National Exams December 2014

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. **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

Question 1 (20 Marks)

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

- **a)** Pseudo-steady state
- **b)** Radius of investigation
- **c)** Type curves
- **d)** Interference test
- **e)** Double porosity reservoir
- **f)** Wellbore storage
- **g)** Sandface pressure
- **h)** Line source approximation
- **i)** Horner time ratio
- **j)** Reservoir limit test.

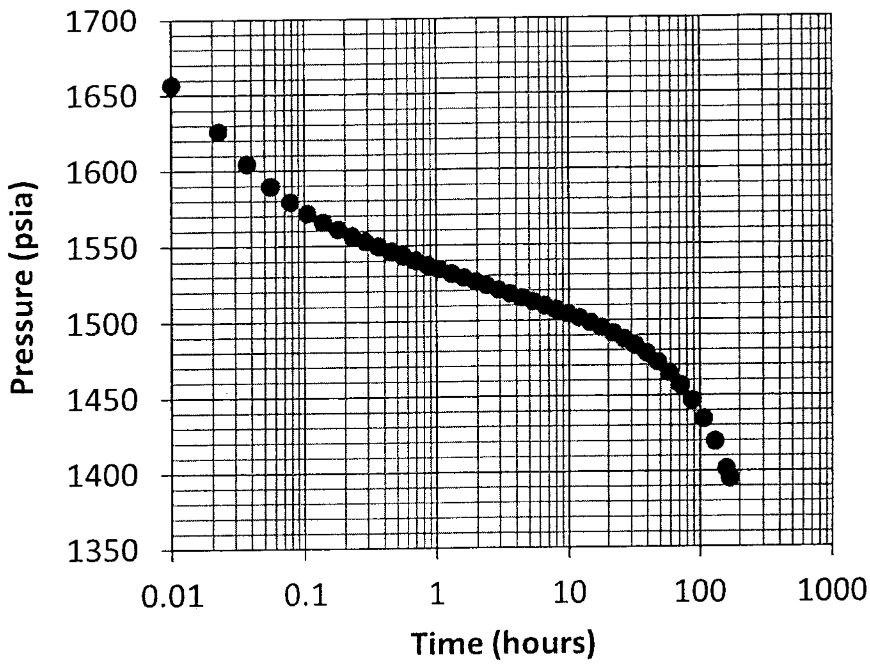
Question 2 (20 Marks)

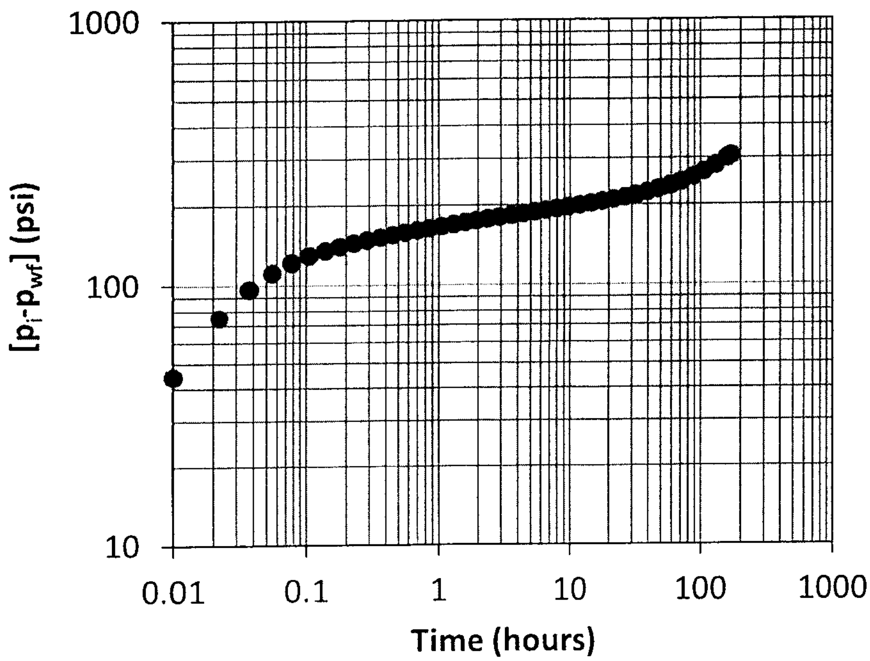
Write down the diffusivity equation for a slightly compressible fluid in a cylindrical reservoir with an initial pressure p_i and a well at the center (5 marks). Assuming there is no skin effect and no wellbore storage, what is the inner boundary condition if the well produces at constant rate (5 marks)? What is the outer boundary condition if the reservoir is an infinite acting reservoir (5 marks)? What is the outer boundary condition if the reservoir is a bounded (finite) reservoir (5 marks)?.

Question 3 (20 Marks)

A new well has been drilled in a closed reservoir, and drawdown test was run. Use the log-log plot and semi-log plot to estimate the radius of investigation at the end of wellbore storage given the following formation and fluid properties:

Oil production rate, q	400 STB/D;
Initial reservoir pressure, p_i	2000 psi;
Formation thickness, h	20 ft;
Porosity, ϕ	0.25;
Wellbore radius, r_w	0.25 ft;
Oil formation volume factor, B_o	1.2 bbl/STB;
Total compressibility, c_t	1×10^{-6} psi^{-1};
Oil viscosity, μ	1 cp.

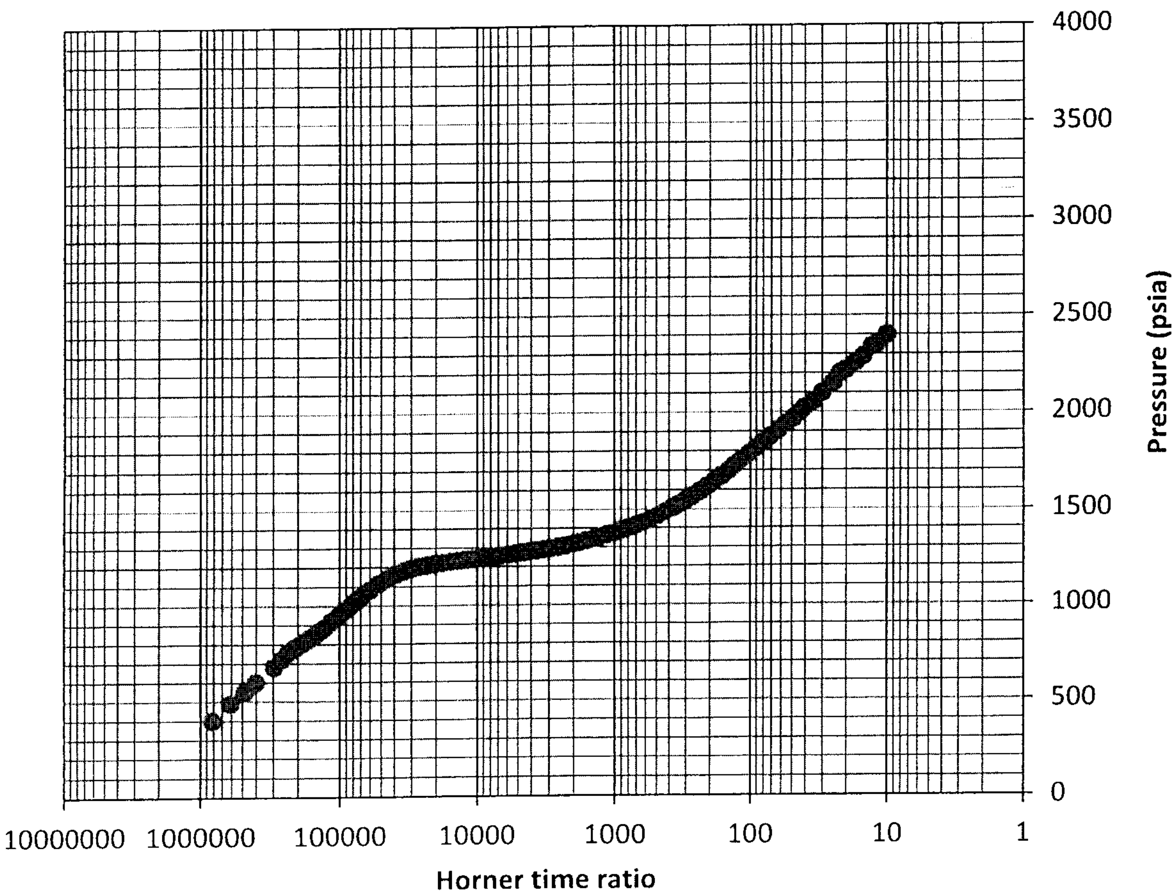

1700
1650
1600
1550
1500
1450
1400
1350
Pressure (psia)
0.01
0.1
1
10
100
1000
Time (hours)


1000
100
10
[pi-pwf] (psi)
0.01
0.1
1
10
100
1000
Time (hours)

Question 4 (20 Marks)

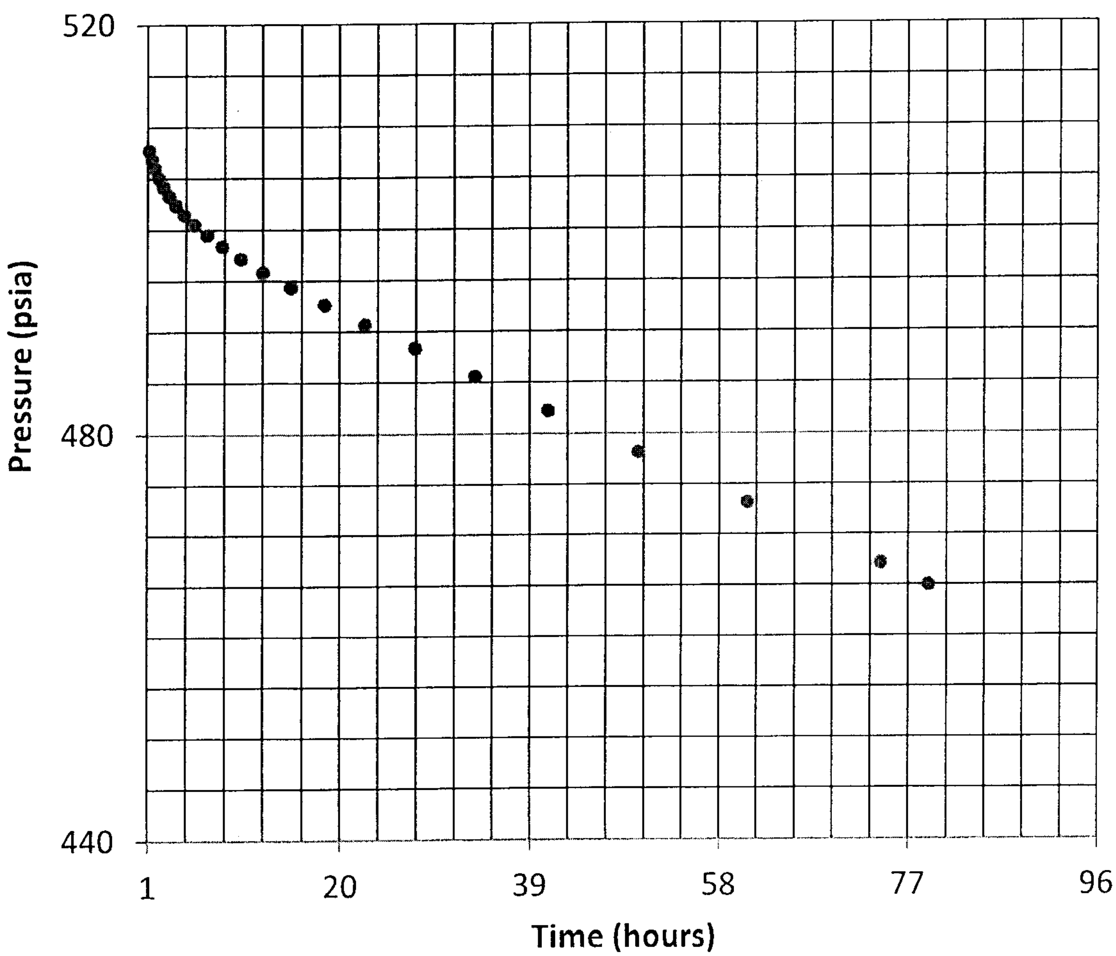
The following data are provided for a pressure build up conducted in an oil well in a naturally fractured reservoir (double porosity reservoir). Use these reservoir data and the semi-log plot given in the following to estimate the storativity, the average fracture permeability, skin factor and the average reservoir pressure.

Oil production rate, q	500 STB/D;
Formation thickness, h	5 ft;
Porosity, ϕ	0.1;
Wellbore radius, r_w	0.3 ft;
Oil formation volume factor, B_o	1.2 bbl/STB;
Total compressibility, c_t	5×10^{-6} psi^{-1};
Oil viscosity, μ	3 cp;
Flowing pressure prior to shut in, p_{wf} (Δt=0)	700 psia;
Production time prior to shut in, t_p	10,000 hours.



Question 5 (20 Marks)
An extended flow test was conducted in an oil well and the following pressure versus time data was collected during the test. Using the reservoir data given in the following estimate the reservoir pore volume and the initial reservoir pressure. Assume a cylindrical reservoir.

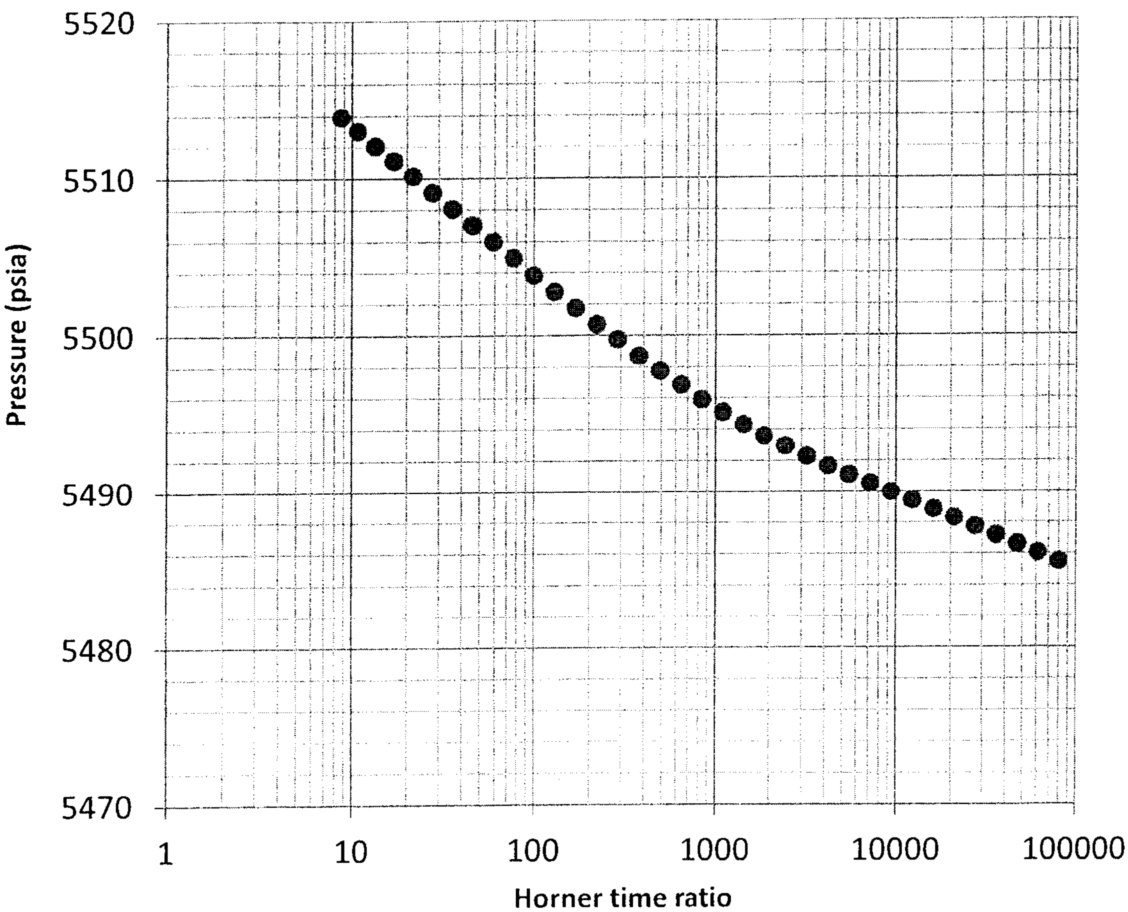
Oil production rate, q	1000 STB/D;
Oil formation volume factor, B_o	1.2 bbl/STB;
Total compressibility, c_t	1×10^{-5} psi^{-1},
Wellbore radius, r_w	0.3 ft;
Oil viscosity, μ	1 cp;
Formation thickness, h	25 ft;
External radius of reservoir, re	2185 ft;
Reservoir permeability, k	50 mD;
Skin factor, S	2.



Question 6 (20 Marks)

Geological data suggests a fault close to a production well. To confirm geological data a pressure build up test has been conducted in the well. The following semi-log has been obtained based on the collected data. Assume that the wellbore storage effects are negligible and determine distance to the fault. Compare the time required for the slope to double with the duration of the build up test and comment on validity of the test.

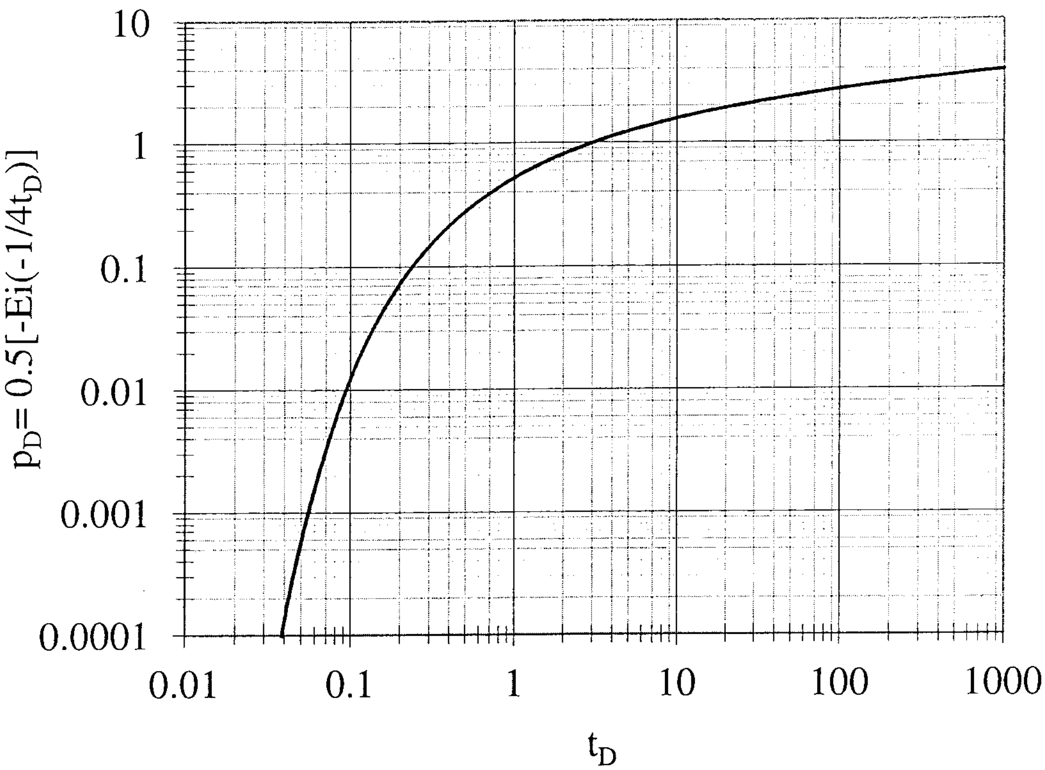
Porosity, ϕ	0.1
Formation volume factor, B_o	1.2 bbl/STB
Oil production rate, q	500 STBD
Oil viscosity, μ	1 cp
Production time prior to shut in, t_p	100 hours
Total compressibility, c_t	1×10^{-6} psia^{-1}
Reservoir thickness, h	50 ft
Wellbore radius, r_w	0.3 ft



Question 7 (20 Marks)

Two exploration wells, A and B, 1000 ft apart have been drilled into a newly discovered oil reservoir. Well B begins production at 300 STBD for two days and then the production rate was increased to 500 STBD for one day. Assume an infinite acting reservoir and calculate pressure at the bottom of Well A at the end of three days since production from Well B has started.

Total compressibility, c_t	1×10^{-6} psi^{-1};
Oil viscosity, μ	1.1 cp;
Oil formation volume factor, B_o,	1.2 bbl/STB;
Reservoir permeability, k	100 mD;
Formation thickness, h	25 ft;
Initial reservoir pressure, p_i	2000 psia;
Formation porosity, ϕ	0.25;
Wellbore radius, r_w	0.3 ft



Plot of dimensionless pressure versus dimensionless time

Formula Sheet

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

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

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

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

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

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

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

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

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 $\Delta t=\frac{3.8\times10^5\,\phi\mu c_t L^2}{k}$

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

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

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

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
q	Oil flow rate	STBD
r	Radius	ft
S	Skin factor	dimensionless
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