is called the approximate solution for boundary layer thickness measurement? [(CO5)(Remember/LOCQ, Evaluate/HOCQ)]

(b) Derive the Reynolds analogy using the non dimensional conductive diffusive equations for momentum, heat and mass transfer. [(CO1)(Create/HOCQ)]

(2 + 3) + 7 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	18.75	33.33	47.92

Course Outcome (CO):

After the completion of the course students will be able to

1. The students will be able to identify the inherent analogy between different property transport processes.
2. The students will be able to describe the concept of momentum transport for different flow geometry.
3. The students will be able to describe the concept of mass transport for different flow geometry.
4. The students will be able to describe the concept of energy transport for different flow geometry.
5. The students will be able to solve the flow problems relating all three different transport processes.
6. The students will be able to describe the concept of boundary layer and analyze the flow problem based on the comparative survey on the boundary layer thickness.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question