



NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF APPLIED SCIENCE

DEPARTMENT OF APPLIED CHEMISTRY

TRANSPORT PHENOMENA

SCH 2108

Examination Paper

December 2024

This examination paper consists of 5 pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: None

Examiner's Name: Dr. B. Nyoni

External Examiner: Prof. G. Mehlana

INSTRUCTIONS

1. Answer all questions in Section A and any other three questions from Section B
2. Each question carries 20 marks
3. Show steps clearly in any calculation
4. Start the answers for each question on a fresh page
5. Use of calculators is permissible

MARK ALLOCATION

QUESTION	MARKS
1.	20
2.	20
3.	20
4.	20
5.	20
TOTAL	100

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SECTION A

1 (a) Explain how heat is transferred via the following modes?

- (i) Heat conduction
- (ii) Heat radiation
- (iii) Heat convection

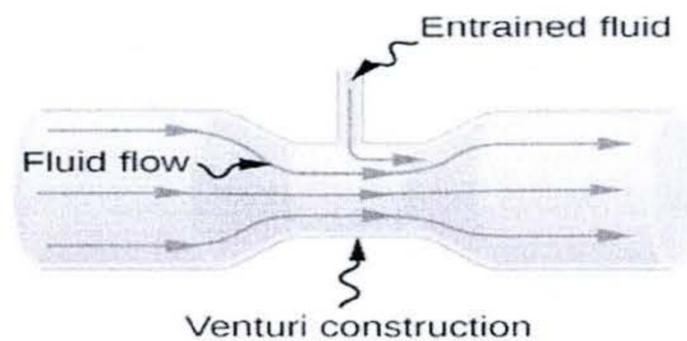
[12]

(b) Prove by using dimensional analysis that the resistance (F) of a sphere with diameter (D) moving at a constant speed (u) through a fluid of density (ρ) and viscosity (μ) is given by

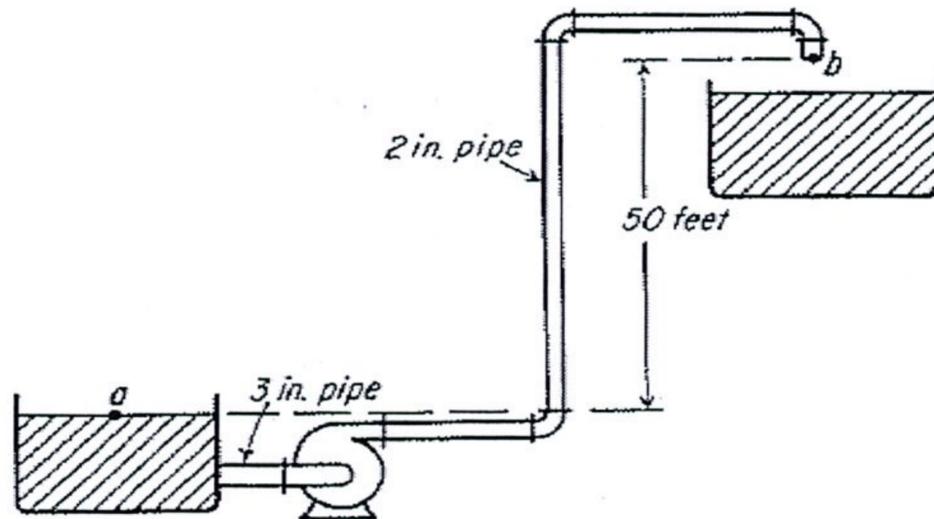
$$F = \left(\frac{\mu}{\rho^2} \right) f \left(\frac{\rho u D}{\mu} \right)$$

[10]

2 (a) A tube with a narrow segment designed to enhance entrainment is called a Venturi such as shown below. Venturis are very commonly used in carburetors and aspirators. Using the Bernoulli principle, explain how this structure bolsters entrainment? [8]



(b) In the equipment shown in the Figure below, a pump draws a solution specific gravity 1.84 from a storage tank through a 75 mm (3 in) steel pipe. The efficiency of the pump is 60%. The velocity in the suction line is 0.914 m/s. The pump discharges through a 50 mm (2 in) pipe to an overhead tank. The end of the discharge pipe is 15.2 m (50 ft) above the level of the solution in the feed tank. Friction losses in the entire piping system are 29.9 J/kg. What pressure must the pump develop? What is the power of the pump? [12]



SECTION B

3 (a) Define the following terms.

- i) Viscosity
- ii) Density

[4]

(b) Describe and explain the difference between a Newtonian and non-Newtonian fluid and give an example of each.

[6]

(c) The table below shows some dimensionless numbers found in the study of Transport Phenomena. Name the dimensionless numbers and describe their physical meaning:

(i)	(ii)
$\frac{\rho u D}{\mu}$	$\frac{h L}{k}$

[8]

4 (a) Derive the basic equation of fluid statics [9]

(b) Consider an open tank of liquid height h , if a hole is drilled at the bottom of the tank so that it is used as a supply of reactants to a continuous flow reactor. The reactants density is ρ . Use Bernoulli's equation to show that the velocity of the reactants at the exit of the hole is given by.

$$u = \sqrt{2gh} \quad [9]$$

(c) Why is the flowrate of reactants an important variable in continuous reactors? [2]

5 (a) List two practical examples where heat is transferred via convection. [2]

(b) Describe any two heat exchanger types of your choice. [6]

(c) It is desired to use Kern's method to design a heat exchanger that will sub-cool condensate from a methanol condenser from 95 °C to 40 °C. The questions that follow are part of the steps in the design calculations.

The flowrate of methanol is 100 000 kg/h. Brackish water is used as the coolant, with a temperature rise from 25°C to 40°C.

Heat capacity of methanol = 2.84 kJ/kg°C

Heat capacity of water = 4.2 kJ/kg°C

$U = 600 \text{ W/m}^2\text{°C}$

Temperature correction, $F_t = 0.88$

Calculate:

- i. The heat load
- ii. Cooling water flow
- iii. ΔT_m
- iv. The heat exchanger provisional area. [12]

6 (a) State the following;

- (i) Two film theory
- (ii) Fick's law of diffusion [6]

(b) Describe any two mass transfer equipment of your choice. [4]

(c) A mixture of He and N₂ is contained in a pipe at 298K and 1 atm total pressure which is constant throughout. At one end of the pipe at Point 1, the partial pressure P_{A1} of He is 0.60 atm and at the other end 0.2 m, P_{A2} is 0.20 atm. Calculate the flux of He if D_{AB} is $0.687 \times 10^{-4} \text{ m}^2/\text{s}$.

$R = 82.057 \text{ m}^3 \text{ atm/kmolK}$. [10]