**Advanced Petrophysics**
**PGE 381L, Fall 2023**
**Unique Number: 20215**

# Homework Assignment No. 2

September 7, 2023
Due on September 14, 2023, before 11:00 PM

Name: ______________________ **Solution** ______________________________

UT EID: ____________________________________________________________________

**Objectives:**

a) To practice assessment of porosity from laboratory measurements
b) To practice assessment of porosity in-situ condition using well logs



**Note:** Please scan your homework assignment and upload it as one pdf file on the Canvas website before the deadline. Please name your homework document as follows:

*PGE381L_2023_Fall _HW02_lastname_name.pdf*

Example: PGE381L_2023_Fall_HW01_Heidari_Zoya.pdf

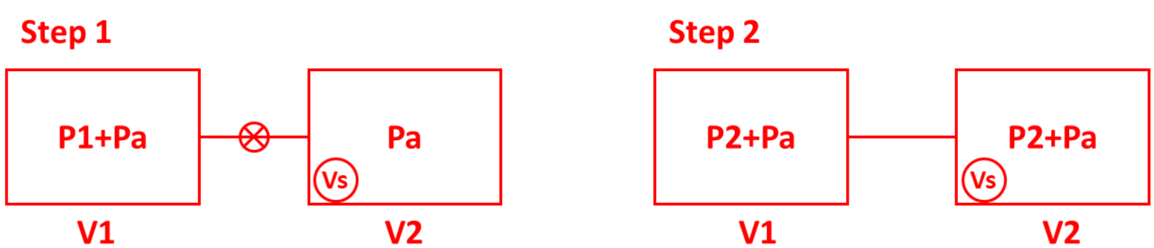
**Question 1:** A two-chamber Boyle's law porosimeter was calibrated with steel spheres. Cells 1 and 2 were initially isolated by closing the connecting valve. The sample was placed in Cell 2 and maintained at atmospheric pressure Pa. Cell 1 was filled with Helium to an absolute pressure of ($P_1$ + Pa). The connecting valve was then opened to interconnect the cells. The final equilibrium absolute pressure in the two cells was ($P_2$ + Pa). Table 1 summarizes the calibration results for three different steel spheres.

**Table 1**

| Sphere Radius (cm) | $P_1$ (psig) | $P_2$ (psig) |
|---|---|---|
| 1.03 | 150 | 35.71 |
| 1.43 | 150 | 40.00 |
| 1.81 | 150 | 50.00 |
| 2.08 | 150 | 66.67 |

a) Derive the relationship between volume of grains/solid content and $P_1$ and $P_2$ assuming Helium is behaving similar to an ideal gas.
b) Plot an appropriate calibration curve for the porositmeter.
c) Determine the volumes of the cells, $V_1$ and $V_2$.
d) Determine the porosity of a rock sample given that the equilibrium $P_2$ was 50.4 psig, when a measurement was performed with the sample at the same $P_1$ as in the calibration tests. The bulk volume of the sample had previously been determined to be 32 cc.
e) Is the porosity in part (d) total or connected porosity?

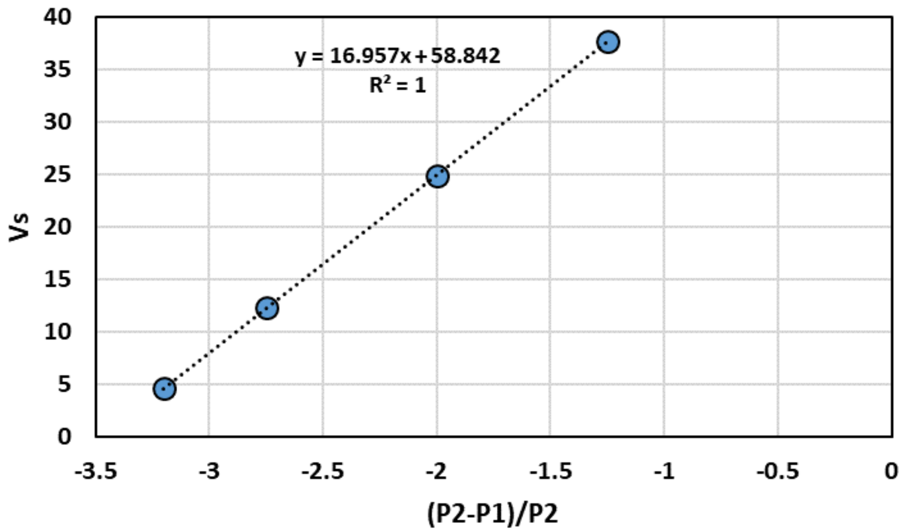
**(a)**




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

$$V_s=V_2+\left(\frac{P_2-P_1}{P_2}\right)V_1$$

**(b)**




**(c) $V_2$ will be the intercept and $V_1$ will be the slope of the equation**

**$V_1$ = 16.95 cc, $V_2$ = 58.84 cc**

**(d)**

$$P_2 = 50.4\,\mathbf{psig}, P_1 = 150\,\mathbf{psig}, V_b = 32\,\mathbf{cc}$$

$$V_s = 16.95\left(\frac{50.4 - 150}{50.4}\right) + 58.84 = 25.34\,\mathbf{cc}$$

$$\phi = \frac{32 - 25.34}{32} = 0.208 = 20.8\%$$

**(e) Connected Porosity**

**Question 2:** A sample is cut from a preserved core for the purpose of determining porosity and fluid saturations. The water and oil in the sample were extracted using a Soxhlet extractor. The results of all the measurements made on the sample are listed as follows:

Weight of sample in air = 54.50 g
Volume of water recovered during extraction = 1.66 ml
Weight of sample after extraction and drying = 51.05 g
Bulk volume of sample = 23.70 cc

Density of oil extracted from core = 0.87 g/cc
Grain density = 2.70 g/cc

Answer the following questions:

a) Calculate porosity of the sample.
b) Calculate water saturation of the sample.
c) Calculate oil saturation and gas saturation of the sample.

**(a)**

$$V_g = \frac{51.05}{2.7} = 18.91\,cc$$
$$V_p = V_b - V_g = 23.7 - 18.91 = 4.79\,cc$$
$$\phi = \frac{V_p}{V_b} = \frac{4.79}{23.7} = 0.2 = 20\%$$

**(b)**

$$S_w = \frac{V_w}{V_p} = \frac{1.66}{4.79} = 35\%$$

**(c)**

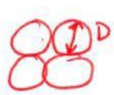
$$W_w = 1.66c, \rho_w = 1g/cc$$
$$W_o = W_{sat} - W_{dry} - W_w = 54.5 - 51.05 - 1.66 = 1.79g$$
$$V_o = \frac{W_o}{\rho_o} = \frac{1.79}{0.87} = 2.06\,cc$$
$$S_o = \frac{V_o}{V_p} = \frac{2.06}{4.79} = 43\%$$
$$S_g = 1 - S_w - S_o = 22\%$$

**Question 3:** Bulk density at depth X in a gas-bearing carbonate formation is measured to be 2.12g/cc. The matrix is composed of 40% calcite and 60% dolomite. Water saturation at depth X is equal to 20%. You can assume that density of gas at in-situ condition is 0.19g/cc. Estimate porosity of this formation at depth X.

$$\rho_b = \phi\left(s_w\rho_w + s_g\rho_g\right) + (1-\phi)\rho_m$$
$$2.12 = \phi\left(0.2(1) + 0.8(0.19)\right) + (1-\phi)\left(0.4(2.71) + 0.6(2.87)\right)$$
$$\phi = 0.28$$

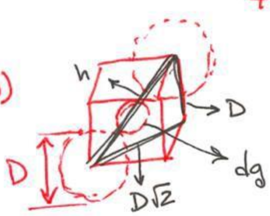
**Question 4:** A synthetic porous medium consists of a cubic pack of solid steel balls of equal diameter. Answer the following questions:

- **a)** Estimate porosity of this porous medium.
- **b)** If the pores of this cubic pack are filled with smaller steel balls that fit exactly in the pore spaces between the larger balls, calculate the porosity of the new porous medium consisting of two grain sizes. Calculate the percent reduction in porosity due to this poor sorting.
- **c)** Repeat part (a) for a hexagonal packing. Calculate the percent difference in porosity due to packing.

a) 


$V_b = D^3 \qquad V_g = \frac{4}{3}\pi\left(\frac{D}{2}\right)^3 \times \frac{4}{4} = \frac{1}{6}\pi D^3$

$$\phi = \frac{V_b - V_g}{V_b} = \frac{D^3(1-\pi/6)}{D^3} = 47.6\%$$

b) 

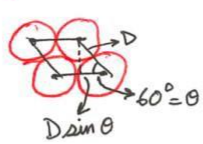

$h = \sqrt{D^2 + (D\sqrt{2})^2} = D\sqrt{3}$

$d_g = h - 2\left(\frac{D}{2}\right) = D(\sqrt{3}-1)$

$$V_g' = \frac{1}{6}\pi D^3 + \frac{4}{3}\pi\left[\frac{D}{2}(\sqrt{3}-1)\right]^3 = \frac{1}{6}\pi D^3 + \frac{1}{6}\pi D^3(\sqrt{3}-1)^3 = \frac{1}{6}\pi D^3\left[1+(\sqrt{3}-1)^3\right]$$

$$\phi' = \frac{V_b - V_g'}{V_b} = \frac{D^3 - \frac{1}{6}\pi D^3\left(1+(\sqrt{3}-1)^3\right)}{D^3} \Rightarrow \phi' = 27.1\%$$

percent reduction = (47.6 − 27.1)/47.6 = 43%

c) 


$V_b = D^2(D\sin\theta) = \frac{\sqrt{3}}{2}D^3 \qquad V_g = \frac{1}{6}\pi D^3$

$$\phi = \frac{D^3(\sqrt{3}/2 - \pi/6)}{\sqrt{3}/2\, D^3} = 39.5\% \Rightarrow \text{percent reduction} = \frac{47.6-39.5}{47.6} = 17\%$$

**I suggest to work on this question after our Tuesday's (9/12/23) lecture. I will distribute some examples in the class on Tuesday.**

**Question 5:** Consider Field Example No. 1 in the well-log data package, which is distributed in the class. Answer the following questions:

Hint: You need to first identify the dominant lithology at each depth of interest. For that purpose, you can use Photoelectric Factor (PEF) measurement, which is sensitive to matrix composition. PEF values for quartz and calcite are approximately 2 b/e and 5 b/e, respectively.

a) Estimate porosity of the formation at depth X550 ft. List your assumptions (if any).
b) Estimate porosity of the formation at depth X380 ft. List your assumptions (if any).
c) Estimate porosity of the formation at depth X440 ft. List your assumptions (if any).

**(a) Dominant Lithology: Quartz, $\rho_m$=2.65g/cc**
**Fluid type: water, $\rho_f$=1g/cc**

$$\phi = \frac{\rho_b - \rho_m}{\rho_f - \rho_m} = \frac{2.43 - 2.65}{1 - 2.65} = 13\%$$

**(b) Dominant Lithology: Calcite, $\rho_m$=2.71g/cc**
**Fluid type: water, $\rho_f$=1g/cc**

$$\phi = \frac{\rho_b - \rho_m}{\rho_f - \rho_m} = \frac{2.7 - 2.71}{1 - 2.71} = 0.6\%$$

**(c) Dominant Lithology: Quartz, $\rho_m$=2.65g/cc**
**Fluid type: water, $\rho_f$=1g/cc**

$$\phi = \frac{\rho_b - \rho_m}{\rho_f - \rho_m} = \frac{2.43 - 2.65}{1 - 2.65} = 13\%$$