School of Engineering and Engineering Technology

Harmattan Semester Exterminations, 2010/2011 Session

PET 403: Reservoir Engineering II. Attempt Any 5 Questions. Time Allowed: 3hrs.

Prof. B. Ob

1(a)(i)With the aid of a well illustrated P-T phase diagram, explain the concept of Retrograde condensation.

(b)Differentiate between the following:

(i) Reservoir barrel and stock tank barrel

(ii) Reservoir pore volume and hydrocarbon pore volume

(iii) High shrinkage oil and low shrinkage oil

2 (a) Explain the following terms:

(i) Oil formation volume factor, Bo

(ii) Solution gas-oil ratio, Rs

(b)A solution gas drive reservoir discovered below bubble point pressure,with an initial oil volume,N,and cumulative oil production, N_p, has the following PVT data at pressure of 900psi,.Show that, Recovery factor at abandonment has an inverse relationship with the Cumulative gas-oil ratio, R_p.

PVT Data : B_{oi}=1.2417 rb/stb, B_o=1.0940 rb/stb, B_g=0.00339 rb/stb, R_{si}=510 scf/stb, R_s=122 scf/stb.

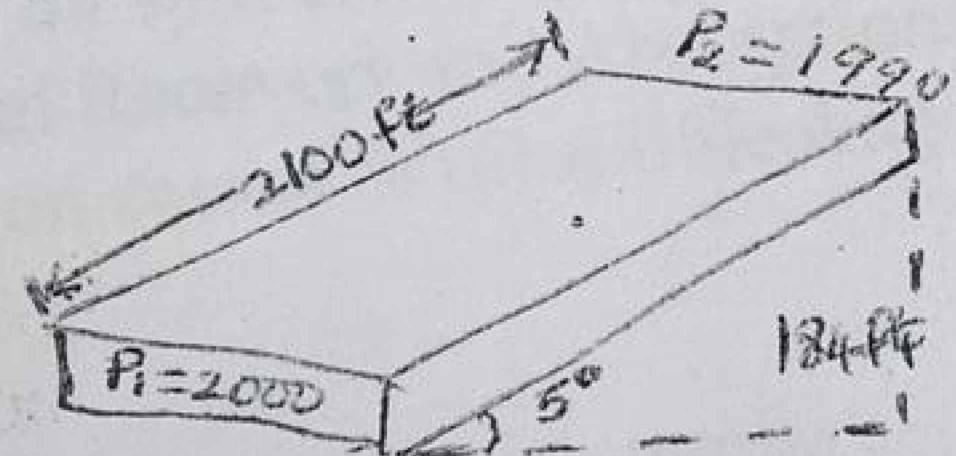
3(a) Explain the principle of Material Balance Equation (MBE)

(b)Calculate the daily underground withdrawal, at an average reservoir pressure of 2400psia, corresponding to an oil production of 2500stb/day and a gas rate of 2.125mmscf/day.

4(a) Show that: $\dfrac{KA_r(dp/dr)_r}{\mu} = \dfrac{0.00708kh(p_e-p_{wf})}{\mu_o B_o Ln(r_e/r_w)}$

(b)An oil well in a nearby field is producing at a stabilized rate of 700bbl/day at a bottom hole flowing pressure of 1900psi. A pressure build up test carried out in the well indicates that the permeability characterizing the pay zone is 130md and a uniform thickness of 24ft. The following data is available r_w=0.20ft, B_o=1.25bbl/stb , μ_o=2.6cp . Calculate the pressure distribution(profile) and list the pressure drop across 2ft intervals from r_w to 2.2ft, 4 to 6ft, 20 to 22ft, 80 to 82ft, 99 to 101ft, 820 to 822ft, 981 to 983ft. State the pressure drop around the wellbore and determine drainage radius given that the well-spacing is 50acres.

5(a)



An incompressible fluid flows in the above linear tilted porous media with the following properties:

K=100md, μ_o=2.5cp, h=25ft, ρ(density)=44 lb/ft3, width 300ft, Ø=15%.

Calculate:(i)the flow rate in bbl/day.(ii)apparent fluid velocity in ft/day.(iii)actual fluid velocity in ft/day.

(b)(i)What conditions favour Darcy's law?

(ii)Differentiate between linear flow of incompressible fluid and radial flow of incompressible fluid in a tabular form.

6(a) Derive the basic differential equation for radial flow in a porous medium. Discuss the conditions of solution of the equation.

(b)Convert flow rate (q) in reservoir cu.cm/second (r.cc/sec) to stock barrel per day (stb/d)

(c) Determine the dimension of permeability (k) for the equation below

$$V = -\frac{k\rho}{\mu}\frac{d\phi}{dL}$$

Where ϕ= potential energy/unit mass.

Federal University of Technology

School of Engineering and Engineering Technology

Department of Petroleum Engineering

2011/2012 Harmattan Semester Examination PET 403-Reservoir Engineering II. Time: $2^1/_2$ hrs

Instructions: Attempt all Qustions

1(a) With the aid of a phase diagram only, differentiate between low shrinkage oil and high shrinkage oil.

(b) A reservoir having no gas cap, with negligible water influx has the following PVT data as in the table below:

Pressure(Psia)	Bo	Rs	Bg
4000P_i	1.2417	510	–
3500	1.2480	510	–
3330P_b	1.2511	510	0.00087
3000	1.2222	450	0.00096
2700	1.2022	401	0.00107
2400	1.1822	352	0.00119
2100	1.1633	304	0.00137

(i) Determine an expression for the recovery factor at abandonment pressure of 2100 Psi, as a function of the cumulative gas oil ratio, R_p

(ii) If R_p is given as 4000 Scf/Stb, determine the recovery factor

2(a) Calculate the daily underground withdrawal from a reservoir at a pressure of 2700 Psi corresponding to an oil production of 2500 Stb/day and a gas rate of 2125 mmsct/day, using the PVT data in the table above

(b) A well is expected to produce 70mstb recoverable reserves and is on exponential decline. The initial rate is estimated to be 100stb/day. The abandonment rate in the region is 5stb/day, Hence;

(i) Determine the life of the well

(ii) Calculate its annual productions.

3(a) An incompressible fluid flows in a linear porous media with the following properties:

L = 2500ft, h = 30ft, width = 500ft, k = 50md, ϕ = 17%, μ = 2cp, inlet pressure = 2100psi, Q = 4bbl/day, $\rho = 45 lb/ft^3$. Calculate and plot the pressure profile throughout the linear system.

(b) If the reservoir linear system described in problem (a) above is tilted with a dip angle of 7°, calculate :(i) the fluid potentials Φ_1 and Φ_2 (ii) the apparent velocity (iii) the actual velocity

4(a) Determine the dimensions of permeability in the equation:

$q = -\frac{KA}{\mu}\frac{d\psi}{dl}$, where ψ is $\rho\Phi$ and is the potential per unit volume.

(b) An well is producing a crude oil system at stablised rate of 1000stb/day and 2000psi of bottom hole flowing pressure. The pay zone and the producing well have the following characteristics:

h = 35ft, r_w = 0.35ft, drainage area = 40 acres, API 45°, γ_g = 0.72, Rs = 700scf/stb, k = 80md, B_o = 1.35bbl/stb, μ_o = 3cp

(i)Calculate the prssure profile across two feet (2ft) interval from r_w to 2.35, 4 to 6ft, 20 to 22ft, 30 to 32ft, 60 to 62ft, and 81 to 83ft. Plot the pressure profile. (ii) Calculate the drainage radius

(c) Assuming steady state flow and an incompressible fluid, calculate the oil rate under the following conditions:

P_e = 2500psi, μ_o = 2cp, P_{wf} = 2000psi, r_e = 745ft, r_w = 0.3ft, k = 60md, B_o = 1.40bbl/stb, h = 30ft.

Federal University of Technology

School of Engineering and Engineering Technology

Department of Petroleum Engineering

2014/2015 Harmattan Semester Examination PET 403-Reservoir Engineering II. Time: 2 hrs

Instructions: Attempt all Questions. Show all calculations

1(a) How would you explain the following terms to a non Petroleum Engineer?

i) Oil formation volume factor ii) Solution gas oil ratio iii) Gas formation volume factor.

(b) A reservoir having no gas cap, with negligible water influx has the following PVT data below:

Pressure(Psia)	Bo	Rs	Bg
4000P_i	1.2417	510	–
3500	1.2480	510	–
3330P_b	1.2511	510	0.00087
3000	1.2222	450	0.00096
2700	1.2022	401	0.00107
2400	1.1822	352	0.00119
2100	1.1633	304	0.00137

(i) Show the expression of MBE of the above scenario

(ii) Determine an expression for the recovery factor at abandonment pressure of 2100 Psi, as a function of the cumulative gas oil ratio, R_p

(iii) If R_p is given as 4000 Scf/Stb, determine the recovery factor

2(a) With the aid of a well illustrated diagram, derive the expression for Underground Withdrawal

(b) Calculate the daily underground withdrawal from a reservoir at a pressure of 2700 Psi corresponding to an oil production of 2500 Stb/day and a gas rate of 2.125 mmsct/day, using the PVT data in the table above

(b) A well is expected to produce 70mstb recoverable reserves and is on exponential decline. The initial rate is estimated to be 100stb/day. The abandonment rate in the region is 5stb/day, Hence;

(i) Determine the life of the well **(ii)** Calculate its annual productions.

3) The following data are available on a well in FUTO field: P_e = 2606 psi, P_{wf} = 1810 psi, well spacing = 60 acres, r_w = 0.26 ft, B_o = 1.25 bbl/stb, μ_o = 2.7 cp, k = 0.14 darcy, h = 30 ft, $C_o = 26 \times 10^{-6}$ psi^{-1}. Assuming a slightly compressible fluid, calculate the oil flow rate and compare the result with that of an incompressible fluid.

4) From isothermal compressibility definition, show that (a) for an incompressible fluid the flow rate Q_o at a bottom-hole pressure, P_{wf} is given as:

$$Q_o = \frac{0.00708kh(P_r - P_{wf})}{\mu_o B_o\left[\ln\left(\frac{r_e}{r_w}\right) - 0.5\right]}$$

(b) for a slightly compressible fluid, the flow rate q_{ref} at a reference Pressure, P_{ref} is given as:

$$q_{ref} = \left[\frac{0.00708kh}{\mu c\left[\ln\left(\frac{r_e}{r_w}\right)\right]}\right] \ln\left[\frac{1 + c(P_e - P_{ref})}{1 + c(P_{wf} - P_{ref})}\right]$$

FEDERAL UNIVERSITY OF TECHNOLOGY OWERRI
DEPARTMENT OF PETROLEUM ENGINEERING
2015/2016 HARMATTAN SEMESTER EXAMINATIONS
PET 403:- RESERVOIR ENGINEERING 11
INSTRUCTION: - ANSWER FIVE QUESTIONS IN ALL: AT LEAST TWO FROM EACH SECTION
TIME ALLOWED: 3 HOURS DATE: 26/04/2016

SECTION A

Question One

a) Using appropriate phase diagram (P-T), describe the various phase changes in a single component system.

b) List 3 Laboratory processes used to obtain PVT data for Oil. Explain with diagram any one above.

c) Determine the fractional oil recovery, during depletion down to a reservoir pressure of 2500 psia, for the reservoir whose PVT parameters are listed in the table below, given the following parameters: $C_w = 3.0 \times 10^{-6}$ / psi $S_{wc} = 0.17$ $C_f = 6.8 \times 10^{-6}$ / psi R_p=1140 scf/stb

Pressure (psia)	B_o (rb/stb)	R_s (scf/stb)	B_g (rb/scf)
3750	1.3121	490	0.00076
3500	1.3420	490	0.00093
3250	1.3632	490	0.00112
3100	1.3231	450	0.00153
2950	1.2924	395	0.00191
2500	1.2433	352	0.00252
1900	1.2122	291	0.00527

Question Two

a) Explain the following terms; i)Solution Gas Oil Ratio ii) Oil Formation Volume Factor iii) Gas formation Volume Factor

b) Using an appropriate diagram, show how solution gas oil ratio vary with pressure

c) Calculate the underground withdrawal rate at an average reservoir pressure of 2720 psia corresponding to an oil production of 1640stb/day and at a gas rate of 1.662mmscf/day, given the following PVT parameters;

Pressure (psia)	B_o (rb/stb)	R_s (scf/stb)	B_g (rb/scf)
3350	1. 2432	387	0.00096
3100	1.2662	387	0.00103
3000	1.2852	387	0.00112
2850	1.2213	355	0.00142
2720	1.1980	331	0.00191
2500	1.1532	318	0.00232
2210	1.1129	291	0.00497

Question Three

a) Write the complete Material balance Equation and enumerate the parameters in the equation

b) List five assumptions made when developing the material balance equation

c) Given the table below, assuming a linear relationship determine B_o and R_s, if from flash expansion B_{obf} = 1.2412 rb/scf and R_{sif} = 495 scf/stb. The PVT analysis was carried out at a pressure of 2600 psia.

Pressure (psia)	B_{od}	R_{sd}
3500	1.2798	540
3300	1.2830	540
3000	1.2534	479
2700	1.2329	428
2400	1.2123	378
2100	1.1930	328

Question Four

a) What are the assumptions for a Gas-cap drive reservoir and state the corresponding material balance equation for a Gas-cap drive reservoir (using the Havlena and Odeh technique).

b) List 3 most common reservoir drive mechanism you know.

c) A Gas-cap reservoir shown is estimated, from volumetric calculations, to have had an initial oil volume N of 95 × 10^6 STB. The cumulative oil production, N_p and cumulative gas oil ratio R_p are listed in the table below, as functions of the average reservoir pressure. Also listed are the relevant PVT data. Under the assumption that, for this particular application, $P_i = P_b$ = 3250 psia.

Pressure, psia	N_p (mmstb)	R_p (scf/stb)	B_o (rb/stb)	R_s (scf/stb)	B_g (rb/scf)
3250 ($P_i = P_b$)			1. 2432	495	0.00096
3200	4.716	1100	1.2662	410	0.00103
3100	6.223	1140	1.2852	387	0.00112
2950	9.245	1190	1.2213	355	0.00142
2500	11.147	1210	1.1980	331	0.00191
1900	14.678	1248	1.1532	318	0.00232
1700	16.933	1280	1.1129	291	0.00497

The size of the Gas-cap is uncertain with the best estimate, based on geological information, giving the value of m = 0.4. Is this figure confirmed by the production and pressure history? If not, what is the correct value of m?

SECTION B

Question Five

a) The derivation of the linear diffusivity equation is made on the basis of three physical laws. Name these laws and write out their governing equations.

b) What is the assumption that is made in the linearization of the non-linear diffusivity equation? Name the three pressure dependent parameters.

c) State two examples of the occurrence of steady state flow in the reservoir.

d) A reservoir is expected to produce at a stabilised bottom hole flowing pressure of 75bar. Use the following reservoir data to calculate the flow rate in stock tank m^3/day.
Porosity: 28%; Oil Formation volume factor: 1.41rm^3/stm3; Net thickness of formation: 15m; Viscosity of reservoir oil: 21×10^{-3}Pas; Wellbore radius: 0.15m; External reservoir boundary radius: 250m; Average reservoir pressure: 83bar; Permeability: 125mD

Question Six

a) With the aid of an illustration of the test tube experiment explain the difference between the three states of flow.

b) What are the initial and outer boundary conditions for the solution of the radial diffusivity equation?

c) Name and explain five assumptions for the use of Darcy's law.

d) The table below shows the data recorded for Darcy's experiment conducted on a core sample

Flow rate at standard condition (cm^3/min)	Mean pressure (atm)	Change in pressure (inlet –Outlet core pressure) (atm)	Fluid phase flowing	Viscosity (cp)	Cross-sectional Area of end of core (cm^2)	Length of Core Sample (cm)
35.6	1.33	0.667	Gas	0.75	20	10

Use the information in the table to calculate the permeability of the core sample [Hint: Standard or atmospheric pressure: 1 atm]

Question Seven

a) Derive the exponential decline curve equation as an equation of a straight line expressing production rate as a function of time. What is the slope of this line?

b) Derive the mathematical relationship between the nominal decline rate and the effective decline rate assuming a unit time period for exponential decline curve analysis.

c) Given that a certain well's production had declined exponentially from a stable rate of 1000stb/day to 850stb/day during a 1-month period,

i) Prepare a table of time, production rate and cumulative production over a 6-month period.

ii) Calculate the expected ultimate recovery for this well.

FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI

SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY

DEPARTMENT OF PETROLEUM ENGINEERING

2017/2018 HARMATTAN SEMESTER EXAMINATION

COURSE TITLE: RESERVOIR ENGINEERING II

COURSE CODE: PET 403

DATE: 17TH April, 2018

TIME: 3 HRS

INSTRUCTION: **Attempt All 5 Questions and show all calculations.**

1 Using appropriate Hydrocarbon phase envelope (P-T), describe the various type of reservoir you know.

(b) List 3 Laboratory processes used to obtain PVT data for Oil. Explain with diagram any one above.

(c) Determine the fractional oil recovery, during depletion down to a reservoir pressure of 2500 psia, for the reservoir whose PVT parameters are listed in the table below, given the following parameters: $C_w = 3.2 \times 10^{-6}$ / psi $S_{wc} = 0.19$ $C_f = 7.2 \times 10^{-6}$ / psi R_p=1170 scf/stb

Pressure(psia)	B_o (rb/stb)	R_s (scf/stb)	B_g (rb/scf)
3250	1.3121	531	0.00076
3200	1.3420	531	0.00093
3150	1.3632	531	0.00112
3050	1.3231	420	0.00153
2950	1.2924	395	0.00191
2500	1.2433	352	0.00252
1900	1.2122	291	0.00527

2. Given the following PVT and Production table:

P (psia)	Np (x10^6 stb)	Rp (scf/stb)	Bo (rb/stb)	Rs (scf/stb)	Bg (rb/scf)
3500	-	-	1.2325	530	0.00089
3330	3.29	1070	1.2212	510	0.00096
3150	8.14	1085	1.2113	490	0.00107
3050	10.65	1105	1.2101	477	0.00112
2950	-	-	1.2077	455	0.00119

Assuming the Production Mechanism is a Gas Cap Drive with the following information:

$S_{wc} = 0.30$ $S_o = 0.40$ $\mu_o = 1$cp m=0.4 $\mu_g = 0.1$cp $\log(\frac{K_o}{K_g}) = 24.7 * S_g - 6.23$

i. Estimate the Initial Oil Volume, N

ii. Given that the relationship between Rp and Rs is given by $R_p = R_s + \left(\frac{K_g}{K_o}\right) \times \left(\frac{B_o\mu_o}{B_g\mu_g}\right)$

Estimate Oil Production at P=2950psia

3 (a) A natural gas with a specific gravity of 0.76 is flowing in linear porous media at 150°F. The upstream and downstream pressures are 2250 psi and 1990.73 psi, respectively. The crosssectional area is constant at 5400 ft². The total length is 2700 ft with an absolute permeability of 68 md. Calculate the gas flow rate in scf/day (psc = 14. 7 psia, Tsc = 520°R)

(b) show that $\frac{1}{r}\frac{\partial}{\partial r}\left(\frac{kp}{\mu} r \frac{\partial p}{\partial r}\right) = \phi c p \frac{\partial p}{\partial t}$

4 (a) Show that for a linear flow of compressible fluid, that the gas flow rate is given as :

$$Q_{sc} = \frac{0.111924k\left(p_1^2 - p_2^2\right)}{TLZ\mu_g}$$

(b) A slightly compressible fluid flows in a linear porous media with the following properties:

L = 2300 ft, k = 100 md, P_1 = 2000 psi, h = 25 ft, ϕ = 15%, P_2 = 1990 psi, width = 350 ft, μ = 2.5 cp calculate the flow rate at both ends of the linear system. The liquid has an average compressibility of 22 × 10−5 psi−1.

5. A well is expected to produce 70mstb recoverable reserves and is on hyperbolic decline with exponent 0.5. The initial rate is estimated to be 100stb/day. The abandonment rate in the region is 5stb/day, Hence; (a) Determine the life of the well (b) Calculate its annual productions.