Key

PETE 301

Exam B

October 27, 2003

(Turn in your 1 cheat sheet with your exam. Show your work. Don't forget the units, if appropriate.)

1. (20 RAW points) A common model for matching relative permeability is the *power curve* which can be expressed in terms of the water saturation, S_w, and two constants, S_{wc} and S_{or} as follows: $k_{rw} = \left(\dfrac{S_w - S_{wc}}{1 - S_{wc} - S_{or}}\right)^3$

Now suppose you have the following lab data:

S_w	k_{rw}
0.31	0.008
0.39	0.025
0.55	0.330

(a) You want to use a "pseudo straight line". Write the pseudo straight line equation. Indicate the expressions for *b* and *m*.

$$\underbrace{\sqrt[3]{k_{rw}}}_{y} = \frac{S_w - S_{wc}}{1 - S_{wc} - S_{or}} = \underbrace{-\frac{S_{wc}}{1 - S_{wc} - S_{or}}}_{b} + \underbrace{\frac{1}{1 - S_{wc} - S_{or}}}_{m} \underbrace{S_w}_{x}$$

(b) What is the independent (x) variable of the pseudo straight-line? Show all three values.

$$x = S_w \qquad S_w = \begin{pmatrix} 0.31 \\ 0.39 \\ 0.55 \end{pmatrix}$$

(c) What is the dependent (y) variable of the pseudo straight line? Show all three values.

$$y = \sqrt[3]{y} = \begin{pmatrix} 0.2 \\ 0.292 \\ 0.691 \end{pmatrix}$$

(d) Now suppose you have calculated that $b = -0.41$ and $m = 2.1$ by linear least squares analysis. From these values, calculate the *connate water saturation*, S_{wc} and the *residual oil saturation*, S_{or}.

$$m = 2.1 = \frac{1}{1 - S_{wc} - S_{or}}$$

$$b = -0.41 = \frac{-S_{wc}}{1 - S_{wc} - S_{or}}$$

$$S_{wc} = -\left(\frac{-S_{wc}}{1 - S_{wc} - S_{or}}\right) \Big/ \left(\frac{1}{1 - S_{wc} - S_{or}}\right) = -\frac{b}{m} = -\frac{(-0.41)}{2.1} = \boxed{0.195}$$

$$1 - S_{wc} - S_{or} = \frac{1}{2.1} = 1 - 0.195 - S_{or}; \quad S_{or} = 1 - 0.195 - \frac{1}{2.1} = \boxed{0.329}$$

MHI

2. (20 points) We want to fit the following gas pressure/production data with the straight line material balance equation: $(p/z) = (p/z)_i\,[1-G_p/G]$. We are not sure of the initial pressure, so we **do not** want our line to go exactly through the point at $G_p = 0$.

G_p MMscf	(p/z) (Bbl/Day)
0	3000
50	2755
120	2410

(a) In the form of a linear equation, $y = b + mx$, what is b, what is m?

$b = (\frac{P}{z})_i$ $\quad m = \frac{P_i}{z_i G}$ $\quad$ −5

(b) Use the linear least squares method to calculate the slope and intercept of the straight line. What is the initial gas-in-place, G?

$$y = b + mx$$

$$\Sigma y = nb + m\Sigma x \quad \text{—— (1)}$$

$$\Sigma xy = b\Sigma x + m\Sigma x^2 \quad \text{—— (2)}$$

$$\begin{vmatrix} n & \Sigma x \\ \Sigma x & \Sigma x^2 \end{vmatrix}\begin{vmatrix} b \\ m \end{vmatrix} = \begin{vmatrix} \Sigma y \\ \Sigma xy \end{vmatrix}$$

$$b = \frac{\begin{vmatrix} \Sigma y & \Sigma x \\ \Sigma xy & \Sigma x^2 \end{vmatrix}}{\begin{vmatrix} n & \Sigma x \\ \Sigma x & \Sigma x^2 \end{vmatrix}}$$

$$m = \frac{\begin{vmatrix} n & \Sigma y \\ \Sigma x & \Sigma xy \end{vmatrix}}{\begin{vmatrix} n & \Sigma x \\ \Sigma x & \Sigma x^2 \end{vmatrix}} = \frac{\begin{vmatrix} 3 & 8165 \\ 170 & 426\,950 \end{vmatrix}}{21800} = \frac{-107200}{21800} = \boxed{-4.917}$$

−3

$\Sigma x = 170$
$\Sigma y = 8165$
$\Sigma xy = 426{,}950$
$\Sigma x^2 = 16{,}900$

−~~B~~

$$b = \frac{\begin{vmatrix} 8165 & 170 \\ 426{,}950 & 16900 \end{vmatrix}}{3(16{,}900) - 170 \times 170} = \frac{65407{,}000}{21800} = \boxed{3000.32}$$

−3

$$OGIP(G) = \frac{P_i}{z_i m} = \frac{3000}{\cancel{4}4.917} = \boxed{610\ \text{MMscf}}$$

−~~3~~

~~HW3~~ RAW

3. (20 points) Consider the following differential equation describing static pressure in a wellbore:

$$\frac{dp}{dx} = (-)\left(\frac{29\gamma_g}{z10.73}\right)\frac{p}{T}$$

where the gas gravity, $\gamma_g = 0.75$. A value of z =1.0 is assumed for simplicity. x is the vertical distance (positive downward). A temperature gradient of 1.1 °R/100 ft is assumed to apply. At the surface the wellhead pressure = 1,500 psia and the temperature is 90 + 460 = 540 °R. Use the Simple Heun method to calculate the temperature and pressure at x = 1,000 ft. Use an increment of x equal to 1,000 ft. Clearly show you calculations.

Step 1. - Euler method.

$$P_{i+1} = P_i + \frac{29\,(0.75)}{(1)(10.73)}\,\frac{1{,}500}{540}(1000) = 1500 + (2.0270)\frac{1500}{540}(1000)$$

2.0270

10

$$= 1500 + 5.63(1000) = \begin{array}{r} 1500 \\ +5630 \\ \hline 7{,}130 \end{array}$$

Step 2. - Heun corrector

$$P^1_{i+1} = P_i + \frac{h}{2}\left[f(x_i, y_i) + f(x_{i+1}, y_i^0)\right]$$

$$= 1500 + \frac{1000}{2}\left[5.63 + 2.027\,\frac{7{,}130}{(540+11)}\right]$$

10

$$= 1500 + 500\left[5.63 + 26.23\right]$$

$$= 1500 + 500\left[31.86\right]$$

$$= \boxed{17{,}430.}$$

Note: derivative was missing $\frac{1}{144}$

RAW

4. (20 points) The pressure near the wellbore of a producing well is assumed to correspond to radial flow and can be calculated with the equation $p(r) = p_{wf} + C\ln(r/r_w)$ where C is a constant that depends on flow rate, viscosity, permeability, thickness, and wellbore radius (r_w). For our case, $C = 30.5$, psia, $r_w = 0.3$ ft, and $p_{wf} = 510$ psia at rw.

(a) Find the derivative, dp/dr (from calculus).

6 $$\frac{dp}{dr} = \frac{C}{r} = \frac{30.5}{r}$$

(b) Use Euler's method to calculate p at $r = 10.3$ ft. Use only one increment ($h = 10$ ft).

$$p_{i+1} = p_i + \frac{dp}{dr}\Delta r$$

$$= 510 + \frac{30.5}{(0.3)}(10)$$

6 $$= 510 + 1016.7$$

$$p(10.3) = \boxed{1,526.7}$$

(c) Calculate the difference between this answer with the answer in the $p(r)$ equation.

4 $$p(10.3) = 510 + 30.5 \ln\left(\frac{10.3}{0.3}\right) = \boxed{617.9}$$

difference

$$\begin{array}{r} 1526.7 \\ 617.9 \\ \hline \boxed{908.8} \end{array}$$

(d) What is the best way to improve accuracy?

smaller increments.

4

MHI

5. (20 points) Indicate the right value of "sum" in the following subroutines.

```
Option Explicit
Sub sumprogram()
Dim n As Interior, sum As Double, i As Integer
sum = 0#
i = 1
Do While (i <= 5)
sum = sum + i
i = i + 1
Loop
End Sub
```

-6

(a) sum = 15

```
Option Explicit
Sub sumprogram()
Dim n As Interior, sum As Double, i As Integer
sum = 0#
i = 0
Do
sum = sum + i
i = i + 1
Loop While (i <= 5)
End Sub
```

-6

(b) sum = 15

```
Option Explicit
Sub sumprogram()
Dim n As Interior, sum As Double, i As Integer
sum = 0#
For i = 1 To 5
sum = sum + i
Next i
End Sub
```

-6

(c) sum = 15