University of Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

English text

SUBJECT: PET 660 Reservoir simulation

DATE: November 29, 2016

TIME: 4 hours

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

THE EXAM CONSISTS OF 6 PROBLEMS ON 3 PAGES + APPENDIX

REMARKS:

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Problem 1

a)
Show that the approximation

$$u_{xx} \approx \frac{u_{i-2} + 2u_{i+1} - 3u_i}{3\Delta x^2}$$

is first order correct.

.

b)
Use stability analysis (harmonic analysis) to determine stability criterion for the difference approximation

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

of $u_{xx} = u_t$.

Problem 2

a)
Given a 3 x 2 x 2 grid.

The following x-permeability distribution is given:

10 mD, i=1,2, j=1,2, k=1
20 mD, i=3 j=1, k=2

and 50 mD elsewhere.

Here i,j,k are indices used in x-, y-, and z-directions respectively.

Which ECLIPSE keyword is used to supply x-permeabilities?
What will the data record for this keyword look like for the permeabilities specified above?

b)
What are the saturation endpoints needed when endpoint scaling of relative permeabilities is used?

c)
What is specified using the ECLIPSE keyword TSTEP?
How can the user influence the selection of time step length?

Problem 3

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

- 20, 10, 20, 30, 50 .

Position of water/oil contact is between layers 4 and 5 and pressure at water/oil contact is 200 bars.

No gas phase is present.

Gravity for each phase is assumed constant:

- oil: 0.5 bars/m
- water: 0.6 bars/m .

Critical water saturation S_{wr} is equal to 0.2 .

Water/oil capillary pressure is given by

$$P_{cow}(S_w) = 5(1 - S_w^{\ 2}) .$$

a)
Compute initial equilibrium pressure distribution.

b)
Compute initial saturation distribution.
Hint: It is recommended to compute maximal value of P_{cow} first.

Problem 4

a)
Write the Black Oil well inflow equations for a production well perforated in one block. Consider a two-phase water/oil problem. Given a total production rate Q, compute oil and water production rates.

b)
When are lift tables (vertical flow performance tables) needed in a simulation study?

Problem 5

a)
What are the two iterative procedures involved in the numerical solution of reservoir equations? Do not present details, simply point out the procedures.
Pay special attention to initial estimates and convergence criteria.

b)
What is the linear equation structure if implicit solution is used?
Consider both Black Oil and compositional cases.

c)
Explain shortly the role played by the ECLIPSE ORTHOMIN parameter NSTACK (called Ncycle in the Notes).

d)
At which stage in the ECLIPSE linear solution procedure is the special structure of the linear equations used?

Problem 6

a)
Write the discretized mass balance equations for a compositional model.
Standard notation (notation also used for Black Oil equations) need not be defined.
Write the additional equations (constraints) needed to compute the unknowns.

b)
The AIM (Adaptive Implicit) method is frequently used for solving compositional equations.
What are the advantages of the AIM method over implicit and IMPES methods?

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:

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