University of Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

SUBJECT: MPE 340 Reservoir simulation, introduction **DATE: June 9, 2006**

TIME: 4 hours

AID: Calculator

THE EXAM CONSISTS OF 5 PROBLEMS ON 3 PAGES

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

Problem 1

a) Make a list of the main steps in the derivation of the Black Oil differential mass balance equations.
Write the Black Oil equations.

b) Write the main assumptions for compositional model formulation.
Write the compositional mass balance equations.

c) Assume a 1D horizontal reservoir without water is modeled using a compositional model with two components.
Write the mass balance equations for this special case using partial derivatives and reservoir parameters.
Write unknowns and outline the solution procedure for this special case.

Problem 2

a) Outline the characteristics of absolute permeability and porosity input data to a standard simulation model.

b) Make a list of all input parameters needed to compute fluid densities in a Black Oil model. Derive a relation between reservoir oil component density and reservoir oil phase density.

c) Make a list of all saturation function data needed for initialization of a Black Oil model. Suppose initial pressures are computed.
Explain how initial saturations are determined.

Problem 3

a) Assume straight lines are used as normalized input saturation functions for a 3-phase Black Oil model.
Sketch the graph of each input function.
Given real end points used for computing oil/gas relative permeabilities k_{rg} and k_{rog}.
Derive formulas for computing k_{rg} and k_{rog} using input normalized straight lines, end point parameters and standard scaling procedure.

b) Assume that the input straight lines are not normalized. Derive formulas for computing k_{rg} and k_{rog} using standard scaling for this case.

Problem 4

a) Given mass balance equations for a non-horizontal 1D reservoir,

$$k\frac{\partial}{\partial x}\left[\frac{k_{rw}}{\mu_w}\left(\frac{\partial p}{\partial x}+\gamma_{w,x}\right)\right]=\varphi\frac{\partial S_w}{\partial t}$$

$$k\frac{\partial}{\partial x}\left[\frac{k_{ro}}{\mu_o}\left(\frac{\partial p}{\partial x}+\gamma_{o,x}\right)\right]=\varphi\frac{\partial S_o}{\partial t}$$

What are the assumptions needed for the equations above to be valid?

b) Write the gravity terms using the dip angle α.
Make a sketch of the reservoir where α appears and explain why the gravity terms appear with a + sign.

c) Derive the water fractional flow function for the case specified by the equations in a).
Write the fractional flow function F as $F(S) = f(S)(1-Gk_{ro}(S))$, f is the gravity free fractional flow function. Write definition of G.

d) Make a list of the parameters effecting *F* but not *f*.
What are the conditions on *G* for *F* to take negative values?

e) Consider water injection in a reservoir where the assumptions of a) are valid. Further, assume gravity effects are moderate such that no counter current flow appears. What will be the most efficient water flooding strategy, water injection at the highest part and production at the lowest part of the reservoir, or vice versa? Support you arguments by analyzing the fractional flow function.

Problem 5

Given the following equation for single phase flow through a 1D horizontal reservoir,

$$\frac{\partial^2 p}{\partial x^2} = \frac{\varphi \mu c}{k} \frac{\partial p}{\partial t}\,.$$

Discretize the equation in space and time by the finite difference method using implicit formulation and explain how the resulting linear set of equation can be solved by direct elimination of unknowns.