MAE 731 / MAE 636 – FUNDAMENTALS OF TURBULENT FLOW (3 credit hours)
Spring 2014

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Class time and location: Tue-Thu 2:00-3:15 PM, Rm ESB 215
Tentative Office Hours: 3:30-5:00 pm all business days except for Tue (or by appointment).

PR: While there are no formal prerequisites for MAE 731 / MAE 636 that have been adopted by the MAE Departmental faculty, you are expected to have completed MAE 532 Dynamics of Viscous Fluids, or the equivalent, and to have completed the usual sequence of four, four- to five-semester hour undergraduate mathematics courses that are customary at all ABET accredited undergraduate mechanical or aerospace engineering programs in the US.

TEXT: Mathieu, J. and Scott, J., An Introduction to Turbulent Flow, CUP, 2000.

COURSE OBJECTIVES: This course presents the fundamentals of turbulent fluid flow, including a review of the derivation of all conservation laws, introduction to statistical methods including probability distribution functions and moments, Reynolds and ensemble averaging of the conservation equations, use of scaling and dimensional arguments, and simple closure models and their application to simple turbulent flows, including channel flow, linear shear flow, jets and wakes, and boundary layers.

LEARNING OUTCOMES: At the end of this course, students will understand the fundamentals of turbulent fluid flow, including applications to simple turbulent flows including jets, wakes, and boundary layers. They will understand and be able to describe the basic features and phenomena in turbulent flows. They will become familiar with some of the basic experimental methods used to quantify and study turbulence. They also will understand the basis for simple closure models of turbulence, and will be able to use these to develop predictive solutions for flow fields of simple turbulent flows, including jets, wakes, and boundary layers. Students will gain experience in computing statistical measures of turbulent flow, including mean and RMS velocities, correlation coefficients, and spectra. They will gain experience in reading papers from the turbulence research literature, and in summarizing and explaining the methods and results of such turbulence research papers.

REFERENCES:
1. Baker, G. L. and Gollub, J. P., Chaotic Dynamics; an Introduction, CUP, 1990.
2. Batchelor, G. K., The Theory of Homogeneous Turbulence, CUP, 1953.
3. Bradshaw, P., An Introduction to Turbulence and Its Measurement, Pergamon Press, 1971.
4. Bradshaw, P., editor, Turbulence: Vol. 12, Topics in Applied Physics, Springer-Verlag, 1976.
5. Cebeci, T. and Bradshaw, P., Momentum Transfer in Boundary Layers, Hemisphere-McGraw-Hill, 1977.
6. Cebeci, T. and Smith, A. M. O., Analysis of Turbulent Boundary Layers, Academic Press, 1974.
7. Chen, C. J. and Rodi, W., Vertical Turbulent Buoyant Jets - A Review of Experimental Data, Pergamon, 1980.
8. Frisch, U., Turbulence, CUP, 1995.
9. Gleick, J., Chaos Making a New Science, Penguin, 1987; fun reading about important new area of research.
10. Hinze, J. O., Turbulence, McGraw-Hill, 1975.
11. Kline, S. J., et al, editors, Proceedings - Computation of Turbulent Boundary Layers,1968, AFOSR-IFP-Stanford Conference, Vols. 1 and 2, 1968.
12. Kline, S. J. and Afgan, N. H., editors, Near-Wall Turbulence, Hemisphere, 1990.
13. Launder, B. E. and Spalding, D. B., Lectures in Mathematical Models of Turbulence, Academic Press, 1972.
14. Lesieur, M., Turbulence in Fluids, 2nd edition, Kluwer, 1993.
15. Libby, P. A., Introduction to Turbulence, Taylor and Francis, 1996.
16. Lumley, J. L. and Penofsky, H. A., The Structure of Atmospheric Turbulence, Interscience, 1964.
17. Lumley, J. L., Stochastic Tools in Turbulence, Academic Press, 1970.
18. Monin, A. S. and Yaglom, A. M., Statistical Fluid Mechanics of Turbulence, Vol. 1, MIT Press, 1965.
19. Ott, E., Chaos in Dynamical Systems, CUP, 1993.

20. Schetz, J. A., Injection and Mixing in Turbulent Flow, Vol. 68, Prog. in Astronautics and Aeronautics, AIAA, 1980.
21. Schlichting, H., Boundary Layer Theory, 7th edition, Ch.18,19, 24, McGraw-Hill, 1979 (very basic coverage).
22. Tennekes, H. and Lumley, J. L., A First Course in Turbulence, MIT Press, 1972.
23. Townsend, A. A., The Structure of Turbulent Shear Flow, CUP, 1956.
24. White, F. M., Viscous Fluid Flow, 2nd Ed., McGraw-Hill, 1991; see Ch. 5: Instability and Ch 6: Turbulent Flow.

COURSE PROCEDURES:
Your grade will be determined by your performance on the following assignments, exams, and in-class presentation(s), with the weighting as listed below:

MIDTERM EXAM		25%
HOMEWORKS		25%
IN-CLASS PAPER TALK or TALKS		20%
FINAL EXAM	(Wednesday, May 2nd, 8 AM)	30%

Grading Procedures: Generally, there have been between six and eight separate homework assignments; I plan to again make between 6 and 8 homework assignments. The homework problems have generally been made up "new" each semester, so the specific assignments are unknown at the start of the semester. Generally there are 4 to 6 problems on each assignment, with most problems being graded on a ten-point scale. Some more difficult problems are graded on a 20 point scale. These points are totaled for each student, and the scores are recorded for each student, for each assignment. A point total is computed, and then a percent of total homework points is computed. This percentage is the students "homework average". This homework average score is weighted by a factor of 0.25 in computing the student's overall average score in the class. The midterm exam score is also weighted by the same 0.25 factor in computing the student's overall numerical score in the course. The student's final exam score is weighted by a factor of 0.30, and the numerical score on the in-class oral presentation about a research paper taken from the turbulence research literature is weighted by a factor of 0.2.

The numerical scores on each problem from each assignment are determined by the level of correctness of the solution submitted by the student. A score of 100% (i.e., 10 out of 10 or 20 out of 20) is assigned to a student solution that is completely correct. Scores of between 90% of total points up to 100% of total points are awarded to outstanding solutions (i.e., "A" work) that are nearly correct, but that contain small errors, such as not completely listing of units of numerical answers, or a minor addition or multiplication error. Scores of between 80% up to 90% (i.e., "B" work) are awarded to above-average problem solutions that are mostly correct, but may contain errors as described above for 90-100% scores, multiple times, and/or may contain minor errors in dimensions or units, but do not contain serious conceptual errors. Scores of between 70% up to 80% (i.e., "C" work) would be awarded to average solutions that contain several errors as described above, and/or contain more serious conceptual errors in the application of the theory and methods covered in class. Lower scores are assigned for below average work (i.e., "D" or "F" work) are assigned to below-average problem solutions that are incomplete, or that contain major conceptual errors or omissions.

Finalized scheduled office hours will be determined in class. Final exam will be open book and notes, and will be comprehensive, while the midterm is expected to be a **closed book** exam (mostly on definitions and basic concepts). At least one homework assignment will require some computer work; using MATLAB will suffice. **Paper talks by students** will be done towards the end of the semester and perhaps near mid-term; students will each either select or be assigned a technical paper or papers from the literature, and **give an oral summary presentation in class**.

Instructors' notes and notation will follow Mathieu and Scott; generally a simpler introduction may be found in Schlichting or White. Tennekes and Lumley give good descriptions of the dimensional/physical reasoning. We will also refer to several original journal articles and papers.

MAE 636 / MAE 731 – Tentative Lecture Schedule

Week	Topics	Books-Chapter
1	Introduction	MS-1, TL-1, S-18, H-1, pp. 1-15, CS-1
2-3	Statistical Tools	MS-2
4	Turbulent Length & Time Scales	MS-3
5	Conservation Equations; Reynolds Averaging; Mixing Length Models	MS-4, TL-2, S-18, 19, H-1, pp 15-35, CS-2 W-6
6-8	Conservation Equations; Reynolds Stresses, Turbulent Kinetic Energy; Vorticity	MS-4, TL-3, H-1, pp. 30-42, 66-78, CS-2, Bradshaw 2, W-6
9-10	Experimental Methods	H-2, Bradshaw
11-12	Free Shear Flows; Turbulent Structure; Self-Preserving Flows, 2-D Jet, 2-D Wake, TKE Budgets	MS-5,TL-4, S-24, H-6, Townsend, Chen & Rodi, Schetz, W-6
13-14	Wall-Bounded Shear Flows; Empirical Concepts of Turbulence; Channel Flow, Pipe Flow, Boundary Layers, Law of The Wake, etc.	MS-5, TL-5, S-20, 21, 22, H-5, 7, CS-4, W-6
15	Student Presentations	

Key:
MS = Mathieu and Scott
TL = Tennekes and Lumley
S = Schlichting
CS = Cebeci and Smith
H = Hinze
W = White

Inclusivity Statement
The West Virginia University community is committed to creating and fostering a positive learning and working environment based on open communication, mutual respect, and inclusion. If you are a person with a disability and anticipate needing any type of accommodation in order to participate in this class, please advise me and make appropriate arrangements with the Office of Disability Services (293-6700). For more information on West Virginia University's Diversity, Equity, and Inclusion initiatives, please see http://diversity.wvu.edu.

Academic Integrity Statement
The integrity of the classes offered by any academic institution solidifies the foundation of its mission and cannot be sacrificed to expediency, ignorance, or blatant fraud. Therefore, I will enforce rigorous standards of academic integrity in all aspects and assignments of this course. For the detailed policy of West Virginia University regarding the definitions of acts considered to fall under academic dishonesty and possible ensuing sanctions, please see the Student Conduct Code http://studentlife.wvu.edu/office_of_student_conduct/student_conduct_code. Should you have any questions about possibly improper research citations or references, or any other activity that may be interpreted as an attempt at academic dishonesty, please see me *before* the assignment is due to discuss the matter.