National Exams May 2014

98-Pet-A7, Secondary and Enhanced Recovery

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is an OPEN BOOK EXAM. Any non-communicating calculator is permitted.
3. FOUR (4) questions constitute a complete exam paper. The first four questions as they appear in the answer book will be marked.

Problem 1 (30 points)

The oil and water relative permeability curves for a particular line drive waterflood are given as follows:

$$k_{rw} = k_{rw}^0[(S_w - S_{wc})/(1 - S_{wc} - S_{or})]^2$$
$$k_{ro} = k_{ro}^0[(S_o - S_{or})/(1 - S_{wc} - S_{or})]^2,$$

where k_{rw} : Water relative permeability

k_{ro} : Oil relative permeability

S_w : Water saturation

S_o : Oil saturation

$k_{rw}^0 = 0.20$

$k_{ro}^0 = 0.80$

$S_{wc} = 0.20$

$S_{or} = 0.30.$

Other pertinent data are given below.

Distance between the wells: 2700 ft

Cross sectional area for the line drive: 3000 ft^2

Porosity: 0.25

Initial S_w: 0.20

Oil viscosity: 5.0 cp

Water viscosity: 1.0 cp

Constant water injection rate: 200 STB/Day

a. (10 points) Calculate and plot the fractional flow curve for the water phase without gravity and capillarity. Use the attached graph sheet 1. Perform the Welge tangent-line construction.

b. (10 points) Calculate the water breakthrough time in days.

c. (10 points) On your answer book, plot the expected 1-D water saturation profile at 0.20 pore-volumes of water injected. The plot should have the water saturation on the y axis and the distance from the injector on the x axis.

Problem 2 (25 points)

On the attached graph sheet 2, carefully plot a binary pressure-composition (P-x) diagram at a temperature of approximately 150°F from the data given in the table below. The binary pair is methane and butane. Clearly identify the bubble point and the dew point curve.

a. (5 points) What is the approximate saturation pressure of butane at 150°F?

b. (5 points) What is the approximate composition at the critical point? What is the critical pressure at this mixture composition?

c. (10 points) If the reservoir pressure is 1000 psia and the in-situ fluid composition is 40% methane and 60% butane, is the in-situ fluid an oil or a gas? What is the liquid molar fraction of the in-situ fluid?

d. (5 points) A gas composed of 90% methane and 10% butane is going to be injected into the reservoir (reservoir pressure is 1000 psia and temperature is 150°F. These are assumed constant). When the injected gas and the reservoir fluid mix, are they first-contact miscible?

Pressure, psia	Methane mole fraction in the liquid phase	Butane mole fraction in the vapor phase
150	0.002	0.97
200	0.02	0.77
500	0.13	0.39
1000	0.31	0.28
1500	0.53	0.32

*Note that temperature is fixed at 150°F.

Problem 3 (25 points)

Preliminary screening criteria for thermal methods indicate that the following conditions are favourable:

- Porosity higher than 0.25
- Reservoir pressure lower than 1300 psia.

a. (10 points) Please explain why the two conditions given above are favourable for thermal methods in general.

b. (5 points) Propagation of thermal fronts can be quite slow in steam flooding. Please explain the effect(s) of porosity on the propagation rate of thermal fronts in steam flooding.

c. (10 points) Suppose that a steam flood at 300 psia requires 5 bbl of water flashed to 80% quality steam to displace a barrel of oil. Please calculate how much volume of wet steam is required to displace just 1.0 bbl of oil in this case. The specific volumes of saturated liquid and vapor water (steam) are 0.0189 ft^3/lbm and 1.543 ft^3/lbm at 300 psia, respectively. [1.0 bbl = 0.159 m^3, 1.0 kg = 2.205 lb, 1.0 ft = 0.305 m]

Problem 4 (20 points)

Please answer the true and false questions given below. Briefly explain reasons for each of your answers.

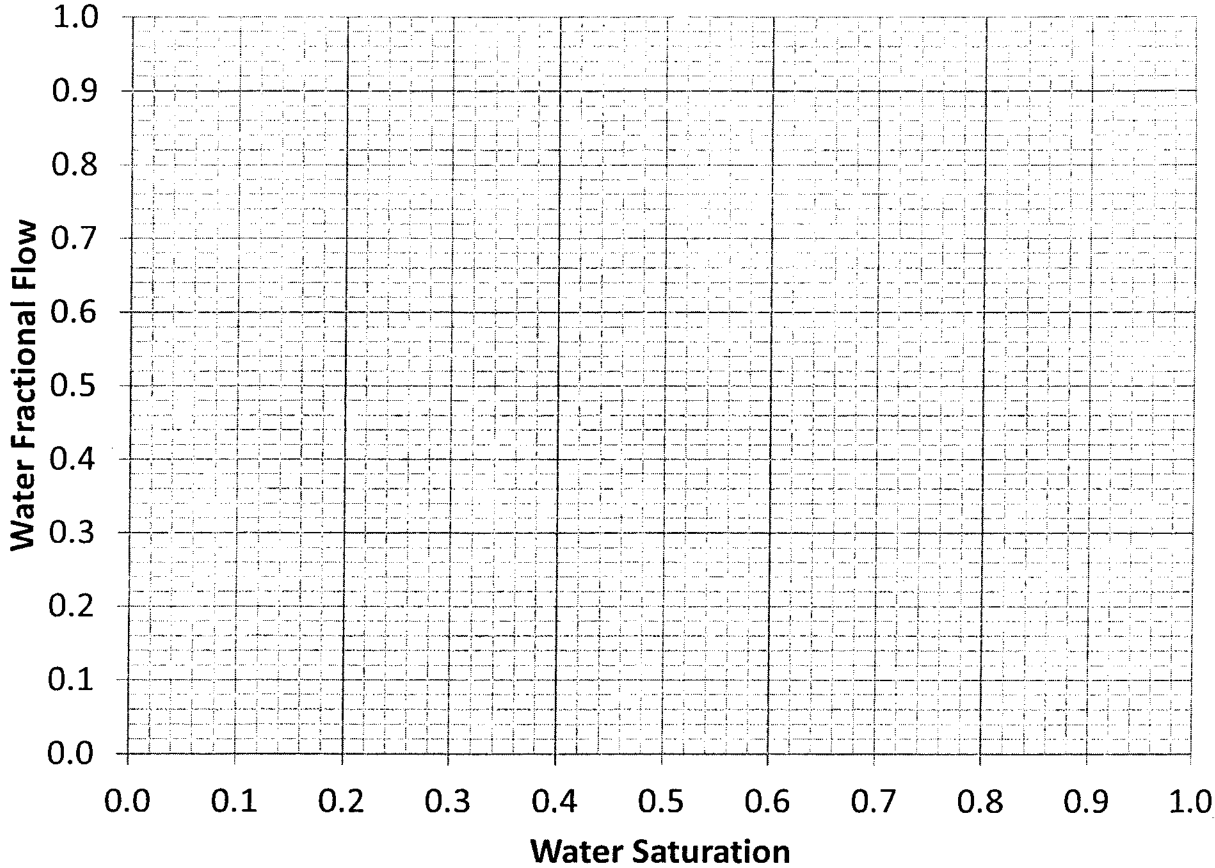
a. (5 points) The effect of dispersion on oil recovery from a miscible gas flood in the lab is likely the same as in the field: True or false? Why?

b. (5 points) Steam flooding is more efficient for a reservoir that has higher water saturations because the convective energy flow is more efficient for such a reservoir: True or false? Why?

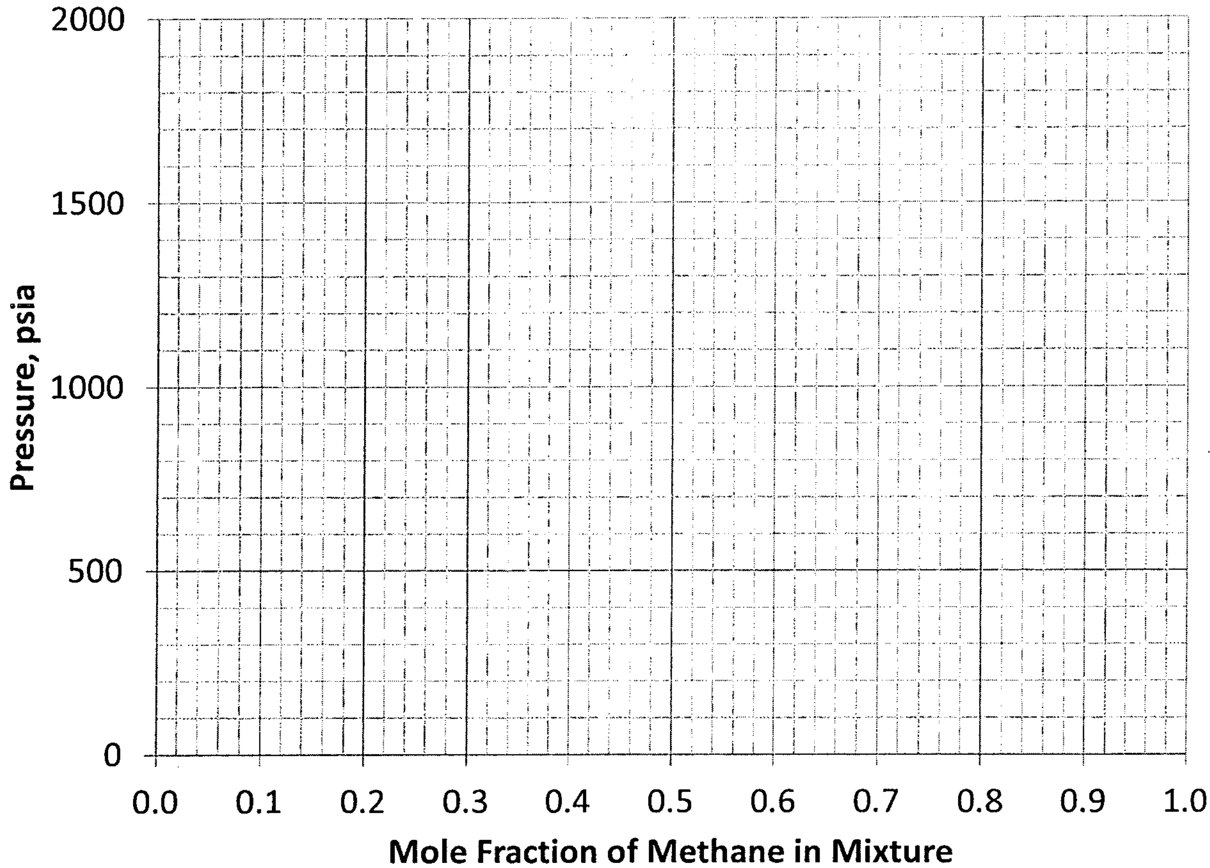
c. (5 points) In general, thermal methods would be more efficient for reservoirs at higher pressures: True or false? Why?

d. (5 points) For water flooding in a reservoir with a dipping angle of 30 degrees, it is better to inject water upward along the dip: True or false? Why?

Graph Sheet 1



Graph Sheet 2



Marking Scheme

1. (a) 10 marks (Fractional flow plot: 5 marks, Welge tangent-line: 5 marks)
   (b) 10 marks
   (c) 10 marks
2. (a) 5 marks
   (b) 5 marks
   (c) 10 marks
   (d) 5 marks
3. (a) 10 marks
   (b) 5 marks
   (c) 10 marks
4. (a) 5 marks (True/false question: 3 marks, Reasoning: 2 marks)
   (b) 5 marks (True/false question: 3 marks, Reasoning: 2 marks)
   (c) 5 marks (True/false question: 3 marks, Reasoning: 2 marks)
   (d) 5 marks (True/false question: 3 marks, Reasoning: 2 marks)