Particle size distribution etc.

- According to MIT particle size classification, soil particles are called gravel (> 2\,mm), sand (2 - 0.06\,mm), silt (0.06 - 0.002\,mm), clay (< 0.002\,mm).

According to USDA classification the classes are gravel (> 2\,mm), sand (2 - 0.05\,mm), silt (0.05 - 0.002\,mm), clay (< 0.002\,mm).

Write a code that prints out the amount of gravel, sand, silt, and clay content given the particle size distribution (PSD) as input. *(your code should have the option of at least two different interpolation methods to extract these quantities)*.

- PSD data is usually plotted with x axis giving particle size in log scale (mm) with y(x) giving the total percentage of particle with size smaller than x.

Given a PSD data write a code that calculates \( D_{10}, D_{30}, D_{60} \). Where \( D_n \) is the size corresponding to y-value of \( n\% \). Print out effective size (\( D_{10} \)), uniformity coefficient (\( D_{60}/D_{10} \)), coefficient of gradation (\( D_{30}^2/(D_{60}D_{10}) \)). *(your code should have the option of at least two different interpolation methods to extract these quantities)*.

- Write a code that converts above data to plot the PSD so that X axis is now the surface area assuming all particle to be spheres.

Do the same for cubic, rectangular, cylindrical, elliptical particles.

Compare the curves obtained for different particle shapes.

- A particular soil sample has particle size(d) distribution \( P(d) \). A well mixed suspension of that soil in water is settling in a beaker. Find out the distribution of the particle of a given size \( d \) in the beaker, after a time \( t \).

- In 2d world, a square piece of rock is subjected to following weathering process: every year any square piece with size \( a \) cracks so that four equal square pieces are created, each with side \( a/2 \). Also the cracks expand so that \( a \rightarrow a(1 + \delta) \).

After \( n \) years, find out the length of the sides of the pieces, no of pieces, total void area, total perimeter.

generalise to D-dimension.

- A gas bubble (radius \( d \) mm, density: 1\,kg/m\(^3\)) is going up through magma (density: \( 3 \times 10^3\,kg/m^3 \), viscosity \( \sim 10^3\,Pa.s \)). Come up with some approximate estimate of the velocity of the bubble. Point out clearly the assumptions made.

- Find out the no of surface electrons in one gram of illite, montmorillonite and Kaolinite.

How does is compare with the no of conduction electrons in one gram of a monovalent metal (say, Atomic weight= 60.23)?

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Weight-Volume relations

With $V_s$ volume of soil solids, $V_v$ volume of voids, $V_w$, and $V_a$ water, air in the void and corresponding weights given by $W_{s/v/w/a}$ following quantities are defined,

- void ratio: $e = V_v/V_s$ (1)
- porosity: $n = V_v/V$ (2)
- degree of saturation: $S = V_w/V_v$ (3)
- moisture content: $w = W_w/W_s$ (4)
- unit weight: $\gamma = W/V$ (5)
- dry unit weight: $\gamma_d = W_s/V$ (6)

Where $W$ and $V$ are the total volume and weight. We denote unit weight of Water by $\gamma_w$ and specific gravity of the soil solids by $G_s$.

Now prove,

- $Se = wG_S$
- $\gamma_d = G_s\gamma_w(1 - n)$
- $\gamma = G_s\gamma_w(1 - n)(1 + w)$
- for saturated soil, $\gamma_{sat} = (e(1 + w))/(w(1 + e))\gamma_w$
- In a particular contaminated soil sample, some pore space is taken up by oil (density $\rho_o$). Here find out the relationship between $\gamma$ and $\gamma_d$. 

Compaction

- In a contaminated sample with some oil of density $\rho_o$ taking up some of the pore spaces($V_o$ and $W_o$), find out $\gamma_{max}^d$.

Darcy Flow, Aquifers etc

- Through some porous media ($K = 1$ unit), find out the flow velocity for flow of air, water, magma for unit head gradient.
- In case of upward flow of magma through porous rock, the elevation head is opposing the flow. Is it possible for magma then to go up? How to estimate the relevant heads?
• For river fed by baseflow from aquifer, the discharge goes down exponentially with time \( t \), \( Q(t) = Q_0 e^{-t/\tau} \). What quantities would control the time constant of the decay, \( \tau \)?

• For a vertical Darcy flow through a soil with conductivity \( k(z) = a + b \cdot z \), find out the effective conductivity \( K_{eff}^v \).

• For a horizontal Darcy flow through a soil with conductivity \( k(x) = a + b \cdot x \), find out the effective conductivity \( K_{eff}^H \).

• In tilted column filled with a soil sample, and having of cross section \( A \), the elevation head \( \Delta h \) would cause a Darcy flow from top to bottom. Now if the same column with its orientation fixed is placed inside a water bath. What is the flow direction and head difference now?

• In a U-tube (a ‘U’ shaped tube) the bottom part is filled with soil (length of soil filled section is \( L \), hydraulic conductivity \( K \)). Also, There is a special membrane separating the two arms, such that only water can pass through but not the solutes. At \( t = t_0 \), the both the sides are filled with water up to height \( h_0 \). What is the configuration after time \( t \)? At \( t = t_1, (t_1 >> t_0) \), some water soluble salt is added to the left tube, so that concentration is \( \rho \text{ kg/m}^3 \). What is the configuration after time \( t > t_1 \)?

• A soil sample has horizontal (vertical) conductivity \( K_H (K_v) \). The flow direction is along some angle \( \theta \). Calculate the flow velocities?

Any comments? For example is direction of flow is along the gradient?

• Let the infiltration capacity be (in mm/hr), \( f(t) = f_c + (f_0 - f_c) e^{(-t/\tau)} \). For a steady rainfall rate, \( r \text{ mm/hr} \). Find out the total infiltrated water after time \( t \).

Do you need to worry about the actual value of \( r \) compared to \( f_0 \) and \( f_c \).