Exam ta3440 Petroleum Engineering

15 April 2013

Instructions

- This exam consists of seven questions, some of which are divided in subquestions. The rating of each question is indicated behind the question in brackets. Bonus: 1 point.
- Duration: 2 hours.
- State your assumptions and explain your answers.

Questions

1. A sandstone core sample with diameter D = 25.4 mm (1 inch) and length L = 0.40 m (1.31 ft), from an oil reservoir with porosity ϕ = 0.25 and average permeability k =2500 mD is used to estimate the recovery factor of the reservoir. To this end the core is subject to the procedure shown in the Table 1. It is assumed that the displacement of oil by water is perfectly described by the Buckley-Leverett theory, with shock water saturation S_w^* = 0.65.

Table 1: Core flooding procedure.		
Step	*Description*	*Water saturation*
1	Saturate the core with reservoir brine (viscosity 1.0 cP)	$S_w = 1.00$
2	Inject oil (viscosity 8.5 cP, formation volume factor B_o = 1.015) into the core till no more water is produced	$S_{wc,av} = 0.245$
3	Water-flood the core until no more oil is produced	$S_{w,av} = 0.72$

1.a) Determine the amount of oil initially in place (OIIP) for the core after step 2. (½ point)

1.b) Sketch carefully saturation profiles at three different times. Estimate roughly the oil recovery factor at the breakthrough time at the end of the water flooding. (1 point)

2. The last section of a well is drilled into an oil reservoir at a depth of 2000 m using a drilling mud with relative density of 1.2. Then the well is completed and production is started.

2.a Name four functions of a drilling fluid. (1 point)

2.b Estimate the hydrostatic pressure at the bottom of the well during drilling. (½ point)

2.c During production the well delivers a flow rate q = 2500 m^3/day and the flowing bottom-hole pressure p_{wf} is 15 MPa. The reservoir pressure p_R was previously estimated to be 20 MPa. What is the productivity index J of the well (in m^3/kPa/day)? (1 point)

Formulae:

$$V = \pi r^2 L$$

$$\Delta p = \rho g \Delta D$$

$$q = J(p_R - p_{wf})$$

3. A gas is injected from the top of a dipping formation, while oil is produced from the bottom. The gas is less viscous and less dense than the oil it is displacing. The operator is concerned that gas may penetrate to the production well before the oil is produced.

3.a Sketch a figure of the situation. (½ point)

3.b Without making any change to the properties of the gas, the oil, or the formation, what can the operator do to ensure that the gas displaces the oil stably to the production well? (1 point)

4. Name two causes of poor sweep efficiency. Specifically, name the *causes*, not the situations in which it occurs. (1 point)

5. What is the main hypothesis underlying 'Closed-loop-reservoir management'? (Multiple choice question, ½ point)

   a. Recovery can be significantly increased by changing reservoir management from a 'batch-type' to a near-continuous model-based controlled activity.
   b. Recovery can be significantly increased by the joint application of robust optimization and system-theoretical model reduction techniques.
   c. The parameters that can be identified from outputs in the wells contain just the information that is required to control the state variables by changing the inputs in those wells.
   d. In closed-loop reservoir management the specific optimization methods are less important than the workflow and human interpretation of the results.

$$\Delta P = \frac{\rho \cdot v^2}{288\, g_c \cdot C^2}$$

6. The pressure drop over a valve for an incompressible liquid is given in 'field units' by

$$\Delta p = \rho v^2 / 288 g_c C^2,$$

where Δp is the pressure drop expressed in psi, ρ is the liquid density in lbm/ft^3, v is the liquid velocity in ft/s, and C is a dimensionless choke coefficient. The magnitude of the nature of the dimensional constant g_c is 32.174 ft s^{-2}. Express the equation in SI units. (1 point)

Table 2: Conversion factors to convert field units to SI units.				
Physical quantity	*Dimension*	*SI units*[1)]	*Field units*	*Conversion factor from field units to SI units*[2)]
Density		kg m^{-3}	lbm ft^{-3}	$1.601\,846 \times 10^{1}$
Length	[L]	M	ft	3.048×10^{-1} (exact)
Mass	[m]	Kg	lbm	$4.535\,924 \times 10^{-1}$
Pressure	[L^{-1} m t^{-2}]	Pa	psi	$6.894\,757 \times 10^{3}$
Velocity	[L t^{-1}]	m s^{-1}	ft s^{-1}	3.048×10^{-1} (exact)

7. Consider the following quarterly reservoir pressure readings and the corresponding Z factors and cumulative produced volumes of a dry gas field:

Table 3: Quarterly data.			
Date	*p_{wf} (MPa)*	*Z (-)*	*G_p (Gm^3)*
2010 Q1	315	5.0	0.18
2010 Q2	304	4.9	0.36
2010 Q3	290	4.7	0.55
2010 Q4	271	4.5	0.73
2011 Q1	250	4.2	0.91
2011 Q2	236	4.0	1.10
2011 Q3	214	3.7	1.28
2011 Q4	205	3.6	1.46
2012 Q1	189	3.3	1.64

The initial reservoir pressure was 336 MPa and the corresponding Z factor is 5.3. What is the estimated GIP? (1 point)

$V_1 = 0{,}993 \cdot (V_1 - 0{,}18 \cdot 10^9)$ $\Delta P \rightarrow 6{,}894757 \cdot 10^3$ $P_1 V_1 = z\, n_1 R Z_1 T$

$V_1 - 0{,}993 V_1 = -0{,}993 \cdot 0{,}18$ $\rho \rightarrow 1{,}6018 \cdot 10^1$ $P_2 V_2 = n R Z_2 T$

$v \rightarrow 3{,}048 \cdot 10^{-1}$ $R \cdot T = \frac{P \cdot V}{n \cdot Z}$

$\frac{P_2 \cdot n_1 \cdot Z_1}{n_2 \cdot Z_2 \cdot P_1} = \frac{V_1}{V_1 - 0{,}18 \cdot 10^9}$ $g_c \rightarrow 3{,}048 \cdot 10^{-1}$

$\frac{P_1 V_1}{n_1 Z_1} = \frac{P_2 (V_1 - 0{,}18 \cdot 10^9)}{n_2 Z_2}$ $\frac{P_1 V_1}{n_1 Z_1} = \frac{P_2 V_2}{n_2 Z_2}$

$V_2 = V_1 - 0{,}18 \cdot 10^9$