# UNENE 901 – Course Description 2026

**Description:**
A nuclear reactor presents a unique environment in which materials must perform. In addition to the high temperatures, stresses and corrosive environments to which materials are subjected in conventional applications, nuclear materials are subjected to various kinds of radiation which affect their performance, and often this dictates a requirement for a unique property (for example, a low cross section for thermal neutron absorption) that is not relevant in conventional applications. The effects of the radiation may be direct (e.g., the displacement of atoms from their normal positions by fast neutrons or fission fragments), or indirect (e.g., a more aggressive chemical environment caused by radiolytic decomposition). This course starts with a review of key materials' phenomenon that are important even outside a reactor, then describes materials typically used in nuclear environments, the unique conditions to which they are subjected, the basic physical phenomena that affect their performance and the resulting design criteria for reactor components made from these materials. The focus is on the CANDU design although some aspects from other designs are discussed.

**Instructors:**
Professors Mark Daymond & Zhongwen Yao, from Queen's University

**Assessment:**
- Participation (10%)

- 4 x Assignments (20%)
Short assignments are provided at the end of each session, and are due 2 weeks later. The assignments review the topics presented in the class sessions.

- Project Presentation (15%)
At the 4$^{th}$ session, students are assigned a research paper or technical document on a specific aspect of nuclear materials. Students will have 2 weeks to prepare and will give an oral presentation (on Zoom), on i) the material covered in the paper assigned, ii) the practical importance of the subject matter, relating the contents of the report to what you have learned in the course.

- Final Exam (55%)
Will be taken in-person approx. 3-4 weeks after the last session, Date June 6.

**Sequence of Lectures:**

**Session 1 – Introduction / Review of key Physical Metallurgy (Daymond)**

Day 1 (April 11)

Lecture 1 – Introduction
Lecture 2 – Crystallography and Point Defects
Lecture 3 – Dislocations and Boundaries
Lecture 4 – Plastic Instability and Fracture

Day 2 (April 12)

Lecture 5 – Texture, Plasticity and Plastic Anisotropy
Lecture 6 – Creep and Fatigue
Lecture 7 – Residual Stress
Lecture 8 – Phase Diagrams

**Session 2 – Reactors and Radiation Effects (Yao)**

Day 3 (April 25)

Lecture 9 – Physics of Nuclear Reactors and relation to material selection
Lecture 10 – Power Reactor Design 1
Lecture 11 – Power Reactor Design 2
Tutorial

Day 4 (April 26)

Lecture 12 – Radiation Effects
Lecture 13 – Evolution of Microstructure and Microchemistry
Lecture 14 – Radiation Induced Deformation 1, without applied stress
Lecture 15 – Radiation Induced Deformation 2, with applied stress

**Session 3 – Fuel Channels (Yao)**

Day 5 (May 9)

Lecture 16 – Overview of Fuel Channel Technology
Lecture 17 – Physical Metallurgy of Pressure Tubes and Calandria Tubes
Lecture 18 – Microstructure of Pressure Tubes
Lecture 19 – Deformation of Pressure Tubes

Day 6 (May 10)

Lecture 20 – Pressure Tube Corrosion and Deuterium Ingress
Lecture 21 – Delayed Hydride Cracking and Fracture
Lecture 22 – Calandria Tubes
Tutorial

**Session 4 – CANDU Fuel and Steam Generators (Daymond)**

Day 7 (May 23)

Lecture 23 – Design and Manufacture of Fuel
Lecture 24 – Fuel Operation
Lecture 25 – Fuel Performance
Lecture 26 – Examination and Testing of Radioactive Components

Day 8 (May 24)

Lecture 27 – CANDU Feeders
Lecture 28 – Steam Generator Design and Degradation
Lecture 29 – Mitigation of Steam Generator Degradation
Tutorial