Revisão da Termologia do Ensino Médio

1- Termometria → medida de temperatura

Lei Zero $\Longrightarrow$ $A \sim B$ e $B \sim C$ $\Downarrow$ $A \sim C$

"$\sim$" $:=$ equilíbrio térmico

→ Propriedades termométricas (X)

sistema $\updownarrow$ temperatura $\Longleftarrow$ outro sistema Termômetro "fácil" medida de alguma propriedade termométrica

Equilíbrio térmico

Termômetro

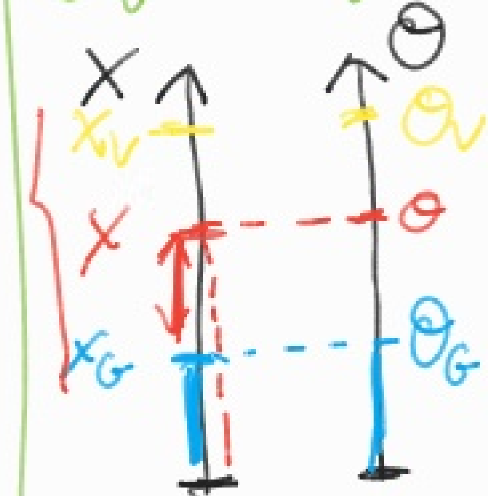
Calibrar

$X \to \theta$

$\theta \equiv$ temperatura empírica.

$\theta_G \equiv$ água em fusão

$\theta_V \equiv$ água em vapor.



$$\frac{x - x_G}{x_V - x_G} = \frac{\theta - \theta_G}{\theta_V - \theta_G}$$

$$\frac{\theta - \theta_G}{\theta_V - \theta_G} = \frac{X - X_G}{X_V - X_G}$$

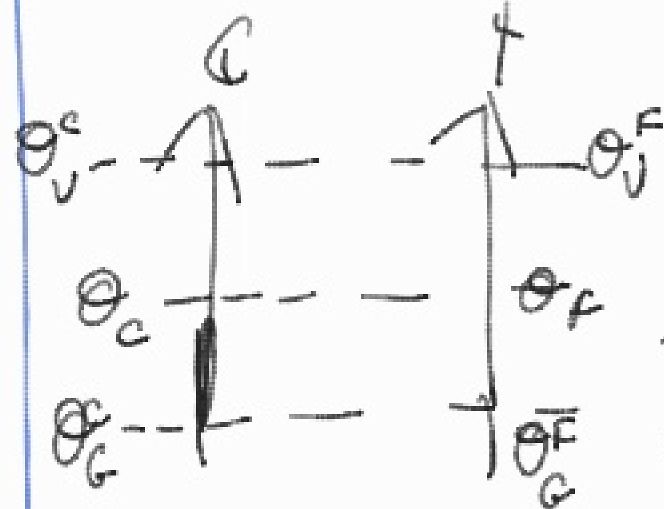
$$\Downarrow$$

$$\boxed{\theta = \theta(X)}$$

Escolhas de valores para θ_G e θ_V $\rightarrow$ Escolhas de Escalas de temperatura

Celsius $\Rightarrow \begin{cases} \theta_G = 0°C \\ \theta_V = 100°C \end{cases}$

Fahrenheit $\Rightarrow \begin{cases} \theta_G = 32°F \\ \theta_V = 212°F \end{cases}$



$$\frac{\theta_C - \theta_G^C}{\theta_V^C - \theta_G^C} = \frac{\theta_F - \theta_G^F}{\theta_V^F - \theta_G^F}$$

$$\frac{\theta_C - 0}{100 - 0} = \frac{\theta_F - 32}{212 - 32}$$

$$\boxed{\theta_C = \frac{5}{9}(\theta_F - 32)}$$

$$\boxed{\theta_F = \frac{9}{5}\theta_C + 32}$$

Escala assoluta Kelvin

$$T = \theta_c + 273{,}15$$

$$\boxed{T \simeq \theta_c + 273}$$

2- Dilatação térmica

Em geral

sistema é aquecido

$\downarrow$

aumento de suas dimensões

2.1 Dilatação dos sólidos

2.1.2 Linear

Δl

$\leftarrow l_0 \rightarrow$

$\Delta\theta \longrightarrow \Delta l$

$\Delta l \propto \Delta\theta \; , \quad \Delta l \propto l_0$

$\Delta l \propto l_0 \Delta\theta \; , \quad \boxed{\Delta\theta := \theta_f - \theta_i}$

$\Delta l = \alpha \, l_0 \, \Delta\theta$

$\hookrightarrow$ coef. de dilatação linear.

$\theta_i = 10°C \longrightarrow \theta_f = 11°C \; , \; l_0 = 100 cm$

$\Delta l \propto \Delta\theta \; , \quad \Delta l \propto l_0$

$\hookrightarrow \Delta l = 1 cm$

$\theta_i = 30°C \longrightarrow \theta_f = 31°C \; , \; l_0 = 100 cm$

$\Delta l' \propto \Delta\theta$ e $\Delta l' \propto l_0$

$\Delta l' = 1,1 cm$

$$\alpha = \alpha(\theta)$$

$$\Downarrow$$

Em geral, desprezamos essa dependência

$$\Downarrow$$

$$\alpha \equiv \text{cte}$$

$$\alpha_n := \frac{1}{l_0}\frac{\Delta l}{\Delta \theta}$$

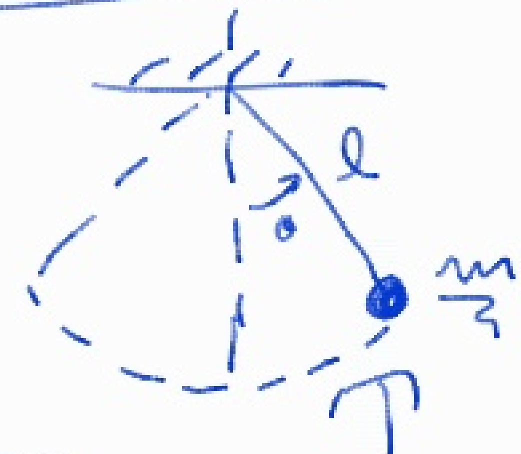
$$\boxed{\alpha := \frac{1}{l}\frac{dl}{d\theta}} \rightarrow \alpha = \alpha(\theta)$$

$$\Delta l = \alpha\, l_0\, \Delta\theta$$

$$l = l_0 + \Delta l$$

$$\boxed{l = l_0(1 + \alpha\,\Delta\theta)}$$

<u>Expto</u> <u>Pêndulo</u>



$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$\theta_0 \longrightarrow T_0 = 2\pi\sqrt{\frac{l_0}{g}}$$

$$\downarrow$$

$$\theta \longrightarrow T = ?$$

<u>solução</u> $\Rightarrow$ $T = 2\pi\sqrt{\frac{l}{g}}$

$$T = 2\pi\sqrt{\frac{l_0(1+\alpha\,\Delta\theta)}{g}}$$

$$T = 2\pi\sqrt{\frac{l_0}{g}(1+\alpha\Delta\theta)}$$

$$T = 2\pi\sqrt{\frac{l_0}{g}}\cdot\sqrt{1+\alpha\Delta\theta}$$

$$T = T_0\sqrt{1+\alpha\Delta\theta}$$

$$\boxed{\frac{T}{T_0} = \sqrt{1+\alpha\Delta\theta}}$$

$$T \simeq T_0\left(1+\frac{1}{2}\alpha\Delta\theta\right)$$

$$\boxed{\Delta T \simeq \frac{T_0}{2}\alpha\Delta\theta}$$

$$dT = d\left(2\pi\sqrt{\frac{l}{g}}\right)$$

$$dT = \frac{2\pi}{\sqrt{g}}\frac{1}{2}l^{-1/2}\cdot dl$$

$$dT = \frac{2\pi}{\sqrt{gl}}\frac{dl}{2}$$

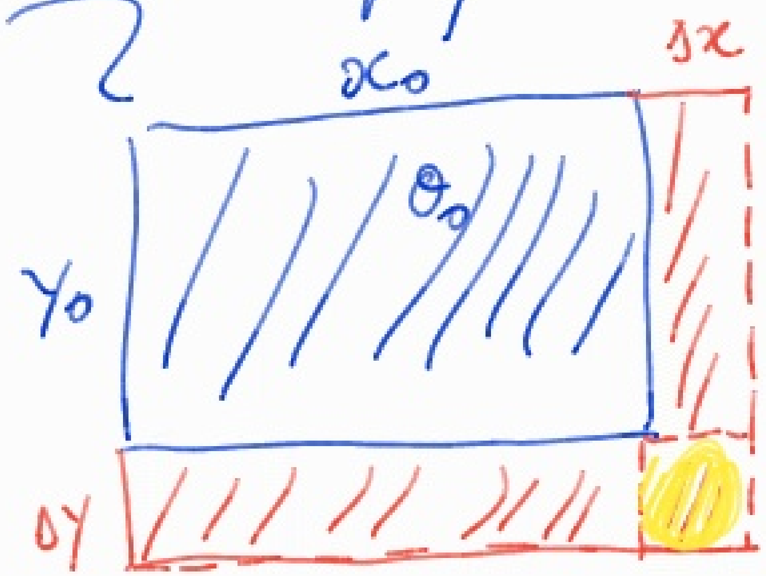
$$dT = \frac{2\pi}{\sqrt{gl}}\frac{\alpha}{2}l\,d\theta$$

$$dT = 2\pi\sqrt{\frac{l}{g}}\frac{\alpha\,d\theta}{2}.$$

$$\boxed{dT = \frac{1}{2}T_0\,\alpha\,d\theta.}$$

$$\sqrt{1+x} \approx 1+\frac{1}{2}x$$

2.1.2 Superficial



$$S_0 = x_0 y_0$$

$\downarrow$

$$S = (x_0 + \Delta x)(y_0 + \Delta y)$$

$$S = x_0 y_0 + x_0 \Delta y + y_0 \Delta x + \Delta x \Delta y$$

$$S = S_0 + x_0 \alpha_y y_0 \Delta\theta + y_0 \alpha_x x_0 \Delta\theta + x_0 \alpha_x \Delta\theta \cdot y_0 \alpha_y \Delta\theta$$

$$S = S_0 + \alpha_y S_0 \Delta\theta + \alpha_x S_0 \Delta\theta + S_0 \alpha_x \alpha_y (\Delta\theta)^2$$

→ muito pequeno $\sim 10^{-6}$

↳ desprezar → correção de 2ª ordem.

$\Delta l_x \cdot \Delta l_y$

$$S = S_0 [1 + \underbrace{(\alpha_x + \alpha_y)}_{\beta} \Delta\theta]$$

$\beta = \alpha_x + \alpha_y$ coef. de dilatação superficial

material isotrópico

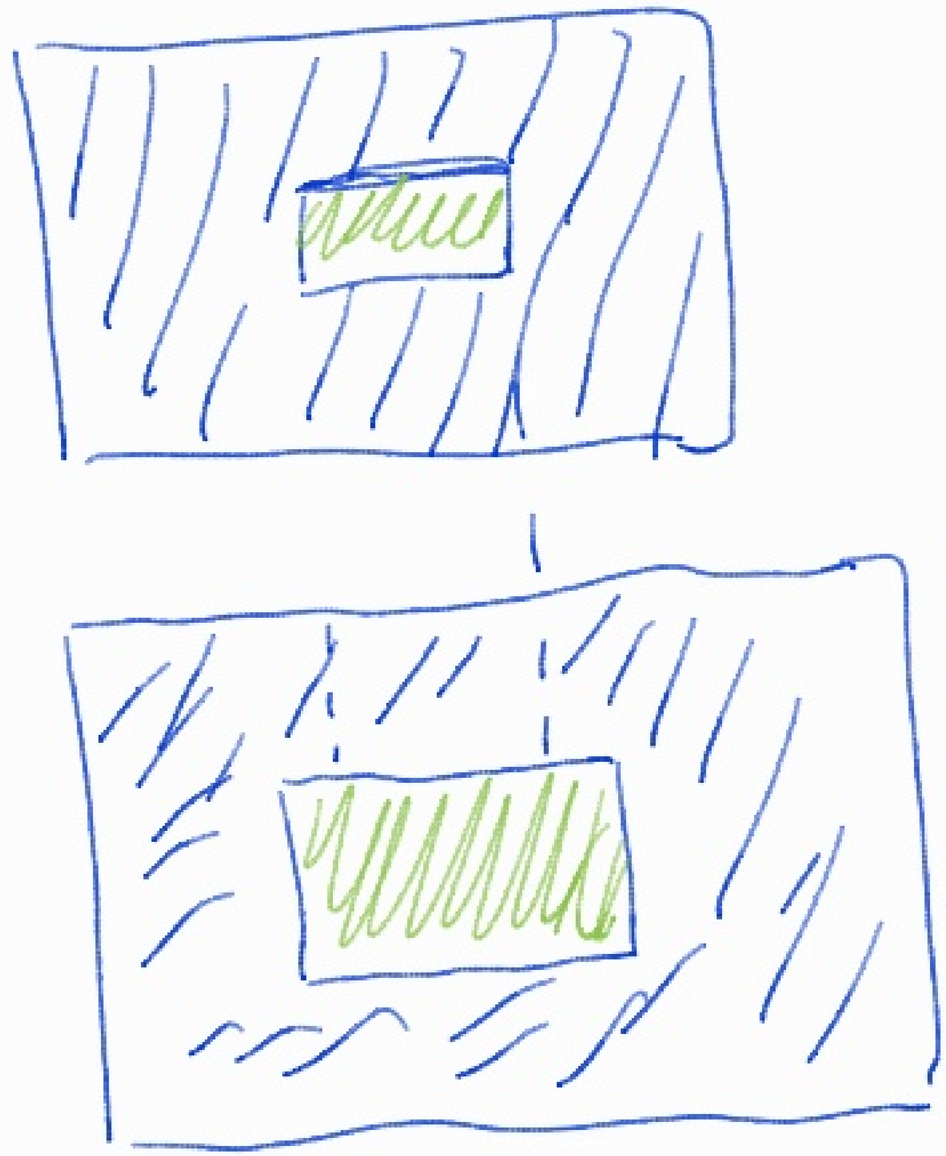
$\downarrow$

$\alpha_x = \alpha_y = \alpha$

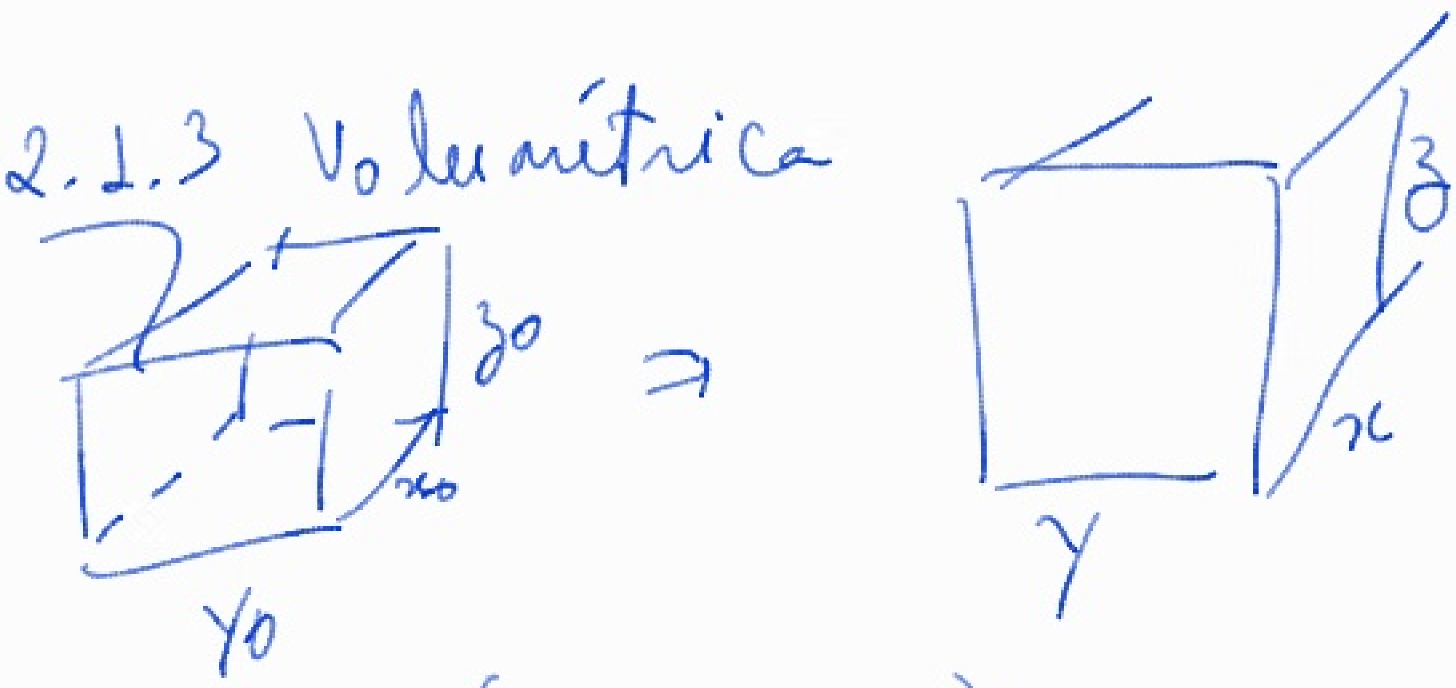
$$\boxed{S = S_0 (1 + 2\alpha \Delta\theta)}$$

$\Rightarrow \beta = 2\alpha$

Buraco!



2.1.3 Volumétrica



$$x = x_0 (1 + \alpha_x \Delta\theta)$$

$$y = y_0 (1 + \alpha_y \Delta\theta)$$

$$z = z_0 (1 + \alpha_z \Delta\theta)$$

$$V_0 = x_0 y_0 z_0$$

$$V = xyz = x_0 y_0 z_0 +$$

$$+ \underline{x_0 y_0 z_0 (\alpha_x + \alpha_y + \alpha_z)} +$$

+ termos de 2ª ordem + termos 3ª ordem

$$V = V_0\left[1 + \underbrace{(\alpha_x + \alpha_y + \alpha_z)}_{\gamma_s \,=\, \text{coef. de dilação volumétrico}}\Delta\theta\right]$$

Isotrópico $\Rightarrow \alpha_x = \alpha_y = \alpha_z = \alpha$

$$V = V_0\left(1 + \underbrace{3\alpha}_{\boxed{\gamma_s = 3\alpha}}\Delta\theta\right)$$

Expto: Como varia a densidade com a temperatura

sólido de massa m $\rightarrow \theta_0 , V_0 \Rightarrow \boxed{\rho_0 = \dfrac{m}{V_0}}$

$\downarrow$

$\theta \rightarrow V \Rightarrow \rho = ?$

$$\rho = \frac{m}{V} = \frac{m}{V_0(1+\gamma_s\Delta\theta)}$$

$$\boxed{\rho = \frac{\rho_0}{(1+\gamma_s\Delta\theta)}}$$

usando derivada

$$d\rho = d\left(\frac{m}{V}\right) = \frac{\cancel{dm}}{V} - \frac{m}{V^2}dV$$

$$d\rho = -\frac{m}{V^2}\gamma_s d\theta \Rightarrow d\rho = -\frac{\rho}{\cancel{V}}\gamma_s \cancel{V} d\theta$$

$$\Delta\rho = -\rho_0\gamma_s\Delta\theta$$

$$\rho = \rho_0 - \rho_0 \gamma_s \Delta\theta$$

$$\boxed{\rho = \rho_0 (1 - \gamma_s \Delta\theta)}$$

$$\boxed{\rho = \frac{\rho_0}{(1 + \boxed{\gamma_s \Delta\theta})}}$$

$$(1+x)^{-1} \approx 1 - x \,, \quad x \ll 1$$

→ estica ⇒ Esfria.

→ comprime ⇒ aquece

Efeitos mecânicos da dilação

$$\theta_0 \longrightarrow \theta \Rightarrow \Delta\theta$$

$$F \propto -\frac{A}{l_0} \Delta l_M$$

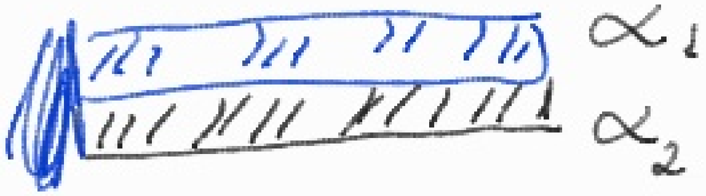
$$F = -\frac{E A \Delta l_M}{l_0} \Rightarrow \boxed{F = \frac{EA|\Delta l_M|}{l_0}}$$

Modulo de elasticidade ou Modulo de Young.

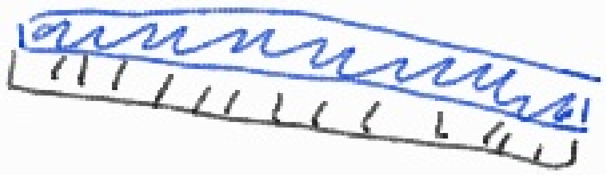
$$\Delta l = \alpha l_0 \Delta\theta$$

$$|\Delta l_M| = |\Delta l| \quad \Big| \; F = E A \Delta\theta$$

Efeitos mecânicos tende a compensar os efeitos térmico e vice-versa.

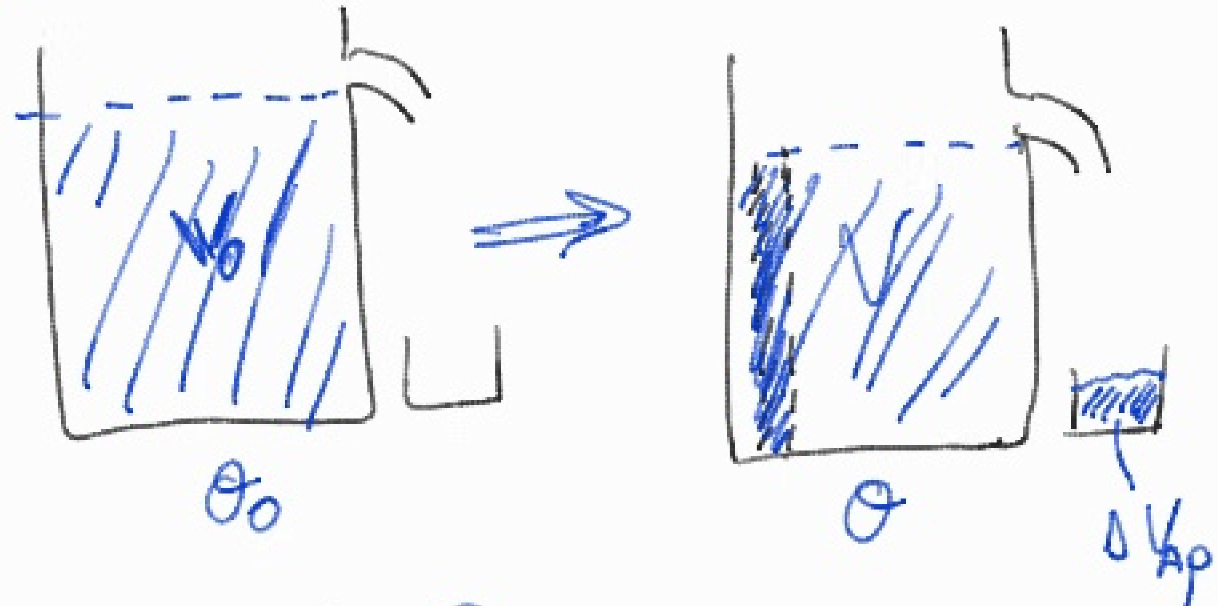


$\alpha_1 > \alpha_2 \quad \theta_0 \rightarrow \theta > \theta_0$



$\beta \rightarrow$ coef. de dilatação volumétrica do líquido.

2.2 Dilatação nos líquidos



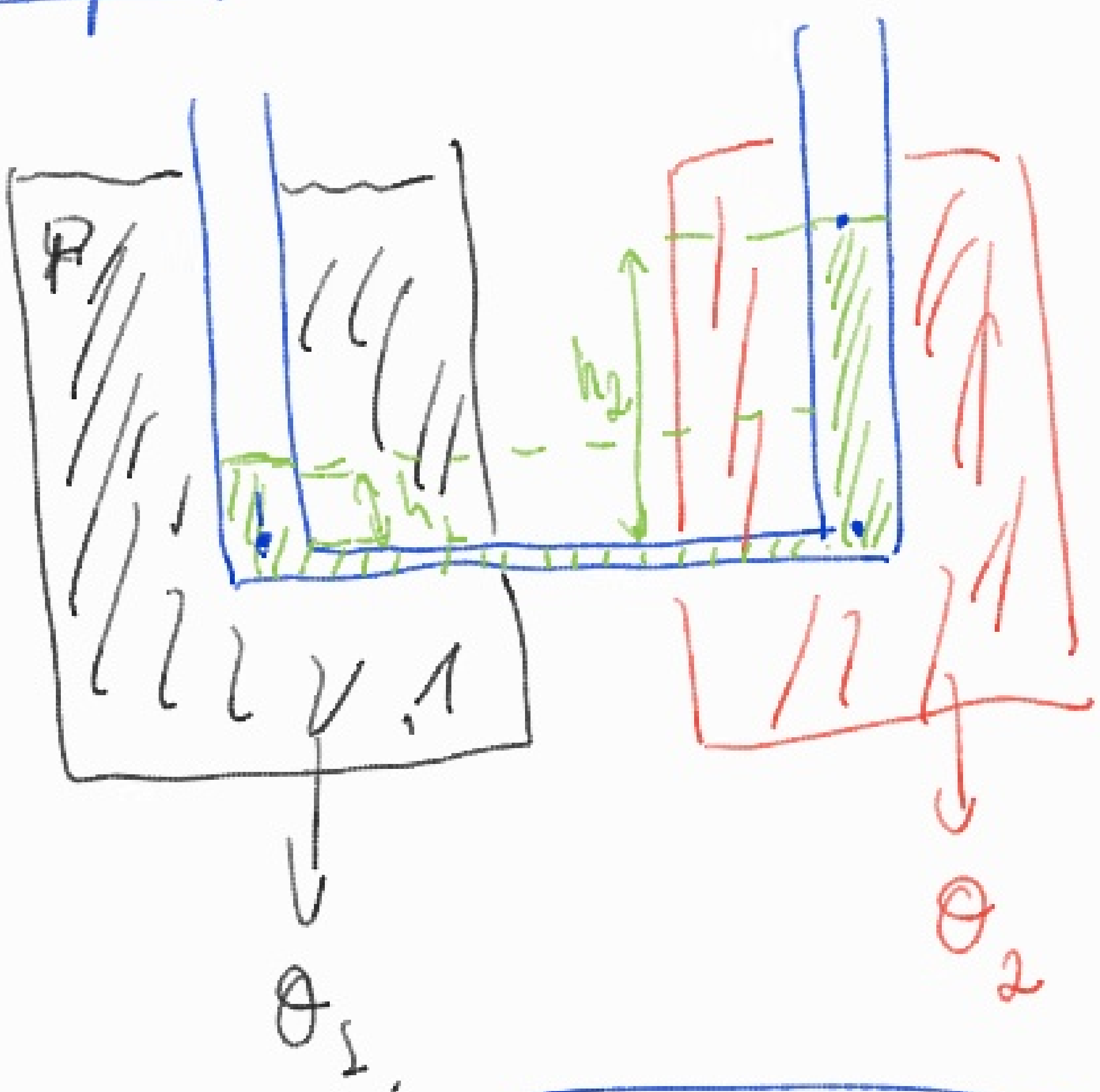
$$\Delta V_{ap} = \beta_{ap} V_0 \Delta\theta$$

$$\Delta V = \Delta V_{ap} + \Delta V_{recip.}$$

$$\beta V_0 \Delta\theta = \beta_{ap} V_0 \Delta\theta + 3 \quad V_0 \Delta\theta$$

$$\boxed{\beta = \beta_{ap} + \beta_{recipiente.}}$$

Explo



$\beta = ?$

$$\cancel{P_{atm}} + \rho_1 g h_1 = \cancel{P_{atm}} + \rho_2 g h_2 \Rightarrow \rho_1 h_1 = \rho_2 h_2$$

$$\cancel{\rho_1} h_1 = \frac{\cancel{\rho_1}}{[1+\beta(\theta_2-\theta_1)]} h_2$$

$$1+\beta(\theta_2-\theta_1) = \frac{h_2}{h_1}$$

$$\boxed{\beta = \frac{(h_2-h_1)}{h_1(\theta_2-\theta_1)}}$$

$$\boxed{\rho = \frac{\rho_0}{(1+\beta\Delta\theta)}}$$

$$\Delta\theta = \theta - \theta_0$$

$\theta_1 = 0°C$

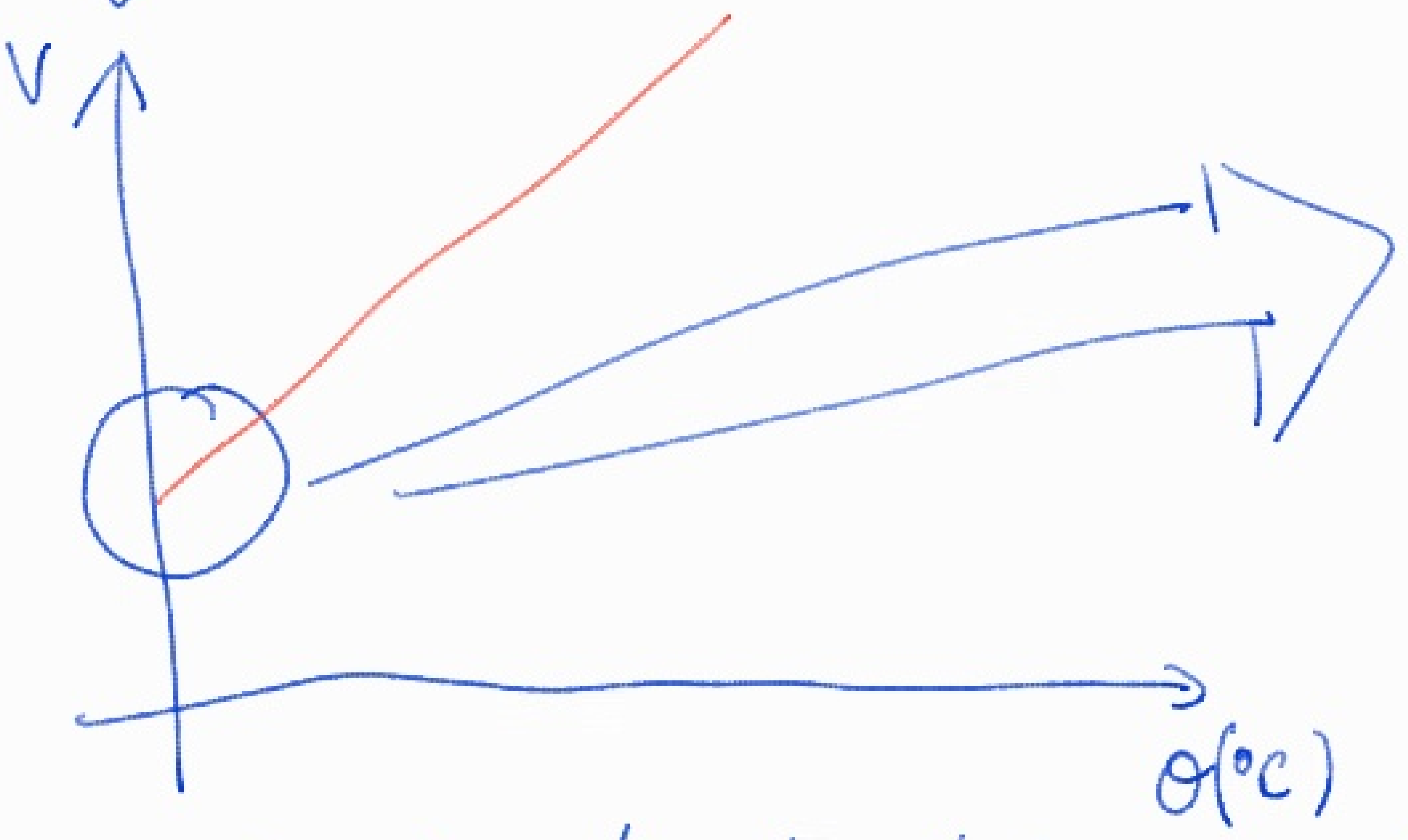
$\theta_2 = 80°C$

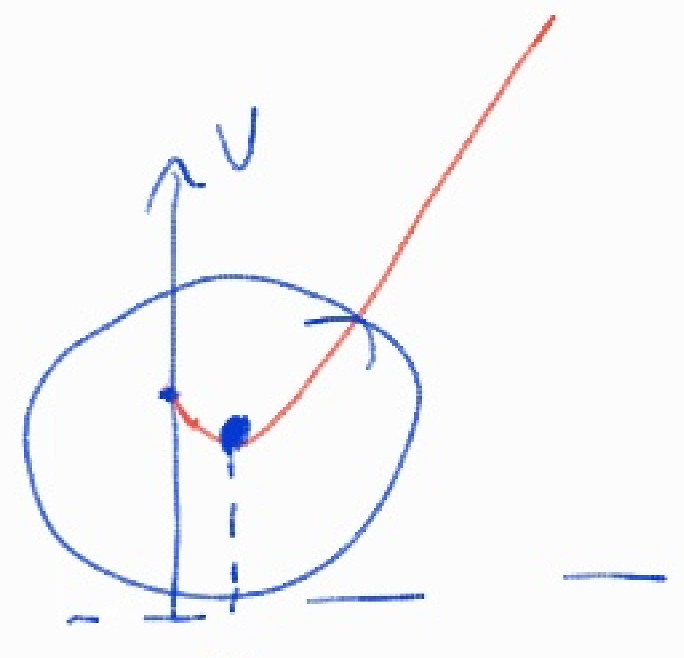
$h_1 = 80{,}0\ cm$

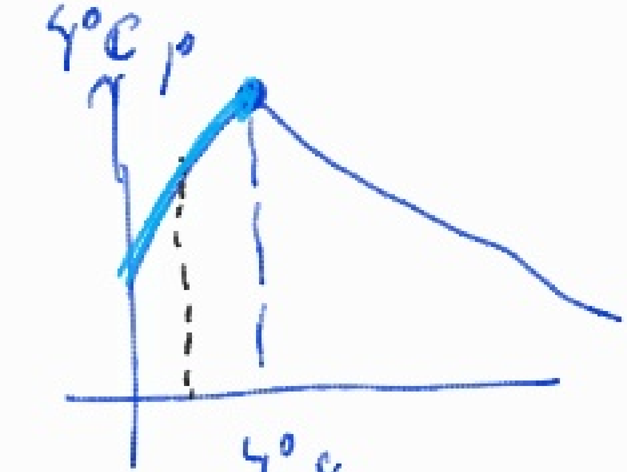
$h_2 = 82{,}0\ cm$

$$\boxed{\beta = 1{,}25\cdot 10^{-3}\ °C^{-1}}$$

Água

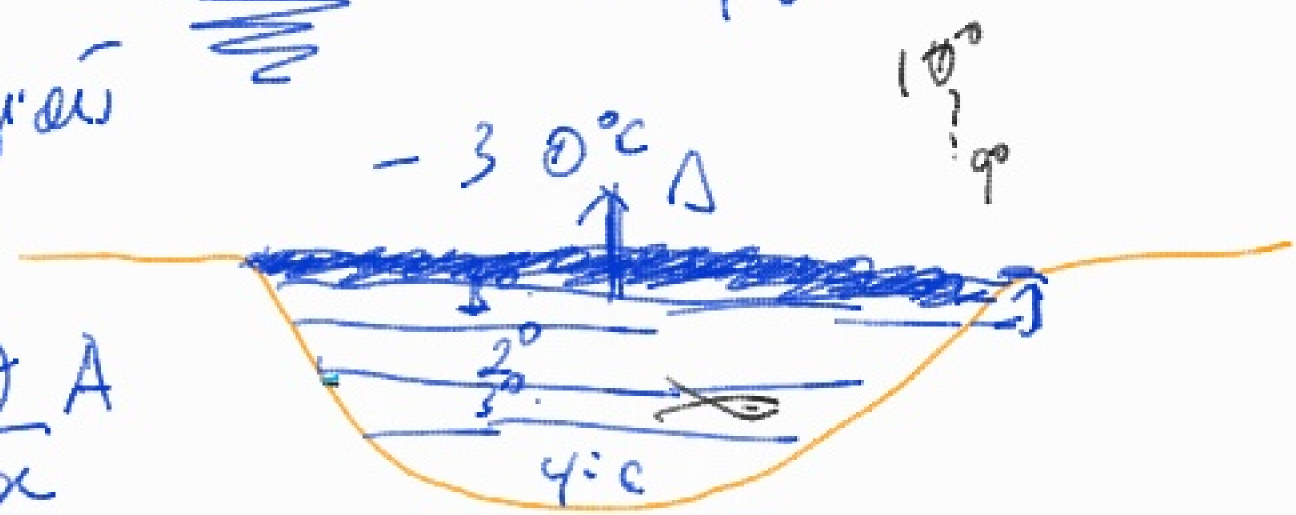






Densidade da água é máxima a 4° C.

⇒ impede dos lagos em inverno
ficar de congelarem



$$\phi = -k\frac{\Delta\theta}{\Delta x}A$$