MAE 551, Airfoil Theory
Fall 2009
Course Description

Instructor
Dr. Ashok Gopalarathnam
ashok_g@ncsu.edu
http://www.mae.ncsu.edu/directories/faculty/gopal.html
2404 Broughton Hall
(919) 515-5669
Office hours: 2:30pm–3:30pm Tuesdays and Thursdays
Other times by appointment

Schedule
Recorded lectures from Fall 2007 will be posted online by Engineering Online
No live lectures
For on-campus students only, instructor will hold “Meet the class” sessions during class times
approximately once a month as notified by email
The recorded lectures may be posted incrementally (not all together). Likewise, the either
or both the course websites may be updated incrementally during the semester.
Course schedule appended to the end of this course outline
Use this course schedule for viewing lectures and completing assignments
Course website for lecture videos and instructor’s scanned notes:
http://engineeringonline.ncsu.edu/onlinecourses/coursehomepages/SPRING09/MAE551.html
Course website for additional material, home works, assignments, and projects:
http://courses.ncsu.edu/mae551

Topics
• Airfoil characteristics, velocity distributions
• Overview of boundary layers and their effect on airfoil characteristics
• Airfoil analysis using XFOIL
• Thin airfoil theory
• Inverse airfoil design, multipoint design
• Airfoils for low Reynolds numbers
• Natural laminar flow (NLF) airfoil design
• Effect of airfoil characteristics on aircraft performance
• Adaptive airfoils
• High lift airfoils
• Introduction to conformal mapping
• Some of the following topics:
  Design of airfoils for complex aerodynamic systems
  Aerodynamic fixes: vortex generators, boundary-layer trips
Introduction to unsteady airfoil aerodynamics
Introduction to transonic airfoil aerodynamics
Roughness effects, icing effects, etc.

Suggested books (not required)

   (Textbook for MAE 355 Aerodynamics I — highly recommended if you do not have a degree in Aerospace Engineering. Earlier editions will also work.)


Other supplemental material will be provided by the instructor.

Assignments, Grading, Projects, Attendance, etc.

- Homework assignments. (30%)
- Two airfoil design/analysis projects. (30%)
- An individual research project with 15–25-min presentation and term paper. Topics to be identified by each student, based on individual research interests. (20%)
  One-page proposal due: 22 September 2009
  Term paper due: 3 December 2009
  Presentations are compulsory for on-campus students and not required for off-campus students. For off-campus students, the student’s term-paper and hardcopy of presentation slides will be graded for the entire 20% of the total grade.
  Presentations: during the week of 30 November 2009 (to be arranged)
- Attendance for on-campus students compulsory on all presentation days.
- One take-home, open-book final examination. To be handed out 4 December, due in one week on 11 December. (20%)
- All homeworks and projects will need to be submitted electronically via Wolfware (http://courses.ncsu.edu/mae561). They can be scanned-in versions of hand-written pages. Pdf files are preferred for the submissions.
- Grading scheme:
  
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<thead>
<tr>
<th>Grade</th>
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<tbody>
<tr>
<td>95+</td>
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<td>90–94</td>
<td>A</td>
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# MAE 551 – Airfoil Theory
## Course Schedule for Fall 2009

<table>
<thead>
<tr>
<th>Week</th>
<th>Week of</th>
<th>Lectures to watch (lecture numbers shown)</th>
<th>Assignments</th>
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<tbody>
<tr>
<td>1</td>
<td>August 16</td>
<td>1. Course outline and motivation</td>
<td>Brush up programming skills to prepare for HW 1</td>
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</table>
| 2    | August 23 | 2. General definitions, velocity and pressure distributions  
3. Velocity and pressure distributions continued, forces and moment on airfoil | Brush up programming skills to prepare for HW 1 |
| 3    | August 30 | 4. Force and moment coefficients, Discussion of HW 1, Part A  
5. More discussion of HW 1, Part A. Center of pressure, aerodynamic center, pitching moment reference point | Start HW 1, Part A (no need to turn in) |
| 4    | September 6 | 6. Effect of alpha change on center-of-pressure location, velocity and pressure distributions. Airfoils for unswept flying wings  
7. Unswept flying-wing aerodynamics, Overview of boundary layers, favorable and adverse pressure gradients, boundary-layer development on an airfoil | Complete HW 1, Part A (no need to turn in)  
Develop an idea related to airfoil aerodynamics for your research project |
| 5    | September 13 | 8. Pressure drag and skin-friction drag (has some relevance to HW 1), boundary-layer development on airfoil continued, laminar boundary-layer characteristics  
9. We discuss the one-page proposal for research project and HW 1, Part B, plotting $V/V_{\text{inf}}$ and $C_p$ plots. Boundary-layer transition, low Reynolds number airfoils, laminar b.l. separation and transition, laminar separation bubbles, turbulent b.l., factors affecting turbulent b.l. separation | Start HW 1, Part B  
Develop the idea for your research project |
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| 6    | September 20 | 10. Some common airfoil design philosophies. Start discussion of the XFOIL code for analysis (chapter 2)  
11. XFOIL theory overview, XFOIL demo, using the XFOIL code for analysis | Work on HW 1, Part B  
Submit one-page proposal for research project – due Sep 22 |
| 7    | September 27 | 12. More on XFOIL. Using PLOT for polar plotting  
13. Start Chapter 3: Thin Airfoil Theory (TAT). Background for TAT: elementary flows | HW 1, Part B due Sep 29  
Install XFOIL  
Start HW 2 |
| 8    | October 4   | 14. Elementary flows, circulation, Kutta condition                       | Work on HW 2  
Fall break |
| 9    | October 11  | 15. Discussions on finite-angle and cusped trailing-edge shapes, starting vortex, unsteady aerodynamics. Derivation of TAT equations  
16. TAT derivation, symmetric airfoil solution, start of derivations for cambered airfoils | HW 2 due Oct 8  
Work on research project |
| 10   | October 18  | 17. Discussion of HW 3 in beginning of lecture, continue cambered airfoil derivation  
18. Cambered airfoil continued, Discussions on ideal angle of attack, example problem with TAT, use of TAT to study camber change and flap deflection | Start HW 3  
Work on research project |
| 11   | October 25  | 19. Taking a break from TAT, we move to Chapter 4: Inverse design of airfoils. We discuss single- and multipoint design and the concept of alpha* for use in the PROFOIL code  
20. Demo of the PROFOIL inverse design code and the MFOIL interface | HW 3 due Oct 29  
Read the two papers provided as recommended reading  
Install PROFOIL and MFOIL |
| 12   | November 1  | 21. More on airfoil design using PROFOIL  
22. Using PROFOIL to design symmetric airfoils, Project 1 | Start Project 1 |
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| November 8 | 23. Using PROFOIL to design cambered airfoils, completed discussion of PROFOIL code  
24. Back to TAT to discuss flap effects (continued from lecture 18). Overview of multi-element airfoil aerodynamics |
| November 15 | 25. Completed multi-element airfoil aerodynamics, answered some questions on PROFOIL. Presentation on NLF airfoil design. Project 2  
26. Introduction to conformal mapping for airfoil aerodynamics, review of complex variables and analytic functions |
| November 22 | 27. Two-dimensional flow and the complex variable |
| November 29 | 28. Joukowski transformation |
| December 6 | 29. Joukowski transformation |

- Work on Project 1  
- Work on Research project
- Project 1 due Nov 17  
- Start project 2
- Work on Project 2  
- Work on Research Project  
- Thanksgiving break
- Project 2 due Dec 1  
- Research project (slides and report) due Dec 3  
- Presentations by on-campus students on Dec 1 and 3 (during class times, if possible)
- Finals due Dec 11