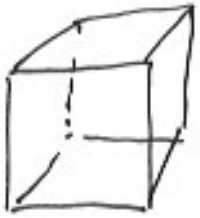


$$m_{osso} = m_{in} + m_V$$

$$\rho = \frac{m}{V}$$

$$\rho^T_{osso} = \frac{m_{in} + m_V}{V} = \frac{m_{in}}{V_T} + \frac{m_V}{V_T}$$

$$V = V_{in} + V_V$$

$$\rho^T_{osso} = \frac{m_{in}}{V_{in}} \cdot \frac{V_{in}}{V_T} + \frac{m_V}{V_V} \cdot \frac{V_V}{V_T}$$

$$\rho^T_{osso} = \rho_{in} \cdot f_{in} + \rho_V \cdot f_V$$

f_V = Porosità

$$\rho^T_{osso} = \rho_{in}\, f_{in} + \rho_V\, P$$

$$\frac{V_{TOT}}{V_{TOT}} = \frac{V_{in} + V_V}{V_{TOT}} \qquad 1 = f_{in} + P$$

$$f_{in} = 1 - P$$

$\rho^{T}_{osso} = \rho_{in}\,(1-p) + \rho_v\, p$

densità apparente.

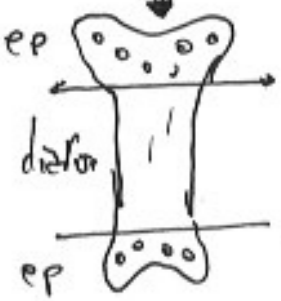
$\rho^{sp}_{in} = 1 \frac{kg}{dm^3}$

$\rho^{comp}_{in} \simeq 2 \frac{kg}{dm^3}$

$\underline{E} = \underline{E_0}\,(1-\underline{p})^{\underline{d}}$

$5 < d < 10$

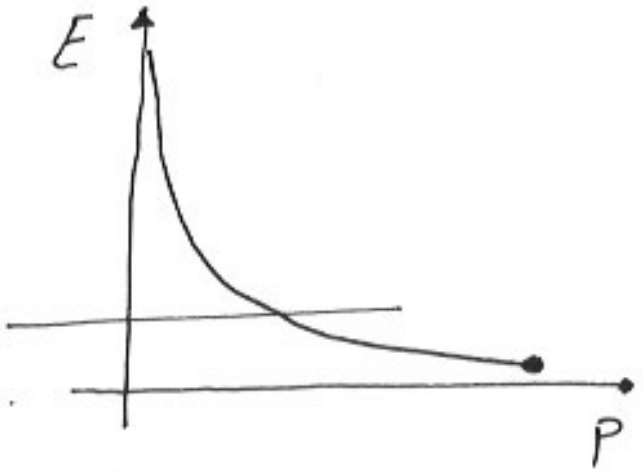
$d = 5$

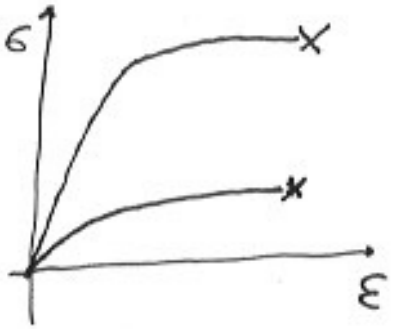


$E_{0\,spongioso} = 0.5\ GPa.$

$E_{0\,compatto} = 17\ GPa$

$E^{*v}_{0\,compatto} = 12\ GPa.$





$$A = \frac{V_{iDR}}{V_T} \cdot 100$$

$$\rho_{osso} = \rho_{in}(1-p) + \rho_V \cdot p$$

$$f_{in} + p = 1$$

$$f_{in} = \frac{V_{in}}{V_T} = \frac{V_{iDR} + V_C}{V_T} = \frac{V_{iDR}}{V_T} + \frac{V_C}{V_T} = f_{IDR} + f_C$$

$$A = f_{iDR} \cdot 100$$

$$f_{iDR} + f_C + p = 1 \qquad f_{IDR} = 1 - p - f_C.$$

$$A = (1 - p - f_C) \cdot 100$$

$$E = E_1 A^{\beta} \quad (1 < \beta < 5) \qquad E_1 = E_0 (1-p)^{\alpha} \qquad E = E_0 (1-p)^{\alpha} A^{\beta}$$

$$E = \Gamma' \cdot \dot{\varepsilon}^{\,c} \, \rho_{app}^{\,d}$$

$$\dot{\varepsilon} = \frac{d\varepsilon}{dt}$$

ρ_{osso} = $\frac{1\ kg}{dm^3}$ spong.

$\frac{2\ kg}{dm^3}$ compatt

$$\rho_T = \rho_{in}(1-p) + \rho_v\, p$$

$\Gamma' = 1$ ρ IDR

ρ c. $c = 0.006$ $d = 1$

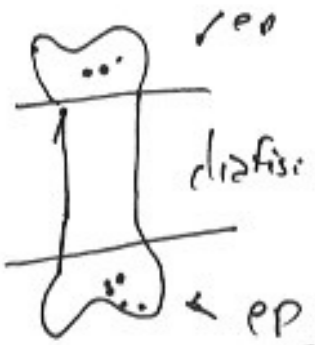
$$E = E_0 (1-p)^a A^B \cdot \dot{\varepsilon}^{\,c} \, \rho_{app}^{\,d}$$

$E \leq 0.1$ GPa.

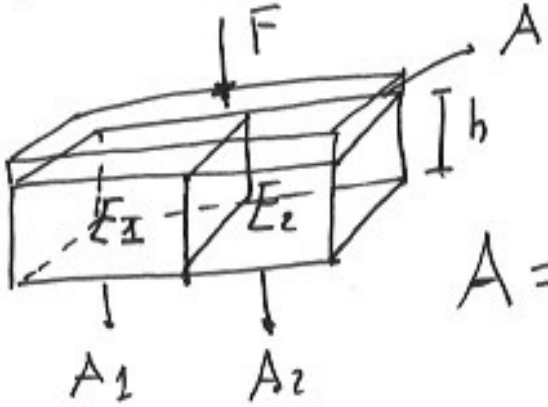
Press-fit $E > 1$ GPa.

Press-comentato $1\ GPa \leq E < 0.5\ GPa$

prec. cementato $0.5\ GPa \leq E < 0.1\ GPa$



Voigt Reuss



$V = A \cdot h$

$A = A_1 + A_2$

$F = F_1 + F_2$

$$\frac{F}{A} = \sigma = \frac{F_1}{A} + \frac{F_2}{A} = \frac{F_1}{A_1} \cdot \frac{A_1}{A} + \frac{F_2}{A_2} \cdot \frac{A_2}{A} = \frac{F_1}{A_1} \cdot \frac{A_1}{A} \cdot \frac{h}{h} + \frac{F_2}{A_2} \cdot \frac{A_2}{A} \cdot \frac{h}{h}$$

$$\sigma = \sigma_1 \frac{V_1}{V} + \sigma_2 \cdot \frac{V_2}{V} = \sigma_1 f_1 + \sigma_2 f_2$$

$\sigma = \varepsilon \cdot E = \varepsilon_1 E_1 f_1 + \varepsilon_2 E_2 f_2$

$\varepsilon = \varepsilon_1 = \varepsilon_2$

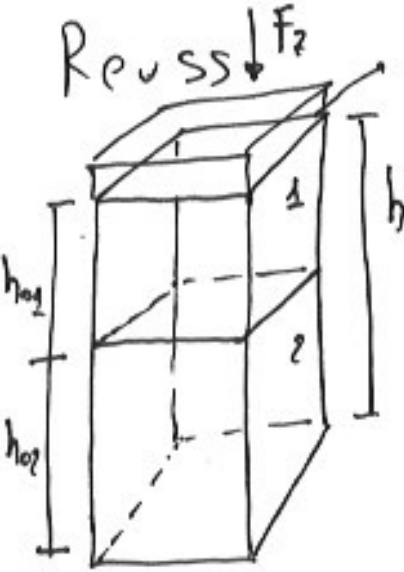
$\sigma =$

$\cancel{\sigma} E = \cancel{\sigma_1} E_1 f_1 + \cancel{\sigma_2} E_2 f_2$

$E = E_1 f_1 + E_2 f_2.$

$f_1 + f_2 = 1$

$$\boxed{E = E_1 f_1 + E_2 (1 - f_1)}$$



$V = A \cdot h_0$

$h_0 = h_{01} + h_{02}.$

$h = h_1 + h_2$

$\Delta h = h - h_0 = h_1 + h_2 - h_{01} - h_{02} = (h_1 - h_{01}) + (h_2 - h_{02})$

$$\frac{\Delta h}{h_0} = \varepsilon = \frac{(h_1 - h_{01})}{h_0} + \frac{(h_2 - h_{02})}{h_0}$$

$$\frac{\Delta h}{h_0} = \varepsilon = \frac{(h_1 - h_{01})}{h_0}\frac{h_{01}}{h_{01}}\cdot\frac{A}{A} + \frac{(h_2 - h_{02})}{h_0}\cdot\frac{h_{02}}{h_{02}}\cdot\frac{A}{A}$$

$$\varepsilon = \varepsilon_1 \frac{V_1}{V_{TOT}} + \varepsilon_2 \cdot \frac{V_2}{V_{TOT}} = \varepsilon_1 f_1 + \varepsilon_2 f_2.$$

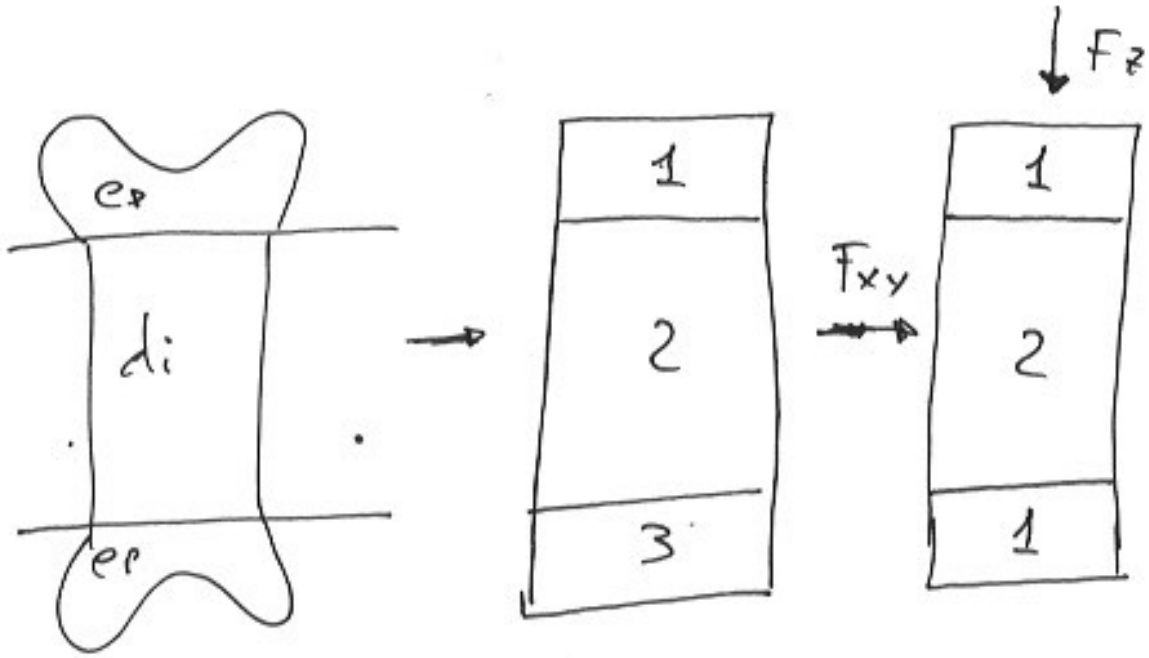
$$\sigma = \varepsilon E \Rightarrow \quad \varepsilon = \frac{\sigma}{E}$$

$$\frac{\sigma}{E} = \frac{\sigma_1}{E_1}\cdot f_1 + \frac{\sigma_2}{E_2} f_2$$

$$\sigma = \sigma_1 = \sigma_2.$$

$$\frac{1}{E} = \frac{1}{E_1}\cdot f_1 + \frac{1}{E_2} f_2.$$

$$E_{TOT} = \frac{E_1 \cdot E_2}{E_1 f_2 + E_2 f_1} = \boxed{\frac{E_1 E_2}{E_1(1-f_1) + E_2 f_1.}}$$



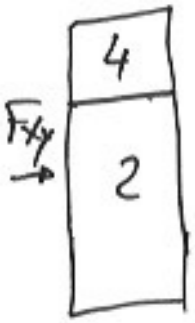
$f_{diaf} = 70\%$

$f_{ep} = 15\%$

$E^{z}_{comp} = 17\ GPa$

$E^{xy}_{comp} = 12\ GPa$

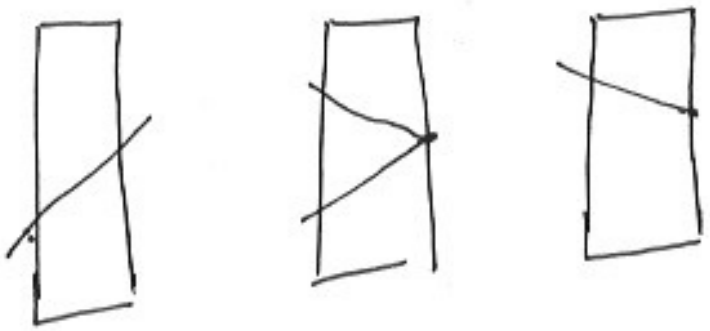
$E_{osso} = 0.5\ GPa$



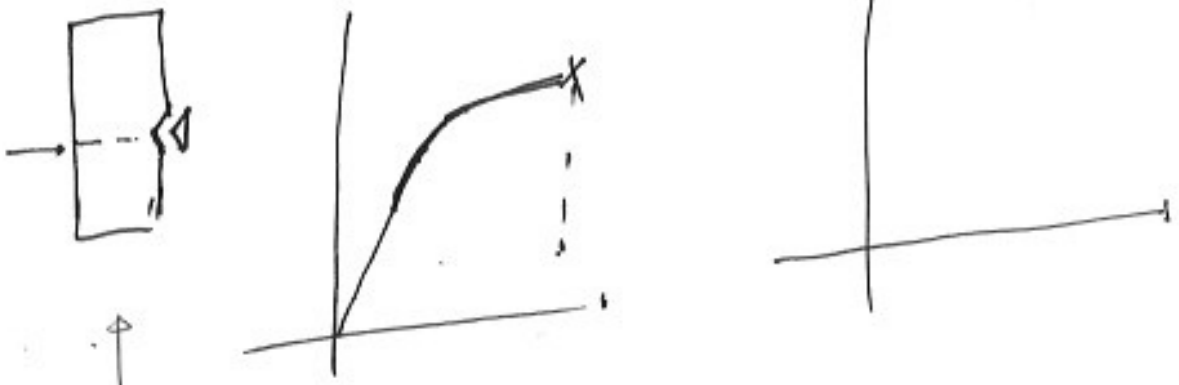
$4 = 2 - 1 \qquad f_4 = 30\% \qquad f_2 = 70\%$

$$E^{R}_{TOT} = \frac{E_4 \cdot E_2}{f_4 \cdot E_2 + f_2 E_4} = \frac{0.5 \cdot 17}{0.3 \cdot 17 + 0.7 \cdot 0.5} = \frac{8.5}{5.1 + 0.35} = \underline{1.56\ GPa}$$

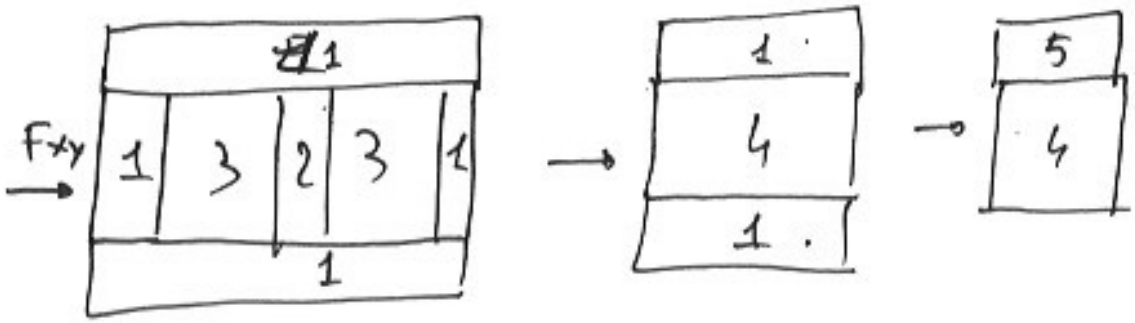
$$E^{V}_{TOT} = f_4 E_4 + f_2 E_2 = 0.3 \cdot 0.5 + 0.7 \cdot 12 = 0.15 + 8.4 = \underline{8.55\ GPa}$$



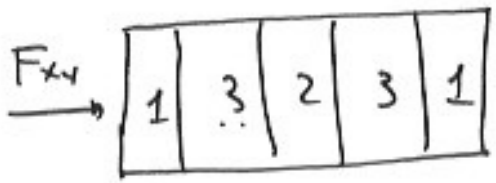
fratture composte

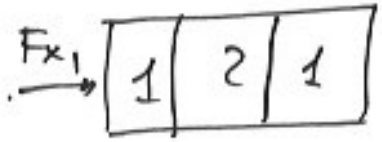


fratture scomposte

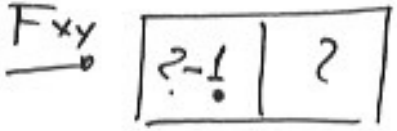


$f_5 = 2 f_1$





$f_4 = 2 f_1 + f_2 + 2p$

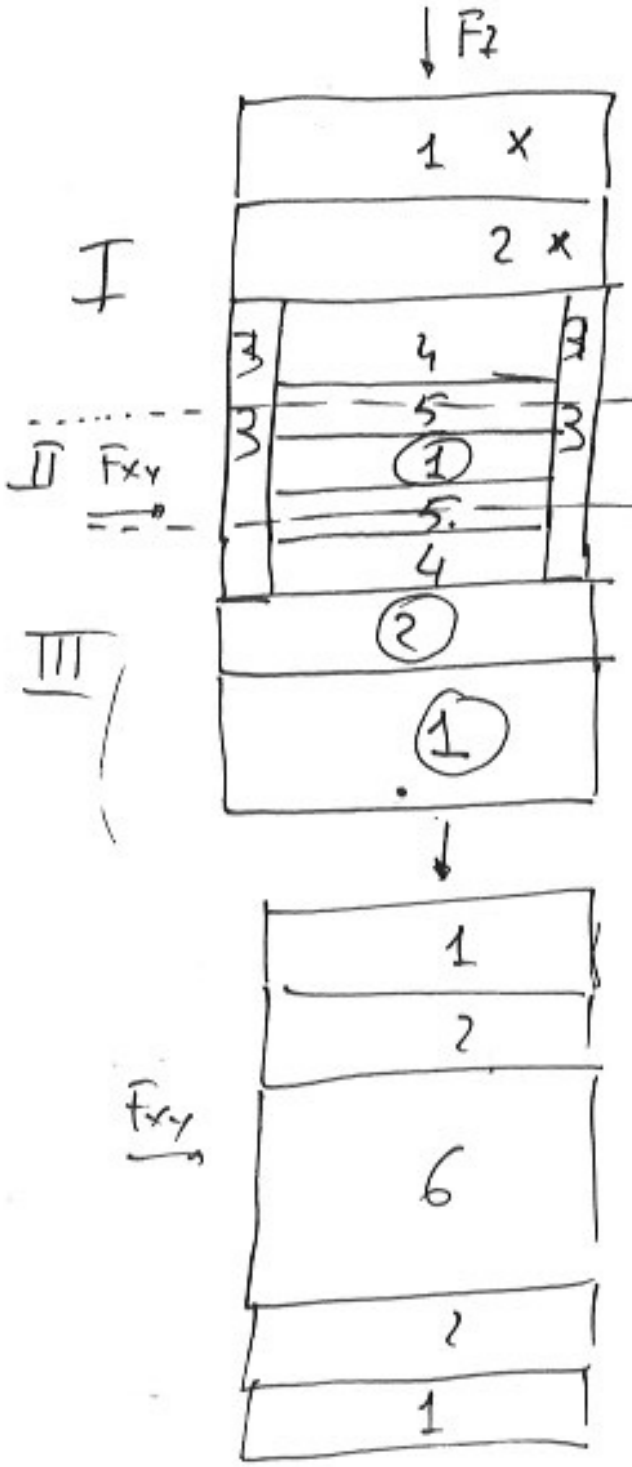


$$E_4 = \frac{E_1 \cdot E_2}{2 f_1 E_2 + f_2 E_1}$$

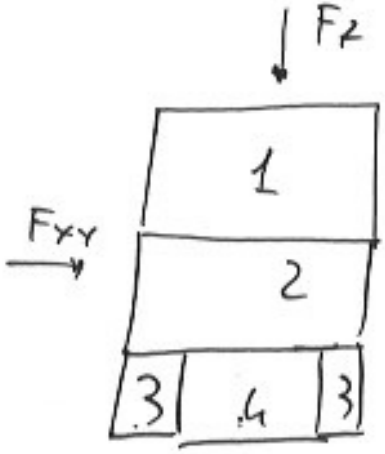
$$E_T = f_5 E_5 + f_4 E_4$$

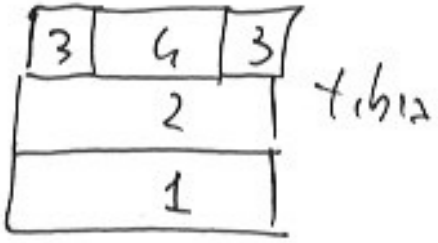
$$E_4 = \frac{E_1 \; E_2}{2 f_1 E_2 + f_2 E_1}$$

$$E_T = 2 f_1 E_1 + (2 f_1 + f_2 + 2p) \frac{E_1 E_2}{2 f_1 E_2 + f_2 E_1}$$

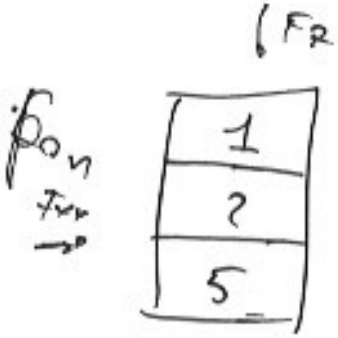


1 Osso compatto
2 osso spongioso
3 legamento
4 capsula/cart
5 liquido sinoviale



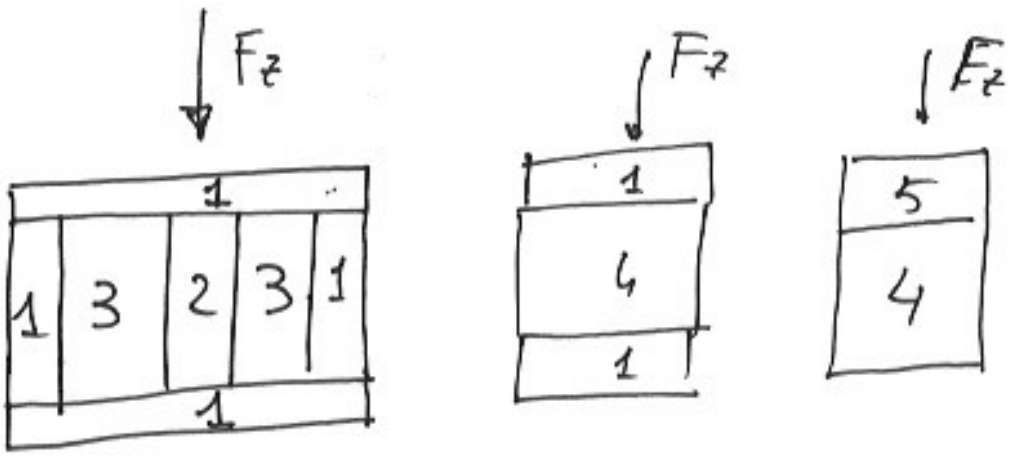


$$f_A = \frac{V_A}{V_T}$$



$$E_T^{xy} = f_1 E_1 + f_2 E_2 + f_5 E_5$$

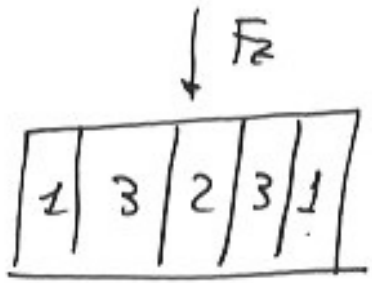
$$\frac{1}{E_T} = \frac{f_1}{E_1} + \frac{f_2}{E_2} + \frac{f_5}{E_5}$$



$f_5 = 2 f_1$ → E_1

$f_4 = 2f_1 + 2f_3 + f_2$

$E_{TOT} = \dfrac{E_5 \cdot E_4}{f_4 E_5 + f_5 E_4}$

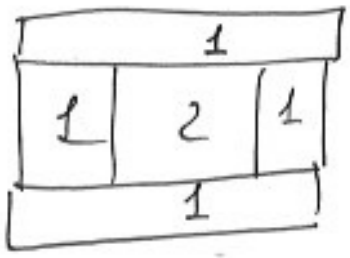


~~$E_4 = 2f_1 + 2f_3$~~

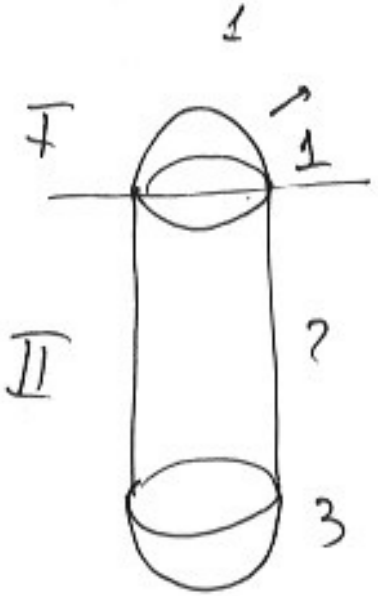
$E_4 = 2f_1 E_1 + 2f_3 E_3 + f_2 E_2$

$\to \varnothing$

$E_4 = 2f_1 E_1 + f_2 E_2$



$2f_3 = P$



$$V_1 = \frac{2\pi r^3}{3}$$

$$V_3 = \frac{2}{3}\pi r^3$$

$$V_2 = \pi r^2 h.$$

$$k_{II} = k_2 + k_3.$$

$$V_{TOT} = V_2 + V_3$$

$$k_2 = \frac{\pi r^2 h}{\frac{2}{3}\pi r^3 + \pi r^2 h}$$

$$V_{TOT} = V_1 + V_2 + V_3 = \frac{4}{3}\pi r^3 + \pi r^2 h.$$

$$k_3 = k_1 = \frac{\frac{2}{3}\pi r^3}{\frac{4}{3}\pi r^3 + \pi r^2 h}$$

$$k_2 = \frac{\pi r^2 h}{\frac{4}{3}\pi r^3 + \pi r^2 h}$$