EN-634 NUCLEAR REACTOR THERMAL-HYDRAULICS
Assignment-3

1(a). A reactor is made up channels with fuel rods of 10 mm diameter. The associated coolant flow area is 1.5 cm^2. The coolant enters at 10 Mpa at a velocity of 3.6 m/s and 250 ^oC. The exit temperature of the coolant is 295 ^oC. The axial power profile in the channel may be assumed to vary as,

$$q'' = q_0'' e^{\frac{\pi z}{H}} \sin(\tfrac{\pi z}{H}),$$

where H represents the height of the core, which is 3.6 m, z=0 represents the bottom of the core and q_0'' is a constant. Compute the location of the maximum fuel surface temperature, given the following:

$\rho_f = 732.3$ kg/ m^3,

c_p of the coolant = 5.51 kJ/kg-K.

Convective heat transfer coefficient = 10 kW/m^2-K

(b) Estimate the maximum fuel surface temperature, given that

$$\int e^{ax} \sin(bx)\ dx = \frac{e^{ax}}{a^2+b^2}\left(a \ \ \sin(bx) - b \ \ \cos(bx)\right)$$

2. You may read slides 22-24 (Lecture 5,6,7 in web) before attempting this problem. This problem is non-dimensional treatment of the material done in those slides

(a) Show that if the heat generation can be approximated as

$q''' = A \ \ I_0(\kappa r)$, where, $\kappa = \dfrac{1}{L_f}$, where L_f is the diffusion length in the fuel material, then the same can be expressed as

$$q''' = \overline{q'''}\left(\frac{\kappa r}{2}\right) \ \frac{I_0(\kappa r)}{I_1(\kappa R)},$$

(b) Having expressed g(α) as $\left(\dfrac{\beta}{2}\right) \dfrac{I_0(\beta\alpha)}{I_1(\beta)}$, where $\beta = \kappa R$, and $\alpha = \dfrac{r}{R}$, proceed to show that

$M_1 = \dfrac{I_0(\beta) - I_0(\beta\alpha)}{2\beta I_1(\beta)}$, where $M_1 = \int_\alpha^1 \frac{1}{\alpha}\left[\int_0^\alpha \alpha g(\alpha) d\alpha\right] d\alpha$. Note that this is the non-dimensional form of the right hand side of the equation in slide 24/35

3. Consider a BWR fuel pellet 12.4 mm OD, gas gap of 0.2 mm and clad thickness of 1 mm. Assuming K_{clad} = 14 W/m-K, the value of $\int kdT$ for fuel as given in Eq. 8.16 (c) in Kazimi and Todreas and clad surface maintained at 275^o C, compute the fuel centre line temperature for q"= 1 MW/m^2 for the cases, (a) uniform heat generation and (b) diffusion approximation with κ = 0.24 cm. You may choose to use 5500 W/m^2-K for the value of gap conductance.

4 The aim of this problem is to check the applicability of plug flow model. Such a model uses for momentum flux the expression, ρu^2, while the rigorous term should vave been,

$$\overline{\rho u^2} = \frac{1}{A}\int_A \rho u^2 dA$$

For a constant density system, density can be cancelled and thus we can get a definition for the average of u^2. Covaiance factor or correction factors are defined so that the plug model can be made exact for 1-D area averaged models. Since this correction comes out close to 1, and there are several empiricism, such as in friction factors, this correction is just ignored most of the times. This has been the basis of our plug flow models outlined in class. To get a feel for the correction factor or the covariance factor, consider the case of fully developed turbulent flow in a pipe. The velocity profile in such a case can be assumed to be $u = u_0\left(1-\frac{r}{R}\right)^{\frac{1}{7}}$ (known as the one-seventh power law) Compute the covariance factor β, given by $\frac{\overline{u^2}}{\overline{u}^2}$. Based on what you have found, can you comment on (a) when the plug flow model would be exact? (b) whether turbulent flow is better modelled by plug flow model than the laminar flow?