Changes to this syllabus will be provided via the ELearning/Sakai platform. Such changes may include those required by policy changes, instructor travel, changes in the speed of course coverage, university closure, errors in previous syllabus versions, and other reasons.

1. Description:

Nuclear applications of fluid mechanics, heat transfer and thermodynamics. Two-phase flow and boiling heat transfer. Heat transfer mechanisms in reactor core and sub-channel thermal hydraulics. Steam generator, power cycles, balance of plant. Introduction to thermal design for reactors.

2. Prerequisite:

EML 4140 + (EGN 3353C or ENU 4133)

3. Program Educational Objectives Supported by Course

1. Graduates will have successful careers in Nuclear Engineering or related disciplines.
2. Graduates will pursue advanced degrees or continuing education.

4. Professional Components Supported by Course

1. Provide students with the ability to apply advanced mathematics, computational skills, science and engineering science, including atomic and nuclear physics, to identify, formulate, analyze, and solve nuclear and radiological engineering problems.

2. Provide students with knowledge of the fundamentals of radiation transport, interactions, and detection and with the principles required for the analysis, design, and safe operation of radiation producing devices and using equipment and systems.

4. Provide students with the skills needed to communicate effectively, work collaboratively, and understand their professional and ethical responsibilities and the impact of engineering solutions in a societal and economic context so they can pursue successful, productive careers in nuclear and radiological engineering.

5. Program Outcomes Supported by Course

Outcome a: an ability to apply knowledge of mathematics, science, and engineering.

Outcome c: an ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

Outcome d: an ability to function on multi-disciplinary skills teams.

Outcome e: an ability to identify, formulate, and solve engineering problems.

Outcome f: an understanding of professional, ethical and regulatory responsibility in engineering practice.

Outcome g: an ability to communicate effectively, using both oral and written presentations, in engineering practice;

Outcome i: a recognition of the need for life-long learning and the ability to adapt this to engineering practice;

Outcome k: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Outcome l: an ability to apply advanced mathematics, science, and engineering sciences, including atomic and nuclear physics, to nuclear and radiological systems and processes

Outcome n: an ability to work professionally in on or more of the areas of: nuclear power systems, nuclear instrumentation and measurement, radiation protection and shielding, and radiation sources and applications

6. Instructor

DuWayne Schubring, Assistant Professor
205 Nuclear Sciences Building
352-392-0852
dlschubring@ufl.edu
Web: Sakai
Office hours: WR 1215-1345, by e-mail, and appointment.

7. Teaching Assistant:

none

8/9/10. Course Meetings:

MF, 1500-1550 ("Period" 8); W, 1500-1655 ("Periods" 8 and 9), NSB 227. Final Exam: December 19, 1730-1930 (also in NSB 227).

11. Material and Supply Fees:

None for on-campus section, $2.00 for EDGE section.

12. Text (Required):

Nuclear Systems I: Thermal Hydraulic Fundamentals, N.E. Todreas and M.S. Kazimi, 2011 (2nd edition). (ISBN: 9781439808870). (No, the cheaper 1st edition is not adequate.)

To complete some of the homework and projects in this course, access to a programming/scripting language such as MATLAB, FORTRAN, C, C++ (etc.) and a spreadsheet application will be required. Property look-up software, such as EES, is strongly recommended, though not strictly required.

13. References

1. *Nuclear Heat Transport*, M. M. El-Wakil, 1978 (1st edition). (ISBN: 0894480146). A second book on nuclear-specific thermal issues.

2. Any undergraduate textbooks (typically aimed at mechanical engineering students) on thermodynamics, fluid dynamics, and heat transfer. *Fluid Mechanics*, F. M. White (7th edition) was the text for ENU 4133 and is recommended.

3. As the steam tables in T&K are not particularly comprehensive, especially in SI units, you'll want access to better ones. These could be found in previous textbooks or via software.

14. Course Outline

The course is organized into 16 modules. The materials for each module are in separate folders on the course website.

1. Nuclear Applications of Fluid Mechanics and Heat Transfer [T&K, Sections 9.6, 10.5.1.1.3)
2. Averaging in Two-Phase Flow [T&K, Sections 5.1 through 5.4]
3. Transport in Two-Phase Flow [T&K, Sections 5.5 through 5.7]
4. Homogeneous Equilibrium Model [T&K, Sections 11.1 through 11.4, 11.5.2]
5. Separated Flow Model and Void Fraction Correlations [T&K, Section 11.5]
6. Pressure Loss in Two-Phase Flow [T&K, Section 11.6]
7. Flow Regimes in Two-Phase Flow [T&K, Section 11.2]
8. Boiling Heat Transfer – Fundamentals [T&K, Sections 12.1 through 12.5, 13.1, 13.2]
9. Boiling Heat Transfer – Correlations [T&K, Section 13.3]
10. Boiling Heat Transfer – Critical Heat Flux [T&K, Section 13.4]
11. Nuclear Heat Transport [T&K, Sections 3.1 through 3.6.1, 3.9, 8.1 through 8.3, 8.5, 8.7]
12. Single Channel Analysis (SCA) Methods [T&K, Chapter 14]
13. Critical Flow [T&K, Section 11.7]
14. Nuclear Power Cycles [T&K, Sections 6.1, 6.3 through 6.7]
15. Steam Generators
16. Thermal Design Principles [Lecture/discussion only – no separated set of notes]

Modules 1-15 are supported by online lecture notes. Since T&K is primarily a graduate-level textbook with relatively few organizational similarities to ENU 4134/6135, these notes are intended to distill the keys points of the modules for use in this class. Particularly for modules 12, 14, and 15, these notes will likely form your primary study material.

Exams

1. Modules 1 through 7
2. Modules 8 through 12
3. Comprehensive, focus on Modules 13-16

Projects

1. Flow Regimes and/or Pressure Drop (TBD)
2. Single Channel Analysis with Your Own SCA Code (Part A: Code Development; Part B: Code Application)

Homeworks

1. Nuclear Applications of Fluid Mechanics and Heat Transfer
2. Averaging in Two-Phase Flow and Transport in Two-Phase Flow
3. Homogeneous Equilibrium Model
4. Separated Flow Model (Void Fraction Correlations)
5. Pressure Loss in Two-Phase Flow

6. Boiling Heat Transfer (Part 1)
7. Boiling Heat Transfer (Part 2)
8. Nuclear Heat Transport
9. Critical Flow
10. Nuclear Power Cycles

The day-by-day outline must be understood as a draft. Lecture coverage may move forward or back, as necessary. Homework and project deadlines will not be earlier than listed, but may be later. Exam dates will not change (excluding university closure).

Week	**Day**	**Date**	**Due**	**Material**
1	M	24 Aug		Introduction and Administrivia
1	W	26 Aug		Nuclear Applications of Fluid Mechanics and Heat Transfer
1	F	28 Aug		Nuclear Applications of Fluid Mechanics and Heat Transfer
2	M	31 Aug		NO CLASS (NURETH)
2	W	2 Sep		NO CLASS (NURETH)
2	F	4 Sep		NO CLASS (NURETH)
3	M	7 Sep		NO CLASS (UF HOLIDAY)
3	W	9 Sep		Averaging in Two-Phase Flow
3	F	11 Sep	HW 1	Transport in Two-Phase Flow
4	M	14 Sep		Transport in Two-Phase Flow
4	W	16 Sep		Homogeneous Equilibrium Model
4	F	18 Sep	HW 2	Separated Flow Model and Void Fraction Correlations
5	M	21 Sep		Separated Flow Model and Void Fraction Correlations
5	W1	23 Sep		Separated Flow Model and Void Fraction Correlations
5	W2	23 Sep		Pressure Loss in Two-Phase Flow
5	F	25 Sep	HW 3	Pressure Loss in Two-Phase Flow
6	M	28 Sep		Flow Regimes in Two-Phase Flow
6	W	30 Sep		Flow Regimes in Two-Phase Flow
6	F	2 Oct	HW 4 & 5	Flow Regimes in Two-Phase Flow
7	M	5 Oct		Boiling Heat Transfer – Fundamentals
7	W	7 Oct	Exam 1	Exam 1
7	F	9 Oct		Boiling Heat Transfer – Fundamentals
8	M	12 Oct		Boiling Heat Transfer – Fundamentals
8	W	14 Oct		Boiling Heat Transfer – Correlations
8	F	16 Oct	Project 1	Boiling Heat Transfer – Correlations & CHF
9	M	19 Oct		Boiling Heat Transfer – Critical Heat Flux
9	W1	21 Oct		Boiling Heat Transfer – Critical Heat Flux
9	W2	21 Oct		Nuclear Heat Transport
9	F	23 Oct	HW 6 & 7	Nuclear Heat Transport

Week	Day	Date	Due	Material
10	M	26 Oct		Nuclear Heat Transport
10	W	28 Oct		Single Channel Analysis
10	F	30 Oct	HW 8	Single Channel Analysis
11	M	2 Nov		Critical Flow
11	W	4 Nov	Exam 2	Exam 2
11	F	6 Nov		NO CLASS (UF HOLIDAY)
12	M	9 Nov		NO CLASS (ANS)
12	W	11 Nov		NO CLASS (ANS & UF HOLIDAY)
12	F	13 Nov	Project 2A [advisory]	Critical Flow
13	M	16 Nov		Critical Flow
13	W1	18 Nov	Project 2A [final]	Critical Flow
13	W2	18 Nov		Nuclear Power Cycles
13	F	20 Nov	HW 9	Nuclear Power Cycles
14	M	23 Nov		Nuclear Power Cycles
14	W	25 Nov		NO CLASS (UF HOLIDAY)
14	F	27 Nov		NO CLASS (UF HOLIDAY)
15	M	30 Nov	HW 10	Steam Generators
15	W	2 Dec		Steam Generators & Thermal Design
15	F	4 Dec	Project 2B	Thermal Design
16	M	7 Dec		Catch-up (if necessary)
16	W	9 Dec		Review for Exam 3

15. Attendance and Expectations

Attendance & Class Conduct

Skip at your peril. Attendance is not considered in the grade. However, some materials in the course will not be covered in the textbook or in the notes provided online – only in class. Some example problems and complex figures (hard to digitize, easy to make on chalkboard) fall into this category. Students are responsible for these materials.

If a student arrives late or leaves early, he/she is expected to do so with minimum level of disruption to the class in progress. There is no tolerance for mobile phones or other electronic disruptions. Such disruptions will lead to the student being told to leave the room for the duration of the class period, *including during examination periods.* The same principle applies to office hours or appointments – if you stop by my office and your phone rings, you will be told to leave the room for the duration of that day's office hours (or your appointment considered over).

The instructor reserves the right to take attendance to prioritize e-mail assistance.

Recorded Lectures

The lectures from 2013 are available for your use. Please keep the following notes in mind:

- Several lectures from 2013 were corrected, via online note correction, e-mail message, and/or in-class announcement (at a later date). These changes are listed on Sakai.
- The quality of lecture videos is somewhat variable (and largely beyond my control).
- In the event of conflicts between the instructions in 2013 lectures and the 2015 syllabus, e-mail messages, assignments, other administrative documents (etc.), the 2015 versions will prevail. Numerous course policies have been changed for 2015 (though the content of the course is 90% the same).
- The specific slides/materials covered by each online lecture are listed, but please note that 2013 and 2015 lectures will usually not match up one-to-one. That is, a "hybrid" strategy of attending some lectures live and some via video will likely cause on-campus students to miss some material and hear others twice.

I encourage on-campus students to attend class in person, as ENU 4134 is optimized for this experience, with accomodations for distance education.

Make-Up Work Policies

Absences and late-work excuses can be grouped into the categories of *professional, medical,* and *personal*.

Professional: Reasonable extensions for job/internship interviews, technical conferences, or other professional/career development reasons should be requested. Requests are typically granted, at instructor's discretion, unless they would grant a student or group of students an unfair advantage over their peers, cause significant disruption to the course or grading schedule, or violate some UF policy.

Medical: Extensions will also be granted for (your own) medical reasons – please do not come to class if you are ill. Per UF policy, in the case of medical absences that are frequent or suspiciously-timed (*e.g.;* you are repeatedly, suddenly ill at deadlines), the instructor may request a signed note from a physician or similar professional practitioner.

Personal: In addition, UF policies require accommodation for several non-academic, non-medical reasons. *Extensions for these personal issues are strictly limited to those mandated by the letter of UF policies.* UF-authorized extensions include UAA competitions, religious observances, and serious illness or death of specified relatives. There is no single document listing all UF-approved personal reasons for absence/extension; further, the list of reasons changes from time to time. If you have a question regarding your personal issue and if it qualifies under one of the excused absence policies, contact the instructor in advance.

Homework

Homework will collected at the beginning of the class period at which it is due. All homework assignments will require submission of hard copy. No type of paper or writing utensil is preferred over others (within reason). You must include your full first and last name on all homework (as well as projects and exams).

For EDGE students only: per EDGE policy, you may submit homework (and projects) via EDGE's electronic system. Submissions to this system must be in PDF only as a single PDF for each assignment. This is generally best achieved by making a hard copy for submission and scanning to PDF. However, please note that the instructor will not provide assistance for conversion to PDF

or extensions for technological issues on your end. No non-PDF or multiple-file submissions will be read, graded, or acknowledged. In the case of group homework/projects, the instructor may assign groups with both EDGE and on-campus students. In this case, the norms of on-campus homework/project turn-in will prevail for those groups.

Direct electronic submission of files used on homework (spreadsheets, etc.) may be required for some assignments, as indicated on the assignment sheet. The allowable level of collaboration on homework assignments may vary throughout the course and is indicated clearly on each assignment.

Homework handed in between the due date and the next scheduled class period is worth 50% credit. Submissions after that are not accepted (0 credit). If your homework is late, the onus is on you to provide it to me; *the clock does not stop until I have homework in hand.*

For those who wish to work more problems (not for credit, but for practice), the Fall 2014 homework sets are available on Sakai. Note that those problems solved in EES were solved with the previous year's version of EES, which may have used different equations of state (fluid properties) and/or slightly different iteration methods. Therefore, answers obtained with the new version of EES may vary slightly from these posted solutions.

Projects

Electronic submission of project narratives is not accepted (see exception for EDGE students, above). Electronic submission of other project components follows the same rules as for homework. You will need to collaborate with and divide labor among the members of you team, but no collaboration among teams is permitted.

Projects handed in between the due date and the next scheduled class period are worth 75% credit. Submissions after that are not accepted (0 credit). If your project is late, the onus is on you to provide it to me; *the clock does not stop until I have homework in hand.*

Certain professional document and figure standards will be enforced on these projects; *the onus is on you to figure out how to meet these standards in whatever programs you use to write the document and make figures.* Your instructor has exactly zero sympathy for those who select a word processor without knowing how to format their text using it – complaints that the standards are not the same as a particular piece of software's defaults will fall on deaf ears.

All projects are to be done in groups. The instructor will assign the groups. A peer review system is in place to assure equitable workload. In the event the workload is not equitable, the instructor reserves the right to adjust individual grades to accurately reflect contributions to the work.

Examinations

For each exam, you will receive an Exam Preview, intended to prepare you for taking the exam (both technically and procedurally). Detailed examination (including grading/curving) policies are included on this document. The preview will also include the specific topics addressed by the problem (for most problems), the way points are distributed among problems, and a brief list of topics within the scope of the exam.

Examinations are due at the end of the examination period. No collaboration is permitted during examinations, although you may prepare for these however you choose. Use of any unauthorized materials or any communication (including mobile phones, laptops, or face-to-face with classmates in the room) is grounds for *immediate and final* collection of your exam with no more

work permitted and any work already completed that, in the instructor's judgement, was aided by said materials/communication not considered in grading. Examinations consist of two stages: a closed-book/note conceptual and open-book/note problem solving.

Grade Appeal

All appeals of grades, including those from clerical/grade-calculation errors, must be made within 1 week of return. (This may be modified for specific assignments. I will announce this via e-mail if needed.)

Grade appeals must be provided in the following format:

- Include your entire assignment *unmodified*.
- Attach (paper clip preferred) a written summary of which problem(s) or part(s) you believe were graded inaccurately. Be as specific as possible.
- Turn in your appeal to me at class time or during office hours.
- I will review your grade appeal, contact you via your ufl.edu e-mail address, and return the assignment in class. Fairly simple appeals provided to me during office hours may be decided upon while you wait, at my discretion.

Appeals will be considered for clerical errors, addition errors, and inconsistent scoring. Grade appeals will not be entertained if you simply do not like that (for example) Part 1 was worth only 2 points with Part 2 worth 5.

On very rare occasions, some denied appeals may be deemed "frivolous", if the instructor believes the student is not acting in a good faith belief that more points are deserved. Following two frivolous appeals, your grade appeal privilege through this method will be *revoked*. Further appeals must be done through the petitions process, which requires formal paperwork and department/program level involvement.

File Formats

The electronic components of homework submissions *must* be in the formats requested. If you do not know how to convert your files to these formats, contact the instructor in advance of the deadline. Not knowing your software is not an excuse for late homework. Acceptable formats may include plain text, .pdf, .csv, and EES files, as well as other file formats at the instructor's discretion.

In particular, the instructor will not open files from students in the following formats: .ppt, .pptx, .doc, .docx. Presentation and word processing documents are best converted to .pdf.

The instructor will open spreadsheets in .csv, .xls, or .xlsx format. Please be aware that .xlsx format has remaining compatibility issues with free office software; .xls is usually a wiser choice.

E-mail

The primary means of communication with the class outside of class time will be e-mail listserv. These listservs will send to your @ufl.edu address only. Any inquiries regarding grading will be directed towards your @ufl.edu address only, per FERPA .

Technical and procedural questions will be answered as a reply to whatever e-mail address you used to send them. If the entire class will benefit from the answer, I may send to the class list

(either in lieu of or in addition to a direct reply to you, at my discretion). If you do not wish to have a specific e-mail to me regarding technical content or course procedures replied to through the class list, you must explicitly state this in that e-mail. In such a case, I will reply directly to you and send a general-purpose announcement to the class list, not indicating who caused me to send it.

Notes on Workload

This may well be the most conceptually difficult course you will take en route to your degree. Two-phase flow, particularly, is a challenging subject – in other fields, it is a graduate-level subject. However, it is sufficiently relevant to nuclear reactors and must be included in the curriculum.

This is likely also the first class you've taken with any appreciable level of engineering judgement. Often, there is not a single "right" way to analyze a problem in two-phase flow and nuclear TH. Instead, there are two or three or ten "good" ways, from which you must select the *best estimate* (under constraints; *i.e.*, the five-minute vs. five-day analysis) and be able to articulate *why* your analysis is good. Critical thinking and communication skills are no longer "extras", but absolutely essential. For many students, this transition in approach is more difficult than any two-phase analysis.

The instructor is well-aware that senior students have extremely busy fall semesters. Reasonable accommodations on homework and projects will be made for professional commitments (conference attendance, taking the GRE, grad school visits, etc.). Some deadlines may be moved back due to other courses. You should always consider yourself free to request an extension, just as I will always consider myself free to deny a request.

As a 4 credit course, ENU 4134 will require a time commitment of approximately 180 hours during the semester (4 credits times 15 weeks times 3 hours per week-credit). A typical breakdown might be:

- Attending lectures (50 hours)
- Completing 10 HW assignments (50 hours, 5 each)
- Completing Project 1 (20 hours)
- Completing Project 2A/2B (30 hours)
- Studying/Reviewing for exams (30 hours, 10 per exam)

These estimates refer to reasonably focused hours (hours spent playing on PinterGram, TwitBook, or FaceSpace with an online lecture playing and homework assignment open in the background don't count) and are for the average student.

ENU 4134 vs. 6135

The undergraduate (ENU 4134) and graduate (ENU 6135) share common lectures and a fraction of common coursework.

Letters of Recommendation/Evaluation Policy

To request a letter of recommendation/evaluation (for graduate school or otherwise), you must provide:

- A hard copy of your UF transcript.

- A hard copy of a résumé (or CV).
- A hard copy of the following form: `http://www.registrar.ufl.edu/pdf/ferparelease.pdf`. You *must* check all four circles.

Letters are typically filed once per week. For students whom I know only through coursework, my letter typically focuses on an estimate of their rank-in-class and on their performance on projects and challenging problems.

I will only file *one batch* of letters per student during the term, for any student currently enrolled in a class with me. (This policy is designed to keep me from looking up slight changes in your rank/performance multiple times for multiple batches of letters.) I recommend that this batch occur as late as possible in the term to allow me sufficient information (sample size) on your performance to write a useful letter.

16/17. Grading

There are 1050 total points in the course.

- Exam 1 (150)
- Exam 2 (150)
- Exam 3 (150)
- Project 1 (150)
- Project 2A (50)
- Project 2B (150)
- Homework (250 – 10 assignments, 25 each)

Each exam is individually curved. The details of this curve and how graduate (6135) students will be affected are included as part of the Exam Previews.

The final grades will be assigned based on:

- A: $> 84\%$ (882+ points)
- B: 76-83.99% (798-881 points)
- C: 67-75.99% (704-797 points)
- E: $< 67\%$ (0-703 points)

The instructor reserves the right to grant higher grades at the end of the course at his sole discretion, including the use of A-, B+, B-, and C+.

You may note that the grade cut-offs for A, B, and C are somewhat lower than the "high-school scale" (90, 80, 70, etc.) under which many UF courses operate. This is not to grant inflated letter grades but rather to account for the inherently challenging nature of two-phase flow and to appropriately award genuinely excellent performances. Typically, the average GPA in ENU 4134, including graduate students in ENU 6135 (formerly 6937), is between 2.9 and 3.2.

You may also note that each major item (3 exams and 2 main projects) are worth just 1/7 of your grade. This emphasizes consistent performance in this course and limits the deleterious effect on your grade of a single poor exam.

Under no circumstances will grades of C- or any flavor of D be used. Regardless, the following statement is required by COE polic: "A C- will not be a qualifying grade for critical tracking courses. In order to graduate, students must have an overall GPA and an upper-division GPA of

2.0 or better (C or better). Note: a C- average is equivalent to a GPA of 1.67, and therefore, it does not satisfy this graduation requirement. For more information on grades and grading policies, please visit:

`http://www.registrar.ufl.edu/catalog/policies/regulationgrades.html`"

18. Make-up Exam Policy

The make-up exam policy is covered by the Make-Up Work Policy in Item 15. All make-up exams will be held after the regular exam, as organized with the instructor. Note that conflicts in instructor-proposed make-up times with your personal business will not, in general, be accommodated.

19. Honesty Policy

All students admitted to the University of Florida have signed a statement of academic honesty committing themselves to be honest in all academic work and understanding that failure to comply with this commitment will result in disciplinary action. This statement is a reminder to uphold your obligation as a UF student and to be honest in all work submitted and exams taken in this course and all others.

Addendum to 19: Violations of UF Academic Honesty policies in this course will be reported through appropriate channels. If you choose to commit academic misconduct in this course, expect to receive a failing grade for the course.

20. Accommodation for Students with Disabilities

Students requesting classroom accommodation must first register with the Dean of Students Office. That office will provide the student with documentation that he/she must provide to the course instructor when requesting accommodation.

21. UF Counseling Services

Resources are available on-campus for students having personal problems or lacking clear career and academic goals. The resources include:

- UF Counseling & Wellness Center, 3190 Radio Rd, 392-1575, psychological and psychiatric services.
- Career Resource Center, Reitz Union, 392-1601, career and job search services.

22. Software Use:

All faculty, staff and student of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

23. Course Evaluations

The University of Florida expects students to provide feedback on the quality of instruction in this course based on 10 criteria. These evaluations are conducted online at

`https://evaluations.ufl.edu`

Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at

`https://evaluations.ufl.edu/results`