Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.Tech (CHE)/SEM-8/CHE-801/2012

2012
TRANSPORT PHENOMENA

Time Allotted : 3 Hours *Full Marks :* 70

The figures in the margin indicate full marks.

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

GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for any *ten* of the following : $10 \times 1 = 10$

   i) If the Kronecker delta, δ^p_q, is mixed tensor then its rank is

   a) 0 b) 1

   c) 2 d) none of these.

   ii) If $\hat{i}, \hat{j}, \hat{k}$ are the unit vectors in x, y and z directions respectively, then

   a) $\hat{j} \times \hat{k} = 1$ b) $\hat{j} \times \hat{k} = -1$

   c) $\hat{j} \times \hat{k} = \hat{i}$ d) $\hat{j} \times \hat{k} = -\hat{i}$.

iii) An ideal fluid

a) is frictionless and incompressible

b) is one, which obeys Newton's law of viscosity

c) highly viscous

d) none of these.

iv) The continuity equation

a) is independent of the compressibility

b) is independent upon the viscosity of the fluid

c) represents the conversation of mass

d) none of these.

v) Cross or Vector product of two identical vectors is

a) 1 b) 0

c) infinity d) – 1.

vi) A fluid behaves as a shear thickening fluid when apparent viscosity

a) increases with increase in stress

b) increases with decrease of stress

c) increases with duration of stress

d) decreases with duration of stress.

vii) Flow behaviour index (n) of pseudoplastic plastic is

a) 0 b) < 1

c) > 1 d) infinity.

viii) The non-dimensional group that appears in viscous heating problem is

a) Brinkman number b) Nusselt number

c) Biot number d) None of these.

ix) In deriving the equation of continuity, the effect of gravitational force

a) is not required to be taken into account

b) is required to be taken into account for fluids with very high density

c) is required to be taken into account for fluids flowing upwards against gravity

d) is required to be taken into account for fluids with high viscosity.

x) If the Reynolds number in a flow system is very high, it would mean that

a) the flow is dominated by convection

b) the flow is dominated by diffusion

c) the flow is isothermal

d) none of these.

xi) Wilkes equation for estimating mass diffusivity of liquid may be best used for

a) CCl_4 - H_2O b) H_2SO_4 - H_2O

c) $KMnO_4$ - H_2O d) none of these.

xii) Newton's law of cooling is used to define

a) local heat transfer coefficient

b) overall heat transfer coefficient

c) both (a) & (b)

d) none of these.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. $3 \times 5 = 15$

2. Compare Fick's law of diffusion with Newton's law of visocity and Fourier's law of thermal conductivity. To what extent are these relations analogous ?

3. What is RANS theorem ? Prove that $\vec{\nabla} . (\vec{A} \times \vec{r}) = \vec{r} . curl\, \vec{A}$ if $\vec{\nabla} \times \vec{A} = \vec{O}$.

4. Derive the continuity equation in Cartesian coordinate in terms of substantial derivative form, considering both of conductive and convective heat transfers.

5. Show that the following equation describes the pressure field in an arbitrary fluid under the influence of gravity $-\nabla \rho + \rho g = 0$, where the symbols have their usual meaning.

6. Consider steady state evaporation of chloropicrin $\left(CCl_3 NO_2\right)$ liquid into air which may be considered to be a pure substance. The temperature is 25°C. The liquid chloropicrin is taken in a tube containing air. Calculate the rate of evaporation in gm hr^{-1} of chloropicrin into air.

Data :

Total pressure	:	770 mm Hg
Diffusivity [chloropicrin-air]	:	$0{\cdot}088$ cm^2 sec^{-1}
Vapour pressure	:	$23{\cdot}81$ mm Hg
Distance from liquid level to top of tube	:	11.14 cm
Density of chloropicrin	:	$1{\cdot}65$ g cm^{-3}
Surface area of liquid exposed for evaporation	:	$2{\cdot}29$ cm^2.

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. 3 × 15 = 45

7. a) Derive the expression for momentum boundary layer using boundary layer concept and Navier-Stokes equation.

   b) Consider a laminar flow of a Newtonian fluid down an inclined plate with a free surface as half of the flow between two fixed parallel plates and obtain the expression for velocity profile and average velocity. 7 + 8

8. a) Heat is flowing through an annular wall of inside radius r_0 and radius r_1. The thermal conductivity varies linearly with temperature from k_0 at T_0 to k_1 at T_1. Develop an expression for heat flow through the wall.

   b) Show that if $(r_1 - r_0)/r_0$ is very small then

$$Q = 2\pi r_0 L\left(\frac{k_0 + k_1}{2}\right)\left(\frac{T_0 - T_1}{r_1 - r_0}\right).$$

   8 + 7

9. A liquid of constant density and viscosity is in a cylindrical container of radius R. The container is caused to rotate about its own axis at an angular velocity ω. The cylinder axis is vertical, so that $g_r = 0$, $g_\theta = 0$, $g_z = -g$ in which g is the magnitude of the gravitational acceleration. Stating with Navier-Stokes equation, find the shape of the free surface of the liquid when steady state has been established.

10. a) Derive the relevant expression for heat conduction with a chemical heat source taking into account a chemical reaction being carried out in a tubular, fixed-bed flow reactor.

b) A thermocouple, inserted in a cylindrical well, is placed into a gas stream for measuring the gas temperature of the flowing gas through the pipe. Estimate the true temperature of the gas stream from the following supplied data :

Temperature indicated by thermocouple = 260°C

Pipe wall temperature = 176·6°C

Heat transfer coefficient = 587·546 kcal/hr.m^2.°C

Thermal conductivity of well wall = 293·773 kcal/hr.m.°C

10 + 5

11. a) An incompressible Newtonian fluid is flowing between two co-axial cylinders of which outer cylinder rotates with constant angular velocity ω. If the surfaces of the inner and outer cylinders are maintained at T_0 and T_b respectively, develop an expression for the temperature distribution due to viscous dissipation of heat inside the cylinders in terms of Brinkman number.

b) Chlorine is being absorbed from a gas in small experimental wetted wall tower (13 cm height and 2·8 cm internal diameter). The absorbing fluid is water which is coming down from top with an average velocity of $17{\cdot}7 \text{ cm sec}^{-1}$. What is the absorption rate in g-moles hr^{-1} if diffusion coefficient $D_{Cl_2\text{-}H_2O} = 1{\cdot}26 \times 10^{-5} \text{ cm}^2/\text{sec}$ in the liquid phase and if the saturation concentration of chlorine in water is 0·823 gm Cl_2 per 100 gm of water (temperature being 20°C) ? Ignore chemical reaction between Cl_2 and H_2O. 9 + 6