TRANSPORT PHENOMENA
(CHE2205)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

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

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) 'E' is an irrotational vector, when ________.
(a) $\nabla \times E = 0$ (b) $\nabla . E = 0$
(c) $\nabla . (\nabla \times E) = 0$ (d) both (b) and (c)

(ii) The characteristic variation shown by the thixotropic fluids in their shear stress versus rate of shear strain graph is ________________.
(a) shear stress increases with increase in rate of shear strain
(b) shear stress decreases with increase in rate of shear strain
(c) shear stress shows variation only after a definite shear stress is reached
(d) shear stress has decreasing constant and then variation relationship with rate of shear strain

(iii) Eddy viscosity is a turbulent transfer of ___________.
(a) fluid (b) heat
(c) momentum (d) pressure

(iv) Thermal diffusivity of a material is __________.
(a) inversely proportional to its heat capacity at constant pressure
(b) independent of heat capacity at constant pressure
(c) dependent on the viscosity of the material
(d) none of the above

(v) Brinkmann number measures the ratio of __________.
(a) heat generated due toviscous dissipation to that of conduction
(b) viscous forces to gravity forces
(c) convective heat transfer to conductive heat transfer
(d) none of above

(vi) The effectiveness factor inside a porous catalyst is close to ___________, if the pore diffusion is high enough.
(a) 0.1 (b) 0 (c) 1 (d) 0.5

(vii) The correlation between the momentum (δ) and mass boundary layer (δ_m) is given by ____________.

(a) $\frac{\delta}{\delta_m} = Sc^{0.33}$ (b) $\frac{\delta}{\delta_m} = St_m^{0.33}$

(c) $\frac{\delta}{\delta_m} = (Re.S\,c)^{0.33}$ (d) $\frac{\delta}{\delta_m} = (Re.S\,t_m)^{0.33}$

(viii) The mathematical expression for the advective part in case with the molar flux (N) of a particular component during mass transfer is ___________________, where x_i (=ratio of molar concentration of i (c_i) and total molar concentration (c)) is the mole fraction of i^th component, D_{ij} is the molecular diffusivity of i through j.

(a) $x_i \sum N_i$ (b) $\sum N_i$

(c) N_i (d) $-D_{ij} c \nabla x_i$

(ix) The mass diffusivity is the function of ___________________.

(a) pressure (b) temperature

(c) concentration (d) energy

(x) Water flows between two plates of which the upper one is stationary and the lower one is moving with a velocity V. The velocity of the fluid in contact with the upper plate is equal to _______________.

(a) V (b) 0.5V

(c) 2V (d) 0

Fill in the blanks with the correct word

(xi) Kronecker delta (δij) in a stress tensor is equal to __________, when i=j.

(xii) Using similarity method the friction coefficient is equal to ____________.

(xiii) The units of thermal diffusivity are ________________.

(xiv) Lewis number is the ratio of ________ to mass diffusivity within the boundary layer.

(xv) If the velocity potential is given by ϕ, the velocity along 'x' direction in terms of velocity potential is _______________.

Group - B

2. (a) If $\vec{u} = (z-y)\hat{\imath} + (x-z)\hat{\jmath} + (y-x)\hat{k}$ find out the value for $|\nabla \times \vec{u}|$.

[(CO2)(Apply/IOCQ)]

(b) For an irrotational two dimensional flow of a fluid (density ρ) show that the value of the exponent m is equal to either 0 or 1, when $u_x(x,y)=Cx^m$, $u_y(x,0)=0$ and $P(0,0)=P_0$. u_x is the x direction component of velocity u, u_y is the y direction component of velocity u and P is the applied pressure to generate flow.

[(CO2)(Analyse/HOCQ)]

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

4 + 5 + 3 = 12

3. (a) "Euler equation is only valid with the inviscid flow." – Justify the statement in light of the Navier-Stokes' equation. *[(CO2)(Remember/LOCQ)]*

(b) How the integral over control surface, integral over control volume and total acceleration will be correlated using Reynold's transport theorem.

[(CO2)(Remember/LOCQ)]

(c) Water flows through a 2 m wide rectangular channel shown in Fig. 1 with a uniform velocity 3 m/s. Determine the mass flow rate (kg/s) across section CD of the control volume using Reynold's transport theorem.

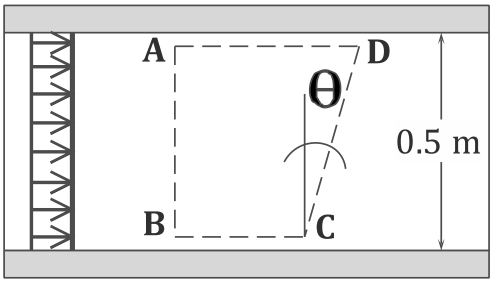

Fig. 1

[(CO2)(Apply/IOCQ)]

3 + 3 + 6 = 12

Group - C

4. (a) Derive x-direction momentum balance equation in Cartesian system for a 2D in compressible steady state Newtonian fluid. *[(CO2)(Apply/IOCQ)]*

(b) What is meant by 'Stream function'? Why it is useful to define a flow field?

[(CO2)(Remember/LOCQ)]

(c) Compute the steady state momentum flux τ_{yx} in Pa, when the lower plate in between two parallel plates (0.03 m apart) is given by a velocity of 1 m/s. Viscosity of fluid entrapped between two parallel plates is 0.7 Pa.s and the top plate is fixed. *[(CO2)(Apply/IOCQ)]*

6 + 3 + 3 = 12

5. (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)(Analyse/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

Group - D

6. (a) A copper ball of diameter 7 cm containing a heating filament is insulated with glass wool of thickness 4 cm. The temperature on the surface of the glass wool is 40°C. The heater inside the copper releases a constant 100 W/cm^3 of energy. The thermal conductivity of copper is 4 W/(cm K) and that of glass wool is 0.023 W/(cm K). Derive the equation for heat flux in copper $q_r^{[C]}$ and that in the insulation $q_r^{[I]}$ as a function of *r* of the ball. *[(CO3)(Analyse/IOCQ)]*

(b) Derive the equation for temperature in copper $T_r^{[C]}$ and that in the insulation temperature $T_r^{[I]}$ as a function of radius, *r* of the ball as given in Q. 6(a).

[(CO3)(Analyse/IOCQ)]

6 + 6 = 12

7. (a) A homogeneous solid sphere of radius R, initially at a uniform temperature T_I, is suddenly immersed at time t=0 in a volume V_f of well-stirred air at temperature T_o in an insulated tank as shown in Fig. 2. Write out the dimensional form of unsteady state governing equation relating the solid and air temperature, T_s and T_f with the radius r of the ball.

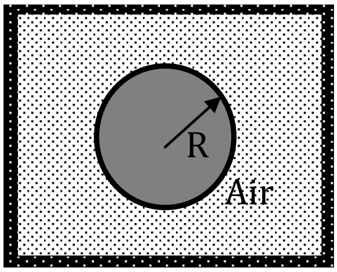

Fig. 2

[(CO3)(Analyse/IOCQ)]

(b) With appropriate forms of dimensionless temperature for solid and air, radius and time, write out the equations in Q. 7(a) in dimensionless form.

[(CO3)(Remember/LOCQ)]

(c) What are the boundary conditions for the solid and fluid regions? Give justifications for choosing the boundary conditions. *[(CO3)(Remember/LOCQ)]*

4 + 4 + 4 = 12

Group - E

8. (a) A droplet of liquid A, of radius r_1 is suspended in a stream of gas B. We postulate that there is a spherical 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 $r=r_2$. If at r_1 the flux is constant at NA1, Show that the molar flux equation for A is given by $N_{Ar_1} = \frac{cD_{AB}}{r_2-r_1}\left(\frac{r_2}{r_1}\right) ln\left(\frac{x_{B2}}{x_{B1}}\right)$ *[(CO4)(Analyse/HOCQ)]*

(b) Show that only one diffusivity of the diffusing component is required to describe the diffusional behaviour of a binary mixture. *[(CO4)(Apply/IOCQ)]*

6 + 6 = 12

9. (a) "The logic behind Reynold's analogy is the similarity between nondimensional form of the convection-diffusion equation for any transport process, when both Pr=1 and Sc=1." – Prove the correctness of the statement. *[(CO1)(Apply/IOCQ)]*

(b) Show that for a wetted wall absorber column, the molar flux of gas at the gas liquid interface is inversely proportional to $z^{0.5}$, where z axis is counted from the top of the wall. *[(CO4)(Analyse/HOCQ)]*

5 + 7 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	22.92	52.08	25