# National Exams May 2016

## 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)** Wellbore storage
**b)** Pulse test
**c)** Diffusivity equation
**d)** Back pressure test
**e)** Non-Darcy flow
**f)** Fall off test
**g)** Line source approximation
**h)** Superposition principle
**i)** Pseudo radial flow
**j)** Formation damage

**Question 2 (20 Marks)**

A downhole pressure gauge has been installed in an observation well located 330 ft away from an oil production well. Use the following reservoir data to calculate the production rate required to create 1 psi pressure drop at the observation well after 5 hours of production. Note: the production rate for the observation well is zero.

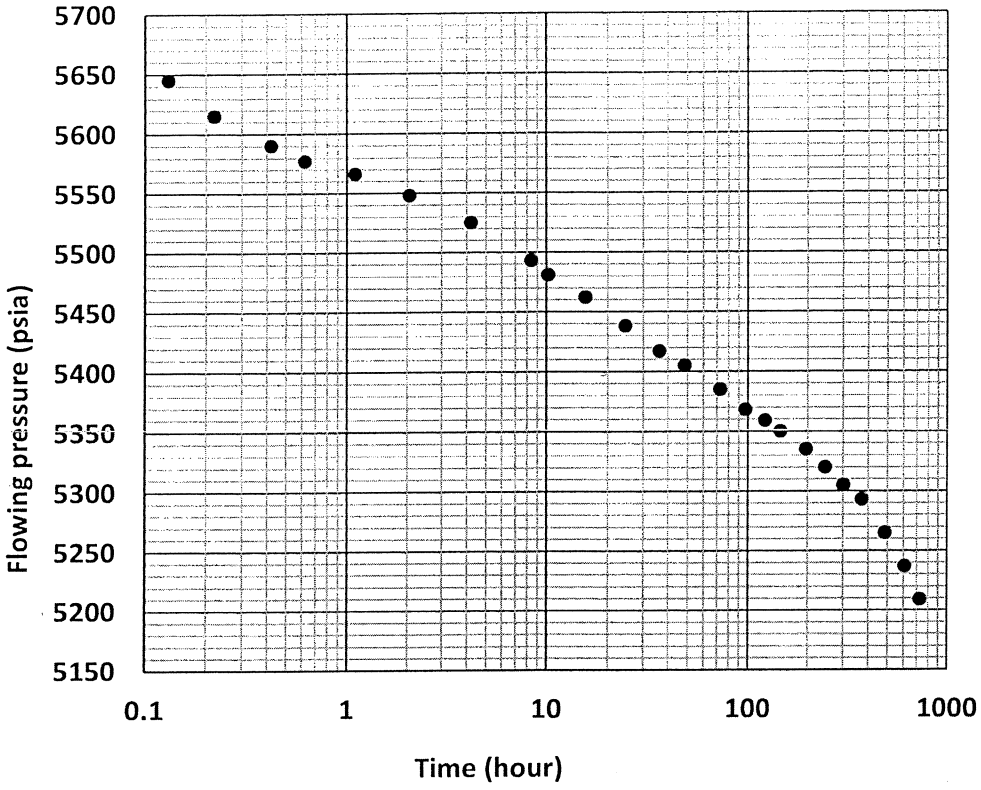
External radius, $r_e$=1452 ft,
Wellbore radius, $r_w$= 0.25 ft,
Total compressibility, $c_t = 5\times10^{-5}$ psi$^{-1}$,
Oil viscosity, $\mu_o$= 2 cP,
Porosity, $\phi$ = 0.3,
Permeability, $k$ = 2500 mD,
Formation thickness, $h$ = 20 ft,
Oil formation volume factor, $B_o$ = 1.2 bbl/STB,
Initial pressure, $p_i$ = 3000 psia.

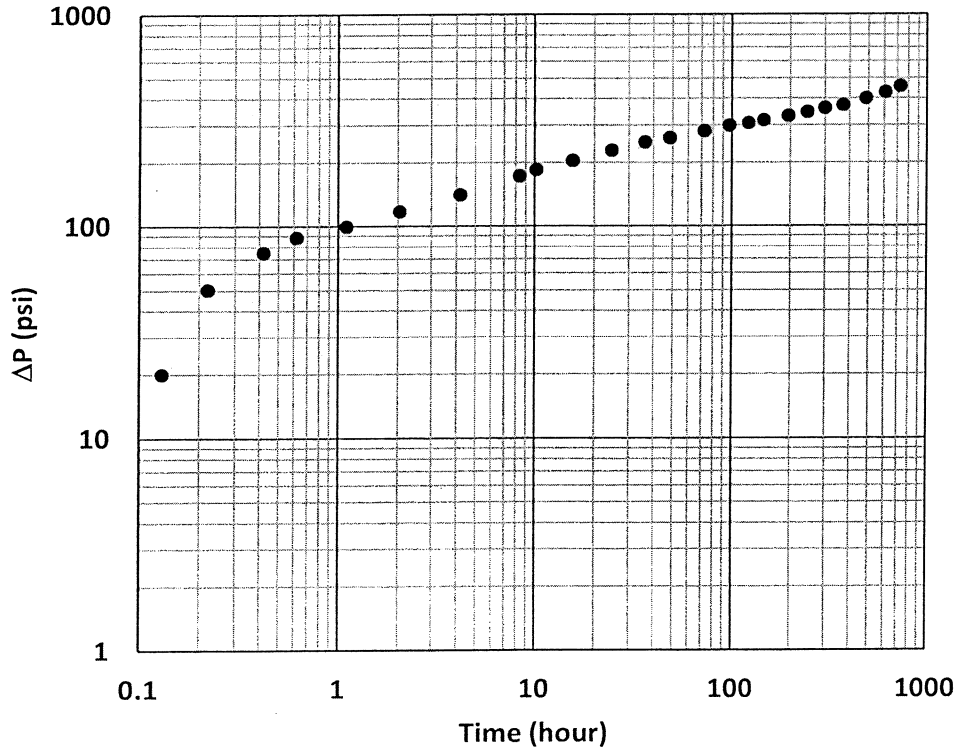
**Question 3 (20 Marks)**

The drawdown test data of a discovery well in an oil reservoir are shown in the following. The well was produced at a single, constant rate of 550 STBD for a total time of 725 hours. Other reservoir and fluid properties data are as follows:

Formation thickness, $h$ = 20 ft,
Initial reservoir pressure, $p_i$= 5665 psia,
Formation volume factor, $B_o$ = 1.45 bbl/STB,
Porosity, $\phi$ = 0.23,
Total compressibility, $c_t = 6\times10^{-5}$ psi$^{-1}$,
Oil viscosity, $\mu_o$ = 0.42 cP,
Wellbore radius, $r_w$ = 0.5 ft.

a) Estimate reservoir permeability,
b) Estimate the well skin factor,
c) Estimate the end of wellbore storage,
d) Do you suggest acidizing this well? Yes or No, and Why?

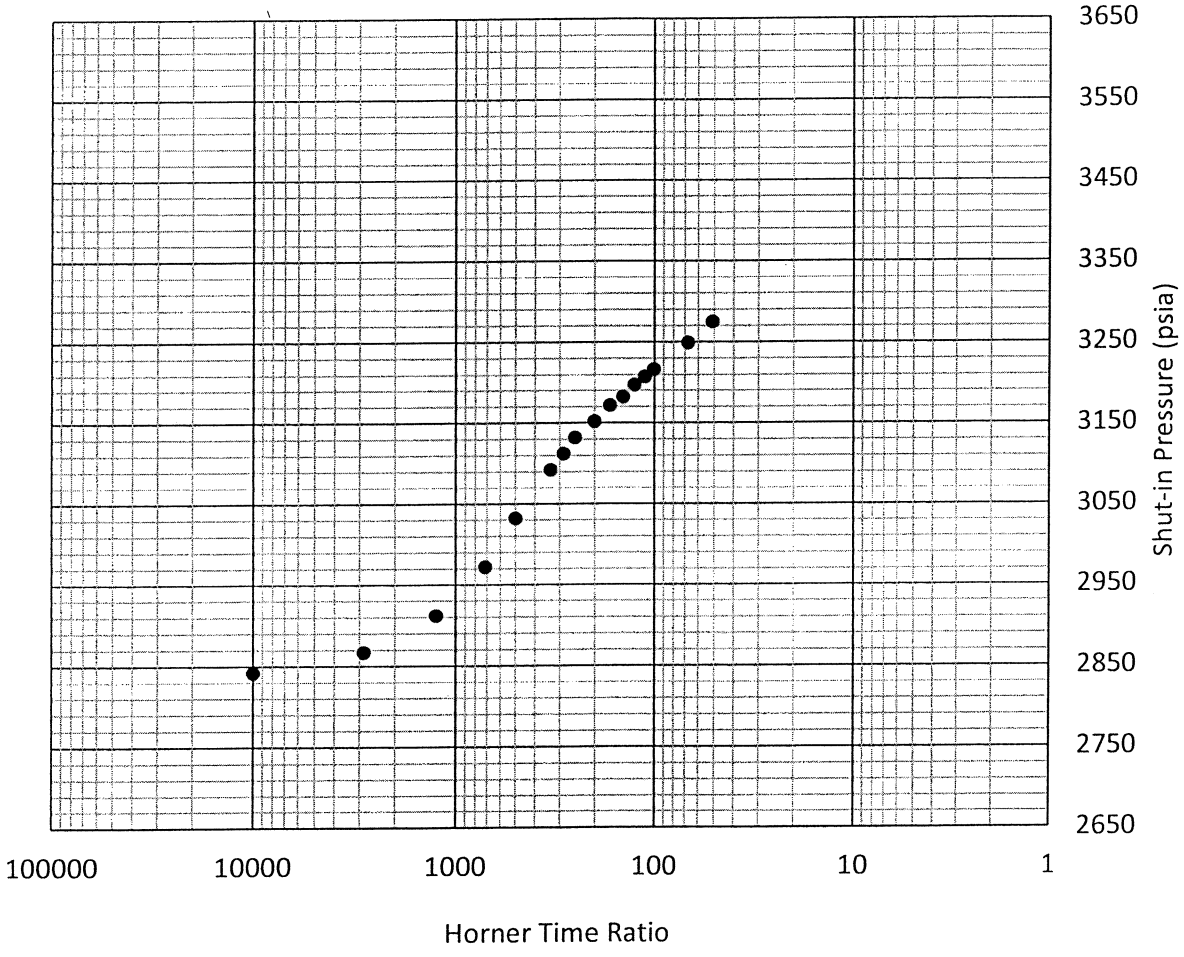

5700
5650
5600
5550
5500
5450
5400
5350
5300
5250
5200
5150
Flowing pressure (psia)
0.1
1
10
100
1000
Time (hour)


1000
100
10
1
ΔP (psi)
0.1
1
10
100
1000
Time (hour)

**Question 4 (20 Marks)**

A well in an oil reservoir was shut-in for a buildup test after producing 20,000 STB at a constant rate of 480 STBD. The shut-in pressures measured versus time are shown in the following. Calculate the effective permeability of the formation, the initial reservoir pressure, and skin factor.

Flowing wellbore pressure prior to shut-in = 2832 psia,
Formation thickness = 20 ft,
Porosity = 18 %,
Wellbore radius = 0.5 ft,
Formation volume factor = 1.2 bbl/STB,
Total compressibility = $2.6\times 10^{-5}$ $psi^{-1}$,
Oil viscosity = 1.5 cp.



**Question 5 (20 Marks)**

Data of an extended drawdown test of an oil well are shown in the following. The well was produced at a single constant rate of 100 STBD. Other reservoir and fluid properties data are as follows:

Formation volume factor, $B_o$ = 1.45 bbl/STB,
Water saturation, $S_{wi}$=0.25,
Total compressibility, $c_t = 1\times10^{-6}$ psi$^{-1}$,

Estimate the reservoir oil in place.

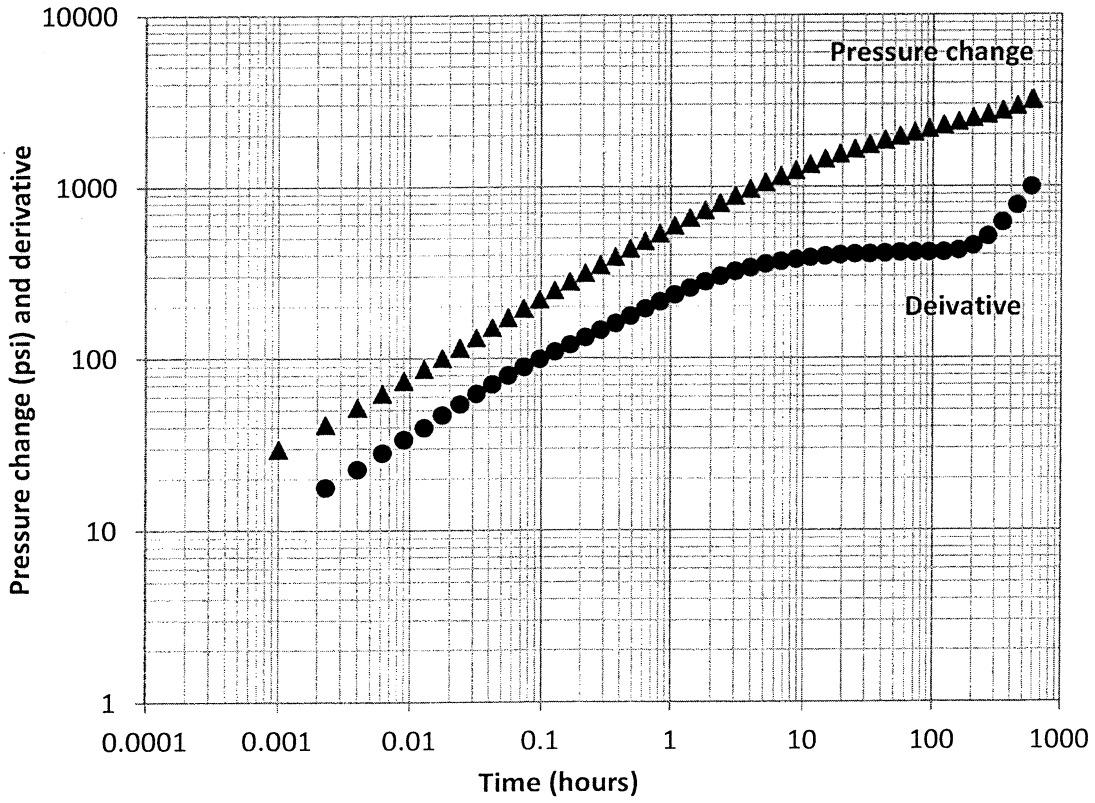
| Time (hours) | Pressure (psia) |
|---|---|
| 36.2 | 5417 |
| 97 | 5368 |
| 196 | 5335 |
| 300 | 5305 |
| 370 | 5293 |
| 485 | 5265 |
| 608 | 5237 |
| 725 | 5209 |

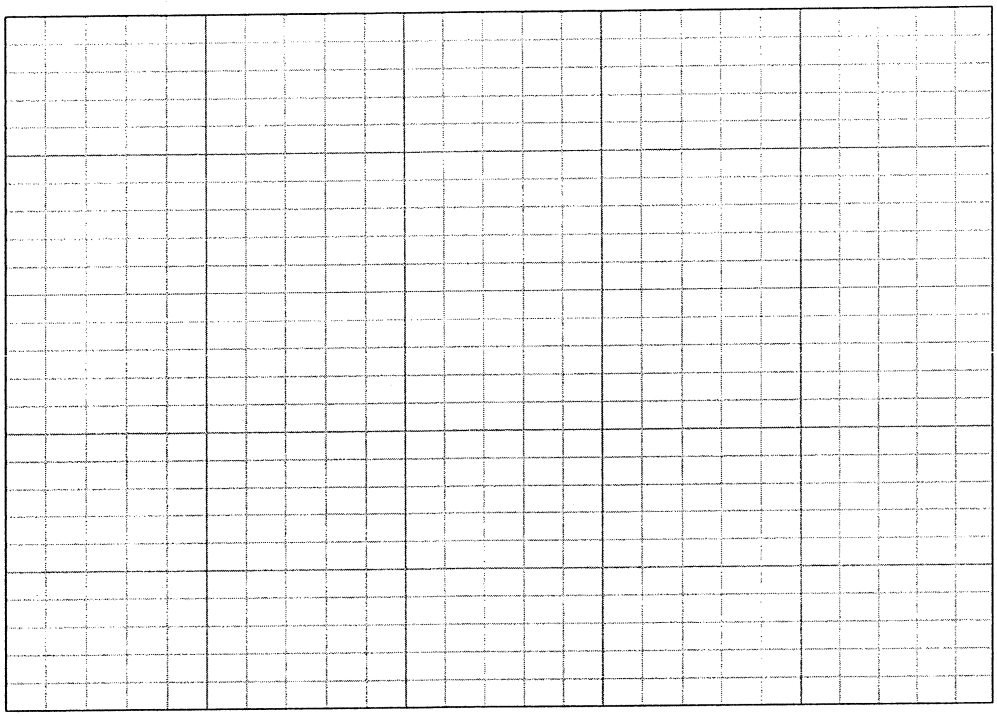
**Question 6 (20 Marks)**

Given the following formation and fluid properties, estimate fracture half-length from the drawdown test conducted in a fractured well interested with an infinite conductivity fracture. The pressure and pressure derivative data are also given in the following. Identify different flow regimes using the pressure change and pressure derivative plots given in the following.

k=4 mD; q = 200 STBD; h = 12 ft; $B_o$ = 1.325 bbl/STB;
$p_i$ = 3343.40 psia; $\phi$= 11.8%; $c_t = 14.7 \times 10^{-6}$ $psi^{-1}$; $r_w$ = 0.25 ft;
$\mu$ = 0.49 cp.

| Time (hours) | Flowing pressure (psia) |
|---|---|
| 0.00 | 3343.4 |
| 0.0062 | 3280.78 |
| 0.0176 | 3243.17 |
| 0.0426 | 3192.27 |
| 0.0743 | 3148.39 |
| 0.1279 | 3095.23 |



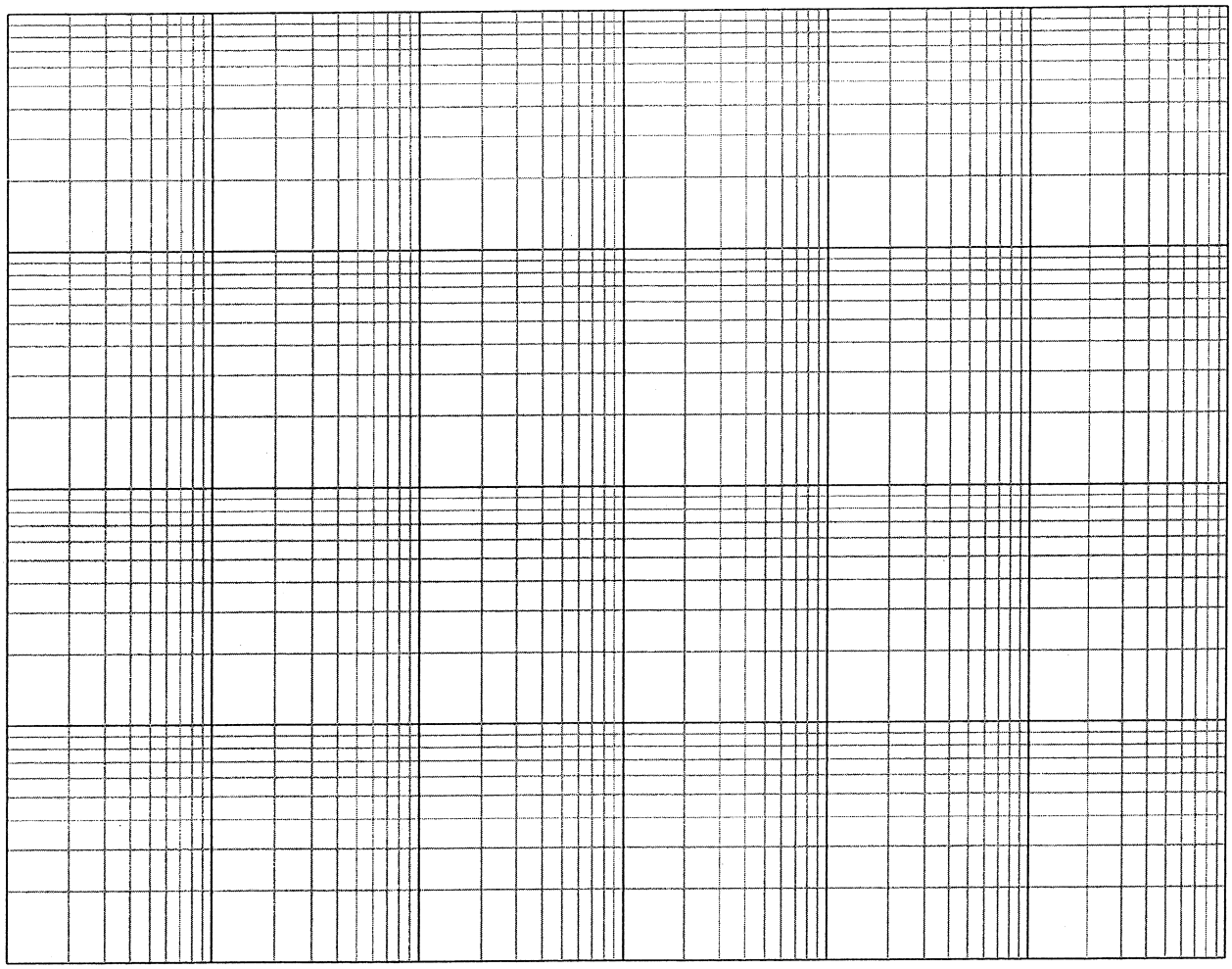


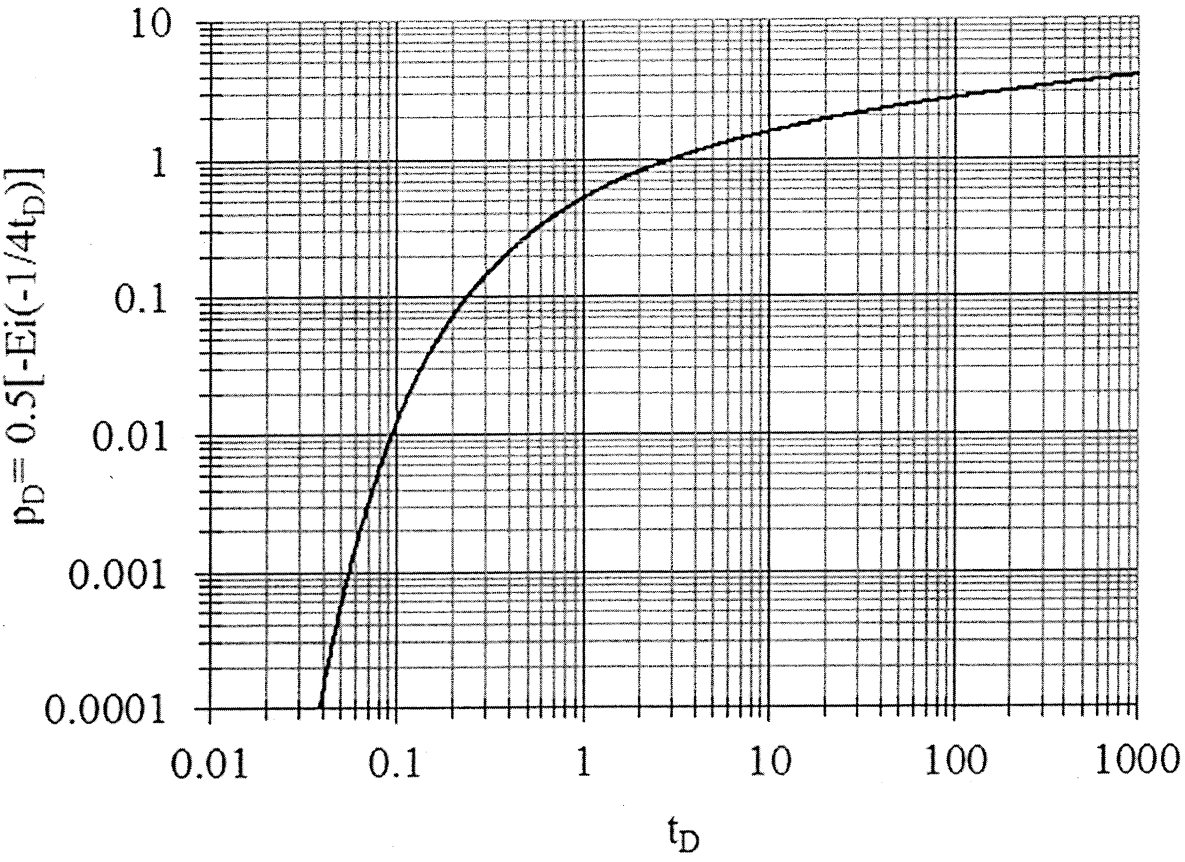
**Question 7 (20 Marks)**

A pressure build up test has been conducted on an oil well. The buildup pressure data versus time recorded during the test and other reservoir and fluid data are shown in the following. Use the given data to estimate the approximate end of wellbore storage and the dimensionless wellbore storage coefficient.

Flowing wellbore pressure prior to shut-in = 2832 psia,
Formation thickness = 20 ft,
Porosity = 18 %,
Wellbore radius = 0.5 ft,
Formation volume factor = 1.2 bbl/STB,
Total compressibility = $2.6\times 10^{-5}$ $psi^{-1}$,
Production rate = 50 STBD,
Oil viscosity = 1.5 cp.

| Time (hours) | Pressure (psia) |
|---|---|
| 0.10 | 2842 |
| 0.35 | 2867 |
| 0.80 | 2912 |
| 1.40 | 2972 |
| 2.00 | 3032 |
| 5.00 | 3152 |
| 9.00 | 3207 |
| 20.00 | 3275 |






**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:

$$L_f = \frac{4.064 q B_o}{mh\sqrt{k}}\left(\frac{\mu_o}{\phi c_t}\right)^{0.5}, \quad L_f = 2r_{we}{}^{-S}$$

Wellbore storage coefficient:

$$C = \frac{qB}{24}\left(\frac{\Delta t_e}{\Delta p}\right)_{USL} \text{ in } bbl/psi$$

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 | $ft^3$ |

**Greek letters**

| | | |
|---|---|---|
| $\phi$ | Porosity | fraction |
| $\mu$ | Oil viscosity | cP |
| $\eta$ | 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 = $9.869233\times10^{-13}$ $m^2$
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