University of Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

English

SUBJECT: PET 660 Reservoir simulation

DATE: February 23, 2015

TIME: 4 hours

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

THE EXAM CONSISTS OF 5 PROBLEMS ON 4 PAGES + APPENDIX

REMARKS:

COURSE RESPONSIBLE: Hans Kleppe
TELEPHONE NUMBER: 51832237

Problem 1

a) What are the main properties of absolute permeability (spacial distribution, time dependence/independence, etc.)?
How many numbers are needed to specify absolute permeability?

b) An ECLIPSE table for oil fluid properties is given below.

```
PVTO
75    120   1.3   0.78  /
80    135   1.32  0.725 /
100   170   1.375 0.64  /
140   230   1.48  0.5   /
175   270   1.56  0.41  /
215   310   1.67  0.34  /
300   390   1.92  0.26  /
345   425   2     0.24  /
430   500   2.14  0.22
      585   2.07  0.25
      690   2.025 0.32  /
/
```

Which data are specified in the different columns of the table?
Which properties are specified in the three last rows?

Problem 2

a) Give a short outline of the procedure used to determine the order of an approximation. Use the procedure to determine the order of

$$u_{xx} \approx \frac{u_{i-1} - 2u_i + u_{i+1}}{\Delta x^2}$$

b) Use harmonic analysis to determine stability criterion for

$$\frac{u_i^{n+1} - u_i^n}{\Delta t} = \frac{u_{i-1}^n - 2u_i^n + u_{i+1}^n}{\Delta x^2}.$$

Problem 3

Given a reservoir divided into six horizontal layers with layer thickness in meters from top to bottom:

- 20, 10, 10, 30, 20, 50 .

Location of fluid contacts:

- gas/oil contact at interface between layers 2 and 3
- water/oil contact at interface between layers 5 and 6 .

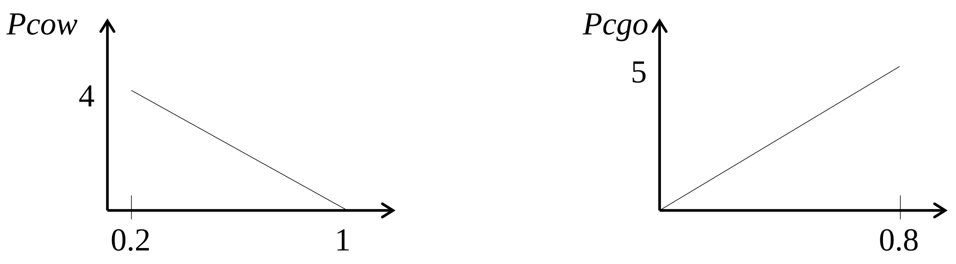
Pressure at gas/oil contact:

- 300 bars .

Gravity for each phase is assumed constant:

- gas: 0.05 bars/m
- oil: 0.4 bars/m
- water: 0.5 bars/m .

Capillary pressure curves are straight lines with *Pcow*(S*wr*) = 4 and *Pcgo*(1-S*wr*) = *5*, S*wr* = 0.2, capillary pressure in bars.



a) Compute initial equilibrium pressure distribution.

b) Compute initial saturation distribution.

Problem 4

Given n algebraic equations

$$
\begin{aligned}
f_1(x_1,...,x_n) &= 0 \\
f_2(x_1,...,x_n) &= 0 \\
&. \\
&. \\
f_n(x_1,...,x_n) &= 0
\end{aligned}
$$

Newton-Raphson iterative method is frequently used to solve equations above.

a) Which equations are solved at iteration step k -> k+1?

b) Consider a part of the oil flow term in the oil equation for a standard Black Oil model

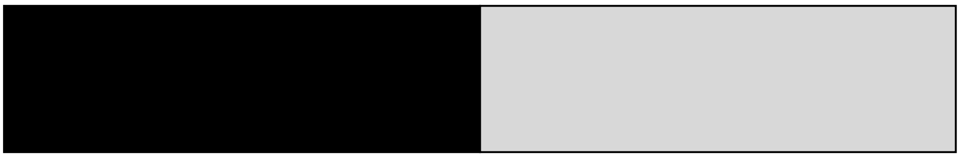
$$F = (T_o)_{i+1/2}(p_{i+1} - p_i)$$

Use upstream evaluation of all inter block terms.

Let p_s denote saturation pressure, where $p_i < p_{i+1}$, $p_{i+1} > p_{s,i+1}$.
Linearize *F*.

Problem 5

a) In Project 1 a 1D, 2-phase piston like displacement of oil by water was studied.



A snapshot of saturation distribution is depicted above. If ECLIPSE is used for simulating this displacement, what will be the difference in computed results using implicit and IMPES methods if a coarse grid is used? Explain the difference. Use water cut curves for illustrations.

b) Consider a field problem with a thin oil zone located between bottom water and a gas cap (Project 2). The production is simulated using vertical production wells.
Using a coarse grid results in higher oil recovery than using a fine grid. Give a short explanation for this fact.
Suggest production scenario that most likely will result in highest recovery.

APPENDIX

Let J denote the complex unit, $J = \sqrt{-1}$, a, b and ϕ real numbers.

$$|a + Jb|^2 = a^2 + b^2$$
$$e^{J\phi} = \cos\phi + J\sin\phi$$
$$e^{J\phi} + e^{-J\phi} = 2\cos\phi$$
$$e^{J\phi} - e^{-J\phi} = 2J\sin\phi$$
$$\cos^2\phi + \sin^2\phi = 1$$
$$\cos(-\phi) = \cos\phi$$
$$\sin(-\phi) = -\sin\phi$$
$$1 - \cos\phi = 2\sin^2(\phi/2)$$

Let A_i denote values of a parameter distributed in a grid with block lengths Δx_i .

Arithmetic mean:

$$\frac{\Delta x_i A_i + \Delta x_{i+1} A_{i+1}}{\Delta x_i + \Delta x_{i+1}} .$$

Harmonic mean:

$$\frac{A_i A_{i+1}(\Delta x_i + \Delta x_{i+1})}{A_{i+1}\Delta x_i + A_i \Delta x_{i+1}} .$$