INTERNATIONAL UNIVERSITY OF EAST AFRICA

'Learning to Succeed'

**FACULTY OF ENGINEERING**

**END OF SEMESTER EXAMINATIONS - APRIL 2025**

**PROGRAMME: BACHELOR OF PETROLEUM ENGINEERING**

**YEAR/SEM: YEAR 4/SEMESTER 2**

**COURSE CODE: PTE4222**

**NAME: NUMERICAL RESERVOIR SIMULATION**

**DATE: 2025-04-25**

**TIME: 2:00-5:00PM**

**INSTRUCTIONS TO CANDIDATES:**

1. Read the instructions very carefully
2. The time allowed for this examination is STRICTLY three hours
3. Read each question carefully before you attempt and allocate your time equally between all the Sections
4. Write clearly and legibly. Illegible handwriting cannot be marked
5. Number the questions you have attempted
6. Use of appropriate workplace examples to illustrate your answers will earn you bonus marks
7. Any examination malpractice detected will lead to automatic disqualification.

**DO NOT WRITE ANYTHING ON THE QUESTION PAPER**

## Section A Attempt any TWO (2) Questions from Section A. Each question carries 20 marks. Any unclear handwriting will lead to loss of marks

**Question 1:**

(a) List the key steps involved in implementing a reservoir simulator
(b) Explain the importance of each step in achieving accurate and meaningful simulations.
(c) Identify common challenges faced during the implementation process.
(d) Suggest strategies to overcome these challenges and improve the implementation workflow.

**Question 2:**

(a) Explain the role of grid resolution in numerical reservoir simulation.
(b) Describe how improper grid selection can lead to numerical dispersion or instability.
(c) Analyse the effect of using unrealistic boundary conditions in a reservoir model.
(d) Suggest strategies to ensure stability and accuracy in numerical simulations.

**Question 3:**

(a) Define one-phase parameter upscaling in the context of reservoir modeling.
(b) Explain the significance of one-phase parameter upscaling in numerical reservoir simulation.
(c) Describe the difference between one-phase and multi-phase parameter upscaling.
(d) Discuss the challenges associated with one-phase parameter upscaling in heterogeneous reservoirs.

**Question 4:**

(a) Explain the role of grid design in reservoir modeling.
(b) Describe how boundary conditions are set in a reservoir model and their significance.
(c) What is history matching, and why is it a critical step in calibration?
(d) Identify key challenges in history matching and propose solutions.

## Section B Attempt any THREE (3) Questions from Section B. Each question carries 20 marks. Any unclear handwriting will lead to loss of marks

**Question 1:**

(a) Write the general form of Darcy’s Law in 3D using vector notation.

(b) Write the expression for Darcy’s Law in 3D using the permeability tensor for an anisotropic medium.
(c) What is the physical interpretation of the terms in Darcy’s Law in vector form?
(d) Derive the equation for the flow rate in a homogeneous isotropic medium in 3D using Darcy’s Law.

(e) In a reservoir simulation model, how would you incorporate Darcy's Law for numerical discretization in a 3D grid? Explain how the pressure gradient and permeability tensor are discretized.

**Question 2:**

(a) (i) Given the following permeability data from a core analysis report, calculate the average permeability of the reservoir:

| Depth (ft) | Permeability (md) |
|---|---|
| 3998-4002 | 200 |
| 4002-4004 | 130 |
| 4004-4006 | 170 |
| 4006-4008 | 180 |
| 4008-4010 | 140 |

(b) (ii) A hydrocarbon reservoir is characterized by five distinct formation segments that are connected in series. Each segment has the same formation thickness. The length and permeability of each section of the five-bed reservoir are as follows:

| Length, ft | Permeability, md |
|---|---|
| 150 | 80 |
| 200 | 50 |
| 300 | 30 |
| 500 | 20 |
| 200 | 10 |

Calculate the average permeability of the reservoir by assuming

(i) Linear flow system

(ii) Radial flow system

(c) Define geometric averaging and explain when it is preferred over arithmetic or harmonic averaging in permeability averaging.

(d) Calculate the geometric average permeability for a reservoir with three layers having permeabilities of 100, 150, and 200 mD.

**Question 3:**

Derive a differential equation for 1D single-phase compressible flow

**Question 4:**

(a) Derive Darcy's Law in 2D using the gradient operator.

(b) Explain the physical interpretation of the gradient operator $\nabla P$ in t

(c) In 3D, write Darcy's Law using the gradient operator and discuss l simulation.

(d) How does the divergence operator relate to the conservation of ma and how is it applied in numerical reservoir simulation?