Key

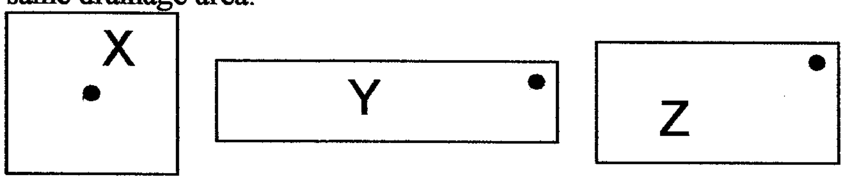
PETE 324

Exam C

April 21, 2004

50 minutes, closed book except for 3 cheat sheets, calculator, and straight edge. Turn in you cheat sheets with your exam. Show your work. Include units. Use symbols instead of values when necessary.

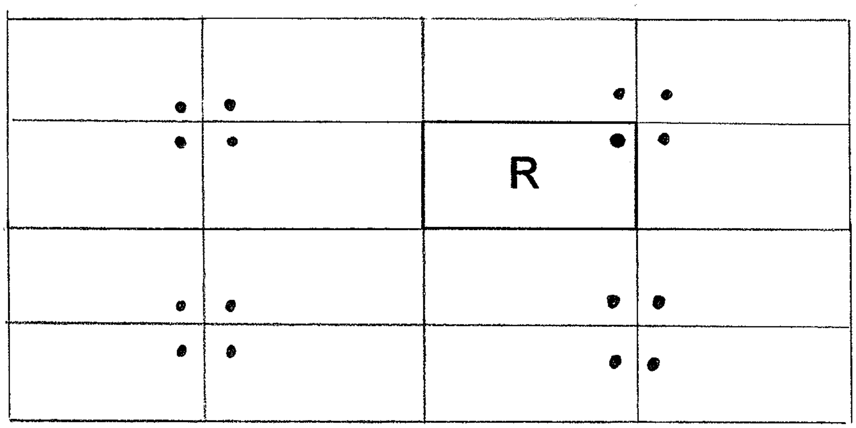
1. (15 points) Consider the following three wells producing from different reservoir shapes. Each reservoir has the same drainage area.



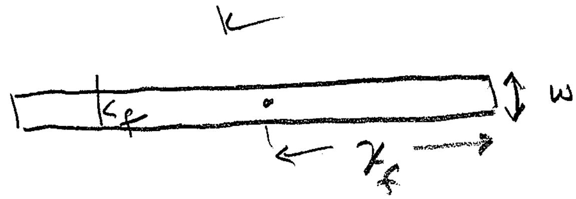
a. Which well reaches pseudo-steady state last? Y

b. Which well will be the best producer? X

c. For well R, sketch the locations of at least 11 image wells that would be used for superposition.



2. (20 points) We use a simplified description of a hydraulic fracture for the purpose of well test analysis.
(a) Draw a sketch of the areal view of the simplified hydraulic fracture. Include labels for the important dimensions.



(b) Write the equation for dimensionless fracture conductivity. What value is considered to be "infinite" for practical purposes?

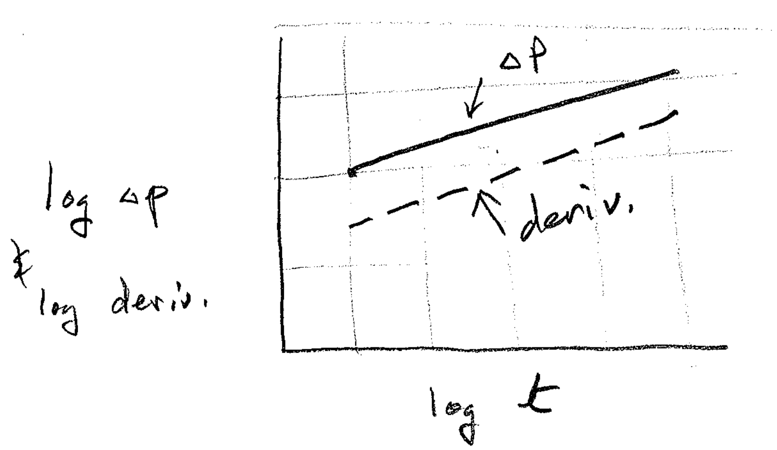
$$F_{CD} = C_{FD} = \frac{k_f w}{k x_f}$$

(c) At very early times, it is possible to have *bilinear flow*. The pressure drop for bilinear flow is $p_i - p_{wf} = C\,(t)^{1/4}$. Derive the "pressure derivative" equation that we would use on a log-log plot for bilinear flow.

$$\frac{d\Delta p}{d\ln t} = t\,\frac{d\Delta p}{dt} = t\left[C\,\frac{1}{4}\,t^{-3/4}\right] = \frac{1}{4}\,C\,\frac{t}{t^{3/4}}$$

$$= \frac{1}{4}C\,t^{1/4}$$

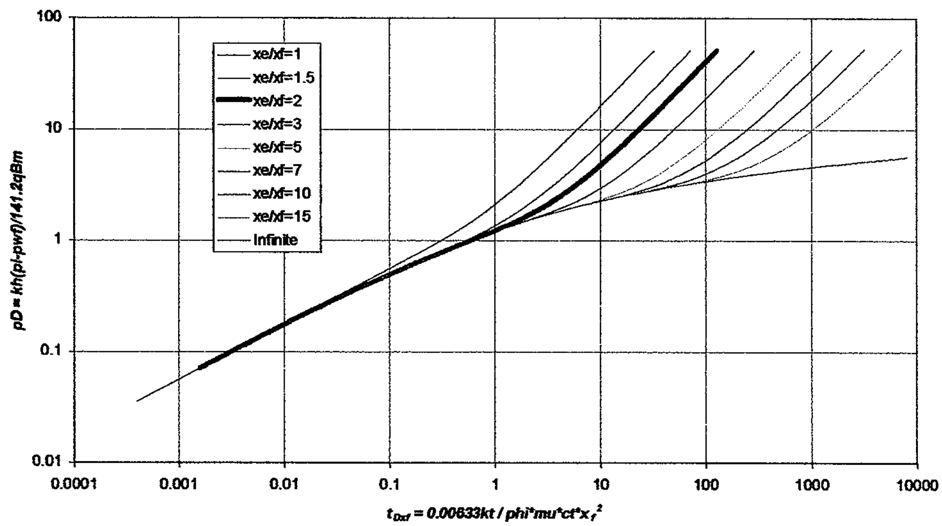
(d) Make a sketch of the two curves, "pressure drop" and "pressure drop derivative", on a log-log plot. Show log-log cycles in your sketch.



3. (15 points) Below is a type curve for a hydraulically fractured oil well. Suppose the field data matches the highlighted curve ($x_e/x_f = 2$). A match point was established where $p_D = 10$ is equivalent to $(p_i - p_{wf}) =$ 186 psi and $t_{Dxf} = 1$ is equivalent to 73 hours. Calculate:

(a) permeability
(b) fracture half-length, x_f
(c) Oil in place.

$p_i = 6{,}287$ psia	$\mu = 2.1$ cp	$h = 85$ ft
$q = 223$ stb/d	$\phi = 0.16$	$r_w = 0.24$ ft
$B = 1.15$ rb/stb	$c_t = 15 \times 10^{-6}$ psi^{-1}	$S_w = 0.22$



(a) $$p_D = \frac{kh(p_i - p_{wf})}{141.2\, qB\mu} = 10 = \frac{k\,(85)(186)}{141.2(223)(1.15)(2.1)}$$

$$k = 48.09 \text{ md}$$

(b) $$t_{Dxf} = \frac{0.000264\, kt}{\phi \mu c_t\, x_f^2} = 1 = \frac{0.000264\,(48.09)(73)}{(0.16)(2.1)(15\times10^{-6})\, x_f^2}$$

$$x_f = 428.82 \text{ ft}$$

(c) $$A = (2x_e)^2 = 16\, x_f^2\ ; \quad \left(\frac{x_e}{x_f} = 2\right)$$

$$A = 4(2 * 428.82 \text{ ft})^2 = 2{,}942{,}185 \text{ ft}^2$$

$$OOIP = \frac{V_p\,(1-S_w)}{B_o} = \frac{Ah\,\phi\,(1-S_w)}{B_o} = \frac{(2{,}942{,}185 \text{ ft}^2)(85 \text{ ft})(0.16)(1-0.22)\left(\frac{rb}{5.61 \text{ ft}^3}\right)}{1.15 \text{ rb/stb}}$$

$$OOIP = 4{,}837{,}744 \text{ stb}$$

4. (15 points) Below is a type curve for a well with radial flow and wellbore storage and skin. Suppose we have a gas well and the field data matches the curve for $C_De^{2s} = 2{,}000$. A match point was established where $p_D = 10$ is equivalent to $[m(p_i) - m(p_{wf})] = 6.2 \times 10^8$ psi²/cp and $t_D/C_D = 1$ is equivalent to 1,230 hours.

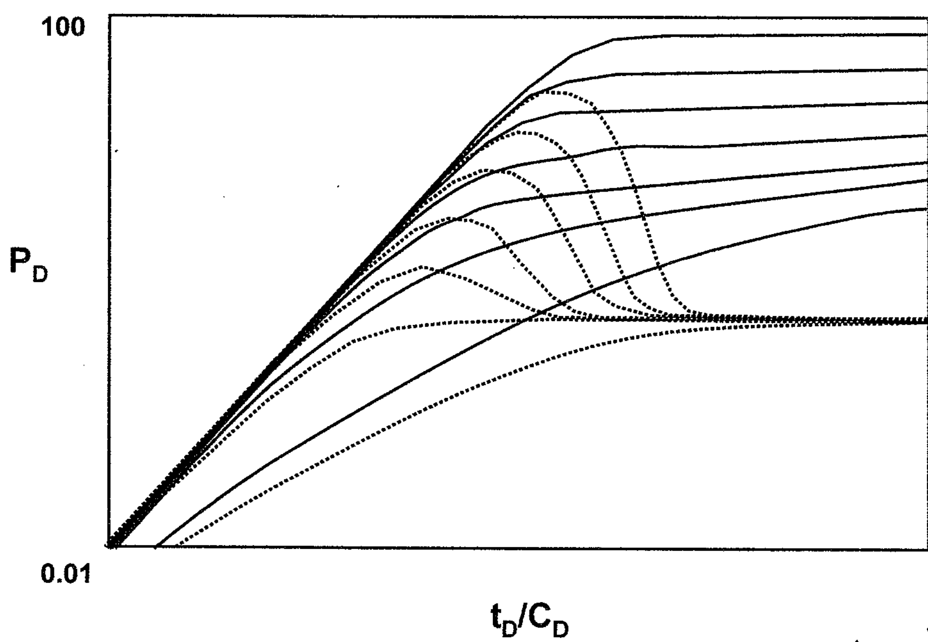
Calculate:

(a) permeability, k

(b) C_D

(c) Skin factor, s

$p_i = 2{,}020$ psia $q_g = 1{,}000$ Mscf/d $B = 1.15$ rb/stb	$\mu = 0.01$ cp $\phi = 0.16$ $c_t = 75 \times 10^{-6}$ psi^{-1}	$h = 150$ ft $r_w = 0.24$ ft $T = 650\ ^oR$



(a) $$p_D = \frac{kh[m(p_i) - m(p_{wf})]}{1422\, q_g\, T} = 10 = \frac{k(150)(6.2\times10^8)}{1422\,(1{,}000)(650)}$$

$k = 0.099$ md

(b) $$t_D/C_D = \frac{0.000264\, k\, t}{\phi \mu c_t r_w^2} \Big/ C_D = 1 = \frac{0.000264\,(0.099)(1230)}{(0.16)(0.01)(75\times10^{-6})(0.24)^2} \Big/ C_D$$

$C_D = 4{,}669{,}123$

(c) $C_D e^{2s} = 2{,}000$

$$2s = \ln \frac{2000}{C_D} = \ln \frac{2000}{(4{,}669{,}123)}$$

$s = -3.88$

5. (15 points) A gas well has been producing for 9 years. Its initial rate, q_i, was 2,300 Mscf/D. Your best fit of the decline curve gives values of $b = 0.3$ and $D_i = 0.21$ year $^{-1}$. Suppose we expect this well to be abandoned after a total life of 20 years because of operational and/or contractual problems.

Calculate:

(a) the production rate at 20 years.

(b) the estimated ultimate recovery (EUR).

(c) the current reserves after 9 years of production.

(a) $$q_g = \frac{q_i}{(1 + b D_i t)^{1/b}} = \frac{(2300) \text{ Mcf/D}}{[1 + (0.3)(0.21)(20)]^{1/(0.3)}} = \boxed{151.8 \text{ Mscf/D}}$$

$$= 151.8 \text{ Mscf/D}$$

(b) $$(G_p)_{20} = \frac{q_i}{D_i (b-1)} \left[(1 + b D_i t)^{\frac{1-b}{-b}} - 1 \right] = \frac{2300}{\left(\frac{0.21}{365}\right)(0.3-1)} \left[(1 + (0.3)(0.21)(20))^{\frac{1-0.3}{-0.3}} - 1 \right]$$

$$EUR = (G_p)_{20} = 4{,}858{,}863 \text{ Mscf}$$

(c) $$(G_p)_9 = \frac{2300}{\left(\frac{0.21}{365}\right)(0.3-1)} \left[(1 + 0.3)(0.21)(9))^{\frac{1-0.3}{-0.3}} - 1 \right]$$

$$= 3{,}708{,}523 \text{ Mscf}$$

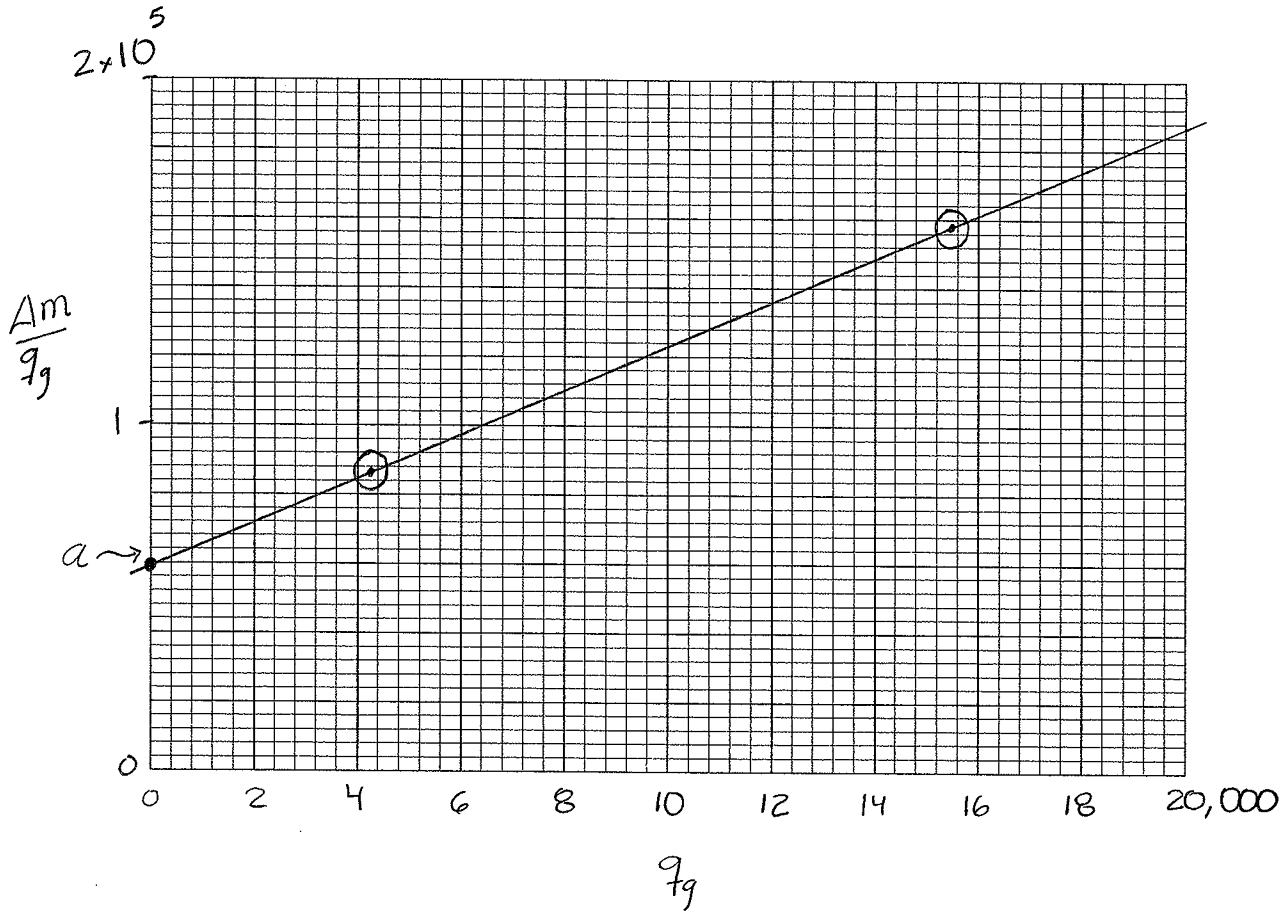
$$\text{Reserves} = EUR - (G_p)_9$$

$$= (4{,}858{,}863 - 3{,}708{,}523) \text{ Mscf}$$

$$= 1{,}150{,}340 \text{ Mscf}$$

6. (20 points) During pseudo-steady state, we can correctly account for gas properties and non-Darcy flow by using the equation $m(\bar{p}) - m(p_{wf}) = a\, q_g + b\, q_g^2$. But we can divide by q_g and have the following equation form: $[m(\bar{p}) - m(p_{wf})]/q_g = a + b\, q_g$. We can then plot $[m(\bar{p}) - m(p_{wf})]/q_g$ vs. q_g to determine a and b. (This is called a Houpert plot). Use this method to make the Houpert plot and determine a and b for the following data:

q_g	$[m(\bar{p}) - m(p_{wf})]/q_g$
4,288	0.8302×10^5
15,552	1.567×10^5



$a = 0.6 \times 10^5$ (from plot)

$$\frac{m(\bar{p}) - m(p_{wf})}{q_g} = a + b\, q_g$$

$$1.567 \times 10^5 = (0.6 \times 10^5) + b\,(15{,}552)$$

$b = 6.218$