BEL 302: Fluid Solid Systems

Major Examination

8th May, 2009
8.00 – 10.00 Hours
II - 378

Answer all questions. Maximum marks 40.

1. (i) A circular disk of diameter 'D' and thickness 't' is falling in a column of liquid. Derive an equation for its terminal settling velocity.
   (ii) What do you understand by 'continuous fluidization'? Mention any one application where continuous fluidization is employed.
   (iii)Why is it difficult to obtain consistent experimental results when carrying out pressure drop measurements in a bed containing random packings.?
   (iv)Explain how one may use the data from batch sedimentation experiments to design a continuous settler. Theoretically, the required area of a continuous thickener can be decreased by increasing the downward velocity. However, this may not always be desirable. Why?

(3+2+2+3 marks)

2. Feed of nearly uniform 2 inch spheres is crushed in a gyratory crusher. The screen analysis is given in the Table. The power required to crush this material is 400 kW, of which 30 kW is required to run the empty mill. By reducing the clearance between the crushing head and the cone, a different screen analysis is obtained. The feed rate is 110 tons/h.
   a. Using Bonds method, estimate the work necessary per ton of material for the first and second grind.
   b. Discuss the three laws of crushing based on the energy required for creating new surface area.

Mesh	4/6	6/8	8/10	10/14	14/20	20/28	28/35	35/48	48/65	-65	65/100	100/150	-150
Grind 1	3.1	10.3	20.0	18.6	15.2	12.0	9.5	6.5	4.3	0.5			
Grind 2		3.3	8.2	11.2	12.3	13.0	19.5	13.5	8.5		6.2	4.0	0.3

<u>Use Tyler Series Mesh (Mesh 4/6 means passing through mesh size 4 and retained on mesh size 6)</u>

(7+3 marks)

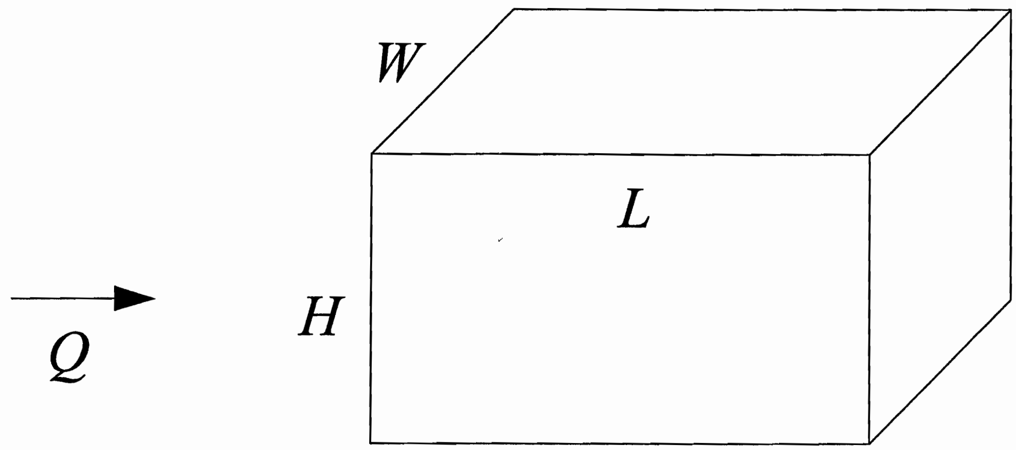

Figure 1: Schematic of the sedimentation tank. The slurry flows at the rate, Q, across the face having dimensions W and H.

3. The *sedimentation coefficient* of a particle subject to a centrifugal force field is defined as the ratio,

$$s = \frac{v_\omega}{\omega^2 r},$$

where v_ω is the terminal velocity of the particle at any radius, r, when the angular velocity is ω. Evidently, s has the units of time. In practice, it is often expressed in svedberg units (1 svedberg $= 10^{-13}$ sec) named after the inventor of the ultracentrifuge. In 1974, Koppel found that the so-called "smaller ribosomes" of *E. coli* had a sedimentation coefficient of 70 svedbergs. Estimate how long it would take to clarify a suspension of these "smaller ribosomes" in a high-speed centrifuge operating at 10,000 rpm. The top of each centrifuge tube is 4 cm from the axis of rotation, and the length of each tube is 1 cm. **(6 marks)**

4. An aqueous slurry containing biological cells of diameter, d_p, and density, ρ_p, flows at the volumetric flow rate, Q, through the sedimentation tank shown in Fig. 1. The density and viscosity of the fluid are ρ and μ, respectively.

a) Show that the diameter of the smallest particle that can be trapped by the sedimentation tank is:

$$d_p = \sqrt{\frac{18\mu}{(\rho_p - \rho)} \frac{WL}{Q}}$$

(6 marks)

b) Suppose the dimensions of the sedimentation tank are $W = H = 10$ cm and $L = 100$ cm, and the volumetric flow rate of the slurry is 1 liter/hr. Can this sedimentation tank successfully trap the particles of a slurry containing (a) bacterial cells ($d_p = 1$ μm), and (b) mammalian cells ($d_p = 10$ μm)? The density of both bacterial and mammalian cells is 1.1 g/cm^3. Assume that the fluid has the physical properties of water, i.e.,$\rho = 1.0$ g/cm^3, $\mu = 0.01$ g/(cm-s). **(4 marks)**

c) Can the abovementioned slurry of bacterial cells be separated in a tubular centrifuge of height 100 cm, radius 10 cm, and rotating at 500 rpm? Assume that the liquid film inside the centrifuge is thin compared to the radius of the centrifuge (i.e., in the notation of the book, $R_0 - R_1 \ll R_0$). **(4 marks)**