## Nuclear Training Course PI27
## TIMS Ref. PI2007

# Nuclear Theory

**NUCLEAR TRAINING DEPARTMENT**

**COURSE PI 27**

**NUCLEAR THEORY**

# NUCLEAR TRAINING COURSE

## COURSE PI 27

## NUCLEAR THEORY

### INDEX

## Nuclear Theory - Course PI 27

## OBJECTIVES

At the conclusion of this course the trainee will be able to:

427.00-2 Radioactivity

1. For $\alpha$, $\beta$, $\gamma$ decays

   (a) Write typical equations for each.

   (b) List the physical properties.

   (c) Discuss interactions with materials.

2. Know how to shield against alphas and betas.

3. Know how to shield against $\gamma$ rays and be able to calculate $\gamma$ ray shielding of 1/2 value layers.

227.00-1 Nuclear Structure

1. Explain the concept of binding energy.

2. Discuss the stability of nuclei in terms of their neutron-proton ratio.

3. From a plot of n against p say what emission a given nuclide is likely to undergo.

4. Be able to follow a decay chain from a radioactive nuclide until a stable nuclide is reached.

5. Define the unit of activity, the Becquerel.

6. State the basic law governing radioactive decay.

7. State the relationship between decay constant ($\lambda$) and half life ($t_{\frac{1}{2}}$).

227.00-2 Neutron Reactions

1. Differentiate between elastic and inelastic collisions.

2. Explain the importance of elastic collisions to the operation of CANDU reactors.

3. State the name of the four types of inelastic collisions giving an example of each ($_ZA^A$) type example is acceptable).

4. Differentiate between spontaneous and induced fission.

5. Explain a self sustaining chain reaction.

6. Write the equations for the formation of $_{94}Pu^{239}$ in our reactors.

7. Define:

   (a) Prompt Neutrons

   (b) Delayed Neutrons
   (c) Delayed Neutron Precursors

   (d) $\beta$ - Delayed Neutron fraction

   (e) $\upsilon$ - Neutrons Emitted per Fission

   (f) Photoneutron

   (g) Fast neutrons

   (h) Thermal neutrons

8. Give the distribution of energy released by the fission of U-235.

227.00-3 Neutron Cross Sections, Neutron Density and Neutron Flux

1. Define:

   (a) Microscopic Neutron Cross Section and the units.

   (b) Macroscopic Neutron Cross Section and the units.

   (c) Neutron Density and the units.

   (d) Neutron Flux and the units.

2. Relate $\sigma_a$, $\sigma_f$ and $\sigma_{n,\gamma}$.

3. Discuss how the microscopic cross sections of U-238 and U-235 vary with neutron energy.

4. Write reaction rates.

5. Be able to extract data from the chart of the nuclides.

227.00-4 Thermal Reactors

1. Discuss the properties of a moderator including the number of collisions required to thermalize a neutron, scattering cross section, and absorption cross section.

2. Define the moderating ratio.

3. Explain the practical significance of the fact that $D_2O$, compared to $H_2O$ has a lower scattering cross section and requires more collisions to thermalize a neutron.

4. Discuss the effect of downgrading the moderator or heat transport fluid.

5. Define lattice pitch.

6. Explain what "over moderated" means and why Hydro's reactor are over moderated.

7. Explain why increasing or decreasing the lattice pitch from its optimum value causes reactivity to change.

227.00-5 Neutron Multiplication Constant and Reactivity

1. Define k both in words and in terms of the six factors.

2. State when the word definition is not valid.

3. Define and explain each of the six factors in k.

4. Sketch a neutron life cycle using the six factors.

6. Define:

   (a) Critical

   (b) Subcritical

   (c) Supercritical

7. State and explain the significance of the four-factor formula for $k_\infty$.

8. Define and calculate values of reactivity and of reactivity worths.

9. Calculate values of the six factors given a neutron life cycle.

227.00-6 Neutron Flux Distribution

1. Discuss the functions of a reflector.
2. Discuss the effects of a reflector.
3. Explain why flux flattening is desirable.
4. Discuss the four methods of flux flattening used.
5. Sketch the flux shapes showing the effect of each of the flux flattening methods.
6. Discuss the effect of reactor size and shape on neutron leakage.

227.00-7 Effect of Fuel Burnup

1. State and explain the units used for fuel burnup.
2. Explain why the combined reactivity worth due to U-235 and Pu-239 initially increases then decreases with burnup.
3. Explain how and why each of the four factors of $k_\infty$ changes with fuel burnup.
4. Explain how and why the delayed neutron fraction ($\beta$) changes with fuel burnup.

227.00-8 Changes in Reactor Power with Time

1. Physically explain the effect of delayed neutrons on changes in reactor power.
2. Given the formula, $P(t) = \frac{\beta}{\beta-\Delta k} P_0 e^{\frac{\lambda \Delta k t}{\beta-\Delta k}}$, solve calculational type problems.
3. Explain the concept of the prompt jump.
4. Define prompt criticality and explain why it is undesirable. Explain its dependence upon fuel composition and fuel burnup.

227.00-9 Source Neutron Effects

1. State the sources of neutrons and their approximate magnitudes.

2. State and use the formula $S_\infty = \frac{So}{1-k}$.

3. Define and explain the significance of the subcritical multiplication factor.

4. Calculate k in a subcritical reactor given appropriate data.

5. State that, for a sub-critical reactor, the closer k is to one, the longer it takes for power to stabilize after a reactivity change.

227.00-10 Power and Power Measurement

1. Explain how thermal power is measured.

2. Explain why neutron power must be calibrated to thermal power.

3. Explain the reasons why neutron power is used for control and protection of the reactor.

4. State the relationship between reactor period and rate log N. (For engineers: Prove the relationship).

5. Make an accurate sketch of the rundown of neutron power after a trip justifying times and power levels used.

6. Discuss the rundown of thermal power after shutdown.

227.00-11 Fission Product Poisoning

1. Explain how xenon and iodine are produced in the reactor and how they are lost from the reactor.

2. Write the differential equations for the concentration of xenon and iodine and define each term.

3. State the magnitude of the production and loss terms for xenon at equilibrium in our larger reactors.

4. Define Xenon Load and Iodine Load.

5. Explain what Xenon Simulation is.

6. Sketch and explain the behaviour of xenon after a trip from full power.

7. State and explain the two conditions necessary for a Xenon Oscillation.

8. Explain what a Xenon Oscillation is and how one may be started.

9. Explain why samarium growth after shutdown is not a problem.

227.00-12 Reactivity Effects Due to Temperature Changes

1. Explain why a negative fuel temperature coefficient of reactivity is desirable.

2. Give two undesirable effects of having a negative fuel coefficient.
3. Explain why the fuel temperature coefficient is more important than either the coolant or moderator temperature coefficient.

4. Explain why the fuel temperature coefficient is negative and why its value changes from fresh to equilibrium fuel.

5. Define the power coefficient and give a typical value.

6. Define the void coefficient.

227.00-13 Reactivity Control

1. List the various in-core reactivity worth changes, typical magnitudes of the changes, and the time period over which the changes occur.

2. Discuss general methods of reactivity control in terms of their effect on the six factors of k.

3. Given a specific method of reactivity control (eg, Moderator Level Control) discuss its advantages and disadvantages.

4. List and discuss the advantages and disadvantages of each of the presently used shutdown systems.

227.00-14 The Approach to Critical

1. Explain why the initial approach to criticality is potentially hazardous.

2. Explain how inverse count rate is used to predict the critical value of the controlling reactivity mechanism.