EGFD 5137/6037: Computational Fluid Dynamics
Spring 2022, 3 credits
University of Cincinnati

Class Meeting   TuTh 12:30 – 01:50 pm
Remote on Zoom or in-person at SWIFT 816

Instructor   Dr. Kishan Bellur
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Office Hours   TuTh 2:00 pm – 3:30 pm
Remote on Zoom or in-person at Rhodes 681A

Office hours are by appointment only. Please book a slot using the scheduler and indicate if you wish to meet "in-person" or on "zoom". Please fill out the form to that we can make the meeting as efficient and productive as possible. You can only schedule a slot one week in advance. If you need assistance outside office hours, email is the preferred method of contact.

Correspondence
Messages about the class will be sent through Canvas or via email. However, if you have any questions or concerns, please contact me via *email* only. Please add a prefix to the subject line: "**CFD: <short title>**". This helps me find the email faster and respond in a timely manner. If I do not respond within 24 hours, please send a follow-up email. Alternatively, you can also use the discussion forum on Canvas to ask questions. The forum is open to the entire class so that your classmates can help answer and/or benefit from your question.

Course Description
The objective of the course is to familiarize students with computational methods to solve thermal-fluid and heat transfer problems. Numerical solutions to 1D equations are implemented using finite difference and validated with analytical solutions. Various discretization techniques, implicit/explicit schemes, stability and error are discussed. Commercial software tools are introduced for 2D/3D applications.

Credits: Three.

Course Learning Outcomes
By the end of this course, you will be able to:
1. Understand the field of CFD and the mathematical behavior of governing differential equations.
2. Classify PDEs into parabolic, elliptic, and hyperbolic forms.
3. Formulate finite-difference solution methods for ODEs and PDEs.
4. Carry out grid transformations and stability analysis
5. Develop home-brewed code to solve fluid mechanics and thermal transport problems.
6. Use a commercial CFD software as a design or research tool to solve engineering problems in thermal-fluid science.

Recommended Textbooks
1. *Computational Fluid Dynamics: The Basics with Applications*, John Anderson, McGraw Hill, 1995.
2. *Computational Fluid Dynamics: An Introduction*, John Wendt (Ed) et al, Springer, 2009.
3. *Computational Fluid Dynamics: Vol 1 and 2*, Hoffmann and Chiag, EES, 2000.

These books are not mandatory, and you do not have to buy them. However, these are very useful reference books if you are interested in CFD. The first book is a cult classic and serves as a good introduction to someone completely new to CFD. The drawback is that it is dated. The second book is a briefer version of the first, includes more applications, perspectives from multiple authors and is generally available as a pdf download through the UC library. The third book is relatively hard to find but does an excellent job of explaining the underlying math. I recommend securing access to at least one of them to use as a future reference.

Grading
Overall grade

A:	≥ 93%,	(Work of Excellent Quality)
A-:	90% – 93%	
B+:	87% – 90%	
B:	83% – 87%	(Work of Good Quality)
B-:	80% – 83%	
C+:	77% – 80%	
C:	73% – 77%	(Work of Satisfactory Quality)
C-:	70% – 73%	
D+:	67% – 70%	
D:	63% – 67%	(Work of Poor, but Passing Quality)
F:	≤ 63%	
I:	Incomplete	

Assessment and weighting

Attendance/Participation	10%
HW Assignments	50%
Project	40%

Tentative Schedule (subject to minor variations)

Week #	Tuesday	Thursday	Deliverable
Week 1	Introduction	Review of Fluid Mechanics	
Week 2	Governing Eqns	Classification	HW1
Week 3	Taylor Series and Root Finding	Discretization, FD and FV	HW2
Week 4	Error and Stability	ODE solutions (Euler, AB and RK)	HW3
Week 5	*ODE solvers: in-class activity*	Parabolic PDE's	HW4
Week 6	*Heat Eqn: in-class activity*	Elliptic PDE's	HW5
Week 7	Hyperbolic PDE's	Solving NS Eqns & Boundary Conditions	
Week 8	Intro to Ansys Fluent	Poiseuille flow (analytical + simulation)	Letter of Intent
Week 9	*Poiseuille flow: in-class activity*	1-on-1 meetings to discuss project	HW6
Break	No Class	No Class	
Week 10	Guest Lecture	*Backward facing step - in class activity*	Project Proposal
Week 11	Airfoil - demo	*Airfoil - in class activity*	HW7
Week 12	1-on-1 meetings to discuss project	Transient model: heat diffusion	HW8
Week 13	Turbulence Modeling	Advanced Topics - TBD	
Week 14	Presentations	Presentations	Project Report

Module 1, Module 2, Module 3, Module 4, Module 5, Module 6, Module 7, project, TBD, *in-class activity*

Class Attendance & Participation

You are expected to attend all classes. More important than simply attending, however, is being present for the active process of learning that occurs in class. Class time is intended to be interactive. You should expect and be prepared to be called on, and to participate in discussions and activities. Participation in class discussions is expected and will count towards your overall grade. You are responsible for the material covered during lecture, which supplements any assigned readings and homework. Announcements concerning changes to homework assignments and other deadlines will be given during lecture or via Canvas. You are responsible for keeping up-to-date with the course. Please turn off or silence your cell phones during the class period.

Homework Assignments

Assignments are the most important aspects of the course. This component of the class develops your critical thinking, problem-solving skills and comprehension. I want you to make a robust attempt and make sure you have the correct approach. There will not be an emphasis on the final numerical answer. Solutions to the homework assignments will be discussed in class or posted to Canvas. All homework must be prepared in a straightforward and professional manner. Late submission will result in a grade reduction of 20% per day. You are welcome to discuss the contents of an assignment with others, but you must submit an individual solution and you must cite any/all help received during the discussion.

Project

Due to the nature of the course and the topics covered, there will not be any exams but will culminate in an individual project instead. You will be given the opportunity to pick the project topic based on your interests. The projects could involve writing custom code, using a commercial CFD software, pencil-on-paper math, or a combination thereof. You will submit a letter of intent (also known as a "one-pager") of your proposed topic in week 8. Next, we will meet one-on-one in week 9 to discuss the project and set up goals. The project goals are set based on your academic standing (grad/undergrad). You are then invited to submit a "full" proposal in week 10. This process emulates a proposal submission to funding agencies. The final project deliverables include a conference style paper and presentation. We will meet 1-on-1 at least twice during semester to discuss the project. I will help you at every step and provide constant feedback. However, you are expected to take ownership of your own project and devote adequate time/effort to do the work.

Extra Credit and Incentives

There will be opportunities to earn extra credit in several assignments. Based on the project results, should you submit an abstract to an academic or industrial conference, your grade will be boosted. If you need additional time to submit to an appropriate conference venue, you are welcome to request an incomplete (I) grade and obtain a maximum of 350 days extension past the last day of instruction. The grade is finalized when the abstract/paper is accepted by the conference, or the 350-day allowance as passed. As an incentive, I will cover the conference registration cost.

Academic Integrity

I have a zero-tolerance policy with regard to cheating. "Intentional, unauthorized use of any study aids, equipment, or another's work on an academic exercise" is cheating. "Knowingly allowing or helping another individual to plagiarize, cheat or fabricate information" also falls under academic dishonesty and will be treated the same as cheating. Using the internet (email, www, listservs, usenet, blogs, wiki's, etc.) or social media to gather information on topics related to homework and projects is permissible. However, do not solicit *solutions* to homework problems and projects from the internet. Academic dishonesty is a serious violation of University Policy and will be dealt with accordingly. Cheating on an assignment, project or exam will result in a grade of zero and trigger an investigation. Any questions regarding permissible collaborations or information sources should be brought to the instructor for clarification.

Misc. Logistics

COVID-19
UC's COVID-19 Public Health Webpage contains the most up-to-date policies and practices regarding COVID-19 precautions at UC. If you are sick and/or quarantined, do not come to class. Instead, please contact me at the earliest opportunity to discuss appropriate online accommodations.

Computer access
All students--whether "remote" or "on campus" need access to a computer to complete their coursework. These can be found on the CEAS website, here.

Dealing with Technical Issues
We are bound to encounter technical issues along the way. Technology is not perfect. Something will inevitably go wrong at some point-either because the technology itself is experiencing an issue, or we as users don't fully understand how to use the technology. Students are expected to take responsibility for proactively dealing with the inevitability of technical difficulties. Here are some guidelines on how to do this:
- Don't wait until the last minute to complete technology-based assignments. Review the instructions for each task well before the due date so that you can predetermine your level of comfort with the technology that will be used. If you have questions, or need assistance, be sure to reach out for help early and leave time for possible troubleshooting.
- Gather visual evidence of any issues that you experience. If a website or software is not working properly, or if you encounter an error, take screenshots of the issue. If that is not possible, take a photo of the issue with your phone. Doing this will allow whoever you contact for assistance (whether it be me, IT, etc.) to better support you.
- Document any efforts you make to solve the problem or seek help. For example, if you contact IT for assistance, make sure that you get a ticket number for the issue. If you contact a software vendor, they will likely send you an email that documents the issue and any troubleshooting steps that were taken.

If technical issues prevent you from submitting an assignment on-time, an extension may be granted on a case-by-case basis only if you have followed the tips listed above.

As the instructor, I am not immune to technical issues. If for some reason, I lose access to a Zoom/Teams session, please wait patiently until I return or provide further instructions via email. If you do not hear from me in 15 mins, consider the class cancelled. If you cannot hear me properly or see my screen during class, please let me know! If you notice something doesn't look right on the Canvas site, tell me! Technical issues are a part of life now, but by working together we can get past them quickly.

Accessibility
UC is committed to providing all students full and equal access to learning opportunities. UC's Office of Accessibility Resources is the official campus office that works to arrange for reasonable accommodations for students with an identified physical, psychological, or cognitive disability (learning, ADD/ADHD, psychological, visual, hearing, physical, cognitive, medical condition, etc.). Students are encouraged to contact the Accessibility Resources office to arrange for a confidential meeting to discuss services and accommodations. Contact should be initiated as soon as possible to allow for adequate time for accommodations to be arranged.

UC is also committed to providing full and equal access to our electronic and information technology, including websites, electronic files, digital course content, and software/applications. If you experience

difficulty in using any of the digital content associated with this course, even with the assistance of available Student Accessibility Resources, please let your instructor know.

Title IX

Title IX is a federal civil rights law that prohibits discrimination on the basis of a person's actual or perceived sex, gender, gender identity, gender expression, or sexual orientation. Title IX also address instances of sexual violence, dating or domestic violence, and stalking. If a student discloses a Title IX issue to a faculty member, the faculty member is required to forward that information to the Title IX Office. The Title IX office will follow up with the student and discuss how the University can take steps to address the impact on the student and the community. They will also inform the student of their rights and direct them to available resources. The priority is to make sure students are safe and successful here at the University of Cincinnati. Students are not required to talk to anyone in the Title IX Office. Students may also directly report any instance of sex or gender-based discrimination, harassment or violence to the Title IX office at 513-556-3349. Students who wish to know more about their rights and resources on campus, they can consult the Title IX website or contact the Title IX office directly at 513-556-3349.

Counseling Services

Students have access to counseling and mental health care through the University Health Services, which can provide both psychotherapy and psychiatric services. UC's Counseling & Psychological Services (CAPS) provides students access to professional counseling services as well as numerous options for help online, via mobile apps, group sessions, and peer-to-peer programs. CAPS conducts free virtual consultations via the "Let's Talk" program. Students are encouraged to seek assistance for anxiety, depression, trauma/assault, adjustment to college life, interpersonal/relational difficulty, sexuality, family conflict, grief and loss, disordered eating and body image, alcohol and substance abuse, anger management, identity development and issues related to diversity, concerns associated with sexual orientation and spirituality concerns, as well as any other issues of concern.

Inclusivity

This class is committed to the fundamental principles of academic freedom and human dignity. Diversity in all forms is something we welcome, we foster, and we prize. We believe that honest attempts to understand the perspectives of others facilitates learning, and we will strive to achieve this goal at all times. We strongly disavow discrimination -- including harassment -- on the basis of race, national or ethnic origin, religion, sex or gender identity, disability, age, sexual orientation, or veteran status. We expect that each of us will hold one another accountable for maintaining these ideals.

All are welcome and considered a valuable addition to the university community. You should consider my classroom as an inclusive and safe space to express your ideas and viewpoints. **No discrimination is accepted or tolerated in this course.** It is the goal for you to be successful and to thrive to your highest potential. UC Notice of Non-Discrimination