

ME 60101 Computational Modeling of Turbulence

Instructor:

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Class Hours:

Monday and Wednesday: 4:30-5:45 pm
SL150

Office Hours:

Monday and Wednesday: 3:00-4:00 pm
SL260H (lecturing days) or Zoom per request

Text Book:

S. B. Pope, *Turbulent Flows*, McGraw-Hill, New York, 2009

- Recommended reference books: H. Tennekes and J. L. Lumley, *A First Course in Turbulence*, The MIT Press.
- Academic interest Journals: *Physics of Fluids*, *Journal of Fluid Mechanics*, *Annual Review of Fluid Mechanics*, *Journal of Turbulence*

Prerequisite (Canvas Completion):

ME 509 or consent of the instructor

Course Description:

This course consists of three parts: (i) turbulence principles including turbulence concepts, statistical description, and Kolmogorov hypothesis; (ii) major modeling concepts and formulations such as direct numerical simulation (DNS), large eddy numerical simulation (LES), and Reynolds averaged Navier-stokes simulation (RANS); (iii) Projects related to DNS/LES/RANS of turbulence with applications in environment, industry, and biomechanics.

Course outcomes:

Upon completion of the course, students are expected to be able to do the following

1. Build up a sound background in the mathematical, physical, and statistical description of turbulence
2. Apply Kolmogorov theory to quantitatively predict turbulence scales
3. Derive governing equations for kinetic energy, vorticity, pressure, etc. from the Navier-Stokes equation and apply them to non-complicated turbulence
4. Apply major modeling tools to turbulence computation at different Re numbers.
5. Numerically analyze turbulence properties for decaying isotropic turbulence with and without rotation, turbulent rectangular jets, biological flows in the presence of turbulence, etc. through provided computation output data.

Grading Scale:

Course grade scale will follow the Letter Grades with +/- on Canvas as.

Name:	Range:	
A+	100%	to 97.0%
A	< 97.0%	to 93.0%
A-	< 93.0%	to 90.0%
B+	< 90.0%	to 87.0%
B	< 87.0%	to 83.0%
B-	< 83.0%	to 80.0%
C+	< 80.0%	to 77.0%
C	< 77.0%	to 73.0%
C-	< 73.0%	to 70.0%
D+	< 70.0%	to 67.0%
D	< 67.0%	to 63.0%
D-	< 63.0%	to 60.0%
F	< 60.0%	to 0.0%

The instructor may or may not provide opportunities for students to earn extra credits based on the entire class performance. Grade upgrade requests based on personal expectation/imagination or special needs will not be issued.

Project -----	30 %
Homework -----	20 %
In-class discussion -----	25 %
Final exam -----	25 %

- **Projects** are to numerically solve either scientific or industrial turbulence problems and explore related underlying physics. The project topics and related instructions, requirements, and grading policy will be specifically announced in Week 4. There will be three milestones to be achieved to assure the completion of the project.
- **Homework** consists of 4 sets. HW is required to be submitted electronically and then graded on Canvas. Students are responsible for high-quality scanning copies in PDF format. If the HW has to be returned because of the non-readable quality such as non-PDF format, 90°/180° rotated layout, too light or noisy to be read, etc., the HW will be requested for rescanning and re-uploading within 24 hours after the notice. Late resubmission and late HW will cause a penalty of 10% of the HW points off per late day. Once the HW grading is completed, neither late resubmission nor late HW is accepted. The grader reserves the right to determine if the HW needs to be returned and resubmitted.
- **In-class discussion** is to read research papers and then share the learning in the class through the presentation in time order as lectures deliver. There will cover 5 topics: exact solutions, turbulence in general, DNS, LES, and RANS. Either individual or team reading/sharing will be assigned with provided papers. The presentation is required to be uploaded to Canvas before the discussion. The student

performance will be scored by both the instructor (75%) and peers (20%) with provided evaluation sheets and attendance (5%). On rare occasion that a student is excused with valid written documents for emergency (e.g. doctor notes or medicine purchase receipts for illness, evidence or witness for vehicle failure, etc.) or a prior written request and approval for non-emergency, the instructor will credit the average score of the class excluding 5% for the attendance.

- **Final exam** will cover the entire learning from the lectures and project. The format of the final exam will be announced in the final review.

Canvas:

The entire course-related communication outside of lectures and office hours are through <http://canvas.iu.edu>.

- All the information and materials will be accessed on this system throughout the semester including messages and announcements, syllabus and course schedule, supplementary handouts, assignments, grades, and so on.
- Students are required to **send course related messages through Canvas/Inbox**.
- Students are responsible to set up notifications on Canvas and check their emails as well as the course web site on Canvas time accordingly for any course information.
- Students are encouraged to discuss course issues on Canvas/Discussion.

~~~~~ IMPORTANT POLICY NOTES ~~~~~

- Extenuating circumstances may result in changes to the assignments or schedule. Please setup **instant Canvas notifications** for any changes, announcements, emails, etc.
- Everyone deserves to be treated with **dignity and respect**. Within this classroom, civility requires mutual respect for all class members and instructor(s) and their knowledge and expertise. All members of this class (instructor and students) are responsible for and expected to promote respectful and courteous language, demeanor, and actions. Behavior that is offensive, disruptive, intimidating, dismissive, or condescending will not be tolerated from either the instructor or the student. Students are required to attend every class in the classroom. A sign sheet will be provided for each classroom lecturing. A written excuse is expected before the class for nonemergency or after the class for an emergency.
- Currently, masks are *optional* on the IUPUI campus. Note that campus guidance on mask-wearing and other health safety protocols may be relaxed or strengthened during the semester in response to updated CDC guidance, changing caseloads, or other factors. The most up-to-date information on current COVID-19 policies in the IU system, including a FAQ and information about drop-off testing, is available at <https://www.iu.edu/covid/>.

- Students are aware of the statements made regarding cheating in the IUPUI “Student Rights and Responsibilities” booklet. **Academic misconducts** will be handled according to the guidelines in that booklet. Penalties for such misconduct include lowering of a student’s grade as well as dismissal from school. A quote from the above-mentioned booklet is worthwhile. “It is the responsibility of the student not only to abstain from cheating but, in addition, to guard against making it possible for others to cheat. Any student who helps another student to cheat is as guilty of cheating as the student he/she assists.” The website for the student code of conduct is <https://studentcode.iu.edu/rights/index.html>
- Accommodations are available for students with special challenges or disabilities that may affect their performance in this class. To determine if you are eligible for accommodations, you must register with **Adaptive Educational Services (AES)**, which can be reached at (317) 274-2050. You must provide your instructor with the documentation from AES showing you have registered with the service. For more information, visit the AES website at <https://diversity.iupui.edu/offices/aes>
- During the semester, if you find that life stressors are interfering with your academic or personal success, consider contacting IUPUI's **Counseling and Psychological Services (CAPS)**. All IUPUI students are eligible for individual counseling services at minimal fees. Group counseling services are free of charge. CAPS also performs evaluations for learning disorders and ADHD; fees are charged for testing. CAPS is located in Walker Plaza, Room 220 (719 Indiana Avenue) and can be contacted by phone (317-274-2548). For more information, see the CAPS website at <https://studentaffairs.iupui.edu/health/counseling-psychological/index.html>. For additional information about general health services, see the Student Health and Wellness website at <http://studentaffairs.iupui.edu/health-wellness/counseling-psychology/index.shtml>.
- What you should know about **sexual misconduct**: IUPUI does not tolerate acts of sexual misconduct, including sexual harassment and all forms of sexual violence. If you have experienced sexual misconduct, or know someone who has, the University can help. It is important to know that federal regulations and University policy require faculty to promptly report complaints of potential sexual misconduct known to them to their campus Deputy Title IX Coordinator(s) to ensure that appropriate measures are taken and resources are made available. The University will work with you to protect your privacy by sharing information with only those that need to know to ensure the University can respond and assist. If you experience or witness any act of sexual misconduct, go to <http://stopsexualviolence.iu.edu/help/iupui/index.html>. If you are seeking help and would like to speak to someone confidentially, you can make an appointment with a Mental Health Counselor on campus (contact information available at https://stopsexualviolence.iu.edu/help/confidential_resources.html).

Course Schedule

Extenuating circumstances may result in changes to the following assignments or schedule. Please check Canvas and email messages often for notices of any changes.

Week	Topics	Due
1	Syllabus and Introduction	
	Math Review	
2	Governing Equations (Ch2)	
	CFD overview	
3	Labor Day (No class)	HW1 (Ch2)
	Lattice Boltzmann Method	
4	Project assignment	
	Statistical description of Turbulence (1) (Ch3)	
5	In-class discussion (Exact Solutions)	
	Statistical description of Turbulence (2) (Ch3)	
6	Mean and filtered equations (Ch 4)	
	The scales of turbulence motion (1) (Ch 6)	HW2 (Ch 3-4)
7	The scales of turbulence motion (2) (Ch 6)	
	The scales of turbulence motion (3) (Ch 6)	
8	In-class discussion (Turbulence)	
	An introduction to modelling and simulation (Ch 8)	
9	Fall Break (no class)	HW3 (Ch 6)
	Project time (no class)	
10	Direct numerical simulation of turbulence (1) (Ch 9)	
	Direct numerical simulation of turbulence (2) (Ch 9)	
11	Decaying isotropic turbulence (Research)	
	In-class discussion (DNS)	
12	RANS modeling (part 1) (Ch10-11)	
	RANS modeling (part 2) (Ch 11)	
13	LES modeling (part1) (Ch 13)	
	In-class discussion (RANS)	
14	Project time (no class)	

	Thanksgiving (no class)	
15	LES modeling (part2) (Ch 13)	
	In-class discussion (LES)	HW4 (Ch 9-13)
16	Final Review	
	Project wrap-up (no class)	
17	Oral Presentation	Project report
	Final Exam	

* The HW due dates are just a guideline. If there is a conflict with the HW assignment, please follow the assignment