1. It is well known that the Chernobyl accident was caused by the positive coolant void reactivity coefficient of RBMK reactor (use graphite as moderator, boiling water as coolant). Please describe the physical meaning of the void coefficient and the mechanism of its impact on the stability of nuclear power reactor. In a boiling water reactor, the void reactivity coefficient is negative. Both of BWR and RBMK are thermal reactor and they both use boiling water as coolant. Please use the four factors formula to explain the drastic difference in their void reactivity coefficient (15%).

   Hint: Four factors formula:

$$k_\infty = \eta_T \, p f \varepsilon$$

k_∞ : infinity multiplication factor;

η_T : fission factor;

p : resonance escape probability;

f : thermal utilization;

ε : fast fission factor.

2. A Boiling Water Reactor (BWR) operate at 1020 psia with thermal power of 3293 MW. The temperature of feedwater is 375 F. The core flow rate is 106.5 x 10^6 lb/hr. The core of the BWR consists of 764 fuel assemblies, each containing a square array of 49 fuel rods on a 0.738 inches pitch. The fuel rods are 175 inch long, but contain fuel over only 144 inch of their length. The outside diameter of the fuel rods is 0.563 inches, the cladding is 0.032 inches thick. The peak to average power density is 2.62. The heat production rate along the axial direction can be approximated as:

$$q'''(z) = q'''_{\max} \cos\left(\pi z / 165\right)$$

(a) Calculate the steam flow rate (4 %);
(b) Calculate the core inlet temperature (4%);
(c) Calculate the maximum-to-average power density in the z-direction (4%);
(d) Calculate the Reynolds number near the entrance of the channel (4%);
(e) The heat transfer coefficient for the convective part of the channel (5%);
(f) The maximum power density (4%) (you can assume that all the fission energy was deposited in the fuel);
(g) The location of the onset of local boiling (5%).

(use 572.5 F for the core inlet temperature)

Equation you need:

Dittus-Boelter Heat Transfer Correlation:

$$Nu = 0.023\,\mathrm{Re}^{0.8}\,\mathrm{Pr}^{0.4}$$

Jens-Lottes Correlation of Boiling Heat Transfer:

$$T_C - T_{sat} = \frac{60\left(q''/10^6\right)^{0.25}}{e^{p/900}}$$

where q'' is heat flux in Btu/hr-ft2

p is pressure in psia

T_c is cladding surface temperature in F

T_{sat} is the saturation temperature in F

Onset of Nucleate Boiling:

$$T_{LB} = T_{sat} + \left(T_C - T_{sat}\right)_{JL} - \frac{q''(Z_{LB})}{h}$$

where h is heat transfer coefficient

T_{LB} is the bulk liquid temperature

Bulk Liquid Temperature:

$$T_b(z) = T_{bo} + \frac{q'''_{\max} A_f H}{wc_p} \int_{-\frac{H}{2}}^{z} \cos\left(\frac{\pi z}{165}\right)$$

Physical Properties of Water

Specific Heat: 1.21 Btu/lb F

Thermal Conductivity: 0.341 Btu/hr-ft-F

Viscosity: 0.235 lb/ft-hr

Density: 47.53 lb/ft3

Saturation steam enthalpy at 1020 psia: 1191.58 btu/lb

Saturation water enthalpy at 1020 psia: 545.4 Btu/lb

Saturation temperature at 1020 psia: 547.09 F

3. The phenomenon of the "Nuclear Doppler Effect" is extremely important to the safe operation of nuclear power reactor. Please describe the Nuclear Doppler Effect and its impact on the safe operation of nuclear reactor (10%). Can a nuclear reactor operate safely without the Nuclear Doppler Effect? Why (5%)?

4. During a hypothetical severe accident of light water reactors, there is a remote possibility that certain amount of radioactive material could release to the environment. Please describe the pathway of these released radioactivity could reach humane body (10%).

5. In the current design of light water reactor nuclear power plant, the philosophy of defense in depth is adopted to protect the public and operators. Please describe the details of each item involves in the philosophy (10%).

6. A typical boiling curve is displayed in the attached Figure. Please explain the physical phenomena occur at the heated solid/liquid interface of point B, C, and D (10%). Note that there are two mechanisms at point C. You need to describe both mechanisms. What are the implications of point C on the operation of light water reactor (5%). Do you expect that point C will cause any problem in a gas cooled reactor? Why (5%)?