Final Exam Review Questions

Chapter 1:

1. Complete the following reactions
   a. ${}^{60}_{?}Co \rightarrow ? + {}^{0}_{-1}e$
   b. ${}^{7}_{3}Li + {}^{1}_{1}H \rightarrow ? + {}^{4}_{2}He$
   c. ${}^{10}_{5}Be + {}^{4}_{2}He \rightarrow ? + {}^{1}_{1}H$
   d. ${}^{9}_{?}Be + {}^{4}_{2}He \rightarrow ? + {}^{2}_{1}H$

2. Calculate the Q-values for all of the reactions listed in problem 1 in addition to following reaction: ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{135}_{53}I + {}^{98}_{39}Yt + 3{}^{1}_{0}n + \gamma(4MeV)$. State whether or not the reactions are exothermic or endothermic.

3. Calculate the Binding Energy and Binding Energy per Nucleon for the following nuclides
   a. ${}^{127}_{53}I$
   b. ${}^{241}_{94}Pu$
   c. ${}^{3}_{1}H$
   d. ${}^{56}_{26}Fe$

4. Sketch the shape of the BE per Nucleon graph discussed in class. How is it that this graph shows us why fission and fusion are possible?

5. In what form is most of the energy from fission released?

6. What is the main difference between a fissile and a fertile isotope? Name two examples for each.

7. Lewis 1.14

8. Lewis 1.19

9. Element A is being produced at a rate RA and is undergoing decay (decay constant λ_A). Element B is being produced directly from the decay of element A but is also undergoing decay as well (decay constant λ_B). Derive the analytic expression for the time dependence of the concentration of B if the initial concentration of A is A_o and the initial concentration of B is 0. What are the equilibrium concentrations for A and B?

Chapters 2 and 3

1. What is the difference between the microscopic and macroscopic cross sections in terms of definition, units and interpretation (the meaning of these values)?

2. Calculate the absorption and scattering macroscopic cross sections for C_8H_{18} (.7 g/cm^3) and PuO_2 (11.5 g/cm^3, Pu-239). For each what is the probability of absorption occurring upon collision? What about scattering?

3. What is the difference between radiative capture and fission? What about elastic and inelastic scattering?

4. Sketch roughly what the shape of the neutron spectrum in a thermal reactor looks like. Label the 3 main regions and briefly discuss their shapes.

5. What is a compound nucleus and what are the two main energy contributions to one (in terms of interaction with a neutron)?

6. Explain what resonance is. How does resonance structure change from lighter to heavier nuclei? Briefly explain why.

7. What is Doppler broadening and why does it occur?

8. For elastic neutron scattering off of an element with atomic mass A, what is the probability that the neutron will scatter from an initial energy E to a final energy E'?

9. What is the average slowing down decrement (what does it mean, what is it describing)?

10. Determine the average slowing down decrement for C_8H_{18}.

11. Determine the number of scatters it will take to slow a neutron moving with 1 MeV of energy to slow down to .1 eV in octane (C_8H_{18}).

12. Determine the slowing down decrement, slowing down power and slowing down ratio for C_8H_{18} and pure Be-9. Which slows down neutrons in faster? Which is the best moderator overall?

13. If the resonance integral for a material X is 95 barns from 1 eV to .1 MeV, what is the average microscopic cross section in the resonance region?

Chapter 4

1. Describe the main differences between a PWR and BWR.

2. Describe the main differences between an LWR and a CANDU reactor.

3. Describe the main difference between an LWR and a graphite moderated high temperature gas reactor (HTGR)?

4. Why are square lattice arrays (fuel/moderator lattice geometry) used primarily in LWR designs while hexagonal lattice arrays are used primarily in fast reactor designs?

5. Write down the 4 factor formula and briefly explain the meaning of each of the terms.

6. How is each term in the 4 factor formula affected by when the enrichment of UO2 in a LWR is increased from 4% to 20%?

7. How would each term be affected if the coolant of an LWR was switched out with heavy water (keeping all other design parameters constant i.e. pitch to diameter ratios, ratio of fuel to moderator number densities, etc.)? What modifications could you make to the design to compensate?

8. An RBMK is a Russian reactor which employs light water as coolant but graphite as the moderator. How does an increase in temperature of the coolant affect the terms of the four factor formula?

Transport Equation and Diffusion Approximation/Equation

1. What 2 main assumptions were made in deriving the neutron transport equation?

2. Write down the full time dependent 3-D neutron transport equation and explain briefly the meaning of each term.

3. For the steady state 1-D neutron transport equation, write down its eigenvalue form.

4. What is the diffusion approximation? What variable does it remove from the transport equation? What is being assumed about the dependence of the angular flux on this variable?

5. Name 2 situations where the diffusion approximation breaks down? Why does it breakdown in these cases?

6. Write down the different terms of the time dependent 1-D diffusion equation (keep energy continuous, no single group or multigroup approximations).

7. List the steps you would take to derive the diffusion equation from the transport equation?

8. Derive the interface conditions between two regions with different material properties using the diffusion approximation.

9. Aside from fission and scattering, what are a couple other possible "gain" mechanisms (source of neutrons in the transport/diffusion equation?

Kinetics and Point Kinetics Equations

1. What are delayed neutrons and how do you include them into the transport equation?

2. Why are delayed neutrons so important in transient reactor scenarios?

3. Aside from neutron emission from decay of fission products, what is another possible source of delayed neutrons (especially important in heavy water reactors)?

4. What main assumption is used to go from the kinetics equation to the point kinetics equation?

5. Write down the point kinetics equations with 1 effective precursor group.

6. What steps do you take to solve for the analytical solution to the point kinetics equation written in problem 4?

7. Find the analytical solution to the point kinetics equation with 1 precursor group for a reaction with Λ=.0001 sec, β=.007, λ=.1 sec^{-1} for a positive step reactivity insertion of $0.20. Assume the reactor power initially at steady state (equilibrium) with an initial power of P_o.

8. What are the 3 basic types of transient scenarios discussed in class? Make a sketch of power over time for all 3 situations, label them and briefly discuss the behavior.

9. What is the prompt jump approximation? What assumption is made?

10. Derive the in-hour equation from the point kinetics equation in problem 4.

Chapters 6 and 7 : Solving the Diffusion Equation

1. For 1-D finite sphere of radius R made of non-multiplying medium with properties D and Σ_a, determine the correct flux shape for a) the case of a point source producing neutrons at a rate of S_o and b) for the case of a distributed neutron source of S_o'''.

2. For a 1-D non-multiplying finite slab of thickness A with properties D and Σ_a and a source of neutrons, So, impinging upon the left facing surface, determine the flux distribution within the slab as well as the fraction of neutrons reflected off of the left facing surface.

3. For all 1-D multiplying geometries with kinf>1 and dimension A (finite slab (thickness A), finite sphere (r=A), cylinder (r=A) (with infinite height)) calculate the flux distributions and geometric bucklings. Don't forget about extrapolation distance.

4. If $\nu\Sigma_f$=.06 cm-1, Σ_a=.045 cm-1 and D=1.5 cm, and A is equal to 50 cm, what is keff for 1) a cube reactor with dimensions AxAxA and 2) a finite cylindrical reactor with a radius and height of A.

5. A sphere of non-multiplying material is surrounded by a blanket of multiplying material with kinf>1. The radius of the non-multiplying material is R/2 and the thickness of the surrounding multiplying material is R/2 (reactor with an internal reflector). There is nothing beyond the multiplying material. Determine the flux shape inside the reflector and reactor, the criticality condition and calculate keff if R=60 cm. Use the same cross sections as in problem 4. Ignore extrapolation distance for this problem.

Multigroup

1. Set up the diffusion equations in matrix form using 3 energy groups. Assume that all fission neutrons are born fast, fission is due only to thermal neutrons and no upscattering occurs.

2. Set up the modified one-group diffusion equation using the 3 group diffusion equations from problem 1.

3. For the two group diffusion case, determine the equation for k-effective. Assume fission neutrons are born fast and no upscattering occurs. You may also assume $\nabla^2 = -B_g^2$.

4. For a cube reactor, use the equation found in problem 2 to determine its critical dimensions. Use the following 2 group constants:

D_1 (cm)	2
Σ_{r1} (cm-1)	0.08
$\nu\Sigma_{f1}$ (cm-1)	0.02
D_2 (cm)	1
Σ_{a2} (cm-1)	0.25
$\nu\Sigma_{f2}$ (cm-1)	0.5
Σ_{s21}	0.058

Feedback Effects

1. Explain briefly what the coolant (moderator) temperature coefficient, fuel temperature coefficient and voiding coefficients are and how they are related to reactor design safety.

2. What is the importance of xenon-135 and samarium-149 in reactor operations? Why?

3. Why does the xenon concentration initially increase when the power of a reactor decreases? Why does the opposite occur when the reactor power increases?

4. Sketch the behavior of xenon concentration over time after a reactor's power increases from steady state and also for when the power decreases from steady state.

5. Explain what xenon oscillations are and how they occur.

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