1. (20 minutes) A cylindrical fuel element is operating at a surface temperature of 320°C and a centerline temperature of 720°C. The radius of the fuel element is 1 cm, and the volumetric heat source density is 20 W/cm³. Assume that due to departure from nucleate boiling, one half of the circumference of the fuel element becomes completely insulated and no heat is removed from that part of the surface. Estimate the new maximum fuel temperature in the fuel element.

2. (30 minutes) In a boiling water reactor fuel assembly, it is estimated that the exit quality is 0.15 and the mass flow rate is 17.5 kg/s. The pressure is the nominal pressure of boiling water reactors and the coolant receives energy at a uniform heat rate. The slip is given as S = 1.5 and the flow area of an assembly is 1.2 x 10⁻² m².

**Calculate:**

(a) The average exit void fraction  
(b) The exit steam superficial velocity  
(c) The average exit void fraction assuming homogeneous flow  
(d) The heat rate to the coolant  
(e) The friction pressure drop gradient assuming the homogeneous flow model and a friction factor of 0.03.

STEAM TABLES ATTACHED

3. (20 minutes) For the conditions of the previous question, it is decided to take the channel transverse vapor volumetric concentration and vapor flux profiles into consideration in the two phase flow calculation for mixture density.

Which of the following models would you use and why? Explain the basis of your selection and fully explain the selected model using sketches as necessary.

(a) Homogeneous flow model  
(b) Separated flow model  
(c) Drift flux model

4. (30 minutes) A commercial PWR is in equilibrium, operating at 100% power 100% flow with the plant parameters listed below.

**Plant Temperature Conditions**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot channel coolant outlet temperature</td>
<td>603 °F</td>
</tr>
<tr>
<td>Core average coolant outlet temperature</td>
<td>532 °F</td>
</tr>
<tr>
<td>Core inlet coolant temperature</td>
<td>499 °F</td>
</tr>
<tr>
<td>Steam generator outlet temperature</td>
<td>475 °F</td>
</tr>
<tr>
<td>Feedwater inlet temperature</td>
<td>400 °F</td>
</tr>
</tbody>
</table>
Plant power is reduced to 50% and the plant is returned to overall equilibrium, thermal hydraulic as well as neutronic. Primary coolant flow remains at 100%.

The plant design is such that secondary system power changes are handled by feedwater flow rate changes only. Therefore, steam generator steam outlet temperature and feedwater inlet temperature remain unchanged from one equilibrium condition to another.

(a) For the equilibrium 50% power level, quantitatively estimate, showing all work:

i) Hot channel coolant outlet temperature
ii) Core average coolant outlet temperature
iii) Core inlet coolant temperature

(b) Describe five reactivity effects which come into consideration for this power change and explain how they change from one steady state condition to the other.

5. (20 minutes) Modern liquid metal cooled reactor designs are made with fuel pins in a triangular array. LWRs use a square fuel pin array.

Explain the reasons for selecting these arrays based on neutronic and thermal hydraulic characteristics of these fuel/coolant systems.
TABLE 19: Saturated Water Subsurface - Pressure Tables (cont.)