UN806
NUCLEAR FUEL ENGINEERING

Course Outline **Apr. – Jun., 2026**

INSTRUCTOR:

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COURSE DESCRIPTION:

This course covers introductory and advanced topics in nuclear fuel engineering that are of practical interest to the Canadian nuclear industry. Topics include the nuclear fuel cycle, fuel design and components, fuel manufacturing, in-reactor behaviour, common failure modes, fuel behaviour under accident conditions, fuel qualification, and other related topics.

COURSE OUTCOMES:

On the successful completion of the course, students should be able to:

(a) Describe the major stages of the nuclear fuel cycle from mining to disposal.
(b) Understand important phenomena pertinent to nuclear fuel behaviour in-reactor under normal operating conditions.
(c) Describe common fuel failure mechanisms of practical interest to industry and strategies that have been used to mitigate them.
(d) Study nuclear fuel behaviour in multiple reactor types, including CANDU, Light Water Reactors, and other advanced fuel technologies.

TEXTBOOKS (essential)

- M. Tayal, M. Gacesa, "Fuel", in: Wm. J. Garland (ed), The Essential CANDU, University Network of Excellence in Nuclear Engineering (UNENE).

TEXTBOOKS (for reference)

- M.H.A. Piro, Advances in Nuclear Fuel Chemistry, Elsevier (2020).
- Several other references will be provided (e.g., IAEA and OECD-NEA reports).

Assessments

Quizzes	10%
Assignments	20%
Project	20%
Final Exam	50%

A late penalty of 5% per day will be applied to late deliverables.

FINAL GRADES

Final grades will be assessed according to the McMaster/UNENE standard grading scheme.

OFFICE HOURS

There are no standing office hours; however, I'd be happy to meet with you on Teams / Zoom / phone by appointment.

SCHEDULE

The schedule below should be viewed as an approximation. There may be slight deviations. All times are in Toronto time (EST).

April 11, 2026

1. Introduction and administration 1.1 Safety brief 1.2 Round table introductions 1.3 Course objectives, outcomes, and scope 1.4 Deliverables, expectations, and schedule	9:00 – 9:15
2. Overview of the nuclear fuel cycle 2.1 Mining and milling 2.2 Refining and conversion 2.3 Enrichment 2.4 Fuel manufacturing 2.5 In-reactor behaviour 2.6 Wet storage and dry storage 2.7 Reprocessing and recycling 2.8 Disposal	9:15 – 10:30
Break	10:30 – 10:45
3. Uranium mining and milling 3.1 Uranium resources and reserves 3.2 Mining operations 3.3 Milling operations 3.4 Tailings, decommissioning, and reclamation	10:45 – 12:00
Lunch	12:00 – 13:00

4. Uranium refining, conversion, and enrichment 4.1 Uranium refining 4.2 CANDU conversion 4.3 LWR conversion 4.4 Enrichment techniques	13:00 – 14:15
Break	14:15 – 14:30
5. Fuel designs, materials, and components 5.1 Materials and components 5.2 CANDU fuel design 5.3 BWR fuel design	14:30 – 15:45
Quiz #1	15:45 – 16:00

April 12, 2026

6. Administration 6.1 Review upcoming deliverables	9:00 – 9:15
7. Fuel manufacturing 7.1 Fuel pellet fabrication 7.2 Fuel cladding fabrication 7.3 Fuel bundle manufacturing 7.4 CANDU fuel manufacturing plants	9:15 – 10:30
Break	10:30 – 10:45
8. Fuel performance: Thermal behaviour 8.1 Introduction to fuel performance 8.2 Material properties 8.3 Heat generation and neutronic effects 8.4 Burnup effects 8.5 Compositional effects 8.6 Fuel-clad gap conductance 8.7 Heat transfer calculations	10:45 – 12:00
Lunch	12:00 – 13:00
9. Fuel performance: Mechanical behaviour 9.1 Material properties 9.2 Thermal expansion 9.3 Creep 9.4 Fission product swelling 9.5 Irradiation induced densification 9.6 Fuel cracking 9.7 Radiation damage	13:00 – 14:15
Break	14:15 – 14:30
10. Fuel performance: Fission product behaviour 10.1 Brief review of isotopic depletion, decay, and transmutation 10.2 Fission product evolution in CANDU and LWR fuel 10.3 Fission product groups 10.4 High burnup structure and high fission area	14:30 – 15:45
Quiz #2	15:45 – 16:00

April 25, 2026

11. Administration 11.1 Take up assignment #1	9:00 – 9:15
12. Fuel performance: Fission gas release 12.1 Grain growth 12.2 Intragranular and intergranular diffusion 12.3 Recoil and knockout 12.4 Fission gas release 12.5 Effects of power ramping	9:15 – 10:30
Break	10:30 – 10:45
13. Fuel performance: Fuel chemistry 13.1 Effects of oxidation on UO_2 fuel 13.2 UO_2 fuel melting behaviour 13.3 Irradiated UO_2 fuel chemistry 13.4 Chemistry of other oxide fuels 13.5 Fuel/water chemistry	10:45 – 12:00
Lunch	12:00 – 13:00
14. Fuel performance: OPEX (I) 14.1 Pellet Cladding Interaction (PCI) 14.2 Fuel manufacturing	13:00 – 14:15
Break	14:15 – 14:30
15. Fuel performance: OPEX (II) 15.1 Corrosion/CRUD 15.2 Debris fretting 15.3 Grid-To-Rod Fretting (GTRF)	14:30 – 15:45
Quiz #3	15:45 – 16:00

Apr. 26, 2026

16. Administration 16.1 Discuss upcoming deliverables	9:00 – 9:15
17. Fuel handling: CANDU 17.1 Refueling CANDU stations	9:15 – 10:30
Break	10:30 – 10:45
18. Fuel handling: BWR 18.1 Refueling BWR stations	10:45 – 12:00
Lunch	12:00 – 13:00
19. Reprocessing and recycling 19.1 The PUREX process 19.2 MOX recycling	13:00 – 14:15
Break	14:15 – 14:30
20. Spent fuel storage and disposal 20.1 Wet storage 20.2 Dry storage 20.3 Geological disposal	14:30 – 15:45
Quiz #4	15:45 – 16:00

May 9, 2026

21. Administration 21.1 Take up Assignment #2	9:00 – 9:15
22. Accident scenarios (Part 1) 22.1 Overview of state classifications 22.2 Loss Of Coolant Accidents (LOCA)	9:15 – 10:30
Break	10:30 – 10:45
23. Accident scenarios (Part 2) 23.1 Case study: Fukushima	10:45 – 12:00
Lunch	12:00 – 13:00
24. Fuel qualification 24.1 CANDU fuel qualification experience 24.2 37M fuel development and qualification	13:00 – 14:15
Break	14:15 – 14:30
25. IST Fuel Codes 25.1 ELESTRES 25.2 ELOCA 25.3 SOURCE	14:30 – 15:45
Quiz #5	15:45 – 16:00

May 10, 2026

26. Administration 26.1 Discuss upcoming deliverables	9:00 – 9:15
27. Alternative Gen II/III fuels 27.1 Thorium based fuels 27.2 DUPIC fuel 27.3 MOX fuel 27.4 Accident tolerant fuels	9:15 – 10:30
Break	10:30 – 10:45
28. Gen IV/SMR fuels (part 1) 28.1 TRISO fuel	10:45 – 12:00
Lunch	12:00 – 13:00
29. Gen IV/SMR fuels (part 2) 29.1 Metallic fuel 29.2 Molten salt fuel	13:00 – 14:15
Break	14:15 – 14:30
30. Non-proliferation and safeguards 30.1 Non-proliferation treaty (NPT) 30.2 Canadian compliance to NPT 30.3 Case studies	14:30 – 15:45
Quiz #6	15:45 – 16:00

May 23, 2026

31. Administration 31.1 Take up assignment #3	9:00 – 9:15
32. **Final exam preparation (Part 1)**	9:15 – 10:30
Break	10:30 – 10:45
33. **Final exam preparation (Part 2)**	10:45 – 12:00
Lunch	12:00 – 13:00
34. Project presentations (Part 1)	13:00 – 14:15
Break	14:15 – 14:30
35. Project presentations (Part 2)	14:30 – 16:00

May 24, 2026

36. Administration 36.1 Questions	9:00 – 9:15
37. Project presentations (Part 3)	9:15 – 10:30
Break	10:30 – 10:45
38. Project presentations (Part 4)	10:45 – 12:00
Lunch	12:00 – 13:00
39. Project presentations (Part 5)	13:00 – 14:15
Break	14:15 – 14:30
40. Project presentations (Part 6)	14:30 – 16:00

June 6, 2026

FINAL EXAM	12:00 – 15:00