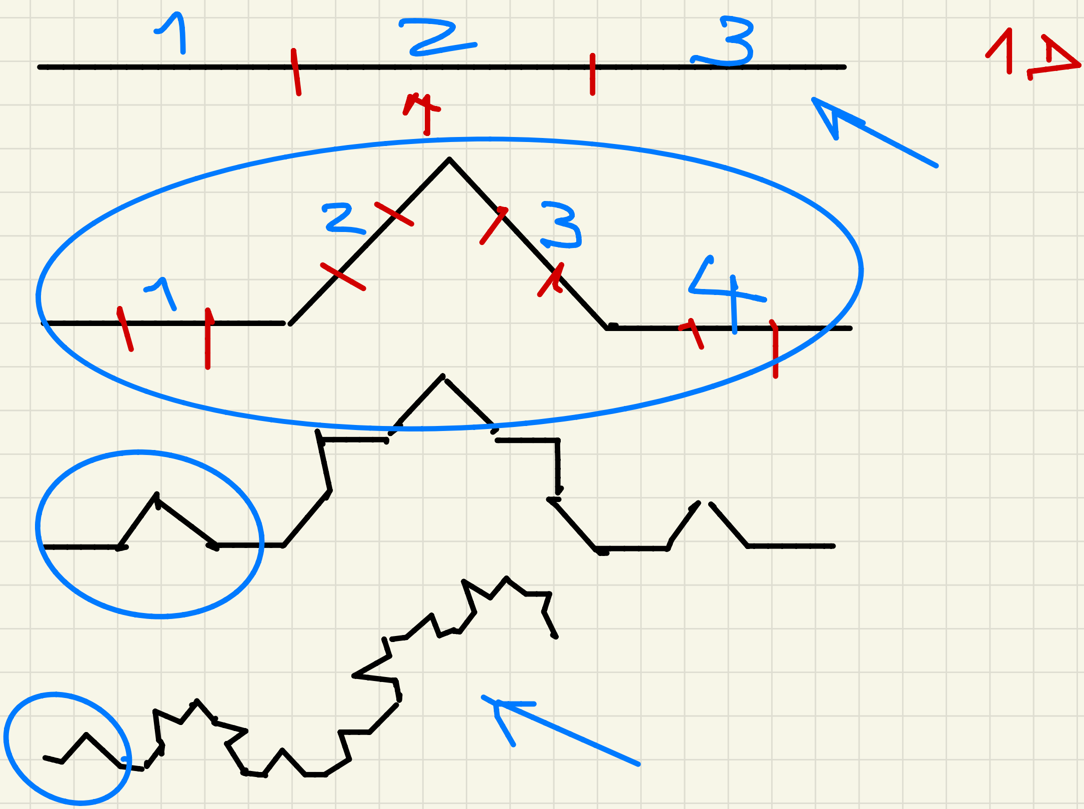
Shs 5896

2020

Edson Wendland

EESC / USP

número fractal
auto-similaridade

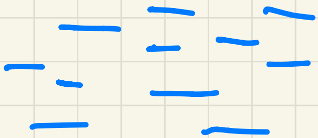


$$N = \frac{4}{3} = 1{,}33 \; D$$

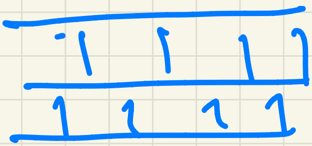
Simbología

arenosos

limo =
arcilla.



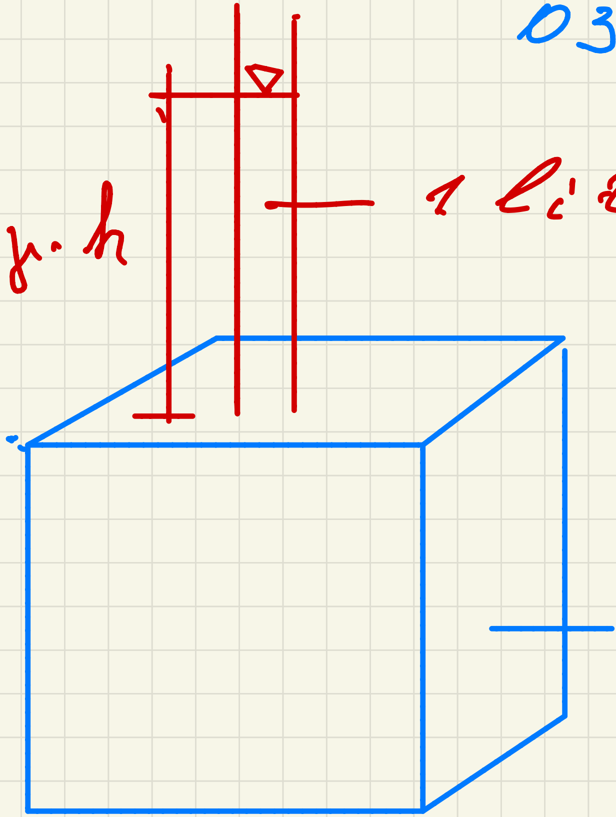
calcáreos
carbonatos



magmáticas

03/09/2020

$p = \gamma \cdot h$



$h = 20\ m$, $100\ m$, $1000\ m$

$250\ m$, $100\ m$, $1000\ m$

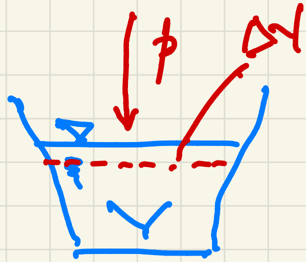
$500\ m$

$p = 1\ MPa = 10^6\ Pa$

Compressibilidade

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

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



$$\gamma = 9789 \ N/m^3$$

$$V = 1 \ m^3$$

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

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

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

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

$$p \cong 2 \ MPa$$

$$p = \gamma \cdot h \ \therefore \ h = \frac{p}{\gamma} = \frac{2 \cdot 10^{6}}{9789} \cong 200 \ mca$$

$$\dot{m}_x = \rho \cdot u_x \cdot A_x$$

$$= \frac{kg}{\cancel{m^3}} \cdot \frac{\cancel{m}}{s} \cdot \cancel{m^2}$$

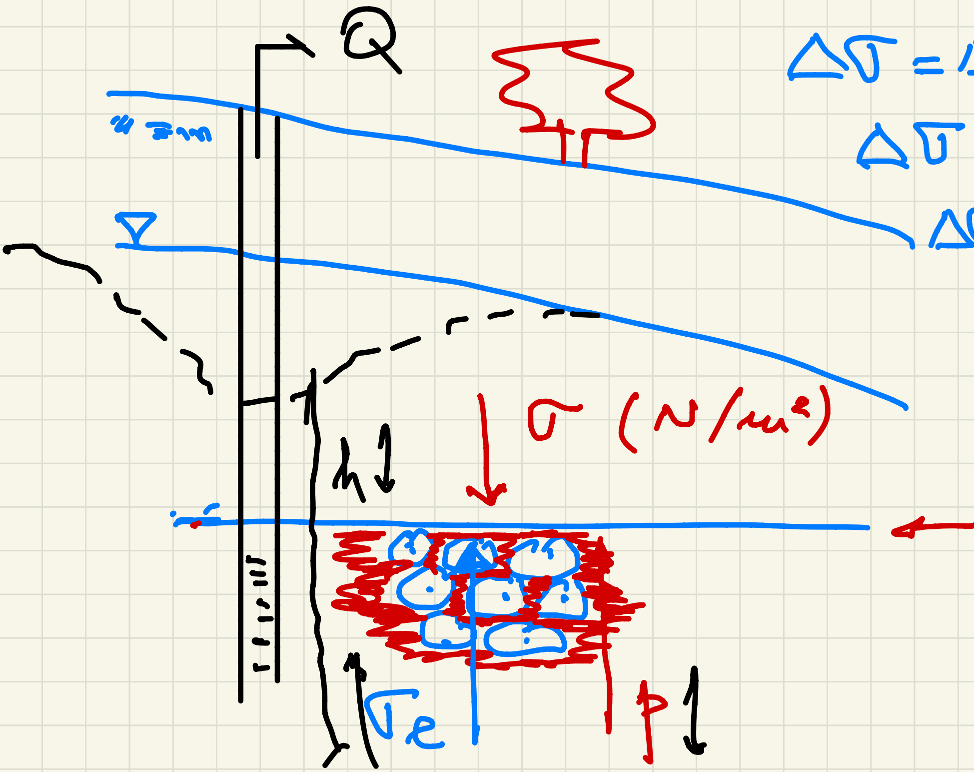
$$\dot{m}_x = kg/s \qquad \frac{\partial m}{\partial t} = \frac{kg}{s}$$

$$\sigma = \sigma_e + p$$

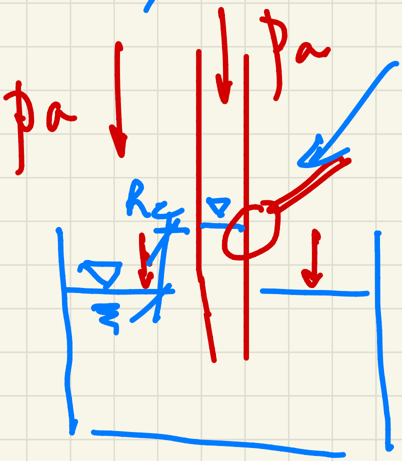
$$\Delta\sigma = \Delta\sigma_e + \Delta p$$

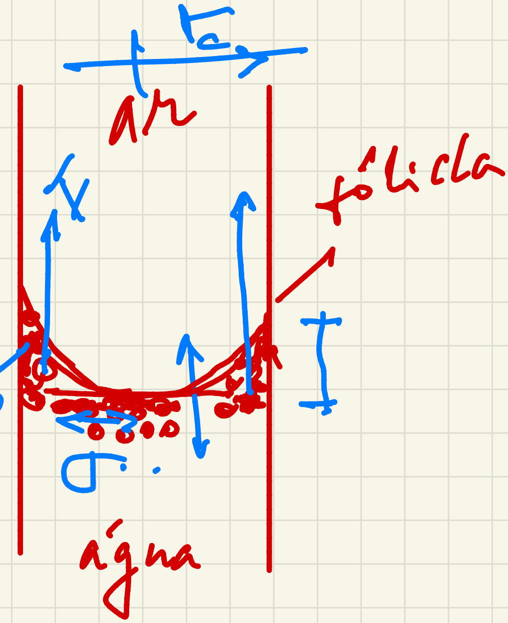
$$\Delta\sigma = 0$$

$$\Delta\sigma_e = -\Delta p$$

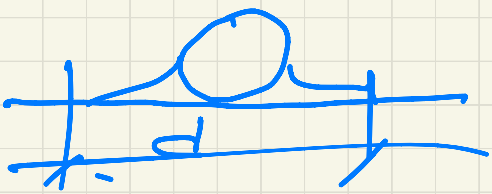


Capilaridade





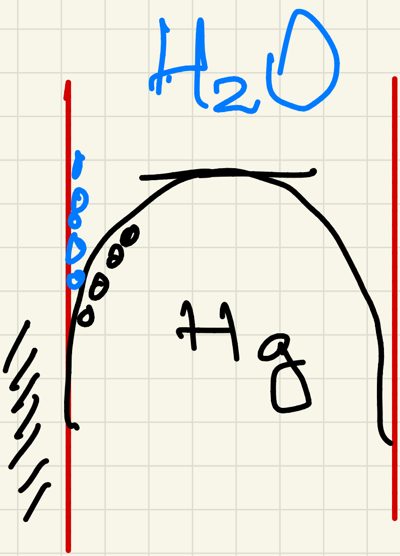
molhabilidade



$$h_c = f(\sigma_e, \gamma_c)$$

$$\gamma_c = \gamma_{H_2O} - \gamma_{ar}$$

$$p_c = p_a - p_0$$



EDP flusso 10/09/2020

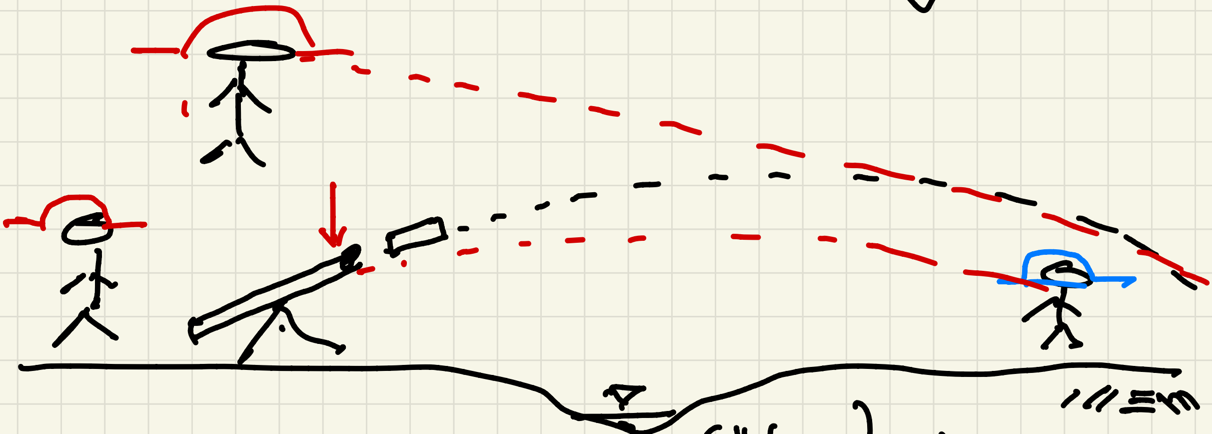
$$S_0 \frac{\partial h}{\partial t} = -\nabla(K \nabla h) + Q$$

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

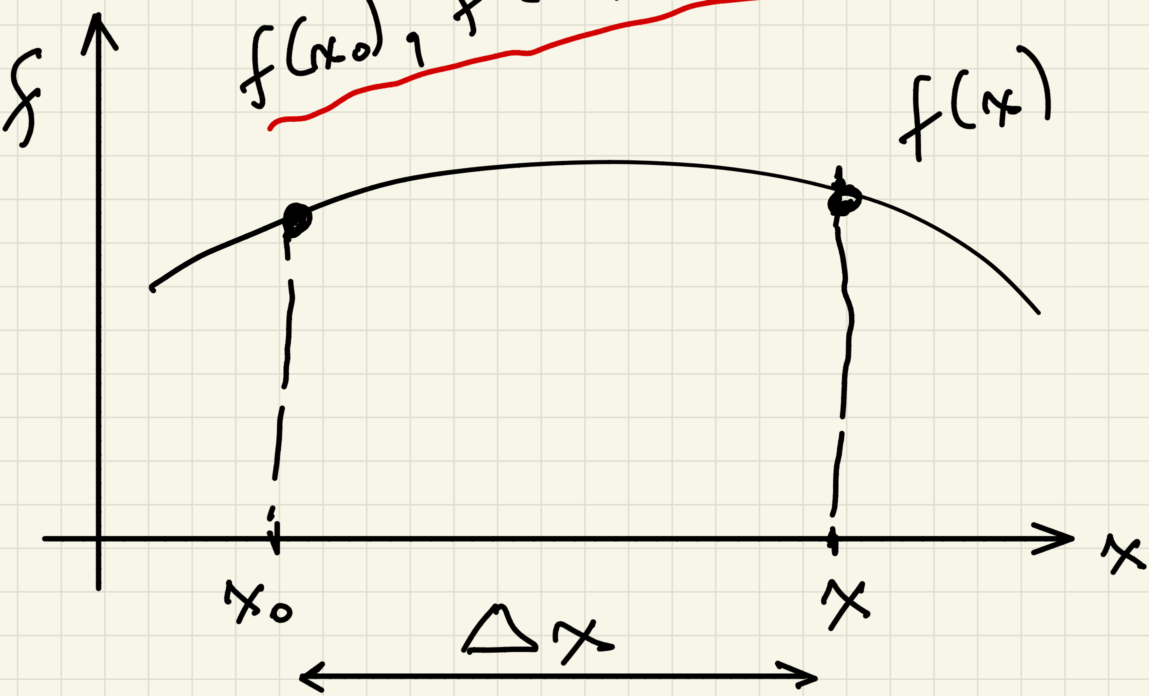
$$\bar{h} \cong \sum_{i=1}^{n} a_i \cdot \varphi^i$$

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

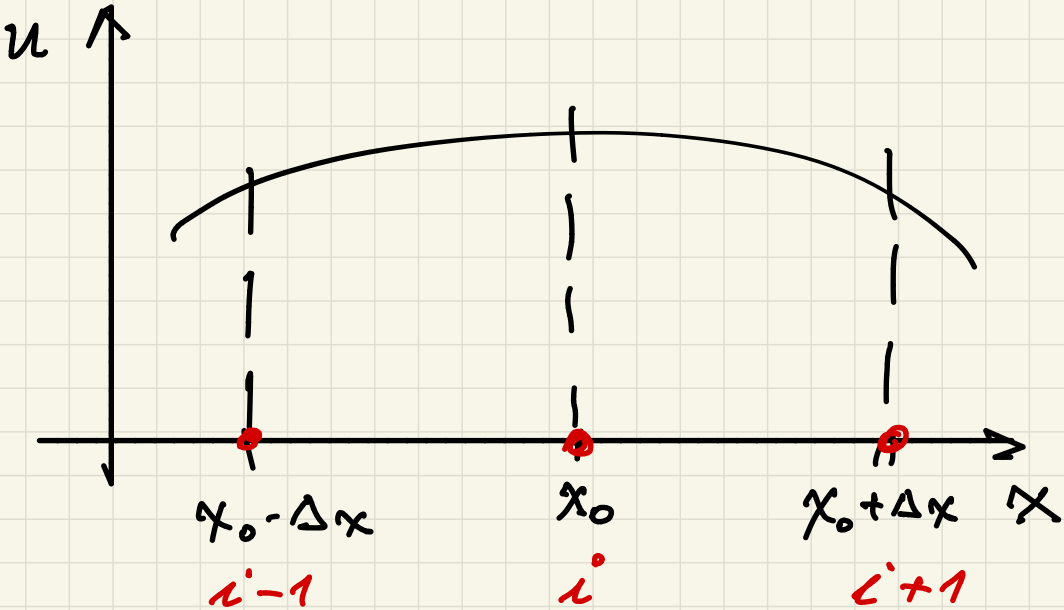
Séries de Taylor



$f(x_0),\ f'(x_0),\ f''(x_0)\ldots$



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



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

modelo mat.

$$\boxed{\frac{\partial^2 u}{\partial x^2}} = \frac{\partial u}{\partial t} \Rightarrow u''_x = u'_t$$

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

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

$$u'_t = \frac{u^{n+1} - u^n}{\Delta t} + O(\Delta t)$$

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

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

$$\underbrace{f_{x_0+\Delta x}}_{i+1} + \underbrace{f_{x_0-\Delta x}}_{i-1} = 2 \underbrace{f_{x_0}}_{i} + \cancel{2}\frac{\Delta x^2}{\cancel{2}!} f'' + \dots$$

$$f'' = \frac{f_{i+1} - 2f_i + f_{i-1}}{\Delta x^2} + \frac{1}{\Delta \cancel{x^2}}\left[\frac{2\Delta x^{\cancel{4}\,2}}{4!} f^{IV} \dots\right.$$

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

central difference

$O(\Delta x^2)$

$$u_x^{4} = \frac{U_{i+1} - 2U_i + U_{i-1}}{\Delta x^2} + O(\Delta x^2)$$

modelo mat.

$$\frac{\partial^2 u}{\partial x^2} = \frac{\partial u}{\partial t} \Rightarrow u''_x = u'_t$$

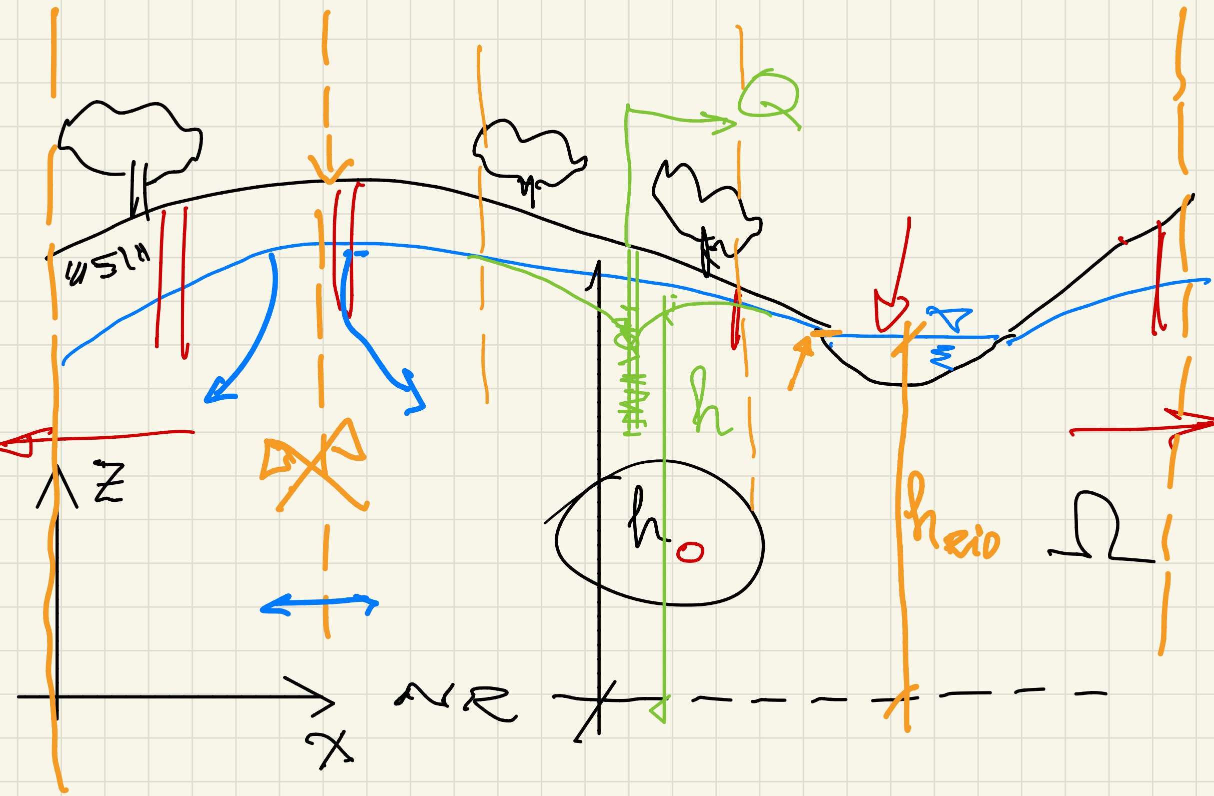
$$u''_x = \frac{u_{i+1} - 2u_i + u_{i-1}}{\Delta x^2} + O(\Delta x^2)$$

$$u'_t = \frac{u^{n+1} - u^n}{\Delta t} + O(\Delta t)$$

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

17/09/2020

Condições de contorno



EDP

$$S_0 \frac{\partial h}{\partial t} = -\nabla\left(K \nabla h\right) + Q \quad , \ \Omega , t$$

$$h = f(h_0, x) \quad , \ \forall \ \Omega, \ t = t_0$$

↳ condição inicial

Condições de contorno

1 - carga hid. conhecida

$h = h_{RIO}$ → condição do 1º tipo (Dirichlet)

→ variável de interesse é conhecida

2 → derivada normal é conhecida

$$\frac{\partial h}{\partial n}$$

$q_0 = -K \dfrac{\partial h}{\partial n}$ ⇒ fluxo através do contorno (fronteira) é conhecido

$q_0 = 0$ (fluxo nulo)