(v) For a creeping flow of fluid around a sphere moving against the gravity, the Reynold's number is

(a) less than 0.01 (b) less than 0.1
(c) less than 1 (d) less than 10.

(vi) For turbulent flow the magnitude of turbulent fluctuation is measured by

(a) $\sqrt{\left(\overline{v_z'^2}\right)} \Big/ \langle \overline{v_z} \rangle$ (b) $\overline{v_z v_z'}$ (c) $\overline{\overline{v_z}}$ (d) $\overline{v_z'^2}$.

(vii) Reynolds decomposition

(a) is related to the Reynolds number of flow
(b) takes into account velocity fluctuation in turbulent flow
(c) is only valid in laminar flow
(d) is valid for transition flow.

(viii) The effectiveness of a cooling fin

(a) is a linear function of the dimensionless heat transfer coefficient
(b) is dependent only on the surface area of the fin
(c) is a hyperbolic function of a parameter containing h, the heat transfer coefficient
(d) is dependent on heat capacity of material of construction of the fin.

(ix) Brinkman number measures the ratio of

(a) viscous dissipation and inertia
(b) viscous dissipation and thermal conduction
(c) buoyant forces and thermal conduction
(d) none of the above.

(x) For a dense gaseous mixture the diffusivities appearing in Maxwell-Stefan equation are

(a) binary diffusivity (b) concentration dependent diffusivity
(c) knudsen diffusivity (d) both (b) and (c).

(b) Predict the thermal conductivity of methane at 110.4 atm and 6(using Fig. 1 and Table 1 at the end.

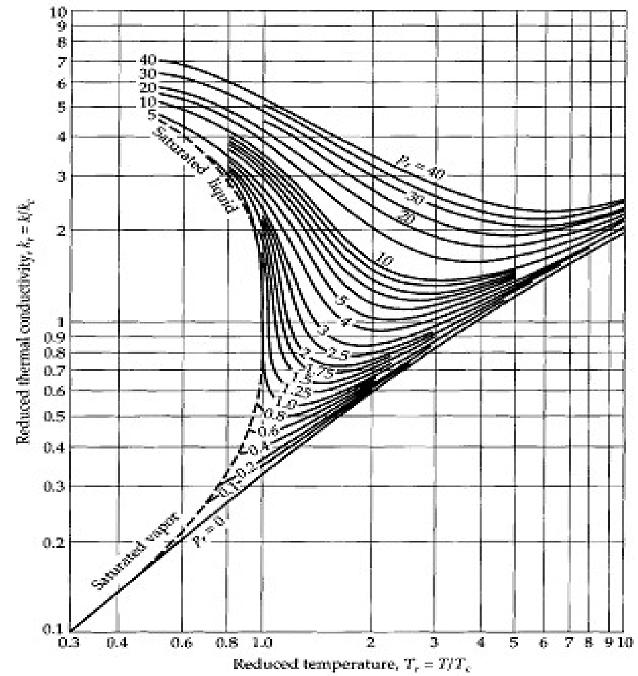

Fig. 1

Table 1

Substance	MW	Lennard-Jones Potential		Critical Properties				
		σ (A°)	ε/k (K)	T_c (K)	p_c (atm)	$\overline{V}_c$ (cm³/ gmole)	μ_c (g/cm.s) ×10⁶	k (cal/s. ×1
C_2H_6	30.07	4.388	232	305.4	48.2	148	210	2(
CH_4	16.04	3.780	154	191.9	45.8	98.7	159	15

7 + 5

8. (a) In a system with N chemical species, choose component N to b solvent, where $j_\alpha^N = \rho_\alpha(V_\alpha - V_N)$ be the mass flux with respect t solvent velocity. Show that for a binary system, where α = A and N = equation for mass flux with respect to the velocity of B can be writte

$$j_A^B = -\frac{(\rho_A + \rho_B)^2}{\rho_B} D_{AB} \nabla \omega_A$$. (where ω_A is the mass fraction of A.)

(b) Chlorine is being absorbed from a gas in a small experimental wetted-wall tower as shown in the fig.2. The absorbing fluid is water, which is moving with an average velocity of 17.7 cm/s. What is the absorption rate in gmoles/hr, if the liquid-phase diffusivity of the chlorine-water system is 1.26 X 10^{-5} cm^2/s, and if the saturation concentration of chlorine in water is 0.823 g chlorine per 100 g water (these are the experimental values at 16°C)?

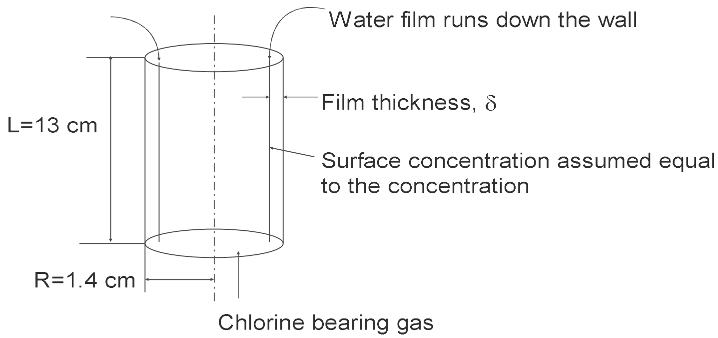

Fig. 2

Given:

$$\frac{\partial u_z}{\partial t}+u_r\frac{\partial u_z}{\partial r}+\frac{u_\theta}{r}\frac{\partial u_z}{\partial \theta}+u_z\frac{\partial u_z}{\partial z}=-\frac{1}{\rho}\frac{\partial P}{\partial z}+g_z+\nu\frac{\partial^2 u_z}{\partial r^2}+\frac{\nu}{r}\frac{\partial u_z}{\partial r}+\frac{\nu}{r^2}\frac{\partial^2 u_z}{\partial \theta^2}+\nu\frac{\partial^2 u_z}{\partial z^2}$$

5 + 7= 12

9. (a) What are the assumptions for Reynold's analogy? Show that with the assumptions one can say $St = \frac{f}{2}$, where f is the drag coefficient.

(b) At 20°C, how many grams of liquid n-octane will evaporate into N_2 in 24.5 hr at 1 atm pressure? The area of the liquid surface is 1.29 cm^2, and the vapor pressure of n-octane at 20°C is 10.45 mm Hg.

$$D_{AB}(cm^2/s)=\frac{0.001568}{p(atm)\sigma_{AB}^2}\sqrt{T^3\left(\frac{1}{M_A}+\frac{1}{M_B}\right)}$$

n-octane: Molecular weight (M)=114.23, mean free path (A°)=7.035

N_2: Molecular weight (M)=28.013, mean free path (A°)=3.667

The volume of vapour produced is given by

$$V_A = 0.00859\times(\text{Surface area})\times\sqrt{4D_{AB}t}$$

(3 + 4) + 5 = 12

TRANSPORT PHENOMENA
(CHEN 4101)

Time Allotted : 3 hrs **Full Marks : 7**

Figures out of the right margin indicate full marks.

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

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

Group – A
(Multiple Choice Type Questions)

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

(i) The Lennard-Jones potential function is given by

(a) $4\varepsilon\left[\left(\frac{\sigma}{r}\right)^6-\left(\frac{\sigma}{r}\right)^{12}\right]$ (b) $4\varepsilon\left[\left(\frac{\sigma}{r}\right)^{12}-\left(\frac{\sigma}{r}\right)^{6}\right]$

(c) $4\varepsilon\left[\left(\frac{\sigma}{r}\right)^3-\left(\frac{\sigma}{r}\right)^{12}\right]$ (d) $4\varepsilon\left[\left(\frac{\sigma}{r}\right)^{12}-\left(\frac{\sigma}{r}\right)^{3}\right]$.

(where r is the actual distance between a pair of molecules, σ collision diameter and ε is the characteristic energy of the molecul

(ii) E vector is said to be irrotational when

(a) $\nabla \times E = 0$ (b) $\nabla \bullet E = 0$ (c) $\nabla^2 \times E = 0$ (d) both (a) anc

(iii) Boussinesq approximation
(a) assumes density to be a linear function of temperature
(b) assumes density to be independent of temperature
(c) is valid for forced convection flow
(d) is valid for free convection.

(iv) Grashoff number is
(a) the ratio of buoyant to viscous forces
(b) the ratio of inertial to viscous forces
(c) a measure of forced convection effect
(d) the ratio of conductive to convective diffusion.

Group - B

2. For a creeping flow around the sphere of radius R, show that the velocity close to the surface is given by

$$\frac{u}{U}=\left[1-\frac{3}{2}\left(\frac{R}{r}\right)+\frac{1}{2}\left(\frac{R}{r}\right)^{3}\right]\cos\theta\hat{e}_{r}-\left[1-\frac{3}{4}\left(\frac{R}{r}\right)-\frac{1}{4}\left(\frac{R}{r}\right)^{3}\right]\sin\theta\hat{e}_{\theta}$$

(U is the free stream velocity)
The continuity equation is given as,

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(\rho r^2 u_r\right)+\frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}\left(\rho u_\theta\sin\theta\right)+\frac{1}{r\sin\theta}\frac{\partial}{\partial\phi}\left(\rho u_\phi\right)=0$$

12

3. (a) Using Reynold's transport theorem, show that the continuity equation for an incompressible fluid can be derived as $\rho\nabla\vec{u}=0$.

(b) The following data are available for the viscosities of mixtures of hydrogen and Freon-12 (dichlorodifluoromethane) (MW 120.92) at 25°C and 1 atm:

Mole fraction of H_2	0	1
μx10^6 (poise)	124	88.4

Find out the viscosity of the mixture, when 50% of hydrogen is mixed with 50% of Freon-12.

5 + 7 = 12

Group - C

4. (a) Using shell momentum balance show that for a flow of a Newtonian fluid of viscosity μ and density ρ inside a vertical cylindrical tube of radius R and length L, the average velocity is exactly 0.5 times of the local velocity.

(b) Water at 20°C is flowing down a vertical wall with Re = 10. Calculate the flow rate, in cubic meter per hour per meter of wall width. Viscosity of water 1.0019 mPa.s and density of water 1000 kg/m^3.

6 + 6 = 12

5. (a) For turbulent flow in smooth circular pipes, the following express used for velocity,

$$\frac{\bar{v}_z}{\bar{v}_{z,max}}=\left(1-\frac{r}{R}\right)^{1/n}$$

with the value of n being a function of Reynolds number as follows:

Reynolds Number	**n**
4000	**6**
110000	**7**
3200000	**10**

Derive an expression for the ratio of average to maximum velocity

(b) How is the intensity of turbulence measured? Derive the equat continuity for turbulent flow.

6 + (2 + 4)

Group - D

6. (a) Oil is acting as a lubricant for an annular cylindrical space. The cylinder rotates at 7908 rpm. The outer cylinder has a radius of 5 c the annular space is 0.03 cm wide. What is the maximum temperat oil if both wall temperatures are known to be 100°C? The viscosity is 92.3 cp and density is 1.22 g/cm^3. Thermal conductivity is 0 cal/(s.cm.°C). First derive the equations that will lead to the expr for maximum temperature and then calculate it.

(b) What are the assumptions used in the above derivation? List all of th

8 + 4

7. (a) Assuming that natural convection effects dominate and Bous approximation holds, derive an expression for velocity, v_z as a fu of y.