Department of Chemical Engineering IIT Kharagpur
Mid Semester Examination 2009 Autumn Semester
Subject: Advanced Fluid Dynamics Subject No. CH 61011

USE SEPARATE ANSWER BOOKS FOR EACH PART

PART – I

Full Marks: 30 (For Part I) **Closed Book, Closed Notes**

All Questions are Compulsory. Clearly state all assumptions/ approximations and assume any missing data (if necessary) giving proper justification. Answers must be brief and precise.

1. Derive the Kinematic Boundary Condition on the free surface of a thin film with perturbed surface. (4)
(Libnitz Rule for differentiation of an integral is as follows:

If $\Phi(y) = \int_{a(y)}^{b(y)} F(x,y)\, dx$, *then*

$d/dx\, [\Phi(y)] = F(b,y)\, d/dy\, [b(y)] - F(a,y)\, d/dy\, [a(y)] + \int_{a(y)}^{b(y)} d/dy\, [F(x,y)]\, dy$

2. What is Shear Thickening? In what type of a system would you expect shear thickening to occur? Possible choices are:
   a. A dilute Slurry; **b.** A 2 phase liquid mixture
   c. A concentrated slurry **d.** All the above.
   Explain the Physical Origin of Shear thickening. (1+1+2=4)

3. What is the physical significance of the term τ_{YX} for a 3-D flow field? What is its expression for a Newtonian Fluid? Under What condition is the statement "**τ_{YX} signifies the X momentum transferred in Y direction**" valid? (2+1+1=4)

4. From which approach (The Eulerian or the Lagrangian) does the definition of pathline originate from? For what type of a flow they **cannot** intersect each other? (1+1=2)

6. A flow has no temporal acceleration but has only convective acceleration. What type of a flow is it? Give an example where such a flow can occur. (1+1=2)

5. (a) Find out the expression for shear stress for the flow of a liquid of thickness "H" over an inclined plane making an angle **θ** to the horizontal. Use the Navier Stokes Equations for the Cartesian System as provided.
(b) State all the assumptions/ conditions that you have used for simplifying the N-S equations in part (a).
(c) Find the expression for Volumetric Flow rate for a Power Law fluid, assuming that the width of the inclined surface over which the flow is occurring is B. (6+5+3=14)

The Expressions for Navier Stokes Eqn for X-Y-Z system:

$$\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right)=-\frac{\partial p}{\partial x}+\left(\frac{\partial \tau_{xx}}{\partial x}+\frac{\partial \tau_{xy}}{\partial y}+\frac{\partial \tau_{xz}}{\partial z}\right)+\rho g_x$$

$$\rho\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}\right)=-\frac{\partial p}{\partial y}+\left(\frac{\partial \tau_{xy}}{\partial x}+\frac{\partial \tau_{yy}}{\partial y}+\frac{\partial \tau_{yz}}{\partial z}\right)+\rho g_y$$

$$\rho\left(\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}\right)=-\frac{\partial p}{\partial z}+\left(\frac{\partial \tau_{zx}}{\partial x}+\frac{\partial \tau_{zy}}{\partial y}+\frac{\partial \tau_{zz}}{\partial z}\right)+\rho g_z$$

All The Best!

Part II
Closed Book/Closed Notes
Answer all the questions in Part II

1. (i) A conical wind box below the fluidized bed performs as a distributor. Is the statement correct? If so, why is it so?
(ii) What is "channeling" in a fluidized bed ? How does it affect the performance of a fluidized bed?
(iii) What is"weeping"in a fluidized bed ? Is it desirable in a fluidized bed-explain
(iv)How one can experimentally determine "Turbulent - beginning and end of velocity" in a fluidized bed ? Explain , if need be, with the help of necessary figure.
(v) What is dead zone in a fluidized bed? Why does it occur? Is it desirable in a fluidized bed?
(vi) What are the differences (with respect to performance) between a "Perforated plate" and Nozzle type" distributor? Explain with the help of sketches.
[1x6=6]

2. (i) An industrial scale fluidized bed is generally developed in different stages : from Lab scale to proto type to demonstration stage and finally to actual scale. It is usual that as we scale up its performance deteriorates and conversion reduces. List out the reasons why it happens so?
(ii) Wen and Yu gave the following equation to determine the minimum fluidization velocity:

$$K_1 Re_{p,mf}^2 + K_2 Re_{p,mf} = Ar$$

Deriving from Ergun equation, find out what are the values of K_1 and K_2. Why the values of K_1 and K_2 may be assumed to be constant for a particular system for wide range of Reynold's number.
[2x2=4]

3. Mustard seeds ($d_{p,mean}$= 1635μm) and and density 1250 kg/m^3 and ε_{mf} = 0.36 are fluidized with air in a lab scale fluidized bed with 20cm in diameter with air at room temperature. Find out the minimum fluidization velocity of the mustard seeds. If the bed is fluidized with 7m/s, find out the regime at which the bed is operating.
Air density: 1.22x 10^{-3} g/cm^3 Viscosity of air =1.8x10^{-4} g/cm.s
[10]

4. A fluidized bed combustor operates in lab scale fluidized bed (20cm ID) and also in a pilot plant (1m ID) mode. It has been observed that in the pilot plant mode the conversion deteriorates. The bed material is sand and fluidizing medium is air. Both the bed operates with the same bed material , with same operating velocity of 30cm/s and same bed height of 2m. Both the bed rests on porous plate distributor. The designer is worried why does it happen so and look for reasons. Since the bubble diameter remains the same and there is not much change in emulsion phase velocity, one possible reason might be the bubble rise velocity. So, they tried to find out the bubble rise velocity in both the cases. The equilibrium bubble diameter in both cases is 3cm. Other data given are:
d_p= 70μm, ε_m =0.45 , ε_{mf} = 0.50, u_{mf} =0.36 cm/s
Other data ,if need be required may be assumed.

Calculate the bubble rise velocities and offer your considered reasons for this drop in conversion with the scale up of the combustor.
[10]

12/9/09

Ergun Equation

$$\frac{\Delta P_{fr}}{L_m} g_c = 150 \frac{(1-\varepsilon_m)^2}{\varepsilon_m^3} \frac{\mu u_o}{(\phi_s d_p)^2} + 1.75 \frac{1-\varepsilon_m}{\varepsilon_m^3} \frac{\rho_g u_o^2}{\phi_s d_p}$$

$$Ar = \frac{d_p^3 \rho_g (\rho_s - \rho_g) g}{\mu^2}$$

Minimum fluidization Velocity

For coarse particles

$$Re_{p,mf} = \left[(28.7)^2 + 0.0494\, Ar\right]^{1/2} - 28.7$$

3. ## Bubble rise velocity

$$u_{br} = 0.711 (g\, d_b)^{1/2}$$

$$u_b = \psi (u_o - u_{mf}) + \alpha u_{br}$$

where ψ is the fraction of visible bubbles $\simeq 1.0$

~~For~~ Geldart-type solids

	A	B	D
α	$3.2 d_t^{1/3}$	$2.0 d_t^{1/2}$	0.87
d_t (m)	0.05 - 1.0	0.1-1.0	0.1-1.0

For A type solids, $d_t \leq 1$ m

$$u_b = 1.55 \left\{ (u_o - u_{mf}) + 14.1 (d_b + 0.005) \right\} d_t^{0.32} + u_{br} \quad (m/s)$$

For B type solids, $d_t \leq 1$ m

$$u_b = 1.6 \left\{ (u_o - u_{mf}) + 1.13\, d_b^{0.5} \right\} d_t^{1.35} + u_{br}, \quad (m/s)$$

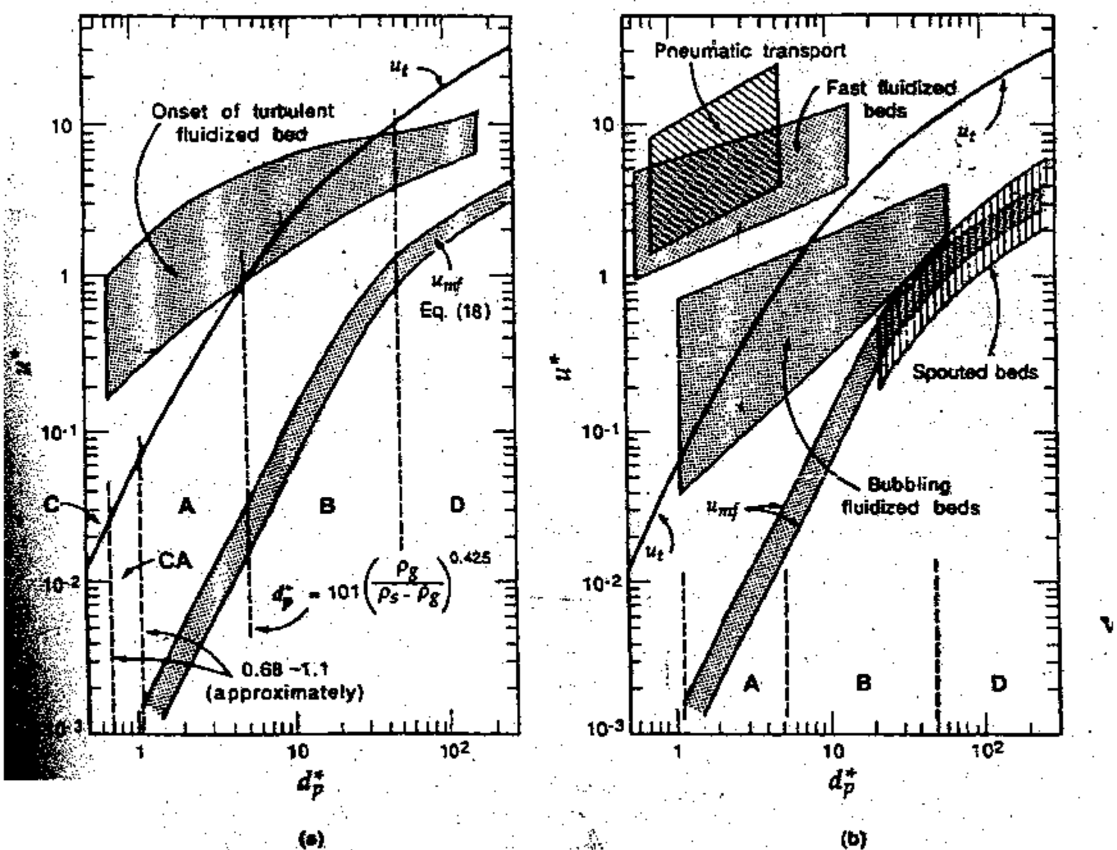

FIGURE 16

General flow regime diagram for the whole range of gas-solid contacting, from percolating packed beds to lean pneumatic transport of solids; letters C, A, B, and D refer to the Geldart classification of solids; adapted from Grace [53], but also including information from van Deemter [68], Horio et al. [73], and Čatipović et al. [67].

.09.09

Chemical Engg Deptt.

Chemical Process Calculations

Sub : CH 20003 (CPC). Sept 09 For 2/ChE & 3/BT students. (No 90)

Instruction: Stepwise results must be shown. **Answer all.**

Full Marks: 30 Time: 2 hours

1st page of your answer script must be reserved to write only the answers clearly in ascending order

Q1. Eqn for a weir: h, in = 0.5 [(Q, gal/min) /L, in]$^{0.5}$ if converted to h', m = K [(Q', m^3/sec)/ L' , m]$^{0.5}$. Find the value of K. [1 gal = 3.785 litre] (10)

Q2. Find out H, H_m, %RH, %saturation of wet air [P_{atm} 100 kpa, T= 300K, Dew Pt 290K]
Data: VP 2.06 kpa at 290K & 4kpa at 300 K (2.5 x 4 = 10)

Q3. Producer gas contains (%) CO : 23, CO_2 : 4.4 ,O_2 : 2.6 , N_2: 70 .

Calculate

a) m^3 of gas at 22^{0}C, 750 mm Hg /kg of C present.

b) m^3 of air at the same condition required with 20 % excess for the combustion of 100 m^3 of gas.

c) Composition of the flue gas assuming complete combustion. (3 + 4 + 3 = 10)