Advanced Petrophysics
PGE 381L, Fall 2022
Unique Number: 20270

Instructor: Zoya Heidari, Ph.D.

Midterm Exam

October 25, 2022
3:30 PM to 5:30 PM

Name: _____

UT EID: _____

Instructions:

1. Print your name above. Do not put your name anywhere else on the test. Do not fold the examination booklet. If you un-staple the examination booklet, please staple it before submission.
2. This examination is OPEN BOOK, closed notes. The only books you are allowed to use include volumes 1 and 2 of your "Advanced Petrophysics" textbook. You can also bring to the exam one letter-size page only including formulae and notes of your choice. No solution to any question is allowed. The only other resources you are allowed to use are pencil/pen, eraser, calculator, and straightedge.
3. Use of cell phones or electronic communication devices is not permitted.
4. Answers should be provided in an organized manner, with a clear and readable handwriting. There will be no credit for the vague or unreadable answers.
5. When you complete the examination, sign the statement below and turn in the examination booklet.

Total Number of Questions: 9

"I have neither given nor received unauthorized aid on this academic work."

Acknowledged via Your Signature: _____

Question 1: (15 points)

Figure 1 shows a synthetic porous medium which is made of insulator material and is shaped as a cube of length L. Three cylindrical shape tubes of radius *r* are drilled through the middle of this cube. You can assume:

$$r / L = 1/\left(3\sqrt{\pi}\right)$$

Two of the cylindrical tubes are filled with brine of resistivity R_w, and the third one is filled with oil. Answer the following questions:

a) Calculate the formation resistivity factor (*F*), and the resistivity index (*I*) for the porous medium in the direction parallel to the length of the cylindrical tubes.
b) Determine the relationship between formation factor and porosity.
c) How does this compare with Archie's equation?

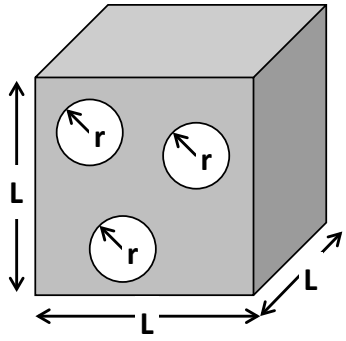

Figure 1: A synthetic porous medium. White and grey regions represent pores and insulator material, respectively.

Question 2: (20 points)

The permeability tensor for a 2D reservoir in the *x*-*y* Cartesian coordinate system is given by

$$\bar{\bar{k}}(x,y)=\begin{bmatrix}70 & 20\\ 20 & 50\end{bmatrix} md$$

Viscosity of the reservoir fluid can be assumed to be 1 cp. The potential gradient is given by

$$\nabla\vec{\Phi}=0.3i+0.2\,j(atm/cm)$$

Answer the following questions:

a) Estimate the maximum directional permeability that can be observed in this reservoir and its direction with respect to *x* coordinate.

b) The magnitude and direction of Darcy velocity with respect to *x* coordinate.

Question 3: (10 points)

Resistivity of a formation at depth X, which is above the capillary transition zone, is equal to 117 ohm-m. You can assume the clay-free rocks at depth X are at irreducible water saturation which is estimated to be 20%. Some other formation properties are given as follows:

Grain diameter = 120 μm

Formation water resistivity = 0.03 ohm-m

Archie's model parameters: a=1, m=2, n=2

Estimate absolute permeability (in Darcy) of the formation at depth X. You can assume that the pore network is circular in cross section.

Question 4: (15 points)

A core prepared for a series of flow experiments consists of a 15 cm long piece of 1 mD rock and a 15 cm long piece of 10 mD rock joined in series (**Figure 2**). Pressure taps are located 7.5 cm from each end of the core. The cross-sectional area of the core is 20 cm^2. The 1 mD core is at the upstream end (where fluid is being injected). The downstream pressure is kept at atmospheric pressure. Brine of viscosity 1 cp is injected into the core at steady-state rate of 5 cm^3/hr. What will be the gauge pressures P_1 and P_2 (in atm) at the pressure taps?

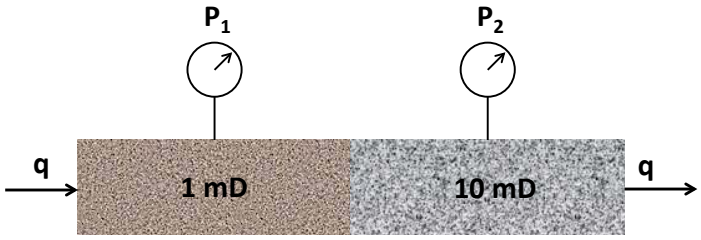

Figure 2: The core setup prepared for flow experiments

Question 6: (25 points)

Consider the well logs provided to you in **Figure 3**. This well is drilled in a siliciclastic sedimentary formation. Archie's parameters, a, m, and n are equal to 1, 1.89, and 1.92, respectively. Answer the following questions:

a) What is the dominant fluid type at 8795 ft? (3 points)

☐ Water ☐ Oil ☐ Gas

b) What is the dominant fluid type at 8500 ft? (3 points)

☐ Water ☐ Oil ☐ Gas

c) What is the dominant fluid type at 8550 ft? (3 points)

☐ Water ☐ Oil ☐ Gas

d) Estimate porosity at 8795 ft. Show your calculations and write the estimated value below. (3 points)

_____

e) Estimate porosity at 8500 ft. Show your calculations and write the estimated value below. (3 points)

_____

f) Estimate resistivity of formation water at reservoir temperature. You can assume the impact of temperature variation is negligible on water resistivity in the depth interval of 8400 ft to 8800 ft. Show your calculations and write the estimated value below. (3 points)

_____

g) Estimate hydrocarbon saturation at 8500 ft. Show your calculations and write the estimated value below. (4 points)

_____

h) Why do we observe separation of resistivity logs at depth 8795 ft, but there is no separation between resistivity logs at depth 8500 ft? (3 points)

Question 7: (10 points)

Assume that you have two rocks, A and B, with the same physical properties such as water saturation, porosity, resistivity of formation water, pore structure, and mineralogy. Rocks A and B are water-wet and oil-wet, respectively. Answer the following questions:

a) Do you expect to observe the same electrical resistivity in these two rocks at low water saturation levels (Yes or No)?

☐ Yes ☐ No

Which one has higher electrical resistivity at the same water saturation (A or B)? Assume they have the same porosity, pore-size distribution, and pore-throat size distribution. (4 points)

☐ Rock A ☐ Rock B

b) Explain your answer to Part (a). How does wettability of grains affect the resistivity of the rock-fluid system? (2 points)

c) Qualitatively plot resistivity index versus water saturation for Rocks A and B? (2 points)

d) It is common to experience oil wettability in carbonate formations. Would you expect to overestimate or underestimate hydrocarbon reserves in oil-wet carbonate formations, if you do not reliably take into account wettability? (2 points)

☐ Overestimate ☐ Underestimate

Question 8: (5 points)

How do the pressures applied in the laboratory for permeability assessment can affect mean free path of the gas molecules? How would that affect estimates of permeability to gas in the laboratory? Would you expect to overestimate or underestimate permeability to gas?

Question 9: (5 points)

What would be the impact of mud-filtrate invasion on skin factor? Do you expect a positive or negative value for skin factor in the presence of mud-filtrate invasion?