National Exams December 2015

98-Pet-B5, Well Testing

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 or a simple equation) the following concepts.

a) Finite acting reservoir
b) Extended flow test
c) Pseudo radial flow
d) Partial penetration
e) Pressure derivative analysis
f) Gas pseudo pressure
g) Dual porosity storativity ratio
h) Interference test
i) Type curves
j) Stimulation

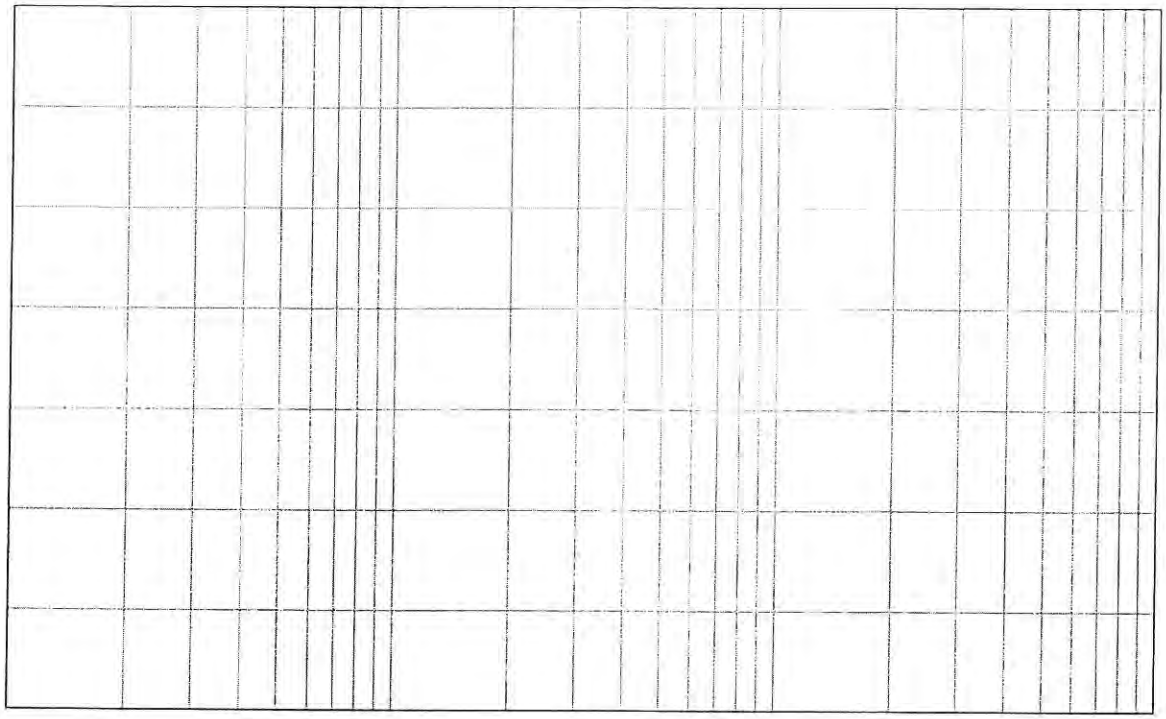
Question 2 (20 Marks)
An oil well in a reservoir with the following production data given in the following starts production. Determine the time required for the reservoir to become finite acting (or the time to reach pseudo steady-state) and calculate bottom hole flowing pressure after 1 hour and after 15 days of production.

External radius, r_e=1452 ft
Wellbore radius, r_w= 0.25 ft,
Total compressibility, $c_t = 5\times10^{-5}$ psi^{-1},
Oil viscosity, μ_o= 2 cP,
Porosity, $\phi = 0.3$,
Permeability, k = 250 mD,
Formation thickness, h = 20 ft,
Oil formation volume factor, B_o = 1.2 bbl/STB,
Initial pressure, p_i = 3000 psia,
Production rate, q=500 STBD.

Question 3 (20 Marks)
A drawdown test has been conducted in an oil well and the following pressure data has been collected during the test. Estimate formation permeability and skin factor from the test data using the following reservoir and fluid properties. The required chart is provided in the following.

Flow rate, q = 1000 STBD,
Formation thickness, h = 32 ft,
Formation volume factor, B_o = 1.333 bbl/STB,
Initial reservoir pressure, p_i = 2500 psia,
Porosity, $\phi = 0.15$,
Total compressibility, $c_t = 12\times10^{-6}$ psi^{-1},
Oil viscosity, μ_o = 2 cP,
Wellbore radius, r_w = 0.333 ft.

Time (hours)	Pressure (psia)
0.3	2377.5
0.7	2369.2
2	2358.9
6	2346.0
14	2333.6
22	2319.8
30	2306.0
38	2292.2
46	2278.4

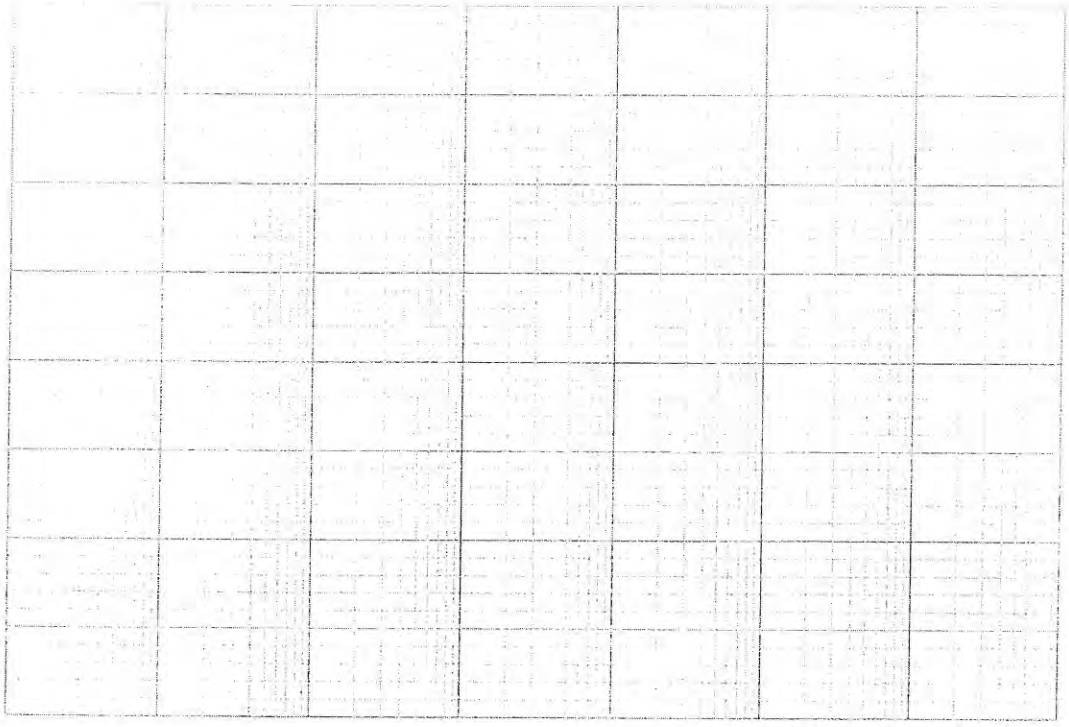


Question 4 (20 Marks)

Use the buildup data for and oil well provided below to estimate formation permeability, skin factor, and the average reservoir pressure given the following formation and fluid properties. Use the chart provided in the following.

Flow rate = 800 STBD,
Production time = 140 hours,
Flowing wellbore pressure prior to shut in = 400 psia,
Formation thickness = 50 ft,
Porosity = 15 %,
Wellbore radius = 0.3 ft,
Formation volume factor = 1.12 bbl/STB,
Total compressibility = 5.8×10^{-6} psi^{-1},
Oil viscosity = 0.9 cp.

Shut in time (hr)	Shut in pressure (psia)
0.000125	406.54
0.001250	464.46
0.006250	704.64
0.031875	1608.16
0.081125	2424.96
0.206250	2939.20
0.526250	3120.00
1.337500	3221.60
3.412500	3315.36
8.125000	3399.84
18.875000	3480.64

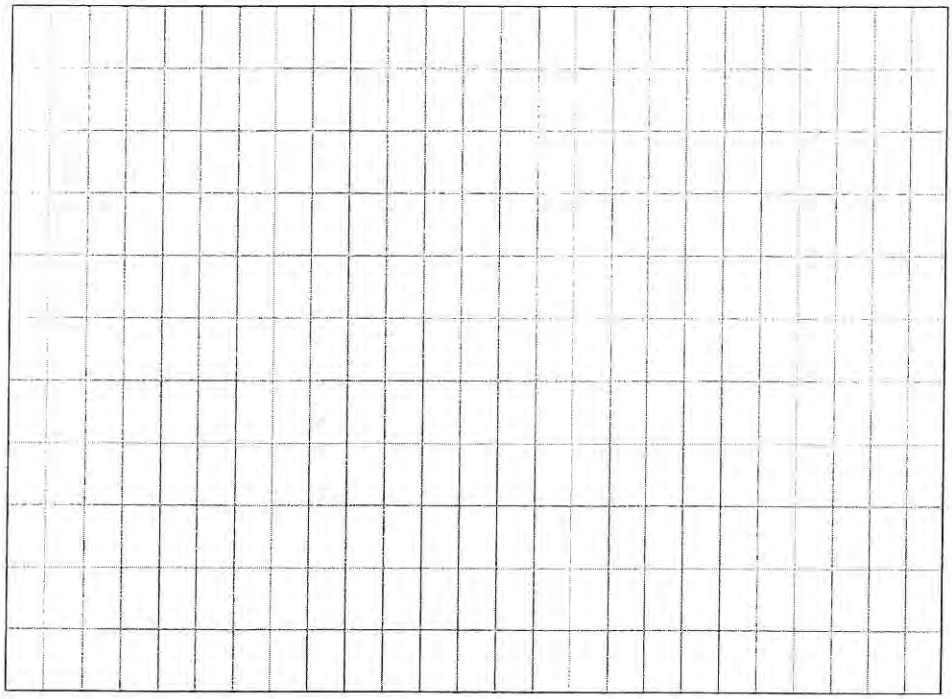


Question 5 (20 Marks)

An extended drawdown (flow) test was conducted in an exploration well in an undersaturated oil reservoir and the following data has been collected. Log data indicated an average water saturation of S_{wi}=0.2. Use the data and the chart provided in the following to estimate the reservoir oil in place. Assume a cylindrical reservoir.

Flow rate, q = 100 STBD,
Formation thickness, h = 50 ft,
Formation volume factor, B_o = 1.1 bbl/STB,
Porosity, ϕ = 0.25,
Total compressibility, $c_t = 1\times10^{-6}$ psi^{-1},
Oil viscosity, μ_o = 1 cP,
Wellbore radius, r_w = 0.25 ft.

time(hours)	Pressure (psia)
1	2365.7
6	2346.0
11	2338.7
16	2330.1
21	2321.5
26	2312.9
31	2304.2
36	2295.6
41	2287.0



Question 6 (20 Marks)

In a multi-rate test an oil well is opened to flow at 200 STBD for one day. The second day its flow rate is increased to 400 STBD and the third day to 600 STBD. Use the following data and calculate the pressure drop caused in a shut-in well 500 ft away after the third day?

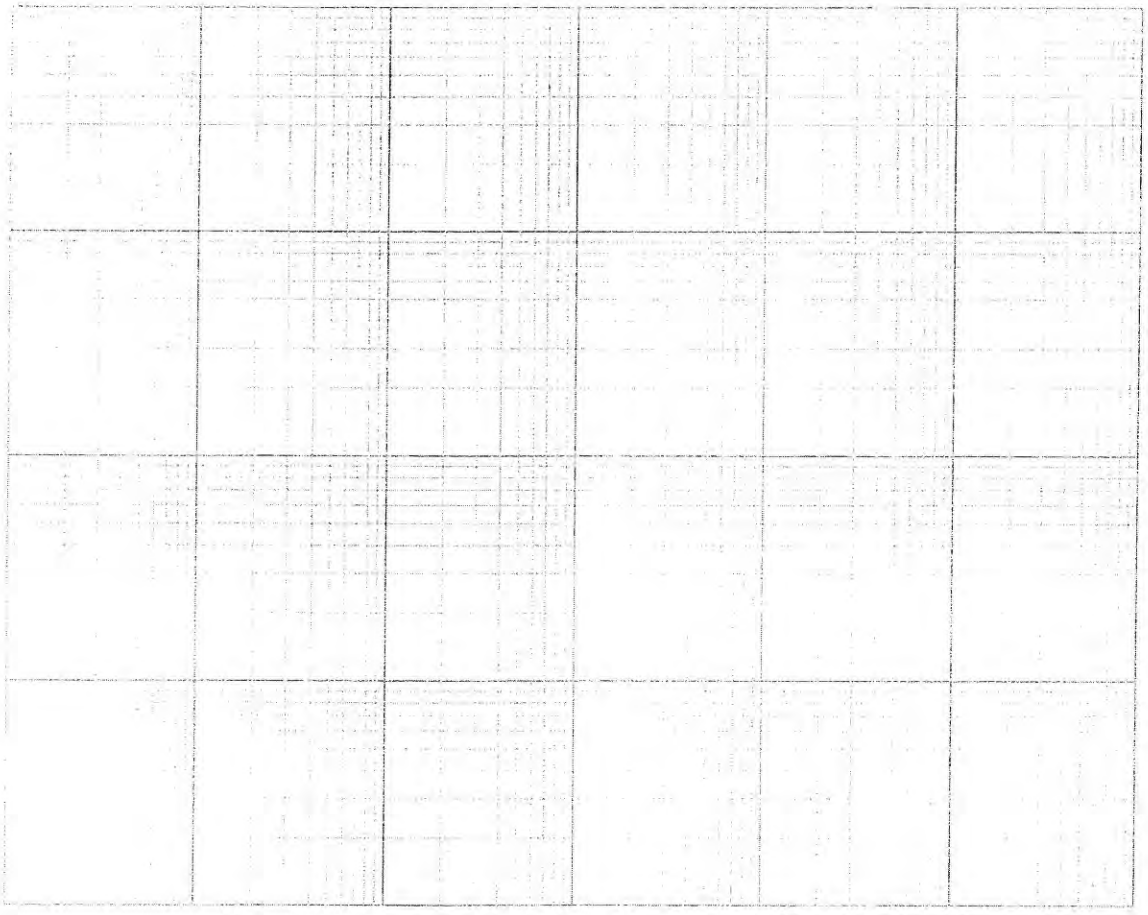
Pressure at external radius, p_e	2500 psia
Well radius, r_w	0.5 ft
External radius, r_e	10000
Well oil production rate, q	300 STBD
Oil formation volume factor, B_o	1.32 bbl/STB
Oil viscosity, μo	0.44 cp
Reservoir permeability, k	25 mD
Formation thickness, h	43 ft
Oil compressibility, c_o	18×10^{-6} psi^{-1}
Porosity, ϕ	16%

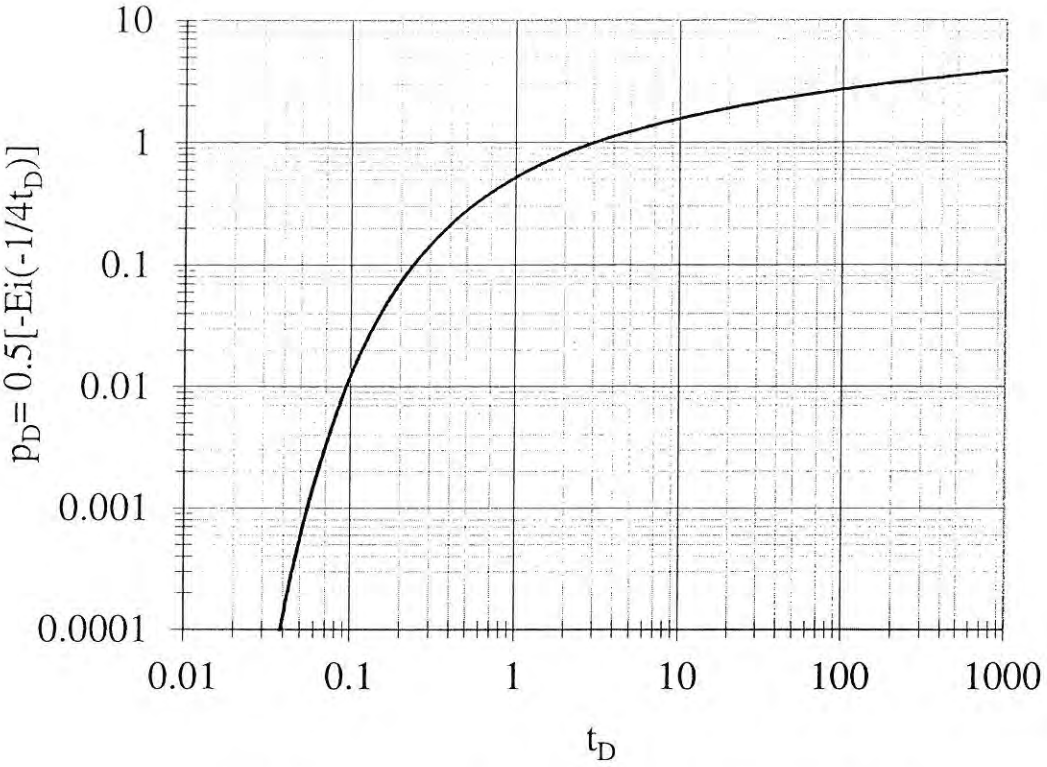
Question 7 (20 Marks)

Estimate approximate end of wellbore storage and dimensionless wellbore storage coefficient using a buildup test data and following formation and fluid properties. Use the chart provided in the following.

Flow rate = 1000 STBD,
Flowing wellbore pressure prior to shut in = 400 psia,
Formation thickness = 70 ft,
Porosity = 20 %,
Wellbore radius = 0.25 ft,
Formation volume factor = 1. 2 bbl/STB,
Total compressibility = 7×10^{-6} psi^{-1},
Oil viscosity = 1 cp.

Shut in time (hr)	Shut in pressure (psia)
0.00025	413.056
0.00100	451.728
0.00625	704.640
0.01250	971.376
0.05075	2021.120
0.33000	3051.840
2.13750	3268.960
13.1250	3445.920





Plot of dimensionless pressure versus dimensionless time

Formula Sheet

Pressure solution for infinite acting reservoirs:

$$p(r,t) = p_i - \frac{q\mu B_o}{0.00708kh} p_D, \qquad \eta = \frac{0.0002637k}{\phi\mu c_t}, \qquad t_D = \frac{\eta t}{r^2}$$

$p_D = \frac{1}{2}(\ln t_D + 0.809)$ only if t_D>100, for t_D <100 use the provided p_D graph.

Pseudo steady state equations: $\frac{dp_w}{dt} = -\frac{0.234qB_o}{c_t V_P}$, (psi/hr)

$$p(r_w,t) = p_i - \frac{0.0744qB_o t}{\phi c_t h r_e^2} - \frac{q\mu B_o}{0.00708kh}\left[\ln\left(\frac{r_e}{r_w}\right) - \frac{3}{4} + S\right]$$

Slope of semi-log straight line, psi/cycle: $m = \frac{162.6q\mu B_o}{kh}$

Radius of investigation. ft: $r \approx \sqrt{\frac{kt}{948\phi\mu c_t}}$

Permeability-thickness product for double porosity reservoirs, mD-ft $(kh)_f = \hat{k}_f h = \frac{162.6q\mu B}{m}$

Average fracture permeability, mD $\hat{k}_f = \hat{k}_f h / h$

Skin factor for buildup test: $S = 1.151\left(\frac{p(1hr) - p_{wf}(\Delta t = 0)}{|m|} - \log\left(\frac{k}{\phi\mu c_t r_w^2}\right) + 3.23\right)$

Skin factor for drawdown test: $S = 1.151\left(\frac{p_i - p(1hr)}{|m|} - \log\left(\frac{k}{\phi\mu c r_w^2}\right) + 3.23\right)$

Horner time ratio: $\frac{t_p + \Delta t}{\Delta t}$

Distance to fault, ft: $L = \sqrt{\frac{0.000148k\Delta t}{\phi\mu c_t}}$

The approximate time required for the slope to double, hr $\Delta t = \frac{3.8\times10^5 \phi\mu c_t L^2}{k}$

Gas wells build up

$$m = \frac{1637q_g T}{kh}$$

$$S' = 1.151\left(\left(\frac{p_{p1hr} - p_{pwf}(@\,\Delta t = 0)}{m}\right) - \log\left(\frac{k}{\phi\mu c_t r_w^2}\right) + 3.23\right)$$

Fracture half length

$$L_f = \frac{4.064qB_o}{mh\sqrt{k}}\left(\frac{\mu_o}{\phi c_t}\right)^{0.5}, \quad L_f = 2r_w e^{-S}$$

Wellbore storage coefficient:

$$C = \frac{qB}{24}\left(\frac{\Delta t}{\Delta p}\right)_{USL} \text{ in } bbl/psi, \text{ USL stands for the unit slope line.}$$

Dimensionless wellbore storage coefficient:

$$C_D = \frac{0.8939C}{\phi c_t h r_w^2}$$

Nomenclature

B_o	Oil formation volume factor	bbl/STB
c_t	Total compressibility	1/psi
h	Formation thickness	ft
k	Permeability	mD
L	Distance	ft
p	Pressure	psia
p_p	Pseudo pressure	$psia^2/cP$
q	Oil flow rate	STBD
q_g	Gas flow rate	MSCFD
r	Radius	ft
S	Skin factor	dimensionless
T	Temperature	Rankin
t	Time	hr
V_P	Pore volume	ft^3
ϕ	Porosity	fraction
μ	Oil viscosity	cP
η	Hydraulic diffusivity	ft^2/hr

Subscripts

D	dimensionless
e	external
f	fracture
i	initial
o	oil
p	production
t	total
w	wellbore

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