**NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY**

**FACULTY OF ENGINEERING**

**DEPARTMENT OF CHEMICAL ENGINEERING**

# FLUID SOLID SYSTEMS 1A

**TCE 3105**

**Final Examination Paper**

**December 2024**

This examination paper consists of 3 printed pages

**Time Allowed: 3 hours**

**Total Marks: 100**

**Special Requirements: None**

## INSTRUCTIONS

1. Answer any four (4) questions.
2. Each question carries 25 marks.
3. Use of calculators is permissible.

## MARK ALLOCATION

| QUESTION | MARKS |
|---|---|
| 1. | 25 |
| 2. | 25 |
| 3. | 25 |
| 4. | 25 |
| 5. | 25 |
| TOTAL | 100 |

**QUESTION 1**

**a)** Explain the relevance of particle characterization to the chemical engineer citing 5 examples of industries and/or processes that rely on particle characterization. For each of the cited processes, explain the relevant characteristics. **[20]**

**b)** Irregular particles of practical interest, most often, cannot be uniquely defined. Their sizes are usually defined based on certain reference properties. The choice of any particular diameter for characterization of an irregular particle depends, in many cases, on the intended application. Many diameters have been defined to characterize the irregular particles. State and define any five of the commonly used equivalent diameters. **[5]**

**QUESTION 2**

**a)** There are many techniques that can be employed to characterize particles according to size, some simple and primitive and some complicated and sophisticated. Almost every technique is associated with intrinsic experimental errors and implicit assumptions. Thus care must be exercised to select proper techniques for your specific applications. Describe with the aid of diagrams, how the two techniques listed below are used to measure particle size.

**i)** Sedimentation **[5]**

**ii)** Microscopy **[10]**

In each case, state the equivalent diameter and the type of size distribution obtained.

**b)** Derive from first principles, the equation for the terminal falling velocity of a spherical particle in the Newton's law regime. **[5]**

**c)** Explain how you would determine the diameter of a falling particle given its terminal velocity when it is not known which region of operation is relevant. **[5]**

**QUESTION 3**

**a)** A mixture of quartz (density 2700 kg/m$^3$) and galena (density 7200 kg/m$^3$) with a particle size range from 0.0035 mm to 0.065 mm is separated in a hydraulic classifier under free settling conditions. Three fractions are obtained, one consisting of quartz only, one a mixture of quartz and galena, and one of galena only. What are the ranges of sizes of particles of the two substances in the three fractions? State all your assumptions. **[20]**

**b)** With the aid of diagrams, explain how the choking velocity is used to mark the boundary between dense phase and dilute phase in vertical pneumatic transport. **[5]**

**QUESTION 4**

**a)** Describe the fluidization behavior of the 4 classes of powders according to Geldart. **[8]**

**b)** With the aid of diagrams, explain the three ways in which the problem of plug formation in pneumatic transport is tackled in commercial systems. **[9]**

**c)** A packed bed of solid particles of density 2500 kg/m$^3$, occupies a depth of 1.5m in a vessel of cross-sectional area 0.4m$^2$. The mass of solids in the bed is 500 kg and the surface volume

mean diameter of the particles is 1mm. A liquid of density 800 kg/m$^3$ and viscosity 0.002Pa s flows upwards through the bed.

**i)** Calculate the voidage (volume fraction occupied by voids) of the bed. **[2]**

**ii)** Calculate the pressure drop across the bed when the volume flow rate of liquid is 0.72m$^3$/h. **[3]**

**iii)** Calculate the pressure drop across the bed when it becomes fluidized. **[3]**

**QUESTION 5**

**a)** The pressure drop across a packed bed is given by the general Ergun equation:

$$\frac{\Delta P}{H} = \frac{150\mu(1-\varepsilon)^2 u}{\varepsilon^3 d_p{}^2} + \frac{1.75(1-\varepsilon)\rho_f u^2}{\varepsilon^3 d_p}$$

The pressure drop across a fluidized bed is given by:

$$\Delta P = H(1-\varepsilon)(\rho_p - \rho_f)g$$

Show that at incipient fluidization

$$Ar = 1406\,\mathrm{Re}_{mf} + 27.3\,\mathrm{Re}_{mf}^2$$

Define all terms. **[12]**

**b)** A bed consists of uniform spherical particles of diameter 3 mm and density 4200 kg/m$^3$. What will be the minimum fluidising velocity in a liquid of viscosity 3 mNs/m$^2$ and density 1100 kg/m$^3$? **[7]**

**c)** There are six components in the equation describing the pressure drop across a pipe carrying solids by pneumatic transport. Write down these six components, in words. **[6]**

**(END OF QUESTION PAPER)**