HOMEWORK 2

1. Consider a bare, homogeneous cylindrical reactor with material composition of a modern PWR and homogenized number densities corresponding to a PWR core operating at full power conditions and with a concentration of 2210 ppm of natural boron dissolved in the water coolant. The fuel is UO_2 enriched to 2.78%. Refer to Table 5-2 of the Nuclear Reactor Analysis book (page 210) for the reactor composition. Compute the following:
    a. Diffusion coefficient
    b. Infinite multiplication constant
    c. Material buckling
    d. Extrapolation distance
    e. Critical core radius (assuming core heigh 370 cm)
    f. Plot the critical radius as the core height varies.

2. Determine the critical composition and the neutron flux of a finite slab reactor with a width of 50 cm, composed of a homogeneous mixture of ^{235}U and H_2O, surrounded by vacuum. The core operates at a temperature of T = 60 °C and it has a power density of $q''' = 25\ W/cm^3$. Assume thermal energies only, v = 2.44 water density 1 g/cm^3 and diffusion coefficient D = 0.16. You are required to use the *SciPy* library and the boundary value solver.

3. Considering the previous exercise, assume now that the core is surrounded on both sides by a blanket region composed of a homogeneous mixture of natural uranium and water with ratio N_U / N_W = 0.01, width of 5 cm and operating temperature of 20 °C. The blanket is further surrounded by a reflector region composed of water and with infinite width, and operating temperature of 20 °C. Determine the criticality equation and compute the critical width of the core. Use the *SymPy* library.

4. Determine the height to diameter ratio of a bare cylindrical reactor that will lead to the smallest critical mass. Use the Lagrange multipliers approach.

5. Consider the steady-state 2D diffusion equation. Using the Finite Difference Scheme, write the equation as a system of linear algebraic equations and solve it using linear algebra. Plot the 2D flux in a square domain assuming:
    a. A constant source homogeneously distributed in the core.
    b. A $\sin^2 x$ source locate in the midplane (y = 0).
    c. An exponential decay source located in a corner.
    d. Plot the discretisation error for the three cases as a function of the number of grid cells
    e. Use the following data: domain 40 X 60 cm; Sigma_t = 0.25; Sigma_s = 0.15

6. A bare spherical reactor is made with ^{235}U uniformly dispersed in graphite (density 1.7) with an atomic ration N_C / N_{25} = 10^4. For the cross-section values given below, calculate the critical size and mass of the reactor using one-group diffusion theory. If the reactor is modified by placing a cavity (vacuum) of half the total radius in its centre, find the critical size for this case. Recalculate the critical radius if the centre void is filled by a perfect absorber. Use as data: sigma_s,C = 4.3 b, sigma_a,C = 0.003 b, sigma_gamma,25 = 105 b, sigma_f,25 = 548 b, D = 0.9 cm

7. A bare spherical reactor is to be constructed of a homogeneous mixture of D_2O and ^{235}U. The composition is such that for every uranium atom there are 2000 heavy water molecules. Calculate:
    a. The critical radius of the reactor using diffusion theory (eta = 2.06, D_w = 0.87 cm, Sigma_a,w = 3.3 X 10^{-5} cm^{-1}, sigma_a,w = 0.001 b, sigma_a,f = 678 b
    b. The mean number of scattering collisions made by a neutron during its lifetime.

8. Consider a neutron source emitting a mono-directional beam of neutrons into a finite medium. Using diffusion theory and the method of Green functions, calculate the neutron flux in the medium (locate your coordinate system with its origin at the source and align the x-axis along the source beam). Please note that the source is anisotropic.