NE 591 Exam 1

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1. This equation is made by the assumption "steady state". ✓
$\left(\frac{\partial T}{\partial t}=0\right)$

- two other assumptions 1-D const. k

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

$$\Rightarrow \quad k\frac{\partial T}{\partial x}=-Qx+C_1 \quad \text{—— ①}$$

use boundary condition $T'(x=x_0=0)=0$ into ①

$$0=0+C_1$$

$$\therefore C_1=0$$

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

$$\Rightarrow \int\frac{\partial T}{\partial x}dx=-\frac{Q}{k}\int x\,dx$$

$$\Rightarrow \int dT=-\frac{Q}{k}\frac{1}{2}x^2+C_2$$

$$\Rightarrow T=-\frac{Q}{k}\frac{1}{2}x^2+C_2 \quad \text{—— ②}$$

use another B.C. $T(x=x_1)=T_1$ into ②

$$T(x=x_1=X)=-\frac{Q}{k}\frac{1}{2}X^2+C_2=T_1$$

$$\therefore C_2=T_1+\frac{Q}{k}\frac{1}{2}X^2$$ Insert this into ② again

$$\Rightarrow T(x)=-\frac{Q}{k}\frac{1}{2}x^2+T_1+\frac{Q}{k}\frac{1}{2}X^2$$

$$T(x)=\frac{Q}{2k}(X^2-x^2)+T_1$$ ✓

2.

$$-\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 k\frac{\partial T}{\partial r}\right)+Q=0$$

$$\frac{\partial}{\partial r}\left(r^2\frac{\partial T}{\partial r}\right)=-Q r^2$$

$$r^2\frac{\partial T}{\partial r}=\int -Q r^2 dr \Rightarrow \frac{-Q}{3}r^3+C_1$$

$$T(r_1)=T_1$$

$$T'(r_0)=0,\quad r_0=0,\ r_1=R \qquad 0=0+C_1$$

$$0=0+C_1$$

$$r^2\frac{\partial T}{\partial r}=-\frac{Q}{3}r^3 \rightarrow \frac{\partial T}{\partial r}=-\frac{Q}{3}r$$

$$T(r)=\int -\frac{Q}{3}r\,dr \rightarrow \frac{-Q}{6}r^2+C_2$$

$$r_1=R,\ T(r_1)=T_1$$

$$T(R)=T_1=-\frac{QR^2}{6}+C_2 \Rightarrow C_2=T_1+\frac{QR^2}{6}$$

$$T(r)=\frac{-Q}{6}r^2+T_1+\frac{QR^2}{6}$$

$$T(r)-T_1=\frac{Q}{6k}(R^2-r^2) \rightarrow \text{spherical 1-D steady state}$$

- this is a fuel pellet, not a triso particle

- do not need spherical coords here

- good derivation, but does not apply

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3.

12/14

```
(*heat generation rate by U3Si2*)

In[1]:= sigma = 570 (*barns*);
        d = 15.67 (*g/cm^3*);
        en = 19.5 (*%*);
        phi = 2*10^12 (*n/cm^2-s*);
        Ef = 200 (*MeV*);
        M = 3* (en*0.01*235 + (1 - en*0.01) *238) + 2*28;
        Nf = (d*6.02*10^23/M) *3*en*0.01;
        Q = Ef* (10^6*1.6*10^(-19)) *Nf*phi* (sigma*10^-24)

Out[1]= 262.045
```

✓

```
(*heat generation rate by UO2*)

In[4]:= sigma = 587 (*barns*);
        d = 10.97 (*g/cm^3*);
        phi = 2*10^12 (*n/cm^2-s*);
        Ef = 200 (*MeV*);
        M = (x*0.01*235 + (1 - x*0.01) *238) + 2*16;
        Nf = (d*6.02*10^23/M) *x*0.01;
        Solve[262.045 == Ef* (10^6*1.6*10^(-19)) *Nf*phi* (sigma*10^-24), x]

Out[4]= {{x → 28.4279}}
```

→ we were assuming 570 barns here

→ will not change if T & neutron spectrum do not change

-process correct

4.

12/12

```
In[ ]:= (*Calculate LHR considering variability in Z*)

In[13]:= Z = 180 (*cm*);
         Z0 = 150 (*cm*);
         L0 = 150 (*W/cm*);
         r = 1.1;
         LHR = L0*Cos[Pi/(2r) (Z/Z0 - 1)]

Out[13]= 143.924
```

✓ → I would like to see units on this

```
(*Calculate Tcool for water considering variablity in Z*)

Z = 300 (*cm*);
Z0 = 150 (*cm*);
L0 = 150 (*W/cm*);
r = 1.1;
m = 0.22 (*kg/s*);
Cp = 4200 (*J/kg-K*);
delta T = 2*r/Pi (Z0*L0/(m Cp)) (Sin[Pi/(2r)] + Sin[Pi/(2r) (Z/Z0 - 1)])

Out[17]= 33.7575
```

✓

```
(*Calculate Tcool for sodium considering variablity in Z*)

In[19]:= Z = 300(*cm*);
         Z0 = 150 (*cm*);
         L0 = 150 (*W/cm*);
         r = 1.1;
         m = 0.12 (*kg/s*);
         Cp = 1404(*J/kg-K*);
         delta T = 2*r/Pi (Z0*L0/(m Cp)) (Sin[Pi/(2r)] + Sin[Pi/(2r) (Z/Z0 - 1)])

Out[19]= 185.137
```

✓

– please write final answer as well!

$\Delta T(Na) > \Delta T(H_2O)$

5.

```
(*Backward Euler*)
In[11]:= dt = 0.33;
n = 6;
Do[n = n + dt * (4 (k + dt) - 3 (k + dt) ^2);
 Print[n], {k, 1, 2 - dt, dt}]
6.00439
5.46755
4.17385
(*Forward Euler*)
In[10]:= dt = 0.33; n = 6; Do[n = n + dt * (4 k - 3 k^2); Print[n], {k, 1, 2 - dt, dt}]
6.33
6.33439
5.79755
```

→ I wanted to see your work here

– Yes answers are correct

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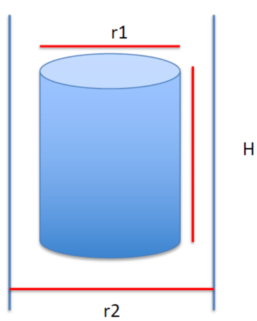
6. 5/5

1) A fertile material is a material that, although not itself fissionable, can be converted into a fissile nuclide by neutron absorption and subsequent nuclei conversions.
2) A fissile nuclide is capable of sustaining a nuclear fission chain reaction with neutrons of any energy.
3) A fissionable nuclide is capable of undergoing fission (even with a low probability) after capturing a high energy neutron.

7. 4/4

We don't use pure metallic U as a fuel form because pure uranium dramatically swells during thermal cycling.
In addition, pure uranium has three phases, including α-phase is orthorhombic, β-phase is tetragonal, ϒ-phase is body-centered cubic. Abd alpha U has both anisotropic thermal expansion and anisotropic irradiation growth.

8.
Smear density is the ratio of fuel volume to internal volume of the fuel element.



4/4

$$\text{Smear density} = \pi r_1^2 h/\pi r_2^2 h$$

From: Professor Beeler's notes

It is important for metal fuel designs to have a low enough smear density to properly allow for fuel swelling over the course of fuel life.

→ I would prefer you paraphrase me ---
→ use your own words

9. Because water has higher neutron absorption. UF6 and UO2. Use different mass to separate U-238 and U235.

– Water doesn't absorb neutrons

3/8

10. One broad peak centered around A=95, the other around A=135. 2/4

11. Back Euler and Forward Euler.

space discretization 0/8