Assignment 5

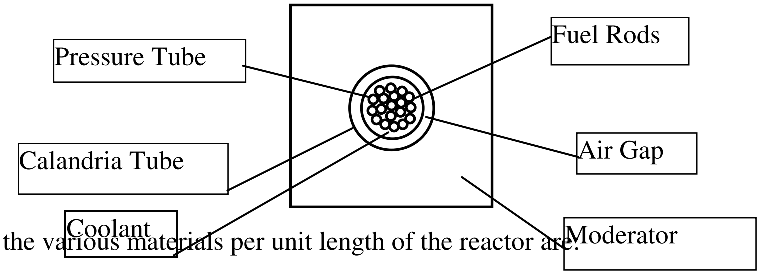
1. Calculate the fuel utilization and infinite multiplication factor for a fast reactor consisting of a mixture of liquid sodium and plutonium, in which the plutonium is present to 3.0 w/o. The density of the mixture is approximately 1.0 g/cm^3 ($\sigma_a^{Pu} = 1.65b$, $\sigma_f^{Pu} = 1.40b$, $\eta = 2.61$ $\sigma_a^{Na} = 0.0008b$) [f=0.887, $k_\infty = 2.31$]
2. A bare cylindrical reactor of height 200 cm and diameter 100 cm is operating steady-state power of 200 MW. If the origin is taken at the centre of the reactor, what is the power density at the point r = 7 cm, z = - 22.7 cm? [421.1 W/cc, (with the condition that flux vanishes at boundary)]
3. In a spherical reactor of radius 45 cm the fission rate density is measured as 2.5 x 10^{11} fissions / cm^3 -sec at a point 35 cm from the centre of the reactor. (a) At what steady-state power is the reactor operating? (b) What is the fission rate density at the centre of the reactor?[9.46 X 10^{11} fissions/cm^3-s]
4. A bare thermal reactor in the shape of a cube consists of a homogeneous mixture of U^{235} (for property values refer to next problem) and graphite ($\sigma_a^C = 0.0008b$) The ratio of atom densities of $N_{Fuel}/N_{moderator}$ = 1.0 x 10^{-5}. Using the modified one-group theory, calculate (a) the critical dimensions; (b) the critical mass; (c) the maximum thermal flux when the reactor operates at the power of 1 kW. [3.43 m, 12.6 kg, 6.45 X 10^8 neutrons/cm^2-s]
5. At a fuel reprocessing plant, aqueous solution of Uranyl Sulphate ($U^{235}O_2SO_4$) is to be stored in cylindrical pipes. If the maximum concentration of the Uranyl Sulphate in the solution is expected to be 100 g/litre, what is the maximum size (radius) of the pipe which can be safely used to avoid any accidental criticality. Assume pipe to be an infinite cylinder and use one group approach. You may assume for simplicity that the density of UO_2SO_4 solution is 1g/cc. Additional data: [Ans: R = 15.1 cm]

Material	σ_a(barns)	σ_f(barns)	ν	L (cm)
U^{235}	681	581	2.5	---
H_2O	0.664	---	---	2.85
O^{16}	0.0	0.0	---	---
S^{32}	0.0	0.0	---	---

6. A spherical nuclear reactor (fast) of 0.5 m radius, is fuelled with mixed $Pu^{239}O_2$ - $U^{235}O_2$ (density = 10.5 g/cc) with weight per cent of PuO_2 being 15%. Further, the reactor has Fe^{56} (structural material, 7.9 g/cc) and Na^{23} (coolant,0.97 g/cc) such that the volume fractions of fuel, Fe and Na respectively are, 0.3, 0.2 and 0.5. Using the average properties as specified in the table, compute the diffusion length of the reactor system as given by one speed theory.
   [Ans:L=0.165 m]

Material	σ_a(barns)	σ_f(barns)	ν
U^{235}	0.404	0.05	2.5
Pu^{239}	2.4	1.95	3.0
Na^{23}	0.0018	---	---
Fe^{56}	0.0087	---	---
O	0.0	0.0	---

7. The typical unit cell of a Rajasthan Atomic Power Station (RAPS) is shown in the following figure.



The computed volumes of the various materials per unit length of the reactor are:

UO_2	29.2 cm^3
Zr (A=91)	20.3 cm^3
D_2O (coolant)	19.1 cm^3
Air gap	27.4 cm^3
D_2O (moderator)	426.6 cm^3

It may be assumed that air may be treated as a non-participating medium (does not react with neutrons) and the Uranium in UO_2 is natural.

(a) Given that the density of UO_2, Zr and D_2O to be 10.5, 6.5 and 1.1 g/cc respectively, calculate the number density of each material.

(b) Given the volumes as above, calculate the macroscopic absorption cross section of UO_2, Zr and D_2O, given the following

Material	σ_a (barns)	σ_f (barns)	ν	L (cm)	τ (cm^2)
U^{235}	681	581	2.5	---	---
U^{238}	2.7	0.0	---	---	---
Zr	0.198	---	---	---	---
D_2O	4.6×10^{-4}	---	---	100	120
O	0.0	0.0	---	---	---

(c) Compute fuel utilisation factor, f [Ans: 0.966]

(d) Compute k_∞ [Ans: 1.318]

(e) Assuming L/D for the reactor to be 1, calculate the critical diameter for the reactor. [2.18 m]