Multiphase Convective Heat Transfer
EML 6156, fall, 2022
3rd Period (9:35 am – 10:25 am) MWF
Section : CAMP, 2FED

1. Catalog Description: Credits: 3; Detailed coverage of advanced convection heat transfer topics: boiling and condensation, high-velocity convection, transpiration cooling, convection around bodies, free jet flow, oscillating fluids, and microelectronic cooling.

2. Pre-requisites and Co-requisites: *Engineering Thermodynamics (EML3100), Fluid Dynamics (EGN3353C) and Heat Transfer (EML4140).*

3. Course Description: This course provides fundamental physical concepts of phase change thermodynamics, fluid flow, heat transfer and transport physics applied to boiling and condensation processes. In particular, Mechanisms and modeling of nucleate, transition and film boiling processes; critical heat flux; Leidenfrost point; forced convection boiling and post dry-out heat transfer; condensation processes; heterogeneous nucleation; dropwise and filmwise condensation; flow condensation; liquid-solid phase change processes; moving phase fronts; mathematical modeling.

4. Course Objectives: This course focuses on the fundamental physics associated with liquid-vapor phase-change phenomena. The goal is to prepare engineers and scientists to address problems they will encounter when studying transport phenomena in boiling, condensation, and two-phase flow. The objectives of the course will be to:

- Introduce concepts in interfacial transport phenomena during liquid-vapor phase change process;
- Provide an appreciation for the application of interdisciplinary principles from thermodynamics, fluid mechanics and heat transfer to understand phase change phenomena;
- Provide students with sound tools to approach problems they will encounter when studying liquid-vapor phase change processes.

5. Course Outcomes:

1. The student will become proficient in physical concepts and theories of the liquid-vapor phase-change heat and mass transport phenomena.
2. The student will become familiar with the mathematical modeling of liquid-vapor phase-change heat and mass transport phenomena.
3. The student will become adept in the engineering analysis of various controlling boiling and condensation transport processes. The analysis will include heat and mass transfer rates, and system temperature profiles.
4. The student will be able to apply engineering analysis techniques to the emerging cooling and power technologies of the 21st century (e.g. electronics cooling devices and advanced nuclear reactor cooling systems), and to understand the context in which the design of cooling and power systems takes place.

6. Instructor: Dr. J. N. Chung, Professor
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Tel (352) 392-9607/Fax (352) 392-1071, e-mail : jnchung@ufl.edu
Office Hours: Wednesday and Friday 7th period.

7. Teaching Assistants: None

8. Meeting Times: MWF 9:35 am – 10:25 am (3rd Period)

9. Meeting Location: CSE E112

10. Class Homepage: On Canvas

11. Material and Supply Fees: None

12. Textbooks and Software Required: Liquid-Vapor Phase-Change Phenomena, Van P. Carey, Second Edition, 2008, Taylor and Francis, ISBN: 978-1-59169-035-1

13. Recommended Reading: Convective Boiling and Condensation, J.G. Collier and J.R Thome, 1996, Third Edition, Oxford Science Publications, ISBN 0-19-856296-9

14. Course Outline and Schedule:

Unit	Week	Topics
Ch. 1 Introduction	1-2	Outline of the Course. Phase-Change Heat Transfer Importance, Fundamentals of Thermodynamics on Boiling and Condensation. Types of Liquid-Vapor Phase-Change Processes.
Ch. 2 Boiling Heat Transfer Fundamentals	2-5	Boiling Heat Transfer Nucleation Theory – Homogeneous Nucleation and Heterogeneous. Bubble Nucleation Criteria. Bubble Growth, Dynamics and Departure.
Ch. 3 Pool Boiling Heat Transfer	6-8	Boiling Curve, Heat Transfer Rates in Nucleate, Transition and Film Regimes. Critical Heat Flux and Leidenfrost Point.
Ch. 4 Two-Phase Flows in Convective Boiling	9	Two-Phase flows in pipes and Tubes. Flow Regimes and Maps.
Ch. 5 Convective Nucleate	10-11	Heterogeneous Convective Nucleate Boiling – In Tubes, Pipes and Channels. Heat Transfer Regimes and Thermodynamics. On-set of Nucleate Boiling.

Boiling	12	Fully Developed Subcooled Nucleate Boling. Saturated Nucleate Boiling. Correlations. Heat Transfer in Liquid Films. Critical Heat flux. Heat Transfer in Post-CHF Regime.
Ch. 6 External Condensation Heat Transfer	13	Film and Dropwise Condensation on External surfaces, Noncondensible Gas Effects.
Ch. 7 Internal Condensation Heat Transfer	14	Convective Film Condensation – In Tubes, Pipes and Channels.
Ch. 8 Cryogenic Phase-Change Heat Transfer	15	Cryogenic Quenching Heat Transfer in a Pipe. Space Liquid Acquisition Device.

15. Exam Schedule

Course exam : during the 12th week.

16. <u>Attendance Policy and Class Expectations</u>:

Attendance is mandatory, it is extremely important that students attend the class regularly. Irregular attendance always results in poor or mediocre performance. Excused absences will be given for documented medical reasons, UF related travel or job interview travel. Documentation must be in the form of a doctor's note, or a letter from the sponsor of the travel. Excused absences must be consistent with university policies in the Graduate Catalog (https://catalog.ufl.edu/graduate/regulations) and require appropriate documentation. Additional information can be found here: https://gradcatalog.ufl.edu/graduate/regulations/

<u>Re-grading Policy</u>: Any re-grade requests must be submitted in writing within two weeks after return of the graded paper. The written request must explain in detail what you want the grader to do and where you believe a mistake in grading was made. These requests will be accepted by Dr. Chung only. The request must have a date on the top of the page, your name, your telephone number(s), and e-mail address. **<u>Policy on Homework Assignments</u>:** Homework problem sets will be assigned during the semester with due dates indicated and **for on-campus students you need to turn hard copies in class**. Edge students turn in scanned copies. You may not turn homework assignments in early. Late homework is not accepted without a legitimate reason. Homework handed in after solutions are posted will not be accepted. **<u>Miscellaneous Policies</u>:** Students will be held responsible for knowledge of all scheduling and policy announcements made in class. You may contact Dr. Chung or send him an e-mail 24 hours a day, 7 days a week. Please make sure you leave a phone number if you call and can't find him. If you send

an e-mail please also list a phone number where you could be reached. Sending an e-mail along with the voice message can also help alert him to your request.

17. Make-up Exam Policy: There will be no make-up exams. Unless there is a **documentable extreme medical or family emergency**, you must contact the instructor prior to the exam or no credit will be given for a missed exam. It is the student's responsibility to make sure he/she is available to take the exam.

18. Grading:

Homework	35%
Course Exam	35%
Project	30%

19. Grading Scale (department standard, used as a reference):

90 – 100: A, 87 – 89.9: A-, 83– 86.9: B+, 80 – 82.9: B, 78 – 79.9: B-
76 – 77.9: C+, 74 – 75.9: C, 70 – 73.9: C-, 67 – 69.9: D+, 63 – 66.9: D
60 – 63.9: D-, 0 – 59.9: E

20. Accommodation for Students with Disabilities – Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting https://disability.ufl.edu/students/get-started/. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

21. Course Evaluation

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at https://gatorevals.aa.ufl.edu/students/. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via https://ufl.bluera.com/ufl/. Summaries of course evaluation results are available to students at https://gatorevals.aa.ufl.edu/public-results/.

22. In-Class Recording

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A "class lecture" is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part

of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To "publish" means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

23. University Honesty Policy

UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Honor Code (https://sccr.dso.ufl.edu/process/student-conduct-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

24. Commitment to a Safe and Inclusive Learning Environment

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Jennifer Nappo, Director of Human Resources, 352-392-0904, jpennacc@ufl.edu
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, nishida@eng.ufl.edu

25. Software Use

All faculty, staff, and students 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.

26. Student Privacy

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: https://registrar.ufl.edu/ferpa.html

27. Campus Resources

Health and Wellness

U Matter, We Care:

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Counseling and Wellness Center: https://counseling.ufl.edu, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Discrimination, Harassment, Assault, or Violence

If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

Sexual Assault Recovery Services (SARS)

Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or http://www.police.ufl.edu/.

28. Academic Resources

E-learning technical suppor*t*, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://lss.at.ufl.edu/help.shtml.

Career Connections Center, Reitz Union, 392-1601. Career assistance and counseling; https://career.ufl.edu.

Library Support, http://cms.uflib.ufl.edu/ask. Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring. https://teachingcenter.ufl.edu/.

Writing Studio, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers. https://writing.ufl.edu/writing-studio/.

Student Complaints Campus: https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/;https://care.dso.ufl.edu.

On-Line Students Complaints: *https://distance.ufl.edu/state-authorization-status/#student-complaint*.