NTNU – Trondheim
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Department of Petroleum Engineering and Applied Geophysics

Examination paper for TPG4150 Reservoir Recovery Techniques

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Examination time (from-to): 0900-1300

Permitted examination support material: D/No printed or hand-written support material is allowed. A specific basic calculator is allowed.

Other information:

Language: English

Number of pages (front page excluded): 5

Number of pages enclosed: 0

Informasjon om trykking av eksamensoppgave
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Date Signature

Symbols used are defined in the enclosed table

Question 1 (8 points)

This question relates to the group project work.

a) Discuss the main uncertainties in the Gulltopp group project?
b) What was the probable reason for pressure decline in the reservoir before oil production started?
c) Due to the pressure decline before production started, it is expected that oil moved into the aquifer due to fluid expansion. Was all of this oil lost, and did this migration of oil have a significant influence on the final reservoir oil recovery?
d) Which sensitivity calculations did your group make, and did you observe significant variations in reservoir behavior?

Question 2 (12 points)

This question applies to an oil-gas-water reservoir at initial equilibrium conditions and with known WOC and GOC.

a) Make sketches of the capillary pressure curves required for computing the initial equilibrium saturation distributions in such an oil-water-gas reservoir.
b) Using the capillary pressure curves above, and known fluid densities, as well as a measured oil pressure somewhere in the oil column, outline using sketches the procedure for computing initial equilibrium saturation distributions.

Question 3 (12 points)

Consider a reservoir with following initial conditions:

- Undersaturated oil
- Irreducible water saturation

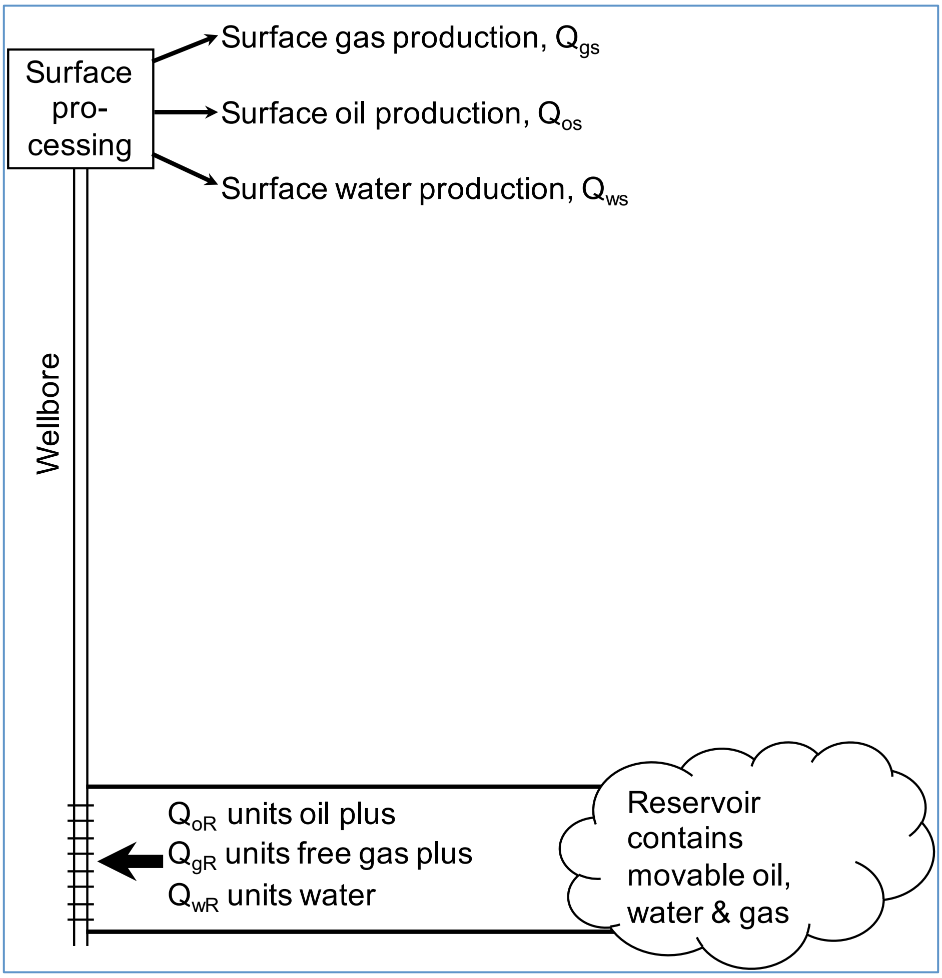
The reservoir is being produced with water injection to a pressure **BELOW** the initial bubble point.

a) Sketch the relevant PVT properties for oil and gas, indicating initial and final conditions on the curves, and compressibility relationships for water and rock needed for material balance calculations.
b) **DERIVE** the complete material equations for oil, gas and water, including production terms for oil, gas and water and injection term for water.
c) Combine and simplify the equations for the following conditions, and find an expression for oil recovery factor, RF:
    - Neglect rock and water compressibilities
    - The standard volumes of cumulative water injected (Wi) and cumulative water produced (Wp) are equal.

Question 4 (12 points)

For the production system below where the oil production rate at surface, Q_{oS}, is specified and given that oil, gas and water mobilities are known and capillary pressures may be neglected:

a) Derive formulas for Q_{oR}, Q_{gR} and Q_{wR}
b) Derive formulas for Q_{gS} and Q_{wS}



Question 5 (12 points)

a) List all assumptions made in the derivation of the following equation:

$$\frac{\partial^2 P}{\partial x^2} = \left(\frac{\phi \mu c}{k}\right)\frac{\partial P}{\partial t}$$

b) Derive the equation, showing all steps and formulas/equations/definitions.
c) Sketch typical pressure profiles vs. x in a one-dimensional horizontal porous medium at several time levels. Label steady and unsteady parts.

<u>Question 6</u> (6 points)

Discuss the Buckley-Leverett method. Include:

a) The basic assumptions behind the method
b) A sketch of a typical Buckley-Leverett displacement situation
c) A <u>short</u> discussion of when the method is applicable

<u>Question 7</u> (6 points)

Discuss the Dietz method. Include:

a) The basic assumptions behind the method
b) A sketch of a typical Dietz displacement situation
c) A <u>short</u> discussion of when the method is applicable

<u>Question 8</u> (6 points)

Discuss the Dykstra-Parson's method. Include:

a) The basic assumptions behind the method
b) A sketch of a typical Dykstra-Parson displacement situation
c) A <u>short</u> discussion of when the method is applicable

<u>Question 9</u> (6 points)

Discuss the Vertical Equilibrium (VE) method. Include:

a) The basic assumptions behind the method
b) A sketch of a typical Vertical Equilibrium (VE) displacement situation
c) A <u>short</u> discussion of when the method is applicable

<u>Question 10</u> (6 points)

a) What do we mean with "microscopic" and "macroscopic" recovery factors?
b) How can we improve the "microscopic" recovery of a reservoir?
c) How can we improve the "macroscopic" recovery of a reservoir?

<u>Question 11</u> (14 points)

For water displacement of oil in a fractured reservoir the wetting conditions of the reservoir rock may greatly influence the recovery process.

a) Sketch the following capillary pressure curves:
   - A typical imbibition curve for a 100% water wetted system
   - A typical imbibition curve for a system that is partly oil wet.

   Mark the following items on the curves:
   - End point saturations
   - The area for spontaneous imbibition
   - The area for forced imbibition
b) What is the final (theoretical) oil recovery factor for a 100% water-wet fractured reservoir under water flooding? Write the appropriate expression.

c) The vertical continuity (contact) between matrix blocks in the reservoir may in some cases influence significantly the oil recovery. Explain shortly for which situations this is true for the following processes:
   - Water displacement
   - Gas displacement

Attachment - Definition of symbols

B_g	Formation volume factor for gas (res.vol./st.vol.)
B_o	Formation volume factor for oil (res.vol./st.vol.)
B_w	Formation volume factor for water (res.vol./st.vol.)
C_r	Pore compressibility (pressure^{-1})
C_w	Water compressibility (pressure^{-1})
ΔP	$P_2 - P_1$
G_i	Cumulative gas injected (st.vol.)
GOR	Producing gas-oil ratio (st.vol./st.vol.)
G_p	Cumulative gas produced (st.vol.)
k	Absolute permeability
k_{ro}	Relative permeability to oil
k_{rw}	Relative permeability to oil
k_{rg}	Relative permeability to oil
m	Initial gas cap size (res.vol. of gas cap)/(res.vol. of oil zone)
M_e	End point mobility ratio
N	Original oil in place (st.vol.)
N_{ge}	Gravity number
N_p	Cumulative oil produced (st.vol.)
P	Pressure
P_{cow}	Capillary pressure between oil and water
P_{cog}	Capillary pressure between oil and gas
q_{inj}	Injection rate (res.vol./time)
R_p	Cumulative producing gas-oil ratio (st.vol./st.vol) = G_p / N_p
R_{so}	Solution gas-oil ratio (st.vol. gas/st.vol. oil)
S_g	Gas saturation
S_o	Oil saturation
S_w	Water saturation
T	Temperature
V_b	Bulk volume (res.vol.)
V_p	Pore volume (res.vol.)
WC	Producing water cut (st.vol./st.vol.)
W_e	Cumulative aquifer influx (st.vol.)
W_i	Cumulative water injected (st.vol.)
W_p	Cumulative water produced (st.vol.)
ρ	Density (mass/vol.)
ϕ	Porosity
μ_g	Gas viscosity
μ_o	Oil viscosity
μ_w	Water viscosity
γ	Hydrostatic pressure gradient (pressure/distance)