UNIVERSITY OF MINES AND TECHNOLOGY, TARKWA

SECOND SEMESTER EXAMINATIONS, MAY, 2015

COURSE NO: PE 276
COURSE NAME: **RESERVOIR ENGINEERING I**
CLASS: PE II TIME: **3 HOURS**.

Name**:** _____ Index Number: _____

INSTRUCTIONS

ATTEMPT ALL QUESTIONS.

Write **all** your answers in the answer booklets provided.

Show **all** the necessary workings and state any assumptions made on your answer sheets.

This exam consists of sections A, B and C.

Each question under section A carries 1mark and the marks for each question under sections B and C are indicated in brackets at the end of the question.

SECTION A

PROVIDE THE MISSING WORDS TO MAKE THE STATEMENTS VALID

1. If a single best estimate of reserves is made based on known geological, engineering, and economic data, the method of estimation is called ……..
2. The technique usually used for estimation of hydrocarbons in place before production is the …….method.
3. Reserves are categorised as proved and unproved in order to indicate……..
4. The straight line material balance is diagnostic in that a deviation of an actual plot from a straight line expected for a particular drive mechanism signifies……
5. The highest sustainable daily oil or gas withdrawal rate from a reservoir which will permit economic development and depletion of that reservoir without detriment to ultimate recovery is called…….

ANSWER TRUE OR FALSE

1. Recovery factors for water drive gas reservoirs are usually higher than those for closed gas reservoirs.
2. The ultimate recovery of a volumetric gas reservoir depends on the production rate.
3. The non-recoverable hydrocarbons that remain in the reservoir are called remaining reserves.

4. The material balance equation alone can predict when things will happen in a reservoir.

5. In Gravity-drainage reservoir wells should be located as structurally high as possible in order to conserve the reservoir gas.

SECTION B

1. We have acquired a licence area which we **intend to explore**. We **anticipate it to contain** a STOIIP of 2000 MM stb, and recovery factor of 65% using primary methods (30%), secondary (25%) and tertiary (10%) recovery methods. What are **t**he reserves by SPE/WPC definitions? **[2 marks]**

2. What are the importance of the following in contributing to the ultimate recovery of a gas-cap-drive reservoir: (i) Conservation of the gas (ii) Dip of the structure. **[2 marks each]**

3. For a gas reservoir, successive computation of $G = \frac{G_p B_g}{B_g - B_{gi}}$ will normally result in increasing values of the gas initially in place G with time if water influx is occurring. Explain why this occurs in a maximum of 5 lines. **[2 marks]**

4. Briefly discuss the rate sensitivity of gas cap drive reservoirs. **[3 marks]**

5. After natural or injected water drive, residual oil is left within that part of the rock contacted by the water. Comment briefly why this might be. **[3 marks]**

6. Describe briefly the drive mechanisms associated with producing an undersaturated oil reservoir with good vertical permeability and no supporting aquifer, down to a pressure well below the bubble point. **[6 marks]**

7. Give two conditions that will make instantaneous GOR be equal to solution GOR. **[2 marks]**

8. Edge water drive is preferred to bottom water drive, give one reason for this. **[2 marks]**

9. Portray the reservoir pressure profiles of solution gas drive and gas cap drive with time on the same sketch and explain the briefly (4 lines maximum) the reason behind the pressure profile of the solution gas drive mechanism. **[5 marks]**

10. (a) Identify the various elements in the material balance equation below. **[3 marks]**

    e.g. ($G_{inj}B_{ginj} + W_{inj}B_w$) = total volume injected

    $(N - N_p)B_o = NB_{oi} - [NR_{si} - N_pR_p - (N - N_p)R_s]B_g - (W_e - W_pB_w) -$

$$mNB_{oi}\left(\frac{B_g}{B_{gi}} - 1\right) - NB_{oi}(1+m)\left(\frac{s_{wi}c_w + c_f}{1-s_{wi}}\right)\Delta p - (G_{inj}B_{ginj} + W_{inj}B_w)$$

(b) Simplify the material balance equation above so that it can be used for an undersaturated reservoir without water drive, water production and fluid injection. **[3 marks]**

SECTION C

1. The following data are available on a volumetric undersaturated oil reservoir:

p_i = 4000 psi	p_b = 3000 psi	N = 85 MMSTB
$c_f = 5\times10^{-6}$ psi^{-1}	$c_o = 15\times10^{-6}$ psi^{-1}	$c_w = 3\times10^{-6}$ psi^{-1}
S_{wi} = 30%	B_{oi} = 1.40 bbl/STB	

2. Estimate cumulative oil production when the reservoir pressure drops to 3500 psi. The oil formation volume factor at 3500 psi is 1.414 bbl/STB. **[7 marks]**

3. A volumetric gas reservoir has the following production history.

P (psi)	z	G_p (MMMscf)
1720(p_i)	0.86	0.0
1653	0.87	1.0
1584	0.88	2.0
1513	0.89	3.0

i) Estimate the initial gas in place. **[12 marks]**

ii) Estimate the gas produced at an abandonment pressure of 500 psia. Assume z_a = 1.00, temperature of 180^{o}F, reservoir rock porosity of 12%, the initial water saturation of 25%, reservoir thickness of 35 ft and reservoir area of 2000 acres. **[6 marks]**

iii) What is the recovery factor at the abandonment pressure of 500 psia? **[2 marks]**

4. The production history and the PVT data of a gas-cap-drive reservoir without water drive, water production or fluid injection are given below:

p psi	N_p MSTB	G_p MMscf	$R_p = G_p/N_p$ Scf/STB	B_t bbl/STB	B_g bbl/scf
5000	–	–	–	1.630	0.00075
4500	492	765	1554.88	1.680	0.00079
3000	1015	2409	2373.40	1.796	0.00080

The initial gas solubility R_{si} is 977 scf/STB. Estimate the initial oil and gas in place.

a. Assuming the initial oil in place, N and the ratio of original gas cap volume to that of oil, m are unknown, re-write the linear form of the general material balance equation (supplied in the equations part), modify it to suit this gas cap drive mechanism and re-arrange the resultant equation to get the equation of a straight line that can be plotted to find N and m. **[4 marks]**

b. Calculate and tabulate the variables you would plot from the data above in order to find N and m. **[9 marks]**

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c. The slope of the straight line from the plot of the variables in (b) above is found to be 4.0 x 10^6 STB and the intercept found to be 16.0 x 10^6 STB. Find the STOIIP and the initial volume of the Gas cap. **[5 marks]**

EQUATIONS

$F = N [E_o + m E_g + E_{f,w}] + (W_e + W_{inj} B_w + G_{inj} B_{ginj})$

Where

$F = N_p [B_o + (R_p - Rs) B_g] + W_p B_w$ or $F = N_p [B_t + (R_p - R_{si}) B_g] + W_p B_w$

$E_o = B_t - B_{ti}$ or $E_o = (B_o - B_{oi}) + (R_{si} - R_s) B_g$

$E_g = B_{oi} [(B_g/B_{gi}) - 1]$ or $E_g = B_{ti} [(B_g/B_{gi}) - 1]$

$$E_{f,w} = (1+m)B_{oi}\left[\frac{S_{wi}c_w + c_f}{1-S_{wi}}\right]\Delta p$$

$$N = \frac{N_p\left[B_t + (R_p - R_{si})B_g\right] - (W_e - W_p B_w)}{(B_t - B_{ti}) + mB_{ti}\left[\frac{B_g}{B_{gi}} - 1\right] + B_{ti}(1+m)\left[\frac{S_{wi}c_w + c_f}{1-S_{wi}}\right]\Delta p}$$

$$P.V = \frac{NB_{oi}(1+m)}{1-S_{wi}}$$

$$N = \frac{N_p B_o}{(B_o - B_{oi}) + B_{oi}\left[\frac{S_{wi}c_w + c_f}{1 - S_{wi}}\right]\Delta p}$$

$\Delta G_p = (GOR)_{avg}\ \Delta N_p$ $\qquad$ $G_p = \sum (GOR)_{avg}$

$$N = \frac{N_p\left[B_o + (R_p - R_s)B_g\right] - (W_e - W_p B_w) - G_{inj}B_{ginj} - W_{inj}B_w}{(B_o - B_{oi}) + (R_{si} - R_s)B_g + mB_{oi}\left[\frac{B_g}{B_{gi}} - 1\right] + B_{oi}(1+m)\left[\frac{S_{wi}c_w + c_f}{1 - S_{wi}}\right]\Delta p}\ \Delta N_p$$

$$c_e = \frac{S_{oi}c_o + S_{wi}c_w + c_f}{1 - S_{wi}} \qquad E_{f,w} = B_{oi}\left[\frac{S_{wi}c_w + c_f}{1 - S_{wi}}\right]\Delta p \qquad N_p = Nc_e\left(\frac{B_o}{B_{oi}}\right)\Delta p$$

$$G_p = 43560Ah\phi(1 - S_{wi})\left(\frac{1}{B_{gi}} - \frac{1}{B_{ga}}\right) \qquad B_g = 0.02827\frac{ZT}{P}\ \text{ft}^3/\text{scf},$$

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