UNIVERSITY OF IDAHO
Department of Mechanical Engineering

ME 404/504: Turbulence Modeling
Spring 2017

Course Instructor

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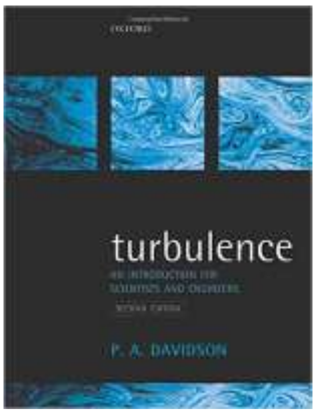
Course Textbook



P. A. Davidson, Turbulence: An Introduction for Scientists and Engineers, 2nd Edition, Oxford University Press, 2015.
In addition to the course textbook, additional handouts and lecture notes will be made available on the course BbLearn website.

Course Schedule:
Lecture: 9:30 am – 10:45 am TR at Mcclure Hall 209
Office Hours: 10:00 am – 11:00 am MWF or by appointment

Course Description

In this course, we will study the characteristics and descriptions of turbulence with an emphasis to engineering modeling of turbulent flows. Characteristics of turbulent flows, Navier-Stokes equations of fluid flows, theoretical and phenomenological analysis of turbulence, homogeneous and isotropic turbulence, scales of turbulence, Reynold's averaging and closure problem, Boussinesq hypothesis, turbulent shear flows: boundary layers, pipe flows, jets, wakes and plumes, turbulence models based on Reynolds averaged Navier-Stokes equation, direct numerical simulation and large-eddy simulation. Examples of turbulence model behavior in internal and external flows, advanced turbulence models and future directions.

Prereq.: Engr 335 (Engineering Fluid Mechanics), and **Math 330** (Linear Algebra).

Course Learning Objectives

Students will:

- Understand the basic laws of fluid mechanics in Cartesian tensor notation.
- Familiarize with the characteristics of turbulence, namely, length scales and time scales.
- Familiarize with statistical description of turbulence, namely, correlations, spectra.
- Understand the turbulence mechanisms in flows near a solid wall and free shear flows.
- Familiarize with Reynold's averaging and closure problem.
- Understand the concepts behind industrial turbulence modelling, including eddy viscosity models, mixing-length models and Reynolds stress models.
- Understand direct numerical simulation (DNS) and large-eddy simulation (LES) techniques.
- Be able to analyze three-dimensional unsteady turbulent fluid flow data (either from measurement or high fidelity simulation) to perform statistical description of turbulent flows.
- Develop computer program for turbulence model in two-dimensional flows (graduate students only).

Course Web Site

All course-related material is available on the course BbLearn website. If you are a registered student in the class, you will automatically receive an invitation to the class website. Check it frequently. Download any items of interest that you find there!

Reading and Homework Assignments

Reading and homework assignments will be posted on the course website. Homework assignments are due at the beginning of the class period posted on the course website. Homework not submitted at the beginning of the class period is considered late and will receive a grade of zero.

Software and programing language

- **Programming:** At least one assignment will be on analysis of a given three-dimensional instantaneous velocity field to calculate turbulent statistics and perform signal analysis using simple computer programs. The students can use any computer programs/languages that they are familiar with, such as FORTRAN, C, C++, EES, MATHEMATICS, and MATLAB. However, MATLAB would be the most convenient as many of the inbuilt functions (MATLAB) can be used. A few of the final projects (only for graduate students) involve writing CFD code for simple turbulent flow problems.
- **CFD package (optional for ME404):** Some of the final projects may involve performing turbulence simulations using CFD packages, namely, ANSYS FLUENT and OpenFOAM. ANSYS FLUENT is part of ANSYS Academic Student Version, which is free. OpenFOAM is an open-source CFD package which can be downloaded freely. Instructions on how to download and install ANSYS Academic Student License and OpenFOAM will be posted on course website. Please note you may need a separate software to post-process and visualize your results.

Course Grading

Your total course percentage will be made up of the following,

Homework	35%
Exam 1	15%
Exam 2	15%
Final Project	35%

Course grades will be assigned on the following scale: 90-100% = A, 80-89% = B, 70-79% = C, 60-69% = D, <60% = F. The instructor reserves the right to adjust the scale according to overall class performance.

Academic Honesty

As a student enrolled at the University of Idaho, you are bound by the UI Student Code of Conduct. Article II, Section 1 of this code addresses academic honesty. This code states …

> *Cheating on classroom or outside assignments, examinations, or tests is a violation of this code. Plagiarism, falsification of academic records, and the acquisition or use of test materials without faculty authorization are considered forms of academic dishonesty and, as such, are violations of this code. Because academic honesty and integrity are core values at a university, the faculty finds that even one incident of academic dishonesty seriously and critically endangers the essential operation of the university and may merit expulsion.*

Violation of this code will not be tolerated in this course and will be reported immediately to the Office of the Dean of Students for review.

Professionalism

You are training yourself, through formal education, for a career in engineering or a related field. Professional integrity is expected in the workplace, and it is also expected in the classroom. This includes, but is not limited to,

- <u>On-time class attendance.</u> In your professional career, you will no-doubt be involved in many things requiring your on-time attendance (meetings, conferences, etc.). Entering a meeting, presentation, or a class lecture late is a distraction for everyone. It can completely derail the proceedings. Distractions like this can cause those who are trying to focus to lose their concentration.
- <u>Attention during class.</u> It is my sincere hope that you never will have to deal with people talking, whispering, laughing, eating, internet-surfing, or doing other distracting things while you are giving a presentation. For the presenter, this is not a pleasant experience at all. It causes one to lose his/her train of thought very quickly. Activity that distracts the presenter also distracts those in the room who *want* to hear the material in more ways than one. Causing a presenter to stumble because of distractions degrades the quality of the presentation. Distracting activity directly affects those around you who are interested in the subject material and *want* to hear the presentation.

Respecting the individual presenting the information and respecting your peers that surround you in the room by refraining from distracting activity is truly professional in every sense of the word.

- Cell phones. This falls under the previous category, but it warrants a separate bullet. Hearing a cell phone ring during a presentation is a huge distraction for everyone. Sending and receiving text messages or surfing the internet is distracting you from the material being presented. I respectfully request that you **turn your cell phone off** during the class period.
- Courtesy and respect. These represent the pinnacle of professional integrity. Exhibiting courtesy and respect to others is absolutely essential for effective communication.

Tentative Class Schedule is in the next page!!

Course Syllabus

Lec	Date	Day	Topic	Reading
	10-Jan	T		
1	12-Jan	R	Introduction to Turbulence I	**Lecture notes**
2	17-Jan	T	Introduction to Turbulence II	**Lecture notes**
3	19-Jan	R	Introduction to Turbulence III	**Lecture notes**
4	24-Jan	T	Historical developments in turbulence	**Lecture notes**
5	26-Jan	R	Governing Equations of Fluid Flows I	**Lecture notes**
6	31-Jan	T	Governing Equations of Fluid Flows II	**Lecture notes**
7	2-Feb	R	Descriptions of turbulence	**Lecture notes**
8	7-Feb	T	Hydrodynamic Instability	**Lecture notes**
9	9-Feb	R	Statistical analysis of turbulence I	**Lecture notes**
10	14-Feb	T	Statistical analysis of turbulence II	**Lecture notes**
11	16-Feb	R	Statistical analysis of turbulence III	**Lecture notes**
12	21-Feb	T	Kolmogorov's Theory of Turbulence	**Lecture notes**
13	23-Feb	R	Reynolds Averaging and Closure problem	**Lecture notes**
14	28-Feb	T	Boussinesq hypothesis and zero equation models of turbulence	**Lecture notes**
15	2-Mar	R	One equation models of turbulence	**Lecture notes**
16	7-Mar	T	Turbulent free shear flows- Jets, Wakes, Plumes	**Lecture notes**
17	9-Mar	R	Wall bounded turbulent flows	**Lecture notes**
	14-Mar	T	Spring recess	
	16-Mar	R	Spring recess	
18	21-Mar	T	Review for Exam 1	
19	23-Mar	R	Two equation models of turbulence I (Exam 1)	**Lecture notes**
20	28-Mar	T	Two equation models of turbulence II (Exam 1 due)	**Lecture notes**
21	30-Mar	R	Turbulence model behavior in canonical flows	**Lecture notes**
22	4-Apr	T	Direct Numerical Simulation	**Lecture notes**
23	6-Apr	R	Introduction and assignment of Final Project	
24	11-Apr	T	Large Eddy Simulation I	**Lecture notes**
25	13-Apr	R	Large Eddy Simulation II	**Lecture notes**
26	18-Apr	T	Reynolds stress and algebraic stress models	**Lecture notes**
27	20-Apr	R	Homework presentation	
28	25-Apr	T	Review for Exam 2	
29	27-Apr	R	Current research trend and future of turbulence simulation (Exam 2)	**Lecture notes**
30	2-May	T	Turbulence Modelling Final Project (Exam 2 due)	
31	4-May	R	Turbulence Modelling Final Project	
	12-May	F	**FINAL Project presentation (7:30 am-9:30 am) Mcllure 209**	