FACULTY OF SCIENCE AND TECHNOLOGY

SUBJECT: MPE 340 Reservoir simulation, introduction **DATE: December 1, 2006**

TIME: 4 hours

AID: No printed or written means allowed. Definite basic calculator allowed.

THE EXAM CONSISTS OF 7 PROBLEMS ON 3 PAGES

REMARKS: You may answer in English or Norwegian. All problem parts are given equal weight.

Problem 1

In this problem Corey type two-phase relative permeabilities are specified using formulas

$$k_{rw}(x) = [(x-0.2)/0.8]^2, \quad 0.2 \le x \le 1$$
$$k_{row}(x) = [(0.8-x)/0.6]^2, \quad 0.2 \le x \le 0.8$$
$$k_{rg}(x) = [(x-0.05)/0.75]^2, \quad 0.05 \le x \le 0.8$$
$$k_{rog}(x) = [(0.7-x)/0.7]^2, \quad 0 \le x \le 0.7$$

Oil relative permeability is computed using Baker's formula

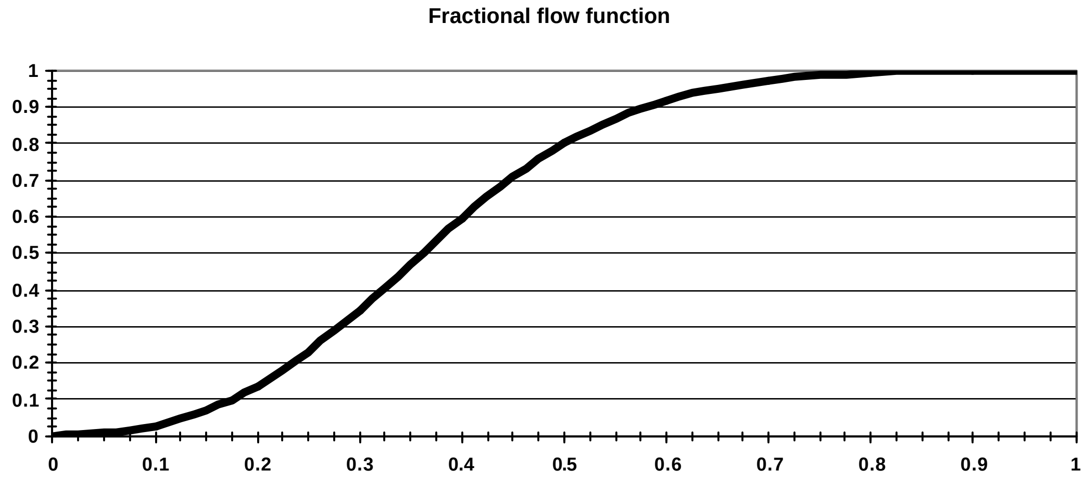
$$k_{ro}(S_w, S_g) = \frac{(S_w - S_{wr})k_{row} + S_g k_{rog}}{S_w + S_g - S_{wr}} \quad .$$

a) Compute oil relative permeability for $S_w = 0.4$ and $S_g = 0.1$.

b) Change critical water saturation to 0.1.
Compute oil relative permeability for $S_w = 0.4$ and $S_g = 0.1$.

Problem 2

This problem deals with water flooding of a 1D horizontal reservoir initially filled with oil. The Buckley-Leverett assumptions are valid and the water fractional flow function is depicted below.



a) Let T_b denote the dimensionless time for breakthrough (time when water production starts). Sketch the water saturation curve at a dimensionless time $T = T_b/2$.
Explain briefly how the solution is computed (mathematical derivation of the solution procedure is not required).

b) Recovery factor is defined as the amount of produced oil divided by the initial oil in place. Derive expressions for oil recovery at dimensionless time T for two cases: $T < T_b$ and $T > T_b$.

Problem 3

a) The formula

$$\varphi(p) = \varphi_0[1 + c(p - p_0)]$$

is frequently used to compute porosity in a simulator.
Define the symbols used in the equation.
Derive the equation. Write the assumptions used at each step.

b) What are the porosity input data needed for a standard Black Oil model?
Make sure you point out the amount of data needed, i.e. how many input numbers are needed.

Problem 4

a) Given oil phase properties

- saturated oil volume factor Bs(p) = βp

- under saturated oil has constant compressibility c, i.e volume factor is computed using

  Bu(p) = Br/[1+c(p-pr)]

  where Br is a reference value at reference pressure pr.

Moreover, p denotes pressure and β is a constant. Write oil volume factor B_o using pressures and β.

b) Write a short outline of the water, oil and gas viscosity input data for a standard Black Oil model. In this presentation make a list of all parameters needed and how those parameters are supplied to the model.

Problem 5

a) Consider the general one-phase continuity equation

$$div(\rho\vec{v}) = -\frac{\partial}{\partial t}(\varphi\rho) + q$$

Write definition of all terms, including the differential operator div, appearing in the equation.

b) Write the general one phase mass balance equation. Outline shortly how this one phase mass balance equation can be derived from the equation in a). Finally, write the mass balance equation for the special case of 1D, one phase vertical flow.

Problem 6

In a reservoir with 12 layers the initial water/oil contact (WOC) is located between layers 10 and 11 and gas/oil contact (GOC) is located between layers 3 and 4.

a) Establish initial saturations in each layer for the case that capillary pressures are assumed to be 0.

b) Give a short outline of the saturation initialization if non-zero Leverett J-functions are used.

Problem 7

Assume a single-phase, one-dimensional diffusivity equation of the form $Kp_{xx} = p_t$ where K is a constant and $p(x,t)$ is the pressure. Show the discretization schemes for implicit, explicit and Crank-Nicolson formulations. Explain briefly why the implicit scheme may be preferred.