Advanced Petrophysics
PGE 381L, Fall 2023
Unique Number: 20215

OPTIONAL
Homework Assignment No. 9

December 4, 2023
Due on Tuesday, December 12, 2023, before 11:00 PM

Name: ____

UT EID: ____

Objectives:

a) To practice assessment of relative permeability
b) To practice interpretation of relative permeability
c) To practice incorporation of relative permeability in understanding performance of water-flooding

Note: Please scan your homework assignment and upload it as one pdf file on the Canvas website before the deadline. Please name your homework document as follows:

PGE381L_2023_Fall _HW09_lastname_name.pdf

Example: PGE381L_2023_Fall_HW09_Heidari_Zoya.pdf

Question 1: A waterflood is to be performed in a reservoir. The relative permeability curves for the reservoir are adequately described by the following analytical models:

$$k_{rw} = \left(S_w - S_{wirr}\right)^3$$

$$k_{ro} = 2\left(1 - S_{or} - S_w\right)^2$$

The other pertinent data are as follows:

$S_{wirr} = 0.15$

$S_{nwr} = 0.25$

$\mu_{nw} = \mu_o = 10 \text{ cp}$

$\mu_w = 1 \text{ cp}$

$B_o = 1.20 \text{ RB/STB}$

$B_w = 1.0 \text{ RB/STB}$

a) Calculate and plot graphs of the relative permeability curves.

b) Calculate and plot graphs of the approximate fractional flow curve $\left(F_w\right)$ and its derivative $\left(\dfrac{dF_w}{dS_w}\right)$.

c) Perform the Welge tangent construction and from it determine the frontal water saturation $\left(S_{wf}\right)$, the average water saturation at water breakthrough $\left(S_{wav}\right)$ and the true fractional flow curve $\left(f_w\right)$ and its derivative $\left(\dfrac{df_w}{dS_w}\right)$.

d) Plot the graphs of the true fractional flow curve and its derivative.

e) Calculate the end point mobility ratio for the waterflood.

f) Calculate and plot graphs of the water saturation profiles at t_D = 0.20, 0.30 and 1.0.

g) Calculate the dimensionless breakthrough time.

h) Calculate the breakthrough oil recovery as a fraction of the initial oil in place.

i) Calculate and plot the graph of oil recovery versus pore volume of water injected before and after water breakthrough.

j) Calculate and plot the graph of water oil ratio versus oil recovery.

Question 2: Repeat Problem 1 using a water viscosity of 100 cp (i.e., polymer augmented waterflood). Comment on the expected performance of a polymer augmented waterflood compared to the ordinary waterflood of Question 1.

Question 3: The oil recovery and pressure data from an unsteady state relative permeability experiment are given in the attached excel sheet. Other data are as follows:

Injection rate	=	200 cc/hr
Irreducible water saturation	=	10.63 %
Length of porous medium	=	54.9 cm
Diameter of porous medium	=	4.8 cm
Average porosity of porous medium	=	30.27 %
Absolute permeability of porous medium	=	3.38 Darcies
Oil viscosity	=	108.37 cp
Oil density	=	0.959 gm/cm^3
Water viscosity	=	1.01 cp
Water density	=	0.996 gm/cm^3
Oil-water interfacial tension	=	26.7 dynes/cm
Effective permeability to oil at irreducible water saturation	=	3.11 Darcies
Oil recovery at water breakthrough	=	36.11 % IOIP
Final oil recovery at termination of experiment	=	55.40 % IOIP

a) Plot graphs of the raw experimental data.

b) Perform the curve fits suggested in Eqs.(8.134) and (8.135) and display the results graphically.

c) Calculate the oil-water relative permeability curves for the porous medium using the Johnson-Bossler-Neumann (JBN) method.

d) Plot the saturation-dependent relative permeability curves.

e) Plot the graph of the true fractional flow curve measured in the experiment.

f) How long was this test?

Question 4: An engineer is injecting water (density = 1 g/cm^3= 1000 kg/cm^3, viscosity =1, cp=0.001 Pa.s) and oil (density = 0.9 g/cm^3=900 kg/m^3, Viscosity=10, cp=0.01 Pa.s) through a porous medium at steady state. The porous medium is a cylindrical core, 2 inches in diameter and 1 ft long. The core is strongly water-wet. The relative permeability and the capillary pressure curves are given by

$$k_{rw} = 0.05\left(\frac{S_w - 0.25}{0.6}\right)^{4.2},$$

$$k_{r0} = 0.9\left(\frac{0.85 - S_w}{0.6}\right)^{1.2},$$

and

$$P_c(S_W) = 2\sigma\sqrt{\frac{\phi}{k}}\left(\frac{0.067}{S_w - 0.25}\right)^{0.2},$$

where k is the absolute permeability (1 Darcy), ϕ is the core porosity (0.2) and σ is the oil-water interfacial tension (30 mN/m = 30 dynes/cm). The core is held horizontally during the experiments described below.

- **a)** Suppose the core is initially fully saturated with oil, and then water is injected at a rate of 1cm^3/min through the core until no more oil is produced. Calculate the pressure drop across the core. Ignore capillary end effect in this calculation.
- **b)** Suppose water and oil are injected simultaneously at equal rates, 1cm^3/minute each, until steady-state is achieved in the core. Calculate the water saturation in the core at steady-state condition. As in part (a), ignore capillary end effect.
- **c)** How would you approach this problem, if capillary end effect is not negligible? You do not need to quantitatively derive equations to answer this question.