FACULTY OF SCIENCE AND TECHNOLOGY

SUBJECT: PET 660 Reservoir simulation
DATE: November 29, 2018
TIME: 4 hours
AID: No printed or written aid allowed. Definite basic calculator allowed.
THE EXAM CONSISTS OF 7 PROBLEMS ON 3 PAGES + APPENDIX
REMARKS:
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Problem 1

Saturation function data are relative permeabilities and capillary pressures.

a)
Keywords SWOF and SGOF are used to specify saturation functions in ECLIPSE. Each table consists of 4 columns. What is specified in each of the columns?

b)
How are 3-phase relative permeabilities obtained from data in the tables SWOF and SGOF?

c)
Given tables for SWOF and SGOF.

SWOF

0.15	0.0	0.84	0
0.2	0.0001	0.72	0.05
0.3	0.0033	0.5	0.2
0.4	0.0428	0.32	0.45
0.5	0.0256	0.18	0.8
0.6	0.0911	0.08	1.25
0.7	0.166	0.02	1.8
0.8	0.27462	0	2.45
0.9	0.42187	0	3.2
1	0.61412	0	3.612

SGOF

0	0	0.343	0
0.05	0	0.2746	0.005
0.1	0.002	0.216	0.02
0.2	0.022	0.125	0.08
0.3	0.062	0.064	0.18
0.4	0.202	0.027	0.32
0.5	0.122	0.008	0.5
0.6	0.302	0.001	0.72
0.7	0.422	0	0.98
0.8	0.562	0	1.28
0.85	0.64	0	1.445

Point out errors introduced in the tables.

Problem 2

a)
Show that the approximation

$$u_x \approx \frac{u_{i-2} - 4u_{i-1} + 3u_i}{2\Delta x}$$

is second order correct.

b)
Use harmonic analysis to determine stability criterion for

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

c)
Use harmonic analysis to determine stability criterion for

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

Problem 3

Consider the differential equation $u_{xx} = u_t, x \epsilon\ [0,1]$, t ≥ 0, with boundary conditions

$$\mathrm{u}(0,\mathrm{t}) = 0, \qquad \mathrm{u}(1,\mathrm{t}) = 0, \qquad \mathrm{t} \geq 0$$

$$\mathrm{u}(x,0) = \begin{cases} 6x, & 0 \leq \mathrm{x} \leq 0.5 \\ 6(1-x), & 0.5 < \mathrm{x} \leq 1 \end{cases}$$

For numerical solution use explicit discretization

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

Use 5 computational points along the x-axis, three interior points in addition to the boundary points x = 0 and x = 1. Distance between computational points is constant. Time step lengths are constant as well.

a)
Set time step length Δt = 1/16 and compute solution after 3 steps.

b)
Set time step length Δt = 1/40 and compute solution after 3 steps.

c)
Relate results of 3a) and 3b) to the findings in 2b).

Problem 4

a)
What are the main differences in model input data between a Black Oil and a Compositional model?

b)
In a Black Oil model mass balance is expressed in terms of surface volumes.
How is mass balance expressed in a compositional model?

Problem 5

a)
In which section in an ECLIPSE data file is initial state specified? Which data are required if keyword EQUIL is used?

b)
What will initial saturation distribution be if water, oil and gas phases are present and capillary pressures are 0?

Problem 6

Consider the discretized mass balance equation for oil in a Black Oil model. The equation consists of three terms, flow term, well term an accumulation term (right hand side term). Use upstream evaluation of all inter block terms.

a)
Linearize the term for flow between blocks i and i+1 in x-direction.
The following pressure relations are given: $p_i > p_{i+1}$ and $p_{si} > p_i$, where p_s denotes saturation pressure.

b)
Given pressure relation $p_{si} < p_{i.}$ Linearize accumulation term for block i.

Problem 7.

a)
Which two iteration procedures are used for numerical solution of the reservoir flow equations?

b)
What will be the structure of linearized equations for fully implicit solution?

c)
Why is fully implicit solution rarely used for solving compositional equations?
What is the preferred solution method for compositional equations?

APPENDIX

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

$$e^{J\varphi} = \cos\varphi + J\sin\varphi$$

$$e^{J\varphi} + e^{-J\varphi} = 2\cos\varphi$$

$$e^{J\varphi} - e^{-J\varphi} = 2J\sin\varphi$$

$$cos^2\varphi + sin^2\varphi = 1$$

$$\cos(-\varphi) = \cos\varphi$$

$$\sin(-\varphi) = -\sin\varphi$$

$$1 - \cos\varphi = 2sin^2(\frac{\varphi}{2})$$