



**NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY**

**FACULTY OF ENGINEERING**

**DEPARTMENT OF CHEMICAL ENGINEERING**

**FLUID SOLID SYSTEMS**

**ECE 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**

<b>QUESTION</b>	<b>MARKS</b>
1.	25
2.	25
3.	25
4.	25
5.	25
6.	25
<b>TOTAL</b>	<b>100</b>

### 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  $2700 \text{ kg/m}^3$ ) and galena (density  $7200 \text{ kg/m}^3$ ) with a particle size range from  $0.0035 \text{ mm}$  to  $0.065 \text{ mm}$  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 four (4) mechanisms of particle capture in deep bed filtration. [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  $2500 \text{ kg/m}^3$ , occupies a depth of  $1.5 \text{ m}$  in a vessel of cross-sectional area  $0.4 \text{ m}^2$ . The mass of solids in the bed is  $500 \text{ kg}$  and the surface volume

mean diameter of the particles is 1mm. A liquid of density 800 kg/m<sup>3</sup> 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<sup>3</sup>/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

$$Ar = 1406 Re_{mf} + 27.3 Re_{mf}^2$$

Define all terms. [12]

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

#### QUESTION 6

- a) The electrostatic precipitation process consists of three fundamental steps. State and explain these three steps. [6]
- b) ESPs can be grouped, or classified, according to a number of distinguishing features in their design. State any four of these features and state the groups in each class. [4]
- c) Describe the principle of operation of bag houses and baffle chambers. [6]
- d) What is meant by the  $x_{50}$  cut size? [1]
- e) Define the two dimensionless numbers which are used in the scale up of cyclones. [2]
- f) A Stairmand HE cyclone is to be used to clean up 5m<sup>3</sup>/s of ambient air (density, 1.2kg/m<sup>3</sup>; viscosity, 18.5x10<sup>-6</sup>Pas) laden with dust of particle density 2600kg/m<sup>3</sup>. The available pressure drop is 900Pa.
  - (i) What size of cyclone is required? [4]
  - (ii) What is the cut size achieved? [2]

(END OF QUESTION PAPER)