Homework #29

Web Problem #12
Nuclear Reactor Safety Analysis

1. a. Derive an expression for the temperature at the surface of a cylindrical fuel rod. Assume that the rod is composed of UO_2 pellets (also known as fuel meat), a helium fuel gap (0.0065 in thick), and Zircaloy-4 clad (0.0225 in thick) with an outer diameter of 0.374in. The gap conductance is 0.234 W/(m*K), and conductivity of the Zircaloy-4 and fuel is 16.2 W/(m*K)and 4.25 W/(m*K), respectively.

   b. Assuming a volumetric heat rate of $q''' = 108.0\ W/cm^3$ in the fuel and a constant clad outer surface temperature of 575˚F, plot the fuel temperature as a function of position in the fuel rod. What is the maximum temperature in the fuel, and at what radius does this occur?

2. BONUS PROBLEM (not required)

a. Repeat problem 1.a for an annular fuel pin. An annular fuel pin is a pin in which there is coolant on the inside and the outside of the fuel pin, with clad and gap on both sides. In essence, instead of being a solid cylinder, it is an annular are with fuel inside and outside, as seen in the figure below. Assume that the rod is composed of the same materials, except that the inner diameter of the fuel pin is 0.12in, the fuel cross sectional area (i.e. the overall amount of fuel meat) should be the same as for a cylindrical rod, the clad is found on both surfaces, and that the gap thickness for the inside and outside clad is 0.0065 in.

Annular fuel rod cross section (left) vs traditional solid fuel rod (right)

b. Assuming similar heat rates and temperatures (inner and outer coolant being the same), what is the maximum temperature in the fuel and where does this occur?