1) $R_F = 0.45\,cm$, $LHR = 250\ W/cm$

a) Max stress? $K_f = 0.1\ W/cmK$ $E = 290\ GPa$ $\nu = 0.25$ $\alpha = 12\times10^{-6}\ 1/K$

Max stress is σ_θ @ $r = R_F$

$$\sigma_\theta = -\sigma^*(1-3\eta^2) \quad \text{where} \quad \sigma^* = \frac{\alpha E \Delta T}{4(1-\nu)}$$

$$\Delta T = T_0 - T_S = \frac{LHR}{2\pi K_F}\left(1-\frac{\cancel{R}^2}{R_F^2}\right) = \frac{250}{2\pi(0.1)} = 397.9K$$

$$\sigma^* = \frac{(12\times10^{-6})(290\ GPa)(397.9K)}{4(1-0.25)} = 0.462 \qquad \eta = \frac{R_F}{R_F} = 1$$

$$\sigma_\theta = -(0.462)(1-3(1)^2) = 0.923\ GPa = 923\ MPa$$

$$\boxed{\sigma_\theta = 923\ MPa}$$

b)

ran out of time.

2) $P = 25\,MPa$ $\quad \bar{R} = 0.52\,cm$ $\quad \delta_c = 0.08\,cm$

$\bar{R} = r_i + \delta_c/2 = 0.52$

$r_i = 0.48\,cm$

$r_o = 0.56\,cm$

a) $\sigma_\theta = \frac{pR}{\delta}$ $\quad \sigma_z = \frac{pR}{2\delta}$ $\quad \sigma_r = \frac{-p}{2}$

$\sigma_\theta = \frac{(25)(0.56\,cm)}{0.08}$ $\quad \sigma_z = \sigma_\theta/2 =$ $\quad \boxed{\sigma_r = -12.5\,MPa}$

$\boxed{\sigma_\theta = 175.0\,MPa}$ $\quad \boxed{\sigma_z = 87.5\,MPa}$

b) $r = 0.5\,cm$ $\quad$ assume $\bar{R} = R$

$\sigma_\theta = p\left[\frac{\left(\frac{r_o}{r}\right)^2 + 1}{\left(\frac{R_o}{r_i}\right)^2 - 1}\right]$ $\quad \sigma_{zz} = p\left[\frac{1}{(R_o/R_i)^2 - 1}\right]$ $\quad \sigma_{rr} = -p\left[\frac{(R_o/r)^2 - 1}{R_o/R_i{}^2 - 1}\right]$

$\bar{R} = r_i + \delta_c/2 = 0.52 \rightarrow R_i = 0.52 - 0.04\,cm = 0.48\,cm$

$r_o = r_i + \delta_c = 0.56\,cm$

$\left(\frac{0.56}{0.5}\right) = 1.12$

$\left(\frac{0.56}{0.48}\right) = 1.1\overline{6}$

$\sigma_{\theta\theta} = 25\left[\frac{\left(\frac{0.56}{0.5}\right)^2 + 1}{\left(\frac{0.56}{0.48}\right)^2 - 1}\right]$ $\quad \sigma_{zz} = (25)\left[\frac{1}{\left(\frac{0.56}{0.48}\right)^2 - 1}\right]$

$\sigma_{rr} = -(25)\left[\frac{(0.56/0.5)^2 - 1}{(0.56/0.5)^2 - 1}\right]$

$\boxed{\sigma_{\theta\theta} = 156.1\,MPa}$ $\quad \boxed{\sigma_{zz} = 69.2\,MPa}$ $\quad \boxed{\sigma_{rr} = -17.6\,MPa}$

c) $\epsilon_{\theta\theta} = \frac{1}{E}\left(\sigma_{\theta\theta} - \nu(\sigma_{rr} + \sigma_{zz})\right)$ $\quad E = 160\,GPa$, $\nu = 0.3$

$$\frac{1}{160000}\left(156.1 - 0.3(-17.6 + 69.2)\right)$$

$$\boxed{\epsilon_{\theta\theta} = 8.79 \times 10^{-4}}$$

3) $R_f = 0.52\,cm$ $\quad t_g^{\circ} = 0.005\,cm$, $\quad T_{co} = 550\,K$ $\quad t_{clad} = 0.08\,cm$

$k_f = 0.04\,W/cmK$ $\quad k_{gap} = 0.003\,W/cmK$, $\quad LHR = 400\,W/cm$ $\quad \alpha_c = 12\times10^{-6}\,1/K$

$\alpha_F = 8\times10^{-6}\,1/K$, $\quad T_{ref} = 300\,K$ $\quad k_c = 0.15\,W/cmK$

$$\Delta t_g = \Delta t_c - \Delta t_F + t_g^{\circ}$$

$$\Delta t_c = \bar{R}_c\,\alpha_c(\bar{T}_c - T_{ref}) \rightarrow \bar{R}_c = R_F + t_g + t_c/2 = 0.565\,cm$$

$$\Delta t_F = R_F\,\alpha_F(\bar{T}_F - T_{ref})$$

$$\bar{T}_c = \frac{T_{ci} + T_{co}}{2} \qquad T_{ci} = \frac{LHR}{2\pi R_f}\left(\frac{t_c}{k_c}\right) + T_{co} = \frac{400}{2\pi(0.52)}\left(\frac{0.08}{0.15}\right) + 550\,K$$

$$= 615.3\,K$$

$$\underline{\bar{T}_c = 582.6\,K}$$

$$\Delta t_c = (0.565)(12\times10^{-6})(582.6 - 300)$$

$$= 0.00192\,cm$$

$$\Delta T_0 - T_s = \frac{LHR}{2\pi k_f} = \frac{400}{2\pi(0.04)} = 1591.5\,K$$

$$T_s = \frac{LHR}{2\pi R_f}\left(\frac{t_g}{k_g}\right) + T_{ci} = \frac{400}{2\pi(0.52)}\left(\frac{0.005}{0.003}\right) + 615.3 = 819.3$$

$T_o = 1591.5k + 819.3K = \underline{2410.8K}$

$T_F = \dfrac{T_o + T_s}{2}$

$= \dfrac{2410.8K + 819.3K}{2} = 1615.05\,K$

$\Delta t_F = (0.52)(8\times10^{-6})(1615.05 - 300) = 0.00547$

$\Delta t_g = 0.00192 - 0.00547 + 0.005$

$\boxed{\Delta t_g = 0.00143\,cm}$

4) $dy/dt = -5y \rightarrow \int \dfrac{dy}{-5y} = \int dt \rightarrow -\frac{1}{5}\ln y = t$ $\quad dt = 0.25$

$y = e^{-5t} + C$

$y(0) = 1 = e^0 + C \rightarrow \underline{C=0}$

$y = e^{-5t} \qquad y' = -5e^{-5t}$

$t=0.25$ $y_1 = y_0 + dt\,y_0'$

$y_1 = 0.287 + (0.25)(-5e^{-5(0.25)})$

$\underline{y_1 = -0.25 - 0.358 = -0.608}$

$t=0.5$ $y_2 = y_1 + dt\,y_1' \rightarrow \underline{y_2 = -0.0205}$

$t=0.75$ $\underline{y_3 = 0.00588}$

$t=1$ $\quad y_4 = -0.00168$

$$\boxed{\begin{aligned} y_0 &= 1 \\ y_1 &= -0.608 \\ y_2 &= -0.0205 \\ y_3 &= 0.00588 \\ y_4 &= -0.00168 \end{aligned}}$$

5)

Max hoop stress @ R_{EO}

$$\sigma_\theta = \frac{\Delta T}{2}\frac{\alpha E}{1-\nu}\left(1 - 2\frac{R_i}{t_o}\left(\frac{R_{EO}}{R_i} - 1\right)\right)$$

$$= \frac{250}{2}\left(\frac{(8\times10^{-6})(250)}{1-0.3}\left(1 - 2\frac{(0.55)}{0.1}\left(\frac{0.65}{0.55} - 1\right)\right)\right)$$

$$\boxed{\sigma_\theta = -649.4\ \text{MPa}}$$

	Strength	Weak
6) Finite difference		
Finite volume		
Finite element		

7) Strain hardening is permanent deformation of the material dislocation changes in the microstructure that harden the material if stopped mid-test / load.

9) 0-D - Point defect i.e. Vacancies
3-D - Voids or precipitates

10) Due to varying system conditions, fuel microstructure changes with stress, temperature, pressure and other conditions. Modeling can be used to predict fuel performance based on material microstructure. This informs optimal fuel design.

11) ran out of time

12) Microstructure is ~~another~~ way of describing the lattice structure in a material (FCC, BCC, HCP, etc). It changes based on the material type within varying system conditions (T, P, σ).