9/14/2023

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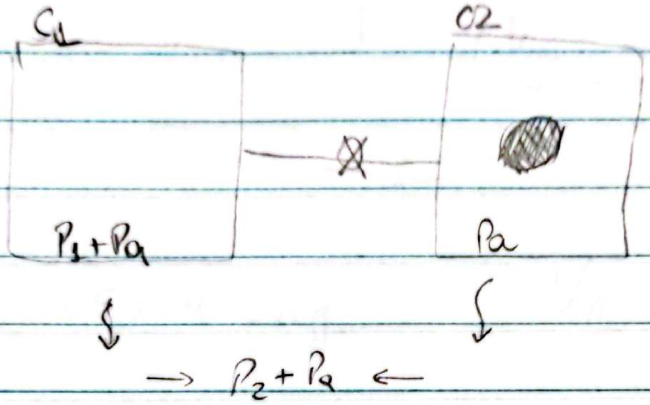
Advanced Petrophysics Fall 2023
PGE 381L

Homework #2

1

a



Boyle's law:

$$V_1 \cdot (P_1 + P_a) + (V_2 - V_s) P_a = (V_1 + V_2 - V_s)(P_2 + P_a)$$

$$\underline{V_1 P_1} + \cancel{V_1 P_a} + \cancel{V_2 P_a} - \cancel{V_s P_a} = \underline{V_1 P_2} + \underline{V_2 P_2} - \underline{V_s P_2} + \cancel{V_1 P_a} + \cancel{V_2 P_a} - \cancel{V_s P_a}$$

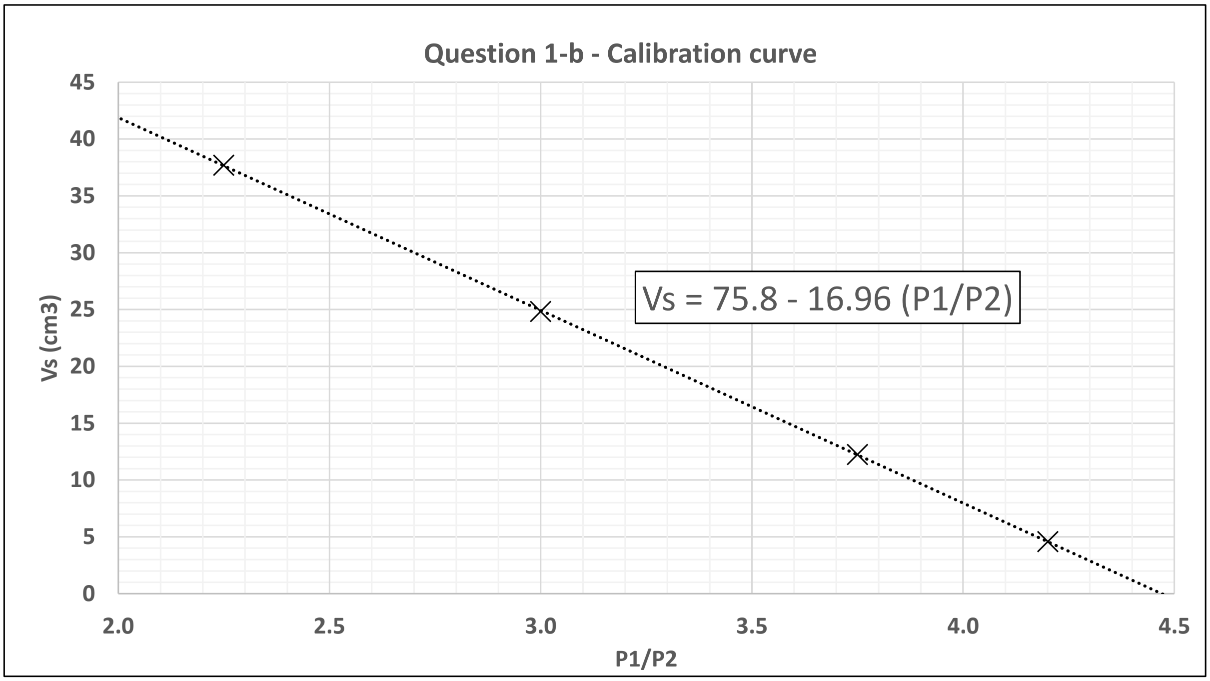
$$V_s P_2 = V_1 (P_2 - P_1) + V_2 P_2$$

$$V_s = V_2 + V_1 \frac{(P_2 - P_1)}{P_2} \Rightarrow \boxed{V_s = (V_1 + V_2) - \frac{P_1}{P_2} V_1}$$

b Excel sheet

Sphere Radius (cm)	P1 (psig)	P2 (psig)	Vs (cm3)	P1/P2
1.03	150.00	35.71	4.58	4.20
1.43	150.00	40.00	12.25	3.75
1.81	150.00	50.00	24.84	3.00
2.08	150.00	66.67	37.69	2.25

(V1+V2)	**75.8**	**cm³**
V1	**16.96**	**cm³**
V2	**58.84**	**cm³**



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(c) $V_s = 75.80 - 16.96\left(\frac{P_1}{P_2}\right)$

$\boxed{V_1 = 16.96\ cm^3}$

$V_2 = 75.80 - 16.96$

$\boxed{V_2 = 58.84\ cm^3}$

(d)

$P_2 = 50.4$ psig $\qquad V_B = 32\ cm^3$

$P_1 = 150$ psig

$V_s = 75.8 - 16.96\left(\frac{150}{50.4}\right) \Rightarrow V_s = 25.32\ cm^3$

$\phi = 1 - \frac{V_s}{V_B} = 1 - \frac{25.32}{32} \Rightarrow \boxed{\phi = 20.9\%}$

(e) The porosity calculated in part (d) is the connected porosity, as it is the porous space the gas could enter.

(2) $W_{sat} = 54.50\ g$ $\quad V_{water} = 1.66\ ml$

$W_{dry} = 51.05 g$ $\quad V_B = 23.7\ cm^3$

$\rho_{oil} = 0.87\ g/cm^3$ $\quad \rho_{grain} = 2.7\ g/cm^3$

(a) $V_s = \frac{W_{dry}}{\rho_{grain}} \Rightarrow V_s = 18.9\ cm^3$ $\quad V_p = V_B - V_s$

$V_p = 4.8\ cm^3$

$\phi = \frac{V_p}{V_s} \Rightarrow \boxed{\phi = 20.2\%}$

(b) $S_w = \frac{V_w}{V_p} = \frac{1.66}{4.8} \Rightarrow \boxed{S_w = 34.6\%}$

(c) $W_{sat} - W_{dry} = W_o + W_w$

$54.5 - 51.05 = V_o(0.87) + (1)(1.66)$

$V_o = 2.06\ cm^3$ $\quad S_o = \frac{V_o}{V_p} \Rightarrow \boxed{S_o = 42.9\%}$

$S_g = 1 - S_w - S_o \Rightarrow \boxed{S_g = 22.5\%}$

3) $\rho_B = 2.12\ g/cm^3$ $\qquad S_w = 20\% \rightarrow S_g = 80\%$

$\rho_{gas} = 0.19\ g/cm^3$

$\rho_{grain} = 0.4\rho_{calc.} + 0.6\rho_{dolom}$

$\rho_{grain} = 0.4(2.72) + 0.6(2.85)$

$\rho_g = 2.798$

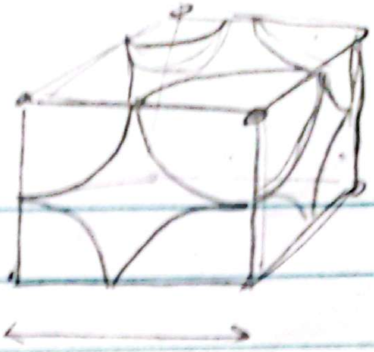
$$\rho_B = \phi(\rho_g S_g + \rho_w S_w) + (1-\phi)\rho_{grain}$$

$$2.12 = \phi[0.19(0.8) + 1(0.2)] + (1-\phi)(2.798)$$

$$2.12 - 2.798 = \phi(0.352) - \phi(2.798)$$

$$\boxed{\phi = 27.72\%}$$

4 a



$V_{cube} = r^3$

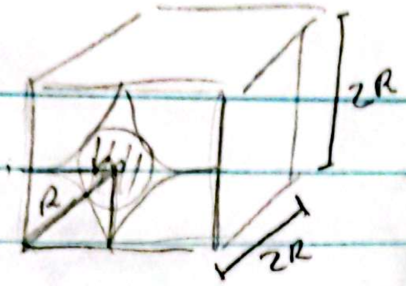
$V_{\substack{full\\sphere}} = \frac{4}{3}\pi\left(\frac{r}{2}\right)^3 = \frac{1}{6}\pi r^3$

Each corner has 1/8 of a sphere. There are 8 corners:

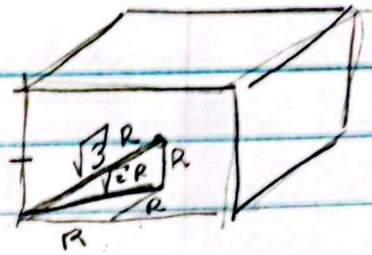
$V_{solid} = 8 \times \frac{1}{8} \times V_{\substack{full\\sphere}} = \frac{1}{6}\pi r^3$

$\phi = 1 - \frac{V_{solid}}{V_{cube}} \Rightarrow \phi = 1 - \frac{1}{6}\pi \Rightarrow \boxed{\phi \cong 47.6\%}$

4-6



$r = ?$



r = radius of the small spheres
R = radius of the large spheres

$R + r = d/2 \qquad d = \sqrt{3} \cdot 2R$

$R + r = \frac{\sqrt{3} \cdot 2R}{2} \rightarrow r = R(\sqrt{3} - 1)$

$V_{solid} = V_R + V_r = \frac{4\pi}{3} \cdot \left[R^3 + (0.732R)^3\right] = 5.83R^3$

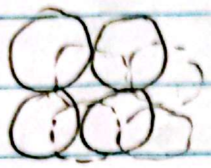
$V_{cube} = (2R)^3 = 8R^3$

$\phi = 1 - \frac{5.83}{8} \Rightarrow \boxed{\phi = 27\%}$

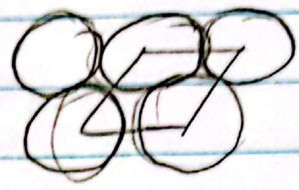
$\frac{47.6 - 27}{47.6} =$ 43.3% reduction in porosity

4c

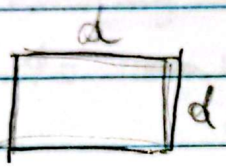
Front view



Bottom view

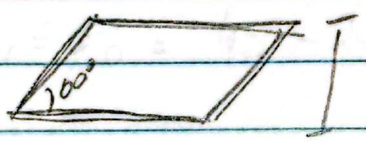


Front:



$A_B = d^2$

Bottom:



$h = d \sin 60°$

$V = d^3 \sin 60°$

Each slice of the space holds the volume of solid of a single sphere

$$V_{sphere} = \frac{4}{3}\pi\left(\frac{d}{2}\right)^3 = \frac{1}{6}\pi d^3$$

$$\phi = 1 - \frac{V_{sphere}}{V_{slice}} = 1 - \frac{1}{6}\pi \cancel{d^3} \cdot \frac{1}{\cancel{d^3}\sin 60} \Rightarrow$$

$$\boxed{\phi = 39.54\%}$$

Percent difference between cubic and hexagonal packets.

$$\Delta\phi = \phi_C - \phi_H = 44.6 - 39.54 \Rightarrow \boxed{\Delta\phi = 8\%}$$

5

a) X550 ft

→ PEF ≈ 2 b/e ⇒ quartz,
→ low GR ⇒ low clay.
→ low Resistivity ⇒ water saturated ($\phi_N = \phi_D$)
→ $\phi_N \cong \phi_D$ ⇒ we can read porosity directly
(sandstone rock)

$\phi \cong \phi_N \cong \phi_D = 45 - 2.5 \times 12 \cong 15\%$.

b) X380 ft

→ PEF ≈ 5 b/e ⇒ calcite
→ low GR → low clay
→ $\phi_N \approx \phi_D$ (limestone rock)

$\phi \approx \phi_N \approx \phi_D = -15 + 12 \times 1.5 = 3\%$

c) → PEF ≈ 2 b/e ⇒ quartz
→ low GR → low clay
→ $\phi_N \approx \phi_D$

$\phi \approx 45 - 2.8(12) = 11.4\%$.