(-)

$$t_{gap} = t^{\circ}_{gap} - \Delta t_{gap} \quad \text{where} \quad \Delta t_{gap} = \Delta \bar{R}_c - \Delta R_f$$

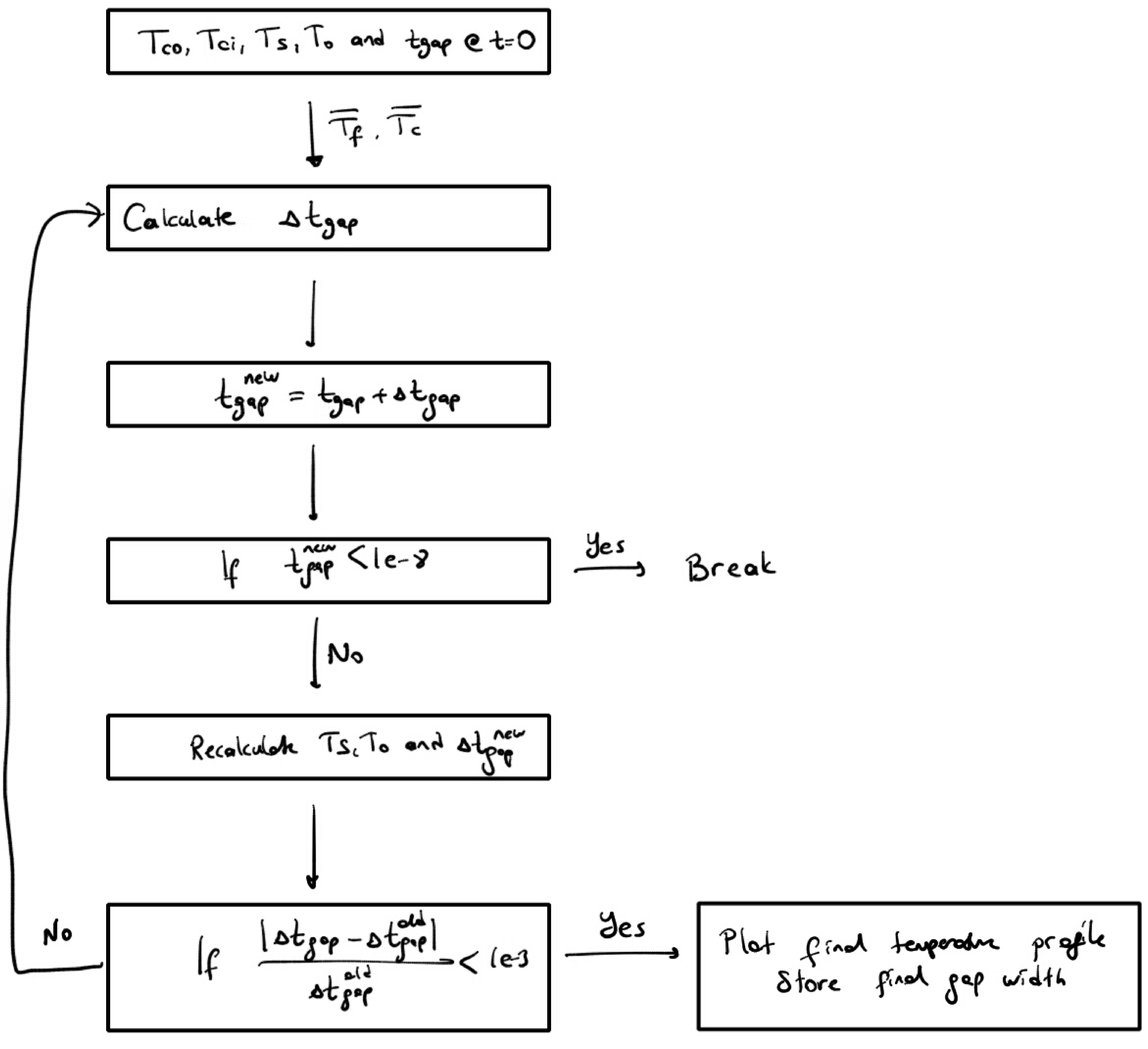
$$\frac{\Delta \bar{R}_c}{\bar{R}_c} = \alpha_c \left[\bar{T}_c - T_{fab}\right] \longrightarrow \Delta \bar{R}_c = \bar{R}_c \alpha_c \left[\bar{T}_c - T_{fab}\right]$$

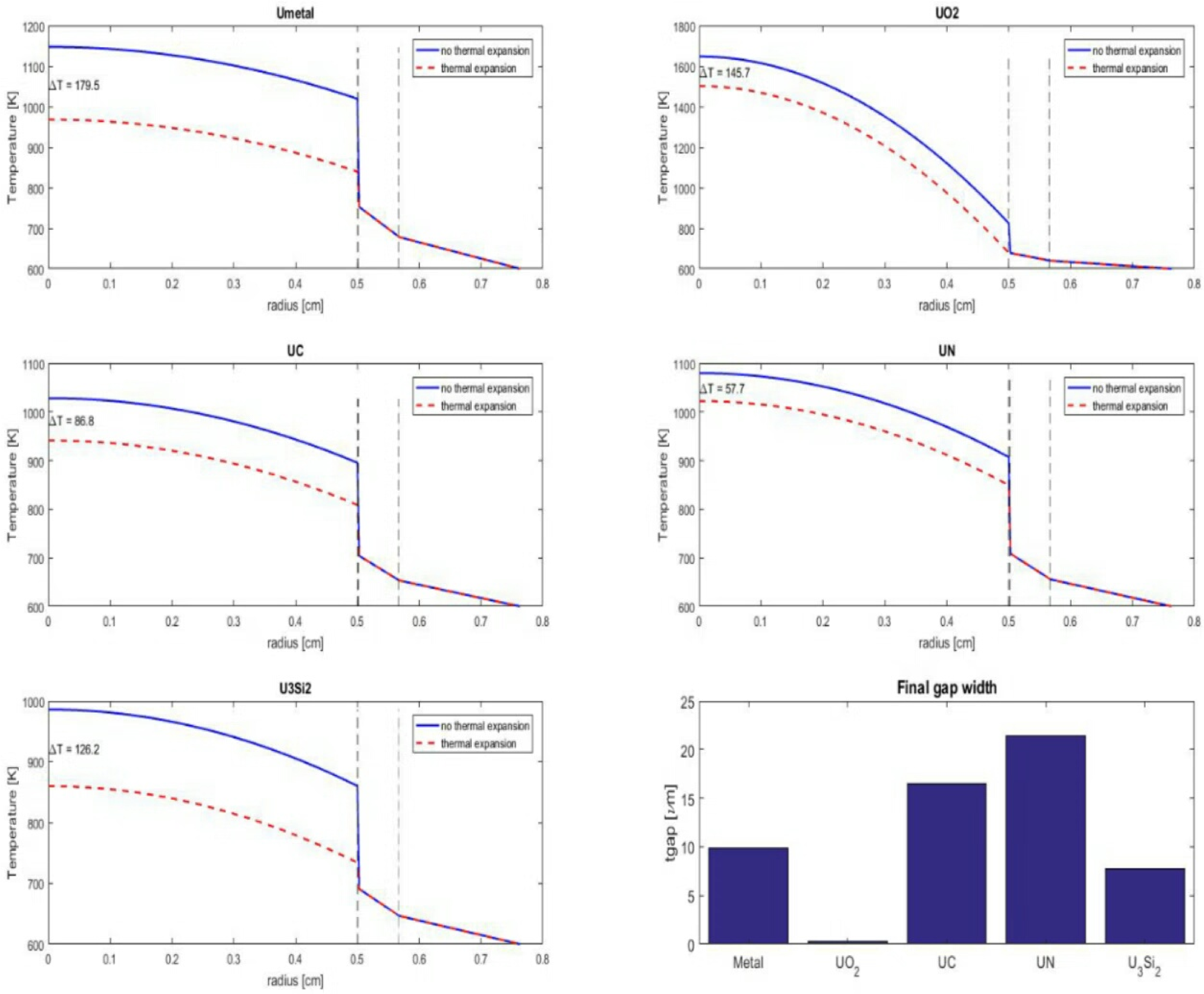
- $\bar{R}_c = R_f + t_{gap} + t_{clad}/2 = 0.5 + 30\times10^{-4} + \frac{0.065}{2} = 0.5355\,cm$
- $\bar{T}_c = \frac{T_{co} + T_{ci}}{2} \approx 614\,K$ [calculated from HW-2]

$$\Delta \bar{R}_c = 1.2\times10^{-3}\ cm$$

$$\frac{\Delta R_f}{R_f} = \alpha_f \left[\bar{T}_f - T_{fab}\right] \longrightarrow \Delta R_f = R_f \alpha_f \left[\bar{T}_f - T_{fab}\right] \quad \text{where} \quad \bar{T}_f = \frac{T_o + T_s}{2}$$

Note that ΔR_f will change with time since gap thickness changes due to thermal expansion. Change in gap also affect $\bar{T}_f$. Therefore, we solve it iteratively as discussed in the class (Lec-15). by applying the following algorithm:





Q-2)

a) Since we assume that He behaves as an ideal gas; we can find # of moles by using ideal gas law:

$$PV = nRT$$

$$n_{He} = \frac{PV}{RT} \quad \text{where} \quad P = 2\ \text{MPa},\ T = 273\ \text{K},\ R = 8.314\ \frac{\text{MPa cm}^3}{\text{K-mol}}$$

Volume associate with He gas can be calculated as:

$$V_{He} = V_{gap} + V_{plenum}$$

$$V_{gap} = \pi\, h_{pellet}^{total} \left[R_{ci}^2 - R_f^2\right] = 4.994\ \text{cm}^3$$

$$V_{plenum} = \pi\, h_{plenum}\, R_{ci}^2 = 27.5\ \text{cm}^3$$

$$V_{He} = 4.994 + 27.5$$

$$= 32.5\ \text{cm}^3$$

$$n_{He} = \frac{(2)(32.5)}{(8.314)(273)} \cong 0.03\ \text{moles}$$

b) The max. stress by the zirconium cladding is hoop stress, $\sigma_{\theta\theta}$. Based on the thick wall assumption, its value can be calculated as:

$$\sigma_{\theta\theta} = P \cdot \frac{(R_o/r)^2 + 1}{(R_o/r)^2 - 1}$$

Max. stress occurs at $r = R_i$. Right after the reactor begins to operate, He gas pressure will reach to $P_{operation} = \left(\frac{T_{operation}}{T_{initial}}\right) P_{initial} = \left(\frac{620}{273}\right) 2 \cong 4.54$ MPa. Therefore, the max. stress is:

$$\sigma_{\theta\theta} = 4.54 \left[\frac{(4.75/4.18)^2 + 1}{(4.75/4.18)^2 - 1}\right]$$

$$= (4.54)(7.87)$$

$$= \boxed{35.71 \text{ MPa}}$$

c) $\sigma_{\theta\theta} = \sigma_y = P[7.87]$ → calculated in the previous part

$381 = P[7.87]$

$P = 48.41$ MPa

Then;

$$n_{He} = \frac{(48.41)(32.5)}{(8.314)(620)}$$

$n_{He} = 0.31$ moles

$$n_{He}^{enter} = n_{He}^{total} - n_{He}^{initial}$$

$$= 0.31 - 0.03$$

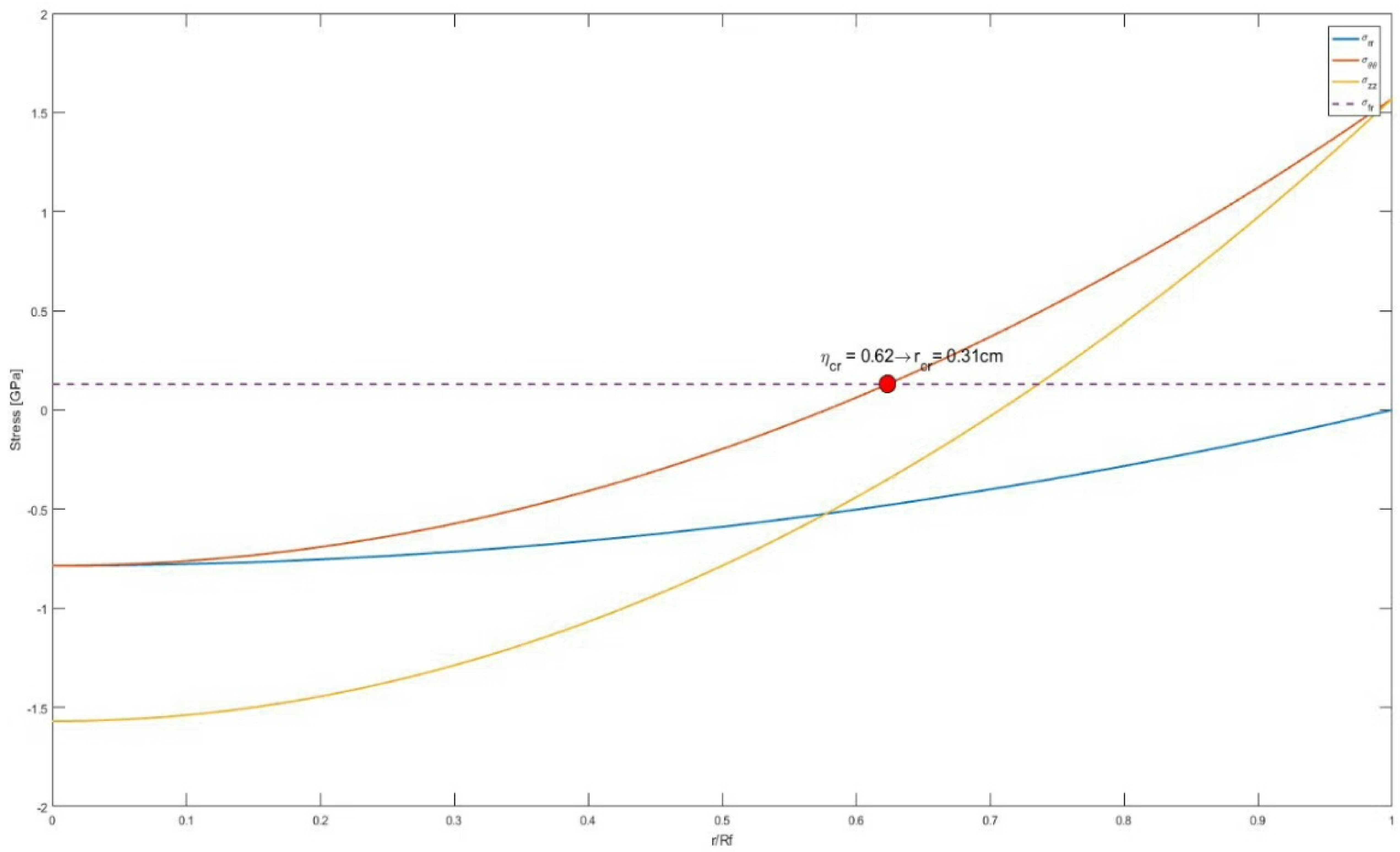
$$= \boxed{0.28 \text{ moles of He}}$$

Q-3) a)

$$\sigma_{rr}(\eta) = -\sigma^* [1-\eta^2]$$

$$\sigma_{\theta\theta}(\eta) = -\sigma^* [1-3\eta^2] \qquad \text{where} \qquad \sigma^* = \frac{\overset{11e-6\ 1/K}{\boxed{\alpha}}\,\underset{200\ GPa}{\boxed{E}}\,\underset{\text{determined from HW2}}{(T_0-T_s)}}{4(1-\underset{0.345}{\boxed{\nu}})}$$

$$\sigma_{zz}(\eta) = -2\sigma^* [1-2\eta^2] \qquad \eta = r/R_f$$



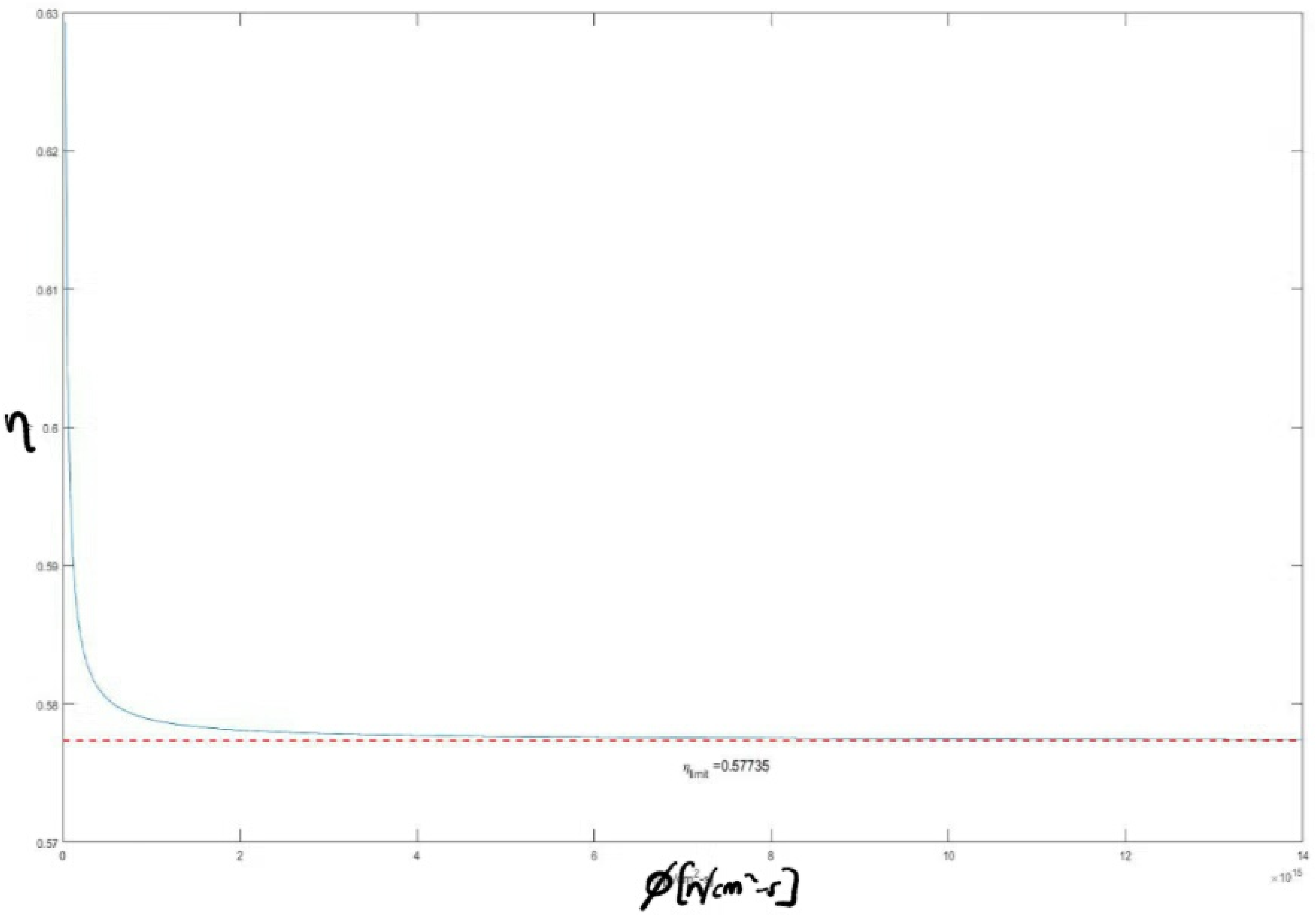
b) $\sigma_{\theta\theta} = \sigma_{fr} = -\sigma^* [1-3\eta^2] \longrightarrow$ solve for $\eta \cong \sqrt{\frac{1}{3}\left[1+\frac{\sigma_{fr}}{\sigma^*}\right]} = 0.62$

OR

$r = R_f \eta = (0.5)(0.62) = 0.31$ cm

c) If the cracks will penetrate 60% of the distance from the outer edge ; $\eta = 1-0.6 = 0.4$

Recall that η is function of σ^*. and σ^* varies with $T_0 - T_s$ which is proportional to neutron flux, ϕ. Then, we can plot η vs. ϕ by using $\eta = \sqrt{1/3\left[1+\frac{\sigma_f}{\sigma^*}\right]}$ relation

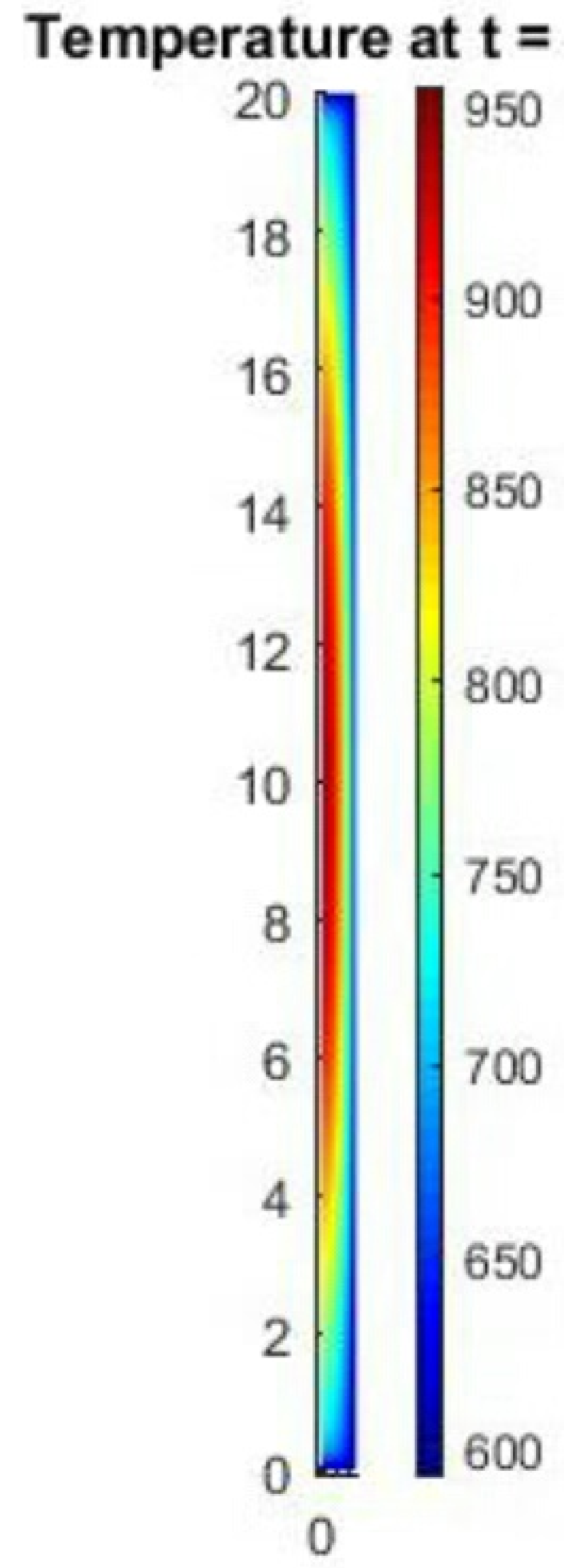


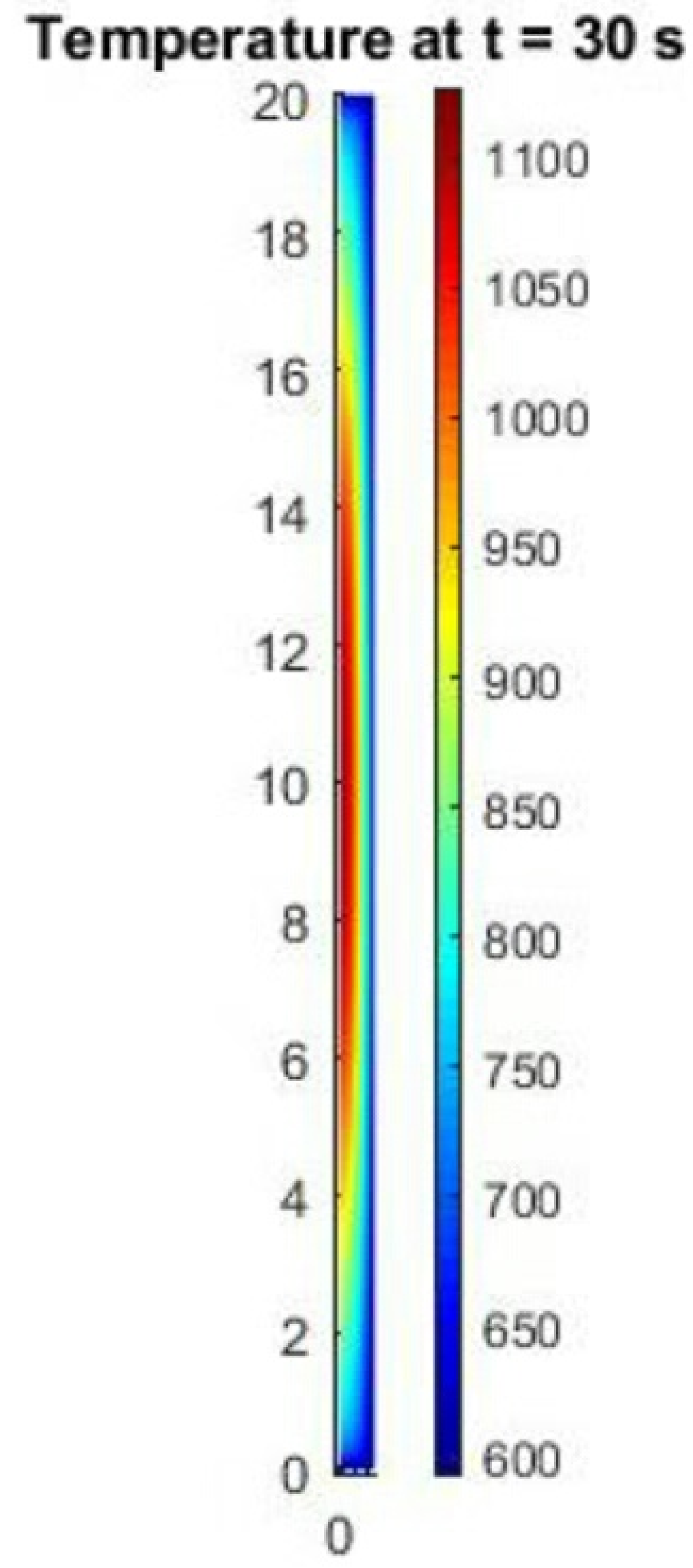
Minimum η value can be achieved if $\sigma^* \to \infty$ [or $\phi \to \infty$] which yields:

$$\eta_{min} \cong \sqrt{\frac{1}{3}[1+0]} = \sqrt{1/3} = 0.5775$$

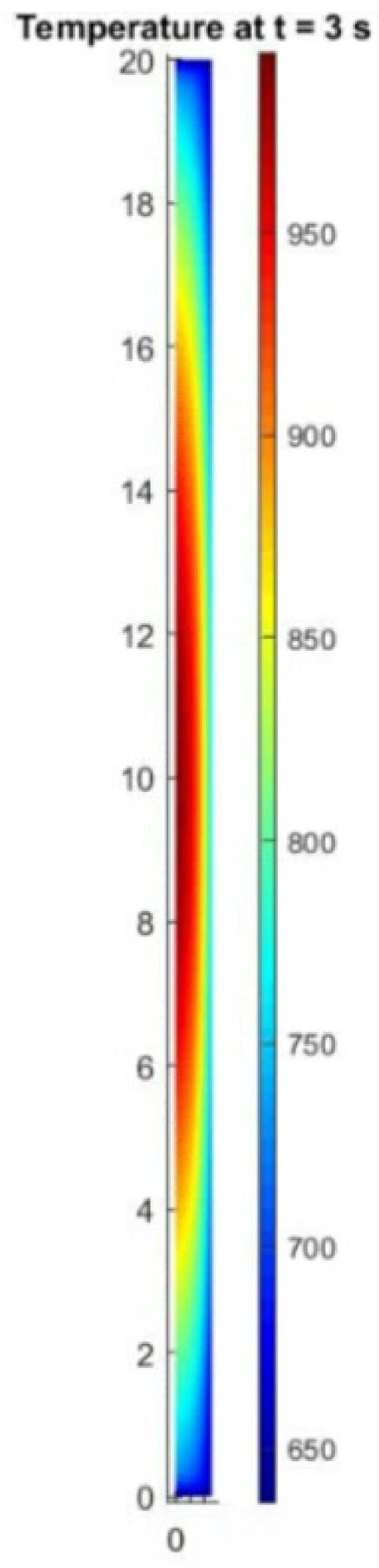
Therefore, it is NOT possible to find a neutron flux yielding $\eta = 0.4$.

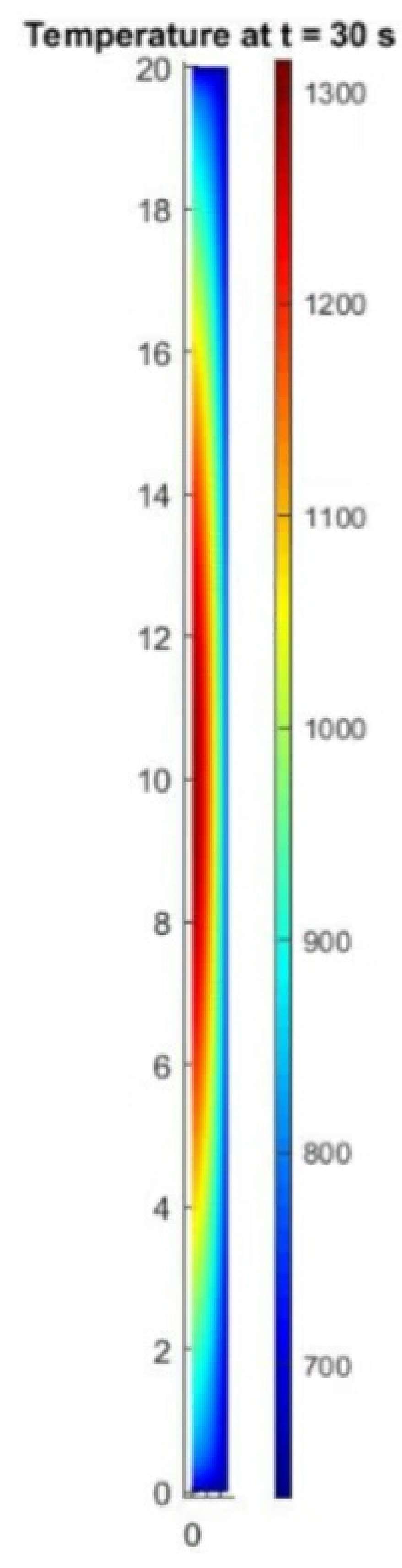
Q-4) with thermal expansion:





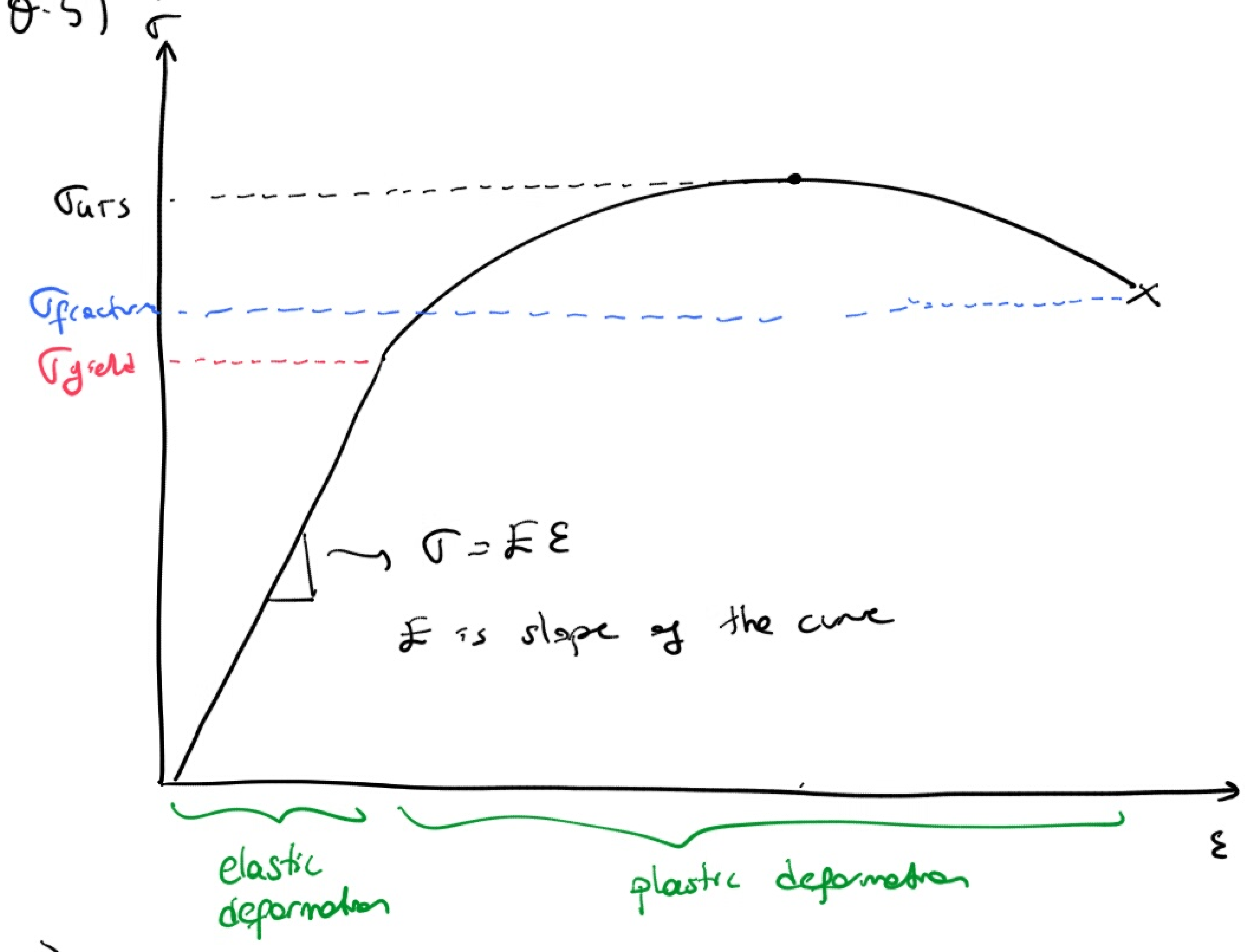
without thermal expansion (HW2)





Due to thermal expansion, gap thickness decreases in time yielding less thermal resistance. Therefore, fuel temperature decreases as we expected!

Q.5) a)



b)

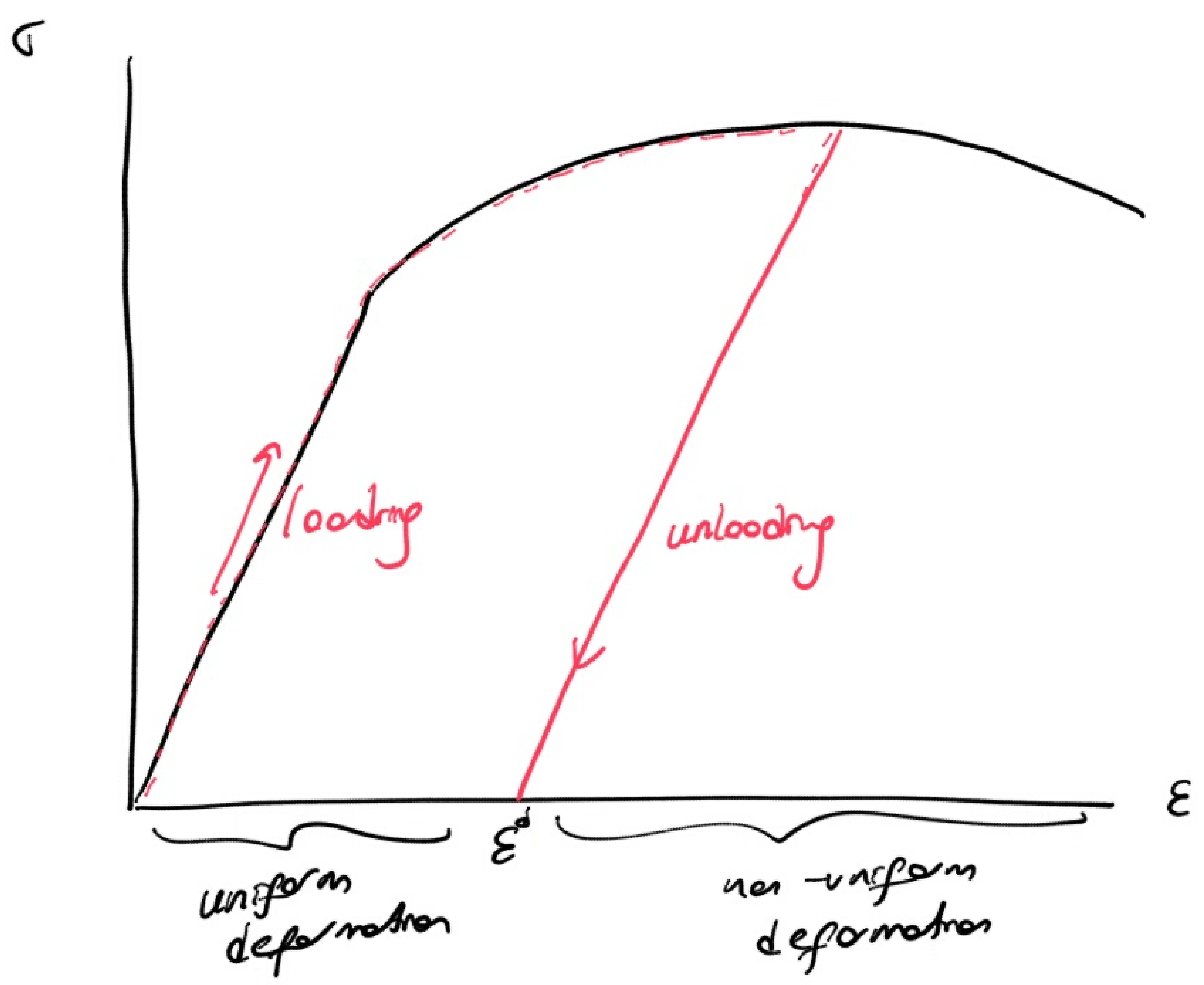
In the elastic region, we are stretching the atomic bonds. When we release the load, the atoms spring back into their lattice sites. Therefore, there is no permanent deformation.

σ_{yield} is stress that elastic to plastic deformation starts to be observed. Beyond σ_{yield}, preexisted dislocation start to move. During the further load, additional dislocations are created as well.

Once the stress reaches to the σ_{uts}, material starts necking. Since cross-sectional area decreases during this deformation, stress necessary to deform the material becomes less. This is because all of the deformation is concentrated in the region where necking occurs.

At $\sigma_{fracture}$ material fails

c)



When we unload the sample at the σ_{UTS}, we will have a permanent deformation, ε^{d}. Since up to this point, we will be creating further dislocations in our sample, resulting material will be more brittle compared to its initial state.