SOUTHEAST COMMUNITY COLLEGE
CONSTRUCTION, MANUFACTURING AND TECHNOLOGY DIVISION
Energy Generation Operations Technology Program
Revision Date: August 21, 2023

I. CATALOG DESCRIPTION

Course Number:	ENER2135
Course Title:	Atomic Structures
Prerequisite(s):	ENER2102
Catalog Description:	Topics include atomic structure, a review of atoms and their fundamental structures, review of the chart of the nuclides, nuclear reactions, mass to energy conversion, industrial and science applications of nuclear processes, radioactive decay, half-life determination, and radioactive interaction with matter.
Credit Hours:	2
Class Hours:	30
Lab Hours:	0
Total Contact Hours:	30

II. COURSE OBJECTIVES: *Course will:*

A. Provide students a review of atoms and their fundamental structures.
B. Explain fundamental characteristics of atoms as they relate to nuclear power including mass defect, binding energy, and nuclear stability.
C. Provide a basic understanding of radioactive decay and how it relates to nuclear power and safety systems.
D. Explain the role of neutrons and reactivity coefficients in nuclear power systems.

III. STUDENT LEARNING OUTCOMES AND GENERAL EDUCATION LEARNING OUTCOMES:

A. Student Learning Outcomes**:** *Student will be able to:*
- **1.** Discuss nuclear chemistry and physics.
- **2.** Calculate K-effect and coefficients.
- **3.** Explain the neutron life cycle.
- **4.** Identify moderator conditions.
- **5.** Explain fuel depletion and fission products.
- **6.** Understand temperature effects on reactivity.
- **7.** Describe how reactor criticality may be predicted through the use of a reactivity balance.
- **8.** Identify changes that will affect reactivity within the reactor core during and after operation.

B. General Education Learning Outcomes (GELOs)
- **1.** GELO #5: Analytical, Quantitative, and Scientific Reasoning
Outcome 4: Manipulate formulas, data sets, graphs, tables, etc. in a way to produce a meaningful outcome.

IV. CONTENT/TOPICAL OUTLINE

A. Review of atoms and fundamental structures
B. Module 2: Mass Defect and Binding Energy
- **1.** DESCRIBE the characteristics of Electrostatic and Nuclear Forces with respect to the following:
  - **a.** Relative Effective Distance

   - **b.** Change with Distance
   - **c.** Nucleons
2. STATE the role of neutrons in establishing stability within a nucleus.
3. DEFINE the following:
   - **a.** Binding energy
   - **b.** Binding energy per nucleon
   - **c.** Fission
   - **d.** Mass defect
   - **e.** Mass-energy equivalence
   - **f.** Nuclear Stability
4. STATE the purpose of radioactive decay.
5. IDENTIFY the four basic types of radiation.
6. DISCUSS the following with respect to the four types of radiation:
   - **a.** Electrical charge. Relative ability to penetrate substances when compared to the other three types of radiation.
   - **b.** Size and/or mass.
   - **c.** Each radiation type's penetration ability of substances when compared to the other types of radiation.
7. Provided a Chart of the Nuclides, or equivalent information, CALCULATE the following for a given nucleus:
   - **a.** Binding energy
   - **b.** Binding energy per nucleon
8. EXPLAIN the changing slope of the curve associated with a plot of binding energy per nucleon.

C. Module 1: Nuclear Cross Section, Fission, and the Classification of Neutrons

1. STATE the difference between "microscopic cross section" and "macroscopic cross section."
2. DEFINE the following:
   - **a.** Mean free path
   - **b.** Critical energy
   - **c.** Fissile material
   - **d.** Fissionable material
   - **e.** Fission
   - **f.** Ternary fission
   - **g.** Prompt neutron
   - **h.** Fast neutron
   - **i.** Intermediate neutron
   - **j.** Slow neutron
   - **k.** Thermal neutron
   - **l.** Delayed neutron
   - **m.** Source neutron
3. Utilizing the liquid drop model method, DESCRIBE neutron induced fission.
4. CHARACTERIZE the Fission Product Yield Curve, including the reasoning for its shape.
5. LIST the resulting components and energy breakdown associated with the fission of U-235.
6. EXPLAIN how the fission process results in heat within the reactor.
7. STATE the meaning of the term "decay heat".
8. EXPLAIN why "decay heat" is a concern for a nuclear power plant.
9. DESCRIBE the presence of decay heat during and following reactor operation.

10. IDENTIFY three variables that will affect the amount of decay heat present following reactor shutdown.
11. Given a time of one hour following a reactor shutdown, ESTIMATE the approximate amount of decay heat that will exist.

D. Module 2: Neutron Life Cycle

1. DEFINE effective multiplication factor.
2. DISCUSS the relationship between effective multiplication factor and the state of the reactor.
3. DEFINE the following reactor terms:
   - **a.** Neutron generation time
   - **b.** Critical
   - **c.** Subcritical
   - **d.** Supercritical
4. DESCRIBE the following terms associated with neutron life cycle:
   - **a.** Fast fission factor
   - **b.** Fast non-leakage probability factor
   - **c.** Resonance escape probability factor
   - **d.** Thermal non-leakage probability factor
   - **e.** Thermal utilization factor
   - **f.** Reproduction factor
5. DEFINE the term Reactivity.
6. STATE the relationship between reactivity and effective multiplication factor.
7. Provided a value for k_{eff}, CALCULATE the value of reactivity.
8. Provided a value for reactivity, CALCULATE the value of k_{eff}.

E. Module 3: The Role of Delayed Neutrons and Reactor Kinetics

1. DESCRIBE how delayed neutrons are produced.
2. DEFINE the terms:
   - **a.** Delayed neutron fraction
   - **b.** Effective delayed neutron fraction
3. STATE the reasons for variation in the definition of delayed neutron fraction and effective delayed neutron fraction.
4. DEFINE the term doubling time.
5. CALCULATE doubling time using the power equation.
6. EXPLAIN the effect of delayed neutrons on reactor control.
7. DESCRIBE the following terms:
   - **a.** Prompt critical
   - **b.** Prompt jump
   - **c.** Prompt drop
8. DEFINE startup rate.
9. DESCRIBE the factors affecting reactor period and startup rate.
10. Provided the power equation, SOLVE problems associated with the following:
    - **a.** Power changes
    - **b.** Startup rate
    - **c.** Reactor period

F. Module 4: Reactivity Coefficients

1. EXPLAIN the concept of over moderation and under moderation within a reactor core.
2. EXPLAIN why an under moderated design is prevalent in many reactors.
3. STATE the change in moderator to fuel ratio for a given change in moderator temperature.
4. DEFINE the moderator temperature coefficient of reactivity.

5. DESCRIBE the desired benefit to a negative moderator temperature coefficient of reactivity.
6. EXPLAIN why the fuel temperature coefficient is more effective than the moderator temperature coefficient in terminating a rapid power rise.
7. EXPLAIN the concept of Doppler broadening of resonance absorption peaks.
8. IDENTIFY two nuclides that are present in most commercial reactor fuel assemblies which have significant resonance absorption peaks.
9. DEFINE the pressure coefficient of reactivity.
10. EXPLAIN why the pressure coefficient of reactivity is usually negligible in a typical water cooled reactor.
11. DEFINE the void coefficient of reactivity.
12. IDENTIFY the moderator conditions which introduce significance to the void coefficient of reactivity.

G. Module 5: Operational Aspects of the Reactor Plant

1. EXPLAIN why a startup neutron source may be required for a reactor.
2. IDENTIFY four variables typically utilized in a reactivity balance.
3. DESCRIBE how a reactivity balance may be used to predict conditions under which the reactor will become critical.
4. LIST three methods used to shape or flatten the core power distribution.
5. DESCRIBE the concept of power tilt.
6. DEFINE the term shut down margin.
7. IDENTIFY five changes which will affect reactivity within the reactor core during and after a reactor shutdown.
8. EXPLAIN why decay heat is present following reactor operation.

V. INSTRUCTIONAL MATERIALS

A. On-Line Course Content via Canvas
B. PowerPoint Presentation for each Module
C. Chart of the Nuclides
D. Calculator

VI. METHODS OF PRESENTATION

A. Methods of presentation typically include a combination of the following:

1. Classroom or online, to be determined by the instructor.

VII. METHODS OF EVALUATION

A. Methods of evaluation, although determined by the individual instructor, traditionally includes a combination of the following:

1. Class participation
2. Regular assignments
3. Written exams and/or quizzes
4. Performance and observational assessments

VIII. SPECIFIC COURSE REQUIREMENTS

A. A minimum grade of “C” or 70% is required to receive credit for this course.
B. A minimum grade of “B” or 80% is required to earn the NUCP certificate, in accordance with ACAD 08-006, Revision 1, dated October 2016.
C. Cheating within the Manufacturing Division: Any violation of academic integrity on assignments, quizzes, or tests will result in a grade of 0 on that assignment, quiz, or test.

A second violation in any course after the initial infraction will result in a grade of U for that course. Any additional violations while in the program will result in a suspension from the program.

D. Credit by Examination: Credit for the course CANNOT be earned through Credit by Examination.