Instructor
Dr. Ashok Gopalarathnam
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Office hours: 2:00–3:00 pm, Tuesdays (when not on travel).

Due to several travel commitments, communications with the instructor is best done via email and Moodle. If needed, phone discussions can be held by prior arrangement.

Prerequisites
Undergraduate/graduate course in aerodynamics/fluid mechanics, or consent of instructor.

Schedule
Recorded lectures from Fall 2012 will be posted online by Engineering Online.

There will be no live lectures
Course and viewing schedule is appended to this syllabus
Use this course schedule for viewing lectures and completing assignments.

Course website for lecture videos and instructor’s scanned notes is:
Course website for additional material, home works, assignments, discussion forums, and projects is:
http://wolfware.ncsu.edu

Course Objectives
After this course, the student will be able to explain the fundamental aerodynamic characteristics of finite wings in subsonic flow. The student will be able to explain the connection between spanwise lift distributions, trailing vorticity behind a wing, induced downwash, effective angles of attack of the wing sections, and induced drag. The student will be able to discuss theoretical formulations of methods used in characterizing wing aerodynamic behavior. The student will be able to develop computer programs for lifting-line theory and Weissinger method for wing analysis. Using these and similar methods the student will be able to study wing behavior and discuss the effects of wing planform shape on aerodynamic characteristics and their effect on aircraft flight. The student will also be able to use the concepts of basic and additional loading, Munk’s theorems, and minimum-drag solutions in
discussing design impacts of planform shapes and wing-tip geometries. The student will have sufficient background of swept-wing and propeller aerodynamics to permit further study of these subjects.

**Topics**

- Introduction to airfoil aerodynamics
- Lifting line theory
- Weissinger’s method for nonplanar, swept and multiple wings
- Effect of taper, twist, sweep on lift, induced drag, and stall characteristics
- Munk’s theories
- Overview of vortex-lattice and panel methods
- Methods for inverse aerodynamic design and optimization of wings
- Design of winglets and non-planar wings
- Issues involved in tailless, aft-tail, and canard-configured aircraft
  Multidisciplinary considerations: connections to stability & control and structures
- Rotating wings: propellers, helicopters, wind-turbine rotors
  Actuator disk and blade-element momentum theories
- Introduction to high-speed wing theory

**Suggested books (not required)**


John D. Anderson, “Fundamentals of Aerodynamics,” 5rd Edition, McGraw Hill. (Textbook for MAE 355 *Aerodynamics I* — highly recommended if you do not have a background in Aerospace Engineering. Any earlier edition or other similar textbooks will also work.)


Other supplemental material will be provided by the instructor.
Assignments, Grading, Projects, Attendance, etc.

- Homeworks. (25%)
- Quizzes on Moodle. (10%)
- Programming assignments. Can be done in either Fortran, C, C++, Matlab, Python or similar (Excel not recommended) (35%)
- Three short blog posts on individually-identified topics in areas of: “Wings in the natural world”, “Wings in aerospace applications”, and “Wings in non-aerospace applications” All blog posts will be accessible to all students in this course. (7.5%)
- One take-home final examination (given out for approximately 1 week). (22.5%)
- All homeworks and projects will need to be submitted electronically via Moodle (http://wolfware.ncsu.edu). They can be scanned-in versions of hand-written pages. Pdf files are preferred for the submissions.
- Grading will be determined using a curve with the following general guideline for letter-grade cutoffs:
  - 97 – A+
  - 94 – A
  - 91 – A-
  - 88 – B+
  - 85 – B
  - 82 – B-
  - 79 – C+
  - 76 – C
  - 73 – C-

- Academic dishonesty will not be tolerated and will be dealt with as per the NCSU Code of Student Conduct.
- Email and Moodle-based communications will be used throughout the semester to disseminate important information regarding all aspects of the course. It is important that students monitor their email regularly and prevent their email inboxes from getting full to avoid lost messages.
- Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with Disability Services for Students at 1900 Student Health Center, Campus Box 7509, 919-515-7653. For more information on NC State’s policy on working with students with disabilities, please see the Academic Accommodations for Students with Disabilities Regulation (REG02.20.01)
- Students may be required to disclose personally identifiable information to other students in the course, via electronic tools like email or web-postings, where relevant to the course. Examples include online discussions of class topics, and posting of student coursework. All students are expected to respect the privacy of each other by not sharing or using such information outside the course.
<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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| 1     | May 17   | 1. Course motivation and airfoil aerodynamics review  
2. Airfoil aero review continued  
3. Airfoil aero review continued Fundamentals of wing aerodynamics  
4. Finite wing flows                                                                                                                                                             | • Complete self-introduction  
• Complete blog permission  
• Brush up programming skills  
• Quiz 1 (Q1) (on airfoil aero) posted 22 May                                                                                                                                 |
| 2     | May 24   | 5. Finite wing flows continued, Bio-Savart law  
6. Bio-Savart law continued, Lifting line theory (LLT)  
7. LLT continued  
8. LLT continued                                                                                                                                                               | • Q1 due 29 May  
• Blog post 1 due 29 May  
• Start HW 1 – includes one small programming problem using Biot-Savart law  
• Q2 (lecs 5-9) posted 29 May                                                                                                                                                 |
| 3     | May 31   | 9. LLT continued (non-elliptical wings)  
10. LLT numerical implementation  
11. LLT program structure  
Effect of aspect ratio on lift-curve slope  
Effect of wing twist  
12. Basic & additional load distributions                                                                                                                                 | • Q2 due 5 June  
• HW 1 due 5 June  
• Start Prog. Assign 1 (PA 1)  
• Q3 (lecs 9-10) posted 5 June                                                                                                                                                   |
| 4     | June 7   | 13. Stall characteristics, Wing contribution to longitudinal stability and control  
14. Tailless airplanes  
15. Tailless airplanes, Discussion of stall characteristics (HW2 material), Limitation of LLT  
16. Weissinger’s method (error in 16-8)                                                                                                                                            | • Q3 due 12 June  
• Work on PA 1  
• Q4 (lecs 12-15) posted 12 June                                                                                                                                               |
| 5     | June 14  | 17. Weissinger method & numerical implementation  
18. Weissinger method numerical implementation continued                                                                                                                                                                              | • Q4 due 19 June  
• PA 1 due 19 June  
• Start HW 2 – problems based on your LLT code                                                                                                                                                                    |
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<tr>
<th>Date</th>
<th>Description</th>
<th>Notes</th>
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<tbody>
<tr>
<td>June 21</td>
<td>Mon-Wed session break - <strong>Catch up if behind</strong></td>
<td>Start PA 2 – Weissinger method</td>
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<td><strong>June 28</strong></td>
<td><strong>Q5 due 3 July</strong></td>
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<td>21. Far field analysis, Trefftz plane (correct page number 21-19)</td>
<td><strong>HW 2 due 3 July</strong></td>
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<td>22. Munk’s theorems (correct page numbers from 21-* to 22-*)</td>
<td><strong>Blog 2 due 3 July</strong></td>
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<td>23. Munk’s mutual-drag theorem, R.T. Jones’s minimum drag solutions (correct page numbers from 22-* to 23-*)</td>
<td><strong>Q6 due 10 July</strong></td>
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<td>24. Minimum drag solutions continued</td>
<td><strong>Work on PA 2</strong></td>
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<td>7</td>
<td><strong>July 5</strong></td>
<td><strong>Blog 3 due 17 July</strong></td>
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<td>25. Winglets and tip extensions</td>
<td><strong>Complete code for your PA 2 – no need to turn in at this time</strong></td>
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<td>26. Tip extensions continued</td>
<td><strong>Start HW 3 – problems using your Weissinger code</strong></td>
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<td><strong>Intro to swept-wing flows</strong></td>
<td><strong>Q7 (lecs 24-28) posted 17 July</strong></td>
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<td><strong>Start propeller aerodynamics</strong></td>
<td><strong>Work on HW 3</strong></td>
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<td>9</td>
<td><strong>July 19</strong></td>
<td><strong>Q7 due 27 July</strong></td>
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<td>27. Propellers continued</td>
<td><strong>PA2+HW3 due 27 July</strong></td>
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<td>28. Propeller aero wrap up, Adaptive wings</td>
<td><strong>Start finals (open-book, take-home exam), handed out July 28</strong></td>
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<td>(July 29 is last day of summer session “class”.)</td>
<td><strong>Finals due 31 July</strong></td>
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- Q5 (lecs 16-19) posted 19 June
- Start PA 2 – Weissinger method
- **Q5 due 3 July**
- **HW 2 due 3 July**
- **Blog 2 due 3 July**
- Work on PA 2
- **Q6 due 10 July**
- Work on PA 2
- **Blog 3 due 17 July**
- Complete code for your PA 2 – no need to turn in at this time
- **Start HW 3 – problems using your Weissinger code**
- **Q7 (lecs 24-28) posted 17 July**
- **Work on HW 3**
- **Q7 due 27 July**
- **PA2+HW3 due 27 July**
- **Start finals (open-book, take-home exam), handed out July 28**
- **Finals due 31 July**
MAE 561: Wing Theory
General Instructions and Suggestions & Tips
(An evolving document)

General Instructions:

Homeworks & Projects:
1. Please submit only via the submit buttons on Moodle. **Do not email to instructor.**
   DE students: Do not email/snail-mail to Engineering Online.
2. Note that, for each submission (each HW/assignment/project), you will be able to submit only a single file for the main narrative (along with other files as required, for example for the computer code). The file size is restricted by Moodle to 2 Mb. For this file, pdf (preferred) or doc or docx are acceptable. Include all scanned pages, tables and figures in this single file. If you use Excel or Matlab or Postscript to make your plots, paste those figures into the single document that you submit.
3. If you have some problems that you have solved by hand, you may scan these pages and paste into the document. To keep file size small, scan in **B&W** and, if your scanner allows, use the “line drawing” or “line art” or similar setting. Keep scanned pages to a minimum, as they tend to increase the file size. Integrate these scanned pages or drawings into your Word or pdf file.
4. I will be grading all submissions electronically using Adobe Acrobat, as much as possible. That is, I do not print your submission. So make sure you paste your figures so I can view them in portrait format – not landscape.
5. Do not expect me to switch between your text discussion in one file and figures in another. Certainly do not expect me to run your code to generate the figures that are required in the HW.
6. To the extent possible, **keep all the information related to each problem together.** That is, if a HW has four problems, put all your discussion (text), figures, tables for Prob. 1 together, then do the same for Prob. 2, and so on. Avoid having all discussion for all problems at the beginning, followed by all the figures for all the problems later. I do my grading electronically using Adobe Acrobat – I do not print out your submissions. So it is quite inconvenient for me to keep going back and forth several pages to grade each problem. **Do not use colors in plots that become invisible against a white background.** For example, yellow lines on a plot are almost invisible against a white background.
7. If the HW or project asks you to submit your code, you may include that as an appendix.
8. You may consult with your classmates on general questions and procedures regarding the HW and perhaps even help debug a classmate’s code, but each student must work independently on their codes, results, figures, and discussions for their submissions. Discussion groups on Moodle, provided by the instructor, may be used for this purpose. **Joint effort on entire problems or HWs or programming assignments is not permitted.**
**Final Exam:**
1. The finals will be an open-book, take-home exam for approximately 5 days.
2. You are required to do the finals solely by yourself without consulting anyone. So, absolutely no discussion and no collaboration.
3. You will not need 5 days. I give that much time only to provide you some flexibility in accommodating the exam in your schedule.
4. DE students: You will not need a proctor.
5. Submit using the Moodle submit button (just like HWs).

**Quizzes:**
1. Every week, a quiz will be posted on Friday and will be due the next Friday.
2. The quiz will typically cover material discussed during that week, and is expected to have a few short questions. Expected duration is 45 minutes.
3. The quiz will be time-bound, and will only be available during that 1-week period. If you miss the quiz, there will not be any chance to make up that quiz. Every time a quiz is posted, we will send you an email notification of the quiz and its due date and time. The email will be sent only to your NC State email account.

**Blogs:**
1. There will be three blog posts required in this course, as mentioned in the syllabus. The blogs are to be posted via Moodle forums, which will be created by the instructor. Though this forum, write a short blog article on your choice of topic related to the area of the blog. I suggest that your blog post should have between 250 to 300 words, with images and videos to support your write-up. Try to make the topic interesting to everyone; try to add to the knowledge gained in this class. I will have some way of encouraging everyone to read the blogs written by other students. This may take the form of some sort of peer evaluation/rating, where each student rates or ranks blog posts from a few other students.

**Suggestions and Tips:**
1. Asynchronous learning (like with this course) using video lectures provides each of you with tremendous flexibility – you can watch the lectures at convenient times, replay and revisit lectures, etc.
2. It also demands a good deal of responsibility from each of you. It is entirely up to each of you to keep up with the lectures, keep up the attention during the lectures, do the HWs, and finish the course. Some students (DE or on-campus) end up not finishing these courses because they lack the discipline to stick to the schedule. You have signed up for the course. So resolve to stick with it and finish up.
3. Print the course schedule (included in the course syllabus) and pin it up near your work space. Stick with that schedule and use it to check your progress in the course, and to see what deadlines are coming up.
4. Allot a certain number of time slots every week to work on the course (watching lectures and finishing up HWs and projects).
Video Lectures:
1. Watch the lectures as if they are live classroom lectures. Do not multi-task: that is, no TV, phone, text messaging, internet, email, etc. during the lecture time. If you watch these lectures without paying full attention, there is a good chance you will miss out on useful discussion related to HW, project, or exam.
2. Prepare for the lecture. First, go to the course Moodle page (wolfware.ncsu.edu) and download and print any supplemental material related to the lecture. Then go the EOL lecture videos and notes web page and download the scanned lecture notes. I recommend that you print these scanned lecture notes in a 6-pages-in-1 or 4-pages-in-1 format using your Acrobat software. The writing is large enough for this format and you can save paper and printer ink.
3. Take notes during the lecture (just like you would in a real classroom lecture). You may take notes on the printed pages, if that works for you.

Programming:
1. Some students are rusty with their programming skills. Start on programming tasks early, so you don’t fall behind.
3. It may help you if you write your programs in small sections; debug and test these sections individually and then integrate them to create your big program. If you try to write the whole program before your start debugging, you may get overwhelmed trying to sort out the bugs.
4. In trying to debug, you could put temporary write statements to make the program print out the values of several intermediate variables. Using a few hand calculations, you can often debug and isolate mistakes. For example, in HW 1 of Airfoil Theory, you will write a program to integrate surface pressures and stresses to get loads on an airfoil for, say, 200 panels on the airfoil. But for debugging, use just 4 sections (2 on upper surface and 2 on the lower surface, which you can fairly easily solve by hand) and check intermediate values from your program to isolate errors. In Wing Theory, for example, in the Weissinger program you will write the program to solve the wing aerodynamics for, say, 100 sections on the wing. But for debugging, use just 2 sections (which you can fairly easily solve by hand) and check intermediate values from your program to isolate errors.