Aerospace Engineering 452
Fall 2015
Heat Transfer & Viscous Flows
Credit 3: (1-0), Required Course

Instructors:
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Teaching assistants:
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Textbook and Required Material: No required textbook. Notes shared at dayton.tamu.edu/aero452.htm.

Attendance Policy: Students are expected to attend class.

Learning Objective: At the end of this course the student should be able to:
(i) Understand and derive fundamental evolution equations governing viscous flow and also derive exact solutions for some ideal flows.
(ii) Perform order of magnitude analysis of Navier-Stokes equations and derive the boundary layer equations. Derive Blasius and integral solutions to the boundary layer equations.
(iii) Explain fundamentals of instability, transition and most importantly turbulence in fluid flow.
(iv) Understand and apply calculation techniques for 1-D heat transfer.
(v) Solve basic problems involving 2-D and transient heat transfer.

Notice: The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for person with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation, please contact the Office of Support Services for Students with Disabilities in Room 126 of Koldus Building. The phone number is 845-1637.

Course Description: Navier-Stokes and boundary layer equations; exact and approximate solutions; Laminar boundary layers with pressure gradients; Origin of turbulence; one and two dimensional heat transfer; methods for steady and transient heat conduction; convection; radiation.

Syllabus

Part 1 - Viscous flows

<table>
<thead>
<tr>
<th>Fundamental concepts and definitions of viscous flow theory</th>
<th>Hrs</th>
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<tbody>
<tr>
<td>1. Fluid friction and Newtonian fluids</td>
<td>2</td>
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<tr>
<td>a) Boundary layer concepts</td>
<td></td>
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<tr>
<td>b) Separation, Transition and Turbulence</td>
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<tr>
<td>c) Navier-Stokes Equations</td>
<td>4</td>
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<tr>
<td>2. Equation of motion and continuity</td>
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<tr>
<td>a) Stress-Strain concept for fluids</td>
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<td>b) Hagen-Poiseuille flow (Pipe flow)</td>
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<td>c) Suddenly accelerated plate problem</td>
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<tr>
<td>3. Exact solutions of Navier-Stokes equations</td>
<td>4</td>
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<tr>
<td>a) Channel and Couette flow</td>
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<tr>
<td>b) Prandtl's Boundary layer equations</td>
<td>3</td>
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<tr>
<td>Derivation of equations using Order of magnitude analysis</td>
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<tr>
<td>4. Flat plate laminar boundary equations and flat plate solution</td>
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<tr>
<td>5. Boundary layer momentum integral equations</td>
<td>4</td>
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<tr>
<td>6. Boundary layer stability theory, transition criteria</td>
<td>3</td>
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</tbody>
</table>
8. Introduction to turbulence & turbulent boundary layer 4

Part II - Heat transfer

1. Review of first and second laws of thermodynamics and introduction of heat transfer 1
2. One dimensional heat transfer 6
   a) Fourier law of conduction and development of heat conduction equation
   b) Multi layered walls
   c) Use of Electrical analogy in complex problems
   d) Convection at surfaces
   e) Radial and spherical systems
   f) Critical radius of insulation
   g) One dimensional differential heat transfer equations
   h) Conduction with heat source
   i) Heat transfer from fins
3. Steady state two dimensional heat transfer 4
   a) Development of the governing differential equations
   b) Analytical approach
   c) Numerical approach
4. Transient heat conduction 3
   a) Analytical approach (Lumped heat capacity)
   b) Numerical approach
5. Convection heat transfer (Time permitting) 1
   a) Forced convection
   b) Natural convection

Grading policy:
- Quiz (best 4 out of 5) 40%
- Homework 10%
- Midterms and Final (3 x 15) 45%
- Project 5%

Grade Breakdown (guideline):
90% and above = A; 80% to 90% = B; 70% to 80% = C; 55% to 70% = D; below 55% = F

Contributions to professional component:
1. Final course in aerodynamics.
2. Helps prepare students for engineering practice.
3. Builds on foundation established in the core subjects.
4. Prepares students for a future in aerodynamics.

Relationship to program outcomes:

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Assessment Method</th>
<th>ABET Outcome</th>
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<tbody>
<tr>
<td>Learning objective 1</td>
<td>Quiz, mid-term and final exam</td>
<td>3(a), 3(e)</td>
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<tr>
<td>Learning objective 2</td>
<td>Quiz, mid-term, Project and final exam</td>
<td>3(a), 3(e), 3(k)</td>
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<td>Learning objective 3</td>
<td>Quiz, mid-term, Paper and final exam</td>
<td>3(a), 3(e), 3(g)</td>
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<tr>
<td>Learning objective 4</td>
<td>Quiz, mid-term and final exam</td>
<td>3(a), 3(e)</td>
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<td>Learning objective 5</td>
<td>Quiz, mid-term, Project and final exam</td>
<td>3(a), 3(e), 3(g)</td>
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Quiz and exam schedule (subject to change with advanced notice):

1) All quizzes (25 min) are closed notes and occur in the second half of the class.
2) Mid-terms are 50 min in duration
   a. First 15 min is short questions (closed book)
   b. 35 min for work-out problems (Open class notes & in-class material only)
3) Final Exam is semi-comprehensive

Only calculator allowed in quizzes, mid-terms and final

Quiz 1: Sep. 11
Quiz 2: Sep. 25
Mid-term 1: (Pages: 1 – 61)
Quiz 3: Oct. 21
Quiz 4: Nov. 4
Mid-term 2: Nov. 18 (Pages: 62 – 118)
Quiz 5: Dec. 2
Final Exam: (Pages 122 – 180)
Project handed out: Oct. 19
Project due: Nov. 20

The page numbers covered in mid-term and final exams are approximate and subject to change.