

EGM7845 Turbulent Fluid Flow - Fall 2023

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Class Time: Tuesday & Thursday 4 & 5th Periods (10:40am - 12:35pm)

Class Location: MAE-B 328 & PERC Conference Room

Course Description:

Turbulence is one of the fundamental problems in classical physics. In many engineering, environmental and geophysical applications turbulence is at the core of the problem and it is essential to understand its characteristics. Turbulence has fascinated some of the greatest minds of the past. It still remains as one of the most difficult unsolved challenges for scientific community. Although a closed form solution, or a universal closure of turbulence is not likely to occur anytime soon, scientists and engineers have made great progress in our understanding of turbulence. Classical turbulence theories have been developed for canonical isotropic and homogeneous turbulence. Better understanding of turbulent flow structures and their dynamics have lead to improved mathematical formulations and closure models. This course will build upon students' basic knowledge of fluid mechanics and hydrodynamic instability and focus on the theory, structure, modeling and simulation of turbulent flows.

Prerequisite: EGM6812, EGM6813 or equivalent for fluid mechanics knowledge; EGM6341 or equivalent for basic knowledge in numerical methods.

Text: *Class Notes and Handouts*

Grading Policy

Homeworks – 40%, Final report/presentation – 50%, Participation – 10%

A = [90,100], A- = [87,90), B+ = [84,87), B = [80,84), B- = [77,80), C+ = [74,77), C = [70,74), C- = [67,70), D+ = [64,67), D = [60,64), D- = [57,60), E = [0,57).

Homework, Final Presentation and Exam Policy

Homework and assignments are due at the beginning of the period on the due date. All assignments should be neat and legible. Points will be taken off for sloppy work. You may discuss the assignments with other students, but you are expect to put in individual effort. Copying and plagiarizing assignments will not be accepted. You are expected to uphold academic honesty and failure to comply will result in disciplinary action.

Office Hours: Tuesday & Thursday: 12:35 - 2:00. Or at other time over zoom or in person.

Suggested Books:

1. *Turbulent flows*, S. Pope, Cambridge University Press, 2000
2. *Statistical theory and modeling for turbulent flows*, P.A. Durbin & B.A. Peterson Reif, Wiley, 2000
3. *Theory of homogeneous turbulence*, G.K. Batchelor, Cambridge University Press, 1960
4. *A first course in turbulence*, H. Tennekes & J.L. Lumley, MIT Press, 1972
5. *Statistical fluid mechanics*, Vol I & II, A.S. Monin & A.M. Yaglom, MIT Press, 1975
6. *Dissipative structures and weak turbulence*, P. Manneville, Academic Press, 1990

7. *Turbulence and random processes in fluid mechanics*, M. Landahl & Mollo-Christensen, Cambridge University Press, 1986
8. *Turbulent flows in engineering*, A.J. Reynolds, Wiley, 1974
9. *The structure of turbulent shear flow*, A.A. Townsend, Cambridge University Press, 1977
10. *Turbulence*, J.O. Hinze, McGraw-Hill 1975
11. *Turbulence: An Introduction for Scientists and Engineers*, P.A. Davidson, Oxford University Press, 2004

Outline

1. Introduction
 - a. What is Turbulence
 - b. Relation to Instability and Chaos
 - c. Two simple examples
 - i. Logistic Map
 - ii. Lorenz Model
2. Statistical Description
 - a. Random variables and random fields
 - b. Single and multipoint statistics
 - c. Stationary process
 - d. Symmetries and homogeneities
 - e. Ergodicity
3. Averaged equations
 - a. Ensemble vs time vs space averaging
 - b. Reynolds averaged equation for the mean flow (RANS)
 - c. Closure problem
 - d. Reynolds stress equation
 - e. Large eddy equation
 - f. URANS equation
4. Turbulent free shear flows
 - a. Scaling analysis
 - b. Boundary layer equations
 - c. Examples: Jets, wakes, mixing layers, plumes
5. Preliminary turbulence models
 - a. Eddy viscosity models
 - b. Mixing length theory
 - c. Reynolds stress and algebraic models
6. Theory of isotropic turbulence
 - a. Modes, waves, eddies
 - b. Two-point correlation (longitudinal and lateral)
 - c. Fourier transform, energy spectra, spectral tensor
 - d. Navier-Stokes eqn in spectral space
 - e. Eqn for spectral tensor
7. Wall turbulence
 - a. Inner scale and outer scale
 - b. Law of the wall
 - c. Log layer and wake region
8. Structure of turbulence
 - a. Isotropic turbulence – worms

- b. Wall turbulence – Hairpin packets
- c. Shera layer – Kelvin-Helmholtz rolls, ribs and small scales
- 9. Turbulence simulations –
 - a. Phillosophy of DNS
 - b. Phillosophy of LES / URANS
 - c. Pillisophy of RANS
- 10. Multiphase turbulence

Lecture Schedule^(*) (tentative)

Week 1	Thu, Aug 24	Chapter 1	Week 9	Thu, Oct 12	5
Week 2	Tue, Aug 29	No Class	Week 9	Tue, Oct 17	6
	Thu, Aug 31	No Class	Week 10	Thu, Oct 19	6
Week 3	Tue, Sep 5	1, 2	Week 10	Tue, Oct 24	6
	Thu, Sep 7	2	Week 11	Thu, Oct 26	6
Week 4	Tue, Sep 12	2	Week 11	Tue, Oct 31	7
	Thu, Sep 14	3	Week 12	Thu, Nov 2	7
Week 5	Tue, Sep 19	3	Week 12	Tue, Nov 7	7
	Thu, Sep 21	3	Week 13	Thu, Nov 9	8
Week 6	Tue, Sep 26	4	Week 13	Tue, Nov 14	8, 9
	Thu, Sep 28	4	Week 14	Thu, Nov 16	9, 10
Week 7	Tue, Oct 3	4	Week 14	Tue, Nov 21	Thanksgiving
	Thu, Oct 5	4	Week 15	Thu, Nov 23	Thanksgiving
Week 8	Tue, Oct 10	5	Week 15	Tue, Nov 28	Presentation
			Week 16	Thu, Dec 3	Presentation
				Tue, Dec 8	Extra

(*) **Note:** I plan to have Tuesday and Thursday classes to be both 2 periods. This allows me to make up for days I am on travel. The above lecture schedule covers more than required 45 lecture periods.

Attendance Policy, Class Expectations, and Make-Up Policy

It is extremely important that students watch the lecture videos on or before the suggested date in the course schedule. Not watching videos in a timely manner results in poor or mediocre performance. Excused absences at the quizzes and exams must be consistent with university policies in the graduate catalog and require appropriate documentation.

More information on UF grading policy may be found at:

<http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#grades>

Students Requiring Accommodations

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.

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/>.

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/policies/student-honor-code-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.

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
- Robin Bielling, Director of Human Resources, 352-392-0903, rbielling@eng.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

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.

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>

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: <http://www.counseling.ufl.edu/cwc>, 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/>.

Academic Resources

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

Career Resource Center, Reitz Union, 392-1601. Career assistance and counseling. <https://www.crc.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://care.dso.ufl.edu>.

On-Line Students Complaints: <http://www.distance.ufl.edu/student-complaint-process>.