**Use of the 3-phase diagram**

**Soil Relationships**

- \( V_t = V_a + V_w + V_s \)
- \( W_t = W_w + W_s \)
- \( W_w = V_w D_p \) (\( V_w \times 1 \text{ g/cc} \))
- \( W_s = V_s D_p \)

**Definitions**

- Void ratio = \( e = \frac{V_p}{V_s} \)
- Porosity = \( n = \frac{V_p}{V_t} \)
- Water content = \( \theta_m = \frac{W_w}{W_t} \) (moisture content)
- % moisture = \( \frac{W_w}{W_t} \times 100\% \)
- % solids = \( \frac{W_s}{W_t} \times 100\% \)
- Degree of saturation = \( S = \frac{V_w}{V_p} \)
- Particle density = \( D_p = \frac{W_s}{V_s} \) (specific gravity)
- Bulk density = \( D_b = \frac{W_s}{V_t} \)

Note: all of these are normally expressed as a “%”, i.e., times 100%

**Example 1**

A soil has the following characteristics:
- Wet weight = 2500 g
- Dry weight = 2000 g
- Void ratio = 100%
- Particle density = 2.5 g/cc
### Find

**Water content (moisture content)**

\[ \theta_m = \frac{W_w}{W_s} \times 100\% \]

\[ = \frac{500 \text{ g}}{2000 \text{ g}} \times 100\% \]

\[ = 25\% \]

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**Example 2**

A soil has the following characteristics:

- Dry weight \( = \) 2000 g
- Moisture content \( = \) 50%
- Volume \( = \) 2000 cc
- Particle density \( = \) 2.65 g/cc

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### MOISTURE RELATIONSHIPS

**Water (moisture) content**

\[ = 25\% \]

**% moisture**

\[ = \frac{W_w}{W_t} \]

\[ = \frac{500 \text{ g}}{2500 \text{ g}} \times 100\% \]

\[ = 20\% \]

**% solids**

\[ = \frac{W_w}{W_t} \]

\[ = \frac{2000 \text{ g}}{2500 \text{ g}} \times 100\% \]

\[ = 80\% \]

Therefore:

\[ \% \text{ moisture} = 100\% - \% \text{ solids} \]
Find

Porosity \( n = \frac{V_p}{V_t} \)
\[ = \frac{1245 \text{cc}}{2000 \text{cc}} \times 100\% \]
\[ = 62\% \]

Find

Void ratio \( e = \frac{V_p}{V_s} \)
\[ = \frac{1245 \text{cc}}{755 \text{cc}} \times 100\% \]
\[ = 165\% \]

Find

Degree of saturation \( S = \frac{V_w}{V_p} \)
\[ = \frac{1000 \text{cc}}{1245 \text{cc}} \times 100\% \]
\[ = 80\% \]

Measuring water in soil

% moisture \( = \frac{W_w}{W_t} \)
% solids \( = \frac{W_s}{W_t} \)

Measuring bulk density

\( D_b = \frac{W_s}{V_t} \)

Measuring pore space

\( V_p = \text{volume of water used to entirely fill up voids} \)
\( D_p = \frac{W_s}{(V_t - V_p)} \)
Alternate for measuring pore space

\[ V_p = V_t - V_s \]
\[ D_p = \frac{W_s}{V_s} \]

Oven dry sample
determine dry weight

Known volume \( = V_t \)