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Exam 1 NE 533
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1) UN enrichment 19.5%, $\rho = 12.3\,g/cm^3$ $\phi = 5\times10^{12}\ n/cm^2 s$

$\sigma_f = 587$ barns

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a) $Q = E_f N_f \phi \sigma_f$

Mass U = 0.195 × 235 + (1−0.195) × 238 = 237.415 g/mol ✓

assume UN not UN_2 or U_2N_3

1 uranium atom per UN & 1 nitrogen per UN

mass UN = 237.415 + 14 = 251.415 g/mol ✓

$$N_f = \frac{12.3\,g}{cm^3}\cdot\frac{1\,mol}{251.415\,g/mol}\cdot\frac{6.022\times10^{23}}{1\,mol}\cdot\frac{1\,U}{1\,UN}\times(.195)$$

$N_f = 5.75\times10^{21}$ ✓

$$q = (5.75\times10^{21})(587\times10^{-24})(5\times10^{12})(200\times10^{6})(1.602\times10^{-19})$$

$$\boxed{Q = 540.7\ W/cm^3}$$ ✓

b) for UO_2 $\rho = 10.97\ g/cc$

$$N_f = 10.97\cdot\frac{1\,mol}{269.4\,g/mol}\cdot\frac{6.022\times10^{23}}{1}\cdot\frac{1\,U}{1\,UO_2}(e) = ?$$

Assume σ_f & ϕ are same ✓

$N_f = 5.75\times10^{21}$ (calculated above) ✓

$e = 0.234$ ✓

$$\boxed{\text{enrichment needed} = 23.4\%}$$

– would like to see work here for 2nd part

2) $\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)+Q=0$

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$\int \frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right) = \int -Q$ ← assume Q doesn't change w/respect to x ✓

$k\frac{\partial T}{\partial x} = -Qx + C_1$ ✓

$\frac{\partial T}{\partial x} = \frac{-Qx}{k} \cancel{+C_1}$ assume K doesn't change w/respect to X ✓

$\frac{\partial T}{\partial x}(0) \Rightarrow 0 = \frac{C_1}{K} \Rightarrow C_1 = 0$ ✓

$\int \frac{\partial T}{\partial x} = \int \frac{-Qx}{K}$ ✓

$T(x) = \frac{-Qx^2}{2K} + C_2$ ✓

$T(X_1) \Rightarrow T_1 = \frac{-QX^2}{2K} + C_2 \Rightarrow C_2 = T_1 + \frac{QX^2}{2K}$ ✓

$$\boxed{T(x) = \frac{Q}{2K}\left(X^2 - x^2\right) + T_1}$$ ✓

✓ Assumptions Q & K are constant w/respect to X

- Steady State, 1-D

3) $k_{clad} = 0.15 \, W/cm\,K$ $\quad K_{fuel} = 0.03$ $\quad h_{cool} = 2.5 \, W/cm^2 K$ $\quad Q = 350 \, W/cm^3$

$R_F = 0.6\,cm$ $\quad t_g = 0.003\,cm$ $\quad t_{clad} = 0.05\,cm$ $\quad T_{cool} = 550K$

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Clad

$$T_{co} - T_{cool} = \frac{Q}{2h_{cool}} R_{fuel}$$

$LHR = \pi R^2 Q$

$= 395.8 \, W/cm^2$

$$T_{co} = \frac{Q R_F}{2 h_{cool}} + T_{cool} \Rightarrow \underline{T_{co} = 592K}$$

$$\frac{LHR}{2\pi R_F} = 105$$

$$T_{ci} - T_{co} = \frac{LHR}{2\pi R_F} \frac{t_c}{K_c}$$

$$T_{ci} = 105\left(\frac{0.05}{0.15}\right) + 592K$$

$$T_{ci} = 627K$$

$$T_S - T_{ci} = \frac{LHR}{2\pi R_F}\left(\frac{t_g}{k_g}\right)$$

$k_g(He) = 16 \times 10^{-6} \, T^{0.79}$

$k_g(T_{co}) = 0.00259$

$$T_S = 105\left(\frac{0.003}{0.00259}\right) + T_{ci}$$

$$\underline{T_S = 748.6K}$$

$$T(r) = \frac{LHR}{4\pi K_F}\left(1 - \frac{r^2}{R_F^2}\right) + T_S$$

$\boxed{T_{center} = 1027.1K}$ x

$$= \frac{105}{4\pi(0.03)}\left(1 - 0\right) + T_S = 1027.1K$$

LHR = 396

Accounting for K temp dependence

$$\frac{1}{B}\ln\left(\frac{A+BT_0}{A+BT_s}\right) = \frac{LHR}{4\pi}$$

✓

- I assume you used LHR wrong again here

fresh fuel

$A = 3.8 + 200$ ~~FIMA~~

$B = 0.0217$

$$\frac{e^{\left(\frac{LHR}{4\pi}B\right)}(A+BT_s) - A}{B} = T_0$$

✓

$$\boxed{T_{center} = 932.23\ K}$$

Temp goes down ✓

4) $L = 3.2$ $LHR^0 = 360\ W/cm$ $\gamma = 1.1$

7/12

a) Find LHR @ $z = 0.8m$ $\frac{z}{z_0}$ ✓

$z_0 = \frac{L}{2} = 1.6m$ ✓

$LHR(z) = LHR^0 \cos\left[\frac{\pi}{2\gamma}\left(\frac{z_0}{z} - 1\right)\right]$

$LHR(0.8) = 300 \cos\left(\frac{\pi}{2(1.1)}\left(\frac{1.6}{0.5} - 1\right)\right)$

$\frac{0.8}{z_0} = \frac{0.8}{1.6}$

$$\boxed{LHR(0.8m) = 42.69\ W/cm}$$

- this is far too low to make sense

b) $T_{in} - T_{cool} = \frac{2(1.1)}{\pi}\left(\frac{1.6(300\ W/cm)}{(0.3)(4260)}\right)\left[\sin\left(\frac{\pi}{2(1.1)}\right) - \sin\left(\frac{\pi}{2(1.1)}\left(\frac{1.6}{0.8} - 1\right)\right)\right]$ $\frac{z}{z_0}$

$500 - T_{cool} = 0.528$

- temp. increases as z increases

$$\boxed{T_{cool} = 499.47\ K}$$

$T(z) - T_{cool}^{in}$

5) There is very little U-235 naturally occuring, it must be enriched to obtain fissile material ✓

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UF6 is used during enrichment ✓

Centrifuge:

UF6 is supplied to the centrifuge, heavier gas molecules move to the outside of the rotating drum ✓ U-238 is heavier so U-235 congregates in the center ✓

7/8 6) Departure from nucleate boiling is when a thin film of vapor is formed at the interface and the system begins transitioning to film boiling

Critical heat flux is the max heat flux observed - where system dries out & have gas film

3/3 7) Fertile: material not fissionable but that can be converted to be fissile

Fissile: capable of sustaining a chain reaction
Fissionable: capable of undergoing fission w/ high E neutrons

3/3 8) - Pure U has many phases, difficult to control
- Dramatic thermal swelling

3/4 9) Ratio of fuel volume to total volume. It is used to help determine cladding interactions w/ fuel & predict behavior
- allows fuel swelling, decrease PCMI

3/3 10) Layers: Kernel, iPYC, SiC layer, OPYC, outer shell

3/3 11) A better ATF cladding example is FeCrAl.

0/3 12) U-235 - commonly used. Plutonium fission products? Xe, Ce, etc.

3/4 13) Contain fuel & fission products

3/3 14) Fuel, cladding, coolant, gap

4/4 15) - Heat generation (amount of)
- Length of time fuel operates w/out problems
- How well it performs during an accident