National Exams May 2014

98-Pet-A3, Fundamental Reservoir Engineering

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 a CLOSED BOOK exam.
3. Any non-communicating calculator is permitted.
4. FIVE (5) questions constitute a complete exam paper.
5. The first five questions as they appear in the answer book will be marked.
6. All questions are of equal value unless otherwise stated and all parts in a multipart question have equal weight.
7. Clarity and organization of your answers are important, clearly explain your logic.
8. Pay close attention to units, some questions involve oilfield units, and these should be answered in the field units. Questions that are set in other units should be answered in the corresponding units.
9. A formula sheet is provided at the end of questions

Question 1 (20 Marks)

Explain (briefly in one or two sentences) the following reservoir engineering concepts.

a) Critical gas saturation
b) Dry gas reservoir
c) Solution gas drive
d) Secondary gas cap
e) Residual oil saturation
f) Overburden pressure
g) Gas compressibility factor (Z)
h) Interfacial tension
i) Productivity index (PI)
j) Drainage process

Question 2 (20 Marks)

The production data for a volumetric dry gas reservoir is provided in the following table. Use the provided data to:

a) Calculate the reservoir initial pressure
b) Calculate the original gas in place
c) Calculate the cumulative gas that can be produced when the reservoir pressure drops to 1000 psia.
d) Calculate gas recovery factor when the reservoir pressure drops to 1000 psia.

Pressure (psia)	Gas compressibility factor	Cumulative production (MMMSCF)*
Initial pressure	0.85	0
2500	0.80	500
1500	0.75	1000
1000	0.70	?

* MMM=10^9

Question 3 (20 Marks)

A sandstone core of 2 cm in diameter and 10 cm long with a porosity of 15% is prepared for a core flood experiment. The core sample is fully saturated with water by injecting water with a viscosity of 1 cp at a constant volumetric flow rate of 0.02 cc/sec. A pressure drop of 1 atm was recorded across the core during the injection process.

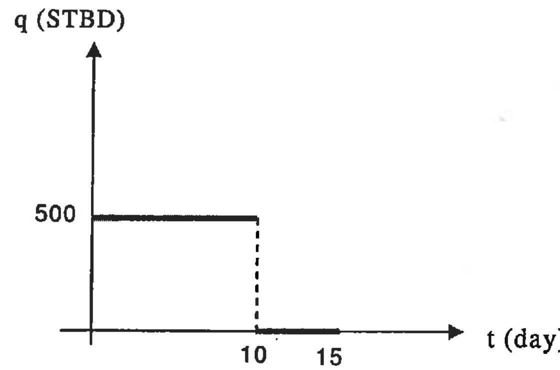
a) What is the absolute permeability of the sandstone core sample in mD?
b) What is the pore volume of the core sample?
c) The core sample is then flooded by oil with a viscosity of 2 cp until a connate water saturation of 25% is established. Calculate the oil volume inside the core at the end of oil flood.
d) The oil inside the core is then flooded by injecting water and at some point during the experiment a pressure drop of 1.2 atm and volumetric flow rates of 0.005 and 0.015

cc/sec were recorded for water and oil, respectively. Calculate oil relative permeability to oil and water

Question 4 (20 Marks)

A production well in an undersaturated oil reservoir was produced at a constant rate of 500 STBD for 10 day. The well was subsequently closed for 5 days. The reservoir data and the rate-time history and the reservoir data are provided below.

Initial reservoir pressure = 2000 psia,
External radius = 20000 ft,
Oil formation volume factor =1.25 res bbl/STB,
Oil viscosity = 1 cp,
Oil compressibility = 6×10^{-6} psi^{-1},
Formation thickness = 10 ft,
Reservoir permeability = 200 mD,
Reservoir Porosity = 20%,
Well radius = 0.3 ft,
Skin factor= -2.



Calculate the bottom-hole pressure in an observation well (shut-in well) located 200 ft away from the production well after 5 days of the shut in time?

Question 5 (20 Marks)

An oil reservoir produced from an initial pressure of 4000 psia down to the current reservoir pressure of 3000 psia. Log data revealed an initial average water saturation of 20%. The following table provides fluid property data for the reservoir.

Pressure (psia)	B_o (bbl/STB)	R_{so} (SCF/STB)	Z	B_g (bbl/SCF)
4000	1.18	1000	0.850	0.000766
3500	1.20	1000	0.785	0.000706
3000	1.10	800	0.765	0.000860

a) Calculate the oil recovery (N_p/N) at bubble point pressure.

b) What is the current reservoir gas saturation if 10% of the original oil in place has been produced at 3000 psia?

Clearly state any assumptions you make in your calculations.

Question 6 (20 Marks)

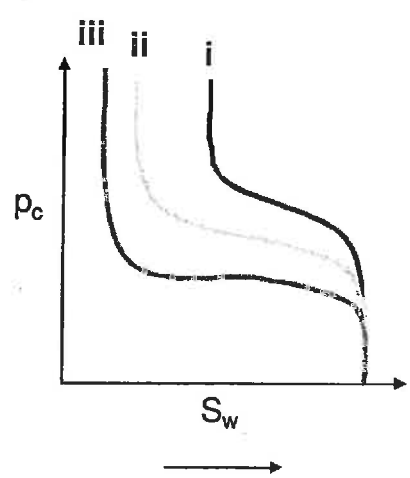
An undersaturated water-drive radial reservoir has produced for several years without considerable change in the reservoir pressure. Core data revealed an undamaged permeability to oil of 150 mD. After a workover operation on one well in this reservoir the formation around the wellbore is damaged to a radius of 3 ft so that the permeability in the damaged zone has been reduced to one third of the original undamaged permeability. Therefore, an acidizing treatment is planned to improve the well productivity.

- **a)** Calculate the oil production rate before the acid job for a bottom hole flowing pressure of 1500 psia.
- **b)** Assume that the permeability in the damaged zone can be fully recovered to its original value of 150 mD and calculate the oil production rate after the acid job if a bottom hole flowing pressure of 1500 psia can be maintained.

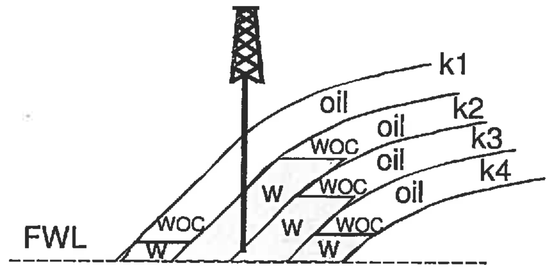
External radius = 3000 ft,
Reservoir pressure at external radius = 2000 psia,
Formation thickness = 10 ft,
Well radius = 0.3 ft,
Oil formation volume factor = 1.25 bbl/STB,
Oil viscosity = 12 cp,

Question 7 (20 Marks)

a) Capillary pressure curves for three reservoir rock types are given in the following figure. Rank the rock types from higher to lower permeability. **(4 Marks)**

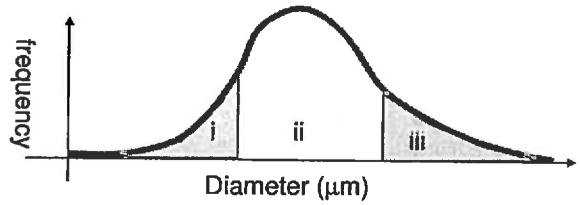


a) The following sketch shows the position of the water oil contact (WOC) for different reservoir rock types in a multilayer reservoir. Rank the rock types from higher to lower permeability. W denotes water in the following sketch. **(4 Marks)**



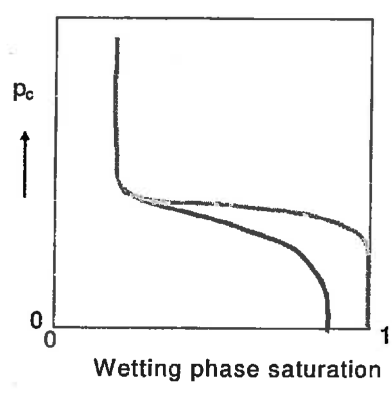
FWL: Free water level
WOC: Water oil contact

b) The following figure shows the pore sizes distribution of a water wet reservoir rock. For a three-phase system (gas-oil-water), determine position (i, ii, iii) of each phase in the pores. **(4 Marks)**



c) The following figure shows the capillary pressure curves for the drainage and imbibition mechanisms. In your exam paper, draw the same sketch and identify the followings: **(8 Marks)**

1) Drainage curve
2) Imbibition curve
3) Threshold or critical pressure
4) Residual non-wetting phase (oil) saturation



Formula Sheet

Equation for steady linear flow in Darcy's unit.

$$q\left(cm^3/\sec\right)=\frac{k(Darcy)A\left(cm^2\right)}{\mu(cp)}\frac{\Delta p(atm)}{L(cm)}$$

Equation for steady-state radial flow in field units.

$$q=\frac{7.08kh(p_e-p_w)}{\mu_o B_o \ln(r_e/r_w)}$$

where k is permeability in Darcy, h is formation thickness in ft, r is radius in ft, p is pressure in psia, B_o is the oil formation volume factor in bbl/STB, and μ is viscosity in cP.

Transient flow equations in field units:

$$\eta=\frac{6.33k}{\phi\mu c}, \qquad t_D=\frac{\eta t}{r^2}$$

$$p_D=\frac{1}{2}(\ln t_D+0.809) \text{ only if } t_D>100,$$

$$p(r,t)=p_i-\frac{0.141q_o\mu_o B_o}{kh}(p_D+S)$$

where ϕ is porosity, t is time in day, t_D is the dimensionless time, k is permeability in Darcy, h is formation thickness in ft, r is radius in ft, p is pressure in psia, c is the oil compressibility in psi^{-1}, B_o is the oil formation volume factor in bbl/STB, μ is the oil viscosity in cP, S is skin factor, and p_D is the dimensionless pressure. The subscript *i* denotes the initial condition.

Gas reservoirs material balance equation

$$\frac{p}{Z}=\frac{p_i}{Z_i}\left(1-\frac{G_p}{G}\right)$$

Where p is pressure in psia, G_p is the cumulative gas production, and G is the original gas in place. The subscript *i* denotes the initial condition.

Oil reservoir material balance

$$N=\frac{N_p\left[B_t+B_g\left(R_p-R_{soi}\right)\right]}{(B_t-B_{ti})+m\frac{B_{ti}}{B_{gi}}(B_g-B_{gi})} \qquad B_o=B_t-B_g\left(R_{soi}-R_{so}\right)$$

where N is the initial oil in place in STB, N_p is the cumulative oil production in STB, B_t is the two-phase formation volume factor in bbl/STB, B_g is the gas formation volume factor in bbl/SCF, R is the gas oil ratio in SCF/STB and m is dimensionless. The subscript *i* denotes the initial condition.

Useful Conversion Factors

1 m^3 = 6.28981 bbl =35.3147 ft^3
1acre = 43560 ft^2
1ac-ft = 7758 bbl
1Darcy = 9.869233×10^{-13} m^2
1 atm =14.6959 psi =101.325 kPa=14.5038 bar
1 cP = 0.001 Pa-sec
1 m = 3.28084 ft = 39.3701 inch