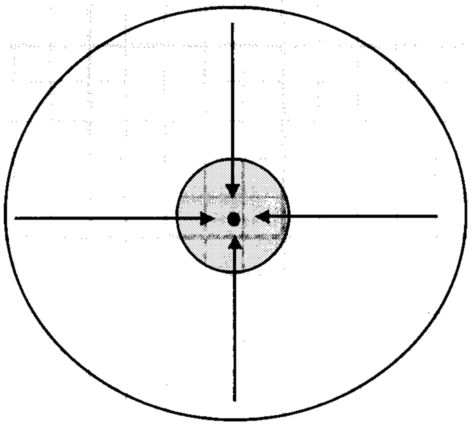
PROBLEM # 2

Consider the radial flow problem show in top view at right. Assume there are three layers and the permeability of the undamaged formation is 50 md in layers 1 & 3 and 5 md in layer 2. Further assume that the radius of damage is 2.5 ft, the permeability of the damaged zone (shaded area) is 1 md in all three layers, and the thickness of the layers are 10, 1, and 10 ft, respectively.



(a) What is the average permeability in each layer if r_w = 0.5 ft and r_e = 500 ft?

(b) What is the average permeability of the three layers?

THEORY

$$\bar{k} = \frac{\sum_j h_j k_j}{\sum_j h_j} \text{(parallel)}, \quad \bar{k} = \frac{\ln\left(r_e / r_w\right)}{\sum_j \ln\left(r_j / r_{j-1}\right) / k_j} \text{(series)},$$

SOLUTION

a) Layers 1 & 3

$$\bar{k} = \frac{\ln(500/0.5)}{\frac{\ln(2.5/0.5)}{1} + \frac{\ln(500/2.5)}{50}} = 4.027 \text{ md or } \underline{4 \text{ md}}$$

Layer 2

$$\bar{k} = \frac{\ln(500/0.5)}{\frac{\ln(2.5/0.5)}{1} + \frac{\ln(500/2.5)}{5}} = 2.588 \text{ md or } \underline{3 \text{ md}}$$

b)

$$\bar{k} = \frac{(4.027)(10) + (2.588)(1) + (4.027)(10)}{21} = 3.959 \text{ or } \underline{4 \text{ md}}$$

PROBLEM # 1

Given the following flow data on a cylindrical core:

Length	= 0.730 inches	p_{atm}	= 1.0 atm	p_{sc}	= 1.0 atm
Diameter	= 0.725 inches	μ_{Air}	= 0.020 cp	T_{sc}	= 15 °C

Absolute Upstream Pressure (atm)	Absolute Downstream Pressure (atm)	Flow rate of Air (cm^3/s @ s.c.)
1.21	1.0	4.028
2.08	1.0	25.90
3.49	1.0	72.52
5.32	1.0	137.2
6.63	1.0	191.3

(a) Determine the absolute permeability by graphing $q_{gsc}p_{sc}/A$ vs $\Delta p^2/2L$.

(b) Determine the absolute permeability and non-darcy flow coefficient by graphing $1/k_g$ vs q_{gsc}

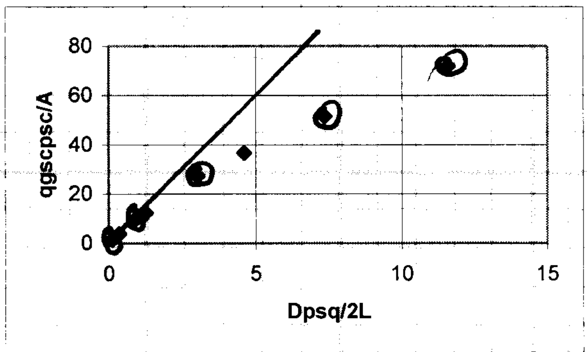
THEORY

$$q_{g,sc} = \frac{k}{\mu_g}\left(\frac{A}{p_{sc}}\right)\frac{\left(p_1^2 - p_2^2\right)}{2L}, \quad \text{plot } \frac{q_{g,sc}p_{sc}}{A} \text{ vs } \frac{\left(p_1^2 - p_2^2\right)}{2L}, \quad \text{slope is } \frac{k}{\mu_g}$$

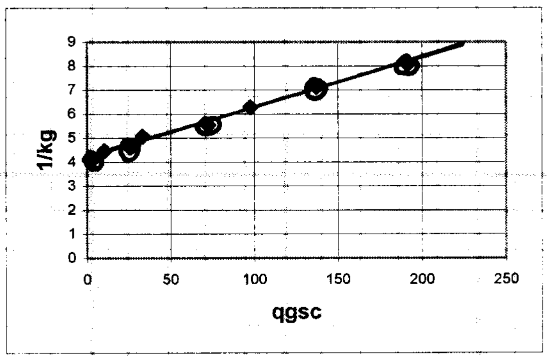
$$\frac{1}{k_g} = \frac{1}{k} + \frac{\beta\rho_g}{\mu_g}q_{g,sc}, \quad \text{plot } \frac{1}{k_g} \text{ vs } q_{g,sc}, \quad \text{slope is } \frac{\beta\rho_g}{\mu_g \mathbf{A}}$$

SOLUTION (see pp 3 & 4 for details)

(a)



(b)



$$\text{Slope} = \frac{60-0 \ \ atm\cdot cm^3/s/cm^2}{5 \ atm^2/cm}$$

$$= 12 \ \frac{cm^2}{s\cdot atm} = \frac{k}{\mu}$$

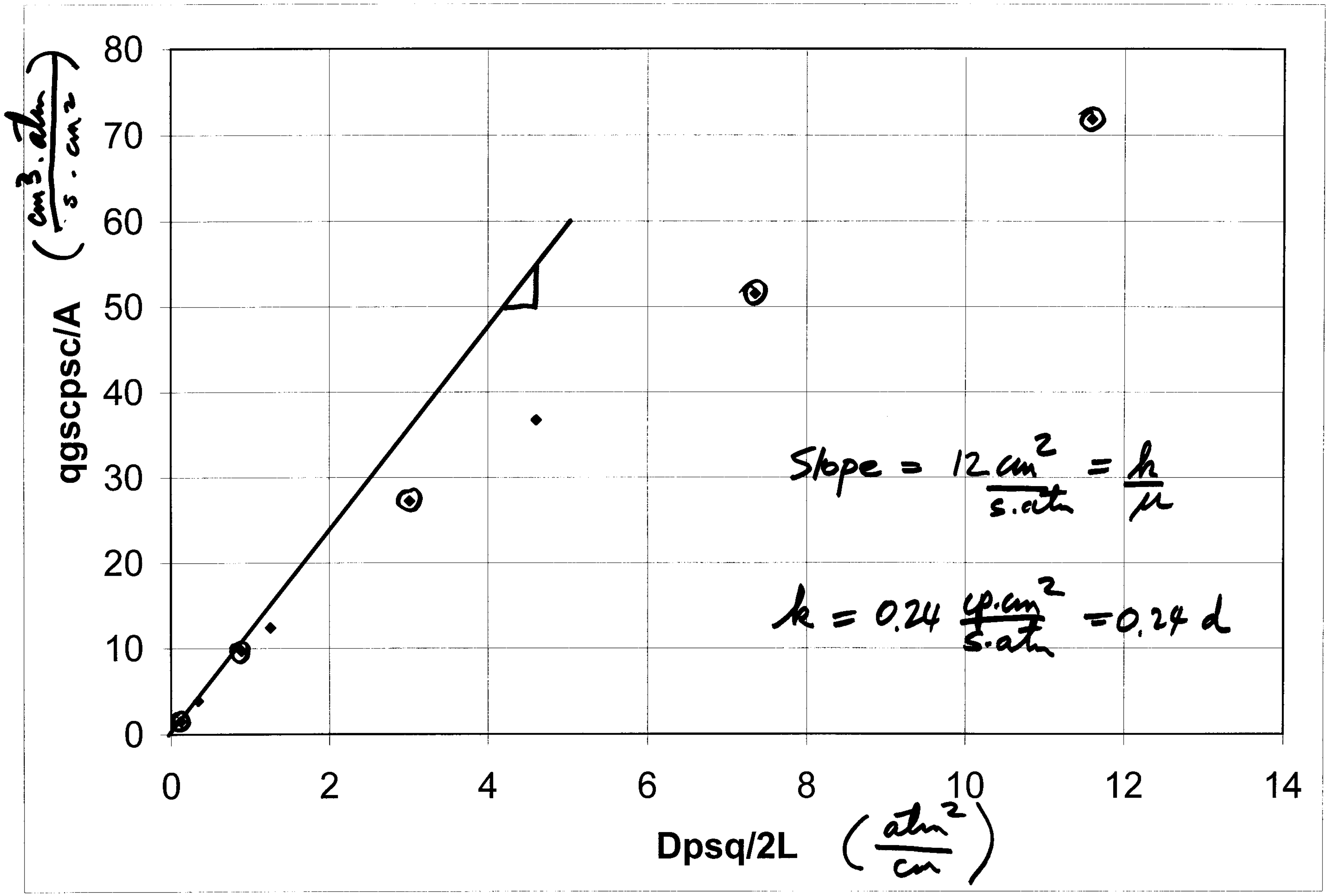
$$k = (12)(0.02) = 0.24 \ \frac{cp\cdot cm^2}{s\text{-}atm}$$

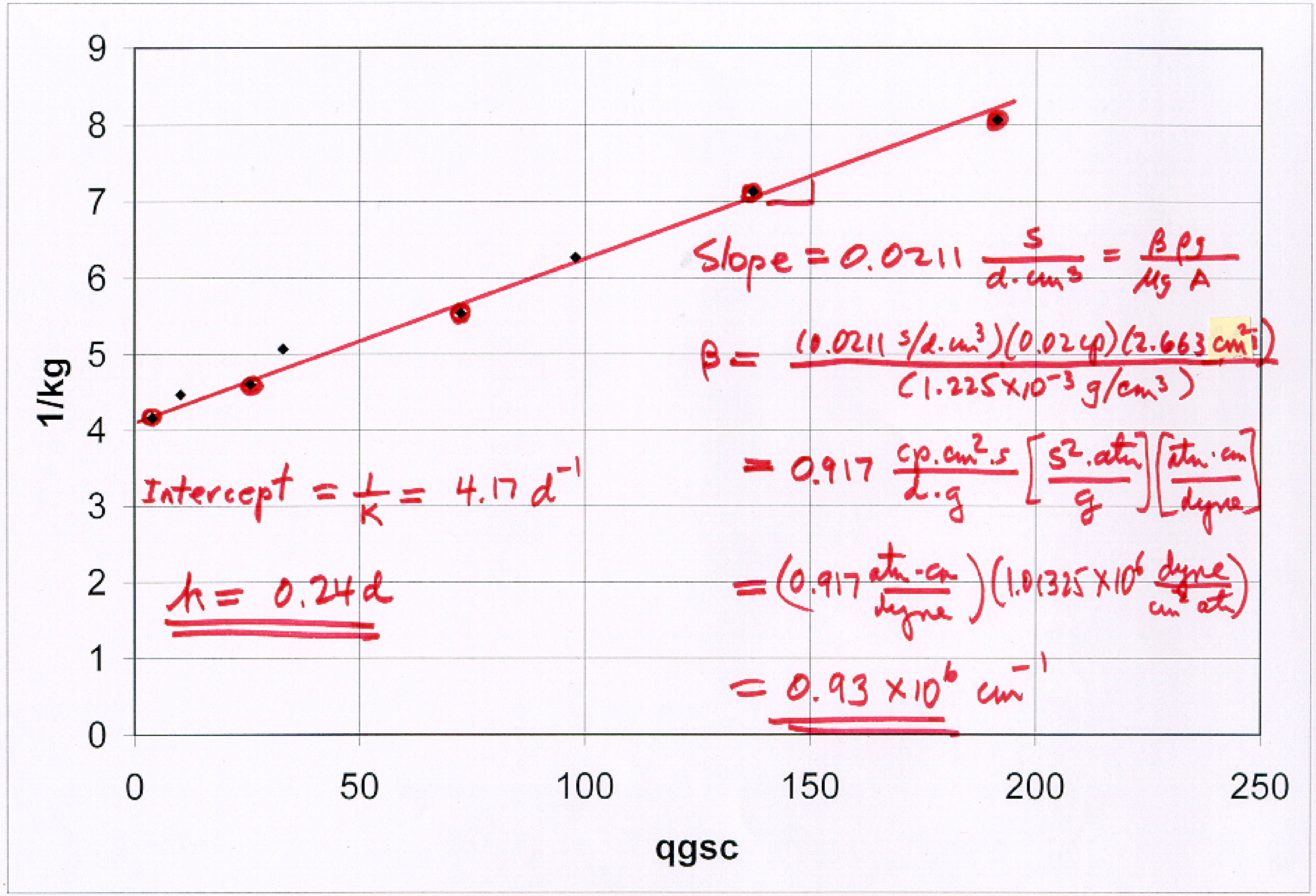
$$= 0.24 \ d$$

$$1/k = 4.166 \Rightarrow k = 0.24 d$$

$$\text{Slope} = 0.0211 \ \frac{s}{d\cdot cm^3} \Rightarrow$$

$$\beta = 0.95 \times 10^6 \ cm^{-1} \quad (0.93)$$


80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
qgscpsc/A $\left(\frac{cm^3 \cdot atm}{s \cdot cm^2}\right)$
Dpsq/2L $\left(\frac{atm^2}{cm}\right)$
Slope = $12 \frac{cm^2}{s \cdot atm} = \frac{k}{\mu}$
$k = 0.24 \frac{cp \cdot cm^2}{s \cdot atm} = 0.24$ d



$$\text{Slope} = 0.0211 \frac{s}{d \cdot cm^3} = \frac{\beta \rho_g}{\mu_g A}$$

$$\beta = \frac{(0.0211\ s/d \cdot cm^3)(0.02\ cp)(2.663\ cm^2)}{(1.225 \times 10^{-3}\ g/cm^3)}$$

$$= 0.917 \frac{cp \cdot cm^2 \cdot s}{d \cdot g} \left[\frac{s^2 \cdot atm}{g}\right] \left[\frac{atm \cdot cm}{dyne}\right]$$

$$= \left(0.917 \frac{atm \cdot cm}{dyne}\right)\left(1.01325 \times 10^6 \frac{dyne}{cm^2\ atm}\right)$$

$$= \underline{\underline{0.93 \times 10^6\ cm^{-1}}}$$

$$\text{Intercept} = \frac{1}{k} = 4.17\ d^{-1}$$

$$\underline{\underline{k = 0.24\ d}}$$