Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.TECH(CHE)/SEM-8/CHE-801/2013

2013
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) The non-dimensional group that appears in viscous heating problem is

      a) Brinkman Number b) Nusselt Number

      c) Biot Number d) None of these.

   ii) Dimensional analysis of Equation of Energy (Heat transfer) results in generating

      a) Prandtl number and Reynolds number

      b) Prandtl number and Biot number

      c) Biot number and Courant number

      d) Reynolds number and Biot number.

iii) In Hagen Poisieulle flow through a cylindrical tube, the radial profile of shear stress is

a) constant b) cubic

c) parallel d) linear.

iv) Apparent viscosity increases with time for the fluid of

a) Thixotropic b) Rheopectic

c) Bingham plastic d) Newtonian.

v) The continuity equation

a) is independent of the compressibility

b) is independent of the viscosity of the fluid

c) represents the conservation of mass

d) none of these.

vi) Sewage sludge is an example of

a) Bingham plastic b) Dilatant

c) Pseudo plastic d) Newtonian fluid.

vii) Molecular momentum flux tensor is

a) τ b) $\rho u \hat{u}$

c) $\tau + p\delta$ d) $\tau + p\delta + \rho u \hat{u}$

viii) Which of the following fluid forces are not considered in the Navier-Stokes equation ?

a) Gravity forces b) Viscous forces

c) Pressure forces d) Turbulent forces.

ix) A_{kl}^{qst} is the component of a mixed tensor of

a) rank 2 b) rank 6

c) rank 5 d) rank 3.

x) Diagonal component of a unit tensor is

a) unity b) 0

c) infinity d) – 1.

xi) Stokes law is valid when the particle's Re No. is

a) greater than 1

b) less than 1

c) lies between 1 and 100

d) greater than 100.

xii) Flow behaviour index (n) of pseudoplastic fluid is

a) 0 b) < 1

c) > 1 d) infinity.

GROUP – B

(Short Answer Type Questions)

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

2. A horizontal annulus of 8m length has an inner radius of 0.0125m and an outer radius of 0.0279m. A 60% aqueous solution of sucrose is to be pumped through the annulus at 20°C. At this temperature the solution density is 1286 kg/m^3 and viscosity is of 7187.2kg/m-s. Calculate the volumetric flow rate when the pressure difference is 37.162 kPa.

3. Parabolic velocity profile for the flow through a vertical circular tube of radius R and length L is given by

$$v_z = \frac{(\wp_0 - \wp_L) R^2}{4\mu L} \left[1 - \left(\frac{r}{R} \right)^2 \right]$$

where, $\wp$ is the combined effect of static pressure and gravity force, μ is the viscosity of the fluid then show that $v_{avg} = \frac{v_{max}}{2}$

4. Define boundary layer thickness.

Calculate the thickness of the boundary layer at a distance of 75mm from the leading edge of a flat surface over which water at 38°C (μ = 1 cp) is flowing at a velocity 10·67 m/s.

5. A 10 cm long copper fin of diameter 6 mm is attached to a vertical wall at 500 K and projected in the room where air is at 300K. The heat transfer coefficient at the fin surface is 30W/m^{2}K and conductivity of the fin material is 390W/mK. Calculate heat loss from fin and fin efficiency.

6. For CO_2 adsorption in a packed tower, mass transfer coefficient is measured as $k = 3.0 \times 10^{-3}$ cm/s. If diffusivity of CO_2 in water is 1.85×10^{-5} cm^2/s, calculate average contact time based on penetration theory and surface renewal theory.

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. $3 \times 15 = 45$

7. a) Define the Kronecker delta symbol. Give the expression of a dyadic product of two vectors v and w. 4

   b) If α is symmetrical and β is anti-symmetrical, show that $(\alpha : \beta) = 0$ 5

   c) Using the continuity equation show that the flow defined by the velocity field

   $$\vec{v} = (2t + 2x + 2y)\,\vec{i} + (t - y - z)\,\vec{j} + (t + x - z)\,\vec{k}$$

   is possible. 6

8. a) Find out the expressions of temperature profile and the maximum temperature in a long nuclear fuel element of spherical form, consisting of a sphere of a fissionable material with radius R^f, surrounded by a spherical shell of Aluminium cladding, having outer radius R^C. Temperatures of centre, inside and outside surfaces of the cladding are T^f, T^c, and T^0 respectively. 9

b) An oil is flowing down a vertical wall having density 0.78×10^3 kg/m^3 and mass flow rate per unit width of the wall is 0.2 kg / (m) (sec). The film thickness is 2.35 mm. Calculate the kinematic viscosity. Also check the Reynolds number. 6

9. An incompressible fluid (density 1.13 gm/cm^3) is flowing upward in steady state in the annular regain between two coaxial circular cylinders of radii 25 mm and 60 mm.

i) Draw the momentum balance and deduce the equation for velocity distribution and calculate the maximum velocity. 9

ii) Also calculate the distance from the centre of the co-axial tube where the maximum velocity occurs.

Data : Viscosity of the fluid = 1.30 gm / (cm) (sec),

Pressure drop of fluid per metre

of tube = $7.0 \times 10^5 \ \frac{\text{dynes}}{\text{cm}^2}$ 6

10. In a gas absorption experiment a viscous fluid flows upward through a small circular tube and then downward in laminar flow on outside. Derive a relation for flow of a fluid film on outside of a circular tube.

a) Show that the velocity distribution in falling film (neglecting end effects) is

$$v_z = \frac{\rho g R^2}{4\mu}\left[1 - \left(\frac{r}{R}\right)^2 + 2a^2 \ln\frac{r}{R}\right]$$ 8

b) Obtain an expression for mass rate of flow in the film. 4

c) Obtain mass flow rate when film thickness is very small. 3

11. a) A fluid with density ρ and viscosity μ is placed between two vertical walls a distance $2b$ apart. The heated wall at $y = -b$ is maintained at a temperature T_2 and cooled wall at $y = +b$ is maintained at a temperature T_1. If β is volume expansion coefficient and $\eta = y/b$ then prove that final expression of the velocity distribution is given by :

$V_z = \rho.\beta.g.b^2.\Delta T.(\eta^3 - \eta) / (12.\mu)$ 10

b) Calculate the radius of a capillary tube using the following data when a viscous fluid is flowing through the tube. Given data :

Length of capillary = 50.02 cm, Kinematic viscosity of fluid = 4.03×10^{-5} m^2 / sec.

Density of fluid = 0.9552×10^3 kg/m^3

Pressure drop across (horizontal) capillary tube

= 4.829×10^5 newton / m^2

Mass rate of flow through tube = 2.997×10^{-3} kg/sec. 5