Θερμοδυναμική μέθοδος – Σχέσεις Maxwell

$$TdS = dU + p\,dV \rightarrow dU = TdS - pdV \rightarrow \left.\frac{\partial T}{\partial V}\right|_S = -\left.\frac{\partial p}{\partial S}\right|_V$$

$$H = U + pV \rightarrow dH = dU + Vdp + p\,dV$$

$$dU = TdS - pdV \rightarrow dH = TdS + Vdp \rightarrow \left.\frac{\partial T}{\partial p}\right|_S = \left.\frac{\partial V}{\partial S}\right|_p$$

$$F = U - TS \rightarrow dF = dU - TdS - SdT$$

$$dU = TdS - pdV \rightarrow dF = -pdV - SdT \rightarrow \left.\frac{\partial p}{\partial T}\right|_V = \left.\frac{\partial S}{\partial V}\right|_T$$

$$G = U - TS + pV \rightarrow dG = dU - TdS - SdT + pdV + Vdp$$

$$dU = TdS - pdV \rightarrow dG = Vdp - SdT \rightarrow \left.\frac{\partial V}{\partial T}\right|_p = -\left.\frac{\partial S}{\partial p}\right|_T$$

Θερμοδυναμικές εξισώσεις καταστάσεως

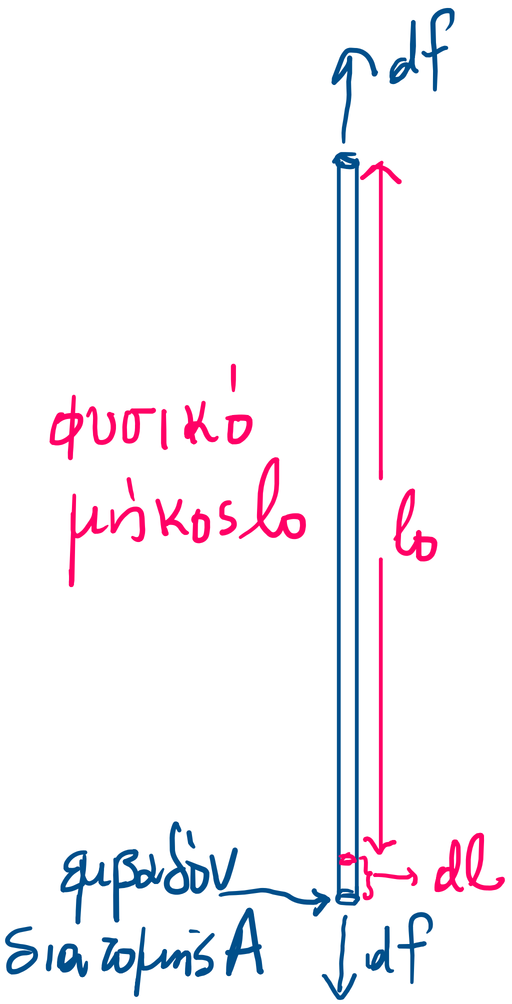
$$dU = T\,dS - p\,dV \;\rightarrow \left.\frac{\partial U}{\partial V}\right|_T = T\left.\frac{\partial S}{\partial V}\right|_T - p$$

όμως $\left.\frac{\partial p}{\partial T}\right|_V = \left.\frac{\partial S}{\partial V}\right|_T$ επομένως $\left.\frac{\partial U}{\partial V}\right|_T = T\left.\frac{\partial p}{\partial T}\right|_V - p$

$$dH = T\,dS + V\,dp \;\rightarrow \left.\frac{\partial H}{\partial p}\right|_T = T\left.\frac{\partial S}{\partial p}\right|_T + V$$

όμως $\left.\frac{\partial S}{\partial p}\right|_T = -\left.\frac{\partial V}{\partial T}\right|_p$ επομένως $\left.\frac{\partial H}{\partial p}\right|_T = V - T\left.\frac{\partial V}{\partial T}\right|_p$

Ελαστική ράβδος



$$\sigma = \frac{df}{A}, \varepsilon = \frac{dl}{l}, \text{μέτρο του Young } \Upsilon = \frac{\sigma}{\varepsilon},$$

$$\frac{df}{dl} = \frac{A\Upsilon}{l} \qquad \left(\left.\frac{\partial f}{\partial l}\right|_T = \frac{A\,\Upsilon}{l}\right)$$

συντελεστής θερμικής διαστολής $a_f = \frac{1}{l}\left.\frac{\partial l}{\partial T}\right|_f$

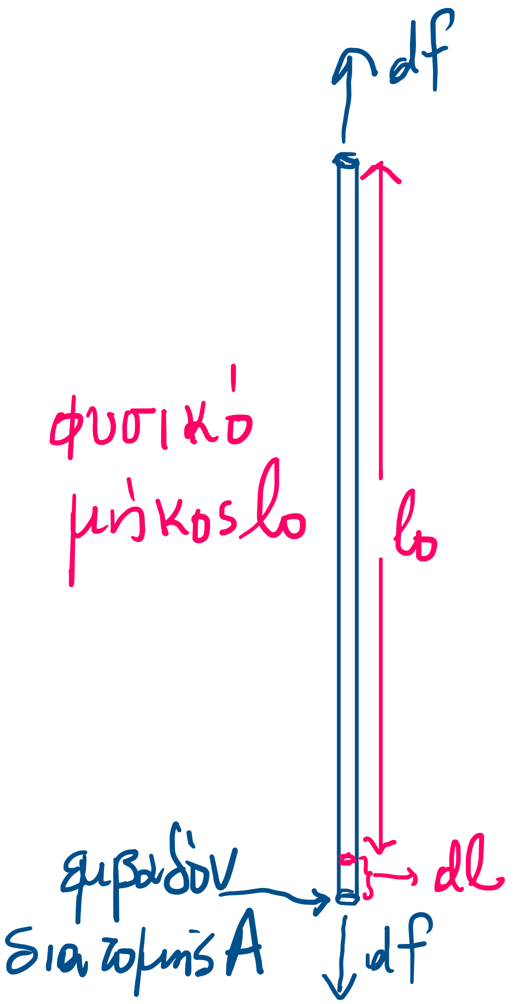
Είναι ένα σύστημα (T, f, l), επομένως

$$dl = \left.\frac{\partial l}{\partial T}\right|_f dT + \left.\frac{\partial l}{\partial f}\right|_T df$$

Θεωρούμε σταθερό l, $\delta\eta\lambda.$ $dl = 0$,

$$0 = \left.\frac{\partial l}{\partial T}\right|_f + \left.\frac{\partial l}{\partial f}\right|_T \left.\frac{\partial f}{\partial T}\right|_l \text{ άρα } \left.\frac{\partial f}{\partial T}\right|_l = -\left.\frac{\partial l}{\partial T}\right|_f \left.\frac{\partial f}{\partial l}\right|_T = -A\Upsilon a_f$$

Ελαστική ράβδος $(\boldsymbol{T}, \boldsymbol{f}, \boldsymbol{l})$



Έχουμε $dU = TdS + fdl$ και ορίζοντας

$$F = U - TS$$

$$dF = -S\,dT + f\,dl$$

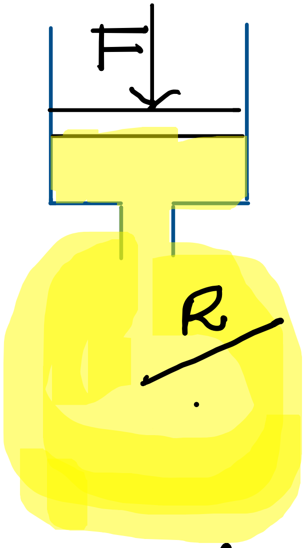
άρα έχουμε τη σχέση

$$\left.\frac{\partial S}{\partial l}\right|_T = -\left.\frac{\partial f}{\partial T}\right|_l$$

και αφού

$\left.\frac{\partial f}{\partial T}\right|_l = -A\Upsilon a_f$ έχουμε $\left.\frac{\partial S}{\partial l}\right|_T = A\Upsilon a_f$

Επιφανειακή τάση $(\boldsymbol{T},\boldsymbol{\gamma},\mathbf{A})$



$$dU = TdS + \gamma\, dA,\; F = U - TS,\; dF = -SdT + \gamma\, dA$$

$$\left.\frac{\partial S}{\partial A}\right|_T = -\left.\frac{\partial \gamma}{\partial T}\right|_A$$

$$\left.\frac{\partial U}{\partial A}\right|_T = T\left.\frac{\partial S}{\partial A}\right|_T + \gamma$$

$$\left.\frac{\partial U}{\partial A}\right|_T = \gamma - T\left.\frac{\partial \gamma}{\partial T}\right|_A$$

$\delta W = \gamma dA$

$\delta W = p dV$

$dA = d(4\pi R^2) \Rightarrow$

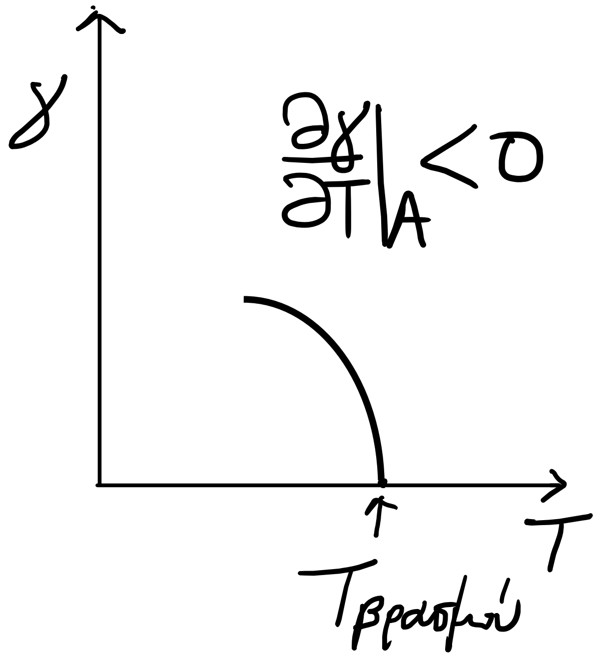
$dA = 8\pi R dR$

$\gamma dA = p dV$

$dV = d(\tfrac{4}{3}\pi R^3)$

$dV = 4\pi R^2 dR$

$p = \dfrac{2\gamma}{R}$



$\left.\dfrac{\partial \gamma}{\partial T}\right|_A < 0$

Παραμαγνητισμός (*T*,*m*,*B*)

$$\chi = \lim_{H\to 0} \frac{M}{H}$$

$$m = M \cdot V$$

για παραμαγνήτες $\chi \ll 1$

επομένως

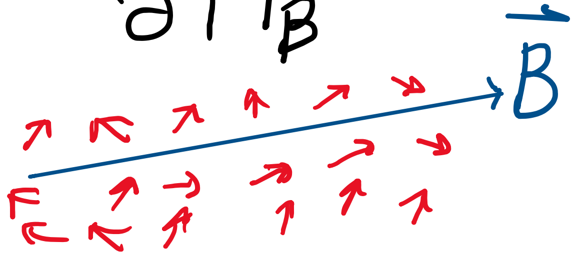
$$B = \mu_0 (H+M) \simeq \mu_0 H$$

$$\chi \simeq \frac{\mu_0 M}{B}$$

Νόμος Curie $\chi \propto \frac{1}{T}$

$$\Downarrow$$

$$\left.\frac{\partial \chi}{\partial T}\right|_B < 0$$



$$dU = TdS - m\,dB,$$

$$F = U - TS, dF = -SdT - m\,dB$$

$$\left.\frac{\partial S}{\partial B}\right|_T = \left.\frac{\partial m}{\partial T}\right|_B \approx \frac{VB}{\mu_0}\left.\frac{\partial \chi}{\partial T}\right|_B < 0$$

$$dS = \left.\frac{\partial S}{\partial T}\right|_B dT + \left.\frac{\partial S}{\partial B}\right|_T dB$$

Θεωρούμε σταθερό S, δηλ. $dS = 0$,

$$0 = \left.\frac{\partial S}{\partial T}\right|_B + \left.\frac{\partial S}{\partial B}\right|_T \left.\frac{\partial B}{\partial T}\right|_S \text{ άρα } \left.\frac{\partial B}{\partial T}\right|_S = -\left.\frac{\partial S}{\partial T}\right|_B \left.\frac{\partial B}{\partial S}\right|_T$$

Ορίζοντας $C_B = T\left.\frac{\partial S}{\partial T}\right|_B$ έχουμε $\left.\frac{\partial B}{\partial T}\right|_S = -\frac{C_B \mu_0}{TVB}\left.\frac{\partial T}{\partial \chi}\right|_B$