

MEM 420 AERODYNAMICS

Course Description: Introduction to Aerodynamics (Low speed, subsonic flow), Derivation of the conservation equations (Integral form and PDE form) for mass, momentum, and energy; Potential flow, Irrotational vs Rotational Flow, Airfoil and Wing Analysis. Boundary layers on plates and airfoils. Introduction to turbulence and vortex-dominated flows.

Text: J. D. Anderson, Fundamentals of Aerodynamics, McGraw Hill, Inc. Fourth Edition (©2007, ISBN 0072950463)

Where to buy the textbook? www.amazon.com, Drexel bookstore, etc.

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Office Hours: TBD

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Grading Policy

Grades will be based on an average grade for 4 quizzes (40%), homework and in-class assignments (10%), a final (40%), and a out-of-class research project (10%). Quizzes will be every other Friday starting on the second week as indicated. Quizzes and the final exam will be closed book and notes; one sheet of strictly equations are allowed and must be turned in with your quiz/ exam.

- A: Average score of 90% or above
- B: between 80% and 89%
- C: between 70% and 79%
- D: between 60% and 69%
- F: below 60%

Course Time and Location: TBD

Homework: Assigned weekly. Due at the beginning of the class, one week from the assigned date, unless otherwise specified.

Notes: Additional notes and handouts will be supplied by the instructor.

Learning Objectives

1. Determine how aerodynamic lift, drag and pitching moment are generated from the pressure and stress distributions on airfoils
2. Apply potential flow theory for basic and combined flows (source, sink, uniform flow, doublet, etc.) and predict the velocity, pressure, and force distributions on aerodynamic bodies

4. Apply thin-airfoil theory and calculate the 2-D incompressible flow over airfoils
5. Compute the induced drag for finite wings and compare the magnitude of the induced drag to that associated with the 2D airfoil.
6. Apply the lifting-line approach for calculating lift and induced drag on thin airfoils
7. Apply simple boundary layer models to evaluate the role of viscous effects on the pressure and shear stress distributions on airfoils
8. Design and fabricate a reduced-scale airfoil using CAD. Test the airfoil in the UG wind tunnel. Measure the lift, drag and moment about the leading edge for different angles of attack. Compare the measured results to those computed numerically as part of the lab.

Prerequisite: MEM 220 Basic Fluid Mechanics

Essential knowledge needed to survive this course

1. Newton's laws of motion
2. Trigonometry
3. Concept of scalars and vectors: dot products, cross-products (curl)
4. Partial derivatives; contour, surface and volume integrals
5. Computer literacy for problem-solving using spreadsheets, making 2-D plots
6. Chemistry background: Perfect gas equation, Avogadro's Number

Lecture Topics

1. **Conservation Laws:** Laws of physics: Mass, momentum & energy conservation. Simplifications. Relating line, area and volume integrals. Incompressible & steady flows. Euler's equation, Bernoulli's equation, pressure coefficient
2. **Fluid Motion:** Streamlines, translation, dilatation, rotation and vorticity, strain, viscosity, circulation
3. **Potential Flow Method:** Velocity potential; Laplace equation; superposition of solutions, boundary conditions. Elementary solutions: uniform flow, source/sink, doublet, vortex, lift and drag coefficients.
4. **Airfoils:** Specifying circulation and the Kutta condition. Airfoil shape. Vortex sheet. Thin airfoil theory, lift curve slope, center of pressure, aerodynamic center.
5. **Panel methods**
6. **Wings:** Observed characteristics, trailing vortices, vortex sheet, starting vortex, downwash, induced drag. Vortex filament and Biot-Savart Law, Helmholtz's vortex theorems. Prandtl's lifting line theory, elliptical lift distribution, induced drag.
7. **Viscosity:** Simple solutions to the Navier-Stokes equations.
8. **Incompressible boundary layer equations:** exact solutions.
9. **Boundary layer flow over a flat plate**
10. **Turbulence and its effects**

WHERE DOES MEM 420 FIT

MEM 420 is a 3-credit elective course and can be applied for those interested in the Aerospace track. The course introduces the students to the equations of motion for incompressible flow and applies them to solve for the velocity, pressure, and shear stress distributions on airfoils and other shapes. Knowing these distributions, the loads and moments on the bodies are then computed. A hands-on lab is also required and provides the students with the basic tools associated with wind tunnel testing.

MEM 420 supports ABET criteria 3 a-k and contributes to the MEM educational objectives.

RELATION TO ABET CRITERIA 3 OUTCOMES:

0 = No content; 1 = Some content; 2 = Significant content

<i>Outcomes a - k</i>	<i>Content</i>	<i>Explanation</i>	<i>Evidence</i>
a. An ability to apply knowledge of mathematics, science and engineering	2	The students apply and synthesize their knowledge of math, science and engineering to solve aerodynamics problems and design and test airfoils.	Homework, Exams, Design project (lab)
b. An ability to design and conduct experiments as well as to analyze and interpret data	1	Students will design, fabricate and test an airfoil of their choosing and measure the associated forces and moments and compare to their calculations and experimental data available in the literature.	Design project (lab report) - data reported, plotted and compared.
c. An ability to design a system, component or process to meet desired needs	1	Design problems provide constraints and require the students to compute the airfoil properties to meet the constraints.	Homework, In-class problems
d. An ability to function on multidisciplinary teams	1	On the design project, the students work in teams.	Lab report.
e. An ability to identify, formulate and solve engineering problems	2	The in-class problems, homework problems, and lab require the students to formulate and solve engineering problems	Homework, In-class problems, Design project (lab report)
f. An understanding of professional and ethical responsibility	1	This is emphasized as part of the engineer's overall responsibility.	Classroom discussion with respect to safety; examples include NASA Space Shuttle tragedies and question the engineer and managers responsibilities
g. An ability to communicate effectively	1	In-class discussions. Homework. Writing a lab report.	In-class discussions Homework Lab report
h. The broad education necessary to understand the impact of engineering solutions in a global/societal context	1	In-class discussions on flight and space flight with relevance to social responsibilities and ethical conduct	In-class discussion of safety issues, and importance of low and high-speed flight for transport of people and goods as well as space travel.
i. A recognition of the need for and an ability to engage in lifelong learning	0	NA	NA

j. A knowledge of contemporary issues	<i>I</i>	Discussions on low and high-speed flight for transport of people and cargo. Environmental issues. Possibilities for future space travel.	NASA examples are provided with emphasis on current events (space Shuttle tragedy) along with in-class discussions. Discussions of the X-Prize and future space travel.
k. An ability to use the techniques, skills and modern engineering tools necessary for engineering practice	<i>I</i>	The analytical tools needed to solve real-world problems. Analytical and numerical techniques are used.	Analytical techniques in HW and in-class problems. CAD used for designing airfoils. Wind tunnel used for testing the students airfoils.