University of Stavanger

English text.

FACULTY OF SCIENCE AND TECHNOLOGY

SUBJECT: MPE 340 Reservoir simulation, introduction **DATE: May 7, 2010**

TIME: 4 hours

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

THE EXAM CONSISTS OF 5 PROBLEMS ON 4 PAGES

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

Problem 1

a) Show how oil phase reservoir density is computed using Black Oil fluid input parameters.

b) Relative permeabilities are heterogeneous parameters. What input parameters are needed to model heterogeneous relative permeabilities (varying end points)?

c) Outline the scaling procedure for relative permeabilities.
Use gas relative permeability to illustrate the procedure.

Problem 2

a) What are the basic assumptions for a Black Oil model.
Write the mass balance equations for a Black Oil model. Definition of differential operators involved (gradient, divergence) is not required.

b) What are the basic assumptions for a compositional model.
Write the mass balance equations for a compositional model.

Problem 3

a) Porosity is computed using the formula

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

Define the symbols appearing in the formula.
What are the basic assumptions needed for the formula to be valid?

b) Absolute permeability represents the ability to transmit fluids through a rock. Porosity is used to compute pore volumes.
What are the differences in grid parameters absolute permeability and porosity regarding basic properties, amount of input data, sources of information.

Problem 4

This problem is about the Buckley-Leverett (B-L) equation for water-oil transport. This equation is given by

(*) $$\frac{\partial}{\partial t_D} S + \frac{\partial}{\partial x_D} f(S) = 0 ,$$

where S is the water saturation and x_D and t_D are dimensionless variables.

a) The Buckley-Leverett equation before dimensionless variables in space and time have been introduced takes the form

(**) $$\varphi \frac{\partial}{\partial t} S + u \frac{\partial}{\partial x} f(S) = 0 .$$

Define φ and u. For a reservoir of length L introduce appropriate dimensionless variables in space and time and demonstrate how to obtain (*) from (**).

b) Fig 1. (left figure) shows solution of the B-L equation when using characteristics. This results in an unphysical solution. What is the physical principle that is used to determine the front height S_f of the physical correct solution shown in Fig 1. (right figure)?

Use this principle and show that S_f must satisfy the relation $\dfrac{f(S_f)}{S_f} = f'(S_f)$.

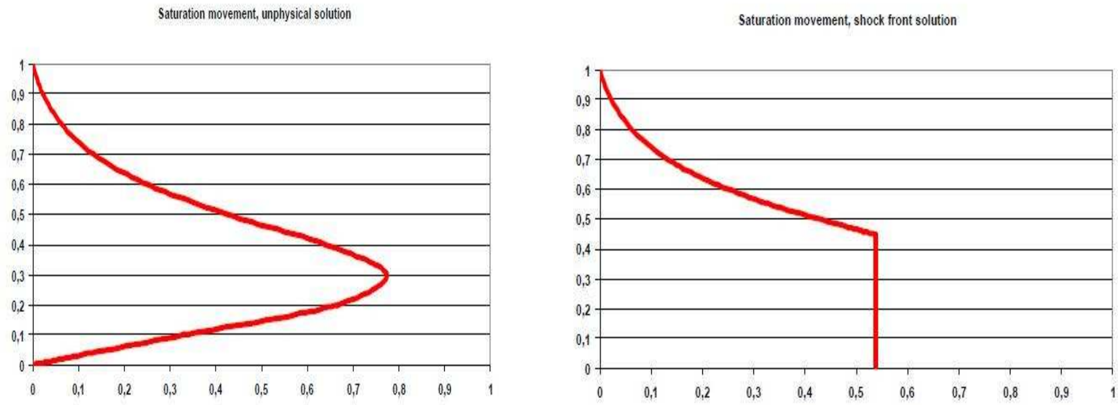

Fig. 1: **Left**: Example of unphysical solution. **Right:** Example of shock front solution.

c) Given the fractional flow function $f(S)$ shown in Fig. 2 (left figure). The corresponding derivative $f'(S)$ is also shown in Fig. 2 (right figure). Sketch the solution at time $T = 0.3$ (dimensionless). In particular, determine (approximately) the front height, position of front, and solution behind front.

d) The parameter M (viscosity ratio) appearing in $f(S)$ and used in c) is 0.5. Now it is set to be M=5. The relative permeability functions, which are based on normalized Corey functions, are unchanged.
   - Make a rough sketch of the new fractional flow function where you compare with the one used in c).
   - Make a rough sketch of the corresponding new solution at time T=0.3. In particular, plot this new solution together with the sketch of the solution obtained in c). What is the main difference between the two solutions (front height and position)?

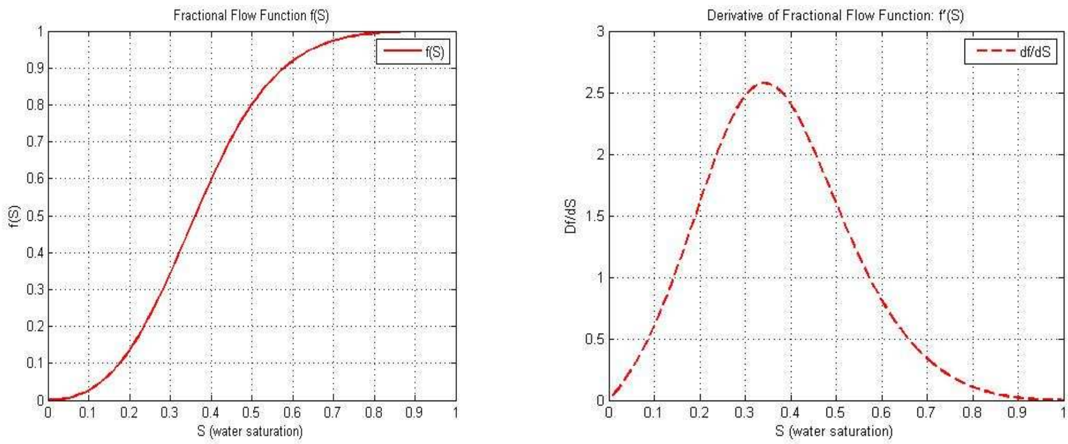

Fig. 2: **Left**: plot of $f(S)$. **Right:** Plot of $f'(S)$.

Problem 5

a) List some of the main assumptions used in the Buckley-Leverett theory.
Assume that normalized Corey type relative permeabilities are used. Define the expressions for the water and oil relative permeability functions as well as the fractional flow function.

b) We assume that the oil and water properties are identical. Explain under what conditions the B-L equation (*) in Problem 4 now takes the form (where we skip the index 'D')

(***) $$\frac{\partial}{\partial t}S + \frac{\partial}{\partial x}S = 0.$$

In particular, use the definition of the fractional flow function $f(S)$ and explain.

c) Propose a discrete scheme for solving (***) by using standard first order discretization in space (upstream/upwind evaluation) and explicit discretization in time. Assume as usual that water is injected at the left inlet and that the reservoir is initially filled with oil.
Specify boundary and initial data.
What is the stability condition (so-called CFL condition) for this scheme?