

# Porosity - Permeability Practical

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Be careful about unit consistency when solving a scientific problem

## PART A: Porosity measurement

In this part, we aim to provide a quick and accurate means to measure the porosity (or the amount of voids) of rocks by saturating them with water. **The related excel spreadsheet is located in the “PART A Porosity” tab of the Porosity\_Permeability.xlsx document.**

*Material needed:*

- Beaker/ graduated cylinder
- Set of scales
- Rock samples

*Method:*

1. Measure the mass,  $m_{dry}$ , the length,  $L$ , and the diameter,  $d$ , of all samples
2. Put all samples in the beaker
3. Weigh each sample after removing excess water (by gently shaking the sample):
  - After 1 minutes; report solid density ( $\text{g/cm}^3$ ) and porosity (%)
  - After 5 minutes; report solid density ( $\text{g/cm}^3$ ) and porosity (%)
  - After 10 minutes; report solid density ( $\text{g/cm}^3$ ) and porosity (%)

Each sample should become heavier as water permeates through the pores. This technique, while being time consuming is the most accurate and is the basic principle behind all porosity measurements performed in laboratories. Importantly, a sample will be saturated once the weight stabilises to a set value. It is worth noting that water infiltration is faster with a greater volume of water.

The determination of both porosity and density is determined by:

Due to the density of water ( $1 \text{ g/cm}^3 = 1000 \text{ kg/m}^3$ ), the mass difference between the corresponding dry sample,  $m_{dry}$ , and after water infiltration,  $m_{wet}$ , directly gives the volume of water inside the pores,  $V_{pores}$ :

$$V_{pores} = m_{wet} - m_{dry}$$

The porosity,  $\phi$ , is calculated from the ratio between the volume of pores,  $V_{pores}$ , and the volume of the rock cylinder calculated in step 1,  $V_{rock}$ :

$$\phi = \left( \frac{V_{pores}}{V_{rock}} \right) \times 100$$

The skeletal volume, or the true volume of solid in the sample (without the volume of pores), is then given by:

$$V_{skeletal} = V_{rock} - V_{pores}$$

This can be used to calculate the solid density,  $\rho$ , (in  $\text{g/cm}^3$ ) using the mass  $m_{dry}$  and the skeletal volume,  $V_{skeletal}$

$$\rho = \frac{m_{dry}}{V_{skeletal}}$$

## PART B: Permeability measurements

Here, we focus on determining the permeability of rock samples using the Constant head method. **The related excel spreadsheet is located in “PART B Permeability” tab of the Porosity\_Permeability.xlsx document.**

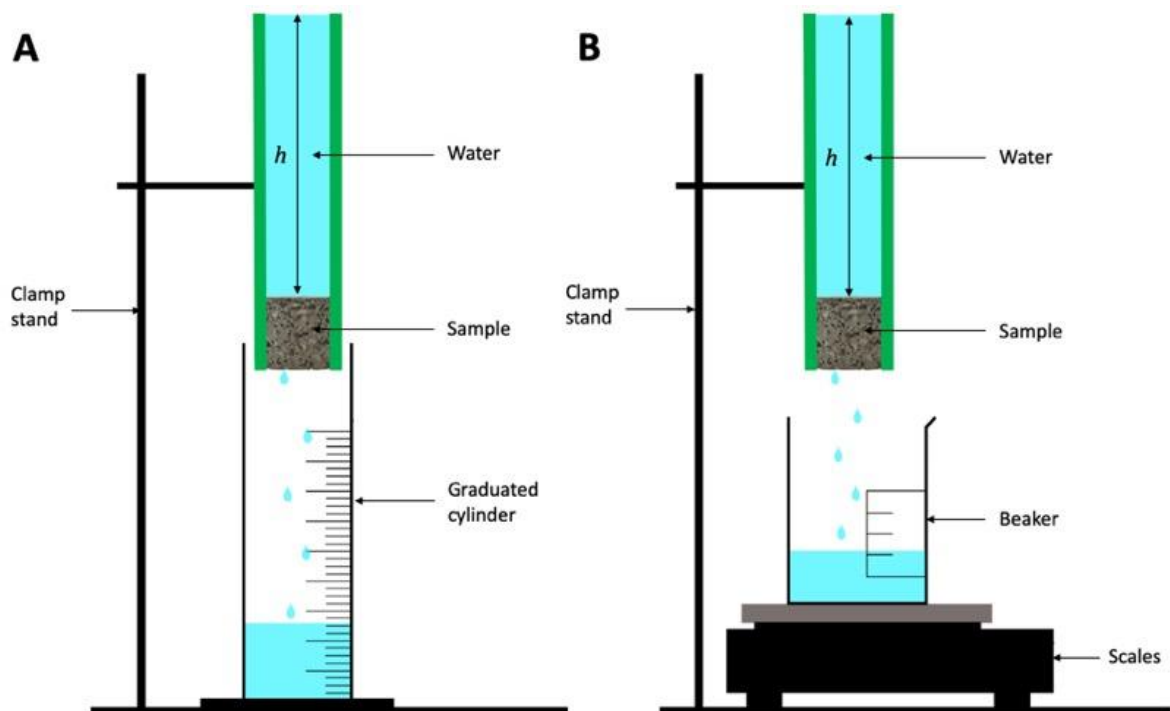
*Material needed:*

- Rubber jacket
- Vertical stand
- Callipers
- Water recipient
- Graduated cylinder or beaker with a set of scales
- Rock samples

1. Measure your sample dimensions (length,  $L$ ; diameter,  $d$ ). The cross-sectional area,  $A$ , of the top of the sample will be calculated via:

$$A = \pi \left( \frac{d}{2} \right)^2$$

2. Place your sample at one end of the green jacket, and measure the height of the empty pipe above the sample (overhead height), then attach the setup to the holding stand. Place the A) graduated cylinder; or B) beaker with the set of scales below the column to collect water and fill in the overhead height with water. Throughout the experiment, you will have to make sure that the water level above the sample stays constant by topping it up continuously.



3. The Pressure differential,  $\Delta P$ , applied is then calculated by:

$$\Delta P = \rho gh$$

where  $\rho$  is the density of water (1000 kg/m<sup>3</sup>),  $g$  is the gravitational acceleration (9.81 m/s<sup>2</sup>),  $h$  is the overhead height (in m).

4. Monitor the volume of water in the graduated cylinder through time (acquisition rate is up to you!) and enter the values in the excel spreadsheet. If using a beaker and set of scales, the weight directly converts to a volume due to the density of water (where mass of water of 1 gram = volume of 1 ml = 1 cm<sup>3</sup> = 0.000001 m<sup>3</sup>).

a. On a Volume versus Time graph, you should reach a linear relationship once the sample is completely saturated with water. Two illustrative examples are provided below: A) sample reaching saturation during measurement; and B) sample already saturated prior to measurement.

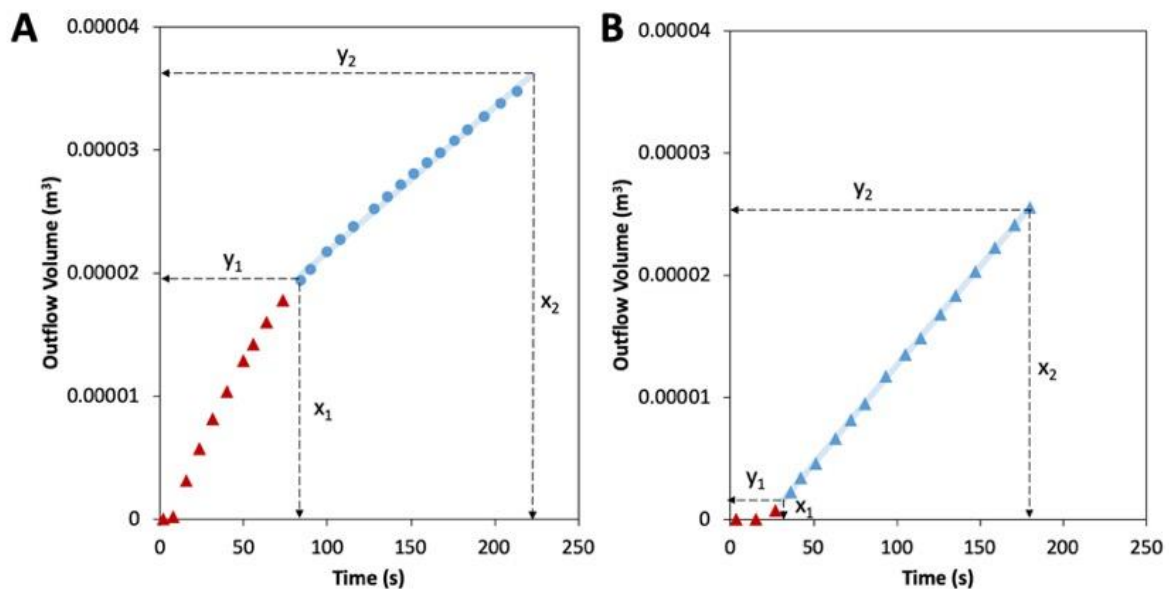
b. Calculate the slope of the line to get the flow rate  $Q$  (in m<sup>3</sup>/s)

$$Q = \frac{y_2 - y_1}{x_2 - x_1}$$

c. The permeability of the sample,  $\kappa$ , can then be determined using the parameters calculated above:

$$\kappa = \frac{0.001 \times Q \times l}{A \times \Delta P}$$

where 0.001 is the viscosity (or resistance to flow) of water.



PART C: Reflecting on validity of the measurements

Here, we test the validity of the porosity and permeability measurements by investigating errors associated to the different quantities involved in the calculations. For instance, determining permeability involves several measurements of each parameter, each involving different errors. For example, calculating the flow rate that itself contains errors associated to the volume determination (i.e. the accuracy of the scales or gradations of the graduated cylinder) and to the time at which the volume measurement is made. Adding all these errors is not linear and can be calculated to prove the validity of a measurement. **The related excel spreadsheet is located in “Errors” tab of the Porosity\_Permeability.xlsx document.**

In this part of the practical, you should calculate the percentage error associated to taking several measurements of the dimensions (length and diameter) of the plug:

1. Determine the mean dimensions,  $\bar{x}$ , for both length and diameter using:

$$\bar{x} = \frac{\sum x}{n}$$

where  $n$  is the number of length measurements you decide to perform and  $\sum x$  is the sum of these measurements.

2. Determine the mean diameter,  $\bar{d}$  of the sample using the same equation.
3. Calculate the percentage error using for both the length and diameter:

$$\% \text{ error} = \frac{2 \times \text{absolute uncertainty}}{\bar{x}} \times 100$$

The absolute uncertainty is determined by taking:

$$\text{absolute uncertainty (+)} = \text{maximum measurement} - \text{mean measurement}$$

and

$$\text{absolute uncertainty (-)} = \text{mean measurement} - \text{minimum measurement}$$

4. In the Errors tab of the excel spreadsheet, fill in cells F2 to F5.

% error (+) on diameter	
% error (-) on diameter	
% error (+) on length	
% error (-) on length	