National Exams December 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. **Only A Casio or Sharp approved calculator models are 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

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Question 1 (20 Marks)

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

a) Volumetric reservoir
b) Wet gas reservoir
c) Gas-oil gravity drainage
d) Gas cap expansion drive
e) Connate water saturation
f) Formation compressibility
g) Formation damage
h) Depletion drive
i) Relative permeability
j) Wettability

Question 2 (20 Marks)

Two wells are located 3000 ft apart. The static well pressure at top of perforation (9000 ft subsea) in well A is 4000 psia and at the top of perforations (9200 ft subsea) in well B is 4020 psia. The reservoir fluid gradient, permeability, and fluid viscosity are 0.35 psi/ft, 0.2 Darcy, and 0.6 cp, respectively.

a) Determine the direction of flow between two wells, i.e. A to B or B to A?
b) What is the fluid velocity in the reservoir between the two wells in ft/day?

Question 3 (20 Marks)

Two exploration wells 3000 ft apart have been drilled into a newly discovered oil reservoir. Well #1 is an observation well (it does not produce oil and has a pressure gauge in the hole to measure the pressure response due to production well #2). Use the reservoir date given in the following and calculate the pressure at well #1 (observation well) after five days of production from Well#2 at a flow rate of 500 STBD.

Reservoir external radius, r_e	4000 ft
Total compressibility, c_t	5×10^{-6} psi^{-1},
Oil viscosity, μ	1 cP,
Oil formation volume factor, B_o	1. 2 bbl/STB,
Reservoir permeability, k	50 mD,
Formation thickness, h	50 ft,
Initial reservoir pressure, p_i	2000 psia,
Formation porosity, ϕ	0.15,
Well radius, r_w,	0.3 ft.
Skin factor of well#1	1

Question 4 (20 Marks)
The following production data are available from a volumetric gas reservoir with a gas gravity of 0.67 and an initial reservoir temperature of 237 °F.

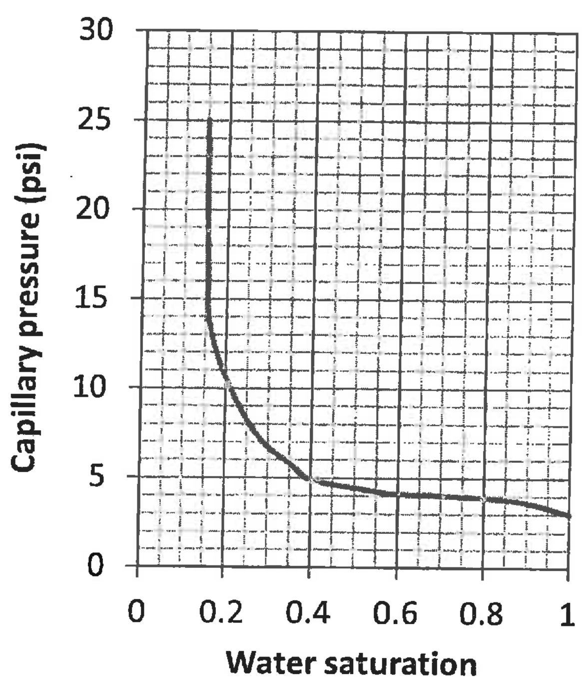
a) What is the initial gas in place?
b) What will be the gas recovery factor at 500 psia?

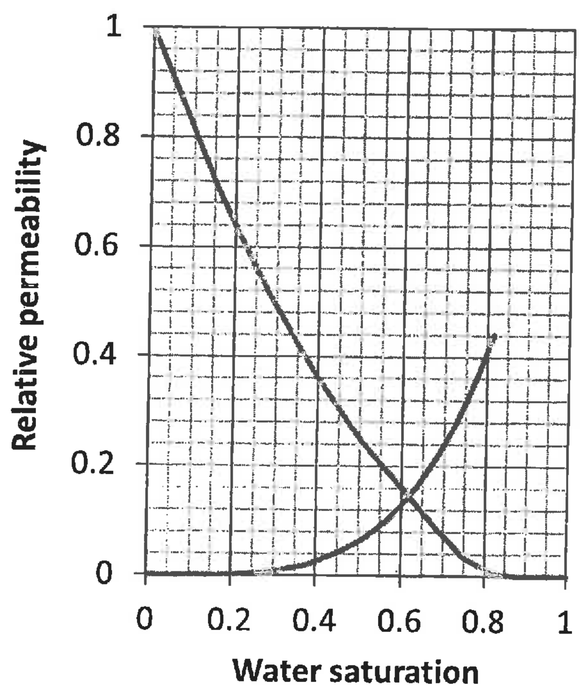
p (psia)	G_p(MMMSCF)
5000	300
4000	520

Question 5 (20 Marks)

The capillary pressure and relative permeability data for an oil reservoir is given in the following. Log interpretations and core analysis established that the free water level (FWL) is located at 3000 ft subsea. The oil and water densities are 45 and 65 lb/ft^3, respectively. The oil and water formation volume factors are 1.2 and 1.02 bbl/STB, respectively. The oil and water viscosities are 2 and 1 cP, respectively.

a) Calculate the depth of the water oil contract (WOC)
b) Calculate the approximate water-oil-ratio for a well, which will be completed 36 ft above the FWL.





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Question 6 (20 Marks)

The following PVT and production data are available for an initially undersaturated volumetric oil reservoir.

Pressure p(psia)	Oil formation volume factor Bo (bb//STB)	Gas formation volume factor B_g (ft^3/SCF)	Solution gas-oil ratio Rs (SCF//STB)
4500	1.31	0.0034831	950
4000	1.32	0.0037471	950
3500	1.31	0.0041198	900

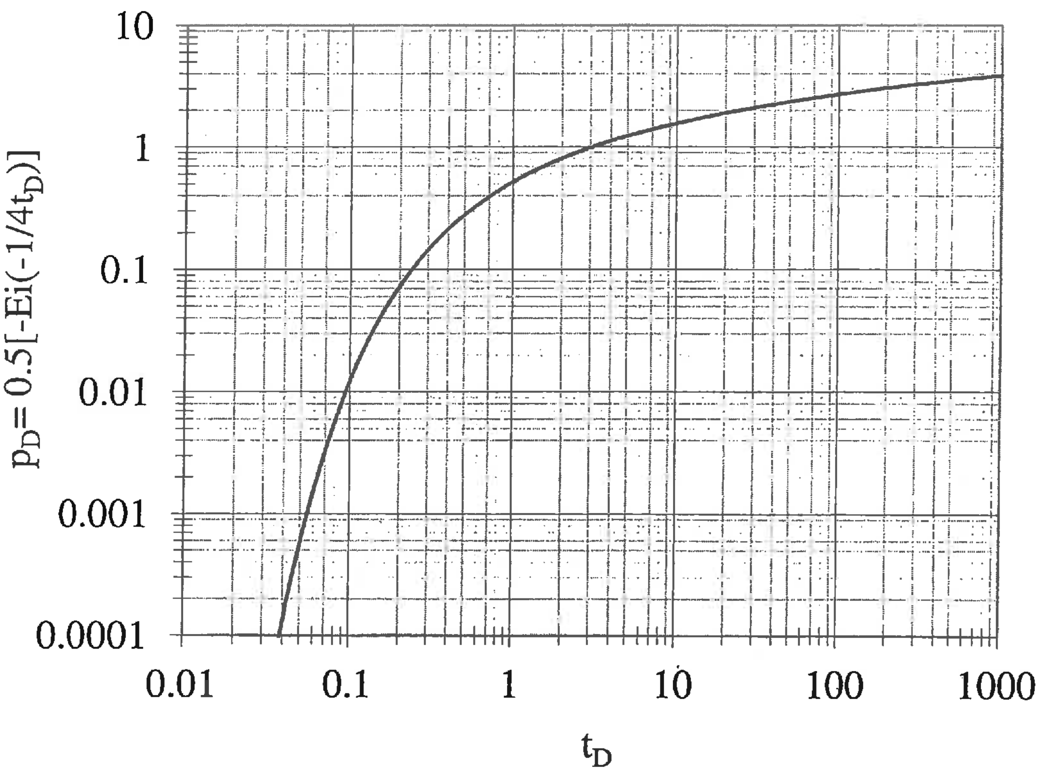
Cumulative GOR at 3500 psia, R_p	3300 SCF/STB
Cumulative oil production at 3500 psia, N_p	1.5 MMSTB

a) Calculate the fractional recovery (N_p/N) at 3500 psia,

b) Calculate the fractional recovery if two-thirds of the produced gas had been returned to the reservoir, at 3500 psia.

Question 7 (20 Marks)

A dry gas reservoir is initially at an average pressure of 6000 psia and temperature of 160 °F. The gas has a specific gravity of 0.65. What will the average reservoir pressure be when one-half of the original gas in SCF has been produced? Assume the volume occupied by the gas in the reservoir remains constant. If the reservoir originally contained 1MMft^3 of reservoir gas, how much gas has been produced at a final pressure of 500 psia?



Plot of dimensionless pressure versus dimensionless time

Formula Sheet

Real gas law

$pV = ZnRT$

where p in psia, T in °R, V in ft^3, R=10.732 psi-ft^3/(lb$_{mol}$-°R)

Gas formation volume factor, $B_g = 0.02827ZT/p$ in ft^3/SCF, where p in psia, T in °R.

Hydrostatic and capillary pressures

$p_o = \rho_o \frac{g}{g_c} \frac{h}{144}$ $\quad p_w = \rho_w \frac{g}{g_c} \frac{h}{144}$ $\quad p_c = p_o - p_w$

where p is pressure in psia, g=32.17 ft/sec^2, g$_c$=32.17 (lb$_{mass}$-ft)/(lb$_f$-sec^2), h in ft and ρ is density in lb$_{mass}$/ft^3, subscripts o and w stand for oil and water, respectively.

Equation for steady-state linear and radial flows in oil field units.

$$q = -\frac{1.127kA}{\mu B_o}\left(\frac{dp}{ds} \pm 0.433\gamma \sin\theta\right),$$ + for upward flow and - for downward flow.

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

where A is the cross-sectional area in ft^2, γ is oil specific gravity, θ is slope with horizontal level in degree, 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:

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

$$p_D = \frac{1}{2}(\ln t_D + 0.809) \text{ only if } t_D>100, \qquad p(r,t) = p_i - \frac{0.141 q_o \mu_o B_o}{kh}(p_D + S)$$

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.

Pseudo critical pressure and temperature

$$T_{pc} = 168 + 325\gamma_g - 12.5\gamma_g^2 \quad \text{in}\ ^\circ R$$

$$p_{pc} = 677 + 15.0\gamma_g - 37.5\gamma_g^2 \quad \text{in } psia$$

Reduced temperature: $T_r = T / T_c$

Reduced pressure: $p_r = p / p_c$

where γ_g is the gas specific gravity (Air=1)

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

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

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.

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 =14.6959488 psi =101.32500 kPa=1.01325 bar
1 cP = 0.001 Pa-sec
1 m = 3.28084 ft = 39.3701 inch

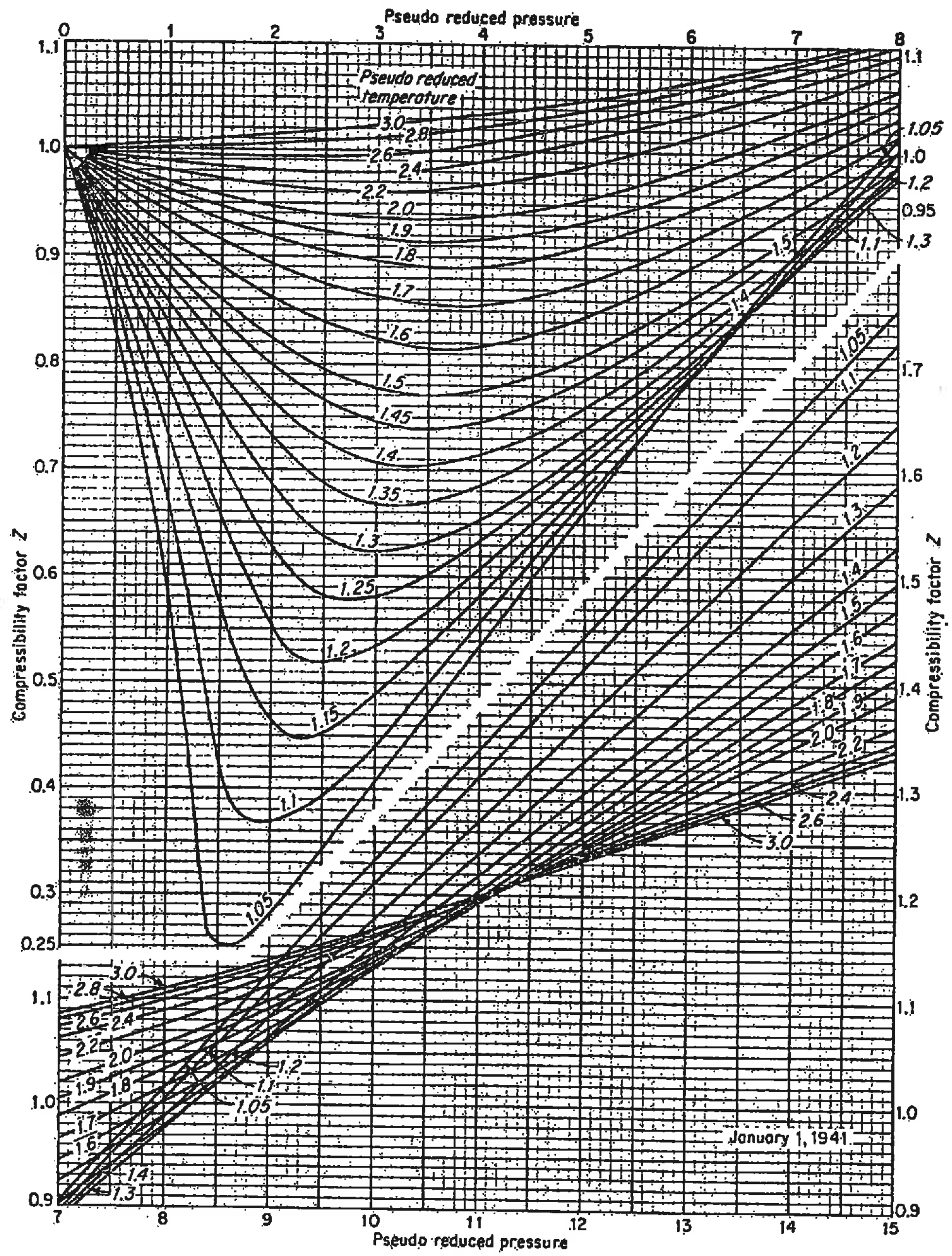


Fig. 4-16. Compressibility factor for natural gases. *(Standing and Katz, 4-87. Courtesy AIME.)*

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