Total marks: 60 Name: ID:

1. *(8 marks)* A neutron and a fissile atom can interact. Describe the possible outcomes, including any nuclear reaction by-products.

2. *(5 marks)* Show the physical processes which are important in a reactor on a graph which has energy as the horizontal axis.

3. *(7 marks)* Consider the equation

$$k_{effective} = P_{FNL} P_{TNL} \varepsilon p f \eta$$

Define, in words, each term.

4. *(6 marks)* Consider the expression

$$B_m^{\,2} = B_g^{\,2}$$

Use mathematics and words to discuss its meaning.

5. *(6 marks)* Consider a parallelepiped core of dimensions X, Y and Z . Assume uniform material properties, and that the reactor is operating at a constant power of P MW. What is the maximum flux in terms of power and reactor properties? Neglect the extrapolation length.

6. The multi-group diffusion equations may be written

$$-\nabla \cdot D_g \nabla \varphi_g + \Sigma_g \varphi_g = \chi_g \sum_{g'=1}^{G} \nu_{g'} \Sigma_{fg'} \varphi_{g'} + \sum_{g'=1}^{G} \Sigma_{g'g} \varphi_{g'}$$

a. *(3 marks)* Develop the two-group equations for an infinite reactor.

b. *(4 marks)* Use your knowledge of physical processes to simplify the equations as much as possible. Do <u>not</u> consider the buckling or “1½-group” approximations.

7. A flux Φ_0 n/cm^{2}s of neutrons of energy E strikes the left side of a slab of thickness w, height h and depth d. Neutron absorption results in complete transfer of the neutron energy to the slab material. Assume (1) the beam cross-section area is larger than the slab face, (2) constant macroscopic cross-sections, and (3) no scattering. *Note: a small sketch indicating your coordinates will help all of us.*

   a. *(5 marks)* Calculate the linear energy deposition rate at the left and right surfaces.

   b. *(4 marks)* What is the total energy deposition rate in the slab?

8. *(6 marks)* Develop the finite-difference formulation for just the leakage term of the diffusion equation in a two-dimensional *x*-*y* geometry where the diffusion coefficient *D* is a function of position. Assume the mesh spacing is constant but not necessarily the same in each direction.

9. *(6 marks)* The three-group fluxes for a bare spherical reactor of radius R = 50 cm are given by the following:

$$\varphi_1(r) = \frac{3\times10^{15}}{r}\sin\left(\frac{\pi r}{R}\right) \quad \varphi_2(r) = \frac{2\times10^{16}}{r}\sin\left(\frac{\pi r}{R}\right) \quad \varphi_3(r) = \frac{1\times10^{16}}{r}\sin\left(\frac{\pi r}{R}\right)$$

The group diffusion coefficients are D_1 = 2.2 cm, D_2 = 1.7 cm and D_3 = 1.05 cm. Neglecting the extrapolation length, calculate the total leakage of neutrons at any point in the core.

Note: in spherical co-ordinates, $\nabla^2 f = \frac{1}{r^2}\frac{\partial}{\partial r}r^2\frac{\partial f}{\partial r}$