UNIVERSITI TEKNOLOGI PETRONAS

# FINAL EXAMINATION
# MAY 2024 SEMESTER

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|---|---|---|
| **COURSE** | **:** | **PDB4133/PEB4133 - ADVANCED RESERVOIR SIMULATION** |
| **DATE** | **:** | **9 AUGUST 2024 (FRIDAY)** |
| **TIME** | **:** | **9:00 AM - 12:00 NOON (3 HOURS)** |

## INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

**Note** :

i. There are **NINE (9)** pages in this Question Booklet including the cover page and the Appendix.

ii. **DOUBLE-SIDED** Question Booklet.

1. a. Explain the undersaturated condition how it works in reservoir simulation.

[5 marks]

b. Elaborate on the relationship between the Newton Iteration and the Non-Linear System.

[5 marks]

c. Steady state condition is hypothesized for well modeling during reservoir simulation. Demonstrate how this can be managed for unsteady state conditions.

[5 marks]

d. Assess the relationship between the oil formation volume factor and dissolved gas oil ratio change.

[5 marks]

2. **FIGURE Q2a** shows a reservoir schematic. The water is connected from the surface to the reservoir, and the oil is trapped by cap rock. Consider constant water and oil densities of 62.43 lb/cf and 54 lb/cf, respectively. Oil-water contact is 5,000 ft below the surface.

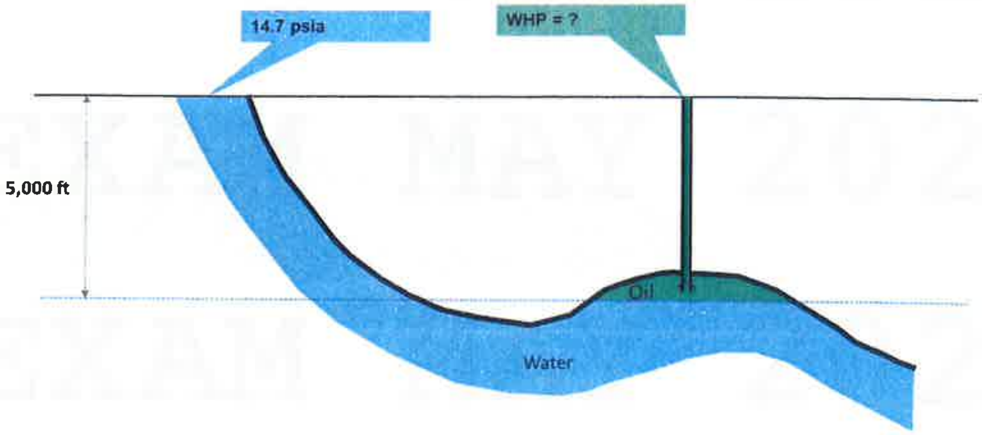


**FIGURE Q2a:** Reservoir schematic

a. Determine the well head pressure (WHP) under static shut-in condition when the water hydrostatic head pressure at the surface is 14.7 psia.

[5 marks]

b. Imagine the well is naturally flowing 100% of oil. Estimate the minimum bottom hole flowing pressure at the datum of 4,900 ft below the surface.

[5 marks]

c. Gas lifting is applied to increase production. The average fluid density in the well is assumed to be 12 lb/cf. Estimate the minimum bottom hole flowing pressure at the datum of 4,900 ft below the surface.

[5 marks]

d. **FIGURE Q2d** shows part of the oil zone in the reservoir. Point A is located 4,650 ft below, and point B is located 4,700 ft below the surface. The oil phase pressure is 1,700 psia for A and 1,715 psia for B, respectively, in current time step of calculation. Indicate fluid flow direction between A and B.


**FIGURE Q2d:** Oil zone in reservoir

[5 marks]

3. **FIGURE Q3a** shows vapor-liquid equilibria for methane, butane, and decane at 280 °F and 1000 psi. The lower-end of the tie line represents liquid compositions and the upper-end is for vapor compositions. Consider mixture of methane, butane and decane are 45%, 30% and 25%, respectively.

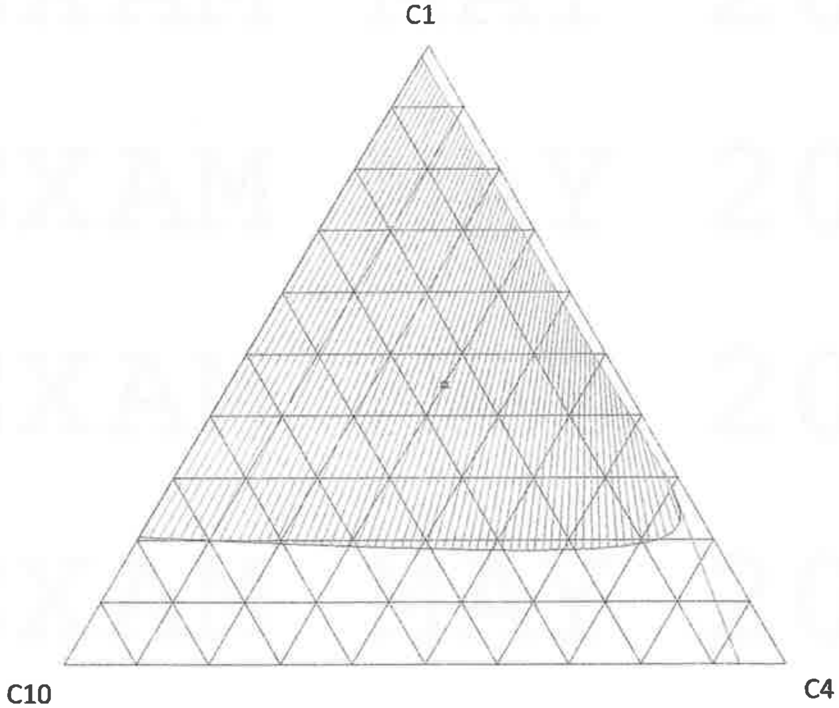


**FIGURE Q3a:** Ternary Diagram at 280 °F and 1000 psi

a. Measure the ratio (by mole) of the liquid-vapor phase and estimate the compositions of each phase (vapor and liquid) using the ternary diagram. Refer to **FIGURE Q3a**

[6 marks]

b. **FIGURE Q3b** shows vapor-liquid equilibria for methane, butane, and decane at 280 °F and various pressures. Imagine the butane is injected as the injection fluid and reaches saturation pressure of 1500 psi. Estimate the mole fractions of each component of this composition under this condition.

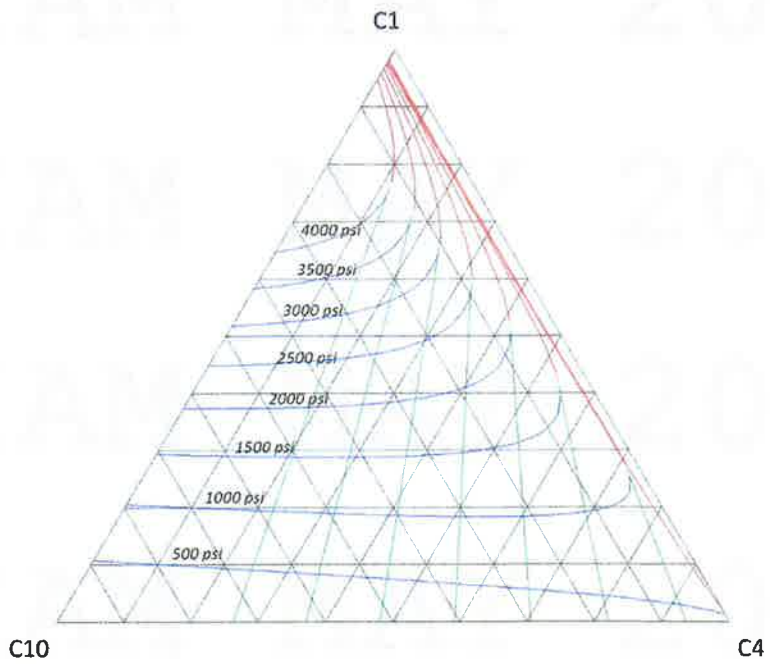


**FIGURE Q3b:** Ternary Diagram at 280 °F

[7 marks]

c. After reaching 1500 psi, the injected fluid is changed to methane and it is injected until 2000 psi which is saturation pressure of this composition. Estimate the mole fractions of each component of this composition.

[6 marks]

d. Ternary diagram is used to describe miscible process. Discuss the benefits and limitations of ternary diagram.

[5 marks]

4. **FIGURE Q4a** shows a reservoir system with four grid blocks arranged vertically. The reservoir top depth is 7,000 ft and the bottom depth is 7,160 ft. Assume stock tank conditions are the same as standard conditions, water compressibility is zero, oil and gas formation volume factors in this reservoir are close to constant. Moreover, ignore rock compressibility. Use the data provided in **TABLE Q4** and **FIGURE Q4a** to answer the questions. Every value needs to be estimated at the grid center.

**TABLE Q4:** Reservoir rock and fluid properties

| **Parameters** | **Values** |
|---|---|
| Oil density, $\rho_o$ (lb/scf) | 54 at standard condition |
| Water Density, $\rho_w$ (lb/scf) | 62.43 at standard condition |
| Gas Density, $\rho_g$ (lb/scf) | 0.067 at standard condition |
| Oil Formation Volume Factor, $B_o$ (rb/STB) | 1.18 at 3,050 psi |
| Solution Gas Oil Ratio, $R_s$ (Mscf/STB) | 0.7 |
| Gas Formation Volume Factor, $B_g$ (rb/Mscf) | 1.1 at 3,050 psi |
| Block Dimension $DX=DY$ (ft) | 1000 |
| Block Dimension $DZ$ (ft) | 40 |
| Initial Reservoir Pressure (psi) | 3,050 at Datum 7,040 ft |
| Gas Oil Contact (ft) | 7,040 |
| Oil Water Contact (ft) | 7,120 |
| Porosity, $\Phi$ (%) | 20 |

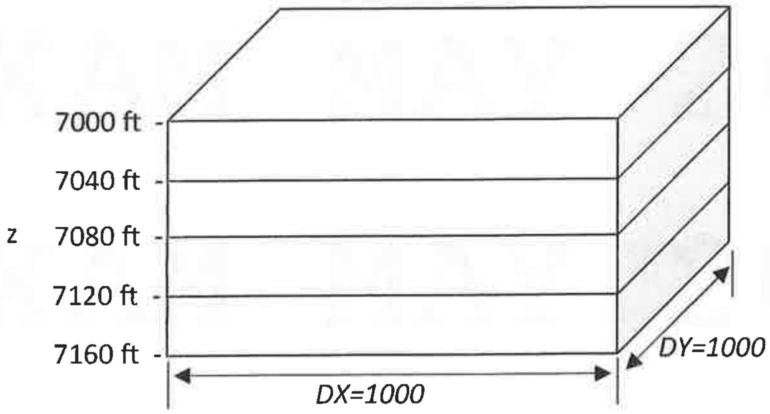


**FIGURE Q4a:** Grid schematics

a. Calculate the initial reservoir fluid densities for gas, oil, and water.

[5 marks]

b. Refer to **FIGURE Q4b,** connate water saturation is 25% in all blocks.

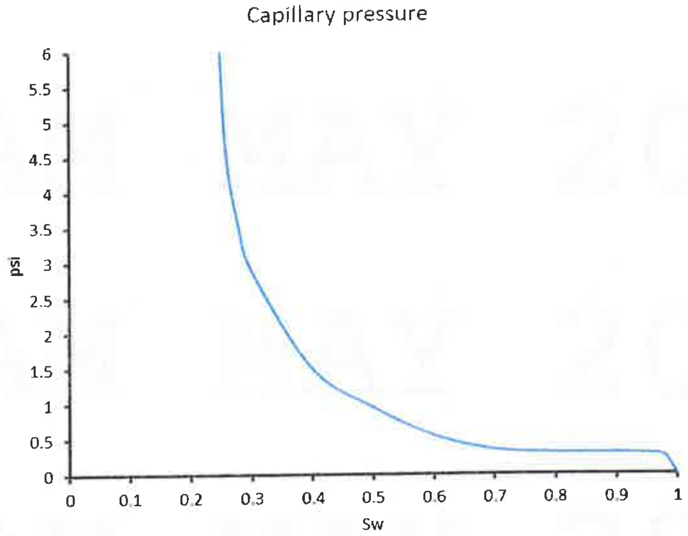


**FIGURE Q4b:** capillary pressure curve

i. Calculate grid block pressures for each block.

[8 marks]

ii. Estimate the initial water saturations for each block.

[8 marks]

c. Estimate the oil in place (OIIP).

[5 marks]

d. Estimate total gas initially in-place (GIIP)

[10 marks]

- END of PAPER -

## APPENDIX

### Darcy's Equation

- $q = -\frac{kA}{\mu}\frac{dp}{dl}$

### Arithmetic Mean of *n* Quantities *A*

- $A = \frac{a_1+a_2+a_3+\cdots+a_n}{n}$

### Harmonic Mean of *n* Quantities *H*

- $\frac{1}{H} = \frac{1}{n}(\frac{1}{a_1} + \frac{1}{a_2} + \frac{1}{a_3} + \cdots + \frac{1}{a_n})$

### Conversion Factors

- 1bbl = 5.615 scf
- 1 rb/Mscf = 0.005615 Mcf/Mscf
- 1g/cc = 0.434 psi/ft = 62.43 lb/scf
- 1 cf : 1 cubic ft ($ft^3$)
- 1 scf : 1 standard cubic ft ($ft^3$)
- 1 Mscf : 1 thousand standard cubic ft
- 1 bbl : 1 barrel
- 1 STB : 1 stock tank barrel
- 1 rb : 1 reservoir barrel