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this is correct!

60 μm   r=1.25

Test 1

1. $\varepsilon = 19\%$ $\rho = 14.3 \frac{g}{cm^3}$ $\sigma_f = 587\times10^{-24} cm^2$ $\phi = 4\times10^{12} \frac{n}{cm^2 s}$ UN

→ start w/ this, 0.5 U / UN

a) $m(UN) = 0.5(0.19\cdot235 + 0.81\cdot238) + 0.5(14) = 125.715 \frac{g}{mol}$

8/8 $N_{U235} = 14.3\frac{g}{cm^3}\frac{1 mol}{125.715 g}\frac{6.022\times10^{23}}{1 mol}\cdot\frac{\cancel{0.5}\,1}{1 mol\,UN}\cdot 0.19 = \cancel{6.5075\times10^{21}} \frac{U235}{cm^3}$ $1.3015\times10^{22} \frac{U235}{cm^3}$

$Q = E_f N_f \sigma_f \phi = (200\times10^6 eV)(1.602\times10^{-19}\frac{J}{eV})(587\times10^{-24} cm^2)(4\times10^{12}\frac{n}{cm^2 s})(\cancel{6.5075\times10^{21}} \frac{U235}{cm^3})$

$= \boxed{\cancel{489.56} \frac{W}{cm^3}}$ $\boxed{979.117 \frac{W}{cm^3}}$

b) What ε UO2 yields $Q_{UN} = Q_{UO2}$; $\rho_{UO2} = 10.97 \frac{g}{cm^3}$

$\cancel{E_{f,UN}} N_{f,UN} \cancel{\sigma_{f,UN}} \cancel{\phi_{UN}} = \cancel{E_{f,UO2}} N_{f,UO2} \cancel{\sigma_{f,UO2}} \cancel{\phi_{UO2}}$ -right process, wrong masses

$\rho_{UN}\frac{1}{molar\,mass}\cdot\cancel{\frac{6.022\times10^{23}}{1 mol}}\cdot\cancel{\frac{0.5}{1 mol\,UN}}\cdot\varepsilon_{UN} = \rho_{UO2}\frac{1}{\frac{1}{3}(\varepsilon(235)+(1-\varepsilon)(238))+\frac{2}{3}(16)}\cdot\cancel{\frac{6.022\times10^{23}}{1 mol}}\cdot\varepsilon_{UO2}$

$\Rightarrow \boxed{\varepsilon = 17.696\%}$ ← should require higher ε for UO2!

2. $k_{clad} = 0.18 \frac{W}{cmK}$; $k_{fuel} = 0.024 \frac{W}{cmK}$; $h_{cool} = 1.5 \frac{W}{cm^2K}$; $Q = 350 \frac{W}{cm^3}$; $R_f = 0.4 cm$; $t_{gap} = 30\times10^{-6} m$
$t_{clad} = 0.05 cm$; $T_{cool} = 500K$

18/18 a) i) $LHR = \pi R_f^2 Q = \pi(0.4cm)^2(350\frac{W}{cm^3}) = 175.929 \frac{W}{cm}$; $\frac{LHR}{2\pi R_f} = \frac{175.929}{2\pi(0.4)} = 70$

$T_{oc} - T_{cool} = \frac{LHR}{2\pi R_f}\frac{1}{h_{cool}} = 70\frac{1}{1.5\frac{W}{cm^2K}} = 46.67K$ $T_{oc} = 546.67K$

$T_{IC} - T_{oc} = \frac{LHR}{2\pi R_f}\frac{t_{clad}}{k_{clad}} = 70\cdot\frac{0.05cm}{0.18\frac{W}{cmK}} = 19.44K$ $T_{IC} = 566.11K$

$T_{fuel} - T_{IC} = \frac{LHR}{2\pi R_f}\frac{t_{gap}}{k_{gap}}$ $k_{gap,He} = 16\times10^{-6}\,T_{IC}^{0.79} = 2.3928\times10^{-3}\frac{W}{cmK}$

$= \cancel{70\cdot\frac{30\times10^{-6}m}{2.3928\times10^{-3}}} = 70\cdot\frac{0.003 cm}{2.3928\times10^{-3}\frac{W}{cmK}} = 87.76K$; $T_{fuel} = 653.87K$

$T_0 - T_{fuel} = \frac{LHR}{4\pi k_{fuel}} = \frac{175.929\frac{W}{cm}}{4\pi(0.024\frac{W}{cmK})} = 350K$ $\boxed{T_0 = 1003.87K}$

ii) $r = 0.1cm$ $T = ?$ $rk\frac{\partial T}{\partial r} = -\frac{Qr^2}{2} + C_1$; $\frac{dT}{dr}\Big|_{r=0} = 0 \Rightarrow C_1 = 0$

$\frac{\partial T}{\partial r} = \frac{-Qr}{2k} \Rightarrow T(r) = -\frac{Qr^2}{4k} + C_2$ $T(0.4cm) = T_{fuel} = 653.87K$

$\Rightarrow C_2 = 1003.87K$

$T(0.1cm) = 1003.87K - \frac{350\frac{W}{cm^3}\cdot(0.1cm)^2}{4(0.04\frac{W}{cmK})} = \boxed{981.995K}$

-we have eqn's for this!!

b) $k_{ox} = 0.015 \frac{W}{cmK}$ $t_{ox} = 0.006 cm$

$T_{oc} - T_{ox} = \frac{LHR}{2\pi R_f}\frac{t_{ox}}{k_{ox}} = 70\cdot\frac{0.006cm}{0.015\frac{W}{cmK}} = 28K$

$\boxed{\text{Increases } T_0 \text{ by } 28K.}$

5/8

3. $L_{rod} = 3.6\,m$ $LHR^{o} = 400\,\frac{W}{cm}$ $\gamma = 1.25$ $LHR(z=2.1m) = ?$

a) $z_0 = \frac{L}{2} = \frac{3.6}{2} = 1.8m$

$LHR(2.1m) = 400\cos\left(\frac{\pi}{2(1.25)}\left(\frac{2.1}{1.8}-1\right)\right) = \boxed{391.26\,\frac{W}{cm}}$

b) $T_{cool} = ?$ $C_p = 4200\,\frac{J}{kg\,k}$ $\dot{m} = 0.1\,\frac{kg}{s\cdot rod}$ $T_{in} = 500k$

$z = 3.6$

$T_{cool}(z) = \frac{2\gamma}{\pi}\frac{z_0\,LHR}{\dot{m}c_p}\left[\sin\left(\frac{\pi}{2\gamma}\right) + \sin\left(\frac{\pi}{2\gamma}\left(\frac{z}{z_0}-1\right)\right)\right] + T_{in}$

$= \frac{2(1.25)}{\pi}\frac{1.8m\cdot 400\frac{W}{cm}}{0.1\frac{kg}{s\cdot rod}\cdot 4200\frac{J}{kgk}}\left[\sin\left(\frac{\pi}{2\cdot 1.25}\right) + \sin\left(\frac{\pi}{2\cdot 1.25}\left(\frac{2.1}{1.8}-1\right)\right)\right] + T_{in} = 501.58k$

180 cm

5/8

4. $\frac{\partial T}{\partial x}\Big|_{x=0} = 0$; $x_0 = 0$; $x_1 = X$; $T(x_1) = T_1$ $\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right) + Q = 0$

$k\frac{\partial T}{\partial x} = -Qx + C_1$; $\frac{\partial T}{\partial x}\Big|_{x=0} = 0 \Rightarrow C_1 = 0$

$\frac{\partial T}{\partial x} = -\frac{Qx}{k}$

$T(x) = -\frac{Qx^2}{2k} + C_2$; $T(x_1) = T_1 \Rightarrow T_1 = -\frac{Qx^2}{2k} + C_2 \Rightarrow C_2 = T_1 + \frac{Qx_1^2}{2k}$

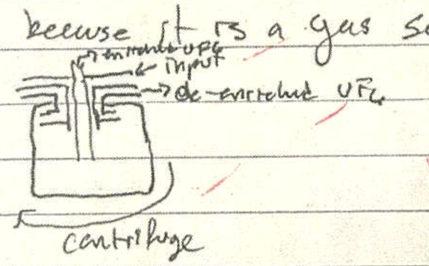
$T(x) = -\frac{Qx^2}{2k} + T_1 + \frac{Qx_1^2}{2k} = \frac{Q}{2k}(-x^2 + x_1^2) + T_1 = \frac{Qx_1^2}{2k}\left(-\frac{x^2}{x_1^2} + \frac{x_1^2}{x_1^2}\right) + T_1$

$= \boxed{\frac{Qx_1^2}{2k}\left(1 - \left(\frac{x}{x_1}\right)^2\right) + T_1}$ $x_1 = \frac{t_{fuel}}{2}$

This assumed steady state, cartesian coordinates, $k(T) = const$; $\frac{d}{dz} = 0$

6/6

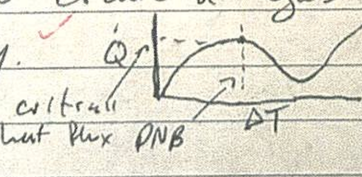
5. a) UF_6 is used in enrichment because it is a gas so its easier to separate by isotope weight. b)



Spinning the centrifuge moves the U238 preferentially outwards due to centripetal acceleration.

6/8

6) DNB is the heat flux where gas formation on the heat transfer surface starts to create a gas cushion over the surface reducing heat flux capacity.

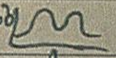


DNBR?

Critical heat flux is the highest heat flux before a gas film covers the heat transfer surface significantly increasing ΔT required.

7. Smear density is the ratio of fuel pellet volume to container/tube
4/5 volume. It is usually >90%, but not 100%. The extra
space around the pellet is filled with He usually and the
Space is used to accept Xe (and other) fission gasses. It
reduces internal pressure on the cladding. ~~and~~
-allows swelling + cladding creep

8. Porosity and impurities ~~are~~ reduce the thermal conductivity
4/4 of UO2 pellets because they inhibit heat transport through
the void space and interrup phonon energy transport.

9. Nutrons + daughter products are new species (also gamma + antineutrinos).
3/4 There are two daughter products a heavier and a lighter one prob 
A neutron exites the atom, it splits, and releases more nutrons due to quantum mechanics. A
-wanted exact elements, e.g. Xe, Kr, ~~Br~~, etc.

10. Cladding protects the UO2 pellets from coolant, maintains
4/4 ~~structural integrity~~ geometric shape of the brittle pellets that break ~~as~~ while
burning up, and retain fission products.

11. The fuel system contains of fuel pellets, cladding
1/4 rods, and the control rod.
-fuel, gap, clad, coolant

12. Heat generation, fuel behavior during accidents, and fuel issues
4/4 creating unscheduled outages.

13. Finite differen methods only work well for rectangular
2/10 systems because they discretize space in a grid.
→ wanted more

14. UO2 fuel pros: high melting temperature (2800°C); radiation resistant
4/10 cons: Brittle; poor heat conductor.

5/5

15. Explicit time integration forecasts state based on current state, while implicit uses future state change when determining the next state. Implicit is more stable because it uses future information as well. ~~but is usually~~