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NE 591 - EXAM #1

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(2) $K_{coat} = 5 W/mK = 0.05 W/cmK$ $h_{cool} = 5.5 W/cm^2K$ 12/18

$K_{clad} = 15 W/mK = 0.15 W/cmK$ $T_{cool} = 800K$

$K_F = 0.5 W/cmK$ $Q = 400 W/cm^3$

$K_{gap} = 25 W/mK = 0.25 W/cmK$ $r_1 = 0.6 cm = r_f$

$r_2 = 0.8 cm$

$r_3 = 0.85 cm$

$r_4 = 0.86 cm$

$$LHR = Q\pi R_F^2 = 400\pi(0.6)^2 = 452.4 W/cm$$

$$T_{coat} = T_{cool} + \frac{LHR}{2\pi R_F h_{cool}} = 800 + \frac{452.4}{2\pi(0.6)(5.5)} = 821.8 K$$ ✓

$$T_{clad} = T_{coat} + \frac{LHR\, t_{coat}^{\to(r_4-r_3)}}{2\pi R_F K_{coat}} = 821.8 + \frac{452.4(0.86-0.85)}{2\pi(0.6)(0.05)} = 845.8 K$$ ✓

$$T_{gap} = T_{clad} + \frac{LHR\, t_{clad}^{\to(r_3-r_2)}}{2\pi R_f K_{clad}} = \frac{452.4(0.85-0.8)}{2\pi(0.6)(0.15)} + 845.8 = 885.8 K$$ ✓

$$T_{fuel} = T_{gap} + \frac{LHR\, t_{gap}^{\to(r_2-r_1)}}{2\pi R_f K_{gap}} = 885.8 + \frac{452.4(0.8-0.6)}{2\pi(0.6)(0.25)} = 981.8 K$$ ✓

$$T_0 = T_{fuel} + \frac{LHR}{4\pi K_f} = 981.8 + \frac{452.4}{4\pi\, 0.5} = \boxed{1053.8 K}$$ ✓

@ $r = 0.4 cm$,

$$T(r) = \frac{Q(R^2 - r^2)}{4K} + T_F \Rightarrow T(0.4) = \frac{400(0.6^2 - 0.4^2)}{4(0.5)} +$$ −1

③ $k = 14.5\ W/mK$ $\qquad U_3Si_2$ enrichment : 19.5%

$\rho = 15.67\ g/cm^3$

$\sigma_f = 570b$

14/14

a) $\phi = 2 \times 10^{12}\ n/cm^2 s$

mass U: $0.195(235) + 0.805(238) = 237.415$ amu

mass Si 28 amu

total mass: $3(237.415) + 2(28) = 768.245$ amu

$$N_f = 15.67 \frac{g}{cm^3} \cdot \frac{mol}{768.245} \cdot \frac{6.022 \times 10^{23}\ at}{mol} \cdot \frac{3U}{1U_3Si_2} \cdot 0.195 = 7.19 \times 10^{21}\ U^{235}/g$$

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

$$Q = (200 \times 10^6\ eV)\left(1.602 \times 10^{-19} \frac{J}{eV}\right)\left(7.19 \times 10^{21} \frac{U^{235}}{g}\right)\left(2 \times 10^{12} \frac{n}{cm^2 s}\right)\left(510 \times 10^{-24}\ cm^2\right)$$

$$\boxed{Q = 262.62\ W/cm^3}$$

b) $\rho_{UO_2} = 10.97\ g/cc$

$$N_f = 7.19 \times 10^{21} = \left(10.97 \frac{g}{cc}\right) \frac{1}{M} \cdot \frac{6.022 \times 10^{23}\ at}{mol} \cdot 1 \cdot x$$

$$\frac{x}{M} = 1.09 \times 10^{-3} \Rightarrow M = \frac{x}{1.09 \times 10^{-3}}$$

262.235

$$M = (x \cdot 235 + (1-x)238) + 2 \times 16) = \frac{x}{1.09 \times 10^{-3}}$$

$$x = 0.2557x + 0.259 - 0.259x + 3.48 \times 10^{-2}$$

$$\boxed{x = 29.3\%\ \text{enrichment}}$$

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(4) $z_0 = 3m$; $LHR^0 = 150 W/cm$; $\gamma = 1.1$

$z_0 = 1.5 = \frac{L}{2}$

a) LHR @ $z = 1.8m$

$$LHR\left(\frac{z}{z_0}\right) = 150 \cos\left[\frac{\pi}{2(1.1)}\left(\frac{1.8}{3} - 1\right)\right] = 16.00$$

-2

b) i) water $c_p = 4200 J/kgK$, $\dot{m} = 0.22 kg/s\,rod$

$$T(z)_{cool} - T_{cool}^{in} = \frac{2 \cdot (1.1)}{\pi} \frac{3(150)}{0.22(4200)}\left[\sin\left(\frac{\pi}{2(1.1)}\right) + \sin\left(\frac{\pi}{2(1.1)}\left(\frac{1.8}{3} - 1\right)\right)\right]$$

-0.54

$$T(z)_{cool} - T_{cool}^{in} = 0.1532 \text{ K}$$

-1

$T_{cool}^{out} - T_{cool}^{in}$

$z = 3m$ $z_0 = 1.5m$

ii) sodium $c_p = 1404 J/kgK$ $\dot{m} = 0.12 Kg/s\,rod$

$$T(z)_{cool} - T_{cool}^{in} = 0.1532 \times \frac{0.22(4200)}{0.12(1404)} = 0.8402 K$$

only need $\dot{m} C_p$

(5) Forward Euler: $f(t_{n+1}) = f(t_n) + dt\, f'(t_n)$

$t_0 = 1$

$t_1 = 0.33$ $f_1 = 6 + 0.33[4(0) - 3(0)^2] = 6$

$t_2 = 0.66$ $f_2 = 6 + 0.33[4(0.33) - 3(0.33)^2] = 6.33$

right process, but wrong I.C.

$t_3 = 0.99$ $f_3 = 6.33 + 0.33[4(0.66) - 3(0.66)^2] = 6.77$

$t_4 = 1.32$ $f_4 = 6.77 + 0.33[4(0.99) - 3(0.99)^2] = 7.11$

$t_5 = 1.65$ $f_5 = 7.11 + 0.33[4(1.32) - 3(1.32)^2] = 7.13$

$t_6 = 1.98$ $f_6 = 7.13 + 0.33[4(1.65) - 3(1.65)^2] = 6.61$

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Backward Euler

$f(t_{n+1}) = f(t_n) + dt\, f'(t_{n+1})$ ✓

Same thing

$t_1 = 0.33$ $\quad f_1 = 6 + 0.33\left[4(0.33) - 3(0.33)^2\right] = 6.33$

$t_2 = 0.66$ $\quad f_2 = 6.33 + 0.33\left[4(0.66) - 3(0.66)^2\right] = 6.78$

$t_3 = 0.99$ $\quad f_3 = 6.78 + 0.33\left[4(0.99) - 3(0.99)^2\right] = 7.12$

$t_4 = 1.32$ $\quad f_4 = 7.12 + 0.33\left[4(1.32) - 3(1.32)^2\right] = 7.14$

$t_5 = 1.65$ $\quad f_5 = 7.14 + 0.33\left[4(1.65) - 3(1.65)^2\right] = 6.62$

$t_6 = 1.98$ $\quad f_6 = 6.62 + 0.33\left[4(1.98) - 3(1.98)^2\right] = 5.35$

(7) → 3 phases in operation temperature cause swelling ✓
→ low melting point (1400K) ✓

4/4

(8) Ratio of fuel volume per total volume ✓ in fuel cell.
Important due to fuel swelling ✓ dure operation

4/4

(9) We enrich U to increase fissile quantity ✓ (U-235) in the fuel. Enrichment is possible due to mass difference between U-235 to U-238 ✓. → details of centrifuge process?

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Blank Questions: 1, 6, 10, 11