

Shs 5896

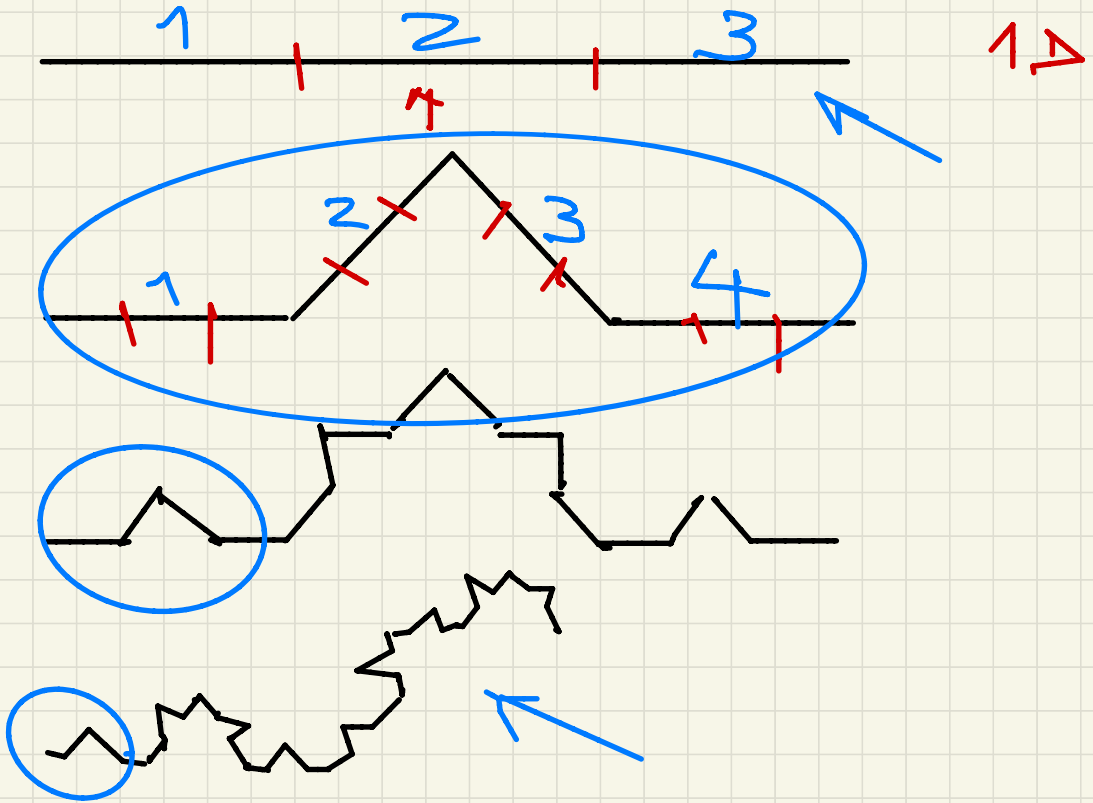
2020

Edson Wendland

EESC / USP



número fractal
auto-simil: Larielade



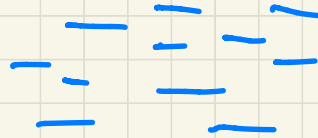
$$N = \frac{4}{3} = 1,33 D$$

Simbologia

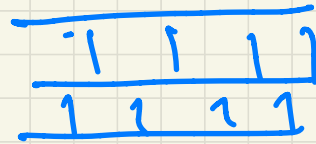
arenosos



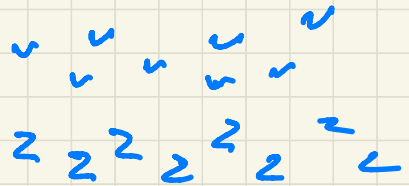
f. l. t. e. =
arg. l. c.



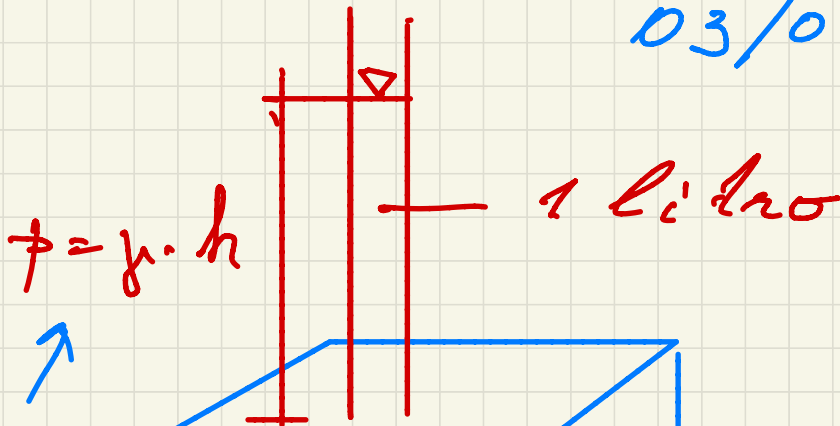
calcáreos
carbonatos



magnéticas



03/09/2020



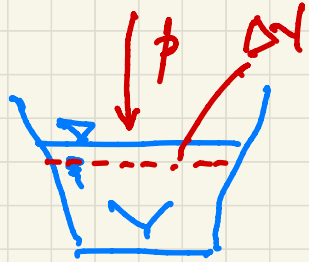
$h = 20 \text{ m}, 100 \text{ m}, 1000 \text{ m}, 250 \text{ m}, 100 \text{ m}, 1000 \text{ m}, 500 \text{ m}$

$$p = 1 \text{ MPa} = 10^6 \text{ Pa}$$

Compressibilidade

$$\beta = 4,8 \cdot 10^{-10} \text{ m}^2/\text{N}$$

$$\beta = - \frac{\frac{\Delta V}{V}}{p}$$



$$\rightarrow \rho = \frac{9789 \text{ N/m}^3}{1 \text{ m}^3}$$

$$\Delta V = -1 \text{ l} = -10^{-3} \text{ m}^3$$

$$p = - \frac{\Delta V}{V} \cdot \frac{1}{\beta}$$

$$p = \frac{10^{-3}}{1} \cdot \frac{1}{4,8 \cdot 10^{-10}} \left[\frac{\text{m}^3}{\text{m}^3} \cdot \frac{\text{N}}{\text{m}^2} \right]$$

$$p = \frac{10 \cdot 10^{-4} \cdot 10^{10}}{4,8} \approx 2 \cdot 10^6 \frac{\text{N}}{\text{m}^2}$$

$$p \approx 2 \cdot \text{MPa}$$

$$p = \rho \cdot h \quad \therefore \quad h = \frac{p}{\rho} = \frac{2 \cdot 10^6}{9789} \approx 200 \text{ mca}$$

$$m_x = \rho \cdot u_x \cdot \Delta x$$

$$= \frac{\text{kg}}{\cancel{\text{m}} \cdot \cancel{\text{s}}} \cdot \frac{\cancel{\text{m}}}{\text{s}} \cdot \cancel{\text{m}^2}$$

$$\dot{m}_x = 1 \text{ kg/s}$$

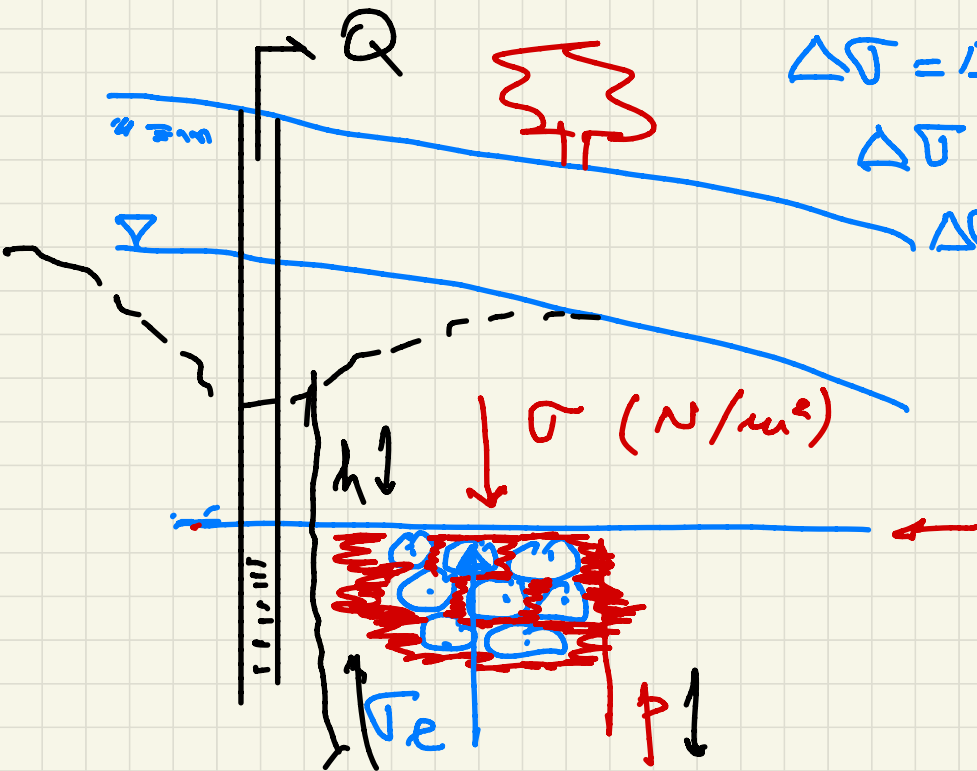
$$\frac{\partial m}{\partial z} = \frac{1 \text{ kg}}{1 \text{ s}}$$

$$G = G_1 + \mathbb{1}$$

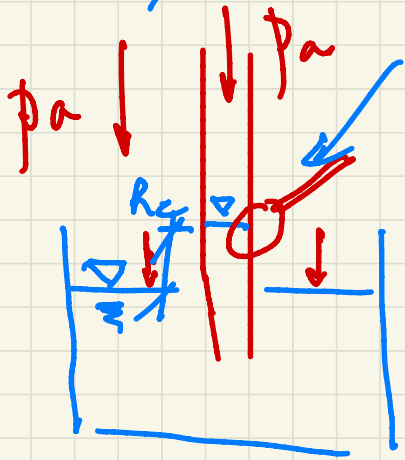
$$\Delta \sigma = \Delta \sigma_e + \Delta p$$

$$\Delta \bar{U} = 0$$

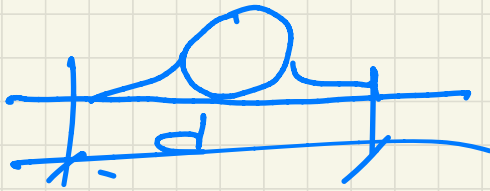
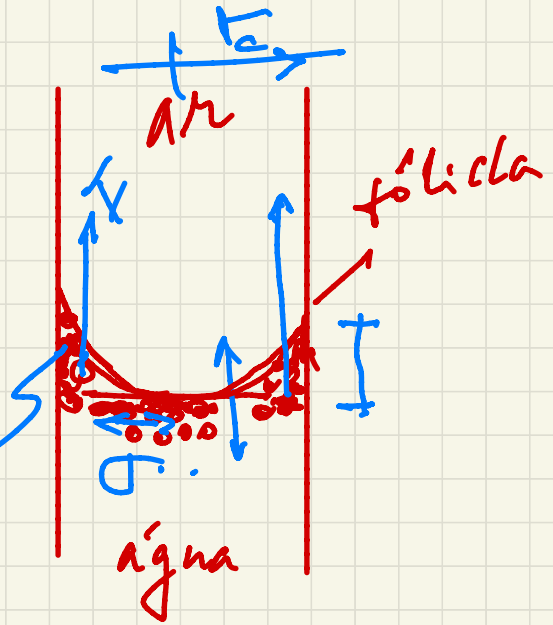
$$\Delta G_e = -\Delta p$$



Capilaridade



molhabilidade

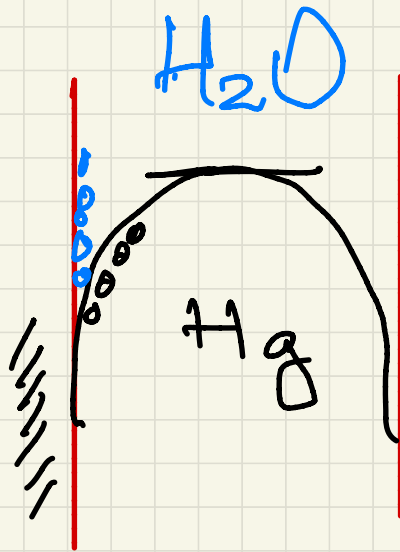


$$h_c = f(\psi_c, t_e)$$

$$\psi_c = \psi_{H_2O} - \psi_{ar}$$



$$p_c = p_a - p_o$$



EDP

fluxo

10/09/2020

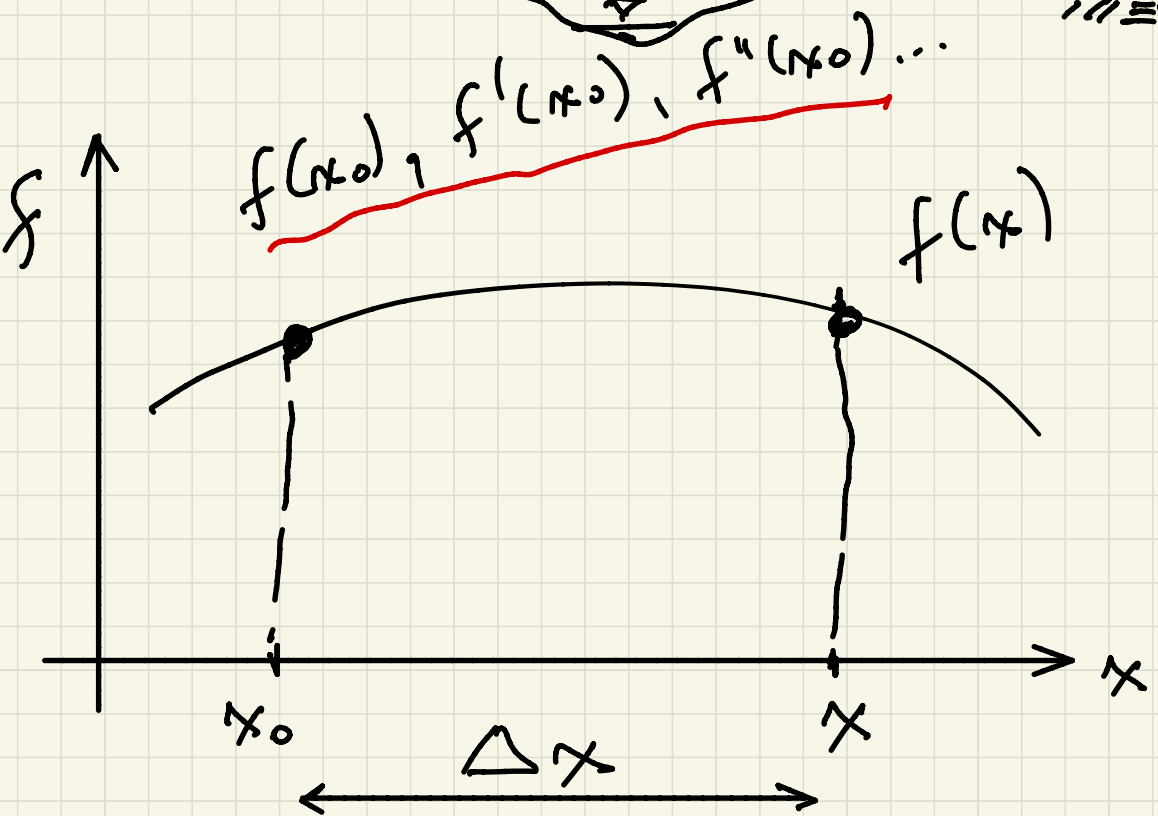
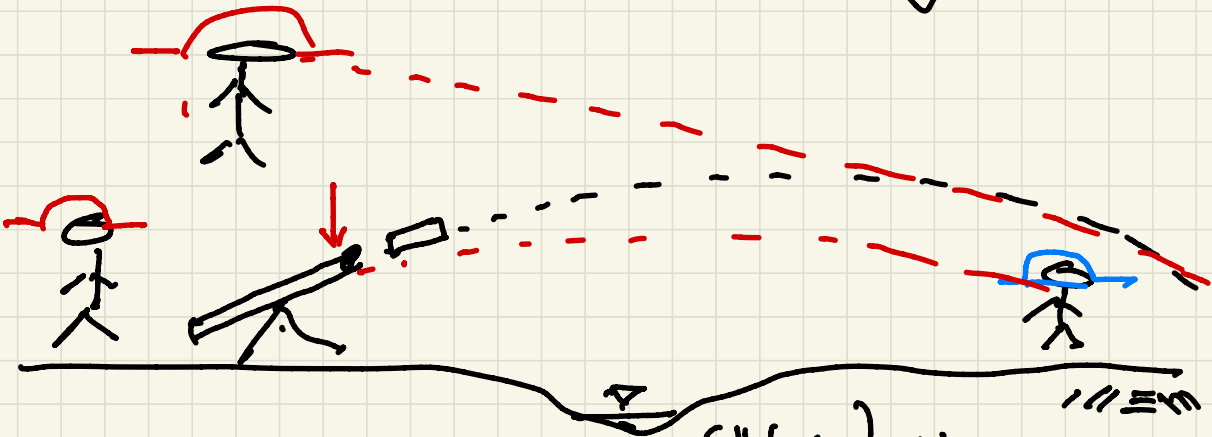
$$\text{So } \frac{\partial h}{\partial t} = -\nabla \cdot (K \nabla h) + Q$$

$$\frac{\partial}{\partial x} + \frac{\partial}{\partial y} + \frac{\partial}{\partial z}$$

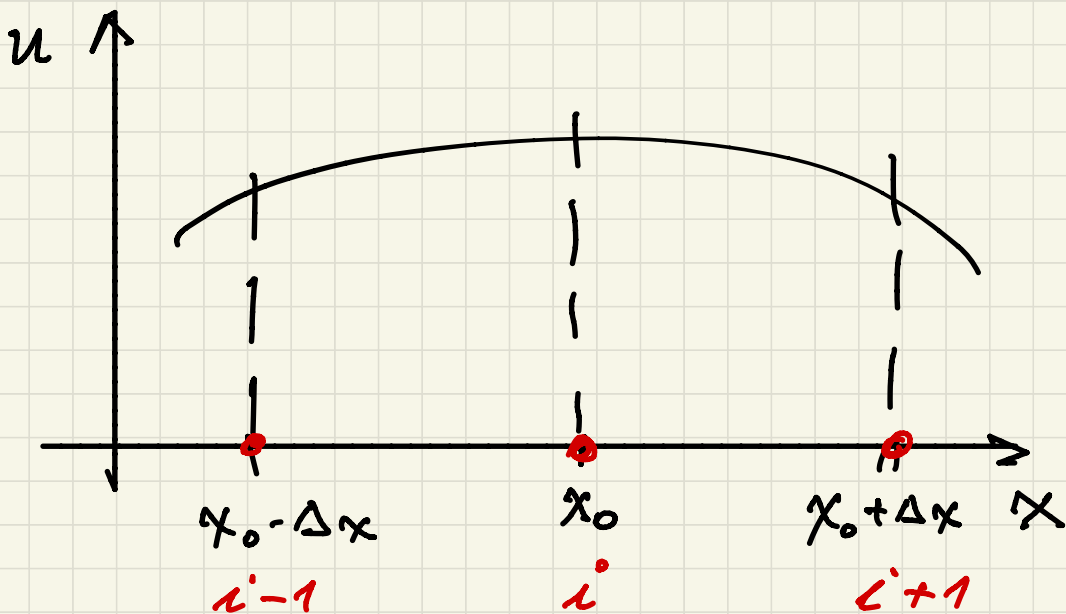
$$\bar{h} \approx \sum_{i=1}^n a_i \cdot \psi_i$$

$$= a_1 \psi^1 + a_2 \psi^2 + a_3 \psi^3 + \dots$$

Séries de Taylor



$$f(x) = f_{x_0} + f'_{x_0} \cdot \Delta x + f''_{x_0} \cdot \frac{\Delta x^2}{2!} + f'''_{x_0} \cdot \frac{\Delta x^3}{3!} + \dots$$



$$i = 1, 2, 3, 4, \dots$$

modelo
mat.

$$\frac{\partial^2 u}{\partial x^2} = \left(\frac{\partial u}{\partial t} \right) \Rightarrow u_x^4 = u_t^1$$

$$\frac{\partial u}{\partial x} \approx \frac{u(x_0 + \Delta x) - u(x_0)}{\Delta x} + O(\Delta x)$$

$$\frac{\partial u}{\partial x} \approx \frac{u_{i+1} - u_i}{\Delta x} + O(\Delta x)$$

$$u_t^1 = \frac{u^{n+1} - u^n}{\Delta t} + O(\Delta t)$$

$$f(x_0 + \Delta x) = f(x_0) + \cancel{\Delta x f'} + \frac{\Delta x^2}{2!} f'' + \dots$$

$$+ f(x_0 - \Delta x) = f(x_0) - \cancel{\Delta x f'} + \frac{\Delta x^2}{2!} f'' - \dots$$

$$f_{x_0 + \Delta x} + f_{x_0 - \Delta x} = 2f_{x_0} + \cancel{2 \frac{\Delta x^2}{2!} f''} + \dots$$

$i+1 \quad i-1 \quad \quad \quad i$

$$f'' = \frac{f_{i+1} - 2f_i + f_{i-1}}{\Delta x^2} + \frac{1}{\cancel{\Delta x^2}} \left[\frac{2\Delta x^4}{4!} f^{(4)} \right]$$

$$f'' = \frac{f_{i+1} - 2f_i + f_{i-1}}{\Delta x^2} + O(\Delta x^2)$$

↑ central difference
 $O(\Delta x^2)$

$$u_x'' = \frac{u_{i+1} - 2u_i + u_{i-1}}{\Delta x^2} + O(\Delta x^2)$$

modelo
mat.

$$\frac{\partial^2 u}{\partial x^2} = \left(\frac{\partial^2 u}{\partial t} \right) \Rightarrow u_x^4 = u_t^1$$

$$u_x^4 = \frac{u_{i+1} - 2u_i + u_{i-1}}{\Delta x^2} + o(\Delta x^2)$$

$$u_t^1 = \frac{u^{n+1} - u^n}{\Delta t} + o(\Delta t)$$

$$\frac{u_{i+1} - 2u_i + u_{i-1}}{\Delta x^2} \approx \frac{u^{n+1} - u^n}{\Delta t} + o(\Delta x^2, \Delta t)$$