(key)

PETE 301

Final Exam

December 16, 2003

(Turn in your 4 cheat sheets with your exam. Show your work. Don't forget the units, if appropriate.)

1. (15 points) Pore volume in the laboratory may be calculated by $V = V_o\, e^{cp}$. Calculate V at p = 5,000 psi if $V_o = 25.5$ cm^3 ± 18% and the compressibility, c, is estimated to be 25 x 10^{-6} (fraction)/psi ± 2 x 10^{-6} (fraction)/psi. Indicate the relative error in %.

@ $p = 5{,}000$

$V = V_o e^{cp} = 25.5\, e^{(25\times10^{-6})(5000)} = \boxed{28.895 \text{ cm}^3}$ -4

$dV = \left| V_o e^{cp}\, p\, dc \right| + \left| e^{cp}\, dV_o \right|$ -4

$= \left| (28.895)(5000)(2\times10^{-6}) \right| + \left| e^{(25\times10^{-6})(5000)} (0.18)(25.5) \right|$

$= 0.28895 + 5.2011$

$= 5.490 \text{ cm}^3$ -4

$\text{rel. error} = \frac{\Delta V}{V} = \frac{5.490}{28.895} = 0.1900$

$= \boxed{19.00\ \%}$ -4

2. (10 points) Answer the following questions by putting true (√) or false (X)

1- The VBA program should start by word sub and end by word end sub (√)
2- A function can return many values (X)
3- When we used Option Explicit in VBA program, we do not have to declare all the variables. (X)
4- We can read the data from spreadsheet without using with sheets keyword. (X)
5- With If…Then …Else statement we should not used End If (X)
6- While ….Wend loop does not work if the condition is not true and the For…Next loop does the same (X)
7- To read array A(3,3) we should use two For….Next loop. (√)

-2 each

3. (10 points) Using Taylor's series, derive the finite difference formula for f "(x_i) using data at points x_i, x_{i-1} and x_{i-2}. Show the formula, the first truncated term, and the order of the approximation.

#1. $f_{i-1} = f_i - h f_i' + \frac{h^2 f_i''}{2!} - \frac{h^3 f_i'''}{3!} + \frac{h^4 f_i^{IV}}{4!} - \cdots$ -3

#2. $f_{i-2} = f_i - (2h) f_i' + \frac{(2h)^2 f_i''}{2!} - \frac{(2h)^3 f'''}{3!} + \frac{(2h)^4 f_i^{IV}}{4!} - \cdots$ -3

Subtract 2 x #1 from #2:

$f_{i-2} - 2 f_{i-1} = f_i - 2f_i' - (2h) f_i' + 2h f_i' + 2h^2 f_i'' - h^2 f_i'' - \frac{8}{6} h^3 f_i''' + \frac{7}{6} h^3 f''' - \cdots$

$f_{i-2} - 2 f_{i-1} + f_i = h^2 f_i'' - \frac{6}{6} h^3 f_i''' + \cdots$

$$f_i'' = \frac{f_{i-2} - 2 f_{i-1} + f_i}{h^2} + h f_i''' + \cdots$$

formula — 1st error term — -2

$O(h)$, 2

4. (10 points) Suppose we have a sand packed core container 10 ft long. We pressure it with air at 1,000 psia. Then we open a valve on the left end to the atmospheric pressure, 14.7 psia, while leaving the right end closed. Consider the finite difference equation for this flow problem in the following form: $p_{i-1}^{n+1} - 2p_i^{n+1} + p_{i+1}^{n+1} = \alpha (p_i^{n+1} - p_i^n)$. Suppose we are using 5 grid points. Fill in the following table of the matrix coefficients for a timestep. Include the proper boundary conditions. Use exact values where you can, but use the math symbols elsewhere.

-3

i	a_i	b_i	c_i
1	X	1	0
2	1	$-(2+\alpha)$	1
3	1	$-(2+\alpha)$	1
4	1	$-(2+\alpha)$	1
5	-1	1	X

-3

-3

5. (10 points) If an LU decomposition subroutine (for solving a system of linear equations) returns with the error message "the determinant of the coefficient matrix is zero", then most probably

a) the system you want to solve has one unique solution
b) the system you want to solve has no solution
c) the system you want to solve has infinitely many solutions
d) either b) or c)
e) none of the above

(d) -10

6. (15 points) Consider the following equation:

$x + 2e^x = 7x^2$

Put this in the form of f(x) = 0. Take 2 iterations to find the root with the Newton-Raphson method. Begin with an initial guess of x = 1.

$f(x) = x + 2e^x - 7x^2 = 0$ -4

$f'(x) = 1 + 2e^x - 14x$ -4

Newton-Raphson

$$x_{i+1} = x_i - \frac{f(x_i)}{f'(x_i)}$$ -5

initially,

$f(1) = (1) + 2e^{(1)} - 7(1)^2 = -0.5634$

$f'(1) = 1 + 2e^{(1)} - 14(1) = -7.5634$

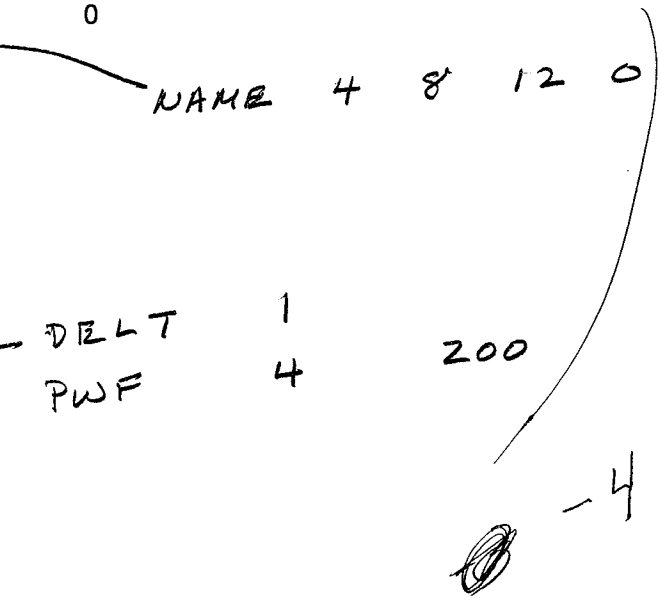
iteration #1 $x_1 = (1) - \frac{-0.5634}{-7.5634} = \boxed{0.9255}$ -5

$f(0.9342) = -0.02413$

$f'(0.9342) = -6.9108$

iteration #2 $x_2 = 0.9342 - \frac{-0.02413}{-6.9108} = \boxed{0.9220}$ -5

```
IMAX            10
JMAX            20
CROC      3.00E-06
GRAV           0.7
PREF          4500
T              610
END
CMNT    grid      data      section----
DELX            40
DELY            30
KX             0.1
KY             0.1
H               45
PHI            0.2
POI           4500
END
CMNT    schedule  data      section----
NAME             1          3          11         0
NAME             2          10         6          0
NAME             3          6          15         0
QG               1          50000
ALPH           1.5
WELL             2
PMAP             2
DELT             1
DTMX            50
TIME             1
TIME            30
DELT             1
QG               2          35000
TIME            60
TIME            90
DELT             1
QG               1          70000
TIME           180
DELT             1
QG               1          90000
QG               3          55000
TIME           365
END
```



7. (10 points) Look at the input data for the attached 2D problem.

(a) Calculate the pore volume of the reservoir.

(b) What is the production rate of each well at t = 195 days

(c) Suppose you wanted to add a fourth well at 60 days at location i = 8, j=12. You want to produce this fourth well at a constant bottom-hole pressure of 200 psia. Indicate on the data page what changes you would make.

(a)

$V_p = 10 \times 20 \ (\Delta x \, \Delta y \, h) \, \phi$

$= 10 \times 20 \ (40)(30)(45)(0.20)$

$= \boxed{2,160,000 \ ft^3}$

-4

(b)

$q_1 = 90{,}000$ scf/D

$q_2 = 35{,}000$ scf/D

$q_3 = 55{,}000$ scf/D

-4

8.(10 points) Suppose that we run Gassim (we can run either as a liquid or gas). We make a couple of runs and notice that when we doubled the rate for the second run, we *did not* get twice the pressure drop at the well.

(a) What *mathematical term* do we use to describe this property of the differential equation for this simulation?

Nonlinear -5

(b) Is this lack of "proportionality" of results more likely for a gas well or oil well?

gas well -5

(Key)

9.(10 points) Set up the grid data section for the following Gassim problem: We are using a 5 x 5 2D model with uniform grid spacing of 60 ft x 60 ft for each gridblock. Porosity is 11%. Permeability is 170 md. Thickness is calculated by a formula (h = 20 +i +j). Initial pressure is 2,500 psia.